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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

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1959 No. 83

VIBRATION TESTS OF BLASTS IN THE M.M.B.W. TUNNEL, SWANSTON STREET, MELBOURNE

by

E.J. POLAK and B.J. BAMBER

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C O N T E N T S

P L A T E S

1. INTRODUCTION.

In response to an application from the construction firm of Prentice Bros. and Minson Pty.Ltd. of Hawthorn, Victoria, measurements of ground movements were made by the Bureau at several properties in Swanston Street, Melbourne, during underground blasting operations.

A tunnel approximately 33 feet below street level is being excavated under Swanston Street for the Melbourne and Metropolitan Board of Works. From a shaft near the Swanston Street-Flinders Lane intersection the tunnel is advancing in opposite directions. To accomplish this, blasting operations take place on the two tunnel faces. Each blast consists of a number of shots varying between 8 and 20. Because the shots are fired with safety fuse the intervals between shots are irregular, resulting in delays between shots of from 0.3 to 5.0 seconds.

The purpose of this investigation is to assess the danger of possible damage to properties near the tunnel line as a result of the blasting operations.

This report deals with the results of three tests, and it is expected that additional tests will be made in compliance with future requests. The tests were made on 25th and 26th May and 2nd June, 1959, by E.J. Polak and B.J. Bamber, geophysicists.

2. RECORDING TECHNIQUE.

Ground movements were recorded inside buildings on firm bases in the vicinity of the tunnel faces being blasted. For the purpose a Leet Vibrograph was used. This instrument contains three inertial mass elements which respond to components of ground displacement in three mutually perpendicular directions. The instrument records photographically and incorporates an optical amplification of 50, so that a ground movement of 0.02 inch is represented on the record by a movement of one inch. The interval between timing lines on the record is 10 milliseconds.

On the record the amplitudes and frequencies of the three components of displacement are measured. The amplitudes are measured as the maximum peak to trough displacements. The total resultant amplitude equals the square root of the sum of the squares of the component amplitudes. Frequency is defined as the predominant frequency in cycles per second at the maximum amplitude of ground displacement. It is obtained by dividing 1000 by t, when t is the time in milliseconds from one peak to the next.

Following the measurements of amplitude and frequency, acceleration may be calculated from the formula -

$$a = 4\pi^2 . f^2 . A$$

in which a is acceleration in inch/sec^2, f is frequency in cycles per second and A is amplitude in inches.

3. RESULTS

Tests were made at three sites, viz: Queens Walk, G.J. Coles Store and Graham Hotel, all of which are approximately 100 feet to 150 feet from the blast centres in the tunnel. Copies of the records are shown in Plates 1, 2 and 3 respectively. The plates also show ground plans of the tests.

At Queens Walk the recorded vibrations were too small to be measured accurately, and the amplitude of ground movement is regarded as being less than 0.0002 inches.

At G.J. Coles Store the maximum amplitude of ground displacement (measured from trough to peak) was 0.0022 inches and the frequency between 60 and 70 cycles per second. The acceleration, therefore, expressed in terms of the acceleration of Gravity, was 1.0.

At the Graham Hotel the maximum amplitude of ground displacement was 0.0019 inches and the frequency 80 c.p.s. In this instance the acceleration was 1.2.

In order that the results from these investigations may be used in assessing the possible danger of damage to properties adjacent to the tunnel line, resulting from the blasting operations, reference should be made to Appendix I of this report. It contains a number of excerpts from reports and regulations dealing with amplitude and frequency of ground displacement from blasting, and recommended safe amplitudes that may be applied to buildings.

APPENDIX I.

The following are references to and extracts from regulations and authoritative publications in the United States and Great Britain covering or recommending safe amplitudes of vibrations that may be applicable to buildings:

(Note: **f** = frequency in cycles per second.
A = peak to trough amplitude, inches).

Reference 1.

State of New Jersey, U.S.A. Extract from rules and regulations governing Quarry Blasting and Related Operations. March 26, 1954.

"6.1. Allowable Limits. Allowable Limits of ground motion and sound pressure contained in this section shall be considered neither to produce structural damage in any structure that has been reasonably well constructed according to accepted engineering practice nor to constitute a nuisance to persons."

