TREATMENT OF EARTHQUAKE ACCELEROGRAMS

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INTRODUCTION

Engineers involved in structural design in earthquake areas are interested in the forces exerted on a structure during strong earthquakes. To evaluate these forces it is necessary to have records of ground motion during such earthquakes. The most convenient motion to record as far as further processing is concerned is ground acceleration. This motion is obtained by using short period pendulums which function as accelerometers.

The question might be asked, "Why do engineers have to obtain these records? Haven't the seismologists been obtaining this information for years?" In answer it should be pointed out that engineers and seismologists have different objectives. The seismologist is interested in general seismicity and also in the internal structure of the earth. He wishes to record as many earthquakes as possible, wherever they occur, and for this reason he uses sensitive instruments with high magnification (up to 100,000) operating continuously. Naturally enough when a strong earthquake occurs near such an instrument the record goes off scale and information useful to the engineer is lost. The engineer on the other hand is concerned with the effects of strong earthquakes. He requires a much reduced sensitivity and, to save recording media, an instrument that operates only during strong ground motion.

This paper describes briefly instruments being used in the Territory to obtain ground accelerations and outlines the method of processing the resultant records. Results are presented for an earthquake felt in Lae on 2nd August 1969.

ACCELEROGRAPH

The instrument being used to obtain accelerations is the MO2 Accelerograph manufactured by Victoria Engineering in New Zealand. This is the cheapest available accelerograph and was designed by R. I. Skinner and P. C. Duflou who were both with D.S.I.R., New Zealand (Ref.1). A survey of world instruments appears in Ref. 2.

Two accelerographs have been installed on campus in Lae and a network of these instruments is being installed throughout the Territory by the Bureau of Mineral Resources. The instrument is triggered by a vertical acceleration of approx. 0.01g and runs for 45 seconds. Three short period pendulums (T = 0.03 sec) with mirrored surfaces reflect a light beam and trace three components of acceleration (two horizontal, one vertical) on 35 mm film. A fourth, stationary, mirror produces a reference trace.

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TREATMENT OF ACCELEROGRAM

1. Digitizing.

Before computer processing can be performed it is necessary to produce a digital record of each trace (x, y co-ordinates). At present this is being done by means of a co-ordinate measuring microscope but plans are in hand to purchase more sophisticated equipment which will give better accuracy and easier operation.

With the co-ordinate microscope the operation is tedious and time consuming.

2. Integration.

In an endeavour to obtain maximum information the record is integrated twice to give velocity and displacement. As part of this process a baseline is fitted to the digitized data. Simpson's Rule is used for the integration and the acceleration trace is assumed to be linear between data points.

3. Structural Response.

For an elastic single-degree-of-freedom structure the response of the structure to the ground motion is given by the equation :

$$\ddot{x} + 2\eta\omega\dot{x} + \omega^2 x = -a(t)$$

where x is the displacement relative to the ground

η is the damping factor

ω is the natural circular frequency

$a(t)$ is the ground acceleration

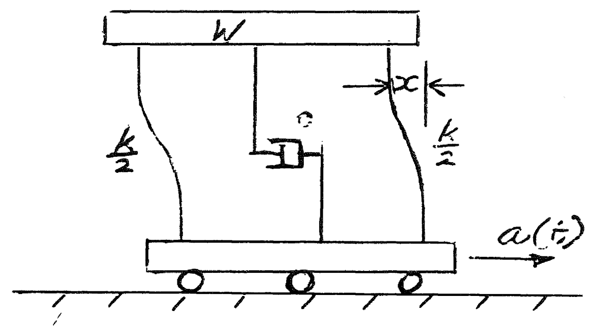

FIGURE 1.

