CHAPTER 3

EXPERIMENTAL STUDY

In this chapter the experimental study of the effect of mechanical vibration on kinetic friction was divided into 5 parts as follows :-

1. Object
2. Apparatus
3. Measuring Equipment
4. Experimental Procedure
5. Experimental Programme.

OBJECT

The object of this experimental study is to investigate the effect of mechanical vibration on kinetic friction. An attempt has been made to measure normal force, friction force, and sliding speed. Normal force to be measured is the force at surfaces of contact. Without vibration normal force is a static force. When vibration is applied to the vibrated mass, inertia force occur. The measured friction force is the force on the contact surfaces. If a motor is used as a dynamometer, the friction of the motor should not be affected by the friction of the testing surfaces, and normal force and the sliding speed should be kept constant. Means of detecting any variation of speed should be provided. Self-induced vibration of the slider should be avoided by careful design of the slider holder and the applied load mechanism, and the rotating parts should be balanced to eliminate vibration of the apparatus.

APPARATUS

The apparatus consists of a motor, a vibrator, a strain gauge torque arm transducer, a strain gauge force transducer, and a spring loading mechanism. (Figs. 3-1., 3-8., 3-10.)

The motor acts as a dynamometer and is freely supported by a pair of tapered roller bearings on each end of the motor shaft. The object of using the tapered roller at both ends is to provide radial rigidity and resistance to axial thrust at both ends. The motor is a D.C. motor of ¼ H.P. (FRACMO, SER.NO. 11), the speed being controlled by a variac (TECHQUIPMENT, UNIT NO. 1241264). A torque arm is fitted on the motor case. A thick disc with a steel ring specimen bolted to it is keyed to the front journal of the motor. The mean radius of the steel ring specimen is 2½ inches. (Fig. 3-1.)

The vibrator is a " GOODMANS " type (PYE-LING, SER.NO. 261), the frequency and amplitude being controlled by an oscillator and a power amplifier (PYE-LING, SER.NO. 1020 P and 1024 P respectively). A trunnion is attached to one end of the force transducer, and the other end of the transducer holds a circular cross section brass specimen of diameter 3/4 inches, which acts as a slider. (Figs. 3-2., 3-3., 3-4., 3-5.)

A torque arm transducer consists of a strain gauge measuring the bending of a flexible steel beam. One end of the steel is rigidly attached to the case of the motor, and the other, through a low friction steel ball mounting, presses against a stop. (Fig. 3-7.)

When the brass slider is pressed against the rotating disc by the spring loading mechanism, the frictional force on the disc is transmitted to the motor case and torque arm. For this apparatus the ratio of the torque arm and mean radius of the ring specimen is 2.4 to 1. The speed of rotation of the disc is measured by

(1) a tachometer at the front end of the motor shaft and

(2) a stroboscope (DAWE, SER. NO. 44724).

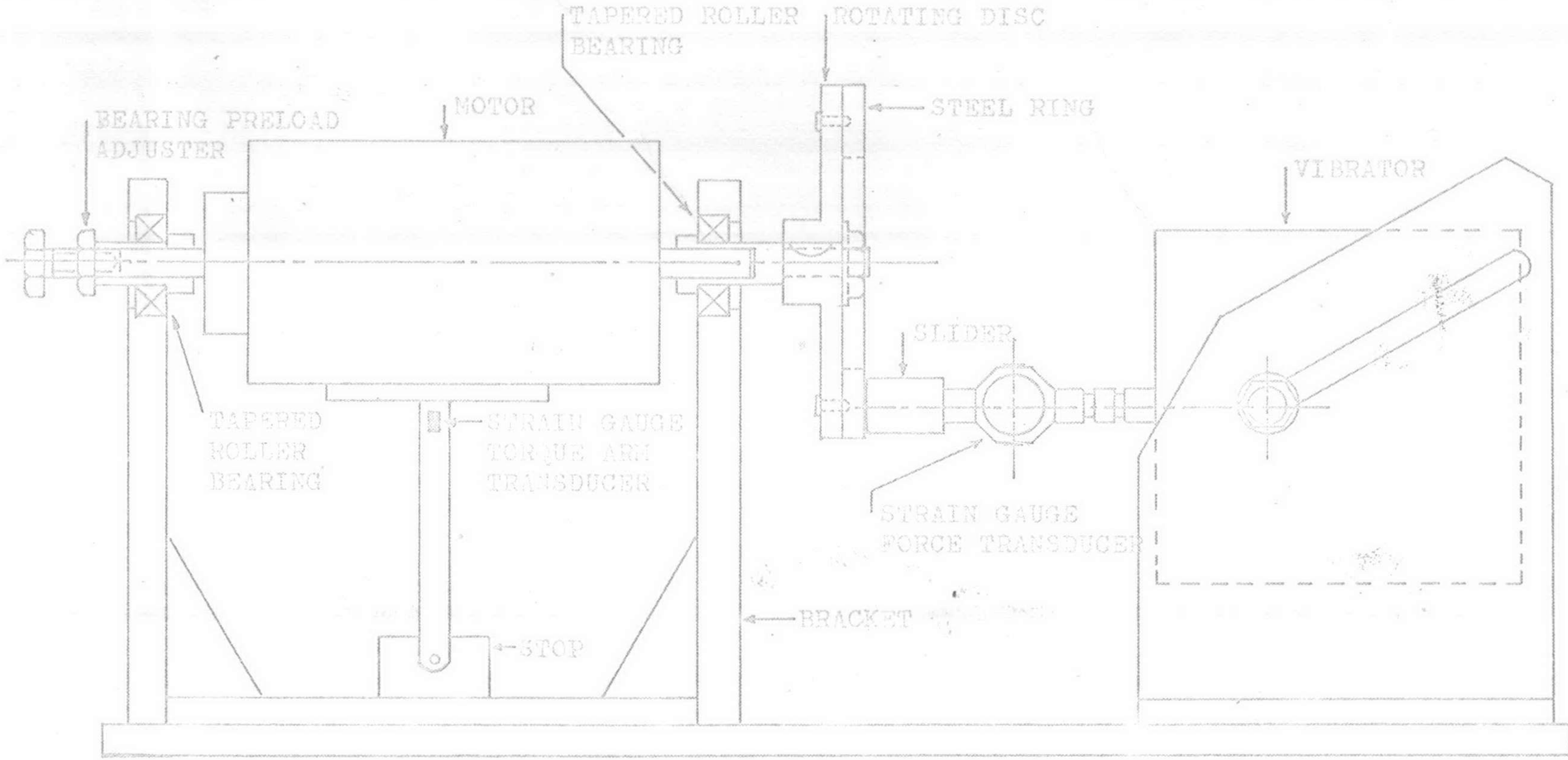


Fig. 3-1. GENERAL ARRANGEMENT OF THE APPARATUS.

