OPTIMUM SEISMIC PROTECTION FOR NEW BUILDING CONSTRUCTION IN EASTERN METROPOLITAN AREAS

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Internal Study Report No. 17

GROUND MOTIONS MEASURED BY VM-1

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Field measurements of vibratory ground motions were carried out in the Boston, Massachusetts area using the portable VM-1 instrument to obtain acceleration records. This report describes the places where the data were obtained. It includes soil profiles and typical records of the motions. Some preliminary analyses of the data and conclusions are provided. Measurements of the ambient vibrations due to traffic were made at five sites. Two five pound dynamite charges were exploded in a boring near Site One as the signal for the measurements at Site Six. The explosions were at a depth of about 50 feet. They were set off between 5:00 and 6:00 A.M. to reduce background noise due to traffic. The profiles of these six sites are presented. The VM-1, Vibration Monitor, consists of an acceleration transducer acting as a sensor and a separate recording and filter unit. The recording is done on heat sensitive paper. Typical ambient motion records made at the first five sites are presented. The predominant frequencies picked out by the visual examination of the records are tabulated. The records from the dynamite explosions are presented and the predominant frequencies are tabulated.

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List of Internal Study Reports

1. R.V. Whitman, "Preliminary Work Plans and Schedules," August, 1971.

2. E.H. Vanmarke and R.V. Whitman, "Background for Preliminary Expected Future Loss Computations," October,1971.

3. P.J. Trudeau, "Identification of Typical Soil Profiles in the Boston Basin Area," November, 1971.

4. J.M. Biggs, "Comparison of Wind and Seismic Forces on Tall Buildings," December, 1971.

5. R.V. Whitman, "Contribution to State-of-the-Art Report of the Earthquake Committee of the IABSE-ASCE Tall Buildings Committee--Economic and Social Aspects," March, 1972.

6. J.E. Brennan and R.J. McNamara, "Inventory of Buildings for Boston and Cambridge," April, 1972.

7. C.A. Cornell and H.A. Mertz, "Analysis of the Seismic Risk on Firm Ground for Sites in the Central Boston Metropolitan Area," January, 1972.

8. R.V. Whitman, J.W. Reed, P. Marshall, "1967 Caracas Venezuela Earthquakes," May, 1972.

9. R. V. Whitman, E.H. Vanmarke, "Damage Statistics from Japanese Earthquakes," May, 1972.

10. E.H. Vanmarke, J.W. Reed, and D. Roth, "Evaluation of Expected Losses and Total Present Cost: Preliminary Sensitivity Analysis," July, 1972.

11. R.V. Whitman, et al., "1964 Alaskan Earthquake Tall Building Damage Review," July, 1972.

12. R.V. Whitman and J.W. Reed, "San Fernando Earthquake Data Base Computer Storage Format," August, 1972.

List of Internal Study Reports

Continued

13. J.W. Reed, and R.V. Whitman, "San Fernando Earthquake Damage Statistics," August, 1972.

14. R.V. Whitman, and S. Anagnostopoulos, "Elastic Analysis of Pilot Building," August, 1972.

15. John Protonotarios, "Soil-Amplification Analyses on Typical Boston Soil Profiles," September, 1972.

16. S. Anagnostopoulos, and J. M. Roesset, "Description and User's Manual of the Inelastic Dynamic Analysis Program," September, 1972.

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Introduction

From May 30 through June 1 field measurements of vibratory ground motions were carried out in the Boston area. Dr. Artur Ravara and Dr. José Jervis Pereira of the National Laboratory of Civil Engineering (LNEC), Lisbon, Portugal, made their measurements using equipment and techniques they have developed over the past few years. They will present their results and analyses in a separate report. At the same time as the activities of Drs. Ravara and Pereira, the authors of this report used the portable VM-1 instrument to obtain acceleration records at the identical sites. Thus, the two sets of measurements should provide a check on the accuracy of the data and an evaluation of the feasibility of using the VM-1 device for microtremor measurements.

This report describes the places where the data were obtained. It includes soil profiles and typical records of the motions. Finally, some preliminary analyses of the data and conclusions are provided.

Sites and Soil Profiles

Measurements of the ambient vibrations due to traffic were made at five sites identified on the map of Fig. 1 and listed in Table 1. The profiles of these five sites and a sixth site where the excitation was by a dynamite explosion are presented In Figs. 2 and 3. Site 1 (The Joyce Chen Parking Lot) lies

between the location of the MacGregor and Westgate borings. It is a site with one of the deepest deposits of Boston blue clay in the greater Boston area. Sites 2 and 3 are near the locations of the M.I.T. Student Center and the Herrmann Building, respectively. Site 2 has a moderate depth of clay, and Site 3 has a shallow deposit. Site 4 (Boston Common) was chosen to represent relatively firm ground. There are few borings on the top of Beacon Hill, and on the Common, except where the underground garage was built. Borings 981 and 1565, identified in Fig. 1, are the closest good borings to the site of the measurements. As shown in Fig. 3, they indicate the site has till overlain by dense sands, gravels, and clays. Site 5 (Copley Square) represents a moderate to deep profile of clay near the deep deposits of the Prudential Center. Site 6 (Briggs Field) is near Site 1.

Excitation

Ambient vibrations mostly due to traffic were the excitations for Sites 1 through 5. At Sites 1 and 3 the traffic was exclusively automobile traffic on Memorial Drive and tended to give small excitation energies. The truck traffic on Vassar Street for Site 2 gave a more intensive signal. Site 4 was shaken by the downtown Boston traffic as well as by the Boylston Street subway tunnel underground. The Copley Square traffic at Site 5 was similarly reinforced by the nearby Massachusetts Turnpike.

