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BRUSSELS EXHIBITION, 1910.

(British Section.)

CATALOGUE

OF

MATHEMATICAL

AND

SCIENTIFIC INSTRUMENTS.

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PREFACE.

The Brussels Exhibition of 1910 is the first International Exhibition in which the organisation of the British Section has been directed by the Exhibitions Branch of the Board of Trade.

The Liberal Arts Committee was one of the many nominated to assist the Department, and to a sub-committee of this body has fallen the task of organising the exhibit of philosophical instruments. Recognising in an exhibition of modern scientific instruments the great importance of detailed descriptions, the Board of Trade have arranged for the compilation of English and French illustrated catalogues, which it is hoped may be of permanent value as books of reference.

For the assistance of visitors some of the more important and interesting exhibits are here mentioned. Dealing first with one of the most ancient branches of science, that of optics, it may be noted that while until the last few years the production of accurate *spherical* surfaces has been almost the sole task of the optician, modern spectroscopic development has made still higher demands for perfection in *flat* surfaces. The exhibits of Messrs. Adam Hilger show conclusively the skill with which they have attained this perfection in the unique Echelon spectroscope of 56 plates and in the Lummer-Gehrcke Plate. Some interesting details are given as to the testing of the glass of these instruments. Among other optical exhibits are the fine series of surveying instruments of many types shown by Messrs. W. F. Stanley, the interesting group of specialised microscopes by Messrs. Swift, and the telescopes and other instruments by Messrs. Steward.

Electricity in its measurement and applications is the branch of science most largely represented, and the apparatus exhibited by the Cambridge Scientific Instrument Co. and by Messrs. R. W. Paul exemplify the wide range of instruments demanded by electricians. Among the most interesting are instruments for the measurement of alternating currents of ordinary

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frequencies as well as of frequencies measured in millions per second. The Duddell and the Irwin oscillographs, the Vibration galvanometer, and the various types of thermo-ammeters are noteworthy examples of this development.

The application of electrical methods to the measurement of temperature has provided apparatus of unique accuracy and range for the laboratory, the workshop, or the furnace, from the precision resistance instrument with an accuracy of 0·001° C. to the many types of direct reading thermometers, the indicating parts of which may, if necessary, be placed at a great distance from the part which is subjected to the temperature which is being measured. For the highest temperatures there is exhibited by the Cambridge Scientific Instrument Co. the Féry pyrometer, which depends solely on the radiation of heat from the furnace. In the modification of this pyrometer a direct reading instrument is provided without the employment of any electrical apparatus.

The Einthoven galvanometer, shown by the Cambridge Scientific Instrument Co., and the unipivot instruments of Messrs. Paul are interesting developments of modern instruments. The latter provide a series of galvanometers of a sensitiveness hitherto unknown in instruments of a portable design. They are of especial use as temperature indicators, even for ordinary atmospheric temperatures, in conjunction with thermo-couples, which may often be of quite inexpensive materials. The Einthoven galvanometer as an instrument for use in cardiac diagnosis promises to have a future the importance of which it is impossible to estimate.

Among general electrical apparatus, the growing use of decade forms of resistance boxes with rotating contacts superseding those of the plug form, affords a much more convenient apparatus for general work. The employment of mercury contacts, as used in resistances of the highest accuracy, has been adopted in the resistances for the Callendar-Griffiths Wheatstone Bridges employed for precision platinum thermometer work. Among other exhibits of the Cambridge Scientific Instrument Co., the Cambridge extensometer, the cup micrometer, and the rocking microtome are instances of accuracy obtainable in instruments which are notable for their simplicity of mechanical design.

The Kelvin electrostatic voltmeters of various types and the current balances of Messrs. Kelvin and White remain the standard instruments for alternating current. Messrs. Gambrell Bros. show a series of simple laboratory galvanometers and special cable-testing switches. Messrs. Nalder Bros. and Thompson show their portable electrostatic apparatus for measuring insulation resistance and a selection of switchboard and other instruments. The Morgan Crucible Co. exhibit a variety of carbon brushes for electrical machinery.

Messrs. Kelvin and White also show modern examples of the mariner's compass and apparatus for sounding, which may be used without diminishing the speed of the vessel; for the perfection of which, and the resulting benefits to mankind, so much is owed to Kelvin's genius.

Messrs. Negretti and Zambra show a representative selection of meteorological and other apparatus, including deep-sea thermometers, and Messrs. Darton and Messrs. Pillischer have a similar exhibit.

A very complete series of apparatus for oculists is shown by Messrs. Gowlland and of surgical instruments by Messrs. Down Bros.

Apparatus for draughtsmen and curves cut to conic sections and other forms are exhibited by Messrs. W. J. Brooks & Co.

Messrs. Cussons exhibit a large number of models of machinery and models illustrating kinematic principles.

The Reflector Syndicate show a series of metallic mirrors of various sizes for searchlights and similar purposes, the perfection of form being assured by their being deposited on a temporary glass mould of the required curvature.

The exhibit of the Synchronome Co. takes the useful form of an electrical time service, a number of dials, driven by an electrically operated master clock, being distributed throughout the British Section.

It is hoped that the exhibition of Mr. Dunscombe's historical collection of spectacles, &c. will contribute to its enlargement.

The references to literature dealing with many of the more special instruments exhibited will be of considerable value.

The Sub-Committee on mathematical and scientific instruments who have been responsible for this section are—

R. T. Glazebrook, D.Sc., F.R.S., Chairman,
Prof. C. H. Lees, D.Sc., F.R.S., Vice-Chairman,
A. N. Disney, M.A.,
W. Duddell, F.R.S.,
R. G. K. Lempfert, M.A.,
E. H. Rayner, M.A.,
R. S. Whipple, Esq., with
Mr. H. Langridge of the Board of Trade as Secretary.

At their request the catalogue has been edited by the National Physical Laboratory under the supervision of Mr. E. H. Rayner.

R. T. Glazebrook.

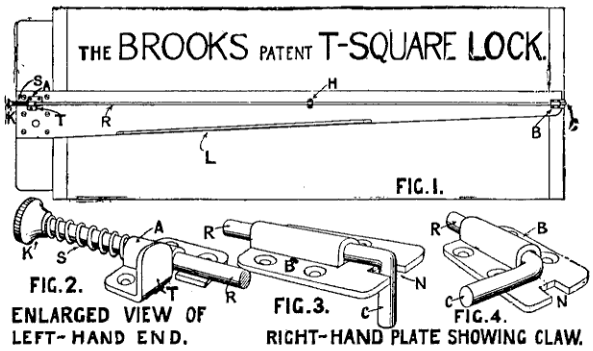
LIST OF EXHIBITORS.

INDEX.

Messrs. Wm. J. Brooks & Co., *Letchworth, Herts.*

Appliances for the use of Draughtsmen and others.

The Brooks Patent " **T***-square Lock"* is a simple device which can be attached in a few minutes by a few small screws to any ordinary **T**-square, enabling the latter to be locked in any position on an inclined drawing board, thus setting both hands free to manipulate the set-square, pen, &c. The **T**-square may, nevertheless, be shifted with the same freedom as an ordinary **T**-square. As shown in Figs. 1, 2, 3, and 4, a light nickel-plated steel rod R slides in the guide plates A and B. At one end of the rod R is the claw C and at the other the knob K. To shift the **T**-square the stock is grasped with the left-hand, the thumb pressing against the thumb-piece T and the forefinger pressing the knob K to the right. On releasing the knob, the **T**-square is automatically locked. When it is desired to use the **T**-square for drawing oblique lines, the claw C may be turned into the position shown in Fig. 4. A narrow ledge L is also provided for holding compasses, pens, &c.



FIGS. 1, 2, 3, and 4.

The Brooks Patent Flexible Curves for draughtsmen are made in several patterns :—

Pattern A, shown in Fig. 5, is made in sizes from 20 cms. to 2 metres and over. It is made of a flexible strip of steel, to one side of which are attached a series of projections. In the small sizes these are held by the

fingers of one hand. In the larger sizes they are held by weights or drawing pins.

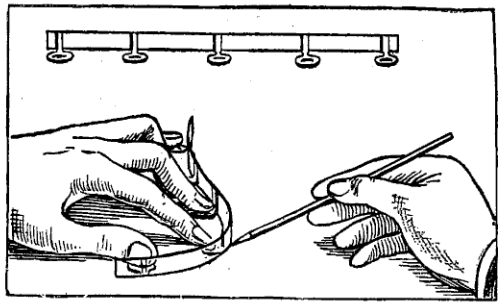


FIG. 5.

Pattern AA is similar to Pattern A; but the steel strip is extremely thin, and the projections are very close together, so that it may be used for curves of as small a radius as 1 cm.

Pattern B, shown in Fig. 6, has a steel strip, and any shape given to it is retained by means of the stiff-hinged linkwork which is hinged to the projections.

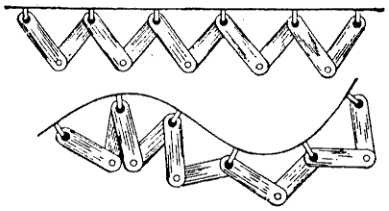


FIG. 6.

Pattern C, shown in Fig. 7, is for drawing long curves such as are required by shipbuilders, and is made in sizes from 30 cms. up to any length.

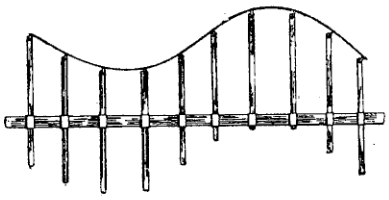


FIG. 7.

Pattern D is a modification of Pattern C in which a tapered lancewood spline is substituted for the steel strip.

The Brooks Patent Pinning Strip, termed "Pinro," consists of a flexible metal strip, from one side of which protrude, at intervals, short points like those of drawing pins. It is used for attaching paper to drawing boards, and offers no obstruction to the free movement of the T-square.

The Brooks Corner Curve (Fig. 8) is a device for draughtsmen. A celluloid disc with a series of small curves cut on its circumference has a small handle at its centre.

This takes the place of the bow compasses in drawing the many small curves, such as those indicating fillets in castings, which are required in engineering drawings.

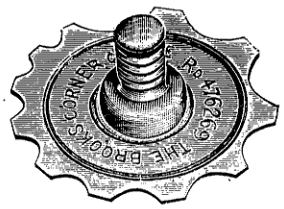


FIG. 8.

The Brooks Mathematical Curves are very accurately cut in transparent celluloid. They include a parabola, a rectangular hyperbola, an ellipse, a cycloid, and a cubic curve. They are cut exactly to special equations, and are to be used with paper divided into inches and tenths.

The Parabola.—Equation $y = x^2$ (Fig. 9) may be employed to solve quadratic equations by graphical methods, to solve sets of equations, and to read off directly the squares and square roots of numbers.

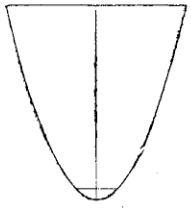


FIG. 9.

The Cubic Curve.—Equation $y = x^3$ (Fig. 10) may be similarly employed to read off cubes and cube roots.

FIG. 10.

The Ellipse.—Major axis, 3 ins. (about 7·5 cms.), minor axis, 2 ins. (about 5 cms.) (Fig. 11).

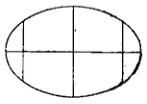


FIG. 11.

The Rectangular Hyperbola.—Equation $x\,y = 1$ in. (about 6·4 sq. cms.) (Fig. 12) for problems on the pressure and volume of gases.

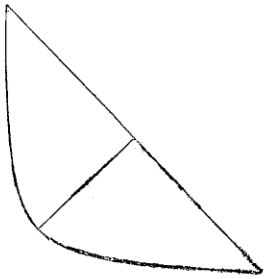


FIG. 12.

The Cycloid.—(Fig. 13) Roulette of a circle 2 ins. (about 5 cms.) diameter, for pendulum problems.

FIG. 13.

The Cambridge Scientific Instrument Company, Limited, *Cambridge, England.*

Duddell Oscillographs. (Figs. 1, 2, and 3.)

(1) "Comptes Rendus," 1893, Vol. CXVI., pages 502 and 748.
(2) "Oscillographs," paper by W. Duddell before the British Association at Toronto, 1897.
(3) "Electrician," Vol. XXXIX., page 636.

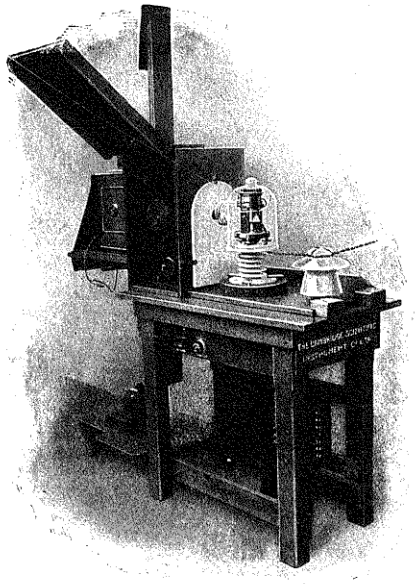


Fig. 1.

