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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

**BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS**

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RECORD No. 1964/184

# GENERAL MOTORS-HOLDENS VIBRATION TEST, FISHERMENS BEND, VICTORIA 1964

by

P.E. Mann and M. Wainwright



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# GENERAL MOTORS HOLDEN

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## ILLUSTRATIONS

## SUMMARY

Vibrations caused by a motor-compressor system at General Motors Holden's factory Fishermen's Bend, Victoria have been measured.

For normal operation the ground acceleration produced should not damage the building.

## 1. INTRODUCTION

This record describes a vibration investigation carried out by the Bureau of Mineral Resources at the request of Atlas Copco Australia Pty. Ltd. The purpose of the test was to measure the vibration produced by a two-stage air compressor driven by an electric motor, at the General Motors Holden's factory, Fishermen's Bend, Victoria.

The investigation was carried out on the 6th November 1964 by P.E. Mann and M. Wainwright of the Bureau.

## 2. INSTRUMENT AND METHODS

The instrument used to record the vibrations was a Sprengnether Portable Blast and Vibration Seismograph, Serial No. 1577. This instrument records three arbitrary mutually perpendicular components of a vibration on a moving strip of photographic paper. The record shows each component of the vibration magnified 50 times, with timing lines at intervals of 0.02 seconds.

Records were taken at four positions in the compressor house for three different operating conditions of the equipment, viz. uncoupled electric motor only operating, electric motor and both compressor stages operating under "no load", electric motor and both compressors operating under full load. A background "noise" test was also taken.

The measurement of the vibration within the motor and compressors is beyond the scope of the present work. The maximum allowable machinery vibration applicable to shipboard equipment specified by a military standard of the U.S. Government is given by Harris and Crede (1961); this may provide some guidance if investigations of this problem are proposed.

## 3. RESULTS

Plate 1 shows the general layout of the motor and compressors and the positions of the seismograph during the tests. Plates 2, 3 and 4 show part of the records obtained during the tests. In each test the record was

run for several seconds, but for convenience of illustration only a part of each record is reproduced. The amplitudes and frequencies of the three components of vibration were scaled from the seismograms. The component accelerations are calculated on the assumption that the vibrations are sinusoidal, from the equation

$$a = 4 \overline{II}^{2} f^{2} A$$

where $a$ = maximum acceleration

$f$ = frequency of vibration

$A$ = displacement of vibration (half peak to trough of displacement on seismogram)

The resultant acceleration is the vector sum of the three component accelerations. Table 1 shows the calculated resultant acceleration for each test given in in./sec$^2$ and in terms of g, the acceleration due to gravity (= 386 in./sec$^2$). The dominant frequency recorded during the tests is 50 c/s, which originates from the electric motor whose speed is about 3000 r.p.m. The frequency 100 c/s is probably a harmonic of the fundamental frequency and the 6 c/s frequency measured on record 12 probably corresponds to the low amplitude 6 c/s vibration recorded in the noise test.

The maximum resultant acceleration occurs when the motor coupled to the compressor stages is on full load; an intermediate resultant acceleration occurs when the uncoupled motor only is operating, and minimum resultant acceleration is generated when the motor coupled to compressor stages is operating under "no load". This indicates that the motor coupled to the compressor stages under "no load" is better balanced as a system than the uncoupled motor only.

At positions 1 and 2, the resultant accelerations calculated for seismograms 14 and 15 are greater than those for seismograms 9 and 10 since the maximum amplitude of the longitudinal and transverse components of vibration are slightly greater on record 14 and 15. This is due to an irregular low frequency "quasi-beat" whose origin in uncertain. Neglecting these 'beats' and using the "normal" amplitude, the resultant acceleration

is equal to 59 in./sec$^2$ and 57 in./sec$^2$ for record 15 and 14 respectively. These figures are in good agreement with the acceleration figures calculated for seismograms 9 and 10. At position 3 the resultant acceleration calculated for seismogram 11 is greater than for seismogram 13. The smaller amplitude recorded on seismogram 13 is probably due to several workmen in addition to the observer standing on the inspection plate during the test; only the observer was on the plate to record seismogram 11.

