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ACRS (1)

NOV 24 1976

MEMORANDUM FOR: John F. Stolz, Chief
Light Water Reactors Branch No. 1
Division of Project Management

FROM: Dennis P. Allison, Project Manager
Light Water Reactors Branch No. 1
Division of Project Management

SUBJECT: SEISMIC REEVALUATION OF DIABLO CANYON NUCLEAR POWER PLANT

The enclosed material which had beeh provided informally by Pacific Gas and Electric Company was provided to the Advisory Committee on Reactor Safeguards for consideration at the Committee's meeting on November 13, 1976 concerning the Diablo Canyon plant.

Original Signed By
Dennis P. Allison

Dennis P. Allison, Project Manager
Light Water Reactors Branch No. 1
Division of Project Management

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November 8, 1976

D. P. Allison:

The enclosed materials will be discussed as time permits by Dr. John A. Blume at the November 13 ACRS meeting. Please distribute to the ACRS members and consultants in advance of the meeting. The documents are identified as follows:

1. Notes re L.A. ACRS Subcommittee Questions on Torsion.
2. Notes Regarding Acceleration and Probabilities of Same, including Figures C, 2A and 4.
3. Design Torsional Response Spectra Hosgri 7.5M . Blume.

Notes re Los Angeles ACRS Subcommittee Questions on Torsion

At the ACRS Subcommittee meeting in Los Angeles October 11, 1976, Dr. Luco questioned certain aspects of torsional response.

1. Apparently Dr. Luco was concerned that our computed fundamental torsional frequency of the containment shell was about 10 hertz while the computed fundamental frequency in translation was about 5 hertz. Our computations for the exterior containment structure, assuming a fixed base, provide the following periods:

	Translation	Torsion
Fundamental mode	0.203 sec	0.108 sec
2nd mode	0.074	0.037
3rd mode	0.048	0.023

The translational modes include the effects of shear and flexure. The torsional modes are, of course, only for torsional shear. The translational shear computation allows for the effectiveness of the cross-sectional shear area which constitutes a ring in which only half of the cross-section is effective in shear rigidity. It may be that Dr. Luco has not included the effect of shape on translational shear distribution and/or flexural deformations. The matter of the shear stress distribution coefficient has been considered by Timoshenko, von Kármán, Prandtl, and Jacobsen, among others.

The assumption of a fixed base is consistent with current NRC policy for rock material of the type found at this site. If base freedom were allowed with appropriate rock properties, the translational and torsional natural modes would have slightly greater periods.

2. Dr. Luco questioned the torsional response curves which showed values of superstructure torsional response about 2 to 2.5 times the torsional response of the base, for 7% damping. It was explained that the curves were approximations proposed for use in combining torsional and translational effects and that even considerable variations in the torsion would have minor effects in the overall results and the structures.

More rigorous methods are also being followed wherein rotational acceleration spectra are developed with the statistical treatment of the same earthquake records as used for translation. Smooth spectra are developed and a time history is then adjusted so as to closely reproduce that smoothed spectrum. This modified time history is then used with a torsional model of the structure to obtain the torsional responses of the various mass points of the models. The following tabulation shows the results from the dynamic analyses for various points in the containment shell and also those from Figure T1, the approximate procedure.

	Mass point	Height above base (ft)	Radius (ft)		Hosgri 7.5M tangential acceleration: From Figure T1 (g)		Hosgri 7.5M tangential acceleration: Dynamic Analysis (g)	
	1	213.1	9.3		0.08		0.09	
	2	185.8	56.5		0.48		0.55	
	3	169.7	65.8		0.53		0.60	
	4	142.4	71.75		0.55		0.61	
Ext.	5	117.0	71.75		0.52		0.54	
	6	92.5	71.75		0.48		0.46	
	7	67.3	71.75		0.42		0.36	
	8	42.0	71.75		0.35		0.25	
	9	21.1	71.75		0.30		0.13	
	Base	0	71.75		0.23			
					From Figure T2			
	1	51.4	15.1	51.5	0.10	0.33	.07	.24
Int.	2	25.4	15.1	51.5	0.08	0.29	.05	.16
	Base	0	15.1	51.5	0.05	0.17		

The results from the approximate method and dynamic analysis compare quite favorably in general. The approximate procedure was based partly on theory and partly on judgment and is therefore difficult to explain. Therefore, dynamic analyses will be made.

It should be noted that Dr. Luco's torsional work has largely been under the assumption of steady state forced vibration which results in considerably greater responses in most cases than using actual earthquake time histories or spectra made from them. Dynamic amplification factors for steady state conditions may well be 2 or more times those for earthquakes at the same frequency and with the same damping value such as 7% of critical.

3. The formula for base torque was also questioned. It involved both theory and judgment as outlined above, and it was part of the approximate procedure that apparently produces reasonable results as also shown above and is adequate for the stated conditions. However, in view of the difficulties in acceptance, it will be abandoned in favor of torsional spectra and analysis. This will probably not change the final results because torsion is generally not a significant factor when combined with translation on the square-root-of-the-sum-of-the-squares probabilistic procedure.

4. The question about base rotation also becomes academic in view of the above, and for the same reasons. Base rotation will be developed directly from the time histories of earthquake motion for cases where tau effects are considered. In this process rigid foundations will be assumed and filters will be used to obtain the torsional time histories.

