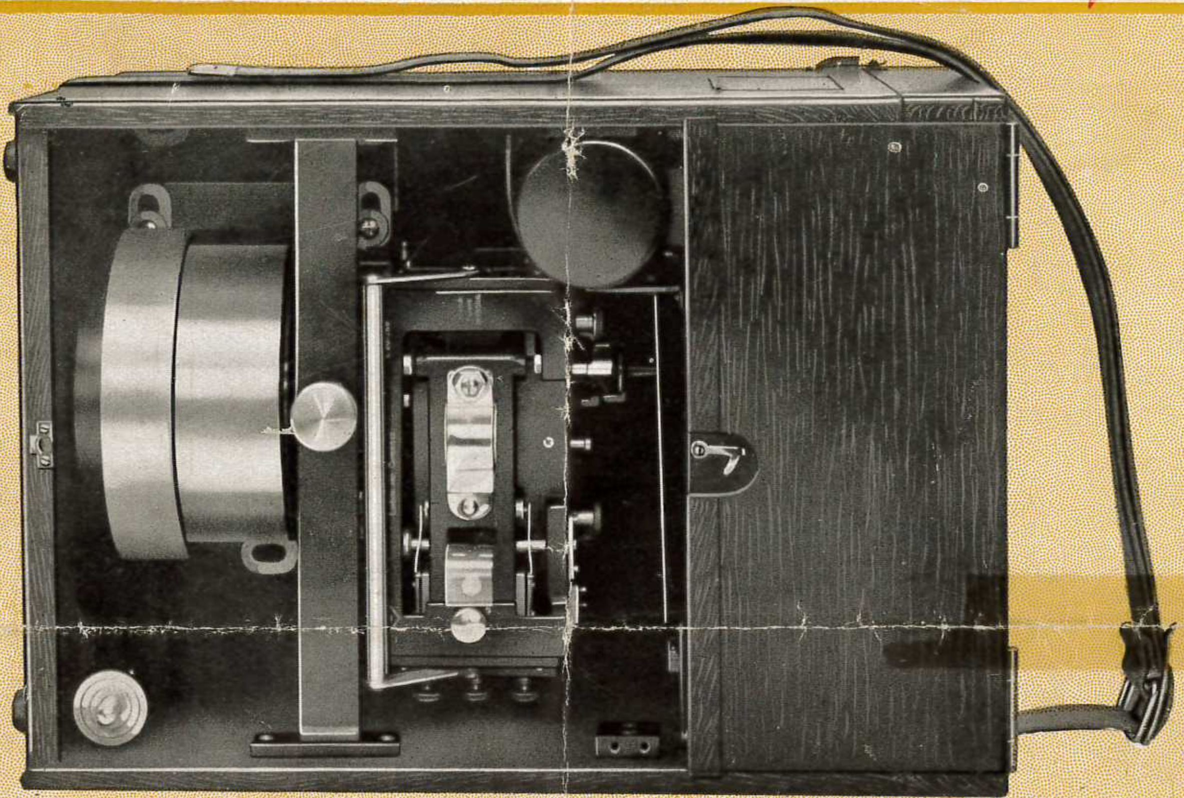


Fig. 1 6081

CAMBRIDGE UNIVERSAL VIBROGRAPH

for

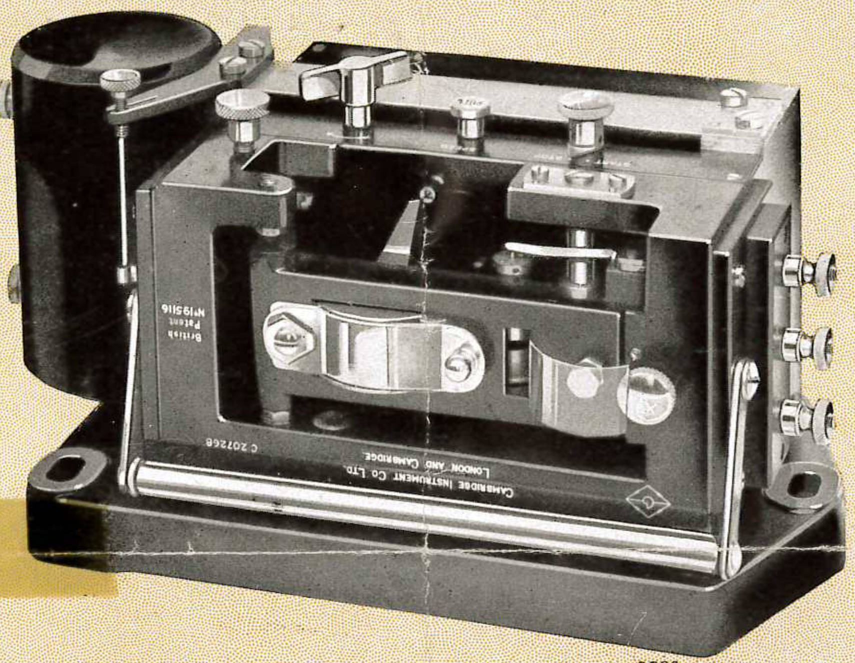
VERTICAL HORIZONTAL ROTATIONAL OR SPOT VIBRATIONS

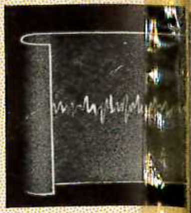
CAMBRIDGE INSTRUMENT CO. LTD.

WORKS:- LONDON & CAMBRIDGE

Head Office & Showrooms :- 13 GROSVENOR PLACE LONDON, S.W. 1.