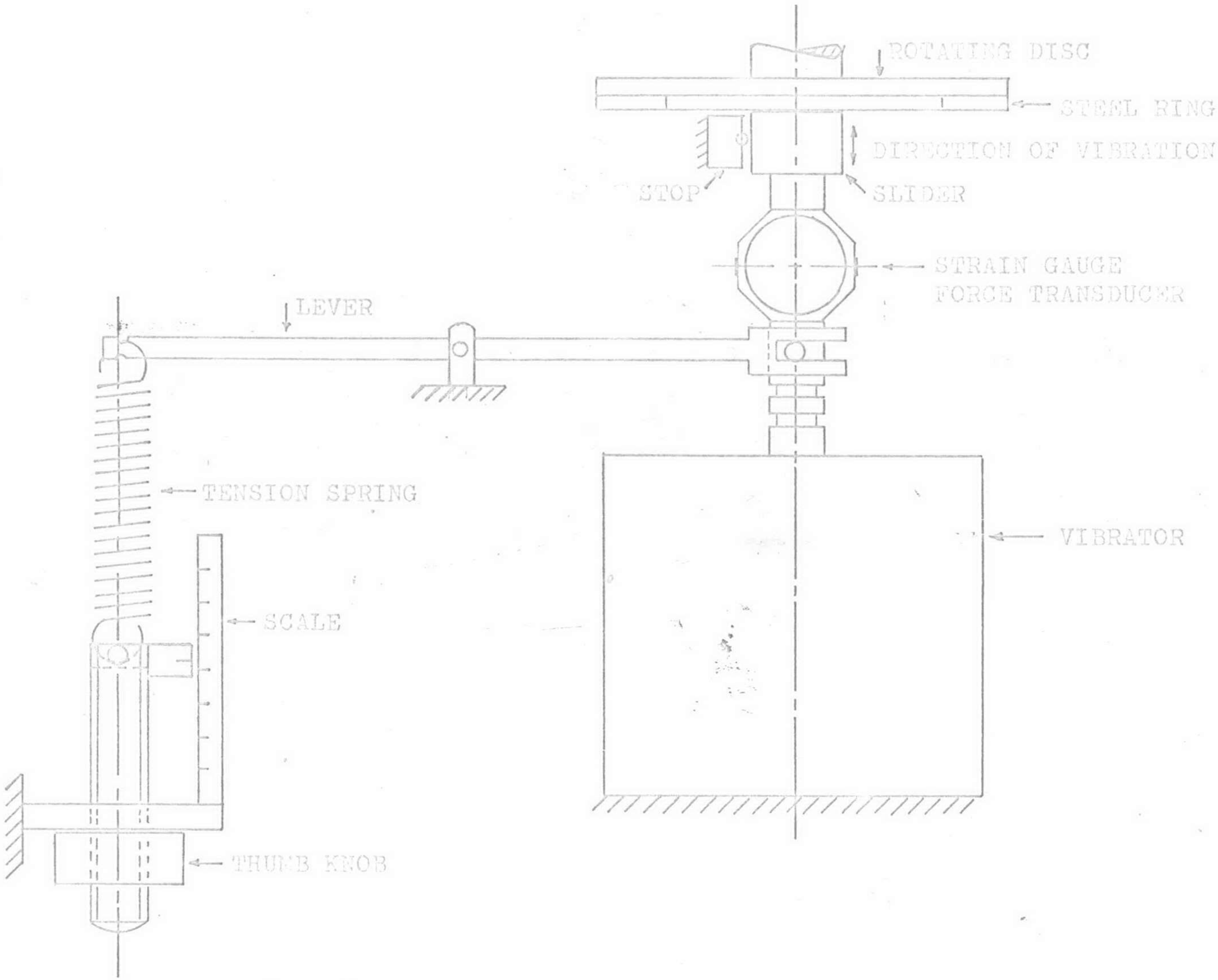


Fig. 3-2. SHOWING THE DIRECTION OF VIBRATION PERPENDICULAR TO THE SLIDING SURFACE IN A PLANE AT RIGHT ANGLES.

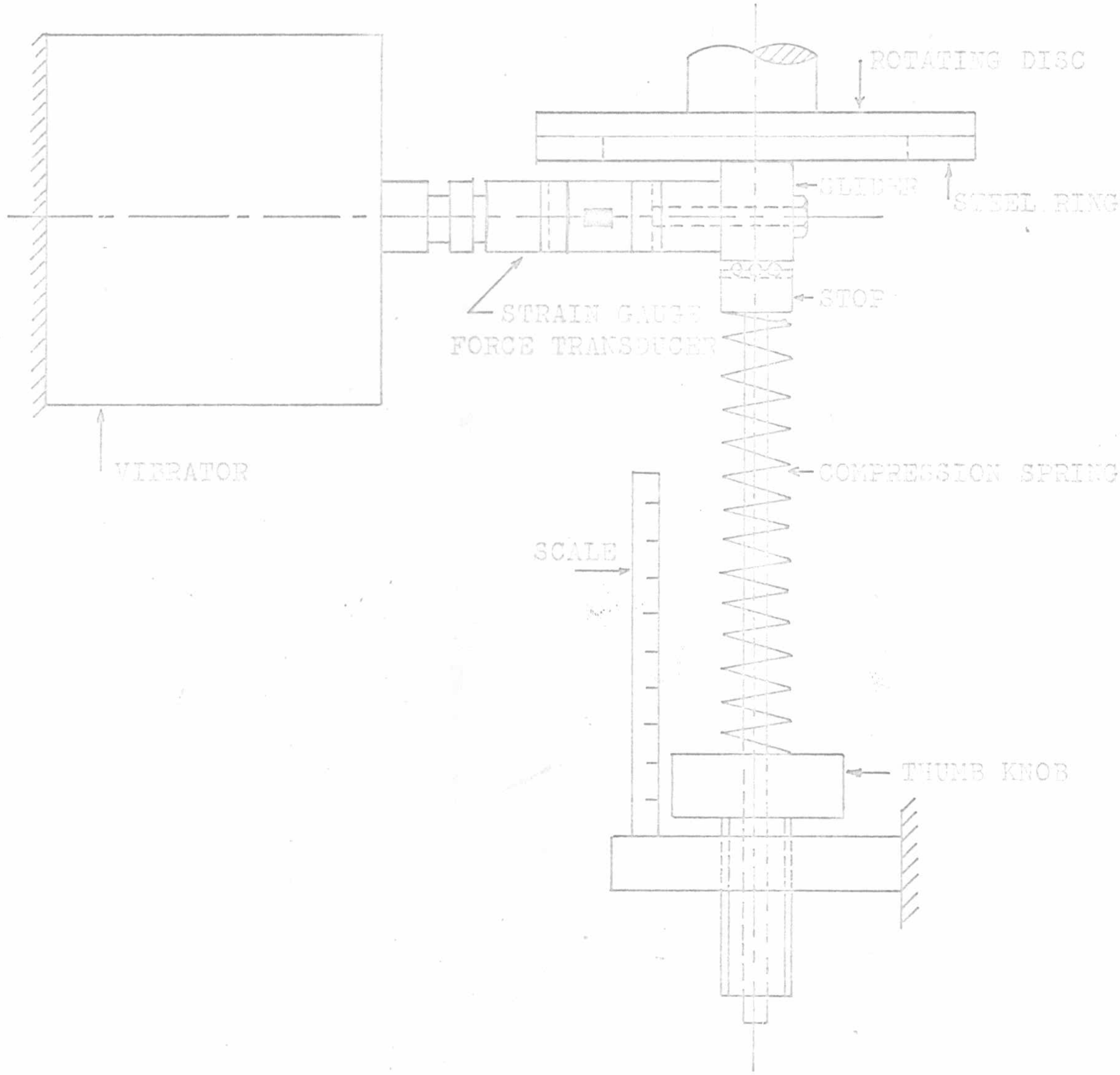


Fig. 3-3. SHOWING THE DIRECTION OF VIBRATION PARALLEL TO THE DIRECTION OF SLIDING BUT IN THE SAME PLANE.