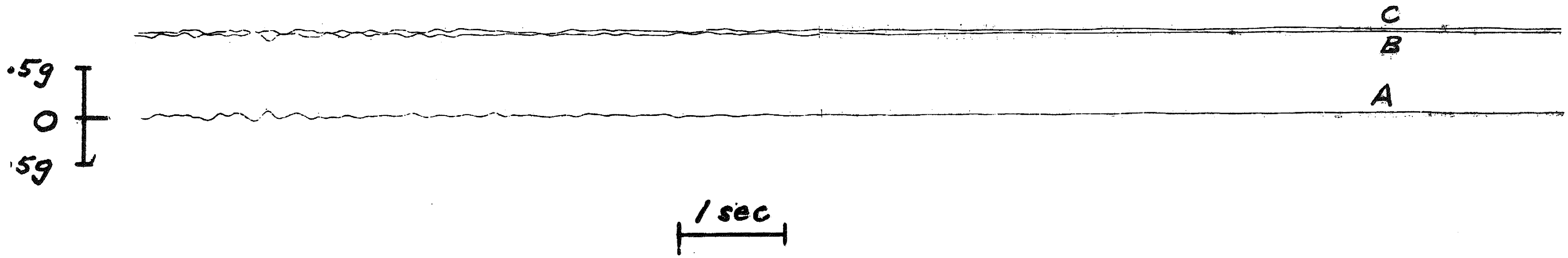

Figure 3. ACCELEROGRAM
2nd August 1969 2.31 pm

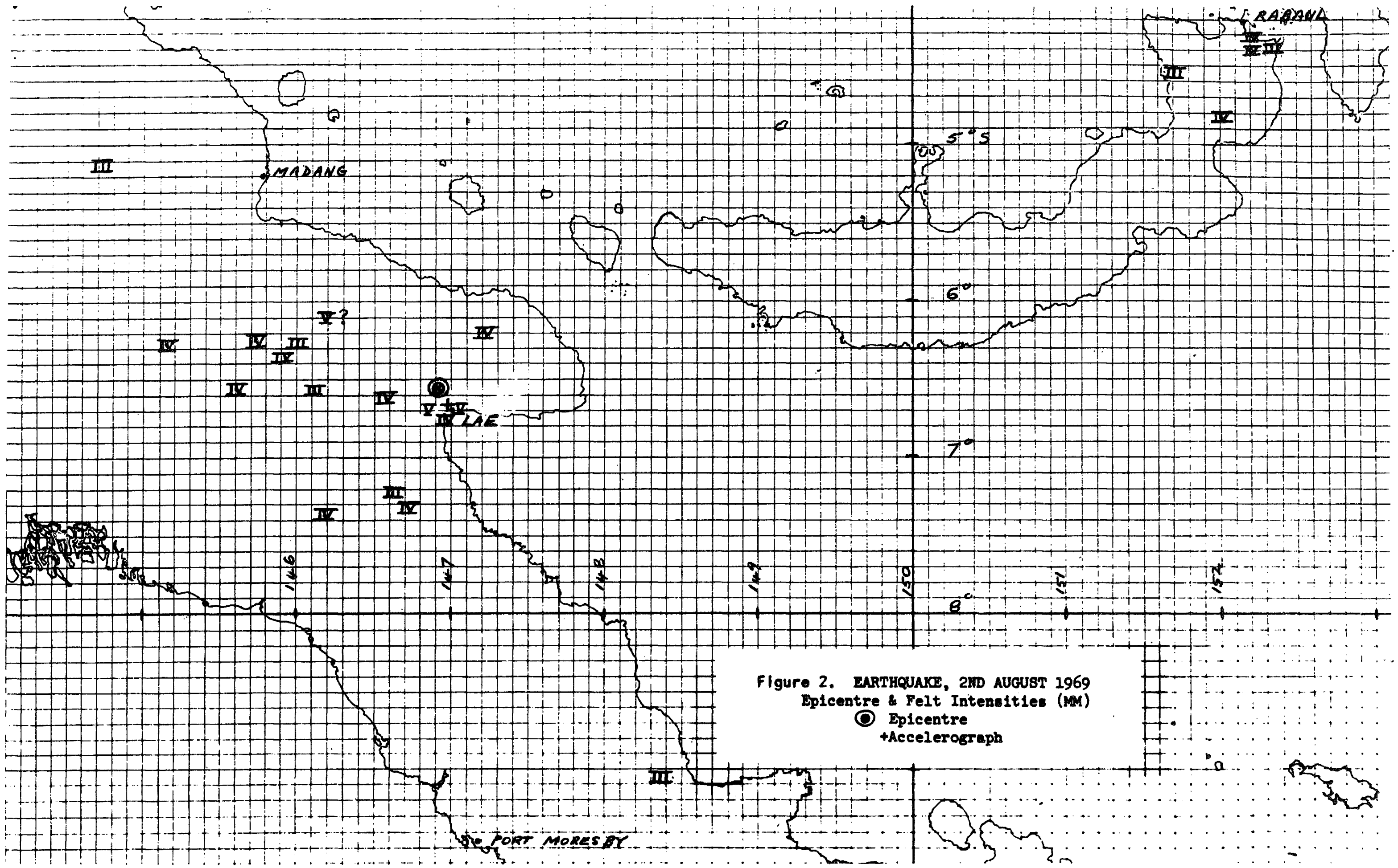

Figure 2. EARTHQUAKE, 2ND AUGUST 1969
Epicentre & Felt Intensities (MM)
◉ Epicentre
+Accelerograph

For a given structure (i.e. period and damping defined) it is possible to determine the values of relative displacement, relative velocity and absolute acceleration as a function of time. The relative displacement is obtained from the expression

$$x(t) = \frac{-1}{\omega_1}\int_0^t a(\tau)\, e^{-\eta\omega(t-\tau)} \sin \omega_1 (t-\tau)\, d\tau$$

where $\omega_1 = \omega\sqrt{1-\eta^2}$

This expression may be expanded and integrated using Simpson's Rule.

4. Response Spectra

For the simple structure shown in figure 1 the period is calculated as

$$T = 2\pi\sqrt{\frac{W}{kg}}$$

and the base shear is given by $F = kx$

By obtaining an expression for k from the period formula the base shear may be re-written

$$F = \frac{W}{g}(\omega^2 x)$$

For design purposes the absolute maximum value is of interest and occurs when x (relative displacement) is a maximum.

The maximum value of x may be found for a range of periods and damping factors. The plot of these gives a response spectrum.

5. Computer Program.

A program has been written for the IBM 1130 computer and this performs steps 2, 3 and 4 as required. Full details of the calculations and a program listing appear in Ref. 3.

EARTHQUAKES, 2ND AUGUST 1969.