Two five pound dynamite charges were exploded in a boring near Site 1 as the signal for the measurements at Site 6. The explosions were at a depth of about 50 feet. The explosions

were set off between 5:00 and 6:00 AM to reduce background noise due to traffic.

Characteristics of the VM-1

The VM-1, Vibration Monitor, is manufactured by Kinemetrics, Inc., 336 Agostino Road, San Gabriel, California. It consists of an acceleration transducer acting as a sensor and a separate recording and filter unit. The recording is done on heat sensitive paper. The particular sensor used in the present measurements is sensitive to horizontal accelerations between 10^{-6}g and 10^{-2}g.

There are four choices of low pass filters on the recording unit: 1.5 cps, 3 cps, 9 cps, and 25 cps. The measurements reported here were done mostly with the 1.5 cps and 3 cps filters, but a few used the 9 cps filter. The low end of the sensitivity of the device is 0.1 cps. Thus, with the 3 cps filter, the device has a flat response from 0.1 cps to 3 cps, and other frequencies are filtered out. With the 1.5 cps filter, the response is flat from 0.1 cps to 1.5 cps.

Typical Ambient Motion Records

Figures 4 through 8 give typical sections from the records made at the first five sites. Bursts of strong motion resulting from traffic occur in all records, but especially in those at the Vassar Street, Copley Square, and Boston Common sites. In the case of the Boston Common site, the "traffic" was street cars in the nearby subway. The measurements made adjacent to Memorial Drive at the Joyce Chen (Westgate) site were very similar to those shown (which were made in the field) except that the bursts of

stronger motion caused by traffic were more obvious.

Table 2 tabulates the predominant frequencies picked out by the visual examination of the records. This table also contrasts the relative strength of the various records. The visually identified frequencies cannot be satisfactorily correlated with the site characteristics, although there is a tendency for the lowest well-defined frequency to increase as the site becomes firmer; that is:

Joyce Chen (Westgate)	≈3 cps
Vassar St.; Copley Sq.	≈3.5 cps
NRC lot; Common	≈5 cps

However, the expected fundamental frequencies of 0.5 cps to 1 cps at the sites with deep soil cannot be satisfactorily identified. Fourier analysis of the records will be attempted.

Records from Dynamite Explosions

The records from the two shots are presented in Figs. 9 and 10. The following tabulation indicates predominant frequencies as determined by visual inspection of the records. The "early part" lasts 3 to 4 seconds; the "decaying part" is the next 2 seconds; and the "late tail" the next 4 to 5 seconds. The "background" motion is similar before and after the shot.

Shot	Filter	Predominant Frequencies			
		Background	Early Part	Decaying Part	Late Tail
1	3 cps	4.5 cps	2.5 cps 4.5 cps	4.5 cps	2.5 cps 4.5 cps
2	9 cps	[4 cps] 10 cps	15 cps	[1.2 cps] 2.5 cps 4.5 cps	5 cps

The frequencies at this site should be similar to those for the Joyce Chen site, but it is not obvious that there is agreement. It is also hoped that Fourier analysis can be made of these transient records.

Conclusions

As the Fourier analysis of the records has not been finished and the LNEC report is still in preparation, general conclusions cannot be drawn yet. However, it does appear that the microtremor data do not show periods as long as would be expected for these sites. Further research in this area is clearly indicated.

Table 1

Sites of Measurements

Site	Applicable Soil Profile	Type of Excitation
1. The Joyce Chen Parking Lot	Westgate and MacGregor	Ambient Traffic
2. Vassar St. behind Rockwell Cage	Student Center	Ambient Traffic
3. National Research Corp. Parking Lot	Herrmann Building	Ambient Traffic
4. Boston Common	Boston Common	Ambient Traffic and Subway
5. Copley Square	Copley Square	Ambient Traffic and Turnpike
6. Briggs Field	Westgate and MacGregor	Dynamite Explosion in Drill Hole

Table 2

APPARENT PREDOMINANT FREQUENCIES

BASED UPON VISUAL INSPECTION OF RECORDS

SITE	FILTER SETTING			AMPLITUDE
	1.5 cps	3 cps	9 cps	OF MOTIONS
BY JOYCE CHEN	[≃1 cps]	3.5 cps	---	NORM
	2.5-3 cps	[≃10 cps]		
BY VASSAR ST.	1 cps	3.5 cps	---	TWICE NORM; HIGHER
	3 cps	[14 cps]		WITH TRAFFIC
NAT. RES. CORP.	[2 cps]	2 cps	---	NORM
PARKING LOT	5 cps	5 cps		
COPLEY SQUARE	2.5-3 cps	3-5 cps	3-4 cps	TWICE NORM; 4X
			10-12 cps	NORM WITH TRAFFIC
BOSTON COMMON	≃1 cps	[≃1 cps]	[≃1.3 cps]	1/2X NORM; EQUAL
	3.5 cps	3.5-5 cps	5 cps	NORM WITH SUBWAY
			10-12 cps	

[---] means frequency is hidden and difficult to pick-up visually.

