PORTLAND GENERAL ELECTRIC COMPANY
121 S. W. SALMON STREET
PORTLAND, OREGON 97204

D. J. BROEHL
ASSISTANT VICE PRESIDENT

November 2, 1978

Trojan Nuclear Plant
Docket 50-344
License NPF-1

Director of Nuclear Reactor Regulation
ATTN: Mr. A. Schwencer, Chief
Operating Reactors Branch #1
Division of Operating Reactors
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Sir:

Enclosed is our response, prepared by Bechtel Power Corporation, to the NRC Staff technical questions of October 31, 1978 which documents the results of analysis and review of all safety-related components, piping, and systems in the Control-Auxiliary-Fuel Building Complex (i.e., those required to prevent an accident or mitigate the consequences of an accident so as to assure that offsite releases exceeding 10 CFR 100 guidelines will not occur, such as ECCS and safe shutdown equipment).

This letter and enclosure is being served on the Atomic Safety and Licensing Board and all parties in the Control Building proceeding.

Sincerely,

DJ Broehl

781107 0112 P

A001 S 1/1

RESPONSE TO

OCTOBER 31, 1978

QUESTIONS FROM THE

NUCLEAR REGULATORY COMMISSION

November 1, 1978

Response to NRC Questions

QUESTION 1

Provide the complete reference for BC-TOP-4A to verify that the techniques incorporated into your analyses are currently approved by the NRC. In addition, state the methods used for any reanalyses of the safety-related components, equipment and piping to verify that these too are currently approved by the NRC and in accordance with the appropriate FSAR criteria. If computer programs are used which do not have prior NRC approval, state how their accuracy has been verified and that they are appropriate for the analyses in which they have been used.

RESPONSE

The complete reference to BC-TOP-4A as employed in our October 27, 1978, response to Question A-4 on spectral peak broadening is "BC-TOP-4A, Seismic Analyses of Structures and Equipment for Nuclear Power Plants, Revision 3, November 1974, Section 5.2, 'Generation of Floor Response Spectra.'"

The methodology used for equipment was described in Paragraph F of the October 27, 1978, response.

The methodology of seismic analysis of safety-related piping is described in FSAR Section 3.7.3.3. The Bechtel computer program, ME-101, "Linear Elastic Analysis of Piping Systems" was employed in the analyses that confirmed the seismic capability of the piping systems. ME-101 has been verified in accordance with NRC Standard Review Plan Section 3.9.1. The verification was performed against the ASME benchmark problems, against commercially available piping computer programs, and against Bechtel computer program ME-632 which was reviewed by the NRC in Bechtel Topical Report BP-TOP-1, September 1976.

The seismic capability of the cable tray support systems was confirmed by a computer program called "CTRAY". This is a simple time share program developed to replace repetitious hand calculations. The correctness and accuracy of CTRAY has been verified by comparing its results against hand calculations.

Response to NRC Questions

QUESTION 2

State the methods by which piping and equipment support displacements have been combined with the inertial loads. Justify the adequacy of these methods. Also, state what displacements were considered and justify their adequacy.

RESPONSE

Most supports to equipment required for ECCS and Safe Shutdown are not affected by interstory structural displacements since they are base mounted. Equipment which is connected between floor and ceiling has sufficient flexibility to accommodate the interstory displacement. The method of combining primary loads (i.e. seismic inertial) with self-limiting secondary loads (i.e. displacement, thermal) and its justification is described in the FSAR (Ref. Sections 3.7.3.3.5 and 3.7.3.3.8). The displacements resulting from the STARDYNE analyses were considered in the most recent confirmation of the seismic adequacy of the ECCS and Safe Shutdown piping systems (See Response to Question 7, infra). Appendix D of the Trojan Control Building Supplemental Structural Evaluation dated September 19, 1978, contains the justification for how these displacements were derived.

Response to NRC Questions

QUESTION 3

In addition to the average floor acceleration values from both the time history and response spectrum analyses reported in Table 5, provide a comparison of the time history and corresponding response spectrum analyses derived accelerations for each of the nodal points considered on the various floors. Also, verify that the envelope of the responses at these five points on a floor system would envelop the responses at every other point on that floor system.

RESPONSE

The comparison of the maximum acceleration values obtained from the time history and the response spectrum analyses is shown in Table 3-1 for the nodal points considered for the various floors. The values shown in this table are the basis from which the average maximum floor accelerations were calculated and tabulated in Table 5 of the October 27, 1978, submittal.

Since the floor slabs within each building are quite rigid in-plane, the horizontal motions of the four corner nodes and a representative center node on each floor in each building adequately covers all major horizontal response motions of the floor. Therefore, the broadened envelope of the response spectra at these five points on a floor would envelop the responses of the floor.

TABLE 3-1 MAXIMUM ACCELERATIONS

(SSE 0.25g, 5% Damping)

			MAXIMUM ACCELERATIONS (G)			
			N-S		E-W	
BUILDING	ELEVATION (FT)	NODE NO.	TIME HISTORY	SPECTRUM	TIME HISTORY	SPECTRUM
Control	61/65	61	0.42	.44	0.33	.25
		25	0.30	.25	0.27	.25
		91	0.63	.65	0.35	.25
		97	0.32	.25	0.27	.25
		151	0.30	.25	0.27	.25
	77	26	0.44	.45	0.46	.37
		32	0.39	.34	0.40	.28
		63	0.63	.63	0.46	.37
		69	0.48	.42	0.39	.28
		174	0.49	.41	0.45	.37
	93	33	0.50	.52	0.59	.51
		39	0.48	.52	0.51	.40
		70	0.68	.68	0.60	.52
		76	0.63	.61	0.51	.42
		189	0.68	.62	0.62	.53
	117	47	0.61	.62	0.73	.66
		90	0.82	.80	0.65	.58
		210	0.74	.70	0.80	.72
Auxiliary	61*	20	0.32	.25	0.25	.25
		237	0.38	.31	0.32	.25
		240	0.32	.25	0.28	.25
		340	0.28	.25	0.33	.25
	77*	243	0.40	.33	0.39	.27
		28	0.41	.39	0.38	.26
		358	0.34	.25	0.40	.28
	93*	35	0.49	.51	0.50	.41
		280	0.44	.39	0.41	.30
		250	0.40	.31	0.42	.31
		373	0.44	.37	0.46	.34

Note: *Other nodes on this floor are shared with the floor of the Control Building.