JAB
11/2/76

(2)

DIABLO CANYON

NOTES REGARDING ACCELERATION AND PROBABILITIES OF SAME

Figure C is based on all earthquake magnitudes in the Hosgri zone up to a hypothetical maximum of 7.5. The rupture length is taken as log l = -4.8 + 0.9009M and the effective distance to the plant is taken from the nearest end of each rupture length. The return period was estimated on the basis of northern California data with a slope factor of -0.92 and one Hosgri event per ten years of magnitude ≥ 4.5. Given the events, magnitudes, distances and the site properties, the site accelerations were obtained by the Blume SAM IV and V procedures* as appropriate. The probabilities shown are joint based upon all the significant random variables in the problem.

A peak acceleration of 0.75g is 736 gals. From Figure C, this value would have a probability of being equalled or exceeded in a year of 1.2×10^{-5}, or the average return period would be 83,300 years.

Figure 2A shows the estimated probabilities of peak accelerations given certain magnitudes at only 8 km hypocentral distance from the plant. The SAM IV and V procedures are used, as appropriate for magnitude, together with the site impedance, ρV_s, of 12,000 fps.

Given a 7.5M hypothetical earthquake opposite the plant, the most probable peak acceleration would be 490 gals or 0.50g. A peak acceleration of 0.75g or 736 gals has a probability of being exceeded of 0.22 given the 7.5M right opposite the plant, an extreme assumption; the corresponding confidence level for 0.75g is 78%.

Figure 4 shows Blume SAM V curves for ρV_s taken at 2,000 fps and M = 7 which is the average magnitude for the circular and square points in the figure. The triangular points, for low magnitudes are to be ignored in this comparison. The points are from USGS Circular 672, Figure 3. The highest point represents the Pacoima Dam record and should be lowered to

*6WCEE paper

allow for the amplified response of the rocky ridge. The symbol y refers to the number of standard deviations above or below the mean for which y = 0. The conclusion to be drawn is that the SAM.V curves for the typical soil condition represented by the points provides good correlation of magnitude-distance-acceleration and probabilistic relationships.

JAB
11/8/76

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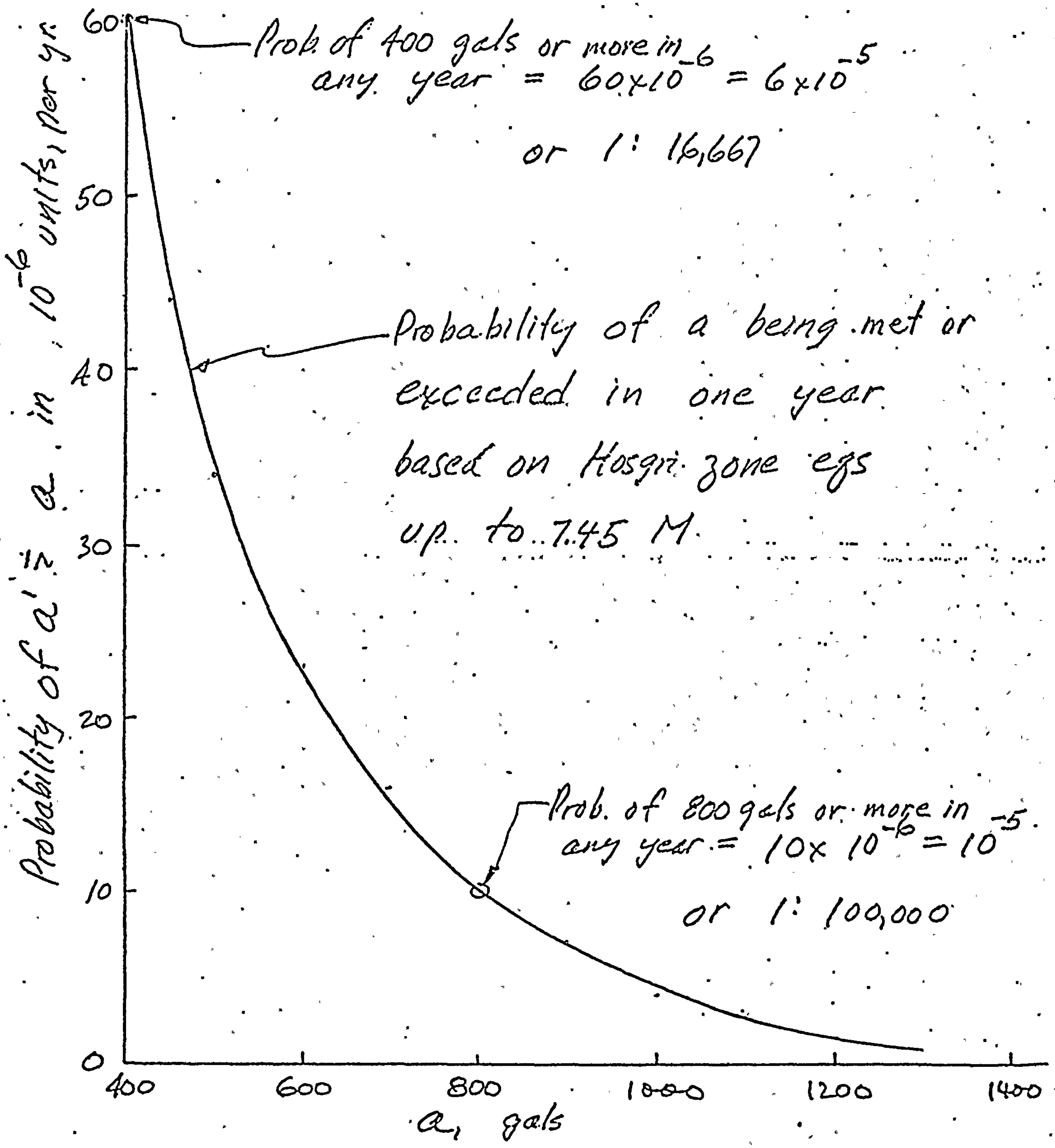
Jossie Street ··· Sheraton-Pala Hotel
San Francisco, California 94105

