COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORDS 1961 No. 34

GENERAL MOTORS-HOLDENS VIBRATION TESTS, FISHERMENS BEND, VICTORIA 1961

by

A.M. Radeski and P.E. Mann

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ABSTRACT

This Record describes the measurement of vibrations produced by two recently installed compressors and other compressors at General Motors-Holdens Pty. Ltd. factory at Fishermens Bend, Victoria.

The accelerations calculated from the vibration records are within the range regarded as safe by the United States Bureau of Mines.

The vibrations are in the range considered to be perceptible, but they should not be annoying to human beings.

1. INTRODUCTION

This Record describes a vibration investigation, carried out by Bureau of Mineral Resources, at the request of Ingersoll-Rand (Australia) Pty. Ltd.

The purpose of the investigation was to measure, assess, and compare the ground vibration of two recently installed Ingersoll-Rand air compressors with respect to each other and also with respect to Atlas Copco compressors. The compressors are located in two separate buildings at General Motors-Holdens factory, at Fishermens Bend, a suburb of Melbourne.

The investigation was carried out on the 3rd March 1961 by Mr. A.M. Radeski, technical officer of the Bureau.

Throughout the Record the word "compressor" is used to mean an air compressor and its associated electric motor.

2. INSTRUMENT AND METHOD

The instrument used in recording the ground vibrations was a Sprengnether Portable Blast and Vibration Seismograph, Serial No. 1577. This instrument records three mutually perpendicular components of the ground vibration on a moving strip of photographic paper. A record shows the ground motion magnified 100 times, with timing lines at intervals of 0.02 seconds.

Details of the nine records taken during the tests are listed in Table 1.

TABLE 1

Record No.	Seismograph position	Compressor under test	Compressor load	Remarks
1	1	IR No. 2	full	On isolated foundation IR No.2; IR No. 1 switched off.
2	2	IR No. 2	full	On concrete floor of building, adjacent to foundation; IR No. 1 switched off.
3	3	IR No. 1	$\frac{3}{4}$	On isolated foundation IR No. 1; IR No. 2 switched off.
4	4	IR No. 1	$\frac{3}{4}$	On concrete floor of building, adjacent to foundation; IR No. 2 switched off.
5	3	IR No. 1	$\frac{1}{4} - \frac{1}{2}$	On isolated foundation IR No. 1; IR No. 2 switched off.
6	5	AC No. 4	Unknown	On front side of concrete foundations.
7	6	AC No. 4	"	On concrete floor in front of compressor, distance approximately 10 ft.
8	7	AC No. 2	"	On concrete foundation at rear of compressor.
9	8	AC No. 4	"	On concrete foundation at rear of compressor.

IR is Ingersoll-Rand

AC is Atlas Copco

3. RESULTS

Plate 1 shows the positions of the seismograph during the tests.

Plates 2 and 3 show the records obtained during the tests. In each test the record was run for several seconds, but only that part of a seismogram where the displacement of each of the components is greatest, has been reproduced. The amplitudes and frequencies of the three components of ground displacement were scaled from the seismograms.

The vibration records taken on the recently installed Ingersoll-Rand (IR) compressors No. 1 and No. 2 indicates that the design of their foundations has isolated much of the vibration and prevented it from reaching the main floor of the building. IR No. 1 produced larger vibrations than IR No. 2, both on the isolated foundation and on the main floor. A comparison of the vibration amplitudes recorded on the isolated foundations of IR Nos. 1 and 2 indicates that No. 2 is the better balanced machine. The vibration produced by a compressor is probably independent of the load but the paucity of observations does not permit a general rule on this point to be established.