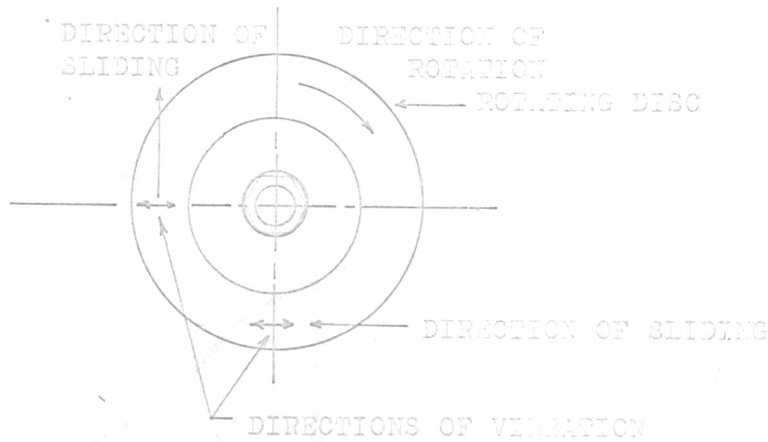


Fig. 3-4. THE DIRECTION OF VIBRATION PERPENDICULAR AND PARALLEL TO THE DIRECTION OF SLIDING.

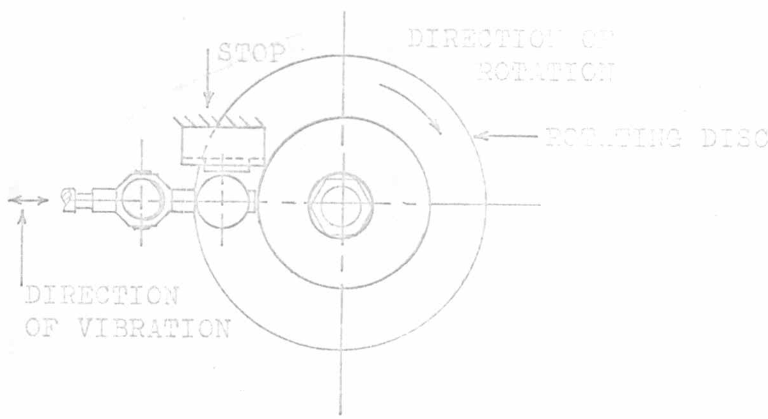


Fig. 3-5. THE DIRECTION OF VIBRATION PERPENDICULAR TO THE DIRECTION OF SLIDING.

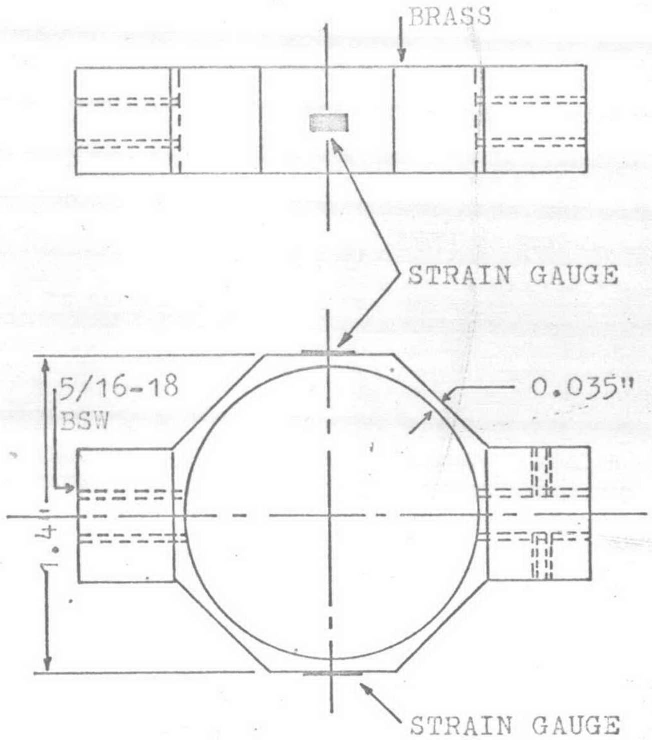


Fig. 3-6. STRAIN GAUGE FORCE TRANSDUCER.

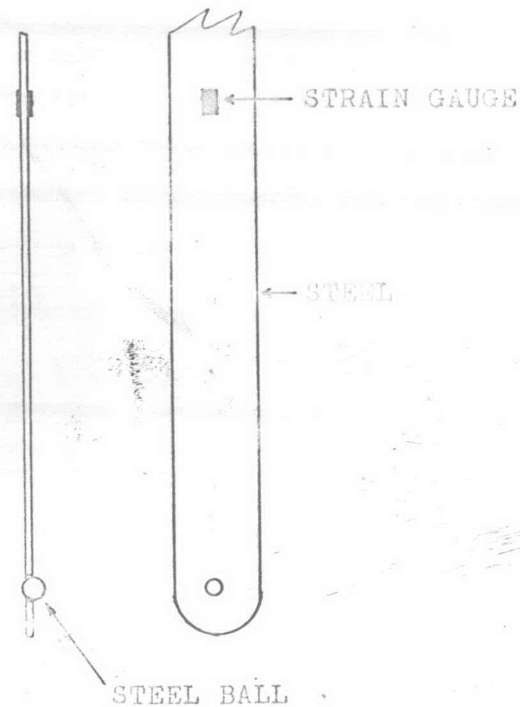


Fig. 3-7. STRAIN GAUGE TORQUE ARM TRANSDUCER.