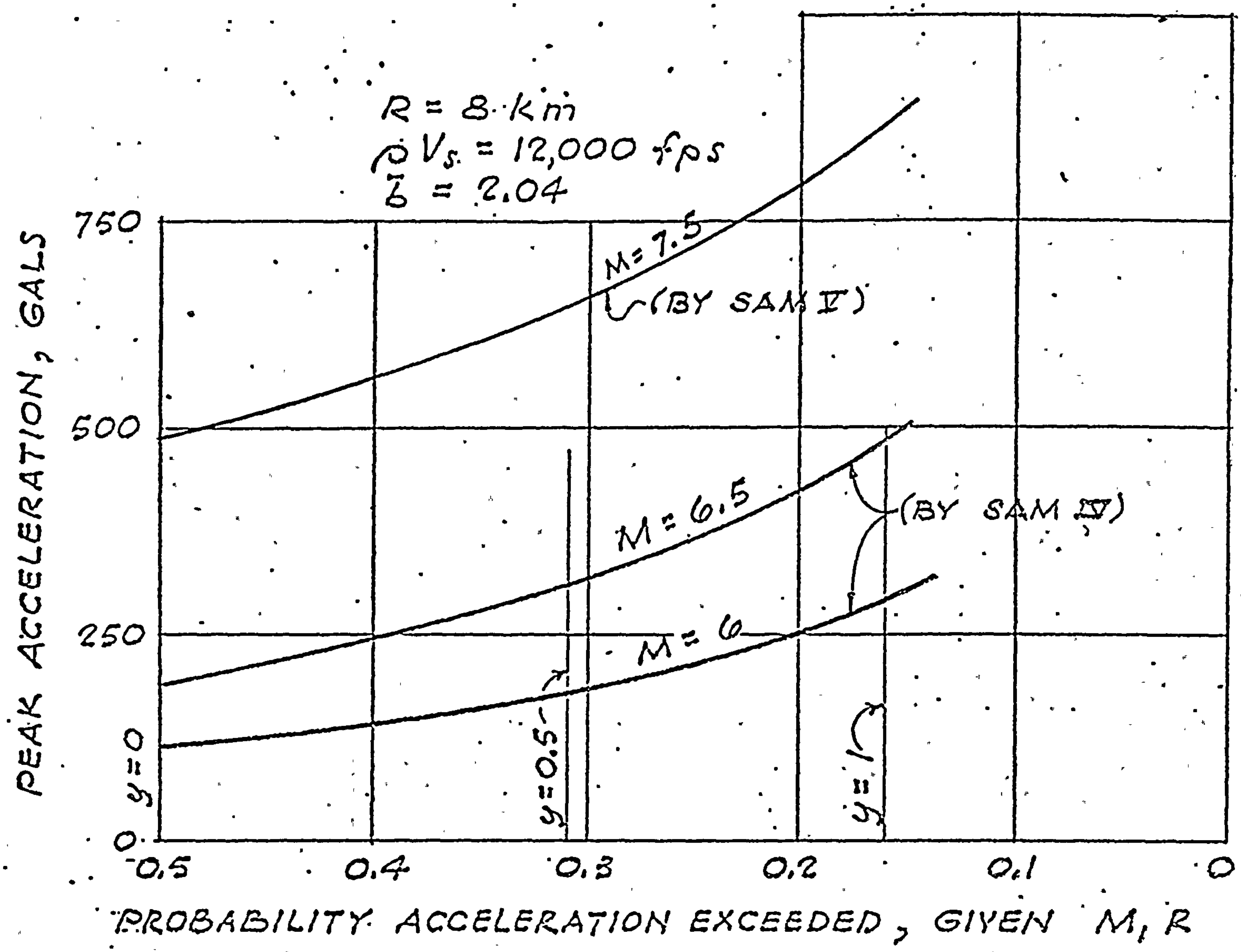
JOB NO. JOB DIABLO CANYON BY gab DATE 1/20/76
CLIENT SUBJECT HOSGRI ZONE EQS. CHK'D DATE



PROBABILITY OF PEAK ACCELERATION AT PLANT

SHEET NO.