Three types of Duddell oscillographs are made, namely :—

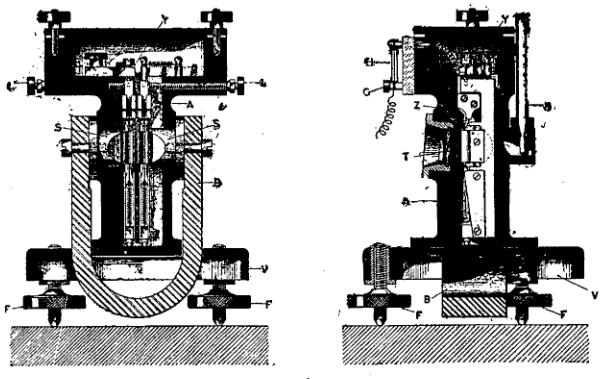
Type 1.—This type has the shortest free period of vibration (about 1/10,000 sec.), and is therefore suited for high frequency and research work, telephone circuits, &c. It is quite accurate for all frequencies up to about 300 per second. The vibrators, with mirrors attached, are fixed side by side in a brass oil bath between the solid steel poles of a powerful electro-magnet, the latter being excited from either a 100-volt. or 200-volt. circuit.

The oil bath is fitted with a thermometer. A plano-convex lens, of 50 cm. focal length, is fixed in the oil bath in front of the vibrator mirrors. This lens is slightly inclined, as T in Fig. 2, so as to avoid trouble due to reflections from its own surface.

The normal distance from the vibrator mirrors to the scale or photographic plate is 50 cms., and at this distance a convenient working deflection on each side of the zero line is 3 or 4 cms. This is obtained with a R.M.S. current through the vibrators of from 0·05 to 0·1 ampere, according to wave form, &c.

Type 2.—This instrument has a lower natural period of vibration (1/3,000 sec.) than Type 1, and therefore is not capable of accurately following wave forms of such high frequency; but it is sufficiently quick acting to follow wave forms of all ordinary frequencies. At the same time it is much more robust, easier to repair, and more portable, owing to the fact that the magnetic field is produced by a permanent magnet instead of an electro-magnet. This also renders the instrument very suitable for use on high tension circuits without earth connection, as, owing to the fact that no direct current excitation is required, the instrument is much more easily insulated than other types. It can be supplied insulated for 50,000 volts.

Fig. 2 shows sections of this type of oscillograph. The permanent magnet B is fitted with steel pole pieces S S,



C.A.I.C.S.

FIG. 2.

between which the vibrators are fixed in an oil bath. The whole is fixed on the base V, and the levelling screws, F, F, F, are added.

Types 1 and 2 may be used with a falling plate or cinematograph camera.

Type 4.—This type has been specially designed for teaching and lecture purposes. Wave forms having a total amplitude of 1 metre can be thrown on a screen. For this purpose the whole of the suspended system has to be greater in size than either Types 1 and 2, besides requiring a much larger current.

The normal scale distance for projection work is 3 metres, at which distance the deflection on each side of zero may be 50 cms. The maximum R.M.S. current through the vibrators should not exceed 0·5 ampere. Each vibrating loop is made as a complete unit, these being separately removable and interchangeable. Each instrument holds two of these units. The same electro-magnet is used for Types 1 and 4.

Accessories for recording and observing are supplied for use with the oscillographs. Fig. 1 shows a complete outfit for use on a 25,000-volt circuit, consisting of a permanent magnet oscillograph and a falling plate camera. For long records a cinematograph film camera may be employed, enabling records up to 50 metres in length to be obtained. With the Type 4 oscillograph a tracing outfit, consisting of a synchronous motor which drives a vibrating or rotating mirror may be used. This vibrating mirror reflects the moving spot of light on to a sheet of tracing paper, on which the curve of E.M.F. or current may be traced.

Fig. 3 is a record obtained on a 50,000-volt circuit, without the use of a transformer.

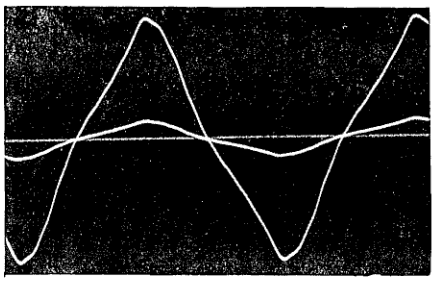


FIG. 3.

The Einthoven String Galvanometer. (Fig. 4.)

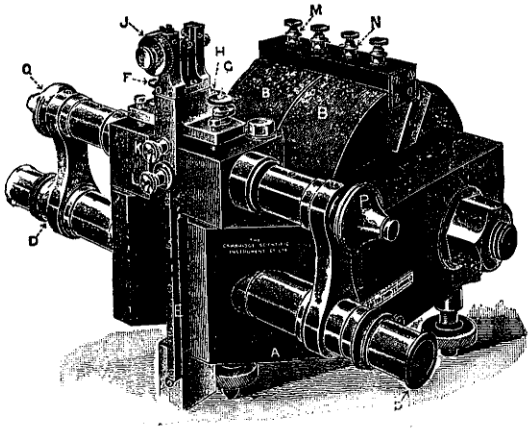


FIG. 4.

(1) W. Einthoven : "Un nouveau galvanomètre," Archives Néerlandaises des Sciences exactes et naturelles, Série II., Tome VI., page 625, 1901.

(2) W. Einthoven : "Ein Neues Galvanometer," Annalen der Physik, Vierte Folge, Band 12, 1903.

(3) W. Einthoven: "On a New Method of Damping Oscillatory Deflections of a Galvanometer," Koninklike Akademie van wetenschappen te Amsterdam, November 23rd, 1904.

4) W. Einthoven: "Further Researches on the Applications of the String Galvanometer," Ann. d. Physik, 21, 3, pages 483–514, November 20th, 1906, and pages 665–700, November 27th, 1906.

(5) A. D. Waller: "On the Electromotive Changes connected with the Beat of the Mammalian Heart and the Human Heart in particular," Phil. Trans. Roy. Soc., 180 B, 169–194, 1899.

This galvanometer has been developed by Prof. Einthoven of the University of Leyden, and the detailed designs for the instrument have been made by Mr. W. Duddell, F.R.S. It is essentially of the "moving coil" type, the coil being reduced to a single "string" stretched in a very narrow air gap between the poles of a powerful electro-magnet. The string is usually a silvered quartz fibre, though in some cases a fine wire is used. The arrangement is shown diagrammatically in Fig. 5. When a current passes through the string *CC*, it is deflected in the direction of the arrow *a*, *i.e.* at right angles to the magnetic field *NS*. This small movement is observed by means of a microscope *A* passing through a hole bored in the pole

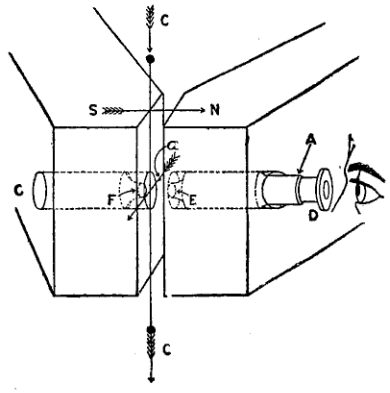


Fig. 5.

shoes, or by throwing an enlarged image of the wire on to a screen by means of an arc lamp and projection lantern. The instrument is extremely sensitive, very dead beat, has a very short period and is practically without self-induction or capacity. Used in conjunction with a photographic recording apparatus it will record alternating or pulsating currents of very small magnitude, or their variations may be observed visually in a rotating mirror. The instrument is extremely valuable in physiological investigations and was in fact developed by Prof. Einthoven mainly for this purpose.

The period depends entirely on the tension of the fibre which is adjusted by means of the micrometer screw J (Fig. 4). With a moderate tension, however, the period is extremely quick, and, by increasing the tension, may usually be reduced to less than $\frac{1}{100}$ second. In practice the limiting condition here is the damping. If the tension is increased too much the instrument ceases to be aperiodic and "overshooting" occurs. The shortness of the period is due to the exceedingly small weight and inertia of the fibre. Its weight is approximately 10^{-6} gramme. If the tension is relaxed the fibre may take several seconds to attain its full deflection with a consequent gain in sensitivity. The indefinite increase of period by slackening the fibre is however in practice limited by unsteadiness of zero and by the fact that, when very slack, the fibre moves out of focus when deflected.

The galvanometer is quite dead beat over a wide range, the damping being partly electro-magnetic and partly due to air friction. The electro-magnetic damping may be varied by altering the strength of the magnetic field and the resistance in circuit with the fibre. The damping may also be controlled by means of a suitable arrangement of capacity and inductance in circuit.

The arrangement of the optical system depends on whether the deflections of the fibre are:—

(a) being observed by means of a microscope (with micrometer eye-piece); (b) being projected on to a screen by means of an arc lantern; (c) being recorded photographically.

The arrangements for case (*a*) are shown in Fig. 5, where—

F is a "substage" condenser; *E* is a microscope objective; *D* is a micrometer eye-piece.

In addition, a specially designed photographic recording apparatus for use with the Einthoven String Galvanometer is particularly useful in medical work for obtaining electrocardiograms.

The following table gives some records of sensitivity tests of Einthoven galvanometers.

Material of Fibre.	Diameter of Fibre.	Resistance in ohms.	Period in seconds.	Deflection in mm.		Factor of Merit.*
				per micro-amp.	per micro-volt.	
Silvered quartz fibre.	0·003 mm.	8,720	0·004	6·1	7×10^{-1}	12×10^{1}
,, ,,	0·002 ,,	6,610	—†	57,000	8·6	—
,, ,,	0·003 ,,	15,400	—†	44,000	2·9	—
Silvered glass fibre.	$0·003_5$,,	3,060	—†	40,000	13	—
			$0·005_5$	11	$3·6 \times 10^{-3}$	17×10^{1}
,, ,,	$0·002_5$,,	15,000	$0·006_5$	16	$1·1 \times 10^{-3}$	$9·6 \times 10^{1}$
,, ,,	$0·002_5$,,	12,030	—†	56,000	4·7	—
Aluminium wire.	0·035 ,,	6·9	0·039	11	1·6	$4·0 \times 10^{1}$
			0·0012	$1·1 \times 10^{-2}$	$1·6 \times 10^{-3}$	$3·9 \times 10^{1}$
Silver wire -	0·017 ,,	8·2	0·082	36	4·4	$2·7 \times 10^{1}$
			0·0026	$4·0 \times 10^{-2}$	$4·9 \times 10^{-3}$	$3·1 \times 10^{1}$

* Factor of merit $= \frac{100 \times D}{T^2 R \frac{2}{5}}$ $D = \frac{\text{mm.}}{M}$ per 10^{-6} amps.

Magnification :—500 times.

† In this case the movement of the fibre was quite dead beat. It took about 10 seconds to attain its full deflection.

Broca Galvanometer. (Fig. 6).

(1) T. Gray and A. Gray: "On a new Reflecting Galvanometer of Great Sensibility and on New Forms of Astatic Galvanometers," Proc. Roy. Soc., Vol. 36, pages 287–296.

(2) "Comptes Rendus": Académie des Sciences, Tome CXXVII., page 101, séance du 13, 7, 1896; Société française de Physique, Ann. 1896, séance du 17, 7, 1896, page 249.

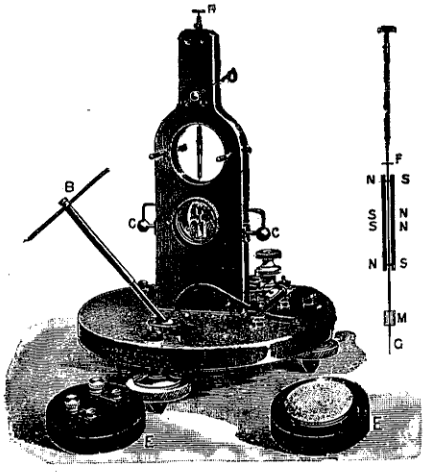


FIG. 6.

This galvanometer is of the "moving vertical magnet" type. The distinctive feature of the Broca galvanometer is in the moving system, which consists of two magnets of steel wire suspended by a fine quartz fibre. Each steel wire is so magnetised that its two ends are of like polarity with consequent poles in the middle. Thus the system is made very astatic, while the moment of inertia is small. Below the magnets is suspended a small mirror M, and an aluminium damping vane G.

The controlling force is supplied partly by the suspending quartz fibre, but chiefly by the controlling magnet B, placed at the back of the instrument.

The faces of the ebonite coil boxes E are covered with a metallic shield which, together with the metal frame, completely protects the moving system from electrostatic forces. One terminal is connected to frame, which prevents large potential differences between frame and coils. The levelling screws are fitted with ebonite insulating toes.

By means of the control magnet B, the period may be varied from about 5 to 20 seconds. The damping is also adjustable, being increased by closing together the damping plates C.

Pairs of coils (E) of three resistances are supplied, viz., about 10, 100, and 1000 ohms when connected in series. Other resistances are obtained by connecting in parallel.

The instrument is very sensitive, the following being the sensitivities of some recently constructed Broca galvanometers :—

Resistance of coils in series in ohms.	Period in seconds.	Deflection in mm. at 1 metre			Factor of Merit.
		per micro-amp.	per micro-volt.	per micro-coulomb.	
8·8	10	350	40	220	147
8·8	17·3	1070	121	380	150
110	10	1000	9·1	630	153
110	17·3	3000	27·3	1100	159
860	10	2200	2·6	1400	148
860	17·3	6500	7·5	2400	146

Ayrton-Mather Galvanometer. (Fig. 7.)