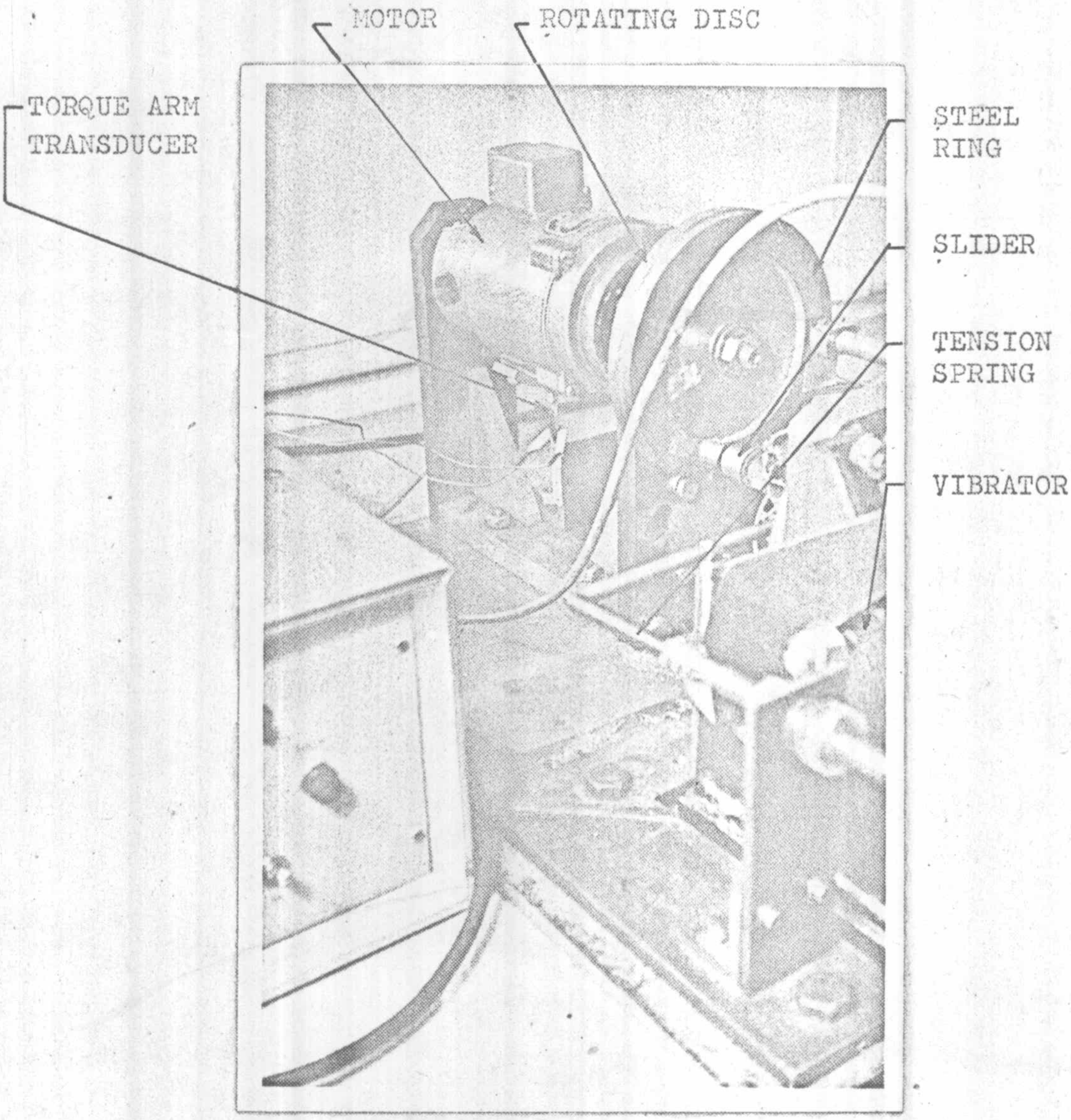


Fig. 3-8. PHOTOGRAPH OF THE FRICTIONAL TESTING APPARATUS.

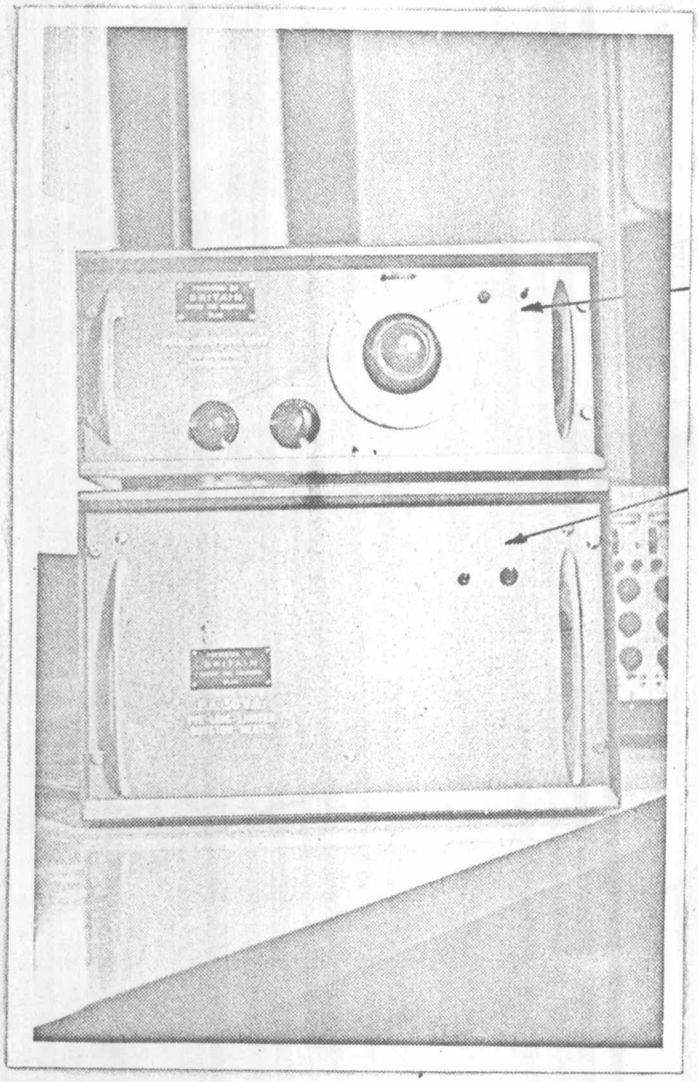


Fig. 3-9. OSCILLATOR AND POWER AMPLIFIER.

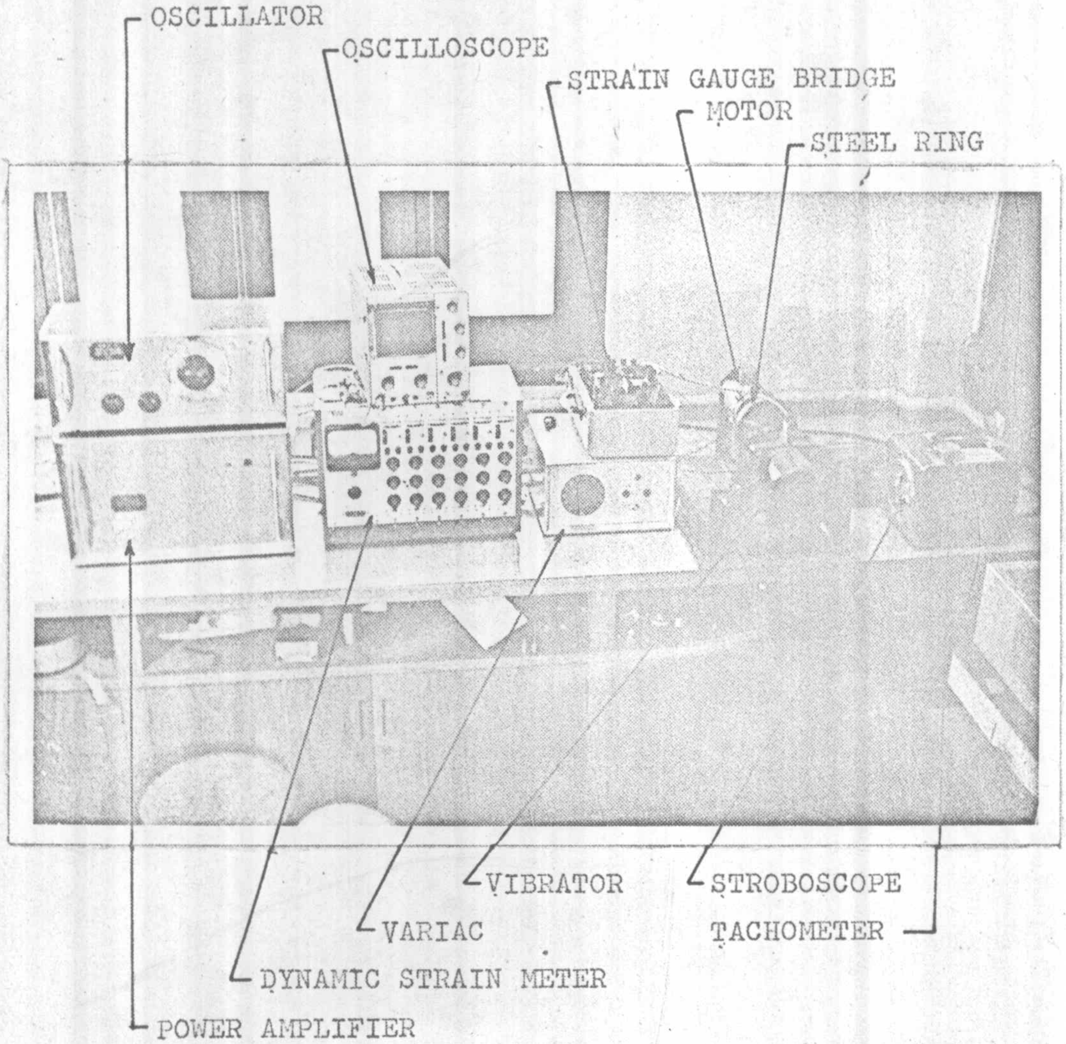


Fig. 3-10. ARRANGEMENT OF THE TESTING APPARATUS AND MEASURING EQUIPMENT.