The dominent frequencies of vibration recorded during tests on the IR compressor are 16 c/s and about 100 c/s. The predominant frequency of 16 c/s is probably a simple multiple of the compressor speed, which is 500 r.p.m. (= 8 revolutions per second, approximately). The origin of the 100 c/s vibrations is uncertain. Their amplitudes on Records 1 and 2 are equal; this probably indicates that these vibrations originate from an external source and equally affect both the compressor foundation and the main building. A similar high-frequency vibration was recorded during tests on compressor IR No. 1 but its amplitude was not as uniform as for compressor IR No. 2, and it became attenuated outside the compressor foundation. It should be noted that high-pressure air pipelines from the compressors to tanks are rigidly attached to the roof of the building. Thus high-frequency vibration due to wind, industrial vibration, or turbulent flow in the pipelines could perhaps be transmitted to the compressor foundation or floor of the building.

For comparison, records were taken of vibrations produced by Atlas Copco compressors (AC) installed on semi-isolated foundations in another building of the factory. The dominant frequencies of vibrations recorded in these tests are 11 c/s, 30 to 50 c/s and approximately 100 c/s. Probably the 11-c/s vibration bears a simple relation to the speed of rotation of the compressors and is equivalent to the 16-c/s vibration recorded at the IR compressors. The origin of the 30 to 50-c/s vibration is uncertain. High-frequency vibrations are often associated with compressor installations; Anthony and Jewell (1960) investigating Atlas Copco compressors recorded 55 and 70-c/s vibrations but their amplitudes were negligible everywhere except on the compressor foundations. The 30 to 50-c/s vibration in the present tests is attenuated with distance. The origin of the 100-c/s vibration is uncertain, but it may arise from one of the sources suggested in the case of the IR compressors.

Table 2 shows the magnitude of the three components of ground displacement (taken as half the peak-to-trough amplitude) corresponding to the various positions of the seismograph. The accelerations shown in Table 2 were calculated, on the assumption that the vibrations are sinusoidal, from the equation

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

Where a = maximum acceleration

f = frequency

A = ground displacement

The resultant acceleration is the vector sum of the accelerations for the three components. The final column of figures shows this resultant acceleration in terms of g, the acceleration due to gravity (= 386 in/sec^2).

Various limiting standards for damaging and non-damaging effects of vibration have been proposed by different authorities (See Appendix). The U.S. Bureau of Mines (Thoenen and Windes, 1942), using acceleration as an index of likelihood of damage, proposed the following classification, applicable to buildings:

Acceleration greater than 1.0g - Damaging

" between 0.1g and 1.0 g - Slightly damaging (caution zone)

" less than 0.1g - No damage (safe zone)

The resultant acceleration of vibrations of all the tests except those of Records 1 and 2 are smaller than 0.1g and thus lie in the "safe zone". The resultant acceleration for Records 1 and 2 is within the "caution zone", but the calculated resultant acceleration in these cases is strongly influenced by the presence of the 105-c/s vibrations. The high-frequency vibration has been neglected when computing the resultant acceleration of the other tests, as its amplitude is considered to be too small to have much effect in the resultant acceleration. It may be concluded therefore that none of the vibrations produced by the compressors will damage buildings.

Various authorities cite different criteria for the effect of vibrations on human beings. The following results of English and German work are quoted by Steffens (1952).

	Minimum displacement (in.) which will cause annoyance		
Authority	5 c/s	10 c/s	20 c/s
Mallock	0.0196	0.0049	0.00122
Melville	0.0370	0.0046	0.00058
Digby & Sankey	0.0039	0.00197	0.00098
Reiher & Meister	0.0032-0.0160	0.0016-0.0050	0.0008-0.0018

Mallock also suggested that the perceptibility of vibrations depends on the magnitude of the maximum ground acceleration, accelerations greater than 0.01g being perceptible. Clearly the resultant accelerations of the present tests are greater than the perceptible minimum according to Mallock. Some of the authorities quoted would regard as annoying the amplitudes of vibration on the compressor foundations, but none of them would regard the amplitude of vibration on the floors as annoying.

4. CONCLUSIONS

The tests permit a comparison to be made between the two recently installed Ingersoll-Rand compressors with respect to each other and with respect to Atlas Copco compressors.

The vibrations ~~produced by~~ measured at IR No. 2 can be classified according to the U.S. Bureau of Mines as slightly damaging to buildings. Vibrations produced by IR No. 1 are considered as safe. A high-frequency vibration recorded at IR No. 2 may originate at an external source; if this is so, the vibrations from the compressor would be classified as "safe".