FIG. C



HYPOTHETICAL EARTHQUAKE ACCELERATIONS

BY SAM IV & V

FIGURE 2A

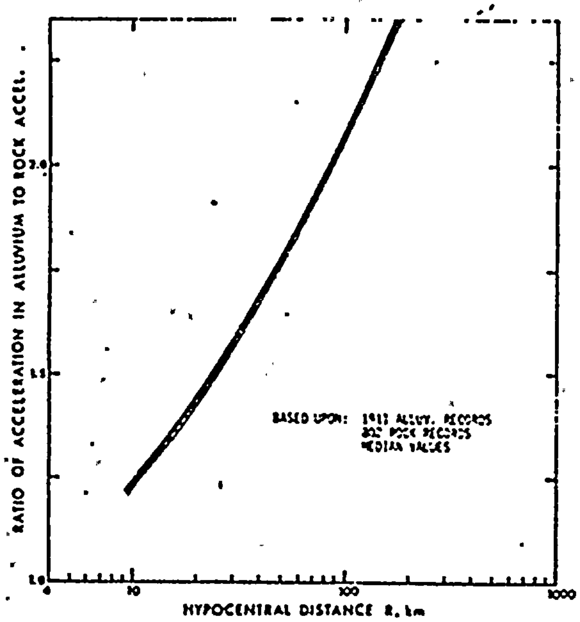


FIG. 1--ACCELERATION RATIOS FOR NUCLEAR EXPLOSIONS

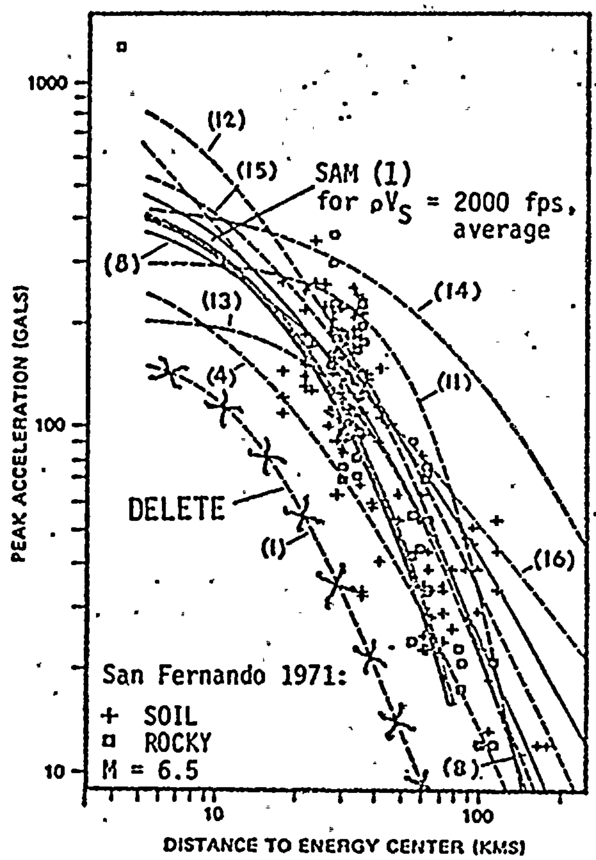


FIG 2--COMPARISON OF ORIGINAL SAM TO REFERENCE 8 DATA

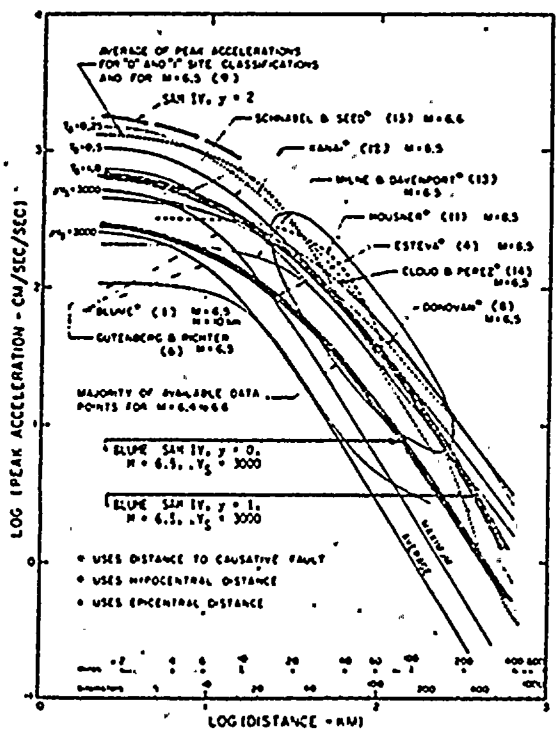


FIG 3--COMPARISON OF SAM IV TO REFERENCE 9 DATA

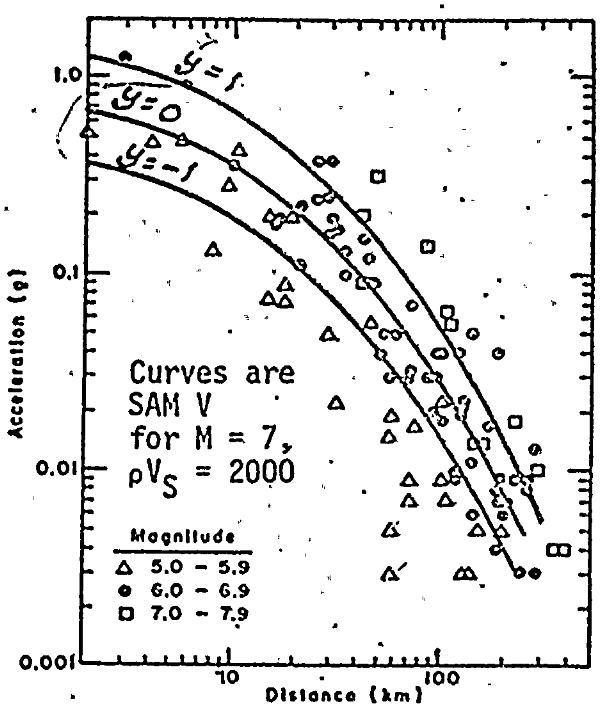


FIG 4--COMPARISON OF SAM V TO REFERENCE 10 DATA

PRELIMINARY

3

DIABLO CANYON

UNITS 1 & 2

DESIGN TORSIONAL RESPONSE SPECTRA

HOSGRI 7.5M BLUME

OCTOBER 25, 1976

PRELIMINARY

10/25/76

DIABLO CANYON UNITS 1 & 2

DESIGN TORSIONAL RESPONSE SPECTRA

HOSGRI 7.5M BLUME

Attached are the HOSGRI 7.5M/BLUME design response spectra to be used as torsional input to the structures. These are given for three values of τ (tau): $\tau = 0.04$ for Containment Structure, $\tau = 0.052$ for Auxiliary Structure, and $\tau = 0.08$ for Turbine Building. Torsional analyses of the structures are to be made with these spectra when the horizontal component response spectra for corresponding values of τ are used in the translational analysis.

The torsional response spectra represent the torsional motions induced in the rigid foundation, along with the high frequency filtered translational motions, when subjected to horizontally incident seismic wave with particle motion in the horizontal plane.