ALTERNATIVE ARRANGEMENTS





6082

Fig. 2

FOR VERTICAL VIBRATIONS

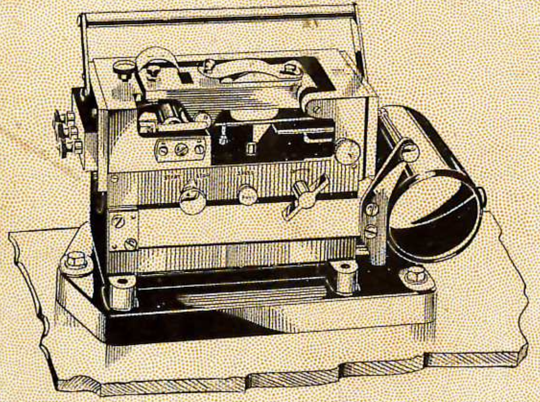


Fig. 3
FOR HORIZONTAL VIBRATIONS

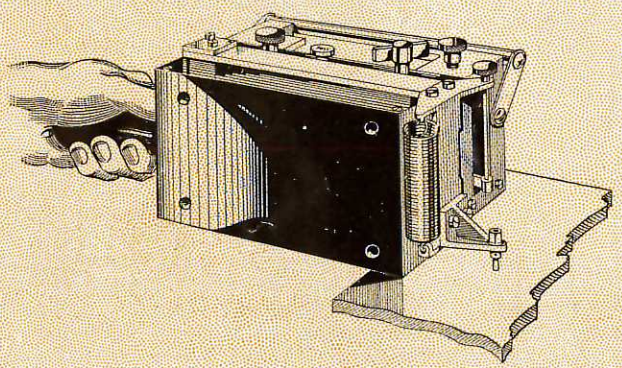


Fig. 4
FOR SPOT TESTS

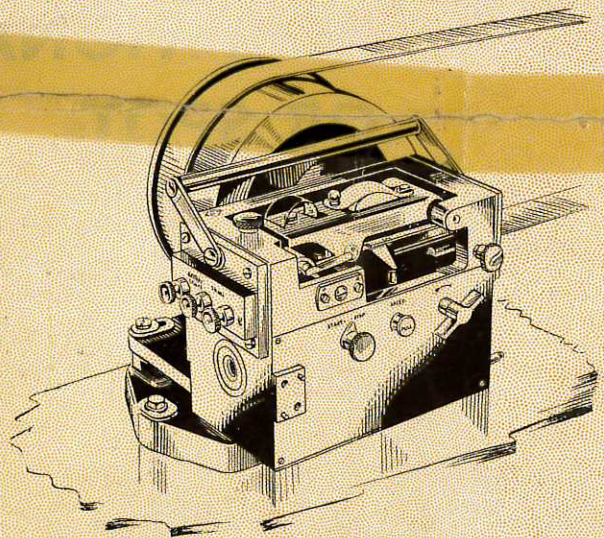


Fig. 5
AS A TORSIOGRAPH

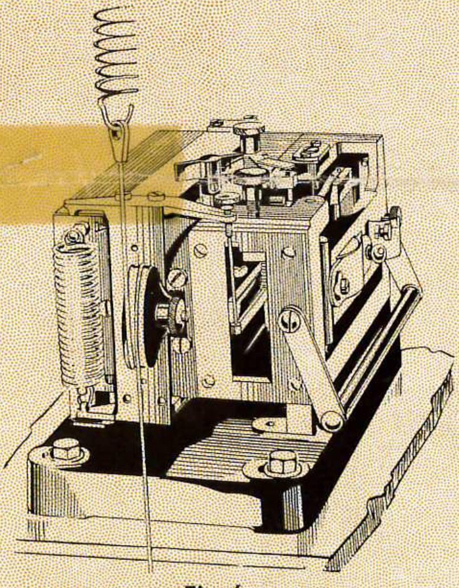


Fig. 6
AS A DEFLECTOGRAPH

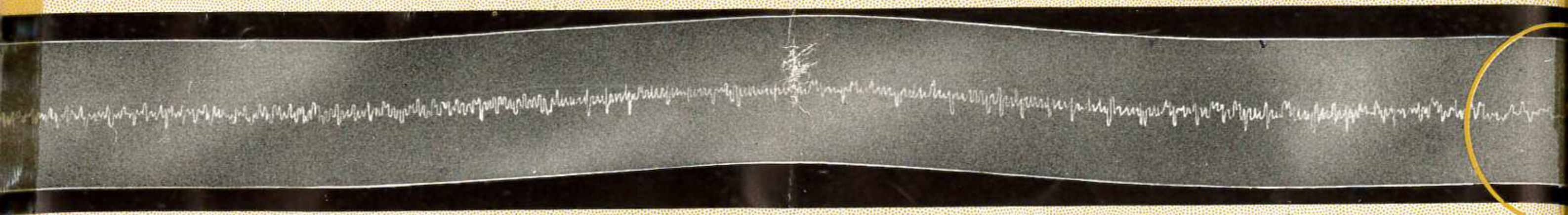


Fig. 7
REPRODUCTION OF ACTUAL RECORD FULL SIZE

CAMBRIDGE UNIVERSAL VIBROGRAPH

This instrument is normally suitable for the investigation of horizontal or vertical vibration problems. By a simple interchange of additional parts, it can be adapted for rotational tests, or arranged as a portable unit in which the vibrations are communicated to the recording mechanism by bringing a projecting toe into contact with the vibrating body. It may also be adapted for use as a deflectograph for testing the deflection of structural parts, for example, on a bridge, when subjected to moving loads, or the displacement of one member of a structure in relation to another. The primary or recording unit contains the clock-work drive for the film, the recording stylus with linkage system, celluloid film, time-marking stylus with a clockwork mechanism which indicates 0.1 second intervals, missing each tenth interval to indicate seconds, and a signal-marking stylus. Terminals are fitted for connecting a 6-volt battery to supply the current for the time marker and signal circuits. Controls are provided for film speed, stylus pressure and for centring the zero position.

For the recording of vertical or horizontal vibrations, a mass, mounted on a spring stirrup, is attached to the recording unit. The complete assembly is then mounted on a base in one of two positions, the mass being arranged for freedom in a vertical or horizontal direction as desired. Fig. 2 shows the instrument arranged as a vertical vibrograph, while Fig. 3 is a line sketch showing the horizontal vibrograph assembly.

