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THE CAMBRIDGE SCIENTIFIC INSTRUMENT COMPANY, LTD., CAMBRIDGE, ENGLAND.

DUDDELL'S PATENT THERMO-AMMETER.

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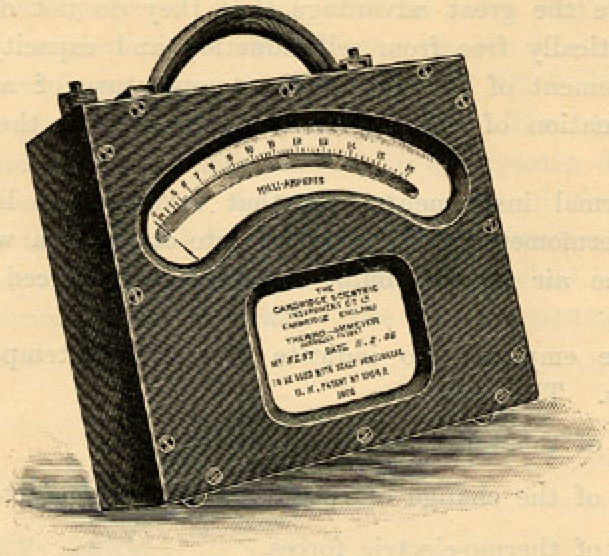

Fig. 1.

In all branches of electrical science there is a steadily increasing demand for the accurate measurement of all the quantities involved. In one branch—namely, the measurement of small alternating currents—the progress, though steady, has not been quite as rapid as could be wished. The want of a convenient portable ammeter for measuring small alternating currents of any frequency and wave-form has been especially felt in connection with telephonic measurements, wireless telegraphy, and for medical purposes. In the present note it is proposed to pass in review the main methods upon which sensitive portable pivoted ammeters can be built, and to describe a new instrument which is being made by the Cambridge Scientific Instrument Co., Ltd., of Cambridge, England, and which, it is believed, constitutes a step forward in providing for the convenient measurement of small alternating currents.

For the measurement of small alternating currents of any frequency the principles on which the instrument can be based may be classified as follows :—

1. *Electromagnetic Instruments.*—Instruments depending on the electromagnetic forces exerted between coils and coils or between coils and iron can be constructed of very high sensibility, but in this case their self-induction is comparatively high, and the electrostatic capacity from layer to layer of the winding may be appreciable.

For frequencies of 1,000 per second, such as often occur in telephone work, these defects become extremely important. In addition, in those instruments which contain iron, the errors due to the calibration depending on the shape of the wave-form of the current to be measured, may be serious.

2. *Electrostatic Instruments.*—Measurements of alternating currents may be made by measuring the P. D. between the terminals of a non-inductive shunt by means of an electrostatic voltmeter. For a small current, however, the P. D. available is small, unless the shunt resistance is very high. Pivoted electrostatic voltmeters for the measurement of very small P. D.s are not yet available. At the same time, for currents of high frequency, an electrostatic instrument, on account of its capacity, takes an appreciable current, and, at frequencies as high as 100,000 per second, it may take actually more current than a thermal instrument.

3. *Rectifying Instruments.*—With these instruments the alternating current to be measured is first rectified by being passed through some form of rectifier, generally of the electrolytic type. Up to the present, the development of instruments based on this principle has not made very great progress, owing to the uncertainty that exists with the present electrolytic cells in the relationship between the magnitude of the rectified current and the alternating current that is being measured.

4. *Thermal Instruments.*—Instruments based on the heating of a conductor by the current to be measured have, so far, given the best results in the measurement of small currents of high frequency.

Thermal instruments have the great advantage that they do not depend for their operation on magnetic fields, and are practically free from self-induction and capacity errors. All thermal instruments depend on the measurement of the rise in the temperature of a conductor when the current is flowing. It is in the estimation of this rise in temperature that the greatest number of practical difficulties are encountered.

One of the earliest thermal instruments was that invented in 1827 by Sir W. Snow Harris, which consisted of an air thermometer, having sealed into its bulb a wire which was heated by the current to be measured. The air in the bulb expanded, and forced the thread of liquid along the tube.

Three other methods are employed to indicate the rise in temperature of the conductor in designing thermal instruments. They are:

(*a*) The measurement of the linear expansion of the wire.