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

Acceleration greater than 1.0g - damaging

" between 0.1g and 1.0g - may be slightly damaging (caution zone)

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

The resultant accelerations measured on the foundation block under full-load conditions lie within the 'caution zone' as defined above; however the acceleration of the compressor house floor under full load operation (seismogram 12) lies within the 'safe' zone, indicating a significant reduction in vibration from compressor foundations to the rest of the building.

It may be concluded that the vibrations will not damage the compressor building.

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 | 50 c/s |
|---|---|---|
| Mallock | 0.196 | 0.00020 |
| Melville | 0.0370 | 0.00004 |
| Digby and Sankey | 0.0039 | 0.00039 |
| Reiher and Meister | 0.0032-0.016 | 0.0003-0.0005 |

Some authorities would regard the measured amplitudes on the floor as annoying.

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 these tests are greater than the perceptible minimum according to Mallock.

## 4. CONCLUSIONS

The amplitude and frequency of vibration produced by a motor-compressor system were measured on the foundation block, floor and the inspection plate. The maximum acceleration, a measure of the stress generated, is greatest when the motor-compressor system is operating under full-load. Resultant maximum acceleration in the foundation block was 0.25g., and that in the inspection plate 0.14g. Resultant maximum acceleration measured on the floor of the compressor house with the motor-compressor system operating under full-load is less than 0.1g and can be regarded as safe.

## 5. REFERENCES


HARRIS, C.M. and CREDE, C.E. 1961 SHOCK AND VIBRATION HANDBOOK, Section 46-31. McGRAW-HILL, NEW YORK.

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 WINDES, S.L. 1942 Seismic effects of quarry blasting. Bull. U.S. Bur. Min. 442

MALLOCK, H.R.A. Vibrations produced by the working of traffic on the Central London Railway. U.K. Board of Trade Report, 1902 Cd. 951

TABLE 1.

| Record No. | Seismo-graph Position | Vibration Source | Component | Displacement (ins.) | Freq. (c/s) | Resultant Acceleration (ins/sec) | Resultant Acceleration (g) | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Electric motor | L | 0.0004 | 50 | | | |
| | | | V | 0.0002 | 50 | 48 | 0.12 | Seismograph on compressor foundation. |
| | | | T | 0.0002 | 50 | | | |
| 2 | 2 | " " | L | 0.0004 | 50 | | | |
| | | | V | 0.0002 | 50 | 48 | 0.12 | Seismograph on compressor foundation. V component not pure sine wave. Beat 11 cps on T component. |
| | | | T | 0.0002 | 50 | | | |
| 3 | 3 | " " | L | 0.0002 | 50 | | | |
| | | | V | < 0.0015 | 50 | < 27 | 0.07 | Seismograph on unsecured inspection plate. Low frequency wave also on V component |
| | | | T | < 0.0001 | 50 | | | |
| 4 | 4 | " " | L | 0.0004 | 50 | | | |
| | | | V | 0.0002 | 50 | 48 | 0.12 | Seismograph on floor 18 ft from centre line of compressor system. |
| | | | T | 0.0002 | 50 | | | |
| 5 | 4 | Electric motor & compressor on no load | L | < 0.0002 | 50 | | | |
| | | | V | 0.0002 | 50 | < 34 | < 0.09 | |
| | | | T | 0.0002 | 50 | | | |
| 6 | 3 | " " | L | < 0.00005 | 50 | | | |
| | | | V | 0.0001 | 100 | 56 | 0.14 | |
| | | | T | 0.0001 | 100 | | | |
| 7 | 2 | " " | L | 0.0001 | 50 | | | |
| | | | V | 0.0001 | 50 | 24 | 0.06 | Minor 100 cps wave also present on L and V component. |
| | | | T | 0.0002 | 50 | | | |
| 8 | 1 | " " | L | 0.0003 | 50 | | | |
| | | | V | 0.0001 | 50 | 37 | 0.10 | Minor high frequency wave present on V and T component. |
| | | | T | 0.0002 | 50 | | | |
| 9 | 1 | Electric motor & compressor on load | L | 0.0005 | 50 | | | |
| | | | V | 0.0002 | 50 | 57 | 0.15 | |
| | | | T | 0.0002 | 50 | | | |
| 10 | 2 | " " | L | 0.0005 | 50 | | | |
| | | | V | 0.00015 | 50 | 60 | 0.15 | Minor high frequency wave present on T component. |
| | | | T | 0.00025 | 50 | | | |
| 11 | 3 | " " | L | 0.0005 | 50 | | | |
| | | | V | 0.0001 | 50 | 54 | 0.14 | Minor high frequency wave present on V and T components. |
| | | | T | 0.0002 | 50 | | | |
| 12 | 4 | " " | L | 0.0003 | 100 | | | |
| | | | V | 0.00008 | 50 | 34 | 0.09 | Low frequency beats present on L and V components. |
| | | | T | 0.0002 | 6 | | | |
| 13 | 3 | " " | L | 0.0002 | 50 | | | |
| | | | V | < 0.0001 | 50 | 30 | 0.08 | |
| | | | T | 0.0002 | 50 | | | |
| 14 | 2 | " " | L | 0.0007 | 50 | | | |
| | | | V | 0.0002 | 50 | 78 | 0.20 | Low frequency beats - Resultant accelerations calculated on basis of maximum displacements. |
| | | | T | 0.0003 | 50 | | | |
| 15 | 1 | " " | L | 0.0005 | 50 | | | |
| | | | V | 0.0002 | 50 | 95 | 0.25 | |
| | | | T | 0.0002 | 100 | | | |
| 16 | 1 | Motor and compressors not operating | L | < 0.0001 | 6 | | | |
| | | | V | < 0.0002 | 6 | Negligible | | Background noise - probably from intermittently used jack-hammer external to building. |
| | | | T | < 0.0001 | 6 | | | |