For use as a portable vibrograph (Fig. 4), a projecting toe is attached, the control spring slightly rearranged, and a handle fitted to the recording unit ; the mass and base unit are not required. With this assembly, the projecting toe is lightly pressed on the vibrating surface, which can be in almost any plane. For recording the deflection of one body in relation to another, this same arrangement is employed, with the base added, and the instrument is attached to the fixed member of the structure under test.

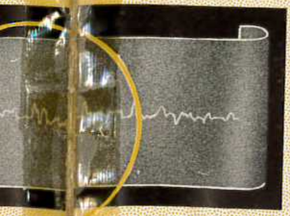
For recording bridge deflections, the mass is omitted, and a fitting carrying a sector is attached to the recording unit (Fig. 6). The instrument is clamped to a portion of the bridge, and a wire, suspended from above by a spring, is passed over the sector and down to a weight placed on the ground below. Any vertical deflection of the bridge will cause a slight rotation of the sector which is recorded by the stylus.

For use as a torsiograph for measuring variations in rotational velocity, a flywheel unit forming the mass is mounted on the base and attached to the recording unit (Fig. 5). The recording stylus is operated by a connecting rod from the flywheel mechanism. Provision is made for alignment and adjusting the position of the flywheel unit relative to the shaft under investigation, a belt or direct drive being employed.

Interchangeable stylus arms are provided to give mechanical magnifications of 1 to 1 or 5 to 1 for recording vertical and horizontal vibrations, and when used as a portable vibrograph. For rotational work, mechanical magnifications of 1 to 1, 3 to 1, or 5 to 1 are available. The recording unit takes spools of film 10 feet long and 20 mm. wide, which are easily inserted. The film speed is adjustable from 21 mm. down to 3 mm. per second.

The whole outfit is fitted into a portable wood case, together with a six-volt battery for the time and signal marking mechanisms. The case also contains an optical system and a ground glass screen, and thus forms a viewer and photographic enlarger for the celluloid records, the illumination being provided by a 6-volt lamp run from the battery. The optical magnification on the viewing screen is × 10. Fig. 8 shows the case arranged for enlarging and viewing the records.

Some notes on the unique characteristics of the records are given overleaf. Four typical stylus-on-celluloid records are illustrated in Figs. 9 to 12.