TABLE 3-1

(Continued)

BUILDING	ELEVATION (FT)	NODE NO.	MAXIMUM ACCELERATIONS (G) N-S TIME HISTORY	N-S SPECTRUM	E-W TIME HISTORY	E-W SPECTRUM
Fuel	61	419	0.39	.43	0.43	.52
		434	0.27	.25	0.26	.25
		462	0.31	.25	0.42	.49
		468	0.25	.25	0.26	.25
		521	0.35	.25	0.31	.25
	77	471	0.28	.25	0.46	.61
		241	0.42	.41	0.39	.30
		438	0.33	.25	0.31	.25
		546	0.34	.25	0.31	.25
		532	0.38	.25	0.34	.25
	93	423	0.46	.50	0.51	.77
		549	0.52	.63	0.52	.80
		565	0.47	.45	0.37	.31
		442	0.37	.25	0.35	.25
		561	0.44	.32	0.45	.34

Response to NRC Questions

QUESTION 4

Delineate and quantify the various factors (e.g. mass and material property variations) considered in the development of the response spectrum peak broadening criteria for the linear, the degraded stiffness, and the nonlinear (those considering ductility) curves to verify their adequacy to account for any uncertainties in the analytical procedures. Also, rather than the "steps" in the spectra considering the frequency shifts due to ductility, the transition should be gradual between the frequency corresponding to zero ductility and the frequency corresponding to a ductility of 1.5. Therefore, consider this and indicate the impact on your analyses. Additionaly, consider the effects of the Control Building's ductility on the Auxiliary and the Fuel Building responses.

RESPONSE

The floor response spectral curves presented in Figures 11 through 30 of the October 27, 1978 submittal consist of the following three separate spectral peak widening criteria:

a. A $\pm$10% widening of the spectral peak for the base set of linear elastic floor response spectra as shown in solid lines.

b. A further widening of the spectral peaks to the lower frequency side based on the frequency shifts calculated using the lower bound elastic stiffness degradation of the structural complex. The resulting widening curves are shown in dashed lines.

c. A further widening of the spectral peaks to the lower frequency side for the Control Building N-S floor spectra due to possible inelastic behavior of the Control Building in the N-S direction under the SSE condition. The resulting widened curves based on an upper bound ductility ratio $\mu = 1.5$, are shown as broken lines.

The $\pm$10% broadening on the base set of linear elastic floor response spectra considers the possible variation in the material strengths and the mass calculation, and the uncertainties in the analytical procedures. Since detailed weight calculations were performed in developing the STARDYNE finite element model, a high confidence level was achieved in the mass calculation and a possible $\pm$5% variation in the structural mass is assumed. This leads to a possible $\pm$2.5% variation in frequency. The elastic moduli used in the STARDYNE model are

RESPONSE TO QUESTION 4 (continued)

based on the design material strength of f'_c = 5000 psi. The actual material strengths are higher than 5000 psi. The upper bound value of f'_c is 6500 psi as shown in the May 4, 1978 submittal results in a 15% variation in the elastic modulus, and therefore a 7.2% variation in frequency. Combining the frequency variations of 2.5% and 7.2% with a minimum 5% frequency variation to account for the uncertainties in analytical procedures, and using the following combination rule in accordance with BC-TOP-4A, Rev. 3, November 1974, leads to:

$$[\ (0.05)^2+(0.025)^2+(0.072)^2\ ]^{1/2} = 0.091$$

Thus, the ±10% widening used is adequate.

The steps in the Control Building N-S floor response spectra shown in broken lines correspond to the upper bound ductility ratio of μ = 1.5. If the ductility ratio is assumed to vary between 1.0 and the upper bound value of 1.5, the following reduction factors in spectral peak frequency and peak magnitude result:

DUCTILITY RATIO μ	FREQUENCY REDUCTION FACTOR $\frac{1}{\sqrt{\mu}}$	SPECTRAL PEAK REDUCTION FACTOR $\frac{1}{\sqrt{2\mu - 1}}$
1.0	1.0	1.0
1.1	0.95	0.91
1.2	0.91	0.85
1.3	0.88	0.79
1.4	0.85	0.75
1.5	0.82	0.71

Using the above factors, Figures 11 through 14 of the October 27, 1978 submittal can be re-plotted. The resulting spectra are shown in Figures 4-1 through 4-4. These revised response spectra have no impact on the results of analyses.

Since the Fuel Building remains elastic under the SSE load, and since the fundamental N-S mode, which governs the response of the structural complex in the N-S direction, is basically a twisting mode pivoting about the Fuel Building, any possible inelastic behavior of the Control Building in the N-S direction will not affect the Fuel Building. However, it may have some slight influence on the Auxiliary Building which is located between the Control and Fuel Buildings.