At least four earthquakes were felt in Lae on the 2nd and 3rd August 1969.

2nd August	2.31 p.m.
	2.35 p.m.
	4.37 p.m.
3rd August	12.15 a.m.

Two of these were strong enough to trigger the MO2 accelerograph in Lae (2.31 and 2.35) and results for the 2.31 p.m. quake are presented here.

The epicentre and the area over which the first two quakes were felt are shown in Figure 2.

Seismological data for the first quake are:

Date	2nd August 1969	
Origin Time	04 30 29.2 G.M.T.	
Hypocentre	(U.S.C.G.S. Solution)	
	Latitude	6.55°S
	Longitude	146.92°E
	Depth	17 Km
Magnitude		
	Local PMG	6.2
	USCGS m_b	5.3

The distance from the epicentre to the recording accelerograph was approximately 14½ miles, and part of the accelerogram is presented in Figure 3. The two horizontal traces were digitized and after fitting a baseline the accelerations are as shown in Figures 4 and 5.

Response calculations were carried out for the two accelerograms and the response spectra are plotted in Figures 6 to 9.

ACKNOWLEDGEMENTS

The seismological data and the copies of felt reports for the earthquakes of 2nd August were provided by the Observer-in-Charge, Port Moresby Geophysical Observatory. The work reported here was carried out in the Civil Engineering Department of the Papua and New Guinea Institute of Technology.

REFERENCES

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3. Boyce, W. H. Analysis of Earthquake Accelerograms. Bulletin No. 1, Civil Engineering Department, Papua and New Guinea Institute of Technology, 1970.