When photographically enlarged records appear as shown below

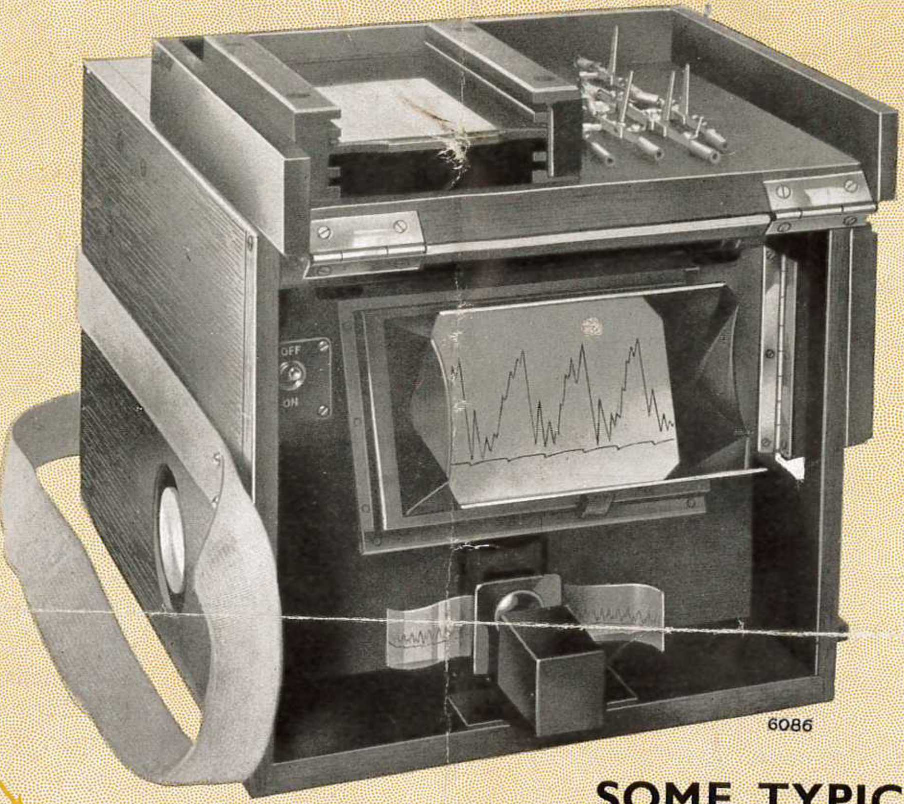


Fig. 8
CASE ARRANGED FOR VIEWING AND ENLARGING THE RECORDS

SOME TYPICAL RECORDS

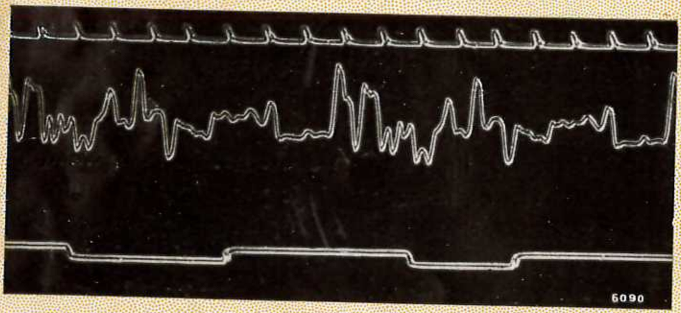


Fig. 9

Angular vibration of a 90-ton flywheel, geared to a 400 h.p. turbine, and driving a 3-cylinder compressor with ratio 100 : 3, time marking 0.1 second ; lower record revolutions. Note how the characteristic repeats with each revolution.

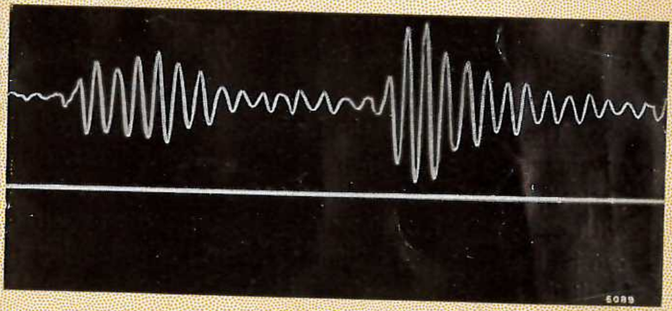


Fig. 10

Horizontal vibrations in a large building, due to pile driving in adjacent ground (magnification about 120 ×).

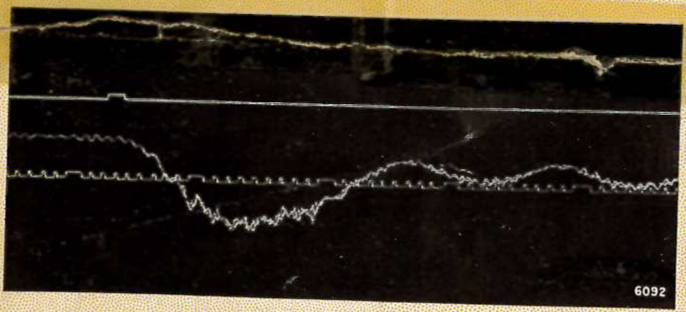


Fig. 11

Vertical deflections on a 35 ft. span steel girder bridge during the simultaneous passage of a goods and a passenger train. The signal in the upper trace marks the arrival of the engine of the passenger train on the down track, the goods train being already on the bridge.

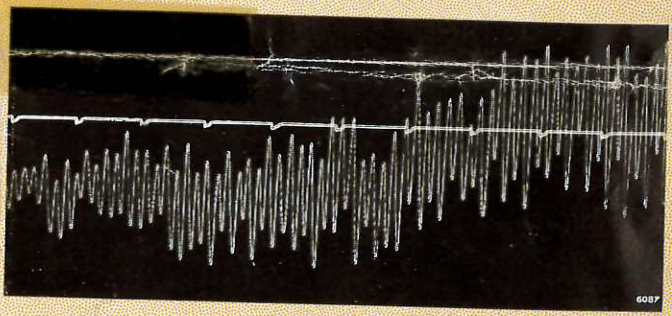


Fig. 12

Record taken by the Portable Vibrograph on cabin window frame of a triple-engined Westland IV monoplane. The central trace shows 0·1 second time intervals.