"6.3. Frequency - amplitude relations. When ground frequency and displacement characteristics in relation to known quantities of detonated explosives in primary blasts have been determined by approved means of instrumentation to the satisfaction of the Commissioner, the allowable limits of the maximum amplitude of ground vibrations related to frequencies of vibration shall be as indicated in the following table:

Frequency of ground motion in cycles per second.	Maximum amplitude of ground movement, in inches.
up to 10	not more than 0.0305
20	0.0153
30	0.0102
40	0.0076
50	0.0061
60	0.0051"

Reference 2.

Rules Concerning Blasting in Strip Mine Operations in the Anthracite Region, Pennsylvania, Act No. 472, June 27, 1947.

"Section 20.

..in no case shall the ground displacement be in excess of 0.03 inches at any dwelling house, public building, school, church, commercial or institutional building."

Reference 3.

Teichman, G.A. and Westwater, R.

Blasting and Associated Vibration.

Engineering, April 12, 1955, pp. 460/465.

> "Because of the variation in the types of structure it has been recommended that they should be broadly classified into four groups:
>
> (a) structures of great value and frailty. This will include certain ancient monuments, such as churches and certain badly designed properties.
>
> (b) Property, houses etc. closely congested.
>
> (c) Isolated property.
>
> (d) Civil engineering structures.
>
> Taking suitable safety factors and after the site has been investigated by a vibrograph caution limits are applied. These limits usually are 0.004, 0.008, 0.016, 0.030 inches, respectively."

Reference 4.

Crandell, working on behalf of a United States Insurance Co., suggests fA as a suitable relationship and quotes -

"fA = 0.745 as the damaging level

fA $\leq$ 0.527 as safe level."

Reference 5.

C. Morris - Vibrations due to blasting and their effect on building structures.

The Engineer, Nov. 3, 1950. pp. 394/395, 414/418.

> "the limiting amplitude of 8.2×10^{-3} (0.0082) inches gives a conservative estimate of the limiting amplitude for conventional structures. The state of repair of the building does not seriously affect this estimate, as an old building technically less strong than a new one will have benefitted by a process of "bedding in" due to long-continued small movement."

Reference 6.

Thoenen, F.R. and S.L. Windes, 1942. Seismic Effects of Quarry Blasting.

United States Bureau of Mines Bull. 442.

"f^2 A $\geq$ 10 Damage

f^2 A $\leq$ 1 Safe "

"Vibrations of very low amplitude and short duration were neglected, even though the accelerations may have been high, because these conditions were noticeable in the records of many tests that did not cause damage."