RESPONSE TO QUESTION 4 (continued)

The upper bound ductility ratio $\mu = 1.5$ used in assessing the nonlinearity effect on the Control Building N-S floor response spectra is based upon the most highly loaded wall (Wall 1) relative to its capacity. The use of $\mu = 1.5$ for the Control Building was for conservative purposes. In reality, Wall 1 cannot behave inelastically independent of the other part of the building complex and, as soon as inelastic response occurs, the seismic load will be reduced due to energy dissipation. Thus, considering the total system behavior of the structural complex, the ductility ratio for the total system will be much smaller than the upper bound value of 1.5 derived for Wall 1. Nevertheless, for the purpose of assessing any possible effect of the Control Building inelastic behavior on the Auxiliary Building, an upper bound ductility ratio of 1.2 is assumed. This value is based on the ratio of the horizontal N-S distance of Wall 1 and the centroid of the Auxiliary Building to the centroid of the elastic Fuel Building as shown in the following relationship:

$$\mu = 1.0 + (1.5-1.0)(88/223.5) = 1.19$$

Corresponding to this upper bound ductility ratio $\mu = 1.2$, the spectral peak frequencies will shift to the lower frequency side by a factor of $1/\sqrt{\mu} = 0.91$; and the spectral peak magnitude will be reduced by a factor of $1/\sqrt{2\mu-1} = 0.85$. Based on these factors, the Auxiliary Building N-S floor response spectra can be further widened to the lower frequency side. As an example, the resulting widened spectra for the Auxiliary Building El. 93' are shown in Figure 4-5 in broken lines. As can be seen from this figure, the effect is negligibly small.

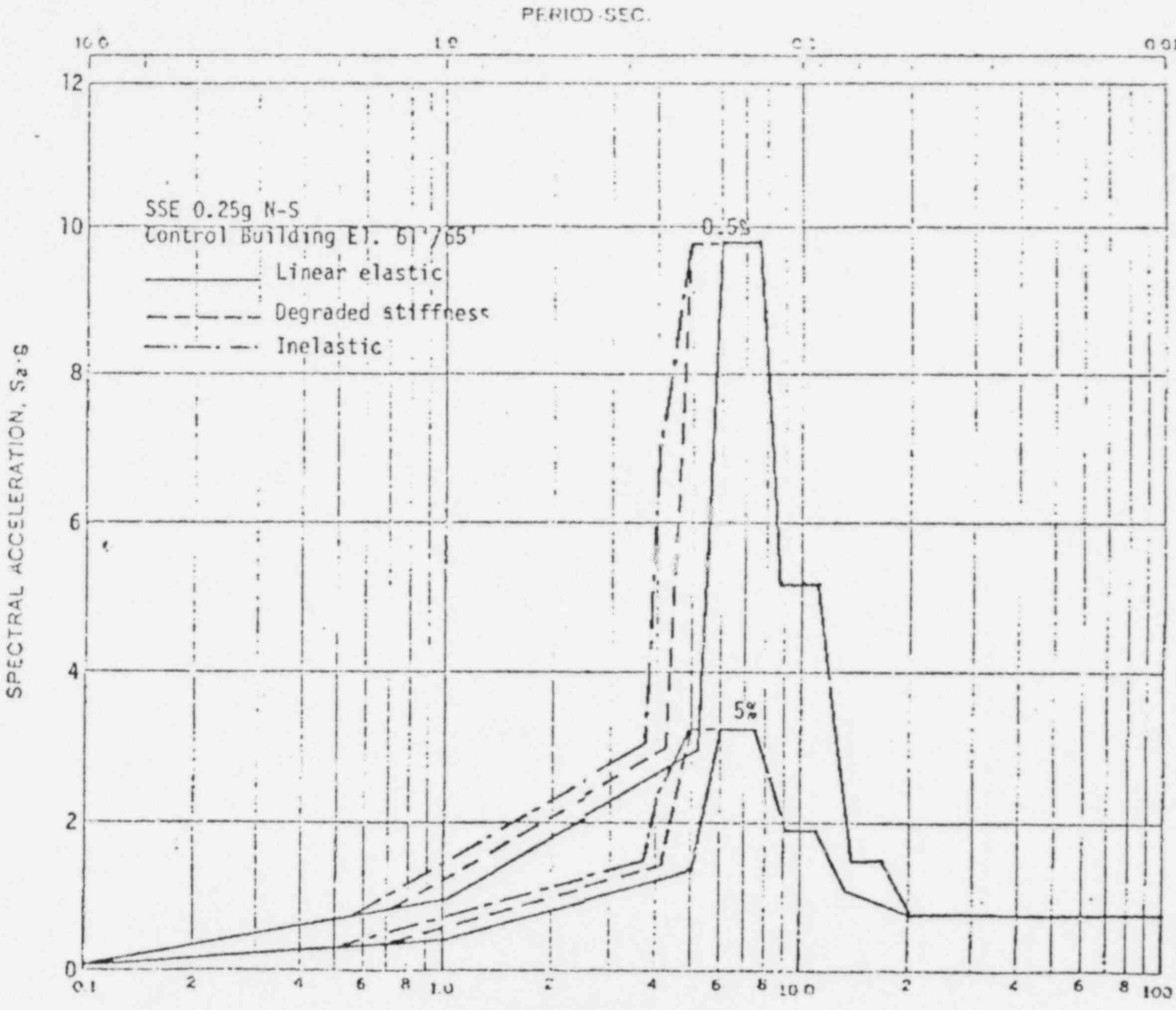
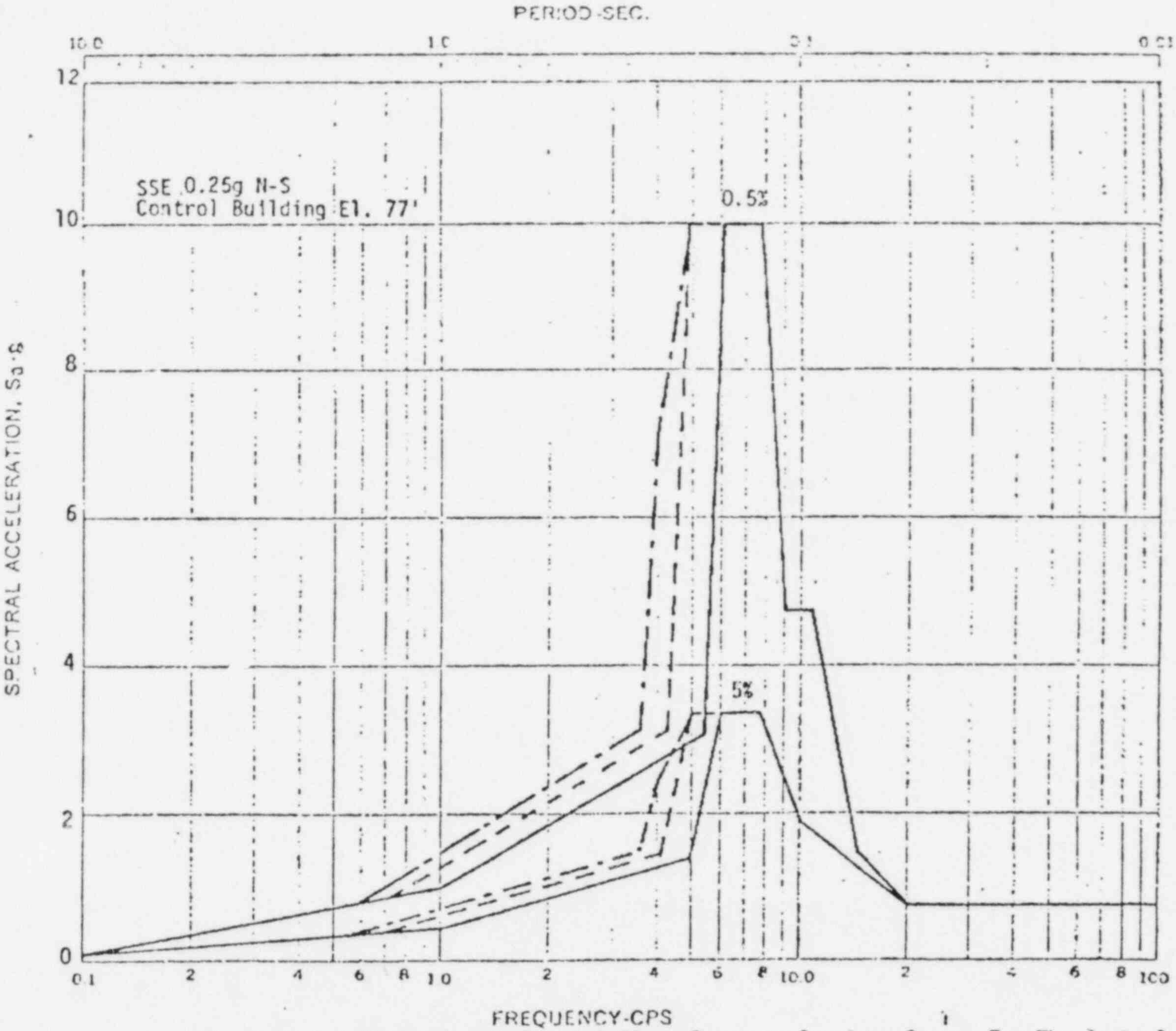