"Galvanometers," by Ayrton and Mather, Phil. Mag., Vol. XXX., page 58, July 1890.

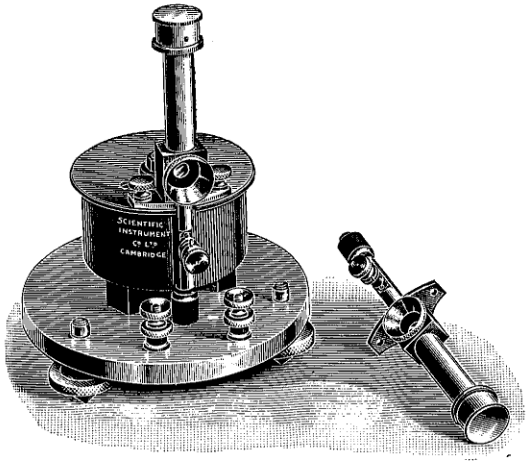


FIG. 7.

This is an instrument of the "moving coil" type, the coil and magnet being of the form found by Messrs. Ayrton and Mather to give the greatest sensitivity for a given period.

The coil is wound with non-magnetic wire, and after winding, it is treated by a chemical process to eliminate all traces of magnetic material in the silk covering of the wire or in the former. The whole of the moving system is enclosed in a dust tight tube, so that suspended systems of different resistance and period, &c., may be quickly interchanged. The suspension is provided with a torsion head and clamping device. One terminal is connected to frame to eliminate electrostatic forces, and the levelling screws are fitted with ebonite insulating toes.

The period of the instrument is usually arranged to be eight seconds, though longer periods may be obtained for ballistic work.

A damping coil, which can be placed in circuit by depressing a key, is fitted to each suspension tube. This coil is so arranged that, when in circuit, the movement is nearly aperiodic.

The following are the data of some Ayrton-Mather Galvanometers recently constructed :—

Resistance of coil in ohms.	Period of coil in seconds out of magnetic field.	Deflection in mm. at 1 metre			Factor of Merit.
		per micro-amp.	per micro-volt.	per micro-coulomb.	
7	3·0	18	2·6	37	90
7	8·0	139	19·8	110	100
20	8·2	245	12·2	190	110
20	3·5	53	2·6	100	130
146	7·8	540	3·7	435	123
400	8·3	757	1·9	590	100

Ayrton-Perry-Duddell Twisted Strip Galvanometer.

(1) "Instruments for the Measurements of Large and Small Alternating Currents," by W. Duddell, Phil. Mag., July 1904.

(2) "L'Industria Rivista Tecnica," May 6th, 1906.

The working portion of this galvanometer consists of a fine metal strip twisted after the manner suggested by Ayrton and Perry. Half the length is twisted in one direction, and the other half in the opposite direction.

In the centre of this strip are fixed a mirror and a mica damping vane. The strip, together with two straight wires of the same metal, is stretched between two blocks by means of a spring.

Any change in the atmospheric temperature will tend to lengthen or shorten equally the strip and wires, and so the mirror does not rotate. If a current, however, is sent through the strip, then it heats and twists up, causing the mirror to rotate.

The instrument is quite dead beat and very quick acting, so that it is able to follow currents varying over a small range as rapidly as one or two cycles per second.

The instrument is very robust and can be carried about in the pocket, is easily set up and requires no levelling, and has an extremely small self-induction and capacity.

It has a wide range of usefulness, and can be used (with suitable resistances) as a voltmeter measuring from 0·1 volt to 10,000 volts, or as an ammeter to measure small or large currents.

The deflections are approximately proportional to the square of the current. With a recent instrument the smallest *measurable* current was $6 \cdot 0 \times 10^{-3}$ amp.; and the smallest *detectable* current $0 \cdot 6 \times 10^{-3}$ amp.

String Electrometer.

(1) "A String Electrometer," by T. H. Laby, Proc. Cambridge Phil. Soc., Vol. XV., Part II.

(2) "Electrician" (London), August 20th, 1909.

This is a delicate instrument for measuring changes of potential and consists of a silvered quartz fibre stretched midway between two vertical plates of invar steel. Initially the fibre is at zero potential, and one plate at + 40 volts, and the other at −40 volts. A change of potential of the fibre causes a lateral deflection of it, which is measured by means of a micrometer microscope. The insulation throughout is of quartz and mica. The special features of this instrument are (1) the means employed to obtain a constant but adjustable tension on the fibre; (2) the insulation; and (3) the microscope and mounting.

The sensitiveness depends on (1) the distance of the invar plates apart; (2) their potential difference; (3) the period of the fibre, which depends upon its tension.

By the use of invar plates, a geometrical knife-edge, and a screw adjustment, the sensitiveness of the instrument may be quickly altered within a wide range, or be kept constant at some desired amount. A sensitiveness of 600 eye-piece divisions per volt has been obtained.

The electrometer can be used as an oscillograph by using a high potential difference between the plates, say, from 40 to 200 volts, with the fibre tightly stretched.

The microscope has a tube 10 inches long, supplied with a Zeiss achromatic objective C, and a No. 3 micrometer eye-piece. For visual work with this arrangement, one division of the eye-piece micrometer corresponds to a movement of the fibre of 0·0038 mm. approximately. The instrument can also be adapted for photographic work, or for projection on a screen.

Dolezalek Quadrant Electrometer.

"A Damped Quadrant Electrometer for Submarine Cable Testing," "Electrician," November 12th, 1909.

This instrument is of the "Quadrant" type, and is mounted upon ambroid pillars, affording very high insulation. The needle is of paper, thinly coated with "silver paper," of a form ensuring ample rigidity. It is suspended by a quartz fibre, which renders the instrument very sensitive. The needle and quadrants being small, the electrostatic capacity is also small. The motion is very nearly dead beat, the deflections being proportional to the potential differences producing them.

A small plane mirror is attached to the needle, which is suspended from the quartz fibre by a V hook in such a way as to prevent slip. Two adjacent quadrants are hinged so that they can be swung open to allow of easy access to the needle. The needle is charged by a simple charging rod.

The base is supported by levelling screws, and the whole of the instrument can be rotated in a horizontal plane about this base, and clamped in any position. The suspension is provided with a torsion head, and a brass cover serves to prevent electrostatic forces from affecting the working of the instrument. This cover is fitted with a lens of 100 cms. focus.

The extreme lightness of the moving system renders it very sensitive. Three quartz fibre suspensions and one of phosphor bronze are supplied, so that a very wide range of sensitiveness can be obtained.

Simple Micro-Electroscope. (Fig. 8.)

(1) "On the Ionization of Atmospheric Air," Proc. Roy. Soc., LXVIII., page 151.

(2) "On Radio-Active Rain," Proc. Camb. Phil. Soc., Vol. XI., Part VI., page 428.

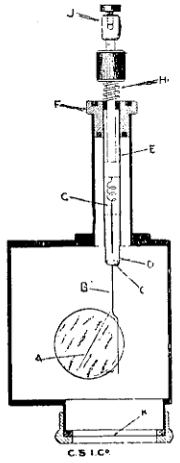


FIG. 8.

This is a gold leaf electroscope in which only a single moveable leaf A is employed, repulsion taking place between this and a prolongation of the wire B, which supports it. It is especially adapted for experiments on ionization and radio-activity. An opening in the case K vertically underneath the gold leaf enables the ionizing agent to exert its influence upon the air within the electroscope case, and openings at the side are provided for viewing the gold leaf. Exceptionally high insulation is obtained by the use of quartz, and a simple charging device is used which may either be connected to the gold leaf momentarily or permanently.

The construction is clearly shown in Fig. 8, in which A is the gold leaf in the form of a narrow strip, and B the supporting wire. This wire is in turn supported by a metal plug C, which is fixed in the lower end of a quartz tube D. The quartz tube is shellaced into a brass tube E, which is itself insulated

from the case by the ebonite bushing F, which has recesses filled with sulphur in its upper end and lower surfaces.

There are two methods of observing the deflections of the gold leaf strip. In the first of these, a microscope with micrometer eye-piece is used. In the second method, no microscope is employed, the deflections being read off without magnification against the reflected image of a millimetre scale.

The instrument will indicate changes of a small fraction of a volt.

Duddell's Thermo-Galvanometer. (Fig. 9.)

(1) "Instruments for the Measurement of Large and Small Alternating Currents," by W. Duddell, Phil. Mag., July 1904.

(2) "Wireless Telegraphy Measurement," by W. Duddell and J. E. Taylor, Journal of Inst. of Elect. Engineers (London), Vol. 35, page 321.

(3) "A Directive System of Wireless Telegraphy," by E. Belline and A. Tossi, "Electrical Engineering" (London), November 14th, 1907.

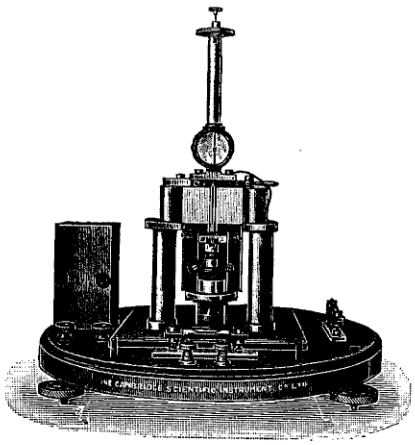


FIG. 9.

In this instrument for measuring high frequency alternating currents, the current to be measured passes through a "heater"

resistance, causing its temperature to rise. Immediately above this "heater" is placed a very small thermo-couple which closes the circuit of a coil consisting of a single turn of wire suspended by a quartz fibre. A permanent magnet produces a magnetic field through the coil.

The thermo-galvanometer (fig. 9) has practically no self-induction or capacity, and can therefore be used on a circuit of any frequency (even up to several million per second), while currents as small as 20 micro-amperes may be measured. It is equally correct on continuous or alternating currents, and can therefore be accurately standardised by continuous current, and used without error on circuits of *any frequency or wave form.* It is especially adapted for telephonic and wireless telegraphic measurements.

The following table gives approximate sensitivities of some thermo-galvanometers, at a scale distance of 1,000 mm.

Resistance of heater.	Current to give 250 mm. deflection.	Current to give 10 mm. deflection.	P.D. to give 250 mm. deflection.	P.D. to give 10 mm. deflection.	
ohms.	micro-amperes.	micro-amperes.	milli-volts.	milli-volts.	
about 1,000	110	22	110	22	heater close to junction.
„ 400	175	35	70	14	
„ 100	350	70	35	7	
„ 40	550	110	22	4·4	
„ 10	1,100	220	11	2·2	
„ 4	1,750	350	7	1·4	
„ 1	3,500	700	3·5	0·7	
„ 1	10,000	2,000	10	2·0	heater lowered away from junction.

Duddell Thermo-Ammeter. (Fig. 10.)

The principle of this instrument is the same as that of the thermo-galvanometer. The moving coil, however, is supported on pivots and fitted with a pointer.

The heater consists of a small sheet of platinised mica in instruments giving a full scale deflection with 20 milliamperes or less, and in other thermo-ammeters, of a platinum grid.

It is direct reading, and will stand a 100 or 200 per cent. overload.

FIG. 10.

Duddell Magnetic Standard.

The principal object of this standard is the calibration of ballistic galvanometers under conditions identical with those under which they are used, thus avoiding the application of corrections for damping, &c.

The instrument consists of two fixed coils through which a known direct current is flowing, in the centre of each of which is placed a small moving coil. These two moving coils are connected in series with the galvanometer which it is desired to calibrate. The moving coils can be rotated suddenly through an angle of 180°, thus cutting the magnetic field produced by the current in the fixed coils, and causing a deflection in the galvanometer. The coils are wound astatically to eliminate the effects of stray fields. The current in the fixed coils remains constant throughout an experiment, so that errors due to the resistance of switch contacts are eliminated. One accumulator cell is sufficient to energise the field coils, whose resistance is 0·075 ohms.

The Weston Normal Cell. (Fig. 11.)

(1) "The Normal Weston Cadmium Cell," by F. E. Smith, Phil. Trans., Series A., Vol. 207, pages 393–420.

(2) "Bulletin of Bureau of Standards," Vol. 4, No. 1.

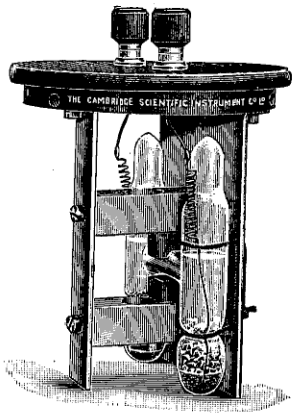


FIG. 11.

The International Conference on electrical units and standards (1908), recommended that this type of cell may be conveniently employed as a standard of electric pressure for the measurement of both E.M.F. and current.

For accurate work, the following formula determined by Wolff is suggested for universal adoption by the International Conference of 1908, for other temperatures than 20°,

$$E_t = E_{20} - 0{\cdot}0000406\ (t - 20°) - 0{\cdot}00000095\ (t - 20°)^2 + 0{\cdot}00000001\ (t - 20°)^3.$$

This means that for changes in temperature of two or three degrees above or below 20° C. the E.M.F. of the cell decreases by between four or five parts in 100,000 per degree rise of temperature, or increases by a like amount per degree fall in temperature.