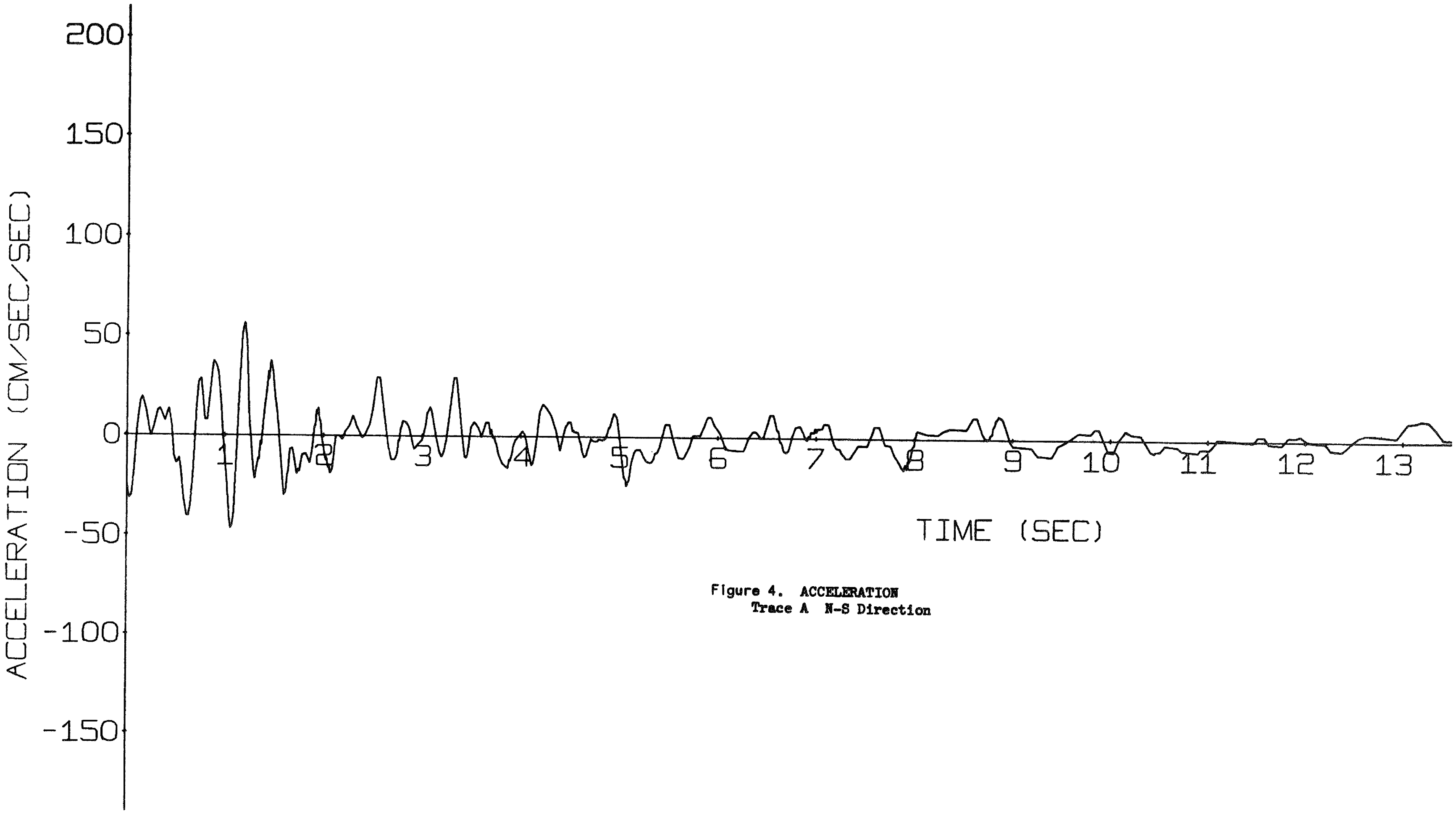

Figure 4. ACCELERATION
Trace A N-S Direction