FIGURE 4-1

The 0.5% And 5% Damping Horizontal Floor Response Spectrum Curves For The Control Building El. 61'/65', SSE 0.25g, N-S Direction



The 0.5% And 5% Damping Horizontal Floor Response Spectrum Curves For The Control Building El. 77', SSE 0.25g, N-S Direction

FIGURE 4-2

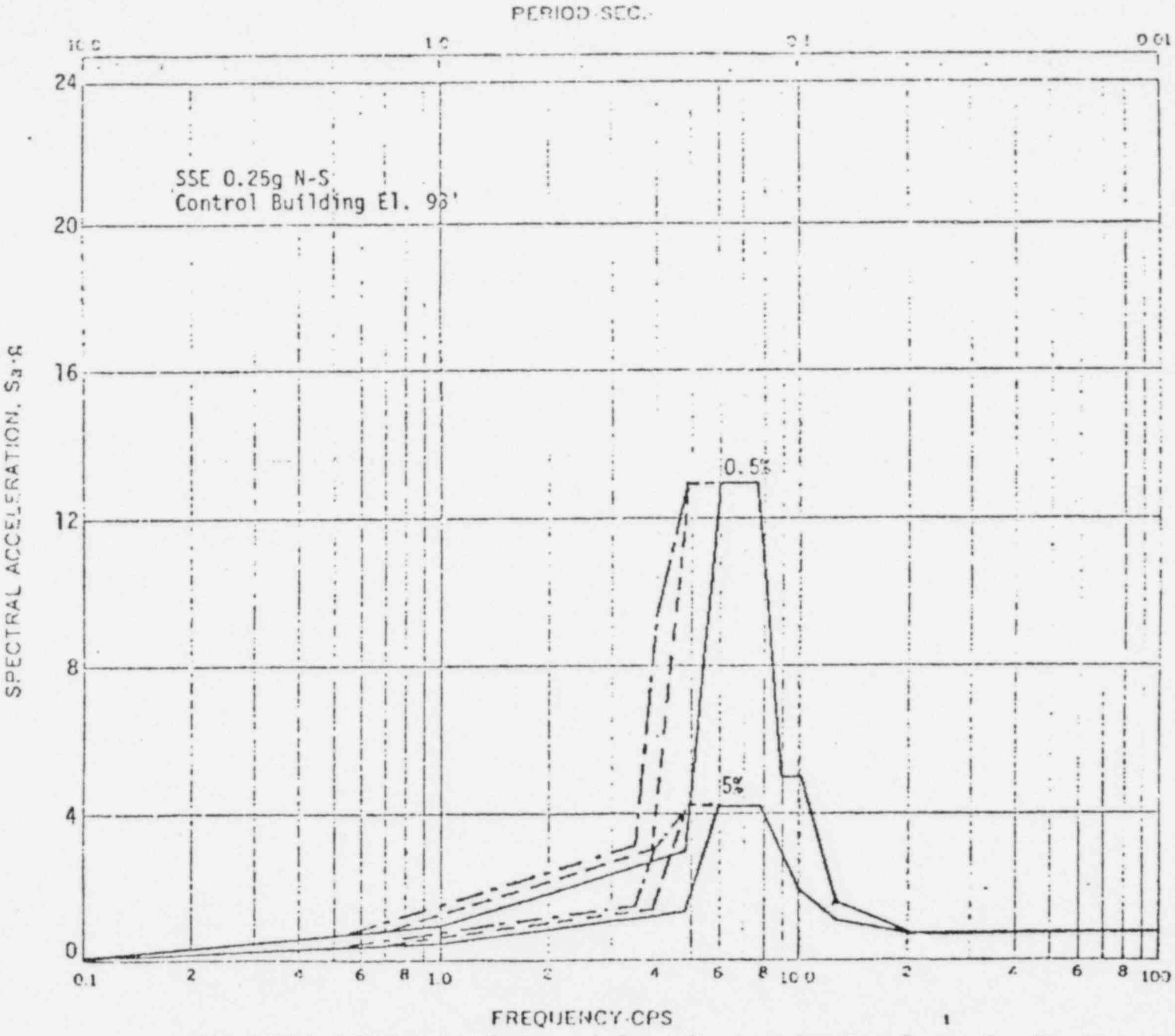


FIGURE 4-3

The 0.5% And 5% Damping Horizontal Floor Response Spectrum Curves For The Control Building El. 93', SSE 0.25g, N-S Direction