SITE AND BORING LOCATIONS FOR VM - 1

FIGURE 1

FIGURE 2

BOSTON QUAKE STUDY PROFILES
LNEC MICROTREMOR MEASUREMENTS

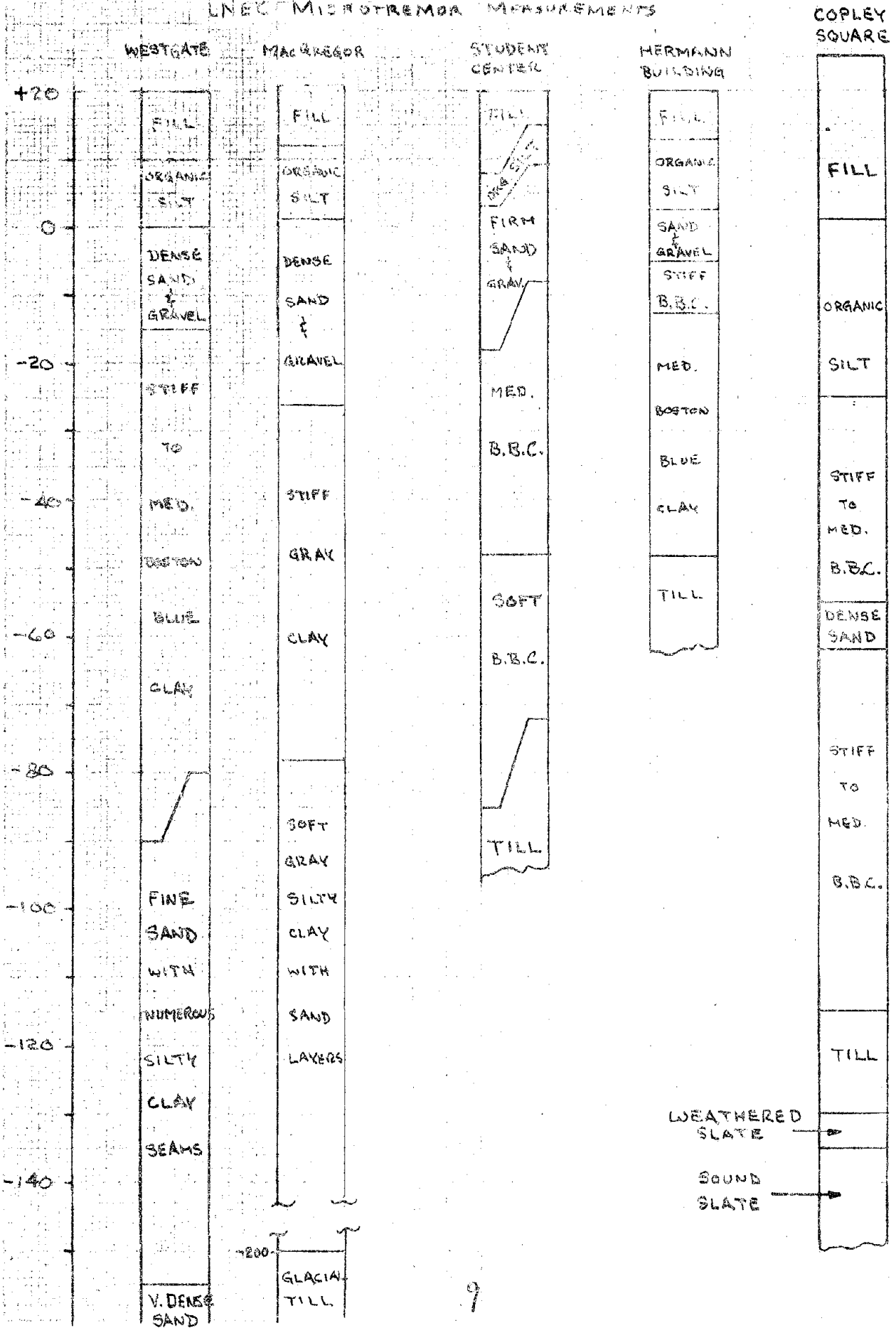
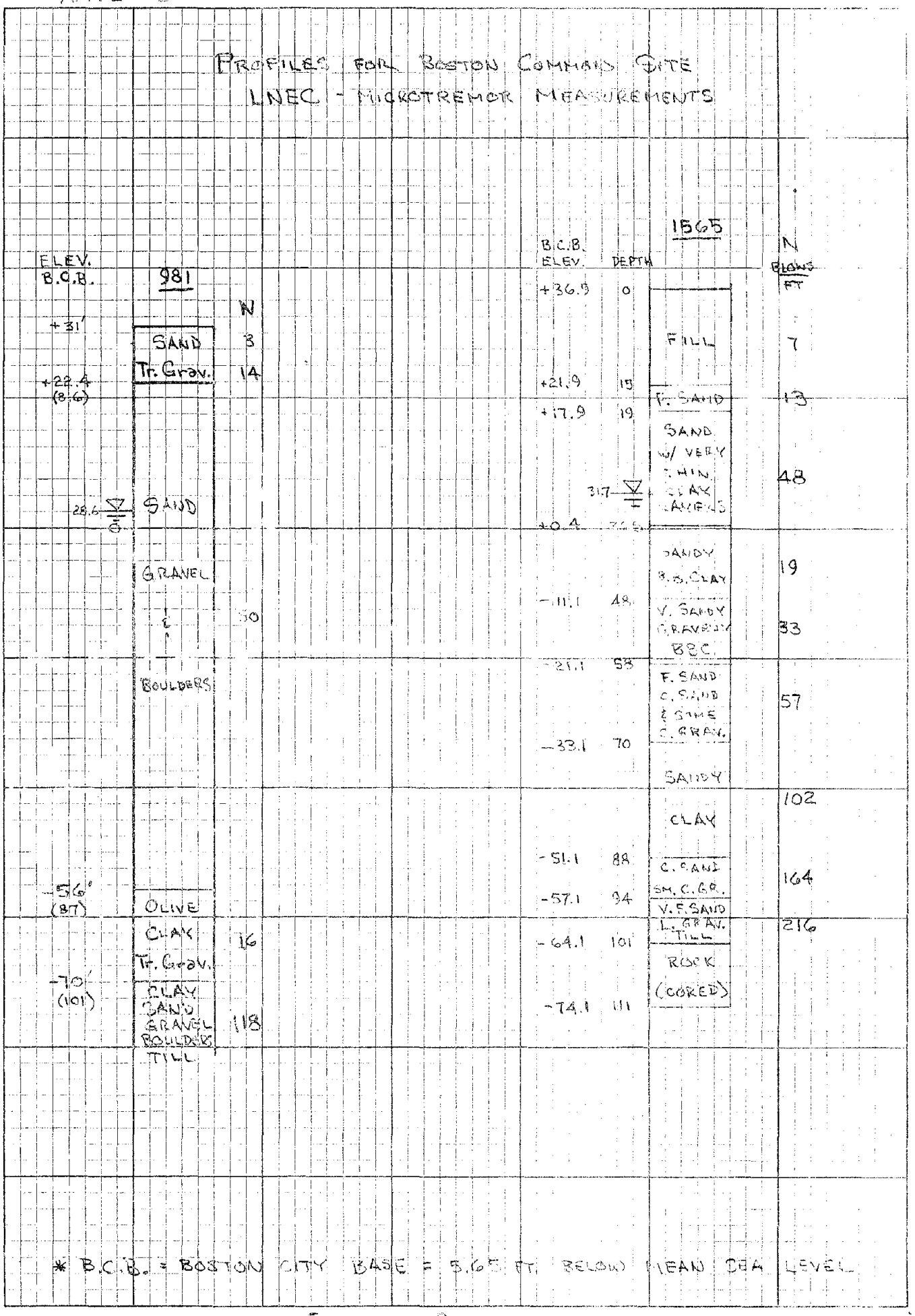