The resistance of the cell is usually about 900 ohms.

The cells are constructed of the "H" pattern, hermetically sealed, and made in all details by the methods recommended by

the authorities of the National Physical Laboratory. The cell is lashed by silk cord to the framework, which in turn is screwed to an ebonite top. A hole in the ebonite top permits the insertion of a thermometer when desired. Two cells can also be supplied mounted in a similar case.

The International Conference on electrical units (1908) recommend that the cell should be taken, provisionally, as having, at a temperature of 20° C. an E.M.F. of 1·0184 international volts.

Hermetically Oil-sealed Manganin Resistance Coils. (Fig. 12.)

(1) " Variation of Resistance with Atmospheric Humidity," by E. B. Rosa and H. D. Babcock, Bulletin of Bureau of Standards, Vol. IV., No. 1.

(2) " Electrician," June 14th, 1907.

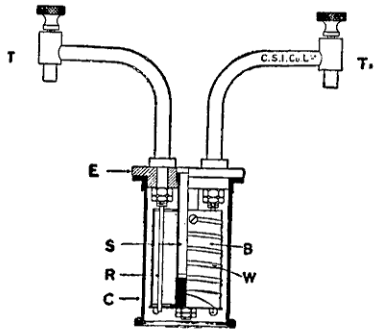


Fig. 12.

The temperature coefficient of these coils is very much less than that of the old type of platinum silver coils. The special feature of this latest type of coil is that it is sealed in a chamber filled with oil, in the manner suggested by Prof. Rosa, so that it is not exposed to the atmosphere. By this means variations in resistance due to the changes in the humidity of the atmosphere are avoided. The coils are supplied in the following values:—1, 10, 100, or 1,000 ohms. They are wound non-inductively.

Galvanometer Lamp and Scale. (Fig. 13.)

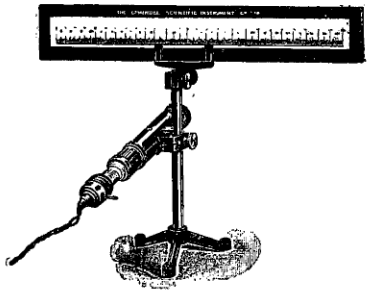


FIG. 13.

A Nernst lamp is mounted in a brass tube carrying a lens. Either the image of the filament or that of a wire stretched across the lens is projected from the galvanometer mirror on to the scale. The scale is 50 cms. long, is translucent, divided into millimeters, and figured. It may be used either horizontally or vertically.

The tripod base is arranged with holes through the feet so that it may be screwed to a wall or table.

Thermo-Electric Pyrometers. (Fig. 14.)

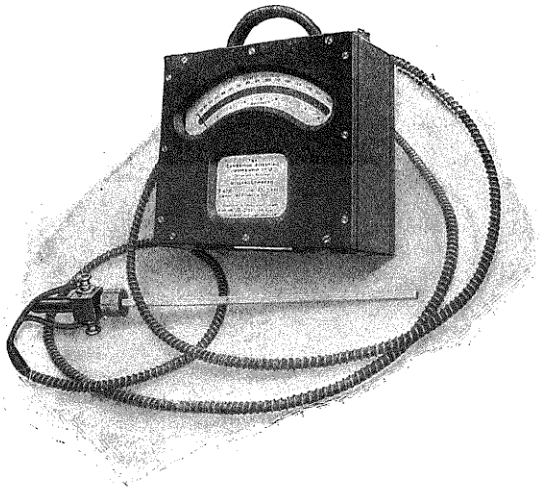


FIG. 14.

" High Temperature Measurements," by Le Chatelier and Boudouard, translated by Burgess.

The essential part of these pyrometers consists of two fine wires of different metals or alloys fused together at one end and connected to a galvanometer or millivoltmeter at their other ends, the fused end being inserted in the source of heat. An E.M.F. is developed by the difference in temperature of the two ends of the couple, this being roughly proportional to the difference in temperature. The most satisfactory couples have been shown to be platinum against platinum alloyed with 10 per cent. rhodium for temperatures up to 1,600° C., and platinum against platinum 10 per cent. alloyed with iridium for temperatures up to 1,000° C.

In commercial work a high resistance millivoltmeter is employed, so that the instrument may be set up at a considerable distance from the source of heat without the necessity of making allowance for the resistance of the conducting wires. The millivoltmeter scales are also calibrated in temperature degrees; a fixed or portable instrument can be supplied.

Thread Recorder. (Fig. 15.)

(1) " On Methods for the Continuous (Photographic) and Quasi-Continuous Registration of the Diurnal Curve of the Temperature of the Animal Body," by A. Gamgee, Phil. Trans. Roy. Soc., Series B., Vol. 200, page 239, /1908.

(2) " Engineer," June 14th, 1907.

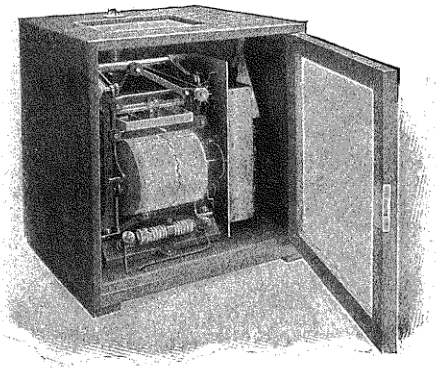


Fig. 15.

When it is required to obtain a continuous record of the temperatures a recording galvanometer is supplied, to which the name of " thread recorder " has been given. This instrument consists of a suspended coil galvanometer, the coil of which carries a boom, which is depressed by clockwork (every minute or half-minute as required) on to an inked thread.

This thread is thus forced against a calibrated chart carried on the drum below, and being inked, marks a dot on the paper. This method leaves the galvanometer boom quite free to take up its own position excepting at the moment when the boom is depressed, and thus pen-friction is avoided. The thread recorder may be used also instead of an ordinary ammeter or voltmeter when records are required.

In addition to the above methods of noting the E.M.F.s generated by a thermo-couple, and consequently the temperature of the source of heat, this E.M.F. can be determined by means of a potentiometer. This is more accurate, but is more laborious than the above methods.

Thermo-electric Potentiometer. (Fig. 16.)

" Electrician," January 31st, 1908.

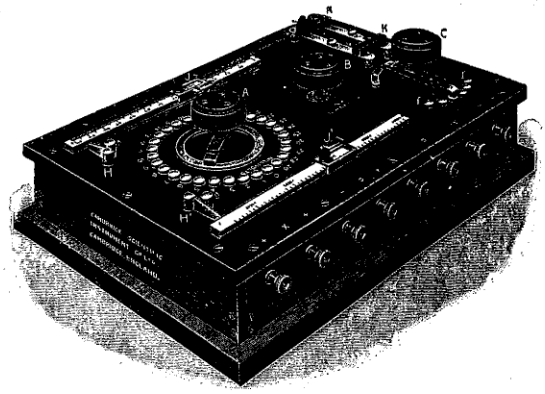


FIG. 16.

This potentiometer, constructed specially for use with thermo-couples, is designed to measure accurately small diffeences of potential not exceeding 30 millivolts. It enables the unknown potential difference to be accurately balanced against the E.M.F. of a standard Weston normal cell. It reads directly to 1/100 millivolt, and by estimation to 1 microvolt.

The total resistance in the circuit is arranged so as to give a fall of potential of about 1 volt per 50 ohms circuit resistance.

The key is a special double key arrangement, by which the galvanometer can be put in circuit either with the standard cell or the unknown P.D. It is thus possible, when measuring the unknown P.D., to test the accuracy of the fundamental adjustment for the standard cell without disturbing the connections. Also, by a device which locks the key when depressed on the " unknown " circuit, it is possible to follow a rapidly changing P.D. In this way the melting point of a substance or the recalescent point of steel may be easily followed.

In order to minimise the troubles due to thermoelectric effects the only metals used in the construction of the potentiometer are copper and manganin.

Platinum Resistance Pyrometers. (Fig. 17.)

(1) C. W. Waidner and G. K. Burgess, "Bulletin of Bureau of Standards," Vol. 6, No. 2.

(2) Harker and Chappuis, Phil. Trans., Vol. 194.

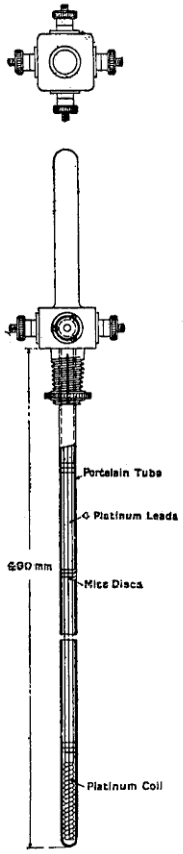


FIG. 17.

The essential part of these instruments is a fine platinum wire wound on a mica frame. This platinum wire is joined by platinum or copper leads to the temperature indicator or

recorder, and the change in resistance of the platinum wire is indicated electrically by a special modification of the Wheatstone bridge. The Callendar and Griffiths' arrangement of compensating leads in adjacent arms of the bridge serves to eliminate all effects due to changes in the temperature of these leads, so that even when they are of considerable length the readings obtained are solely determined by the temperature of the coil of platinum wire. Thus, however inaccessible the place whose temperature is to be measured, the indicator or recorder may be installed wherever it is most convenient to use it. Thermometers are in use 1 kilometer from the recorder.

The wire is enclosed in tubes of porcelain, steel, or brass according to the temperature and other conditions.

Pyrometers and thermometers are supplied suitable for all kinds of works, for instance, for temperatures of chimney shafts, boiler flues, melting points of metals, high temperature furnaces, cold stores, galvanising baths, &c., &c.

Whipple Temperature Indicator. (Fig. 18.)

London Phys. Soc., Vol. 18, page 235, 1902.

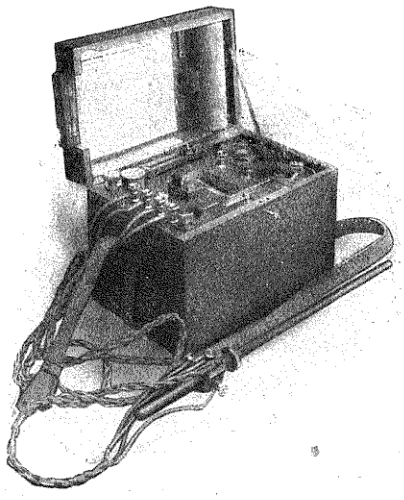


FIG. 18.

This instrument is a special form of Wheatstone's bridge designed for use with electrical resistance pyrometers. Two small dry cells, which are self-contained in the instrument, are sufficient for its operation. To take a reading with it, a handle which controls a sliding contact is turned until a pointer indicates that the "balance point" is obtained. The temperature of the pyrometer can then be read directly off the scale. One of its chief features is the arrangement of the scale in a spiral fashion on a drum, permitting readings to be obtained to one degree, even up to 1,200° C., and rapidly varying temperatures may be followed and measured. A series of pyrometers can be read from one central station by means of an indicator and switchboard. No corrections of any kind have to be applied.

Callendar Electric Recorder.

"Engineering" (London), Vol. 67, page 675, 1899.

Like the Whipple temperature indicator this instrument is also a special form of Wheatstone's bridge, and is used chiefly in connection with platinum resistance pyrometers, or thermometers. The galvanometer of the "bridge" carries a boom, and when deflected this boom operates one or other of two relay contacts, which in turn operate electro-magnets. These electro-magnets release a clockwork mechanism, which then draws a sliding contact on the slide wire of the bridge backwards or forwards according to the direction in which the galvanometer boom has been deflected. The bridge thus automatically maintains the galvanometer in the balanced position. The sliding contact carries a pen which moves over a paper chart carried by a drum which rotates once in 25 hours. The charts can be calibrated to read directly in temperature degrees. The instrument has varied uses, and by adjusting the resistances the temperature range across the charts can be varied within wide limits. The standard chart for blast furnaces is calibrated for the range of 400—1000° C., whilst for use as a clinical recording thermometer the instrument with a range of 10° C. across the scale can be used. For this latter work the instrument is proving itself very useful. In

Fig. 19 a record of the human body temperature obtained with the Callendar recorder and a resistance thermometer is reproduced.

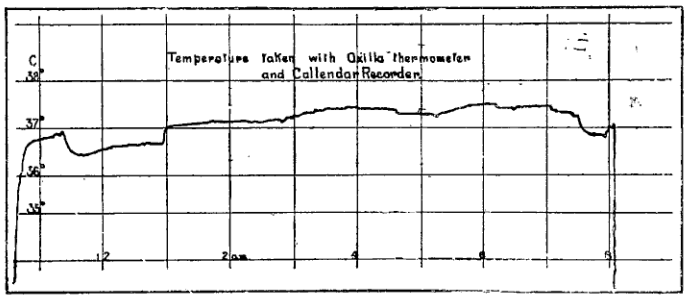


Fig. 19.

Callendar and Griffiths' Self-testing Bridge.

"Electrician," January 1908.

This is a modification of the Wheatstone bridge for use with platinum resistance thermometers. It is designed for accurate work, and with a platinum resistance thermometer of about 2·7 ohms ice resistance the latest type bridge (known as type 3) is capable of directly measuring temperature on the platinum scale to 0·001° C., by means of an improved scale and vernier.