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LOCATION PLAN - ATLAS COPCO COMPRESSOR STATION.

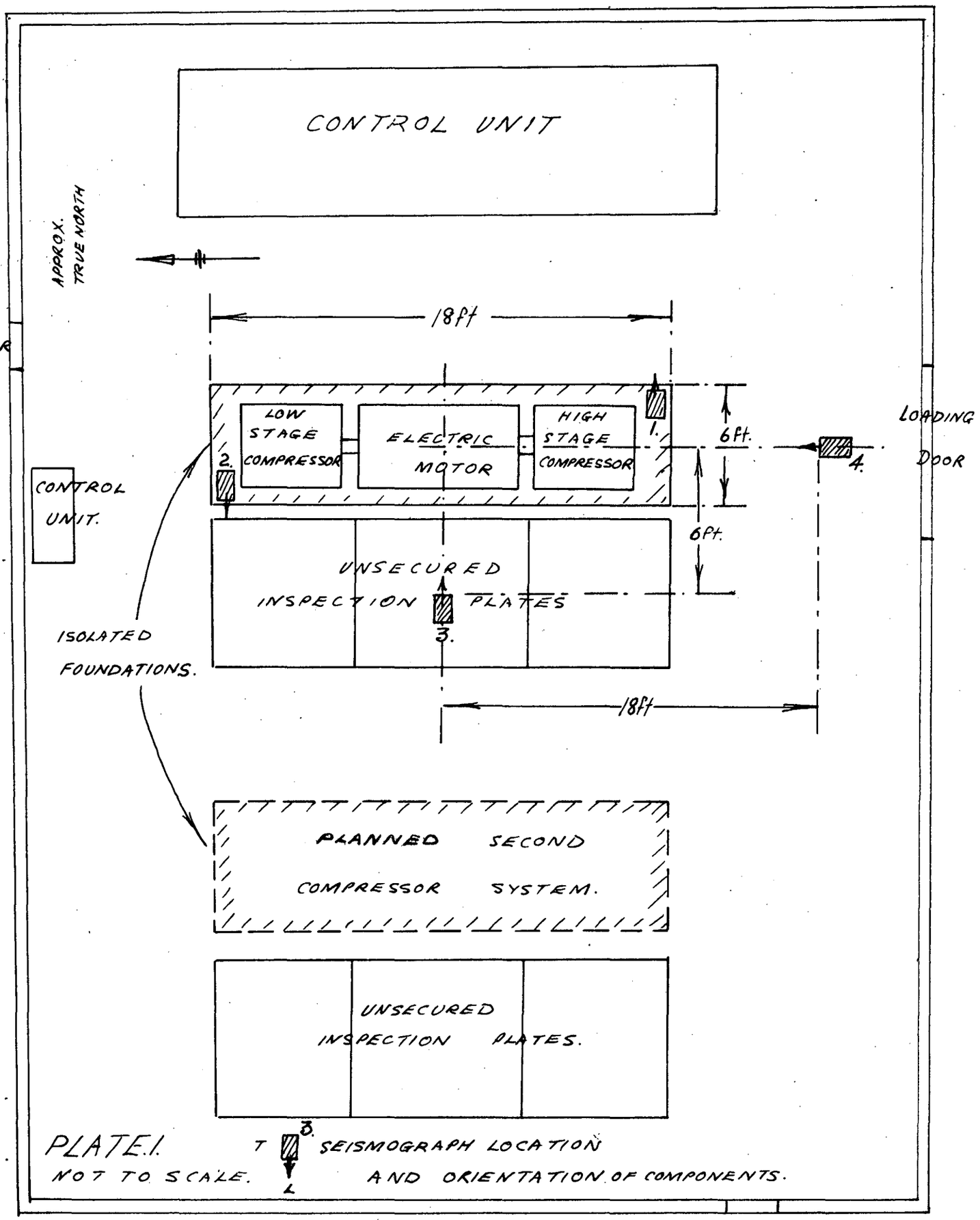
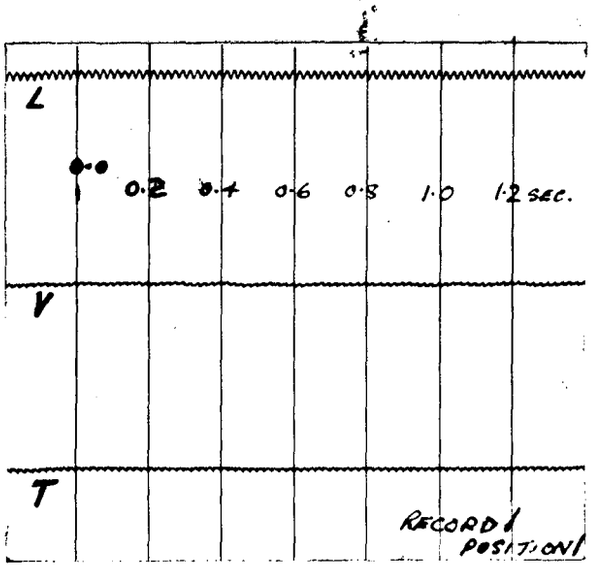
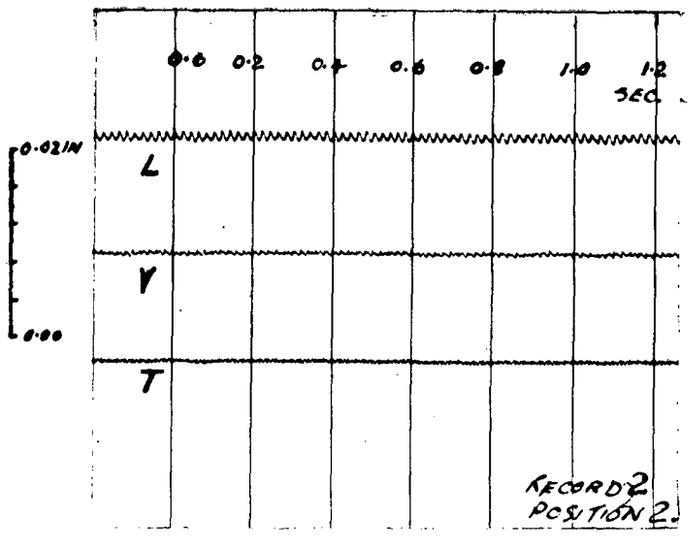