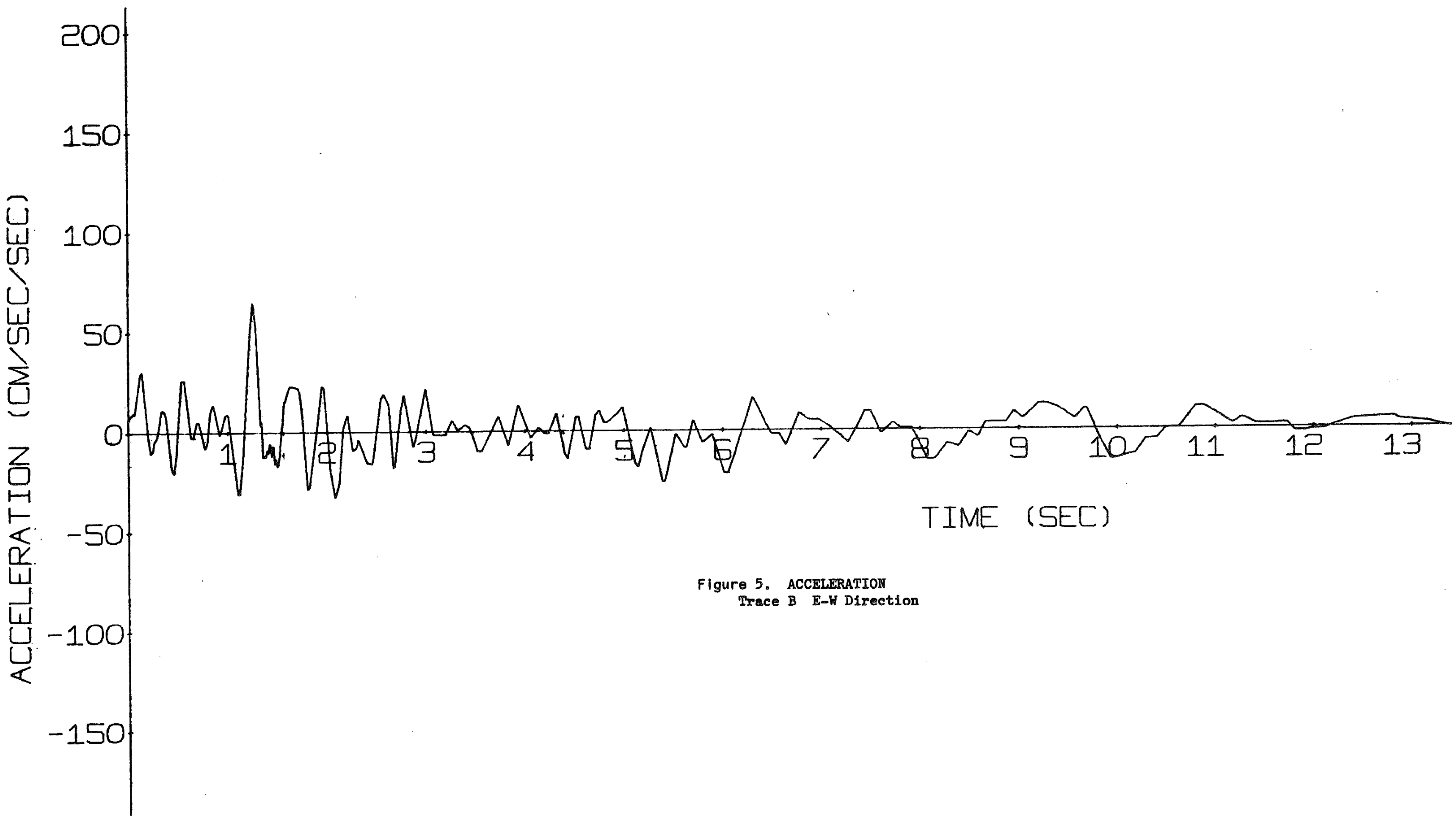

Figure 5. ACCELERATION
Trace B E-W Direction