The particular design spectra are based on the eight components of earthquakes used in developing the design (horizontal) translational response spectra. The eight component time histories (normalized to 0.75g) were filtered through rigid foundation filters (with appropriate τ and vs) to obtain the corresponding torsional time histories. The mean + $1/2\sigma$ response spectra for 7% damping was obtained from statistics of the eight response spectra (7% damping) of these time histories. The 7% damping response spectra presented here are smoothed versions of these mean + $1/2\sigma$ spectra. Response spectra for other values of damping were obtained by appropriate scaling of the 7% damping spectra. These scaling factors are the same as those used for the translational spectra.

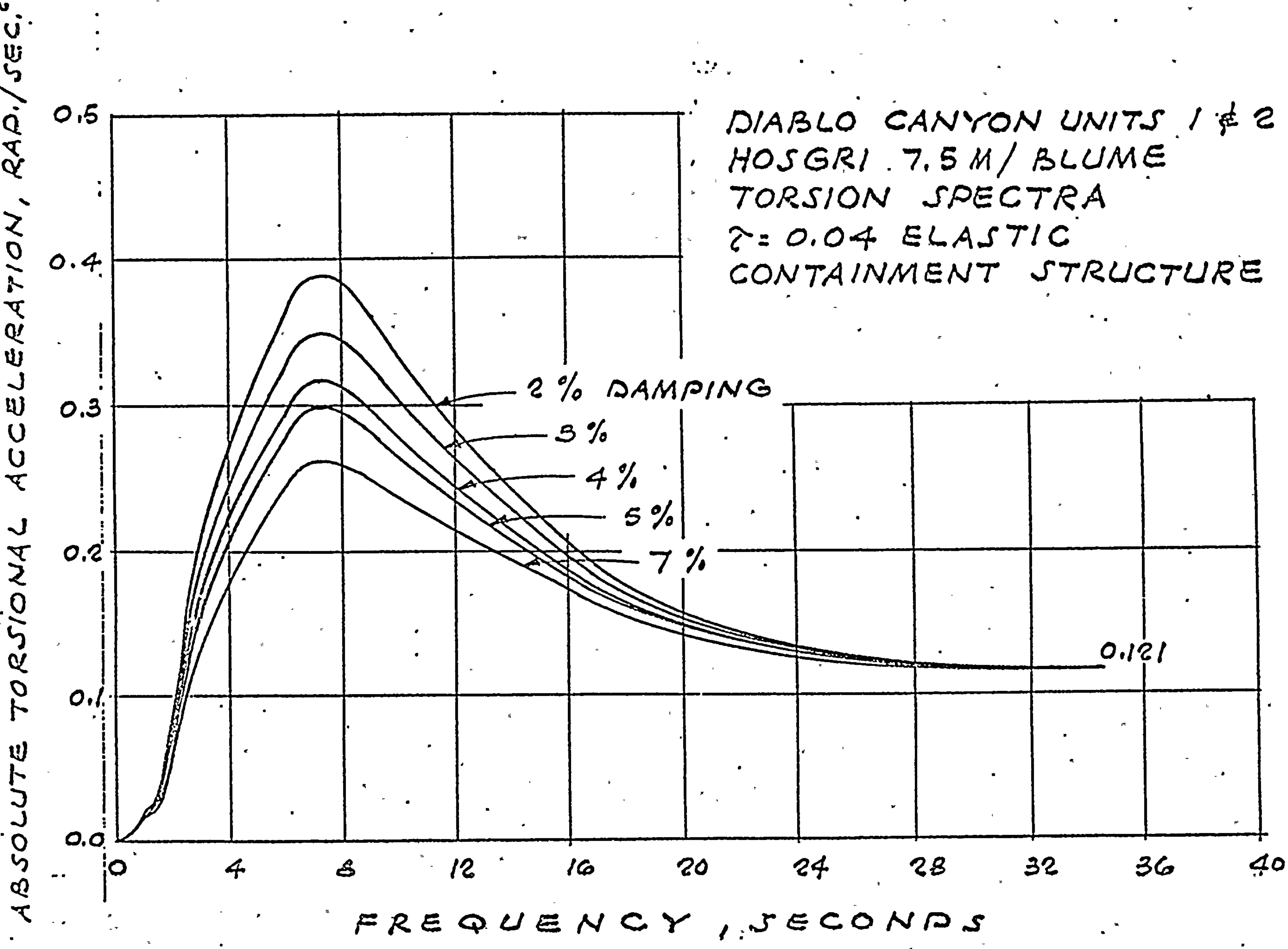

DIABLO CANYON UNITS 1 & 2
HOSGRI 7.5 M/ BLUME
TORSION SPECTRA
τ= 0.04 ELASTIC
CONTAINMENT STRUCTURE
2 % DAMPING
3 %
4 %
5 %
7 %
0.121
0.5
0.4
0.3
0.2
0.1
0.0
0
4
8
12
16
20
24
28
32
36
40
ABSOLUTE TORSIONAL ACCELERATION, RAD./SEC.²
FREQUENCY, SECONDS