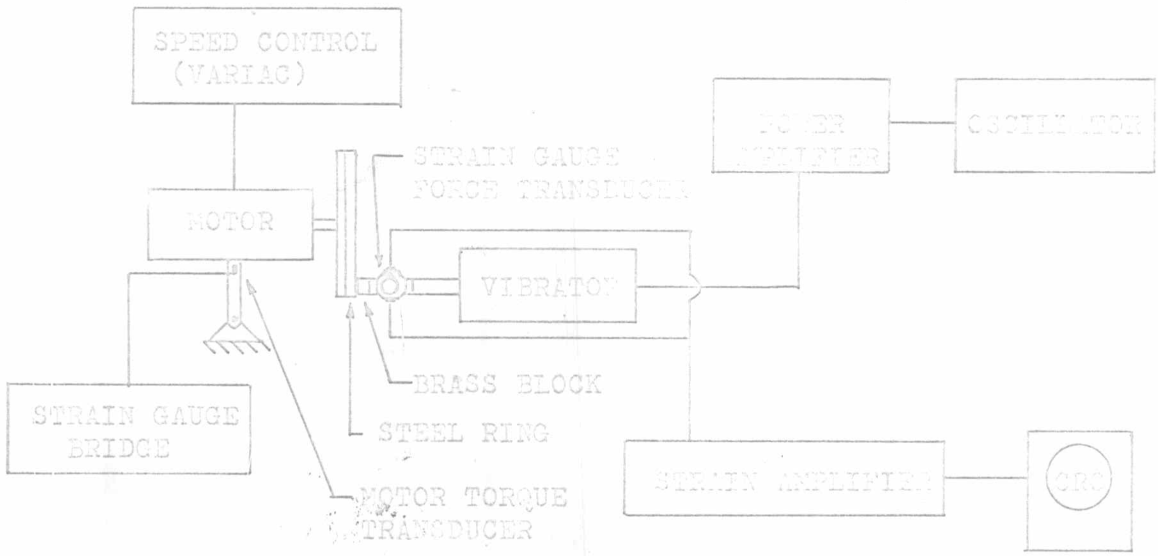


Fig. 3-11. BLOCK SCHEMATIC OF FRICTIONAL TESTING APPARATUS.

MEASURING EQUIPMENT

The measuring equipment used in the experimental study is as follows. (Fig. 3-11A.)

(1) Dynamic Strain Meter is used in measuring the strain of the force transducer. The strain then can be converted to force as previously calibrated. The output can be displayed on an oscilloscope and pictures can also be taken. This instrument has a frequency response from 0 to 700 c/s at 100 % output. The maximum sensitivity for low impedance input of strain gauge resistance of 120 ohms is preferable or of 60-2000 ohms is tolerable.

(2) Single Channel Strain Amplifier and High Speed 2 Pen Recorder. (SER.NO. 277, 1272 respectively). Kelvin and Huges Ltd. (Fig. 3-13.)

The Strain Amplidier is used to amplify strain from the torque arm transducer and then the amplified strain is put into the Recorder to record strain on a recording paper. For pick-ups containing all four arms of a bridge, the input to the bridge is 10 volts at 2 kc/s. The range of pick-up resistance may be from 75 ohms to 5,000 ohms per arm. The sensitivity of the amplifier is about 0.3 mv, at maximum gain the deflection will be three quarters of the full-scale.

(3) Portable Strain Gauge Bridge. Type 5580. H. Tinsley & Co. Ltd. (Fig. 3-14.) The strain of the torque arm transducer is measured by the strain gauge bridge. The Strain can be converted to force as previously calibrated.

(4) Vibration Meter. Type B 731 E (SER. NO. 659)
The Wayne Kerr Laboratories Ltd. (Fig. 3-15.)

The vibration Meter is a portable instrument for accurate measurement of distance and that of vibration amplitude from 50 micro inches to 0.5 inches over the frequency range from 1 c/s to 10 kc/s. The extension or contraction of the force transducer is measured by this instrument.

(5) Sweep-Delay Oscilloscope. Type CX 1444, and Universal Camera. (SER. NO. 200297, 1863 respectively). The Solartron Electronic Group Ltd., Southern Instrument Ltd. respectively. (Fig. 3-16.)

The oscilloscope is used in conjunction with the Universal Camera type M 731. The output from the force transducer is put into the Dynamic Strain Meter and then the output of the Dynamic Strain Meter is put into the Sweep-Delay Oscilloscope. The picture is then taken from the scope by the Universal Camera.

(6) Cathode Ray Oscilloscope. Type D 52.
(Fig. 3-11A.)

This unit is connected to the Dynamic Strain Meter. It shows the strain wave form of the force transducer under various conditions.

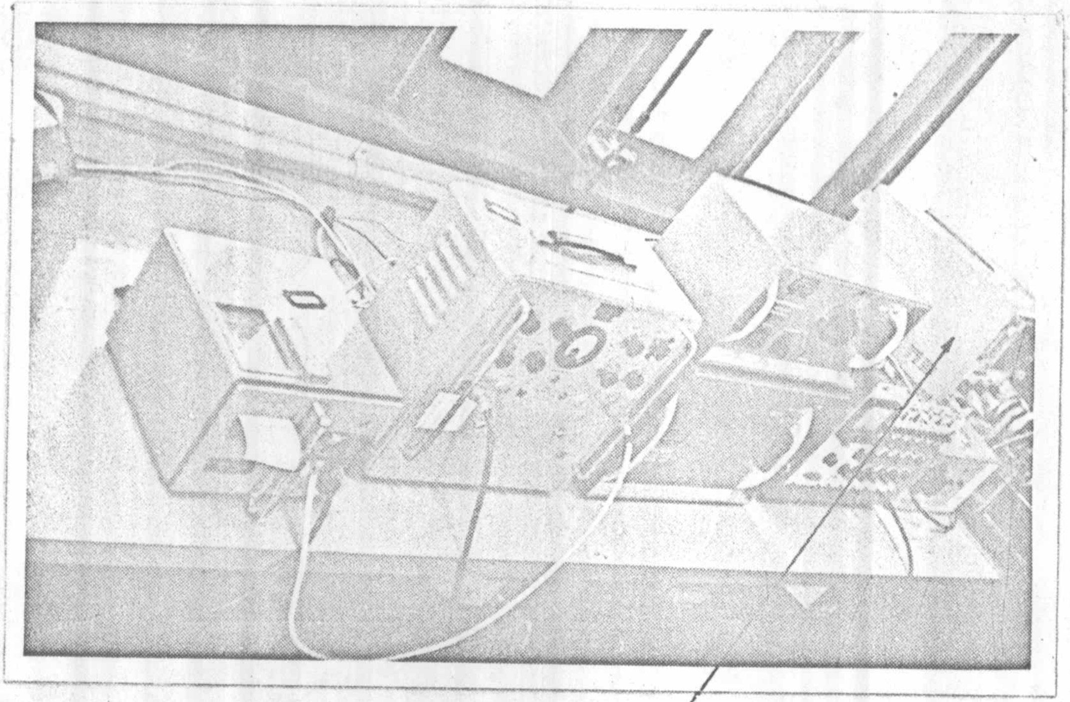


Fig. 3-11A. MEASURING EQUIPMENT.