LEGEND

1 — State of New Jersey as specified by regulation

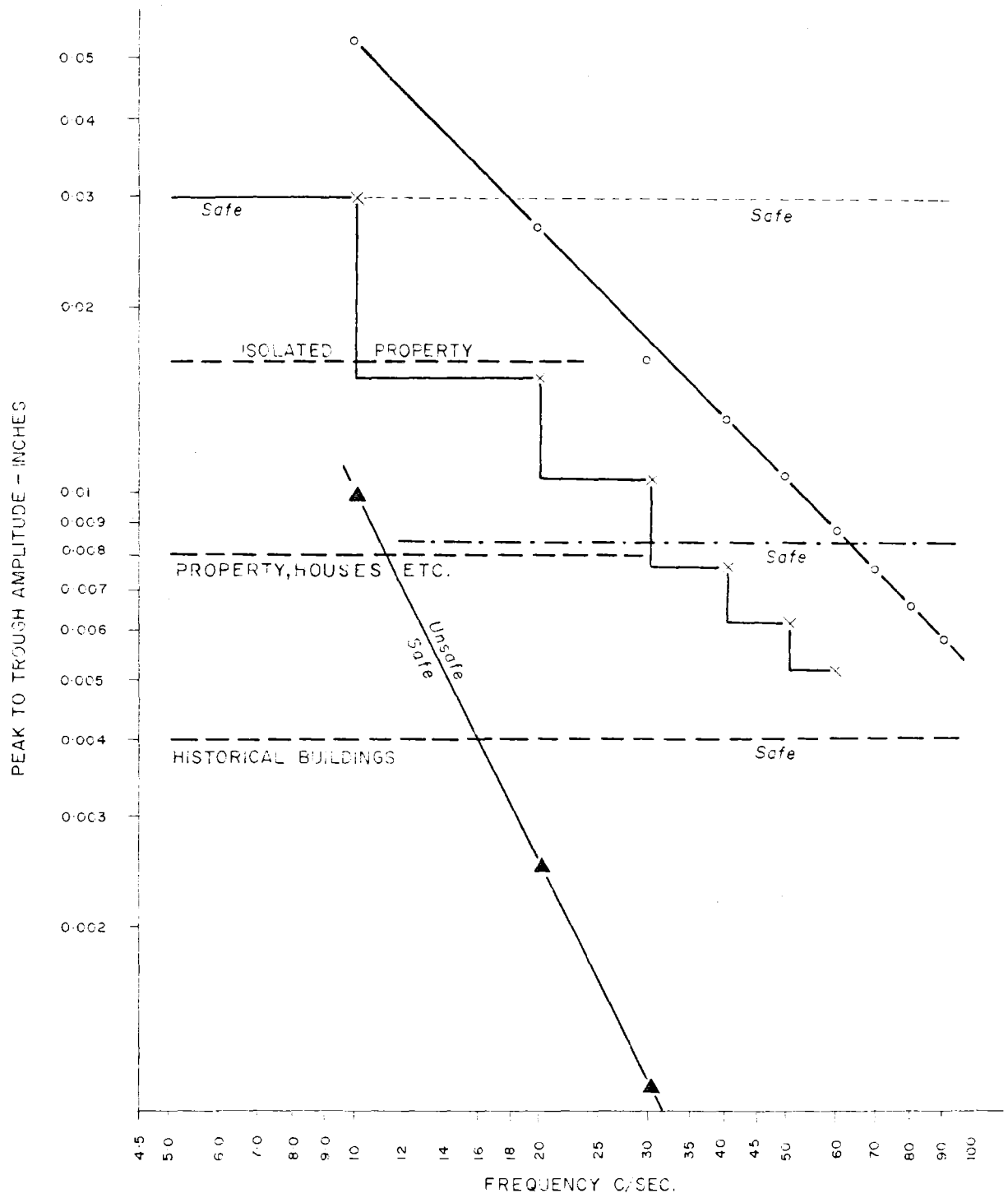
2 — State of Pennsylvania as specified by regulation for any structure

3 — As recommended by Teichman

4 — As recommended by Crandell to a United States Insurance Co.

5 — As recommended by Morris

6 — As recommended by U.S. Bureau of Mines

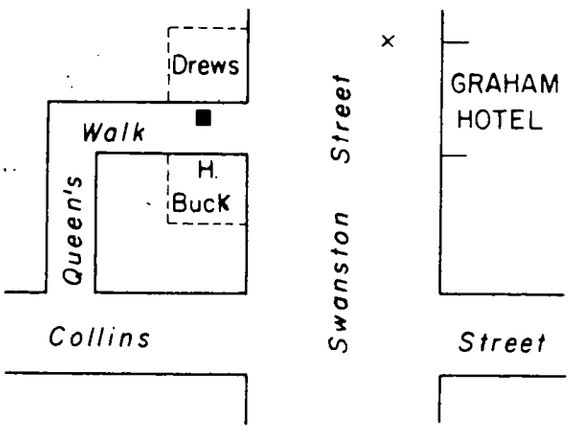


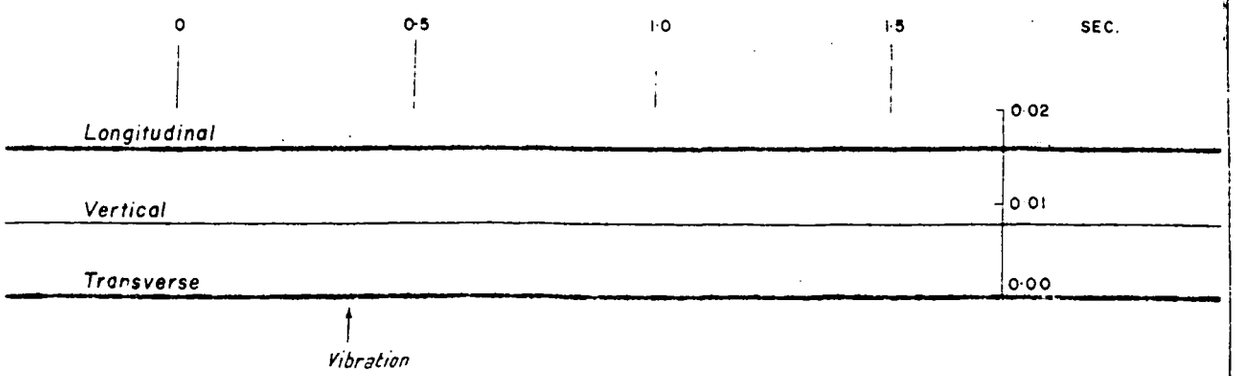
MAXIMUM SAFE PEAK TO TROUGH AMPLITUDE OF VIBRATION PLOTTED AGAINST FREQUENCY AS SPECIFIED AND RECOMMENDED BY VARIOUS U.S. GOVERMENT AUTHORITIES AND BY INDIVIDUALS