FIGURE NO.——

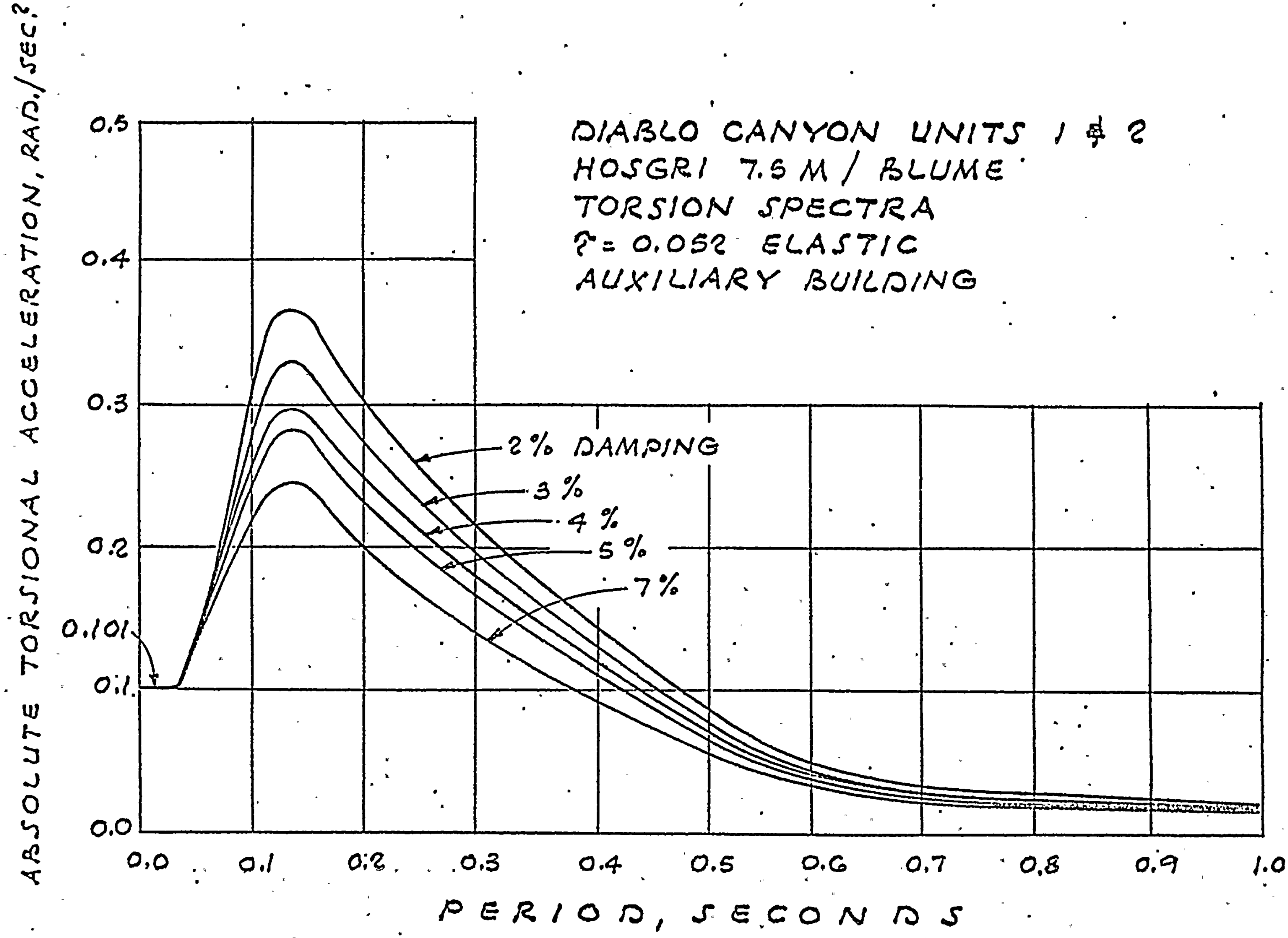