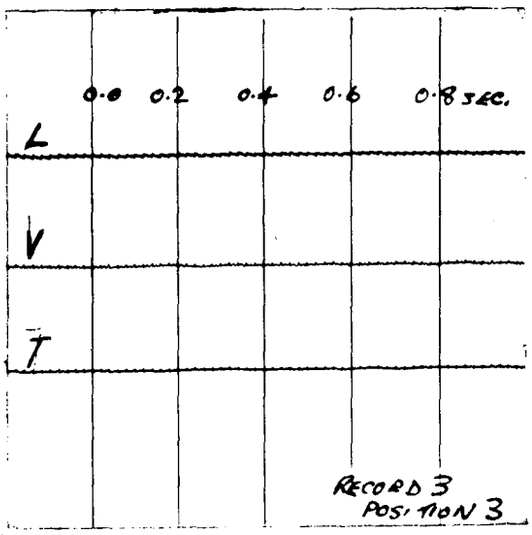

PLATE I.

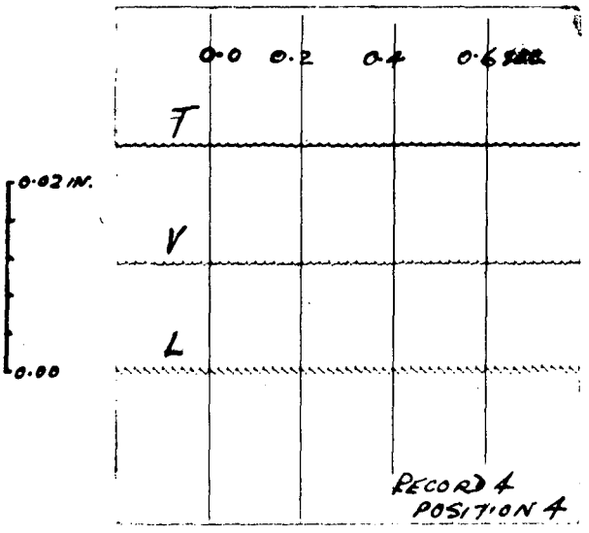
NOT TO SCALE.