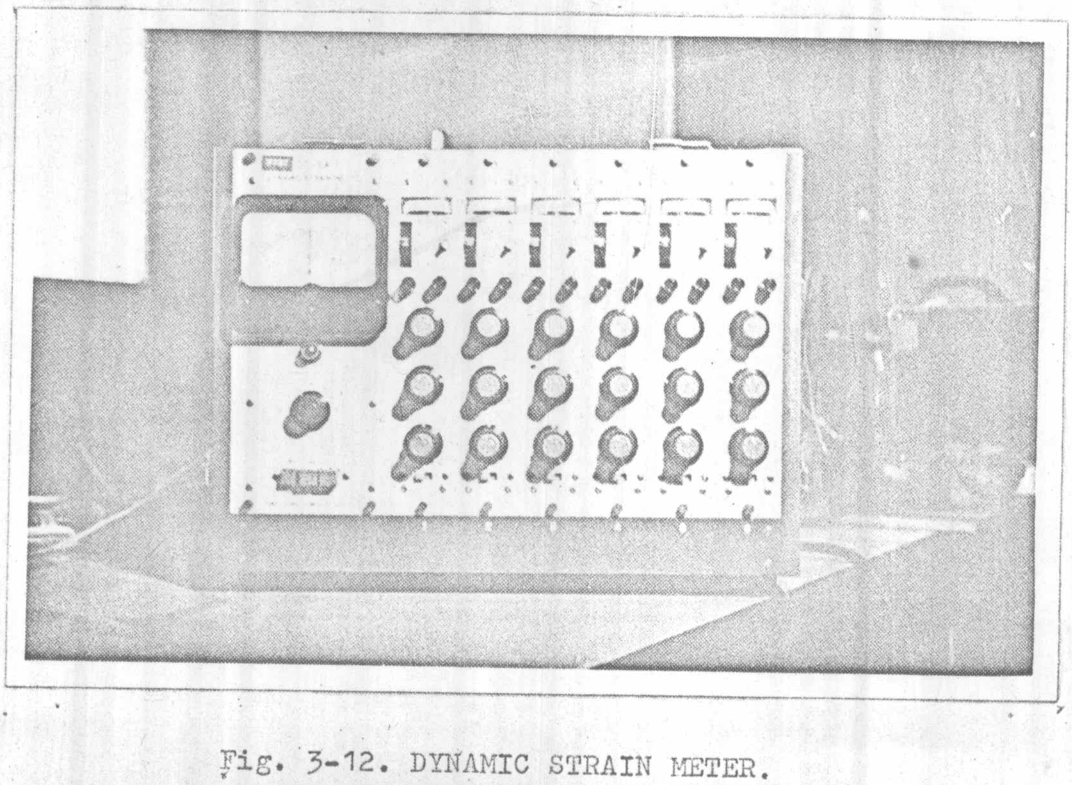
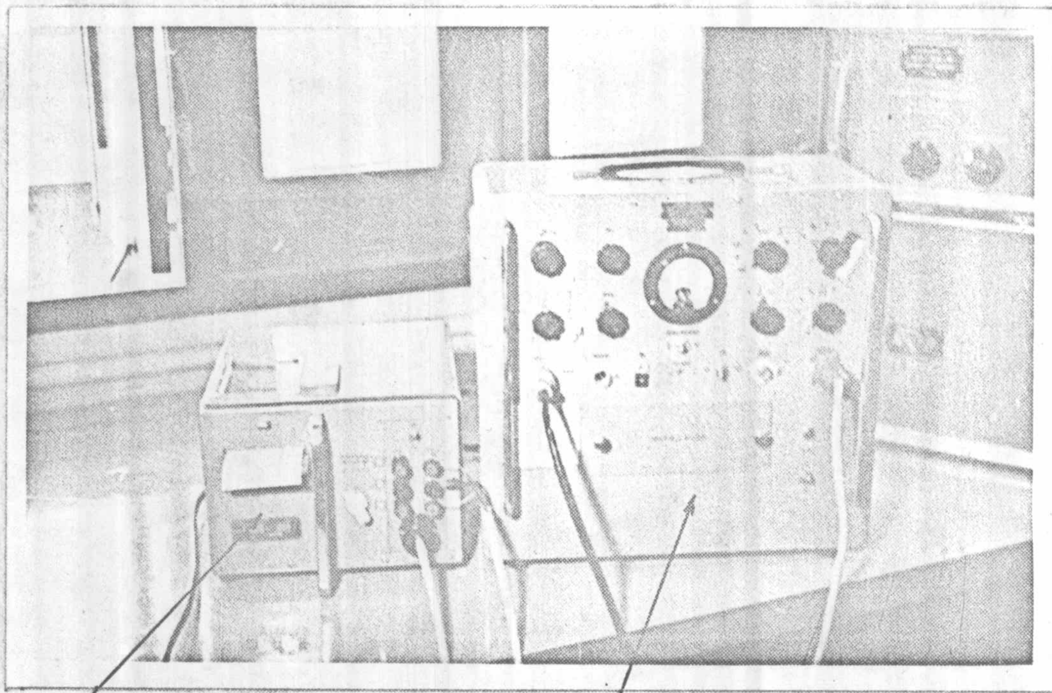


Fig. 3-12. DYNAMIC STRAIN METER.

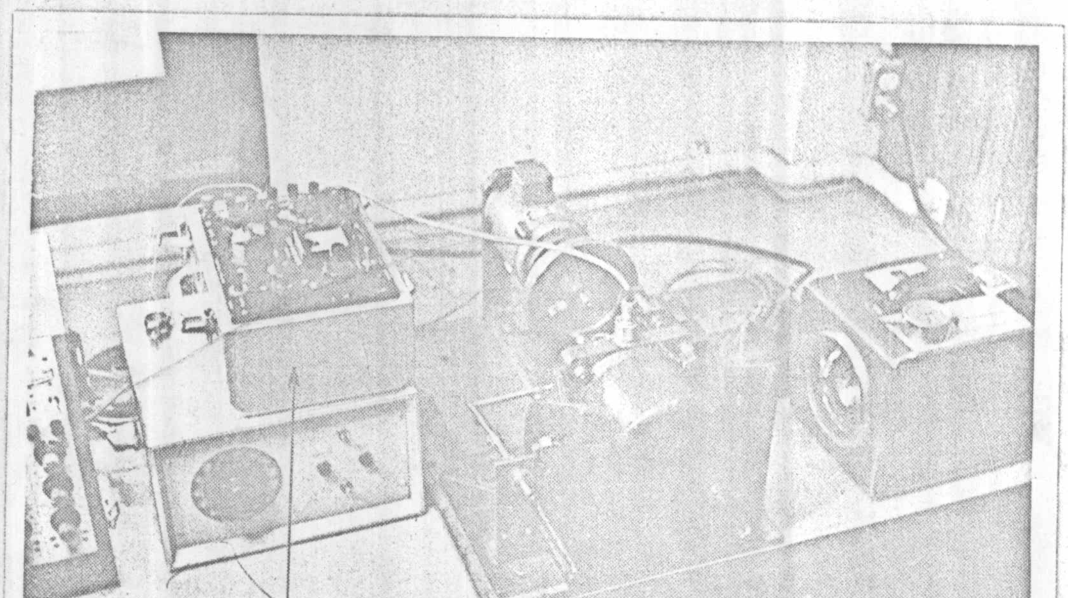
(TOKYO SOKKI KENKYUJO CO. LTD.)



HIGH SPEED 2 PEN RECORDER. SINGLE CHANNEL AMPLIFIER.