FIGURE 3

PROFILES FOR BOSTON COMMONS SITE
LNEC - MICROTREMOR MEASUREMENTS



* B.C.B. = BOSTON CITY BASE = 5.65 FT. BELOW MEAN SEA LEVEL

FIGURE 3

FIGURE 4

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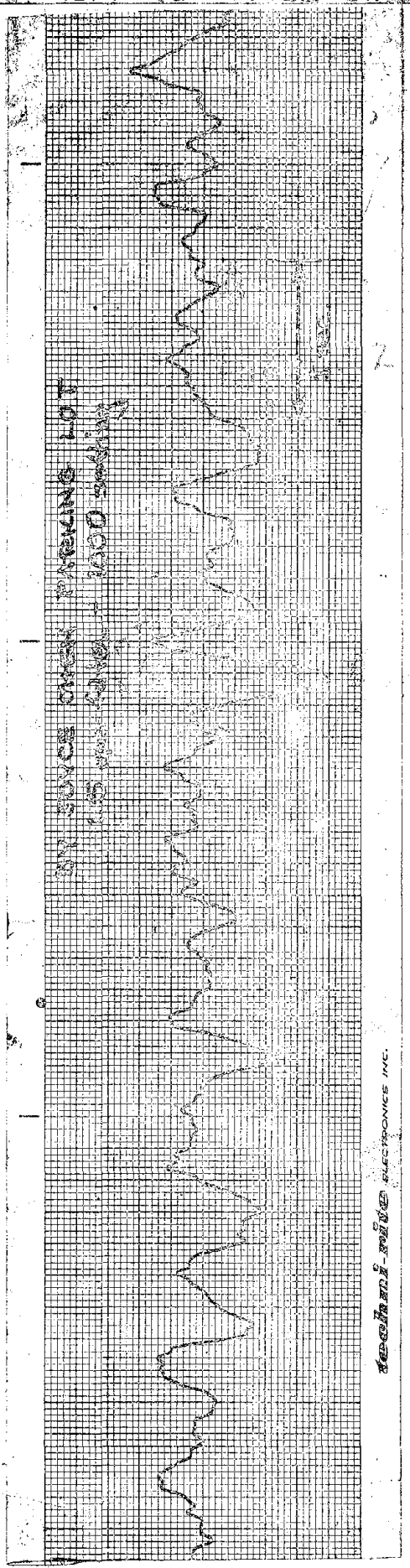
SHEET NO. _____ OF _____