Accelerations recorded on the actual foundations of the four compressors tested are as follows :-

IR No. 1	16.0	in./sec^2		
IR No. 2	4.05	"	"	(ignoring 105-c/s vibration)
AC No. 2	7.2	"	"	
AC No. 4	11.2	"	"	

The vibrations of AC compressors are not as effectively isolated from the floor as those of IR compressors. Floor vibrations from the compressors are classified as perceptible but not annoying to human beings, according to English and German authorities on ground vibrations

5. REFERENCES

ANTHONY, P.J. and JEWELL, F., 1960 Volkswagon vibration tests, Clayton, Vic., 1960. Bur. Min. Resour. Aust. Rec. 1960/55.

STEFFENS, R.J., 1952 The assessment of vibration intensity and its application to the study of building vibrations. Nat. Build. Stud. Spec. Rep. 19

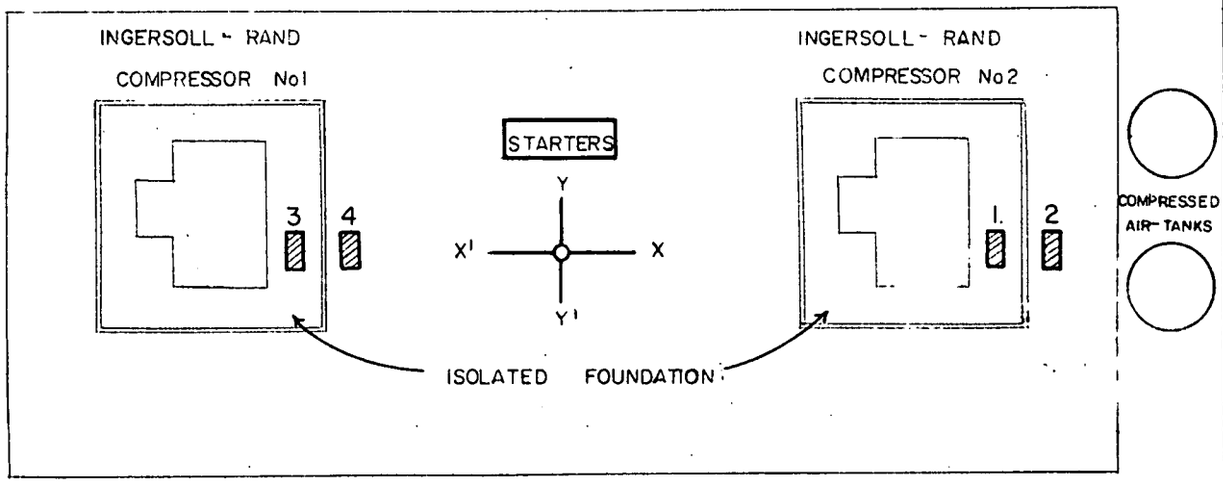
THOENEN, J.R. and WINDS, S.L. 1942 Seismic effects of quarry blasting. Bull. U.S. Bur. Min. 442