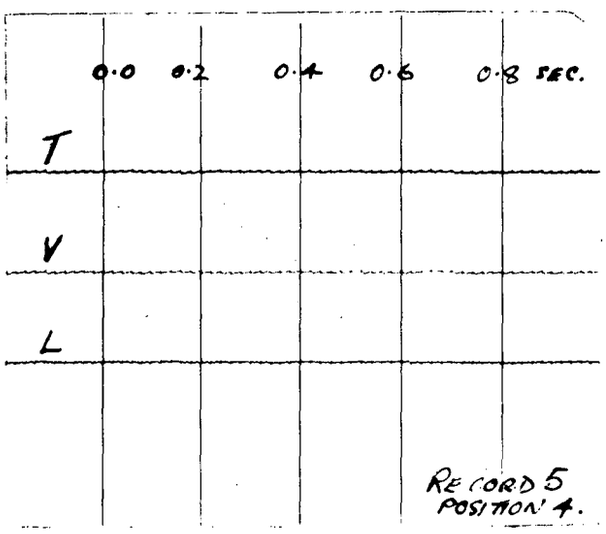
G344-104

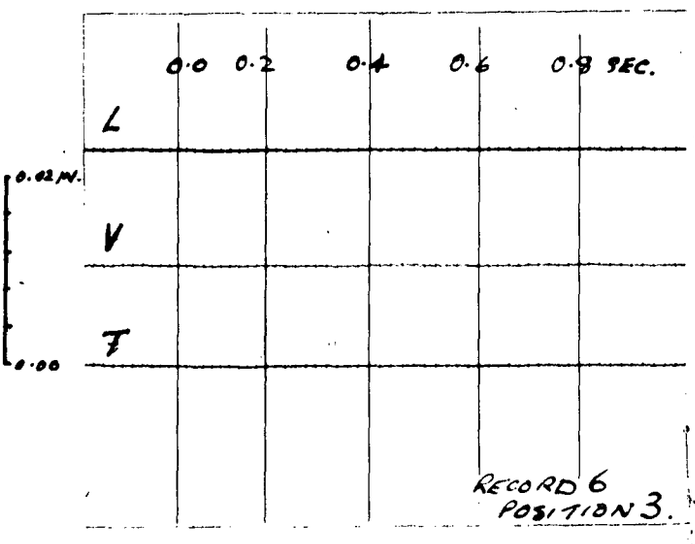
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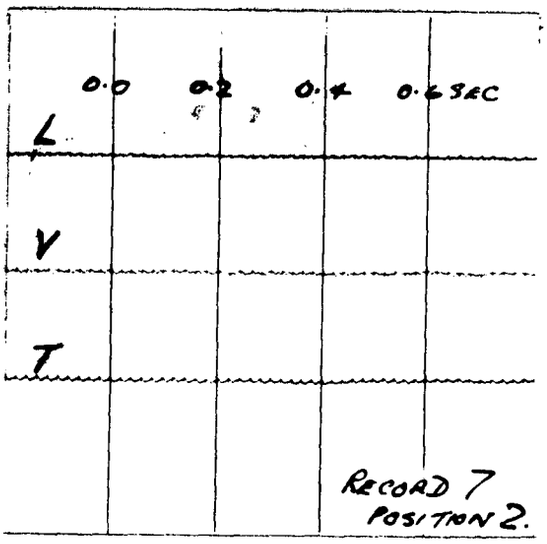
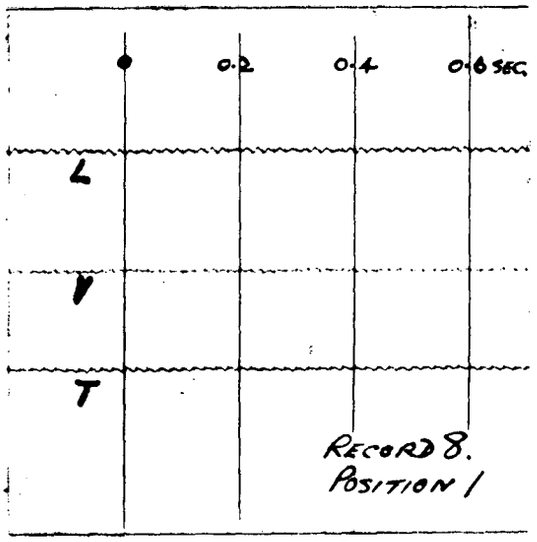
VIBRATION RECORDS

PLATE. 2.