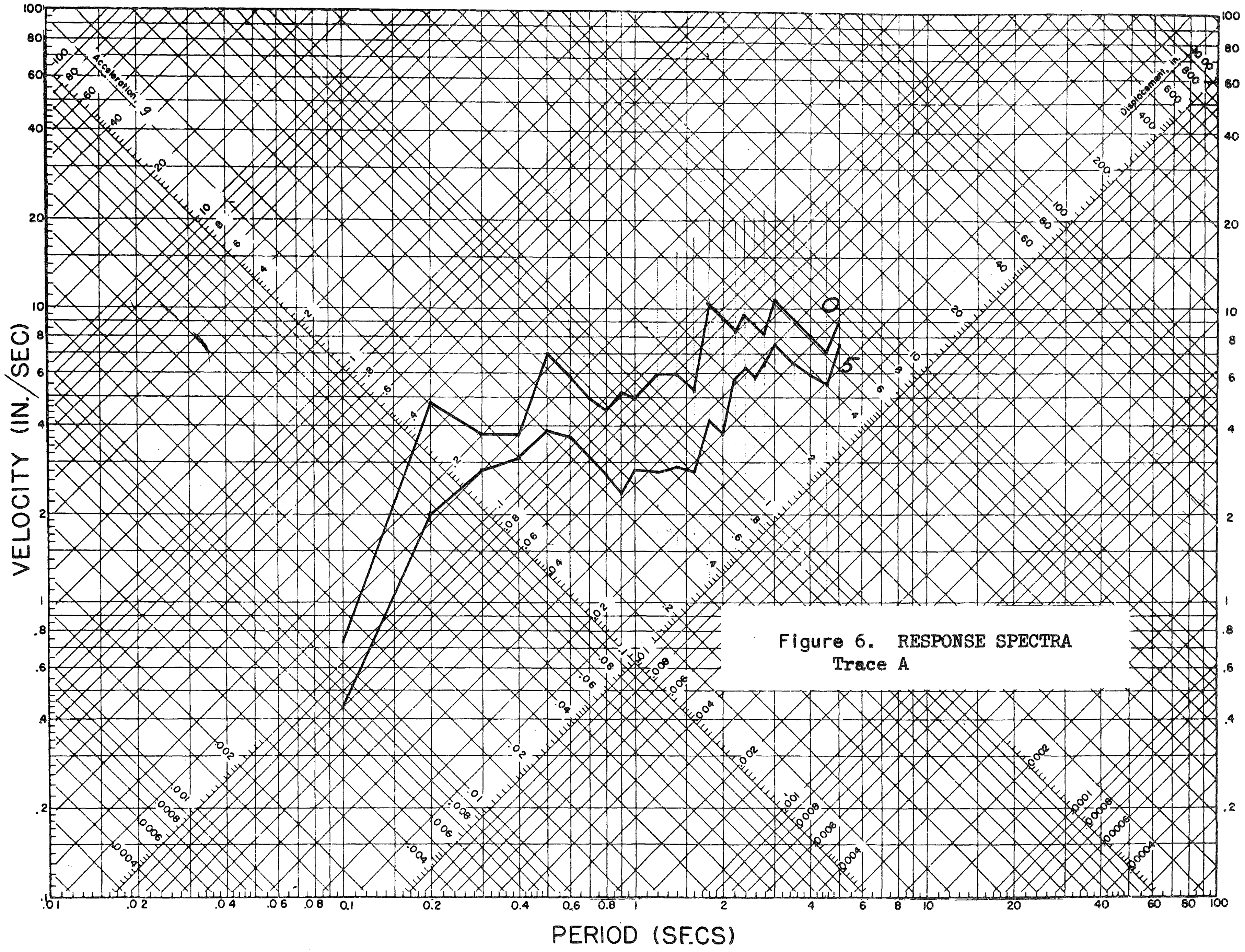

Figure 6. RESPONSE SPECTRA
Trace A

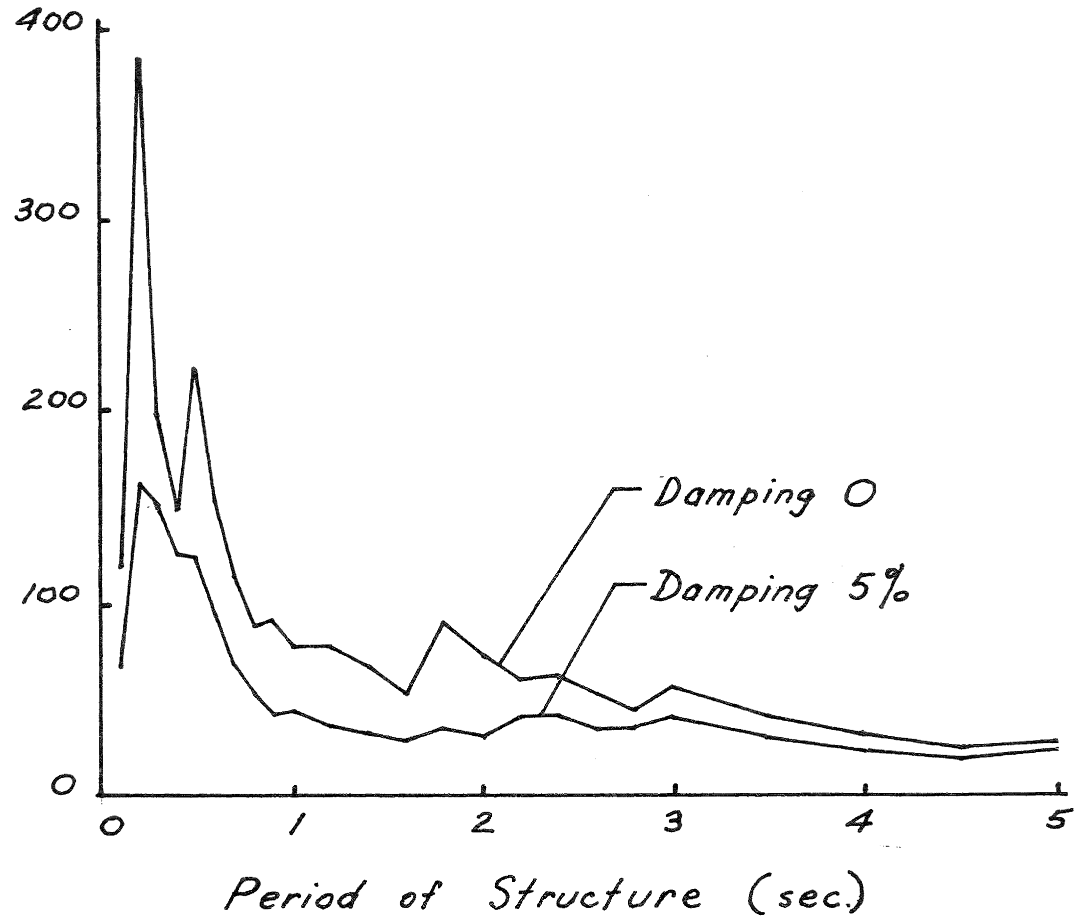