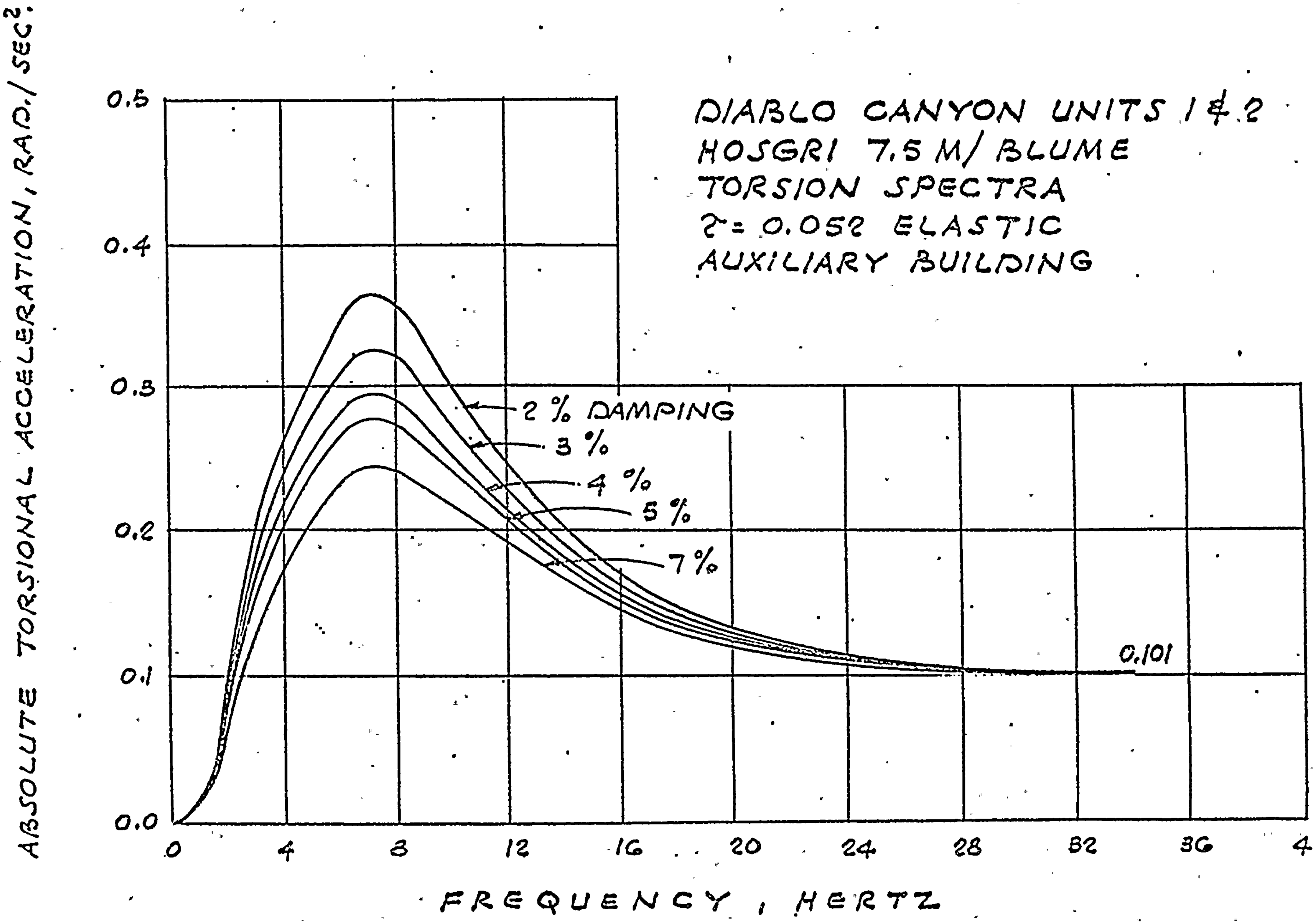
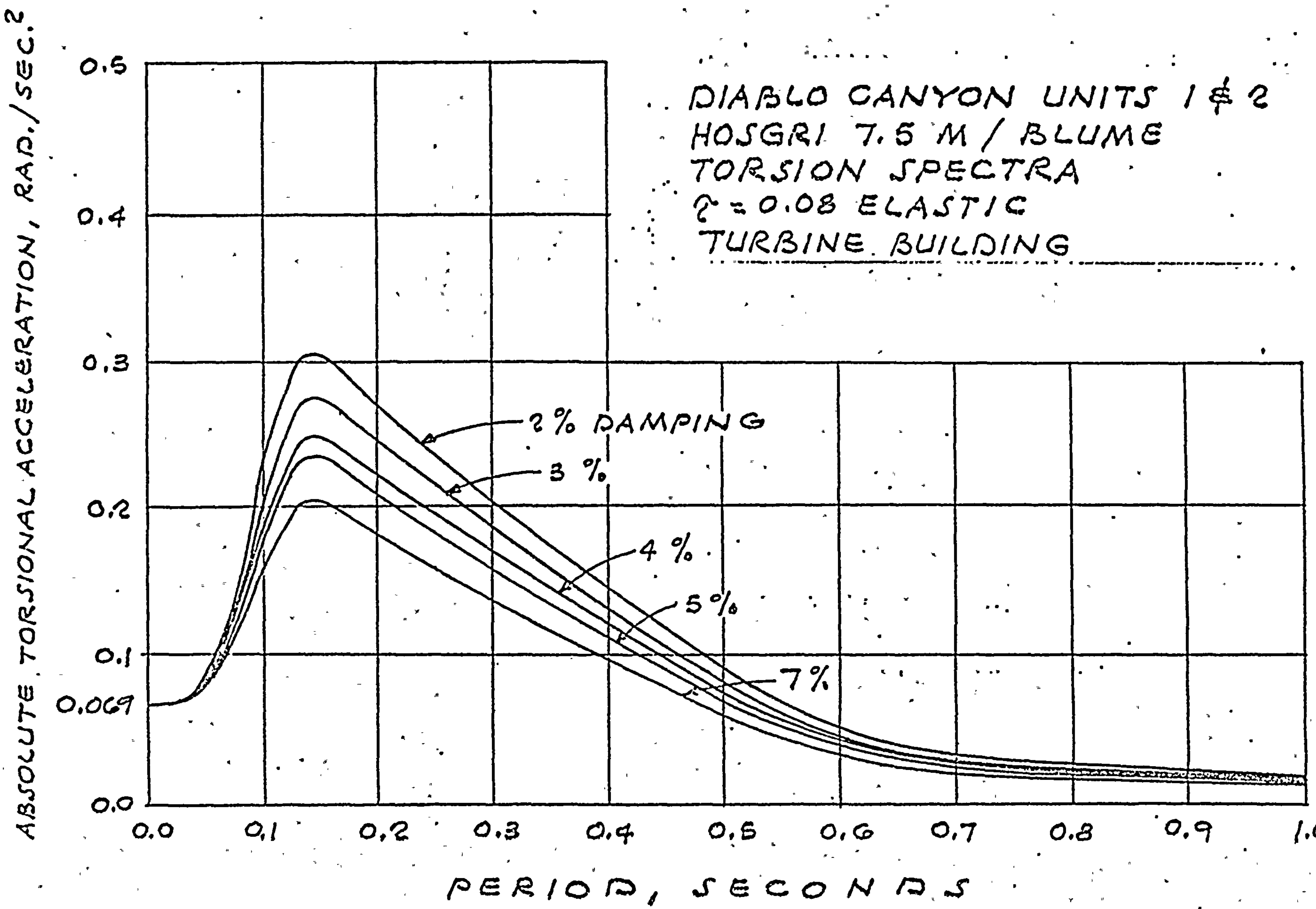