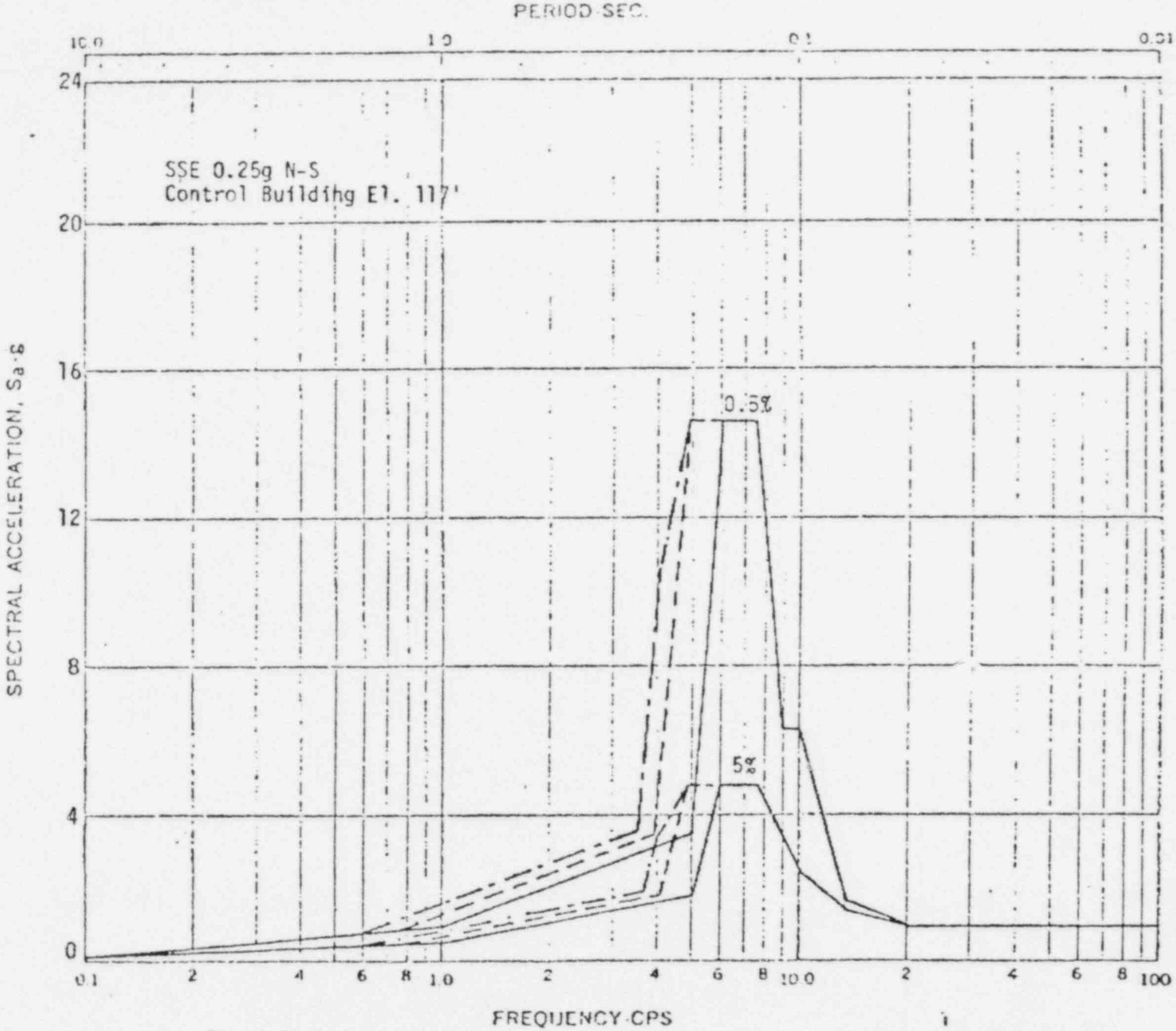


FIGURE 4-4

The 0.5% And 5% Damping Horizontal Floor Response Spectrum Curves For The Control Building El. 117', SSE 0.25g, N-S Direction

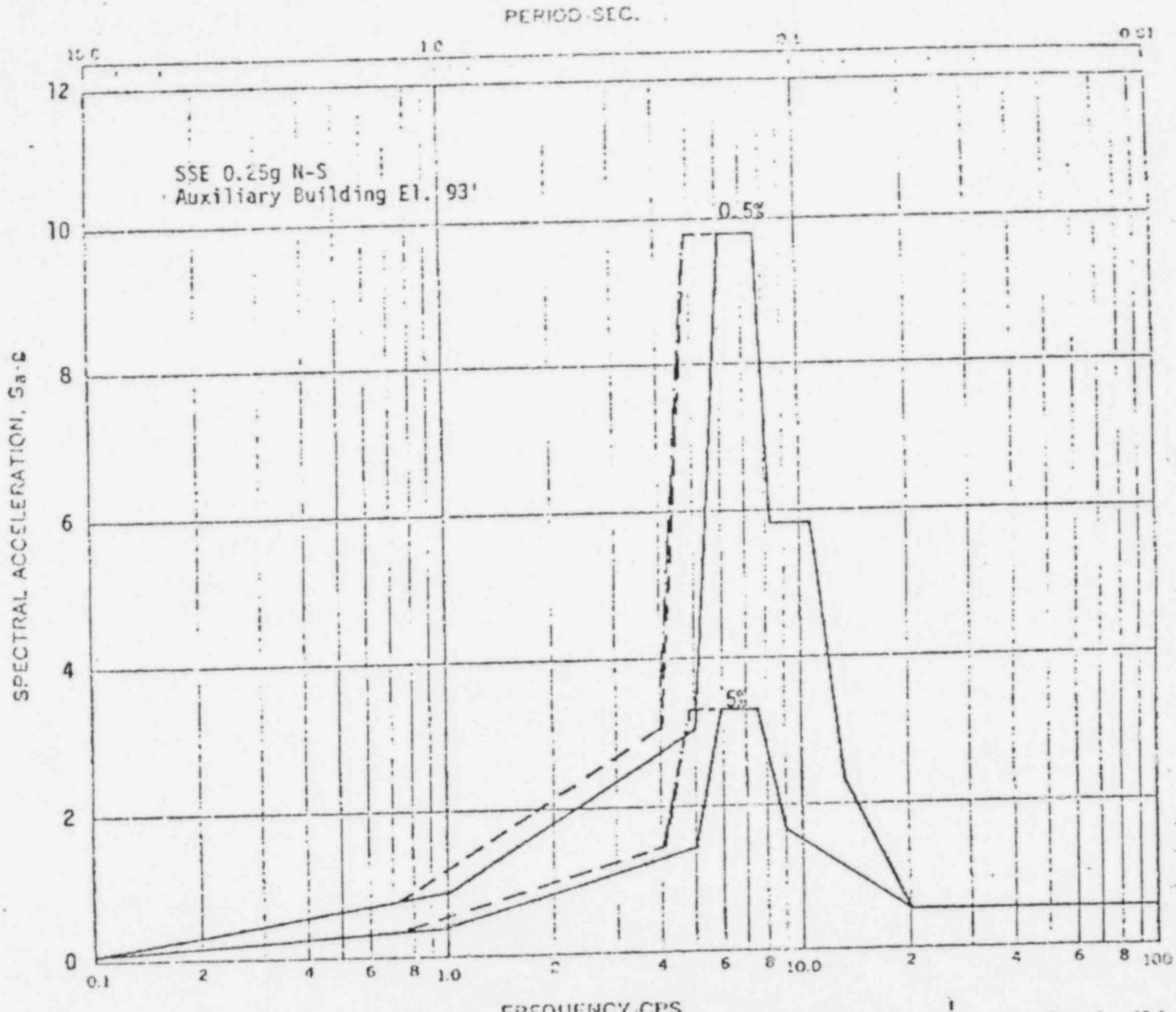


FIGURE 4-5

The 0.5% And 5% Damping Horizontal Floor Response Spectrum Curves For The Auxiliary Building El. 93', SSE 0.25g, N-S Direction

QUESTION 5

State the moduli of elasticity and the Poisson's ratios for the various floor slabs and wall types in the linear elastic STARDYNE analyses and provide your bases for these properties. Also, provide justification for the stiffness degradation factors reported in Table 4 (i.e., provide the relationships between stiffness degradation vs load for the various floor slabs and wall types corresponding to their location in the building complex) considered, and the bases for these relationships.

RESPONSE TO QUESTION 5

The moduli of elasticity used for the various floor slabs and wall types in the linear elastic STARDYNE analysis is based on ACI 318-71 relationship:

$$E = 57{,}000\sqrt{f_c'} \quad (f_c' \text{ in psi})$$

The Poisson's ratio for all walls and slabs is taken as 0.25. The elastic moduli are summarized in Table 5.1.