The coils in the adjustable resistance arm are short circuited, when not in use, by Collin's patent mercury contacts, instead of by the more usual arrangement of plugs and brass blocks, as they have been found to be more satisfactory.

Some of the most serious difficulties which arise in practice with resistance thermometer bridges are due to the temperature variation of the resistance coils of the bridge. In this bridge these difficulties are practically eliminated. The coils are all wound with manganin, and the whole bridge system, including coils, bridge wire, and slider, is immersed in oil, which is kept in circulation by means of a fan driven by a motor.

The motion of the slider along the slider bar is controlled by two movements, a slide movement for rough adjustment and a lever and cam movement for fine adjustment.

Although the bridge is specially designed for platinum resistance thermometry, it is also well adapted for the accurate measurement of small resistances not exceeding 25 ohms, by the usual bridge method, to 0·0001 ohm.

The bridge is " self-testing " in the sense that the comparative value of the resistance coils can be tested at any time by means of the bridge itself, and their comparative errors determined. The accuracy of the bridge for thermometric work depends not upon the absolute value of the resistance coils, but upon their comparative values relative to each other and to the fundamental interval of the thermometer. These relative values are adjusted with the greatest care and, as just explained, they may be tested at any time to any required degree of accuracy.

The absolute value of the resistance unit adopted in the bridge may be taken, with good accuracy, to be 0·01 ohm, but, if required, the absolute value in terms of any specified standard may be determined exactly by measuring a suitable standard resistance with the bridge.

Féry Radiation Pyrometers. (Fig. 20.)

(1) " Optical Pyrometry," by Waidner and Burgess, Bulletin of Bureau of Standards, Vol. 1, No. 2.

(2) C.R., CXXXIV., 997, 1902.

(3) " Ann. de Chim. et de Phys.," XXVIII., page 428, 1903.

(4) " J. de Phys.," 8, page 701, 1904.

For temperatures from 500° C. upwards.

In the measurement of furnace-temperatures, radiation pyrometers are the only pyrometers which are entirely outside the furnace, and they are therefore especially useful for very high temperatures (above 1,200° C.) at which other forms deteriorate rapidly or are quite impossible.

The radiation pyrometers invented by M. Féry, Professor of Physics at the Ecole de Physique et de Chimie, Paris, are placed at some distance from the furnace, while no part of them is raised above the air temperature by more than 80° C.

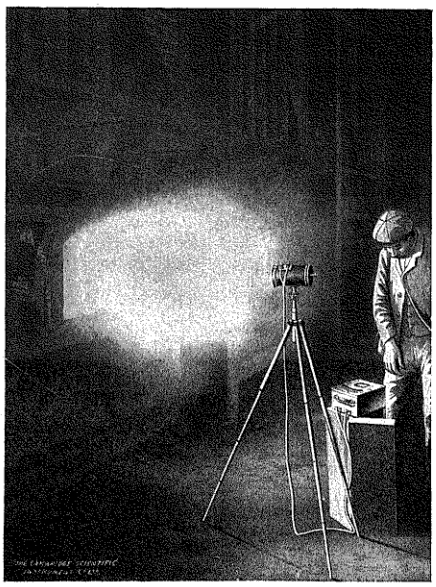


FIG. 20.

The radiation which emanates from a hot body, or which passes out through an observation hole in the wall of a furnace, falls upon a concave mirror and is thus brought to a focus. In this focus is a thermoelectric couple, whose temperature is raised by the radiation falling upon it: the hotter the furnace, the greater the rise of temperature of the couple.

The arrangement of the instruments is such that they are uninfluenced, within wide limits, by the size of the hot body or observation hole, or by the distance which separates them from the hot body or furnace.

The indicating instrument is a portable millivoltmeter as used for thermoelectric pyrometers previously described. For making a continuous record a " thread recorder " is used.

As examples of high temperature measurements it may be mentioned that the temperature of the sun, 5,100° C. absolute, disregarding atmospheric absorption, and the temperature of the electric arc, 3,600° absolute, have both been determined with the Féry pyrometer. The instrument is thus of especial value for taking such high temperatures as those of molten

steel, gas settings, glass furnaces, brick kilns, and electric furnaces, and for taking the temperature of metal in a crucible just before pouring, thus ensuring correct casting temperatures, a point which is now known to be of especial importance in the case of steel castings.

The Féry telescope and the millivoltmeter are supplied fitted in a wooden travelling case, and a wooden tripod is included for mounting the telescope; 12 ft. of leads in flexible steel sheathing are included for connecting the telescopes to the millivoltmeter.

The scale of the indicating instrument is graduated in either of three standard ranges as follows:—

Range 500 to 1,100° C., 600 to 1,400° C., and 800 to 1,700° C.

Féry Spiral Pyrometer. (Figs. 21 and 22.

(1) "Engineering Review," July 1909.
(2) "Electrical Times," July 30th, 1909.

FIG. 21.

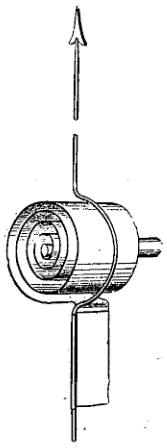


FIG. 22

This instrument, like that just described, measures temperature by concentrating radiated heat to a focus. Instead, however, of heating a thermo-couple, a small spiral is heated, which uncoils itself as its temperature rises, thereby deflecting a needle across a scale. Fig. 21 gives the general appearance of the instrument (back view).

The Féry spiral pyrometer is the simplest instrument yet developed for measuring quickly and easily the temperature of any body which is hotter than a dull red heat.

In general appearance it somewhat resembles a short telescope with a dial and pointer built into it, and it is supplied with a portable tripod. All that is necessary is to sight the instrument on the hot body whose temperature is to be measured, and read the temperature directly upon the dial. The instrument is completely self contained, and works on purely mechanical principles, though a simple optical principle is made use of to aid the operator in sighting on the spot whose temperature is desired.

In the Féry spiral pyrometer the strip, built up of two dissimilar metals, is rolled flat and very thin, and coiled into a spiral shape so that as its temperature is raised the spiral uncoils. This spiral is very small, measuring less than $\frac{1}{8}$ of an inch (3 mm.) diameter, and $\frac{5}{64}$ of an inch (2 mm.) wide. It is fixed at the centre, and its free end carries a light aluminium pointer which moves across a dial. The instrument is calibrated so that the reading of the pointer on the dial indicates directly the temperature of the body on which it is sighted.

After it has been mounted on its tripod, the total time required to sight it and take a temperature observation is only about 30 seconds.

Extreme accuracy is not claimed for the instrument, but each one is carefully calibrated, and an accuracy of from 1 to 2 per cent. at 1,000° C. may be confidently claimed. For most commercial purposes this will be found sufficient.

Its chief limitation is that it cannot be made to give a continuous record of temperature.

Hohmann and Maurer Industrial Thermometers. (Fig. 23.)

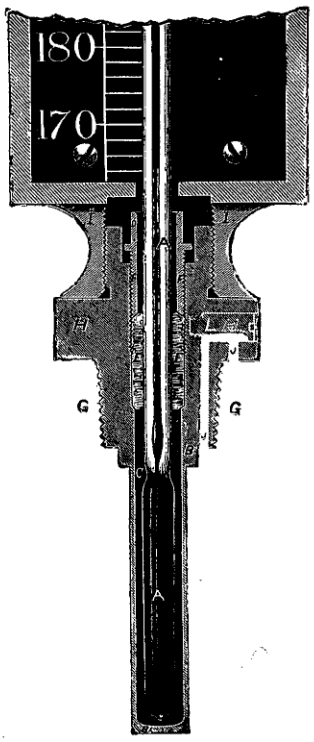


Fig. 23.

These thermometers have been developed by the Hohmann and Maurer Manufacturing Co., of Rochester, N.Y., U.S.A. Each pattern has been specially designed for some particular purpose, and, whilst being accurate and sensitive, they are capable of standing rough handling. The rights for the sale and manufacture of these thermometers outside America and Germany have been acquired by the Cambridge Scientific Instrument Co., Ltd.

The space above the mercury is filled at the time of sealing off with nitrogen gas under a high pressure. This filling of the tubes with gas under pressure makes the thermometer suitable for use in any position, upside down even if required.

The space "C" between the bulb and the thin steel walls of the bulb-chamber is in the case of the lower temperature range thermometers filled with mercury, whilst in the flue-gas and superheated steam thermometers it is filled with copper dust. In either case a direct metallic path for the heat is ensured from the outer walls of the bulb-chamber to the bulb itself.

In the flue-gas thermometers the best boro-silicate glass is employed and the standard range is 530° C. The stem is protected by an inner and outer steel tube. The scales, which are made V shaped with the thermometer tube resting in the angle of the V, are engraved with large figures, and as the glass tube has a lens front, readings can be taken at some distance from the thermometer.

H. & M. Superheated Steam Thermometers. (Fig. 24.)

One special feature which can be fitted to all these thermometers designed for screwing into pipes, but which is particularly desirable in the case of thermometers for use with superheated steam, is a "separable socket."

Fig. 24 illustrates a thermometer of this type and shows also the separable socket. This socket is turned out of a solid piece

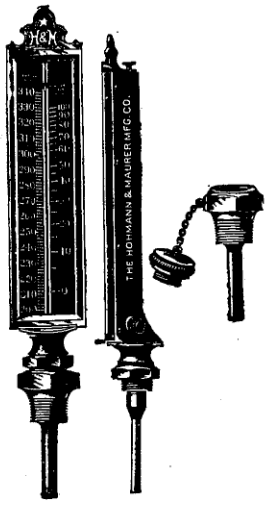


Fig. 24.

of steel and the outside is copper plated. The inside is turned to a slight taper in which the tapered bulb-chamber of the thermometer exactly fits and no mercury or other liquid is required. The socket is screwed permanently into position in the steam pipe or chamber, whilst the thermometer is secured in position in the socket by a union nut.

The union nut which locks the thermometer in place can be turned by hand. There is therefore no strain on the thermometer and it can quickly be removed without the need of tools, or at the most, only a small wrench is necessary.

The face or scale can be turned in any position desired. All sockets and thermometers are interchangeable. A cap is provided to keep the dirt out of a socket when the thermometer is removed. The socket need not be vertical and can be used in a horizontal position, or even in an inverted position.

Besides the ordinary straight stem form of thermometer an angle form is also made in which the scale case may be at any angle, usually 90°, to the direction of the bulb. Thus the socket may be screwed horizontally into the pipe whilst the scale will be vertical.

Gas Works Thermometers.

These are specially designed for determining the temperature in gas mains, inlets and outlets of condensers, &c. The socket can be supplied either of solid steel, nickel-plated bronze, or steel lead covered.

Long Stem Thermometers for use in Oil and Varnish Making.

These thermometers are similar in general appearance to the flue-gas thermometers, excepting that brass stems are used instead of steel. Also, in the case of the varnish thermometers, since great sensitiveness is required, the bulb-chamber is dispensed with. The bulb itself is copper-plated and protected by a brass guard.

Special thermometers are also made for use in jam and sugar boiling, cold stores, &c.

H. & M. Automatic Temperature Regulator.

This instrument is largely used for automatically maintaining hot-water tanks, or steam heated hot rooms at a constant temperature.

The regulator itself is a bi-metallic expansion device consisting of a steel rod in a brass tube. These are fixed together at one end and at the other is a small valve.

The difference in expansion between the brass and steel controls the amount of opening of this valve. In its turn the valve controls the supply of air under pressure, or of water under pressure, to the back of a diaphragm which controls the amount of opening in the main valve of the steam supply. When the regulator is working under normal conditions the small valve is slightly open, which allows a limited amount of air or water to pass through to the back of the diaphragm and thus keeps the main steam valve partially open. If the temperature increases the regulator allows more air or water to pass, which acts on the diaphragm and closes the main steam valve. If the temperature decreases the small valve opens and since there is always a small leak at the back of the diaphragm the pressure is soon relieved from it and the main steam valve opens.

The regulator will control the temperature to within 1° C. provided it is located in a suitable position in the tank or chamber.

The Cambridge Rocking Microtome. (Fig. 25.)

" Nature," November 30th, 1899.

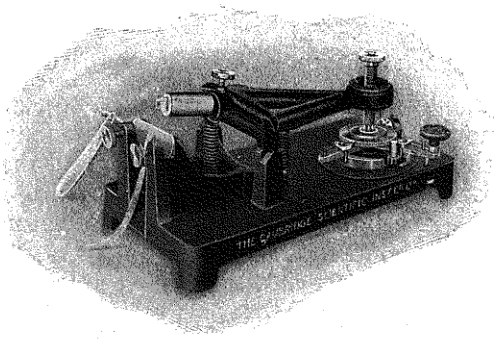


FIG. 25.

The original machine embodying the rocking principle was designed 25 years ago. Detail improvements have been made

since that time. Double-knife edges are fitted to the rocking mechanism, and on the reverse stroke the razor is free from the specimen.

The scale of thickness of sections which can be cut is divided into 12 divisions of successive increments of 0·002 mm.. the thickest being 0·024 mm. Size of object, 12 × 20 mm. A larger machine cuts flat sections up to 30 mm. diameter.

Large Sliding Microtome. (Fig. 26.)