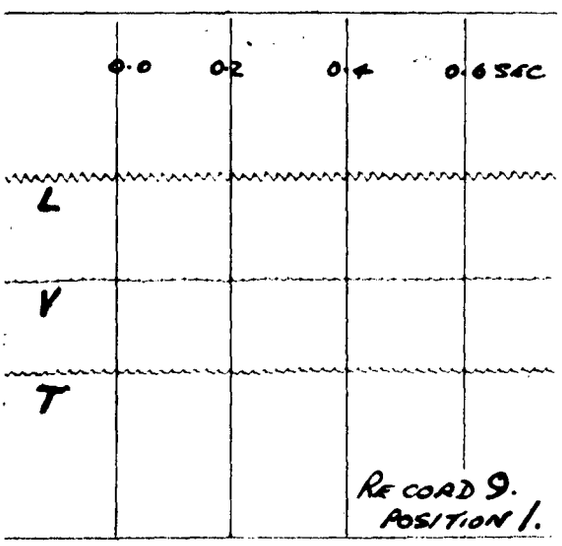
J55/B5-17



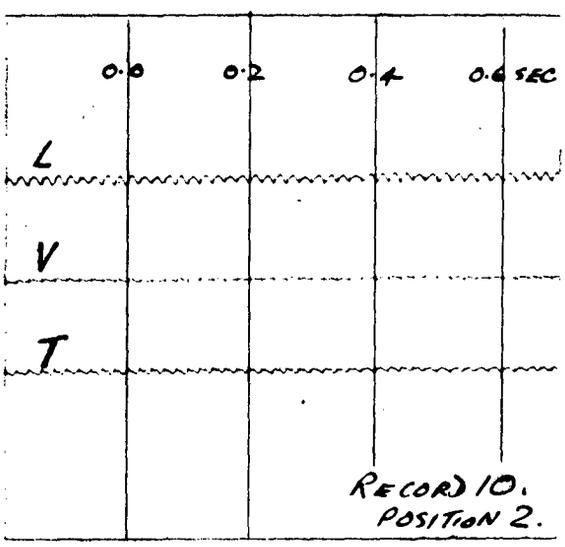

RECORD 7
POSITION 2.

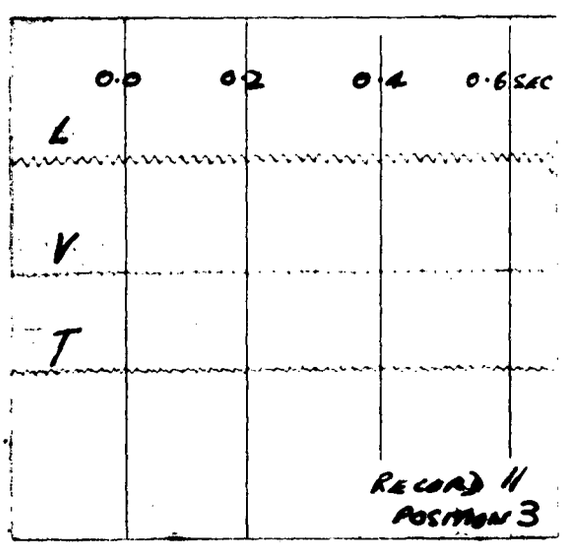

RECORD 8.
POSITION 1



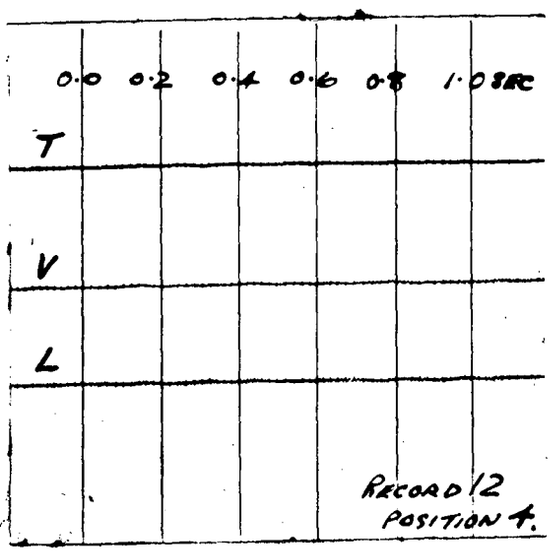

RECORD 9.
POSITION 1.


RECORD 10.
POSITION 2.




RECORD 11
POSITION 3


RECORD 12
POSITION 4.

PLATE. 3.