DATE 30 MAY 1972

SUBJECT AMBIENT GROUND MOTION MEASUREMENTS NEXT TO JOYCE CHEN PARKING LOT

COMPUTED BY _____

CHECKED BY _____



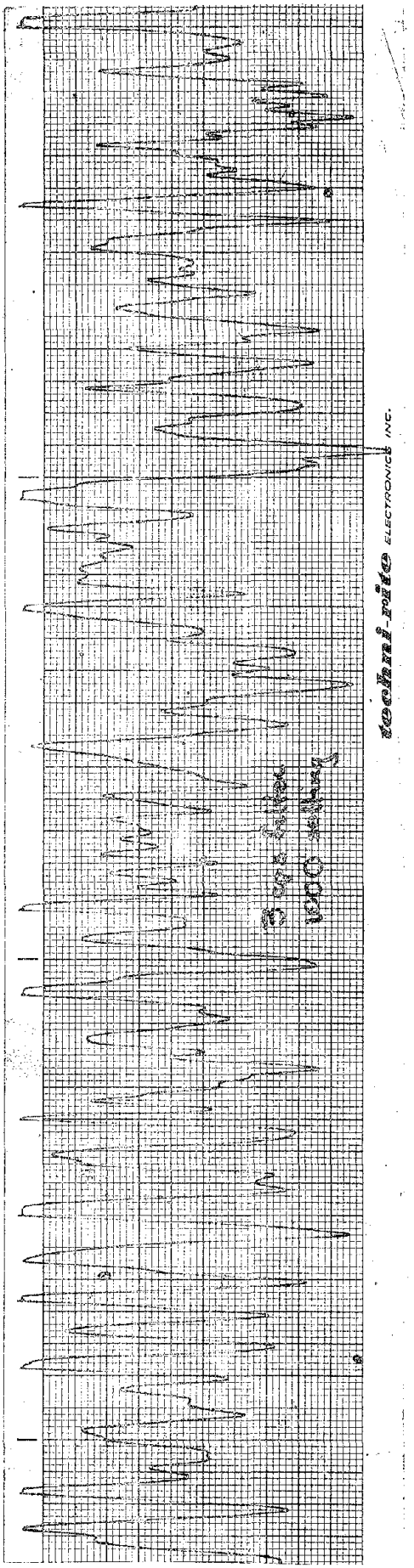


FIGURE 5

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DATE 30 MAY 1972
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CHECKED BY _____