PLATE 1

Date : 25-5-1959
Instrument : Leet Vibrograph
Operators : E.J. Polak, B. Bamber
Number of shots : Fired - 8, Recorded - 7 (Brushing Shots)

Position of Recording Equipment





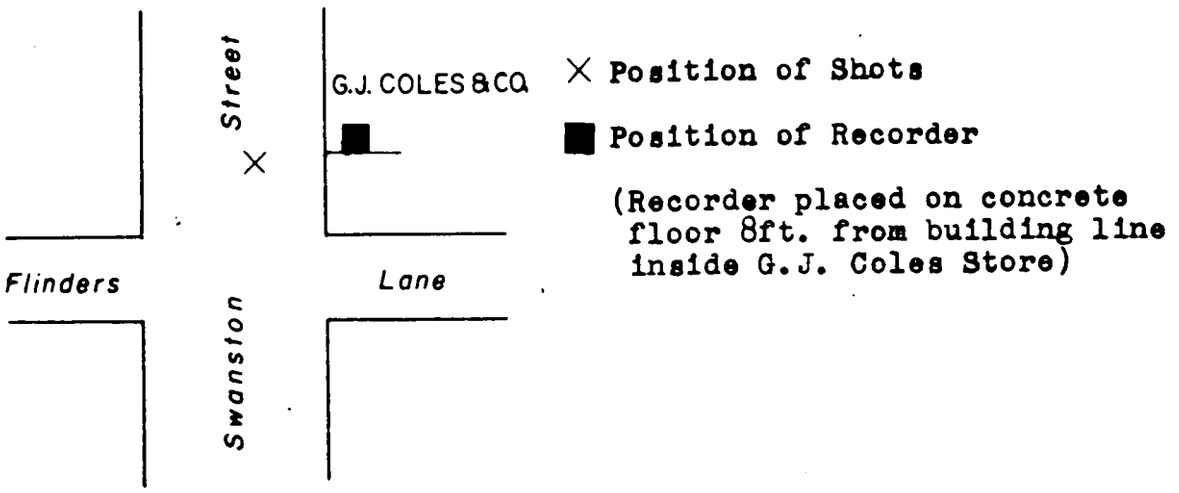
Vibration too small to be read accurately.
i.e. Ground amplitude less than 0.0002 inches.

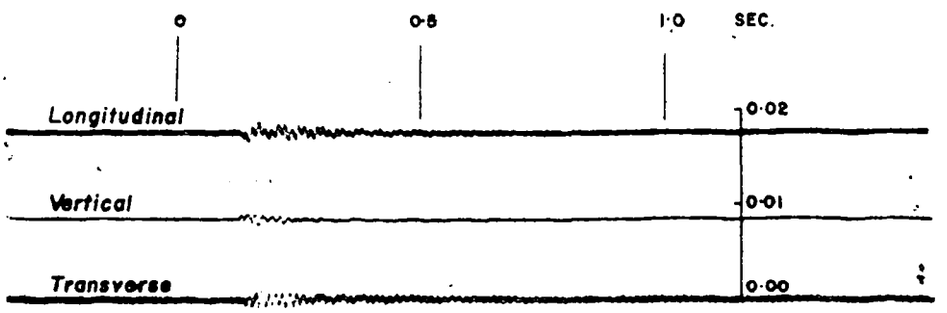
Vibration Tests, MMBW Tunnel,
Swanston Street, Melbourne

TEST No. 1

Date : 26-5-1959
Instrument : Leet Vibrograph
Operators : E.J. Polak, B. Bamber
Number of Shots : Fired - 14, Recorded - 13

Position of Recording Equipment





Ground		Long.	Vertical	Transverse
Amplitude	inches	0.0012	0.0010	0.0016
Frequency	c/sec.	60 - 70	60	70