TABLE 2

Record	Component	Displacement (in.)	Frequency c/s	Acceleration in./sec^2	Resultant acceleration in./sec^2	Resultant acceleration in terms of g	Remarks
1.	X	0.00025	17	2.86	87.5	0.226	If the 105-c/s vibration is ignored, the resultant acceleration is 4.05 in./sec^2.
	Z	0.00025	17	2.86			
	Y	0.0002	105	87.4			
2.	X	0.00015	16.5	1.61	87.4	0.226	Trace of approximately 100 c/s superimposed on Z component. If the 105 c/s vibration is ignored the resultant acceleration is 2.28 in./sec^2.
	Z	0.00015	16.5	1.61			
	Y	0.0002	105	87.4			
3.	X	0.0014	16	14.2	16.0	0.041	Traces of approximately 100 c/s superimposed on Z and Y components.
	Z	0.0007	16	7.1			
	Y	0.0002	16	2.0			
4.	X	0.0003	16	3.0	3.68	0.0095	Traces of approximately 100 c/s superimposed on Y component.
	Z	0.0002	16	2.0			
	Y	0.00005	16	0.5			
5.	X	0.00145	16	14.7	16.6	0.043	Traces of approximately 100 c/s superimposed on irregular component.
	Z	0.00075	16	7.6			
	Y	0.00015	16	1.5			
6.	X	0.00015	33	6.4	[illegible]	0.026	Trace of approximately 100 c/s superimposed on Z and Y components.
		0.00035	11	1.7			
	Z	0.0008	11	3.8			
	Y	0.0009	11	4.2			
7.	X	0.0001	40	6.3	6.6	0.017	Irregular vibration on X component. Trace of high frequency too small to scale on Y component.
	Z	0.0004	11	1.9			
	Y	-	-	-			
8.	X	0.00015	33	6.4	8.2	0.022	High and low frequency component present. Trace of approximately 100 c/s superimposed on Z and Y component.
		0.00025	11	1.2			
	Z	0.0005	11	2.4			
	Y	0.0004	11	1.9			
9.	X	0.0001	50	9.9	12.2	0.032	Trace of approximately 100 c/s superimposed on Z and Y component.
		0.00025	11	1.2			
	Z	0.0006	11	2.9			
	Y	0.00085	11	4.1			

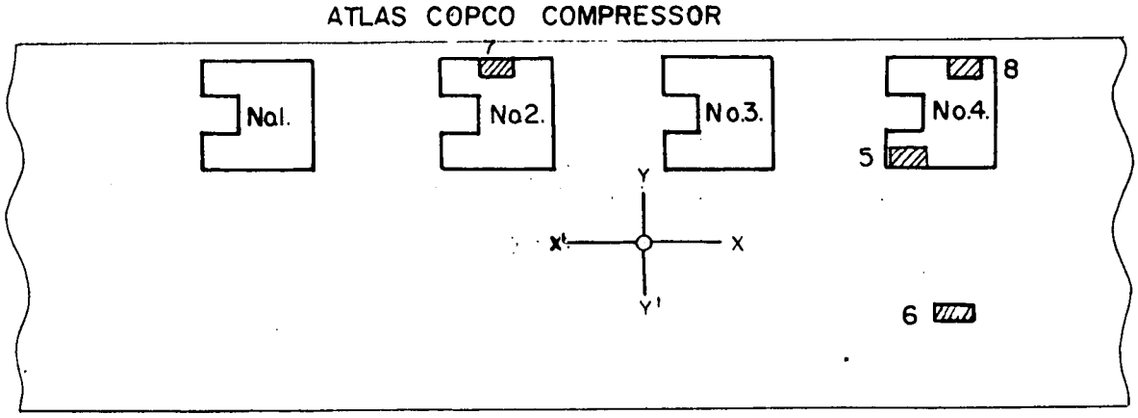
GENERAL MOTORS HOLDENS FISHERMENS BEND VIC.
VIBRATION TESTS 3-3-60

(a) COMPRESSOR HOUSE No1.



Not to Scale

(b) COMPRESSOR HOUSE No2.