(*b*) The measurement of the change of resistance of the conductor.

(*c*) The measurement of thermo-electric forces.

Satisfactory pivoted instruments are constructed on the principle (*a*), but so far their sensibility has been limited by mechanical difficulties. The best pivoted pointer instruments at present available require something like $\frac{1}{10}$ watt to give the full scale deflection.

As their sensibility depends on the magnification of the small expansion of the wire when heated by the current, if the frame which supports the wire and the wire itself have not exactly the same coefficient of expansion then, when the room temperature rises or falls, deflections will be produced on the instrument, producing an uncertain zero.

To get sensibility it is generally necessary to stretch the wire under an appreciable tension. The contraction and expansion of the wire under tension produce fatigue of the material, so that the instrument may fail with a comparatively small overload.

Instruments based on method (*b*) involve the measurement of the resistance of a conductor while the alternating current to be measured flows through it. This leads to rather complicated arrangements and the use of an auxiliary measuring circuit containing a source of current resistances and a galvanometer of some kind. In the laboratory excellent results can be obtained by this method, but it cannot be compared for ease and simplicity with a direct-reading pointer instrument such as the thermal ammeter. In common with instruments of type (*a*) instruments of type (*b*) will only stand a comparatively small overload without damage.

Method (*c*) is represented by the thermo-ammeter.

This instrument is constructed on the same principle as the now well-known Duddell thermo-galvanometer, in which the current to be measured passes through a "heater" resistance, causing its temperature to rise, and heating a thermo-junction attached to a wire loop suspended in the air-gap of a permanent magnet similar to the suspended loop of the "Boys" radiomicrometer. The thermo-ammeter is, of course, a much less sensitive instrument than the thermo-galvanometer, as it is pivoted and fitted with a pointer, and bears much the same relation to the thermo-galvanometer as a sensitive ammeter of the ordinary pivoted moving-coil type does to a moving-coil galvanometer. Nevertheless, it is extremely sensitive and may be used to measure the current in an ordinary telephone line.

The general appearance of the instrument is shown in Fig. 1, while Fig. 2 is a sectional diagram showing the general arrangement of the heater and coil, &c. *D* is the moving coil which moves in the field produced by the permanent magnet *BB*. *AA* are soft iron pole pieces, and *C* is a cylindrical core, so that the field in which the coil moves is truly radial. *EE* are the pivots which it will be seen are fixed *inside* the coil, so that when the instrument is in a horizontal position (the correct position for use) the coil is practically suspended from the top pivot, the lower pivot being almost entirely out of action. By this means pivot friction is reduced to a minimum. The ends of the coil are brought out at the bottom and soldered to the ends of the thermo-junction *LM*, the elements of which are made from special alloys which have a very high thermo-electric force. The lower ends of the couple are soldered to a thin circular "receiving plate." Immediately below the receiving plate the heater *K* is fixed. In instruments to give the full deflection for 20 milliamperes or less, this heater consists of a sheet of platinised mica, the platinum being scraped away to form a sort of gridiron. By this means resistances of several hundred ohms may be easily obtained in a space of less than 0·2 sq. cm. For currents above 20 milliamperes the heater is made of wire. When in use the current to be measured passes through the heater *K*, which, in consequence, becomes heated and so warms the receiving plate *J* and thermocouple *LM*. The resultant E.M.F. of the couple causes a current to flow round the coil which turns in the magnetic field, the deflection being indicated by a pointer moving over a scale in the usual way. It will be seen that no current passes through the control spring *F*; the material for the spring may, therefore, be selected without reference to its electrical resistance; one end of the control spring is attached to the lever *G*, which is connected to the zero adjusting screw outside the case. The whole instrument is contained in a polished teak case with a leather handle.