GENERAL MOTORS-HOLDEN, FISHERMENS BEND, VIC

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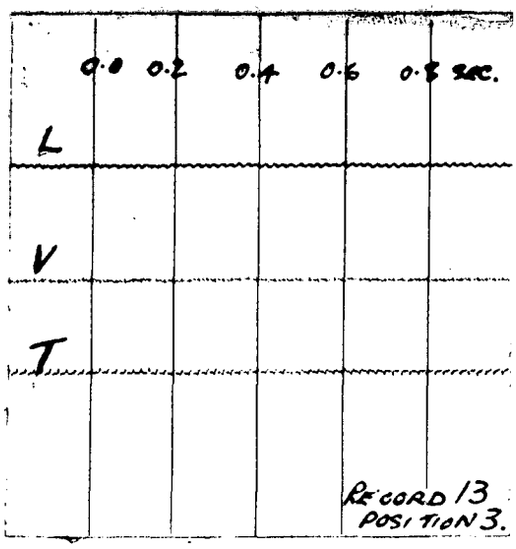
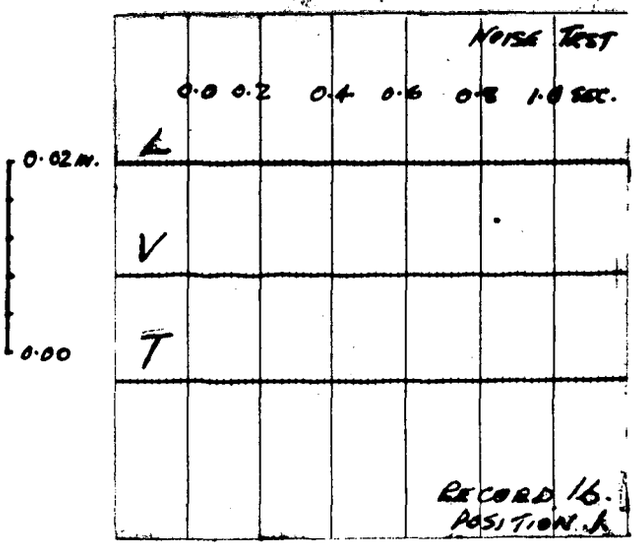
VIBRATION RECORDS.

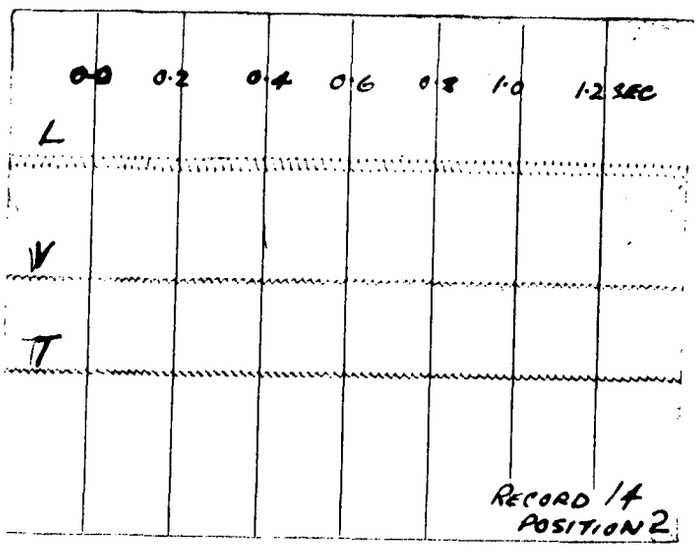
J55/85-18



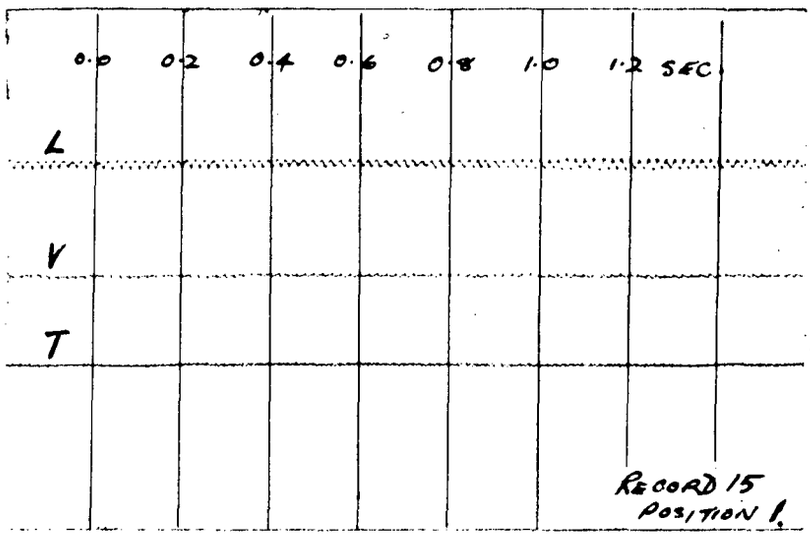















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VIBRATION RECORDS

PLATE. 4.

155/RE-16