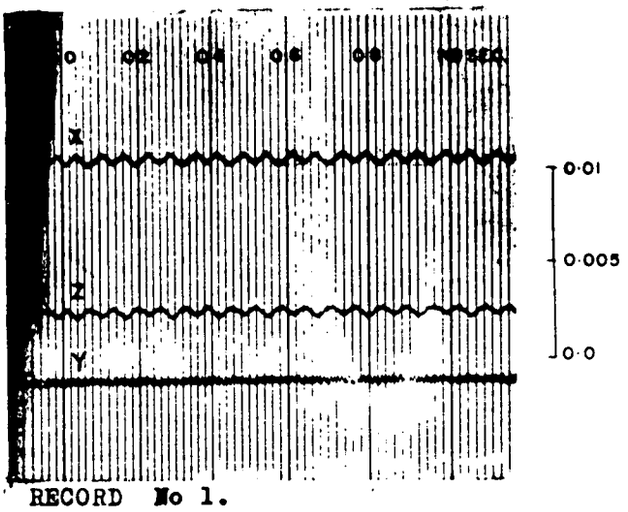


Not to Scale

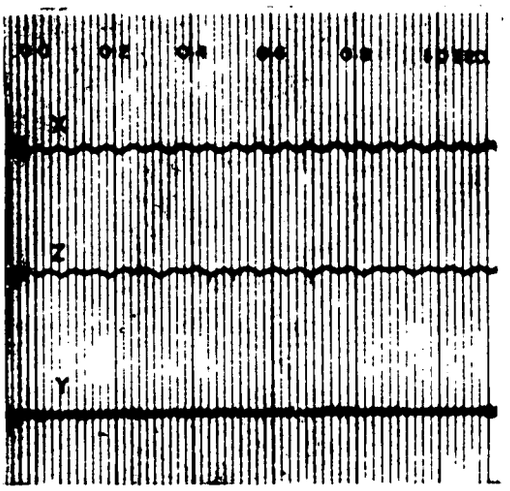
GENERAL MOTORS - HOLDENS, FISHERMENS BEND

VIBRATION TESTS 3/3/60

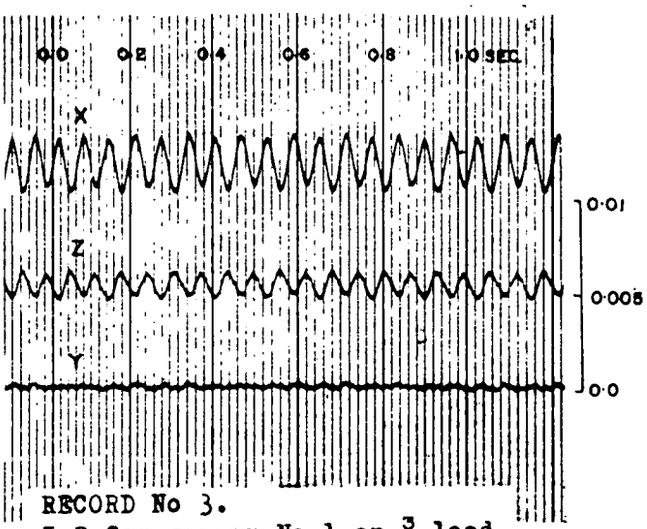
SEISMOGRAPH LOCATIONS



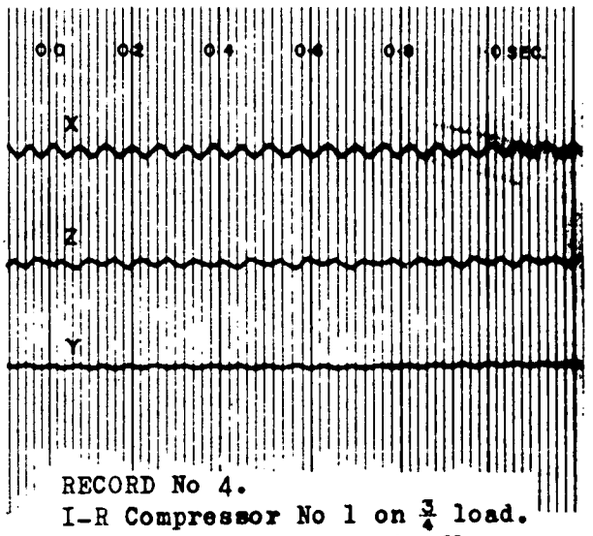
RECORD No 1.
I-R Compressor No2 on full load.
Seismograph below instrument panel on isolated foundation.