Table 5.1 Elastic Moduli

Concrete Slabs	$E = 4.03 \times 10^6$ psi for $f_c' = 5000$ psi
	$E = 3.12 \times 10^6$ psi for $f_c' = 3000$ psi
Concrete Walls	$E = 4.03 \times 10^6$ psi for $f_c' = 5000$ psi
Composite Walls	$E = 3.67 \times 10^6$ psi
Block Walls	$E = 2.85 \times 10^6$ psi for 2500 psi blocks
	$E = 2.55 \times 10^6$ psi for 2000 psi blocks

The maximum shear stresses averaged for the walls of an entire floor at a specific elevation are considered in determination of the stiffness reduction factors. The available experimental data indicates that the degradation of reinforced concrete is not as severe as that of masonry block walls. This is shown in Figure D-1 of Appendix D of the September 19, 1978 Supplemental Structural Evaluation. The composite stiffness was taken as the average of the reinforced concrete and masonry block stiffnesses. Considering the behavior of reinforced concrete, composite and block walls, different reduction factors are applied for walls at different elevations.

For the quasi-nonlinear analysis performed, the stresses that result from the analysis are the maximum stresses the walls experience during a very short duration of the response to a time history of an earthquake. Therefore, the reduced stiffness used in the analysis is the SECANT modulus as against the instantaneous stiffness. This is shown qualitatively in Figure 5-1.

The stiffness reduction factors are determined based on these considerations. For the Control Building walls (all are composite walls) at elevation 45'-77', in the N-S direction, the maximum stress levels are given in Table 3c-1 of the September 20, 1978 response to questions. Wall 1 and Wall 4 in the N-S direction are heavily stressed as given in Table 3c-1. Referring to Figure D-1 of Appendix D of the September 19, 1978 Supplemental Structural Evaluation, the cracked stiffness value of 0.45×10^6 psi is converted to 0.6×10^6 psi when effective thickness is considered. This corresponds to a stiffness reduction factor of 0.38 (elastic $G = 1.59 \times 10^6$ psi). The levels of shear stresses between elevations 77'-117' in the N-S direction and 45'-77' in the E-W direction of the Control Building range between 50-125 psi. Therefore, the reduction factor is taken as 0.6. The stresses in the composite walls of elevation 77'-117' in the E-W direction are much less. Considering small cracks and the resulting nonlinear behavior, the reduction factor is taken as 0.8.

In the Auxiliary Building the shear stresses of Wall 5, a composite wall, are in the 150 psi range (see Table 3c-1 of September 20, 1978 response). The reduction factor is taken as 0.45. At higher elevations, the shear stresses range between 50-75 psi. Therefore, smaller reduction factors (0.6 and 0.8) are used.

The Auxiliary Building block walls are expected to show more severe degradation corresponding to the stress level. For this reason stiffness reduction factors are taken as 0.2-0.4. However, the contribution of these walls to the overall stiffness and strength capacity is insignificant.

In the Fuel Building the shear stresses in all walls are low, ranging from 9 to 65 psi. Due to inherent nonlinear behavior (caused by formation of hairline cracks) experienced for reinforced concrete, composite and masonry walls, a constant reduction factor of 0.8 is applied for all walls.

No reduction was considered for the floor slabs due to the low stress levels and minor effects of the floor slab stiffness on the fundamental system frequency.