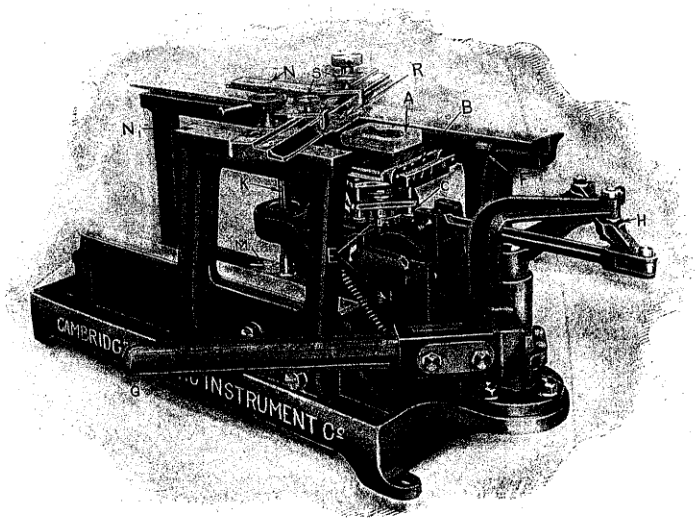


FIG. 26.

This microtome is shown in Fig. 26. It has been designed for cutting flat sections up to 50 mm. × 75 mm. It is capable of cutting through decalcified bone or cartilage, and is suitable for use with objects embedded in either paraffin wax or celloidin. The block of paraffin wax or celloidin is mounted on a piece of wood clamped in an object holder, which is fitted with orientating adjustments very similar to those used in the rocking microtomes. The object holder is fixed on a sliding carriage which only bears on the frame of the instrument at three points. A handle is connected by a system of levers in such a way that it moves the carriage which moves the object holder backwards and forwards underneath the knife.

The knife is clamped to the knife-holder which, in turn, is clamped to the upper faces of the frame.

The feeding arrangement for fixing the thickness of the section cut is practically identical with that employed in the rocking microtomes. It consists of a screw fitted with a toothed wheel and ratchet, and the thickness of the sections cut can be varied from ·002 mm. to ·06 mm., the scale indicating the size directly. On the return stroke the mechanism is such that the whole of the sliding carriage is lowered bodily so that the object does not touch the knife.

Small Embedding Bath with Gas Burner and Regulator.
(Fig. 27.)

"Knowledge," January 1905.

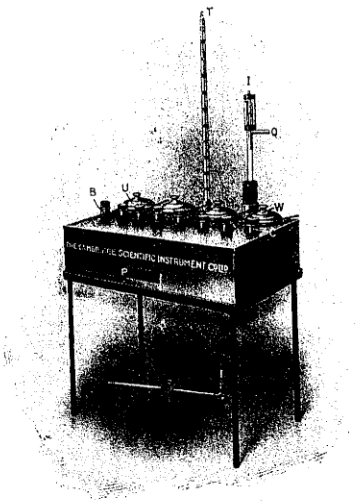


FIG. 27

Two different sizes of embedding baths—the "small" and the "large" size. The small size is also made in two patterns —one for gas heating, equipped with a gas regulator; and the other arranged for heating with an oil lamp, and equipped with a mechanical temperature regulator acting on the chimney damper. All the baths are made of sheet copper.

Dissecting Lens and Stand. (Fig. 28.)

" Knowledge," January 1905.

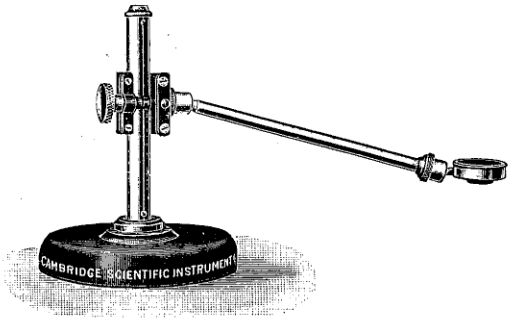


FIG. 28.

This consists of a heavy cast-iron base supporting a brass pillar about 13·5 cms. high, on which a carriage slides up and down (fig. 28). This up-and-down movement is secured by Lucas's Patent Slow Motion Mechanism, which consists of a small pulley with a V groove, turned in its circumference, this groove being forced by a spring to bind on a round steel rod which is screwed to the main pillar. This results in a more delicate movement than the ordinary rack and pinion arrangement gives, since a geometric fit is obtained, and there can be no play or backlash. The moveable carriage carries, through a ball joint, an arm, at the far end of which the lens holder is mounted, a ball joint being used here also. The total length of the arm is 23·5 cms.

Impact (Repeat) Testing Machine. (Fig. 29).

(1) " Engineering," September 25th, 1903, page 431.
(2) Proc. Inst. C.E., 1904, Part I., Plate 43.

This machine is a modified form of that originally designed by Dr. Stanton, of the National Physical Laboratory, and is for subjecting small rods of metal to repeated blows of a definite amount until fracture occurs, the rod being turned through an angle of 180° between each blow, and held stationary during the blow.

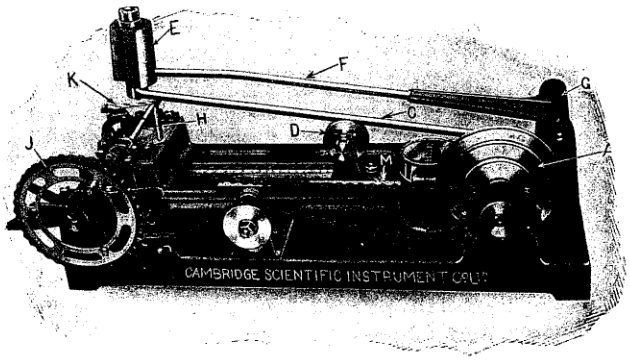


FIG. 29.

The machine is driven by means of the three-speed cone pulley A. At one end of the spindle carrying this cone pulley is a crank B, which serves to give a circular motion to the end of a rod C. This rod is also supported at some point in its length by a roller D, the framework supporting which can be fixed at various distances away from the crank B. The other end of the rod C therefore describes an irregular elliptical path, the amplitude of which in a vertical direction depends upon the position of the roller D. This end of the rod is bent at right angles, case hardened, and arranged to engage during its upward path with a hammer head E weighing $4\frac{1}{2}$ lbs. (2·0 kilos.). This hammer head E is supported by a lever F, which is hinged at G. As the end of the lifting rod C ascends it engages with and lifts the hammer E; when it reaches the top of its path it moves forward and disengages with the hammer, allowing it to fall freely on to the specimen H, this cycle being repeated about 100 times a minute. The scale M shows directly the vertical drop of the hammer, which may be adjusted as desired up to a maximum of $3\frac{1}{2}$ ins. (90 mm.).

The specimen under test H is usually about $\frac{1}{2}$ in. (12·5 mm.) in diameter, with a groove turned at its centre to ensure its fracture there, and is supported on knife edges $4\frac{1}{2}$ ins. (114 mm.) apart. The knife edges are cut slightly hollow, and a spring K holds one end of the specimen in place. The other end is held in a chuck, which is hinged in such a manner that it does not take any portion of the hammer blow, all of which comes on the knife edges.

The specimen remains stationary whilst each blow is struck, but between the blows it is turned through 180°. This is accomplished by means of the chain drive shown in the figure, which causes the wheel J to rotate uniformly, making one revolution for every two hammer blows. This wheel J is connected to the chuck holding the specimen by a spring and trigger arrangement, so that the uniform rotation of J is converted into a step by step motion for the chuck and specimen.

A revolution counter records the number of blows struck. When fracture occurs the specimen falls away; the hammer head continuing to fall, first works an electric switch L, which stops the driving motor and then comes to rest on a steel stop pin.

The Joly Meldometer. (Fig. 30.)

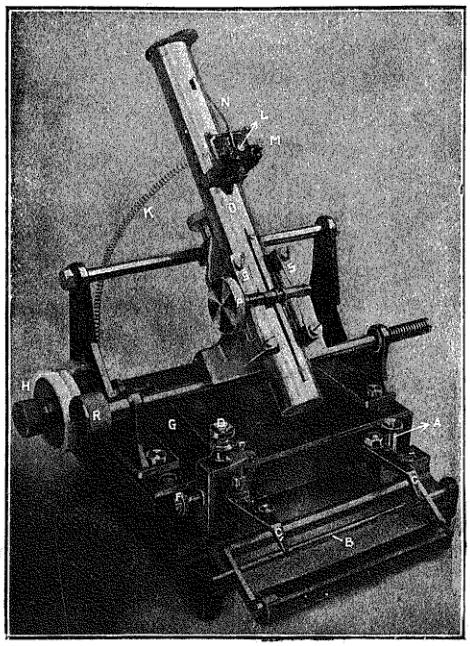


FIG. 30.

(1) Proc. Roy. Irish Academy, Vol. II., 1891.
(2) Ramsay and Eumorfopoules, Phil. Mag., XLI., page 360, 1896.
(3) "Electrician" (London), January 1st, 1909.

This instrument was originally designed by Prof. Joly, F.R.S., for determining the melting points of minerals, salts, metals, and alloys. The special feature of the apparatus is that it only requires a very small quantity of the substance whose melting point is to be determined, and therefore the substance may be obtained in a high state of purity; or, in the case of minerals, fragments can be chipped off museum specimens without destroying their value.

The linear expansion of a strip of platinum with temperature is the principle upon which the working of the instrument depends. The substance to be investigated is placed in the centre of this platinum strip, which is then heated by the passage of an electric current until the substance melts. The length of the strip at this moment is a measure of its temperature, and therefore of the melting point of the substance.

The platinum strip and the substance to be melted are shielded from draughts by a hood. A microscope whose focussing adjustment is made by means of Lucas's Patent Slow Motion Mechanism is focussed on the specimen.

The actual extension of the platinum strip is measured by a micrometer screw, by which it is possible to measure an extension of the strip of 0·0005 mm.

A current of about 6 amperes is required to obtain a temperature of 1,400° C., and the platinum strip glows quite uniformly to within a few millimeters of the supporting clips, owing to the fact that the ends of the strip are tapered. The strip begins to suffer permanent elongations only at about 1,500° C. It is possible to detect differences of 1° C. at 1,000° C.

Callendar's Apparatus for Determining the Mechanical Equivalent of Heat. (Fig. 31.)

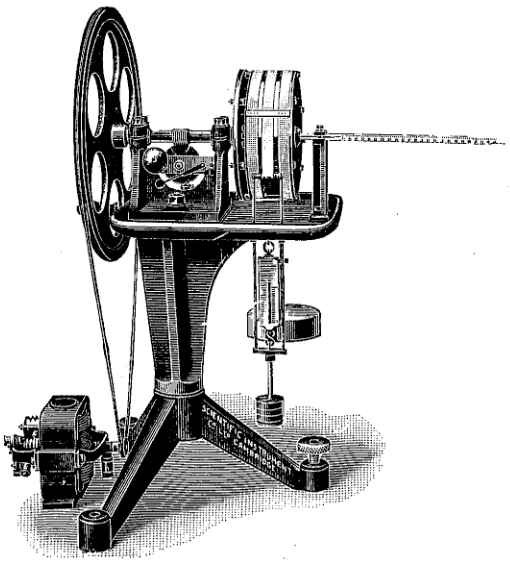


Fig. 31.

This apparatus comprises a cylindrical calorimeter of thin brass, whose axis is horizontal, containing a known quantity of water and is rotated at a moderate speed, either by hand or by means of a water or electric motor. Unequal weights are suspended from the ends of a silk belt slung over the cylinder, and so arranged as to make one and a half complete turns round the cylinder. Stability of equilibrium is secured by the addition of a light spring balance which acts in direct opposition to the lighter weight. Since this spring balance contributes only a small (positive) term to the effective difference of load at the two ends of the belt, small errors in its readings are relatively unimportant. The weights are adjusted by trial to suit approximately the friction of the belt, which is found to be very nearly independent of the speed, and the final adjustment is effected automatically by the spring balance. A counter registers the number of turns which have been given to the calorimeter, while the rise of temperature is read by means of a bent mercury or platinum thermometer, inserted through a central opening in the front end of the cylinder.

Cambridge Extensometer. (Fig. 32.)

(1) "Engineering," December 23rd, 1904, and July 10th, 1908.
(2) "Engineer," May 15th, 1908.
(3) "Nature," May 21st, 1908.

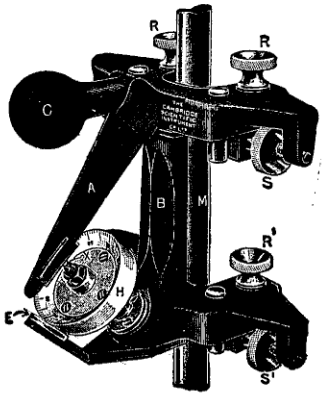


FIG. 32.

This instrument, for measuring the elastic extension and modulus of elasticity of specimens of metal under tensile loads, has been designed as a workshop tool rather than a scientific instrument. Having no delicate parts, mirrors, or microscopes, it is not easily damaged, and yet it gives very accurate readings.

The instrument is made in two separate pieces, each of which is separately attached to the test piece M by hard steel conical points P, P and P', P'. The steel rods carrying these points slide in geometric slides, and after being driven gently into the centre punch marks in the test-piece are clamped in position by the milled heads R, R.