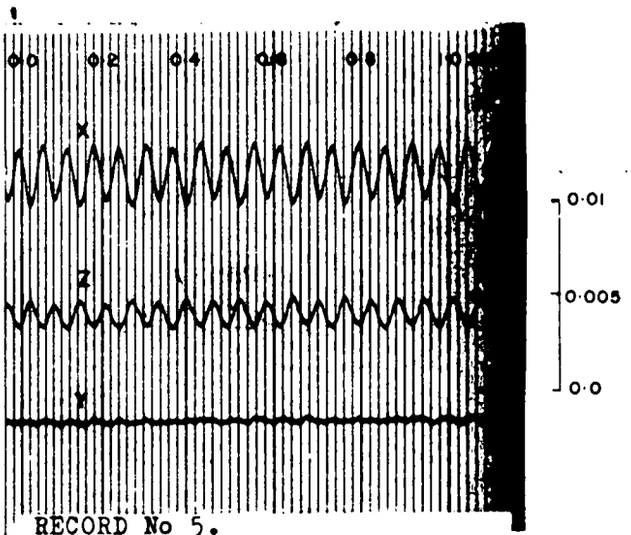
RECORD No 2.
I-R Compressor No2 on full load.
Seismograph on concrete floor of building, adjacent to isolated foundation.



RECORD No 3.
I-R Compressor No 1 on $\frac{3}{4}$ load.
Seismograph below instrument panel on isolated foundation.

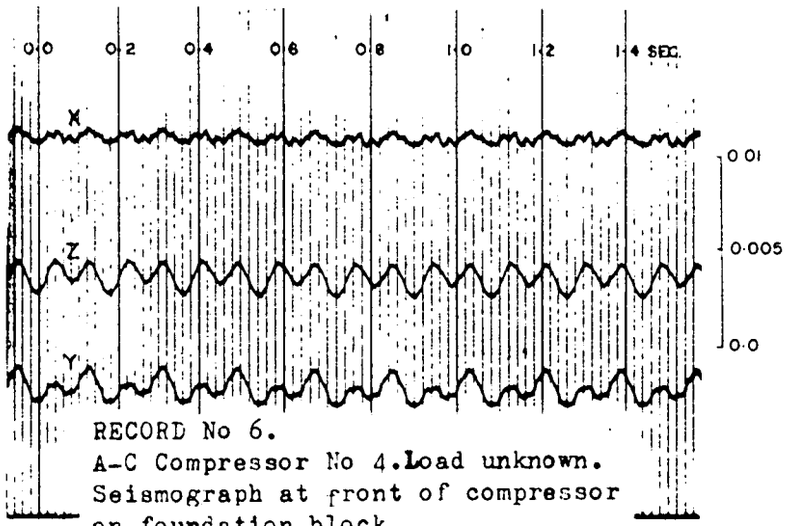


RECORD No 4.
I-R Compressor No 1 on $\frac{3}{4}$ load.
Seismograph on concrete floor of building, adjacent to isolated foundation.

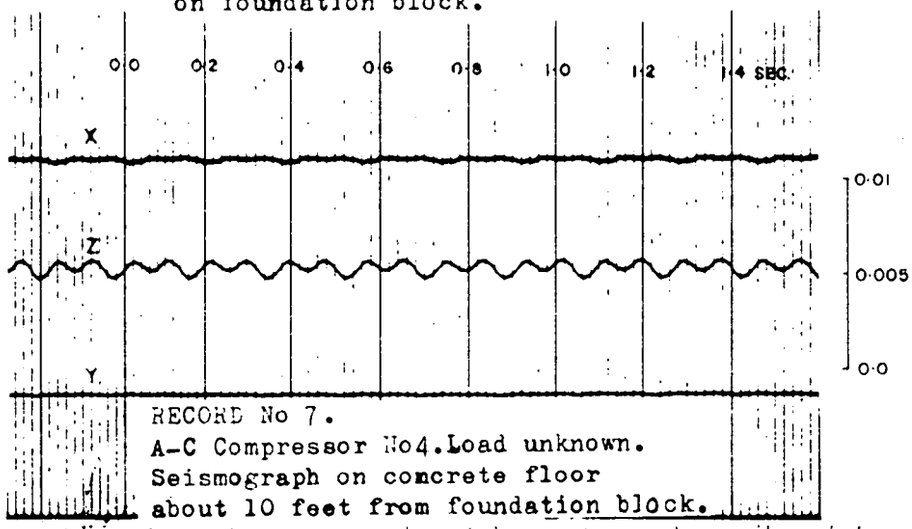


RECORD No 5.
I-R Compressor No 1 on $\frac{1}{4}$-$\frac{1}{2}$ load.
Seismograph below instrument panel on isolated foundation.