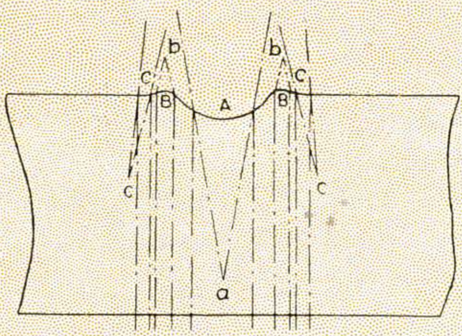


Fig. 13

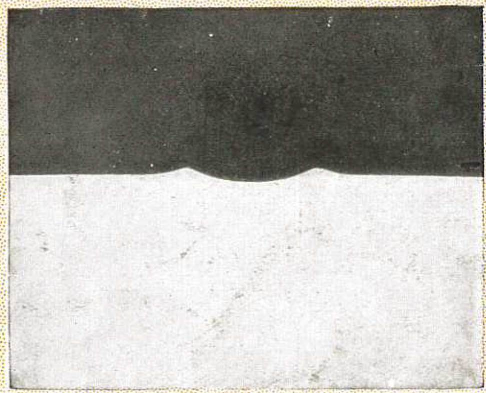


Fig. 14

THE STYLUS-ON-CELLULOID METHOD OF RECORDING

Instruments devised for making measurements or records of rapidly varying phenomena generally consist of a moving member capable of moving proportionately to the subject of investigation and arranged to record its variations on a moving medium. Recording may be mechanical, by means of pen on paper, or optical, by means of a deflected beam of light and a special camera.

The accuracy of the first method, however, suffers from the disadvantage that such moving systems have a large moment of inertia and consequent low sensitivity to high frequency vibrations while the second is inconvenient for use in modern engineering problems. Records should be available on site immediately after a test, and a photographic dark room and facilities for developing long records cannot always be available ; further, photographic equipment is invariably bulky, and in many cases cannot easily be applied.

The patented method of recording employed in the Cambridge Universal Vibrograph possesses many advantages over the other methods. It produces, on a celluloid surface, lines so fine and smooth, that, when optically magnified, readings accurate to about 0.001 millimetres can be made, and it is possible to measure with ease to 0.01 millimetres. To read to an accuracy of one per cent, therefore, the amplitude of the record can be less than one millimetre, so that the moving parts of the instrument can be kept light and small, with negligible inertia, enabling a high frequency response to be obtained. Records taken over long periods occupy little space ; they are immediately available for inspection and measurement by using a simple form of microscope, while they may be photographically enlarged to a considerable magnification. The records are durable and impervious to oil and water. An actual size reproduction of a celluloid record is given in Fig. 7.

The recording member is a stylus having a spherical end which is lightly pressed into contact with a transparent celluloid strip ; the principle is based upon the fact that the elastic limit of celluloid is low, and therefore plastic deformation occurs under comparatively slight pressures. If a stylus with a spherical tip of radius 0.01 to 0.03 mm. is used, a very small pressure applied to the stylus will give sufficient local pressure to cause plastic flow of the celluloid. It has been found that celluloid will flow readily when the deformations are small, that is, from 2 to 4 microns, the result being permanent, and since the force required to produce such deformations is small, the record will present a permanent and true reproduction of the movement under investigation. The shape of the stylus point is important, for if a fine conical point were used, it would cut or tear a jagged line or scratch on the surface and would require the application of comparatively large pressures. It is important that no material is cut or torn from the surface. The characteristics of the record line are shown in Figs. 13 and 14, which are respectively a diagrammatic section enlarged 500 times, and a photomicrograph of a section of a record. Referring to Fig. 13, the record consists of a cylindrical depression A, of small radius, with smooth regular edges forming a minute concave cylindrical lens with focus at " a ". Shallow ridges are also produced on each edge of the record which form quasi-cylindrical convex lenses B, B, of still smaller focal length, b, b. Each of these ridges is bordered by concave cylinders, C, C, focussing at c, c.