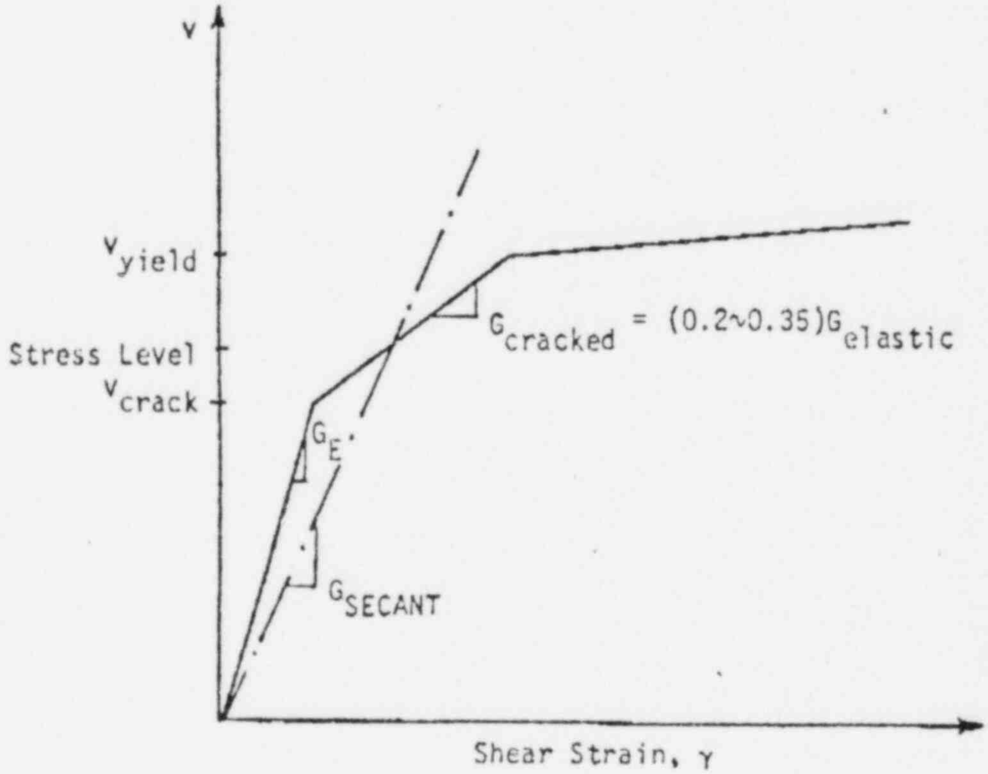


Figure 5-1 Qualitative Definition Of SECANT Modulus

Response to NRC Questions

QUESTION 6

Verify that the original vertical response spectra, considering all vertical building flexibilities, are adequate for the existing Control, Auxiliary, and Fuel Building complex. Also, verify that the vertical response spectra would not be significantly affected by the implications of the STARDYNE analyses, and any potential lateral stiffness degradation of the walls (as indicated in Appendices C and D of your September 29, 1978, submitted supplemental STARDYNE information), thereby significantly impacting the adequacy of the safety-related components, equipment, and piping in the building complex. Provide the appropriate bases for your conclusions.

RESPONSE TO QUESTION 6

The original vertical response spectra of the Control, Auxiliary, and Fuel Buildings were developed based upon the analysis of floor flexibilities. The wall systems are very rigid in the vertical direction as reflected by the high fundamental vertical frequencies: 20.7 cps for the Control Building, 24.6 cps for the Auxiliary Building, and 31 cps for the Fuel Building. At these frequencies, there is very little acceleration amplification in the design ground response spectra. Thus, the vertical response spectra are dominated by the more flexible floor responses, and the contribution due to the frequencies associated with the wall system are insignificant. The floor frequencies and the spectral peak frequency ranges of the original vertical floor response spectra are summarized as follows.

BUILDING	FLOOR ELEVATION (ft)	FLOOR FREQUENCY (cps)	SPECTRAL PEAK FREQUENCY RANGES (cps)
Control	61/77	9.0	8.0 - 11.0
	93	13.0	11.0 - 15.0
Auxiliary	77/93	9.1	8.2 - 11.4
Fuel	61	5.7	5.0 - 7.0
	77	5.8	5.0 - 7.0

As can be seen from the spectral frequency ranges shown above, the spectral peak widening is equal to or greater than $\pm 10\%$ in all cases. Therefore, the spectral peak widening is adequate. The spectral peak magnitudes of the original vertical response spectra were obtained from the time history analysis using the very conservative original synthetic time history. Therefore, the resulting SSE vertical spectra are very conservative.

The lateral stiffness degradation of walls as indicated in Appendices C and D of the September 20, 1978, submittal applies only to lateral deformations of the Control Building's N-S walls and carries no implication as regards the vertical wall stiffnesses. Since both the N-S and the E-W wall systems contribute directly to vertical stiffness of the Control Building, the vertical stiffness variation due to the lateral stiffness degradation, if any, for individual N-S walls would not significantly affect the total vertical wall stiffness of the Control Building. Furthermore, since the vertical responses are dominated by the more flexible floor responses, the effect of the vertical wall stiffness variation on the response spectra is even less.

As an illustration, considering the vertical floor response spectrum for the Control Building elevation 61 ft, and assuming that the total vertical wall stiffness is reduced by a factor of 0.8 for all elevations, the fundamental vertical frequency of the Control Building would be lower by a factor of 0.9, giving a frequency of 18.6 cps. The floor frequency for elevation 61 ft is 9.0 cps as shown previously. Thus, combining the 18.6 cps with the floor frequency of 9.0 cps gives the combined frequency for the floor at 8.1 cps as shown in the following:

$$[(1/9.0)^2 + (1/18.6)^2]^{-1/2} = 8.1$$

This is still within the original vertical spectral peak frequency range (8.0 cps to 11.0 cps).

Based on the considerations stated above, it is concluded that with some limited vertical wall stiffness reduction, the original vertical response spectra would not be significantly affected.

Response to NRC Questions

QUESTION 7

Provide the final results of your revaluation of safety-related equipment, components, and piping. Also, indicate the number of additional restraints added to each of the safety-related systems.

RESPONSE

Our response of October 27, 1978 confirmed the seismic capability of the mechanical and electrical equipment and components including cable trays in the Control-Fuel-Auxiliary building complex. Our response of October 27, 1978, also referred to continued, detailed analyses that would more accurately define the extent of modifications to existing pipe supports and the possible addition of restraints to "tune" the piping systems natural frequencies away from the building natural frequencies based on the new spectra. These analyses have been completed.

A total of 18 additional restraints will be added to the large piping (2" and larger) in the following systems as indicated:

Service Water	- None
Component Cooling Water	- Eleven
Safety Injection	- One
Residual Heat Removal	- None*
Auxiliary Feedwater	- None
Containment Spray	- Four
Containment Isolation	- None
Centrifugal Charging	- None
Chemical and Volume Control	- One
Waste Gas Decay	- None

*A continuation isometric that takes off from RHR through a closed valve will require one restraint, but this is not part of RHR, ECCS, or required for Safe Shutdown.

The capacity of the existing 772 supports on the piping in the systems listed above have been re-evaluated based on the new response spectra. Approximately 25% of these supports whose loads are slightly higher than the original design loads have been reanalyzed to determine whether the increased load is still within the allowable capacity of the support. Calculations have confirmed that 65 supports, or approximately 8% of the total, will require some minor modification. No additional restraints need to be added to any small piping that is required for ECCS or Safe Shutdown; however, approximately 15

RESPONSE TO QUESTION 7 (Continued)

additional holddown clamps will be added to peripheral piping indirectly associated with the ECCS and Safe Shutdown functions. (These additions will be mostly to highly ductile but los code stress allowable copper piping serving such items as small room coolers).