(KELVIN AND HUGHES LTD.)

Fig. 3-13.



PORTABLE STRAIN GAUGE BRIDGE.

(H. TINSLEY & CO.LTD.)

Fig. 3-14.

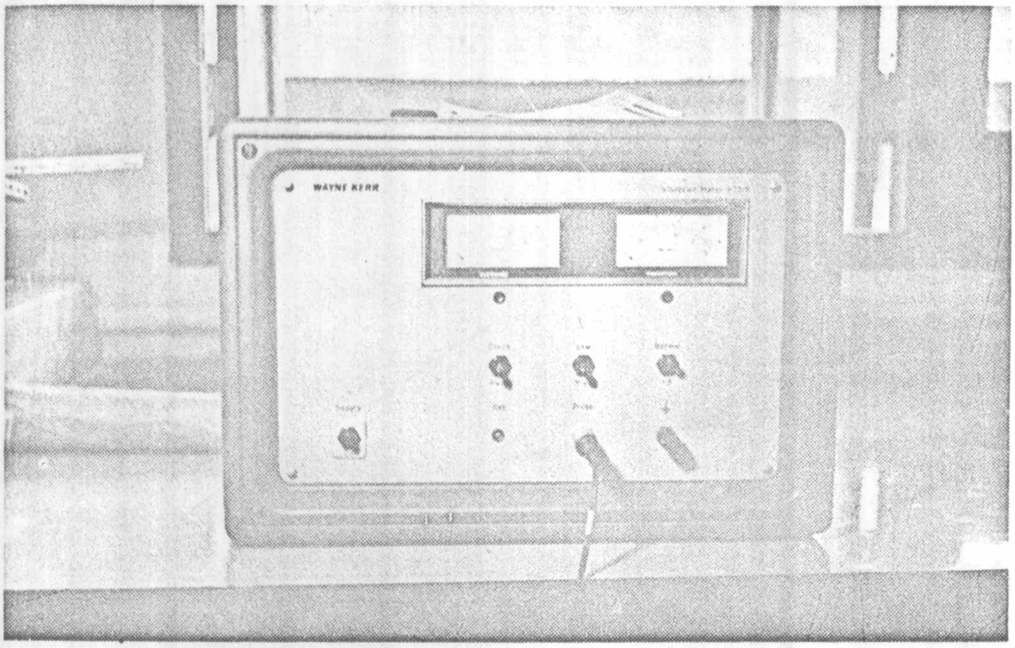
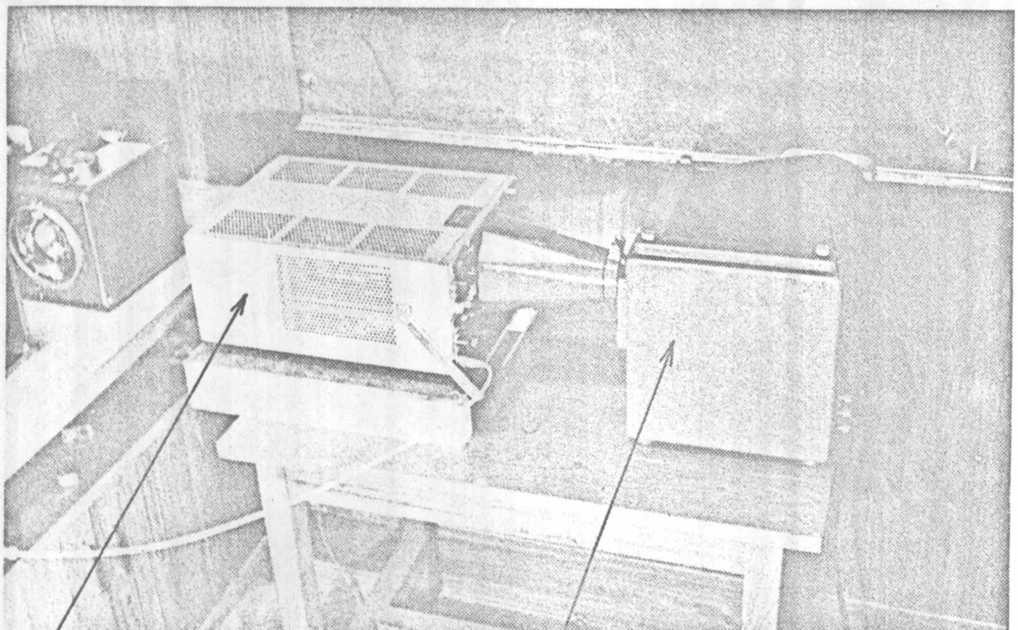


Fig. 3-15. VIBRATION METER.

(THE WAYNE KERR LABORATORIES LTD.)



SWEEP-DELAY OSCILLOSCOPE. UNIVERSAL CAMERA.

(THE SOLARTRON ELECTRONIC GROUP LTD.) (SOUTHERN INSTRUMENTS LTD.)

Fig. 3-16.

EXPERIMENTAL PROCEDURE

The bearing preload adjuster was adjusted to eliminate axial movement of the motor shaft, then the screw adjuster was locked by 2 lock nuts. The steel ring surface was machined on a lathe with the complete set of motor and bracket. The ring specimen surface was also polished by fine emery paper (Silicone carbide, CC-280-CW) before any measurement was taken in order to keep as constant a surface roughness as possible. The slider was pressed against the steel ring at testing load by a spring. The motor speed was adjusted to maintain the testing speed, and the motor speed was first checked by a tachometer. Then the stroboscope was used to indicate any small variation of the motor speed, and the motor speed could be readjusted accordingly. The reason for using the tachometer in conjunction with the stroboscope was to get the right mode of the stroboscope.

EXPERIMENTAL PROGRAMME

The experimental programme was divided into 4 series.

1st series. (Fig. 3-17.)

The direction of vibration of the slider was perpendicular to the sliding surface in a place at right angles.

The frequency was kept constant at 1000 c/s, and the sliding speed varied from 0-300 ft/min, the load at each speed being varied from 0 to 2 lb. The friction force at each load was measured and the experiment repeated without vibration.

The experiment was repeated with the sliding speed kept constant at 100 ft/min and the frequency varied from 700-2500 c/s.

2nd series. (Fig. 3-18.)

The direction of vibration of the slider was parallel to the sliding surface.

The frequency was kept constant at 1000 c/s, and the sliding speed varied from 0-300 ft/min, the load at each speed being varied from 0 to 5 lb. The friction force at each load was measured and the experiment repeated without vibration.

The experiment was repeated with the sliding speed kept constant at 200 ft/min and the frequency varied from 700-2500 c/s.

3rd series. (Fig. 3-19.)

The direction of vibration of the slider was perpendicular to the direction of sliding but in the same plane.

The frequency was kept constant at 1000 c/s and the sliding speed varied from 0-300 ft/min, the load at each speed being varied from 0 to 3 lb. The friction force at each load was measured and the experiment repeated without vibration.

The experiment was repeated with the sliding speed kept constant at 150 ft/min and the frequency varied from 700-2500c/s.

4th series. (Fig. 3-17.)

The object of these experiments was to study the conditions of normal force when a heavy vibration was applied.