(continued overleaf)

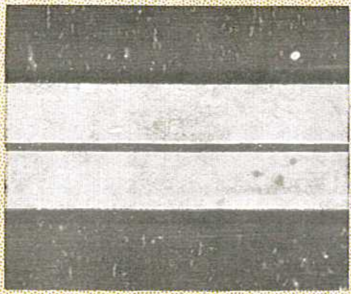


Fig. 15

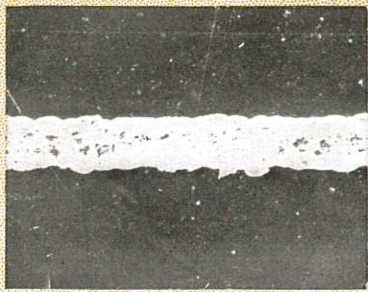


Fig. 16

Fig. 15 shows the appearance of the record when photographically enlarged. The line produced by the recording stylus has optical characteristics entirely different from those of a scratch ; when viewed by transmitted parallel light with a microscope properly focussed, the indentations appear as a narrow, sharply defined, dark band on a bright ground, with a still finer bright line in the centre of the dark band. When photographically enlarged, the effect is reversed, a fine dark line appearing on a broader white band, as is shown in Fig. 15. Measurements of the magnified record can thus be made with high accuracy, while the records are capable of enlargement up to 1,000 diameters, although for practical purposes it is seldom necessary to employ a magnification greater than 150 diameters.

In examining records with a microscope, the objective is focussed on to a point representing the focus of the cylindrical lens or depression formed by the stylus ; the ridges are not sharply in focus, but the small secondary depressions (CC, Fig. 13), having a focus point almost equivalent to the main depression, tend to give concentration of light along the edges, the effect of which is shown in Fig. 15. This is a highly magnified photograph taken with the microscope focussed upon the focal point "a" of the depression (see Fig. 13). A photomicrograph of a scratch on celluloid is reproduced in Fig. 16 ; this shows clearly the difference in the optical characteristics, while the force required to produce a scratch is greatly in excess of that used in producing the plastic deformation of the celluloid surface.

THEORY AND SELECTION OF INSTRUMENT

If we have a simple harmonic movement ($a \sin pt$), then the total amplitude is $2a$, the period $2\pi/p$ and the frequency f is equal to $p/2\pi$. Thus the vibration gives rise to a movement $2a$, a harmonic velocity of maximum value ap, and a harmonic acceleration of maximum value ap^2, or $4\pi^2af^2$, or $40af^2$ approx. The frequency may be determined by comparison with a standard time record which is simultaneously traced on the record. Instruments have been designed to record the movement, velocity or acceleration, and will theoretically give, by calculation, the same information of a simple harmonic motion ; however, the selection of the most suitable instrument will depend on how many separate vibrations or motions are simultaneously present, and whether from the nature of the problem it is better to record vibration or acceleration.

A Vibrograph is characterised by comparatively long natural period and little control. It measures "a" or the extent of a movement, is very sensitive and therefore suitable for recording small vibrations in the absence of other large movements, unless such interfering movements are slow, such as the pitching of a ship. Usually there is little damping and the instruments cease to be accurate when slow vibrations are present which have a frequency approximating to the natural period. On the other hand, an Accelerometer is a short period instrument, and the damping should be aperiodic.

For a complete analysis of vibrations that occur in engineering problems, it is necessary to obtain data of the movements in three dimensions. In the Cambridge Universal Vibrograph the engineer has a single instrument which is capable of recording all this information. Details of other Cambridge Mechanical Recorders, including single and double Vibrographs, a portable Vibrograph designed solely for spot tests in any plane, Accelerometers, Stress Recorders, etc., are given in our List, No. 139.