Resultant amplitude : 0.0022

Acceleration as part of acceleration of Gravity : 1.0

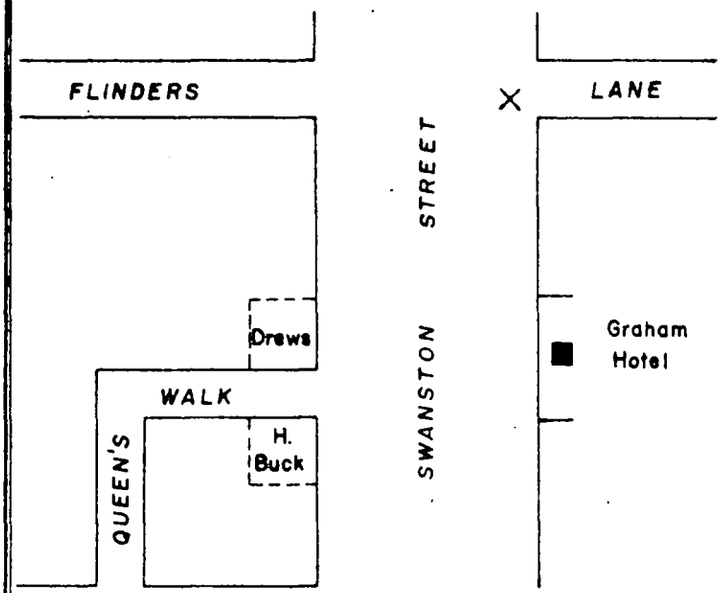
Vibration Tests, MMBW Tunnel,
Swanston Street, Melbourne

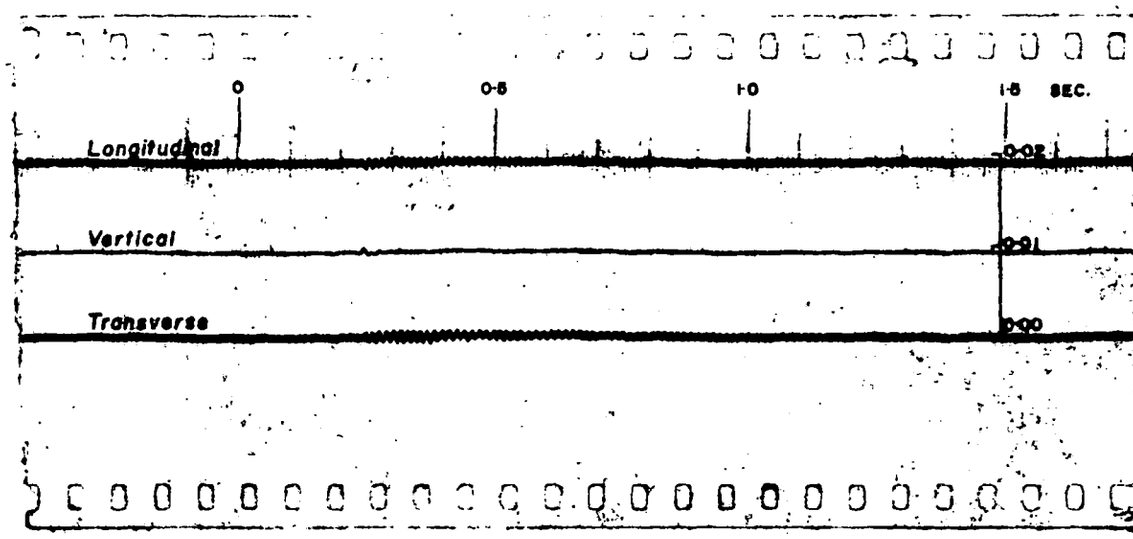
TEST No. 2

PLATE 3

Date : 2-6-1959
Instrument : Leet Vibrograph
Operator : B. Bamber
Number of Shots : Fired - 9, Recorded - 8

Position of Recording Instrument





Trace		Long.	Vertical	Transverse
Amplitude	inches	0.00118	0.00096	0.00118
Frequency	c/sec.	80(approx.)		
Resultant Amplitude :		0.0019		
Acceleration as part of acceleration of Gravity :		1·2		

Vibration Test, MMBW Tunnel
Swanston Street, Melbourne

TEST No. 3
RECORD SHOWING MAXIMUM ACCELERATION RECORDED IN THE TEST

To accompany Records 1959, No 83