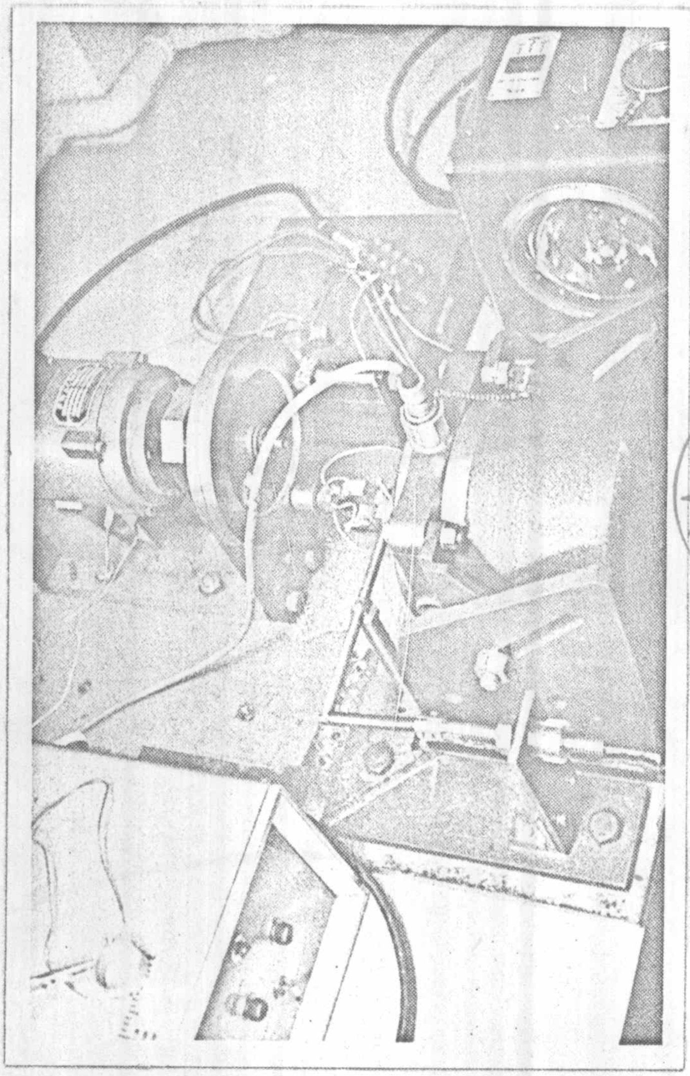


Fig. 3-17. PHOTOGRAPH SHOWS THE DIRECTION OF VIBRATION BEING PERPENDICULAR TO THE SLIDING SURFACE IN A PLANE AT RIGHT ANGLES.

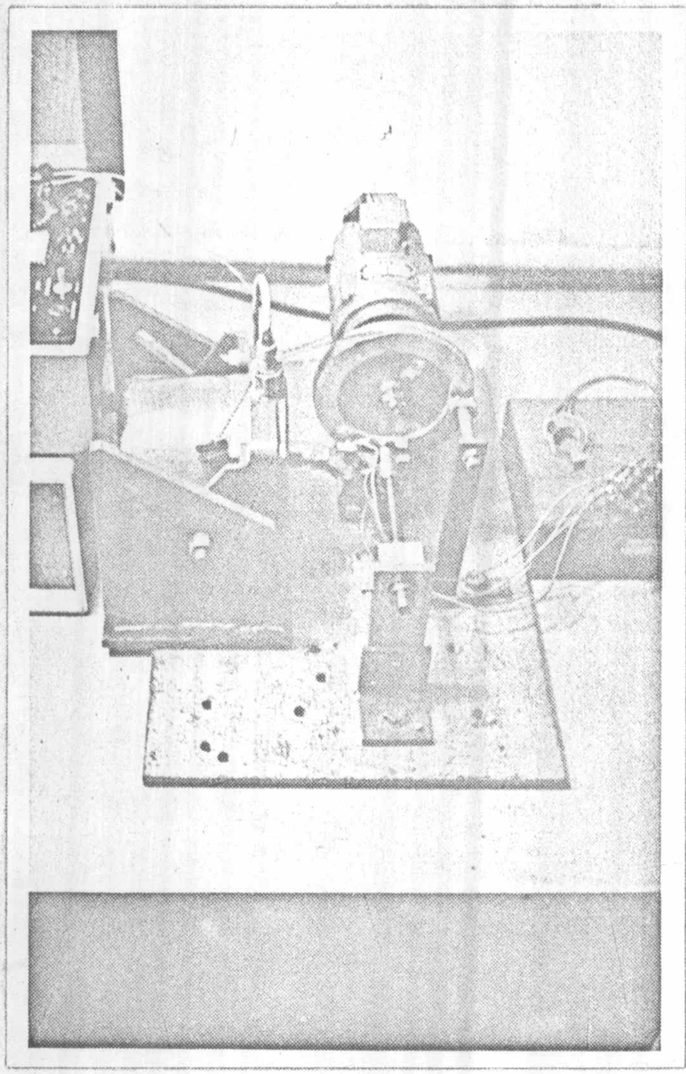


Fig. 3-18. PHOTOGRAPH SHOWS THE DIRECTION OF VIBRATION BEING PARALLEL TO THE DIRECTION OF SLIDING.

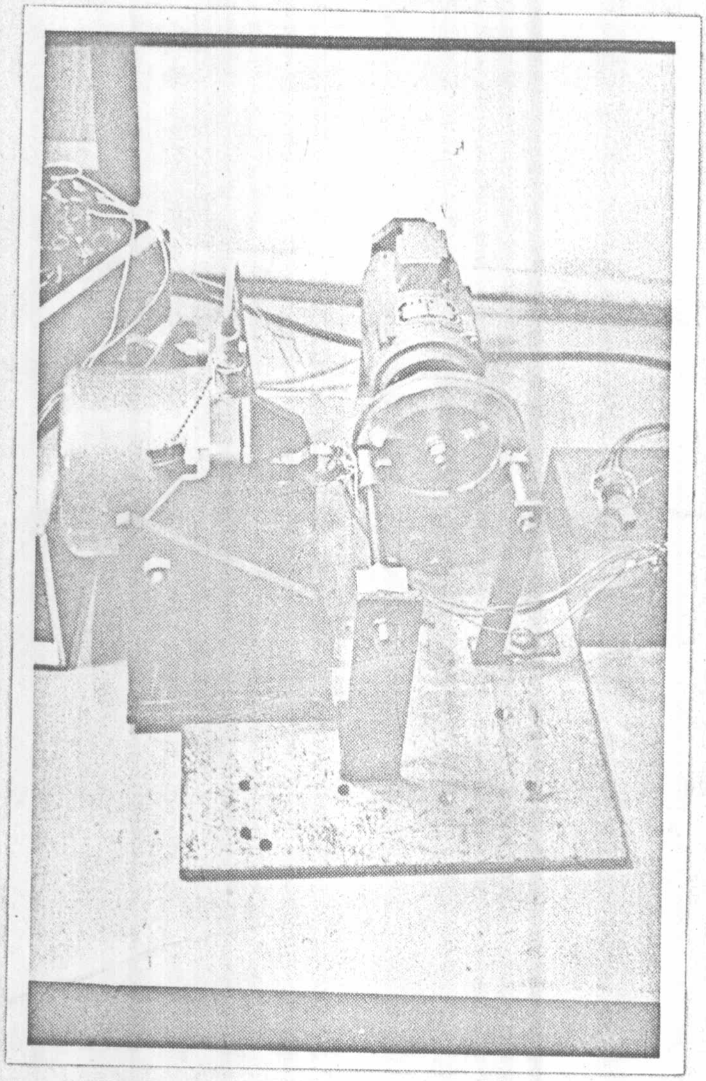


Fig. 3-19. PHOTOGRAPH SHOWS THE DIRECTION OF VIBRATION BEING PERPENDICULAR TO THE DIRECTION OF SLIDING BUT IN THE SAME PLANE.