The lower piece carries a micrometer screw, fitted with a hardened steel point X and a divided head H. It also carries a vertical arm B, at the top of which is a hardened steel knife-edge. The upper and lower pieces work together about this knife-edge. A flexible steel tongue A, forming a continuation of the upper piece is carried over the micrometer point X. This tongue acts as a lever magnifying the extension of the specimen so that the movement of the steel tongue to or away from the steel point X is five times the actual extension of the specimen.

To take a reading with the extensometer the thin steel tongue *A* is caused to vibrate, and the divided head then turned till the point *X* just touches the hard steel knife-edge on the tongue as it vibrates to and fro. This has proved to be a most delicate method of setting the micrometer screw, as the noise produced and the fact that the vibrations are quickly damped out indicate to $\frac{1}{1000}$mm. the instant when the screw is touching the tongue. After the load is applied a second reading is taken in a similar manner, and the difference in the readings gives directly the extension of the test-piece.

If the test-piece is of small diameter, the spring does not vibrate in so satisfactory a manner; the cause of this is the flexibility of the test-piece, the instrument itself vibrating as well as the spring. Still, very delicate readings can be taken by simply deflecting the spring with the finger, and noting the contact as it passes the point. No damage can be done by advancing the micrometer screw too far forward; all that happens is that the point passes the knife-edge on one side or the other.

The standard instrument is for use on centres 100 mm. apart. A similar instrument for use on centres only two inches (50 mm.) apart is also made.

After thoroughly testing one of the 100 mm. instruments the National Physical Laboratory report:—

> "The instrument is evidently reliable to about the one
> " thousandth part of a millimetre under ordinary conditions
> " of test."

Chronograph for Laboratory use.

A strip of Morse paper 25 mm. wide is drawn by means of a motor under three pens attached to the armatures of three electro-magnets. One of these electro-magnets can be connected to a clock making contact every second, the other two being used for recording the events under observation. The movement of the paper can be started or stopped whilst the motor is running.

Deprez Signal, Double Time-Marker. (Fig. 33.)

This is fitted with a fine adjustment (A) for approaching the recording surface. There are two small electro-magnets whose styles have their writing points close together. The moving parts are made very light.

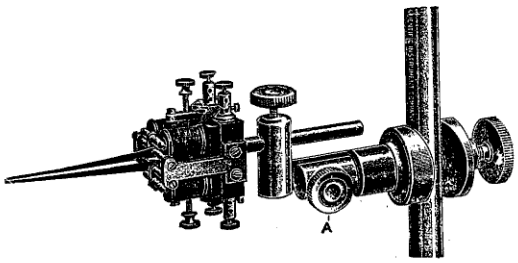


FIG. 33.

Comparator. (Fig. 34.)

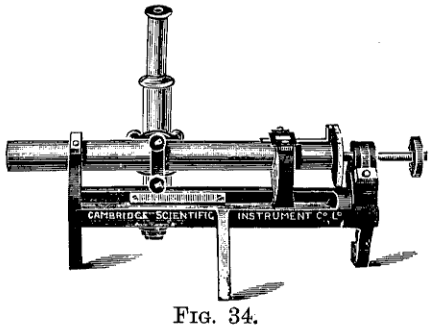


FIG. 34.

A horizontal tube has a slow traverse of 40 mm. directly read to ·01 mm. on a micrometer head. A microscope carrying cross lines can be clamped at any point of the length of the tube, and may have its axis vertical, horizontal or inclined as desired. For supporting the object under examination, a small sliding table with centering adjustments is provided. A tripod stand (with three levelling screws, not illustrated) enables the instrument to be used as a cathetometer.

The instrument is fitted with a Zeiss achromatic objective A combined with ocular No. 2 ; working distance between nose of O.G. and object = 20 mm.

Diameter of visible area = 11 mm.

Cathetometer. (Fig. 35.)

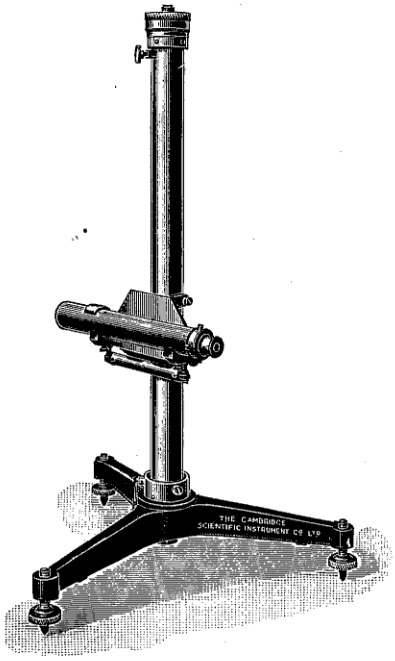


FIG. 35.

For use in conjunction with a standard scale. The whole pillar can turn about its axis, and can be raised or lowered micrometrically through a vertical range of 25 mm. ; the readings of the micrometer-head being used to subdivide the scale readings to ·01 mm. The vertical range of the telescope upon the pillar is 50 cm.

Searle's Apparatus for determining Young's Modulus of Wires.

(1) Proc. Cambridge Phil. Soc., Vol. X., Part 5.
(2) Searle : " Experimental Electricity," page 72.

This apparatus may be used to determine the deviations from Hooke's Law.

The upper ends of two wires are securely fixed to a beam, and from the lower ends hang two brass frames supporting the

two ends of a sensitive level. One end of the level is pivoted to one of the frames; the other end of the level rests upon the end of a micrometer screw; divided and figured on celluloid.

Extensions in the length of the wire under observation can thus be read direct to ·01 mm. The use of the two wires eliminates all effects dependent upon the bending of the supporting beam, or upon changes in temperature.

Cup Micrometer.

A. Bateson: "Annals of Botany," November 1889.

For measuring small vertical movements, to one-hundredth of a millimetre. It is useful in many cases where a cathetometer is commonly used. A cup is fixed to the upper end of the micrometer screw and is partially filled with oil. A needle is attached to the object whose movement is to be measured. It should be vertical, with the point downward, and directly over the oil cup. The micrometer screw is turned and the reading taken when the needle point is seen to touch the surface of the oil; the image of any object reflected in the surface of the oil being distorted at the moment of contact. It is sometimes more convenient to place the oil cup on the object to be measured and to fix the needle to the lower end of the micrometer screw.

Laboratory Stands. (Fig. 36.)

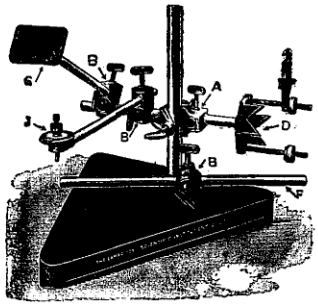


FIG. 36.

A series of stands and clamps of specially rigid construction and stability. The bases have counter-sunk holes drilled so that they may be screwed down if desired.

Fig. 36 is an illustration of a stand base and some clamp fittings. A is a pillar block for clamping on the pillar, drilled with three mutually perpendicular holes with set screws. B is a connector, drilled with three holes (two parallel and the third perpendicular to them), D is a clamp for holding at any inclination pieces from 60 mms. diameter downwards. G is a face-plate drilled and countersunk so that a board or other piece of woodwork may be screwed to it. F is a plain rod, and J is a torsion head, with a graduated circle.

G. Cussons, Ltd., *The Technical Works, Lower Broughton, Manchester, and* 231, *Strand, London, W.C.*

Models and Apparatus for Teaching Practical Mathematics and Theoretical Mechanics.

Tripod Capstan Block System (Fig. 1) is a combination of stands and fittings which are standardised and interchangeable, and capable of being built up and adapted to a great variety of experiments.

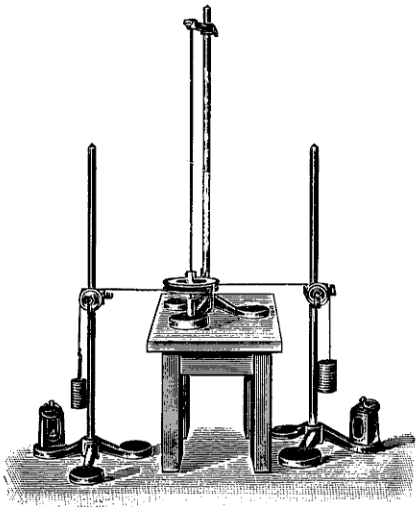


Fig. 1.

The rectangular brass block (Capstan Block) contains various standard holes and screws to which fittings such as pulleys, hooks, knife-edges, studs, &c. may be attached for the purposes of the experiments. The number of experiments possible exceeds 50.

Ribbon (Atwood's) Machine.

(Cussons and Johnson's Patent.)

This machine is used to determine the acceleration of a falling body due to gravity or to a known force acting on a known mass.

The acceleration, velocity, and space are recorded in ink on a paper ribbon as the body falls, by means of a vibrating spring carrying a brush pencil.

The release of the weight and vibrator is automatic. The wheel is of aluminium, and is accurately mounted on ball bearings.

Trolley Apparatus and Inclined Plane (Fig. 2), devised by G. Fletcher, Esq., H.M. Inspector of Schools.

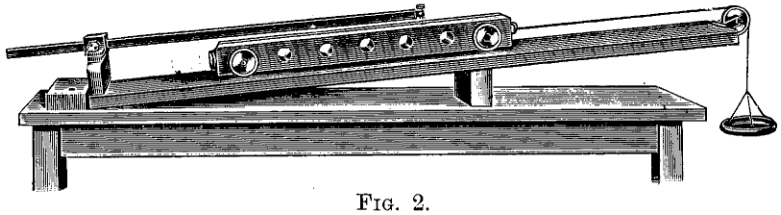


FIG. 2.

This apparatus is used for measuring the acceleration of a heavy carriage travelling down an inclined plane, or the acceleration due to a force pulling up the plane.

It consists of a long loaded trolley on which a strip of paper is fastened. A steel vibrator tuned to a definite period is provided carrying a brush, by means of which a wave curve is described upon the paper.

From this curve the acceleration and velocity of the trolley may be obtained.

Two trolleys may be used in collision, and the acceleration due to impact determined in the same manner.

Models for illustrating Practical and Descriptive Geometry, consisting of folding planes and coloured strings to indicate lines and planes, intersections of planes, planes tangential to solids. The theory of orthographic projection, the conception of points and lines in space, by referring to fixed planes of projection.

Solid Geometrical Models in Section illustrating the penetration of Solids, measurements of solids, volumes and densities.

Microscopical and Lantern Slides for teaching geology, botany, zoology, and other sciences.

Laboratory Apparatus for Experimental Mechanics and Engineering.

These pieces of apparatus are used for experimental verification of the laws of friction, stresses, and strains in materials, energy of mass in motion, the principle of work, the mechanical advantage derived by a combination of wheelwork pulleys and levers, screws, worm and worm-wheel, and the action of springs.

Models of mechanism, linkwork, kinematic pairs, and gyroscopes of various types.

Sectional Model of the Steam Engine (Fig. 3), whereby the action of the piston and slide valve is clearly shown. In the model the distribution of steam may be followed with reference to its admission, cut-off, expansion, and release. The eccentric may be adjusted, and the angle of advance determined and read off. The valve can be set and reset with varying amounts of lap and lead.

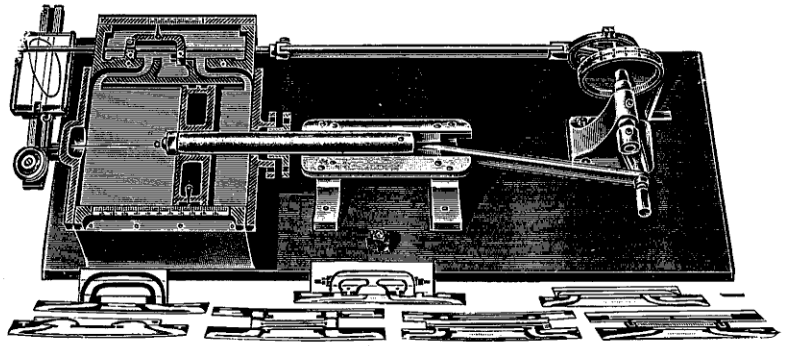


FIG. 3.

A special mechanism is provided for producing autographic diagrams of the valve movements.

Sectional Models of Stephenson's Reversing Gear, Joy's Gear, Walschaert's Gear, Meyer's Gear, and other types.

Sectional Model of the Locomotive Engine Gear for the Instruction of Locomotive Engine Drivers and Firemen.

Sectional Models of Gas Engine and Parsons' Steam Turbine.

Wood Painted Models of Machine Details.

Wood Models of Building and Architectural Details.

Mining Instruction Models to illustrate the processes used in mines for the preparation and classification of metalliferous ores.

Sectional Models to illustrate Mining Operations, e.g., buddles, slime tables, classifiers, long wall system, &c.

Cussons' Calorimeter for Testing Coal.

Instruments and Models for Teaching and Illustrating the Theory of Balancing Engines and Rotary Parts.

Balancing of Engines. Prof. Osborne Reynolds' Balancing Model.—The apparatus consists of a four-crank engine with pistons which can be adjusted at any angle relatively to each other. The whole system is supported by an upright vertical steel spring, and the model is driven by a belt and hand wheel. The theory of balancing can be verified by adjusting the cranks and bob weights until perfect steadiness is observed. When out of balance a violent oscillation is the result. The critical speed may also be observed.