DIABLO CANYON UNITS 1 & 2
HOSGRI 7.5 M / BLUME
TORSION SPECTRA
ξ = 0.052 ELASTIC
AUXILIARY BUILDING
ABSOLUTE TORSIONAL ACCELERATION, RAD./SEC.^{2}
PERIOD, SECONDS
2% DAMPING
3%
4%
5%
7%
0.101
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

FIGURE NO.



DIABLO CANYON UNITS 1 & 2
HOSGRI 7.5 M/ BLUME
TORSION SPECTRA
τ = 0.052 ELASTIC
AUXILIARY BUILDING
ABSOLUTE TORSIONAL ACCELERATION, RAD./SEC.²
FREQUENCY, HERTZ
2 % DAMPING
3 %
4 %
5 %
7 %
0.101
0.0
0.1
0.2
0.3
0.4
0.5
0
4
8
12
16
20
24
28
32
36
40

FIGURE NO.



DIABLO CANYON UNITS 1 & 2
HOSGRI 7.5 M / BLUME
TORSION SPECTRA
ζ = 0.08 ELASTIC
TURBINE BUILDING
2% DAMPING
3 %
4 %
5%
7%
ABSOLUTE TORSIONAL ACCELERATION, RAD./SEC.²
0.5
0.4
0.3
0.2
0.1
0.069
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
PERIOD, SECONDS

FIGURE NO.

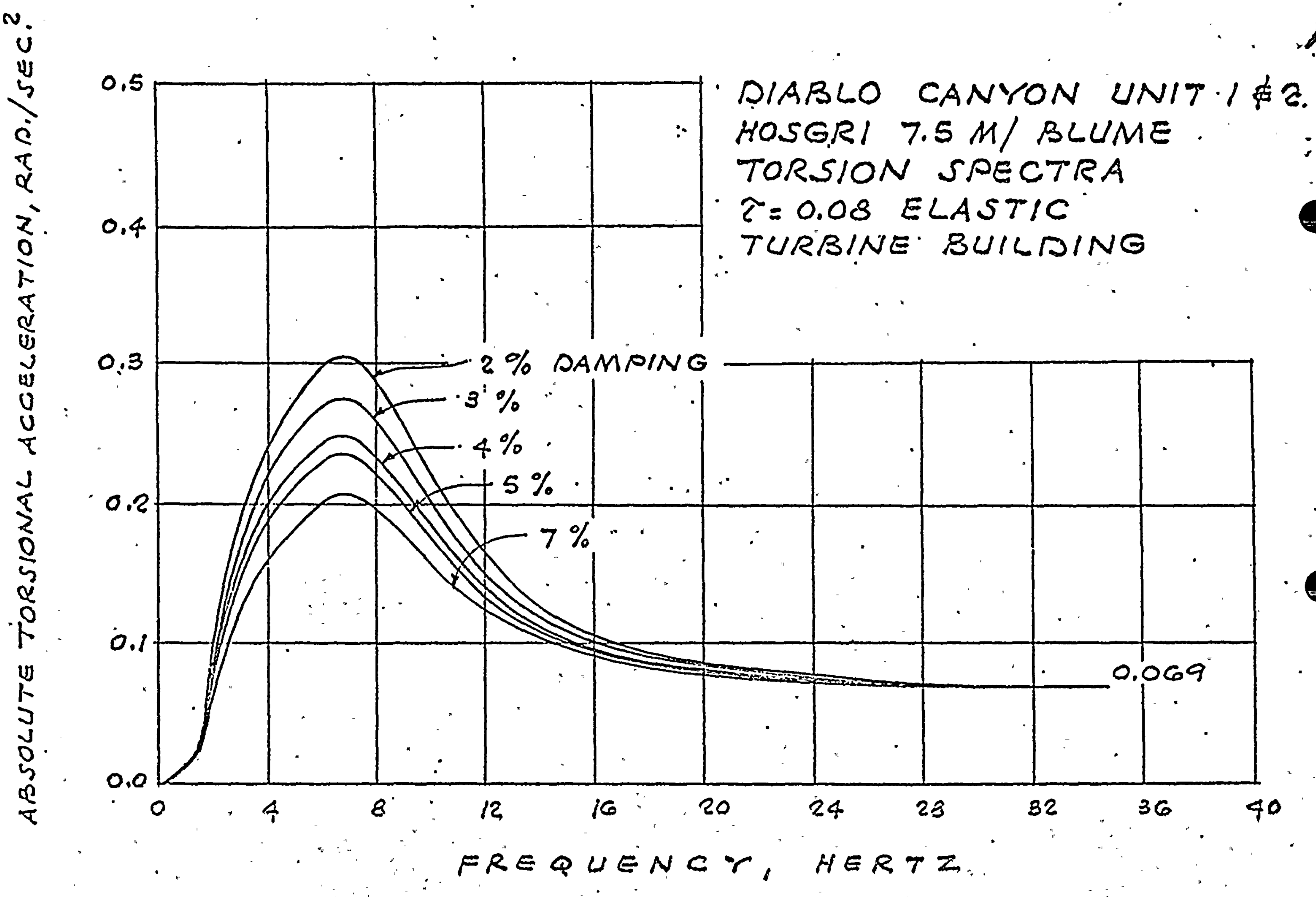

DIABLO CANYON UNIT 1 & 2.
HOSGRI 7.5 M/ BLUME
TORSION SPECTRA
τ = 0.08 ELASTIC
TURBINE BUILDING
2 % DAMPING
3 %
4 %
5 %
7 %
0.069
0.5
0.4
0.3
0.2
0.1
0.0
0
4
8
12
16
20
24
28
32
36
40
FREQUENCY, HERTZ
ABSOLUTE TORSIONAL ACCELERATION, RAD./SEC.^{2}

FIGURE NO.