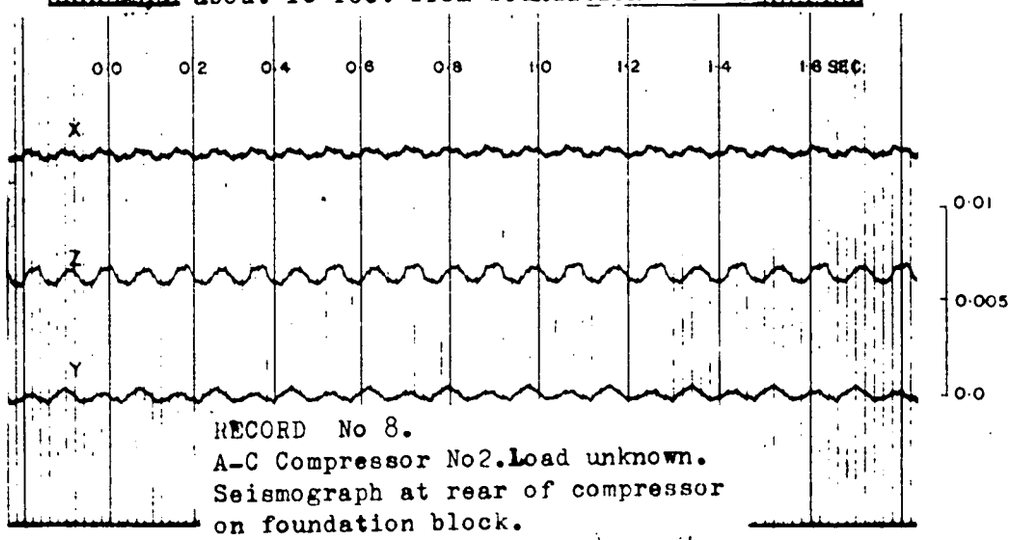
GENERAL MOTORS-HOLDENS, FISHERMENS BEND, VIC.
VIBRATION TESTS 3/3/60.
VIBRATION RECORDS.
(Using Sprengnether vibration seismograph).



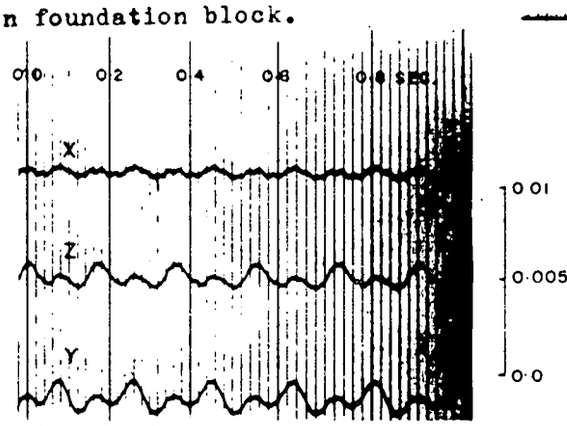
RECORD No 6.
A-C Compressor No 4. Load unknown.
Seismograph at front of compressor
on foundation block.



RECORD No 7.
A-C Compressor No4. Load unknown.
Seismograph on concrete floor
about 10 feet from foundation block.



RECORD No 8.
A-C Compressor No2. Load unknown.
Seismograph at rear of compressor
on foundation block.



RECORD No 9.
A-C Compressor No4. Load unknown.
Seismograph at rear of compressor
on foundation block.

GENERAL MOTORS-HOLDENS, FISHERMENS BEND, VIC.
VIBRATION TESTS 3/3/60.
VIBRATION RECORDS.
(Using Sprengnether vibration seismograph).