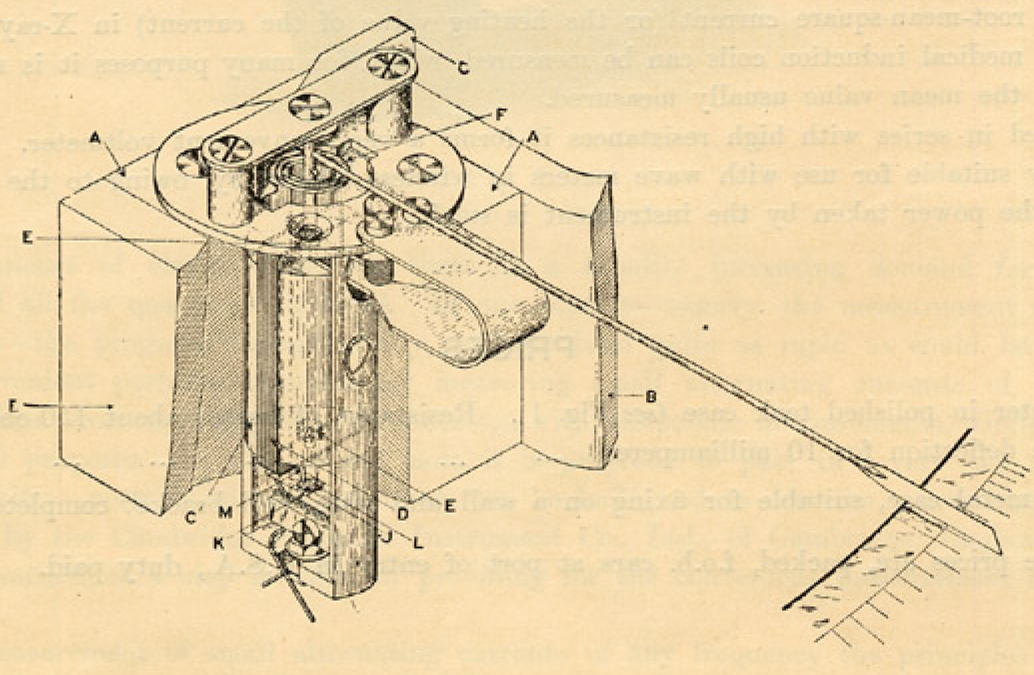

Fig. 2.

In the usual pattern (with a resistance of about 150 ohms) the full scale deflection is produced by a current of 10 milliamperes either continuous or alternating, and by constructing heaters of higher or lower resistance the sensibility to current may be increased or reduced as required. The scale is a long one—viz., 160 mm. The maximum power taken by the instrument is extremely small—namely, about 0·015 watt, which is far less than that taken by the average "hot-wire" ammeter, and it will stand a much greater overload—namely, about three times its maximum working current.

The thermo-ammeter has excessively small self-induction owing to the "gridiron" shape and small size of the heater. The total number of "bends" does not usually exceed eight or nine.

It is perfectly dead-beat, but, like other thermal instruments, takes a certain time to attain its final deflection.

When used as an ammeter the temperature coefficient is about 0·14 per cent. per degree Centigrade. When used as a voltmeter (without series resistance) the temperature coefficient is about 0·1 per cent. per degree Centigrade. Of course, if a high resistance of negligible temperature coefficient is used in series with the instrument, this value will be correspondingly reduced.

The principal advantages and some of the uses of the thermo-ammeter may be summarised as follows:

1. It takes a very small power to give the full scale of deflection.

2. It is extremely sensitive as an ammeter or voltmeter according to whether it is constructed with a high or low-resistance heater.

3. It can be calibrated with continuous and used with alternating currents.

4. It has practically no self-induction or capacity and measures accurate currents of any frequency or wave form.

5. It has a low temperature coefficient.

6. It is very portable and does not require levelling.

7. It is direct reading.

8. It will stand a 100 to 200 per cent. overload easily.

9. The resistance through which the current to be measured passes is not subjected to any tensile or bending strains.

10. The current in telephone lines can be easily measured.

11. The root-mean-square current (or the heating value of the current) in X-ray tubes and in secondaries of medical induction coils can be measured, which for many purposes it is more important to know than the mean value usually measured.

When used in series with high resistances it forms a very convenient voltmeter.

It is very suitable for use with wave meters in wireless telegraphy, owing to the small damping produced, as the power taken by the instrument is small.

PRICES

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Thermo-Ammeter in polished teak case (*see* Fig. 1). Resistance of heater about 150 ohms. Full scale deflection for 10 milliamperes	**140.00**
Ditto, but in metal case, suitable for fixing on a wall and with wall bracket complete...	**148.00**

The above prices are, packed, f.o.b. cars at port of entry in U.S.A., duty paid.

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