Figure 7. Response Spectra Trace A

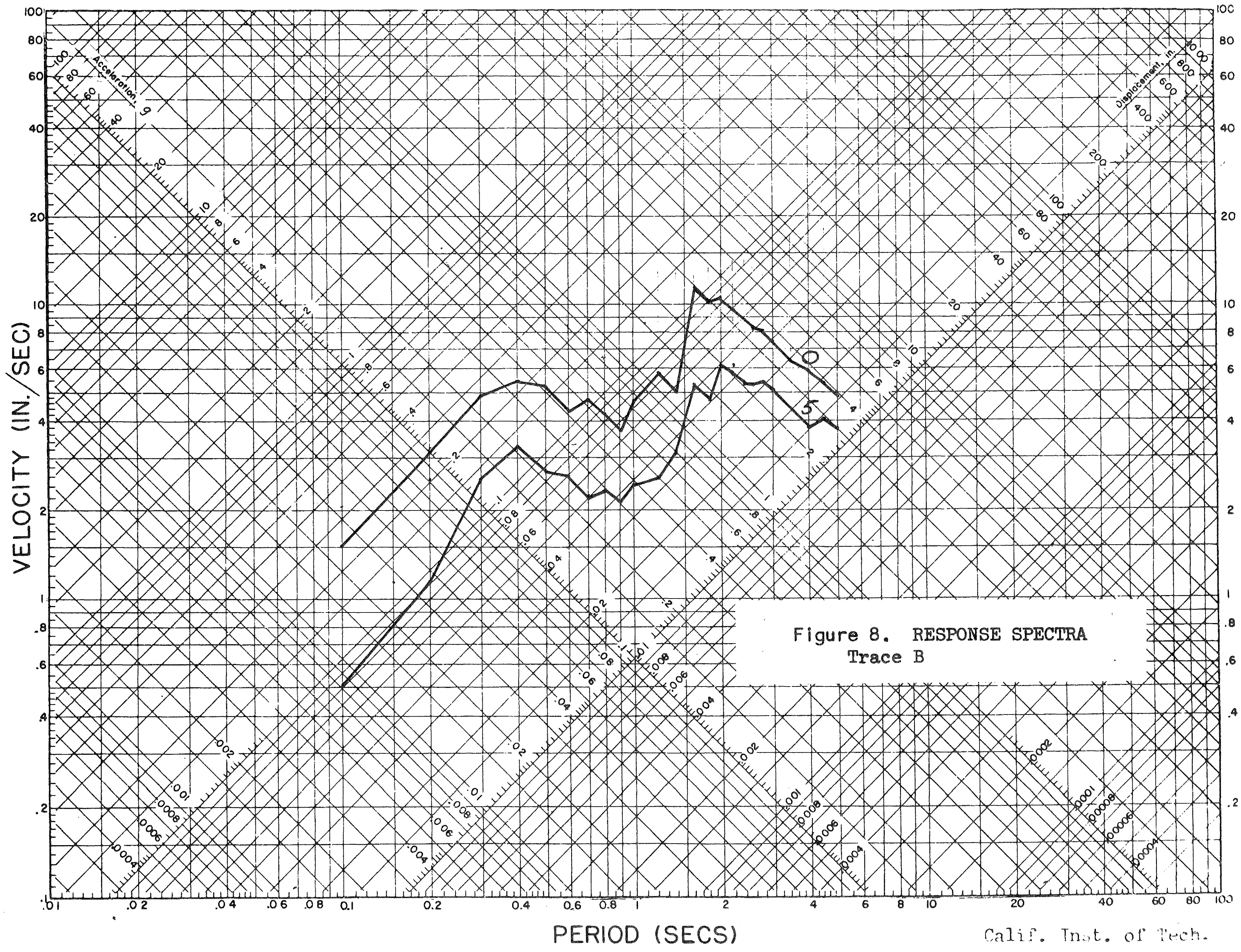

Figure 8. RESPONSE SPECTRA