LEGEND

1 — State of New Jersey as specified by regulation

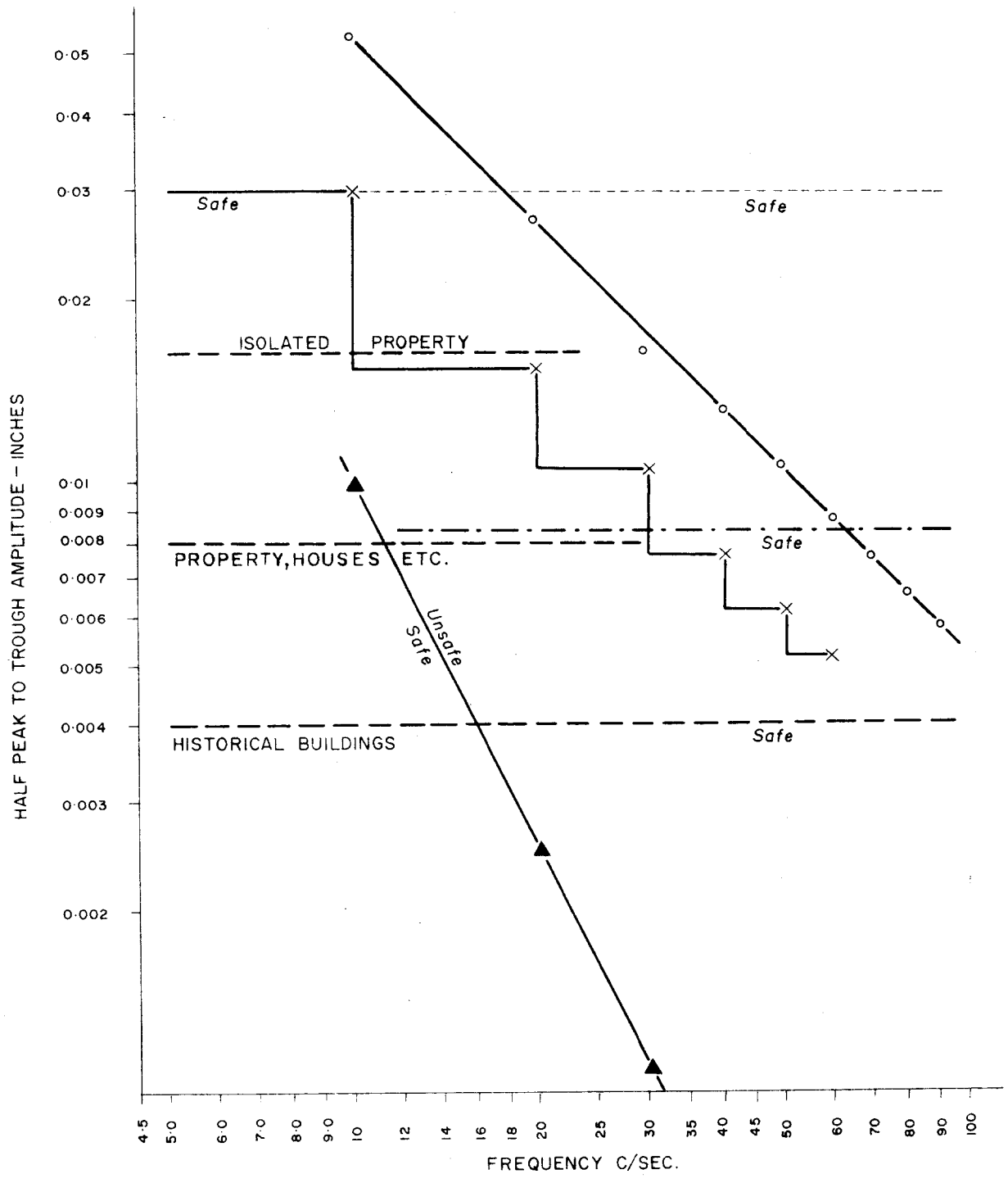
2 — State of Pennsylvania as specified by regulation for any structure

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