SUBJECT AMBIENT GROUND MOTION MEASUREMENTS IN PARKING AREA NEXT TO VASSAR STREET

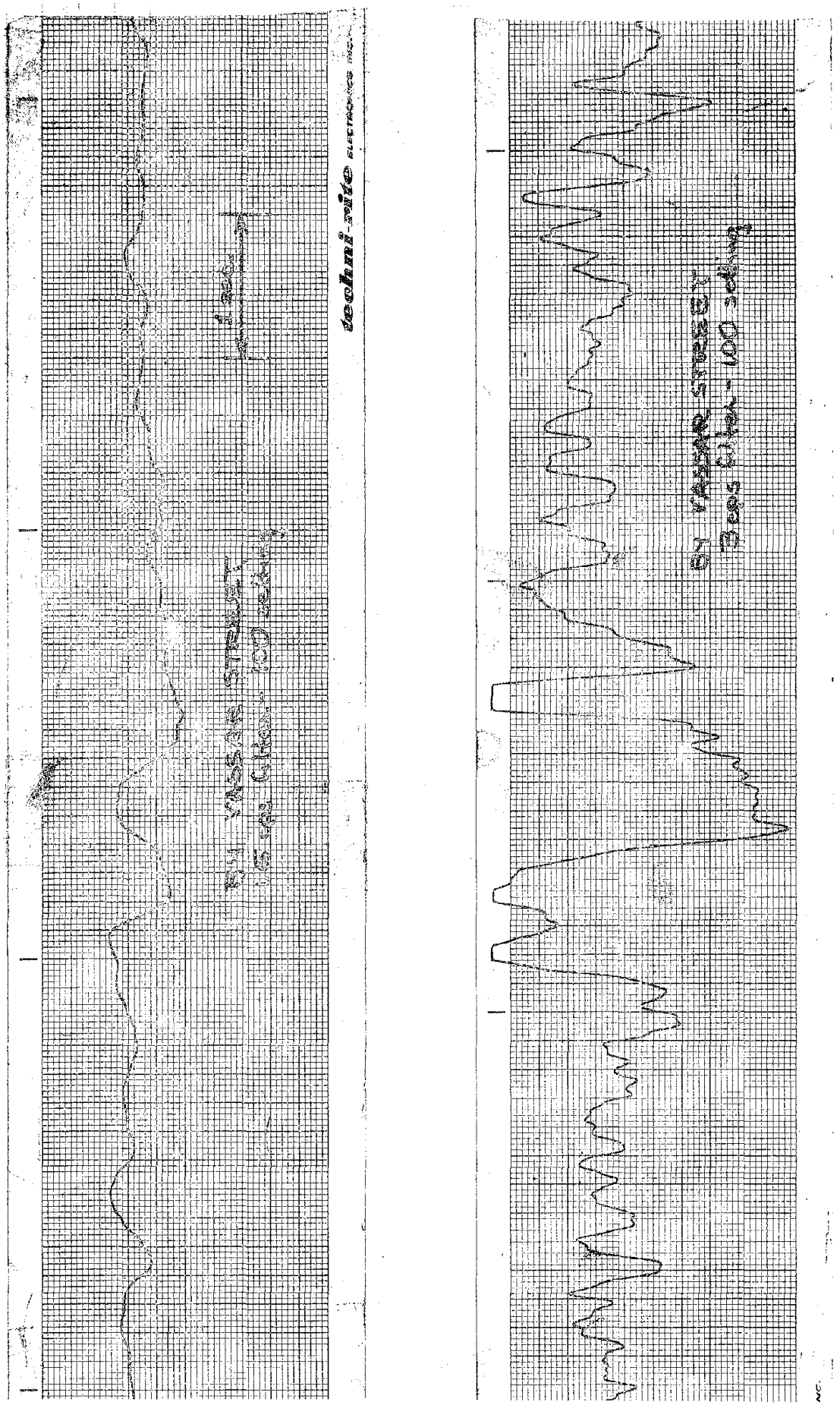

FIGURE 7

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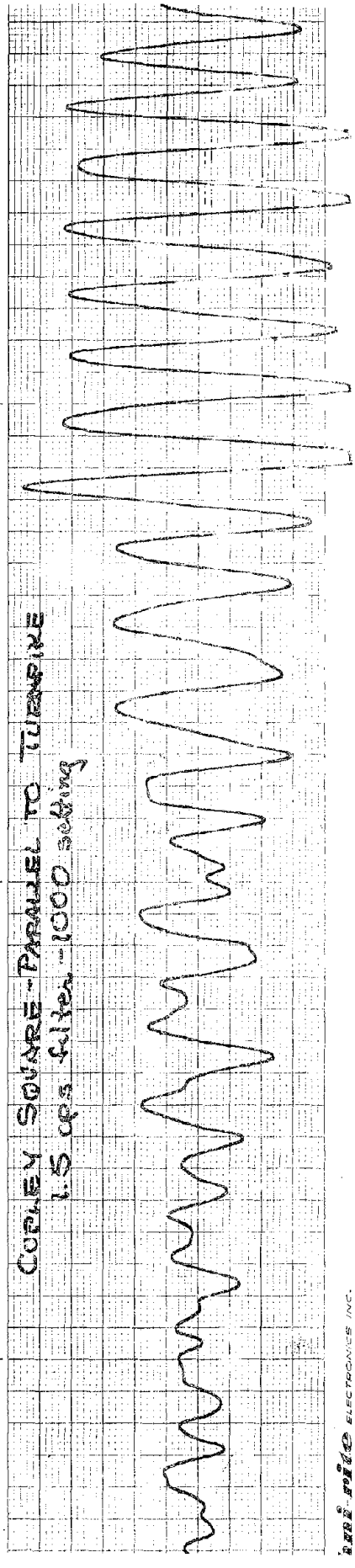
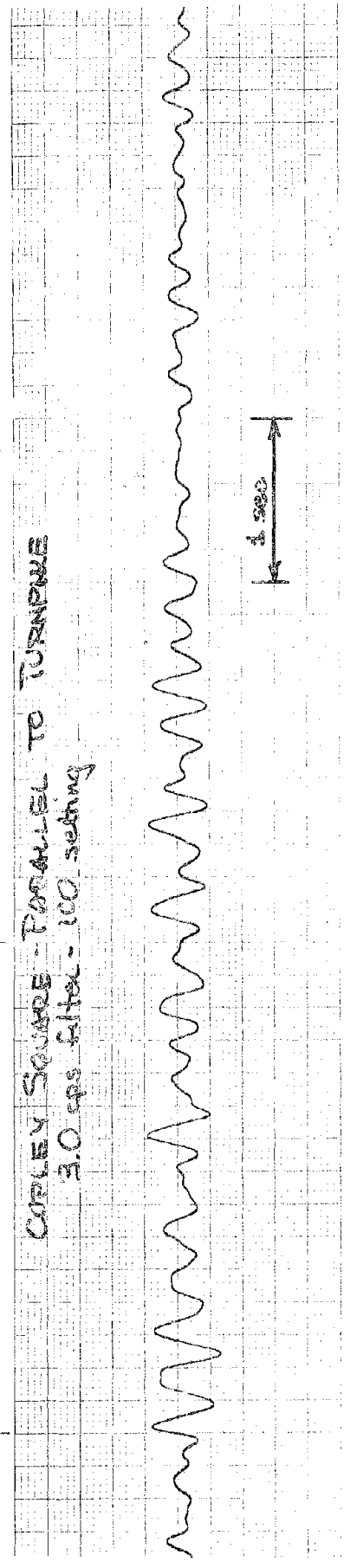
COMPUTED BY ____
CHECKED BY ____