Trace B

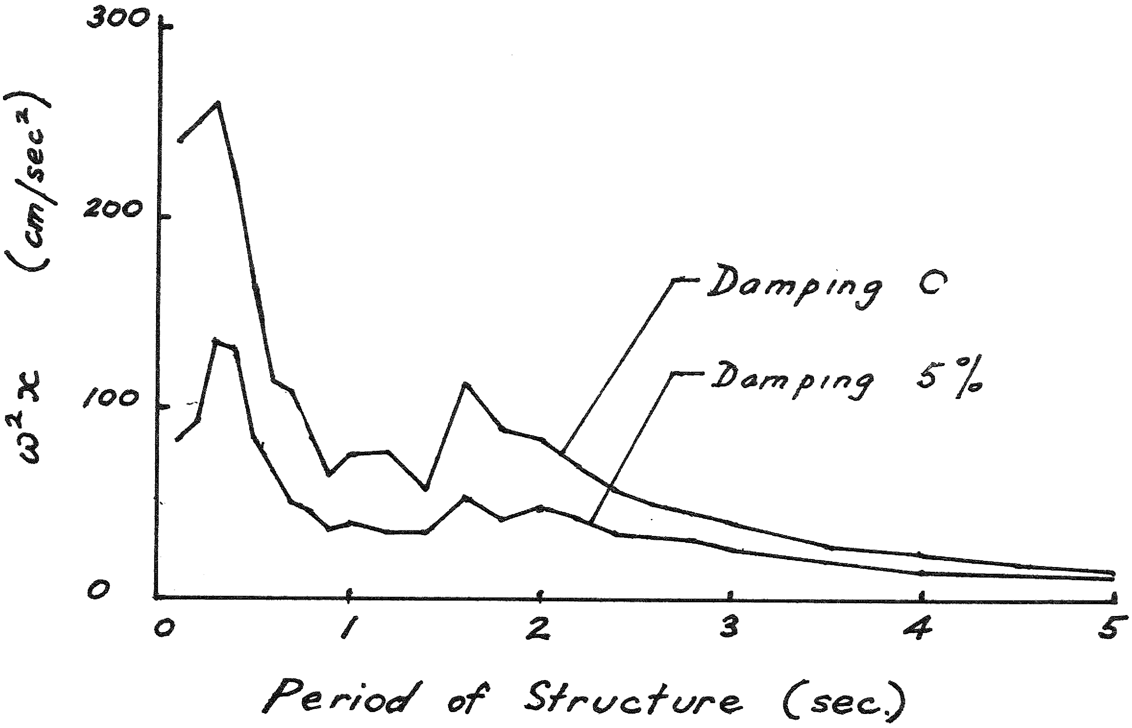

Figure 9. Response Spectra Trace B