SUBJECT AMBIENT GROUND MOTION MEASUREMENTS AT COPLEY SQUARE SITE





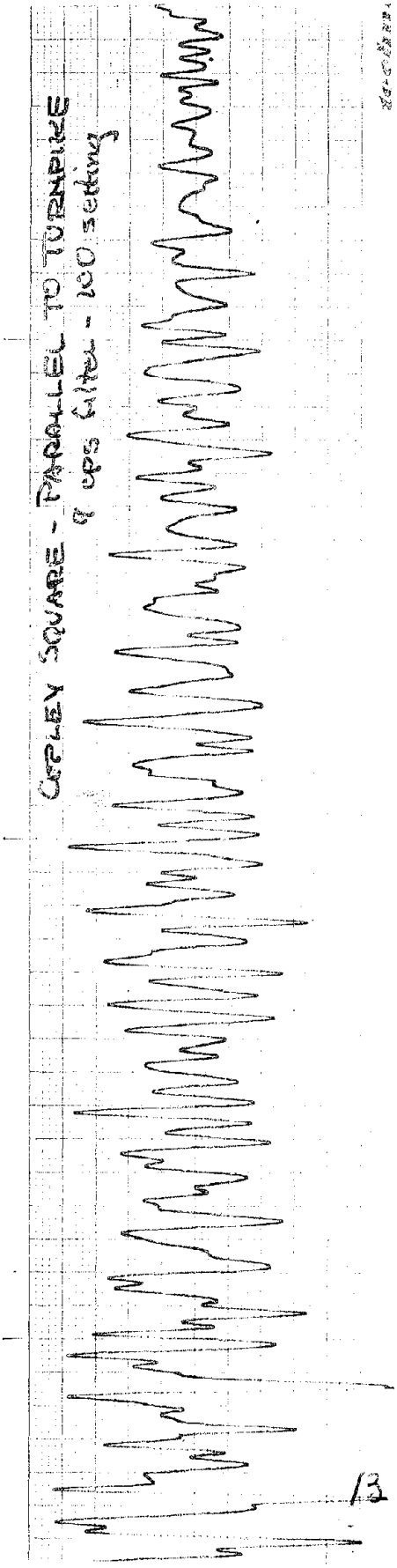


FIGURE 8

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SUBJECT AMBIENT GROUND MOTION MEASUREMENTS AT BOSTON COMMON SITE

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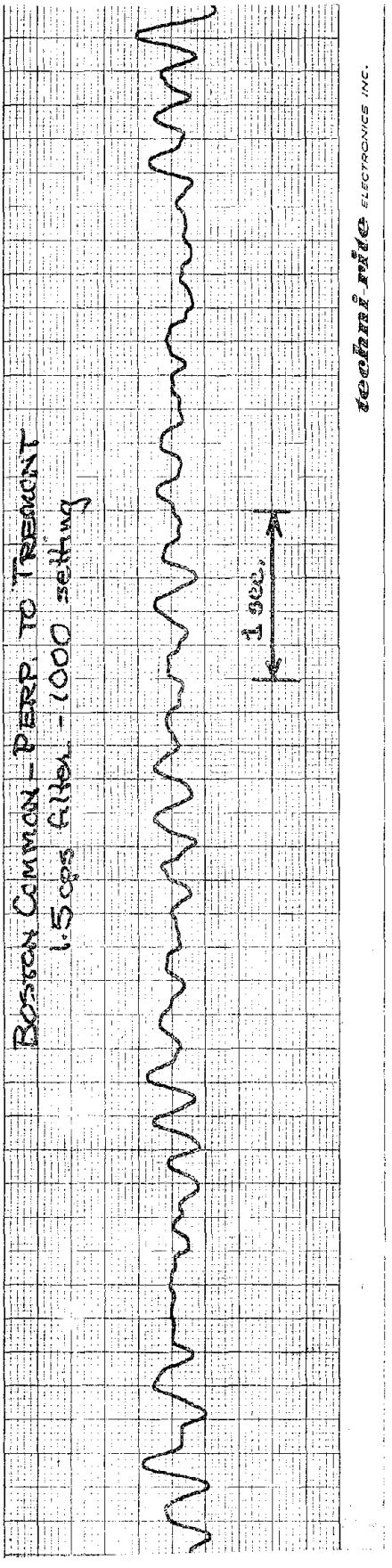
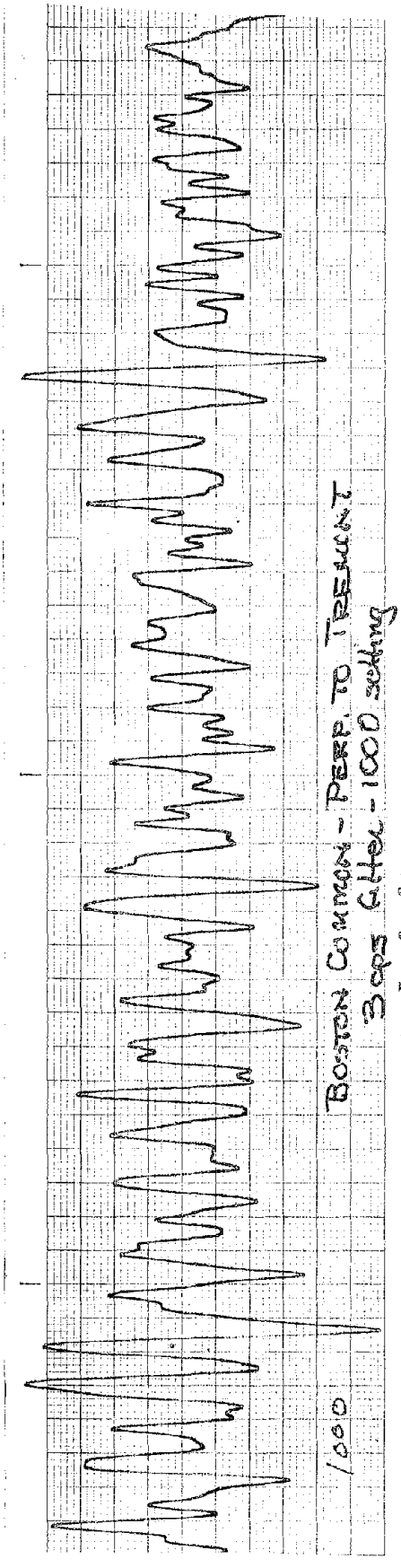
DATE 31 MAY 1972
COMPUTED BY _____
CHECKED BY _____





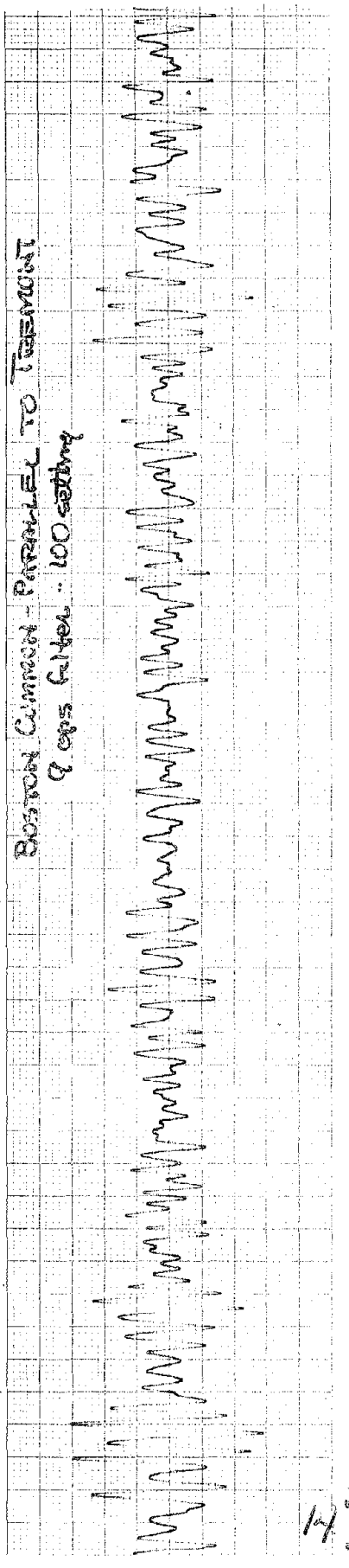


FIGURE 8

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DATE 1 JUNE 1972

SUBJECT GROUND MOTION MEASUREMENTS, DURING FIRST DYNAMITE SHOT

COMPUTED BY _____

CHECKED BY _____

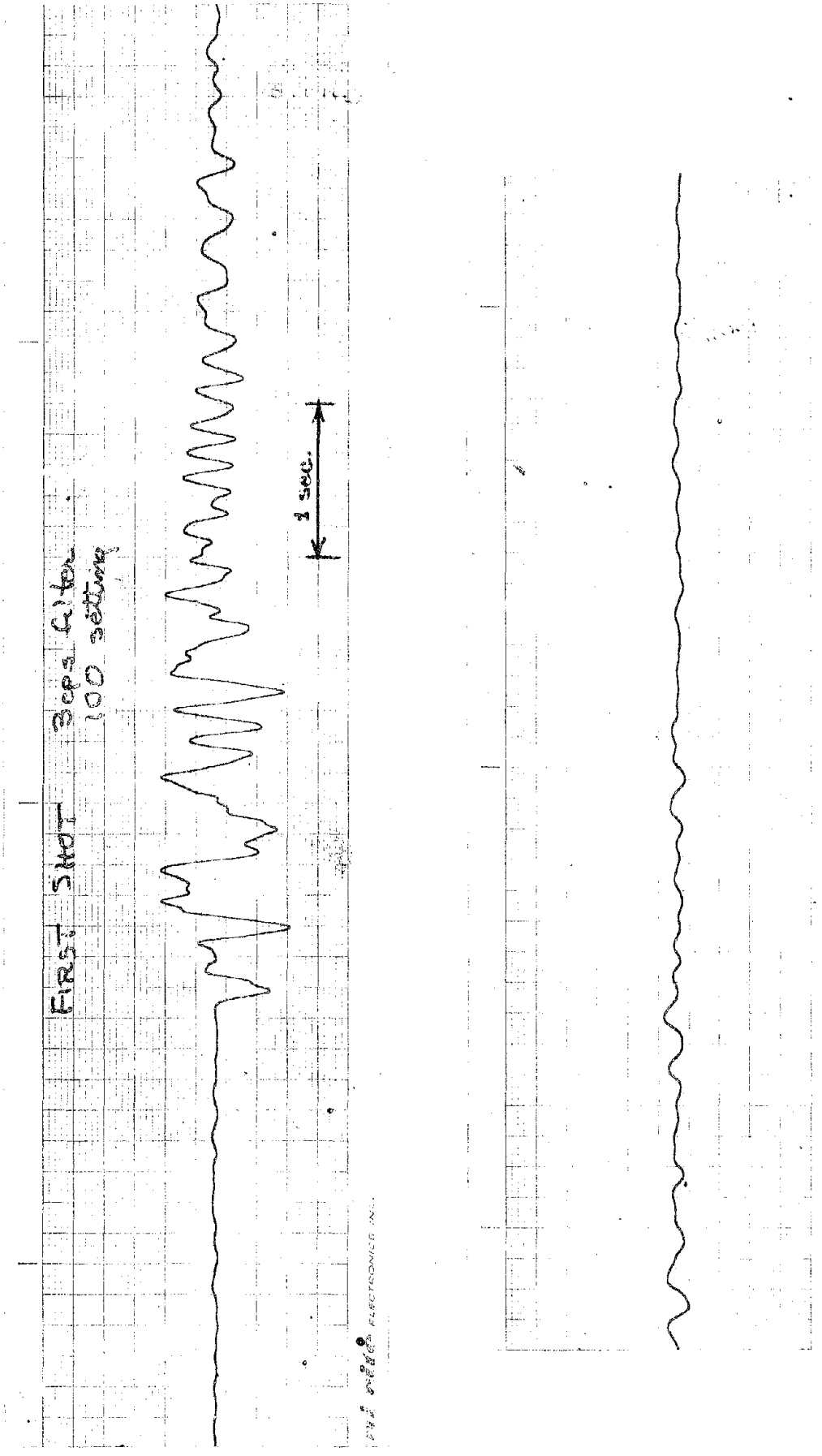

FIGURE 10

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SHEET NO. _____ OF _____

DATE 1 JUNE 1972

SUBJECT GROUND MOTION MEASUREMENTS DURING ~~BEST~~ DYNAMITE SHOT SECOND

COMPUTED BY _____

CHECKED BY _____