Prof. Ewing's Balancing Model.—This consists of a suspended frame on which is a shaft with discs mounted, and to which bob weights can be attached. All the parts are adjustable to any desired angle. The model is driven by an electric motor.

The model as exhibited is designed to illustrate the balancing of rotary parts only.

Prof. Wilberforce's Oscillating Spring showing compound Linear and Rotary oscillations.

A Loaded Spring mounted on a Compression Balance for showing the varying dynamical force during oscillation.

Four-Crank Balancing Model, designed by Prof. Dalby (Fig. 4). —The model consists of four cranks and four piston parts driven by two electric motors. The cranks and connecting rods may be adjusted relatively to each other at any desired angle. The cranks may be loaded by weights, and the piston loads may also be varied.

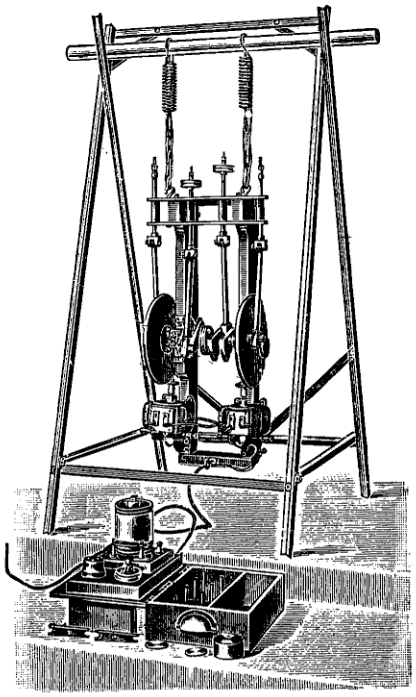


FIG. 4.

The whole system is suspended by springs from a cross-frame, and the theory of balancing may be verified by adjusting the angles and varying the masses until the model ceases to oscillate when thus suspended.

By adjusting the cranks the model may be run to illustrate a one, two, three, or four crank engine.

F. Darton & Co., 142, *St. John Street, Clerkenwell, London, E.C.*

Standard Fortin Barometer (Fig. 1) for public and private observatories. Scale reading to 0·002 in. and 0·1 mm. The bore of the tube is 0·7 in. (17 mm.) diameter. A thermometer is placed in a glass cylinder of the same diameter as the mercury tube, with the bulb immersed in mercury, in order to approximate to the temperature lag of the barometer. The instrument is mounted on a mahogany board with opal reflectors and is provided with levelling screws.

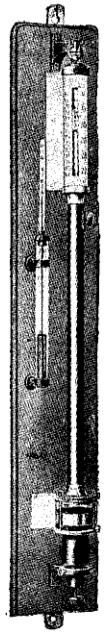


FIG. 1.

Standard Fortin Barometer in glass case as above with internal diameter of tube 0·5 in. (12 mm.) reading to 0·002 in. and 0·1 mm. with thermometer fixed in the case of the mercury tube.

The above barometers are verified at the National Physical Laboratory when required.

Standard Fortin Barometer, reading to 0·01 in. and 0·1 mm.

Thermometers.

Self-registering Maximum Thermometer, graduated on the stem, with opal scale divided and figured. After the temperature falls below the maximum the mercury thread breaks, as in a clinical thermometer, and setting is performed by swinging the thermometer with the bulb downwards. Divided in centigrade or Fahrenheit degrees.

Self-registering Minimum Thermometer, similar to above. The fluid is alcohol, which draws an index along when the temperature falls by the surface tension of the end of the column of liquid. It is set by raising the bulb end of the thermometer, the index moving along to the end of the alcohol column by gravity.

Six's Maximum and Minimum Thermometer, divided on the tubes, with opal scale. The setting is done by a magnet in the usual way.

Wet and Dry Bulb Thermometers.

Small weather screen for thermometers containing maximum, mininum, wet and dry bulb thermometers.

Barographs and Thermographs.

Barographs, of various patterns, recording the pressure for one week on clockwork drum.

Thermographs, in cases suitable for such purposes as cold storage buildings, magazines for explosives, and domestic use.

Combined Barograph and Thermograph. (Fig. 2.)

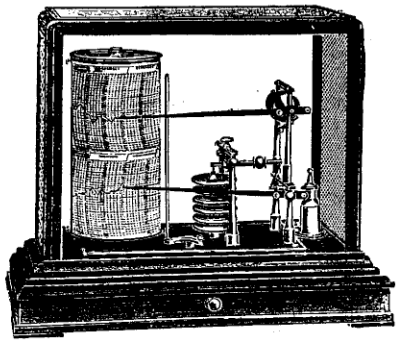


FIG. 2.

This instrument gives a continuous record of both atmospheric pressure and temperature.

Combined wet and dry thermograph, (Fig. 3) the difference of the two records giving an indication of the humidity.

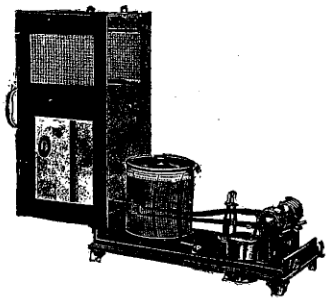


FIG. 3.

Aneroid barometers, of various patterns, including a 5 in. barometer with very open scale reading to 0·01 in. (0·25 mm.), as used in the Japanese Navy, suitable for surveying.

Self-recording rain gauge, registering on a rotating chart the amount of rainfall during a week or more, reading to 0·005 in. (0·12 mm.). It is self-emptying for future measurement in a graduated vessel. The receiving funnel is 5 ins. (12·5 cm.) in diameter.

Down Bros., Ltd., 21 *and* 23, *St. Thomas's Street, London, S.E. (opposite Guy's Hospital). Manufactory, King's Head Yard, S.E.*

Surgical Instruments.

A collection of original models, consisting of new instruments or modifications of existing patterns.

Aseptic Hospital Furniture.

Specimens of the most recent types, and possessing many original features.

Down Bros., Ltd., have prepared a comprehensive catalogue of their own exhibit.

M. W. Dunscombe, Ltd., *5 and 7, St. Augustine's Parade, Bristol, England.*

Collection of spectacles, eyeglasses, and spectacle lenses from the earliest to the present time. Many unique specimens are included:—Spectacles made for and worn by Sir John Herschel; Tortoise-shell spectacles of the time of Queen Anne; wig spectacles of the time of George II., and the early forms of the pantoscopic spectacles; many contrivances for bi-focal spectacles, from the "Franklin" combination of more than 100 years ago, and the solid bi-focal lens of 60 years ago, shown in the Great Exhibition, A.D. 1851, to the latest fused bi-focal lenses of the present century.

A catalogue of this collection will be sent from Bristol on receipt of request, with name and address on prepaid postcard.

Help is invited towards making the collection more complete especially in old Continental spectacles, eyeglasses, and spectacle lenses.

Gambrell Bros., "*Durham House,*" *Clapham Common, London, S.W.*

Moving-coil Galvanometer. (Fig. 1.)

Three-terminal pattern for high sensitivity combined with portability, so constructed that the same galvanometer can be used for either ballistic and aperiodic work. The movement can be securely clamped from the outside of the instrument, and any number of spare suspensions can be supplied with the same galvanometer.

Approximate sensitivity at a metre scale distance. Periodic time, 5 seconds.

With a coil of 1,000 ohms.—1,000 mm. per micro-ampere, or 1,070 mm. per micro-coulomb.

With a coil of 8 ohms.—130 mm. per micro-ampere, or 70 mm. per micro-coulomb.

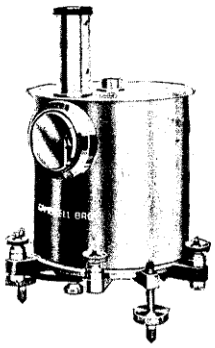


FIG. 1.

Non-Levelling-Moving-coil Galvanometer. (Fig 2.)

FIG. 2.

Designed in conjunction with Mr. B. Davies of "Electra House," and now largely in use on the different telegraph stations throughout the world, for which purpose it was more particularly designed. The movement is damped to work at a speed of two seconds, but for "speaking," an adjustment is provided for reducing the working length of the suspension. High surface insulation is provided for use in bad climates, and all working parts are easily accessible for examination or repair.

With a coil of 750 ohms the approximate sensitivity at a metre scale distance, and at a speed of two secs. is 80 mm. per micro-ampere.

"*Fool-proof*" *Galvanometer.* (Fig. 3.)

Can be handled by a man of no experience without fear of injury. This instrument is of the iron core moving coil type, with magnet shaped to give proportional scale readings, with either the pointer or mirror, and is made in two patterns.

(*a*) With pointer and mirror for use with lamp and scale ;
or
(*b*) With pointer only.

Approximate sensitivity. Coil resistance 100 ohms. Deflection of one degree is obtained with the pointer, with 1·4 volts through one megohm, or 30 mm. under the same conditions with the lamp and scale.

FIG. 3.

Wall Galvanometer. (Figs. 4 and 5.)

Latest pattern iron-core moving coil type, with magnet shaped to give proportional scale readings, either with pointer or with lamp and scale. This galvanometer is supplied with

two terminals only, and movement damped or undamped; with three terminals for both ballistic and aperiodic work. The movement can be clamped from the outside of the cover. As will be seen from the illustration the cover can be easily lowered, so as to give access to all parts.

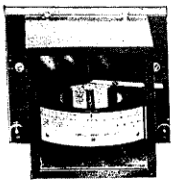


FIG. 4.

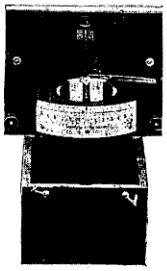


FIG. 5.

Porter's Suspended Needle Reflecting Galvanometer.

Constructed on lines suggested by Mr. Alfred W. Porter, of University College, London, to supply the want for a small sensitive galvanometer of this type at a low cost. The same pattern is also made with four coils and an astatic needle.

Semi-translucent Paper Scale. (Fig. 6.)

Enclosed between glass with vertical and horizontal adjustment, fitted with ventilated brass tube with slit or adjustable lens. Three patterns: (*a*) wall; (*b*) table, with upright for screwing to bench; (*c*) table, with base for standing on bench. These are also supplied without lamp fittings, but with Nernst lamp on stand.

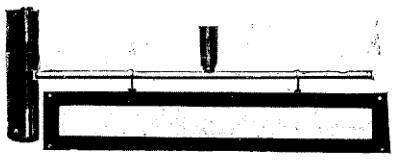


FIG. 6.

Universal Shunt. (Fig. 7.)

Range, 10,000 ohms with 16 resistances. High insulation pattern usually supplied with best form of moving-coil galvanometers.

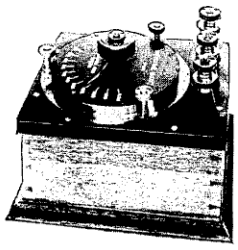


FIG. 7.

Universal Shunt.

Small high insulation pattern ; range, 10,000 ohms.
With or without interpolated thirds.

Potential Divider and Universal Shunt. (Fig. 8.)

Consisting of three dials with double contact arms and 11 equal resistances, and one dial with single contact arm and 10 equal resistances. Laminated contact arms are provided, and the brass covers are removable.

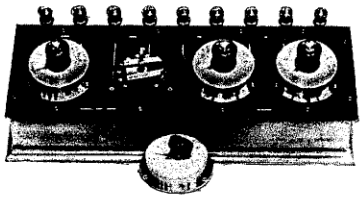


FIG. 8.

Standard Type of Wheatstone Bridge. (Fig. 9.)

For accurate measurements, with coils specially prepared and protected for use in any climate; the outcome of many years' experience with these resistances abroad.

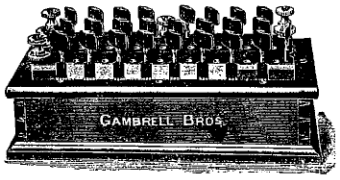


FIG. 9.

Short-Range Series Resistance Box.

For accurate measurements.

Direct Reading Wheatstone Bridge. (Fig. 10.)

Has figures representing the actual resistance in circuit always visible. Four-dial pattern, with laminated switch contact arms. Dust-proof tapper keys are provided as shown in the illustration.

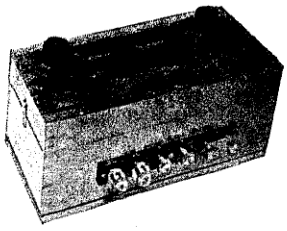


FIG. 10.

P.O. Form of Wheatstone Bridge.

For commercial measurements, with blocks well undercut for insulating and cleaning; all plugs carefully fitted and blocks rigidly fixed.

Full-Range Series Resistance Box.

Same construction as the above.

Sub-divided Megohm.

Ten equal resistances connected to 11 pillar terminals and coils wound for use on high voltage circuit.

Metre Bridge.

With key sliding along brass bar with terminal at end, and so constructed as not to dent the slide wire.

Savages' Special Cable Testing Key. (Fig. 11.)

Designed for use with a concentric or guarded conductor (*see* Ayrton and Mather, Physical Society of London, January 26, 1900). It combines a battery reversing key, charge and discharge key, and short circuiting key, all on the same base. An extra lever, to which the outer conductor of the cable is connected, is linked to the discharge key.

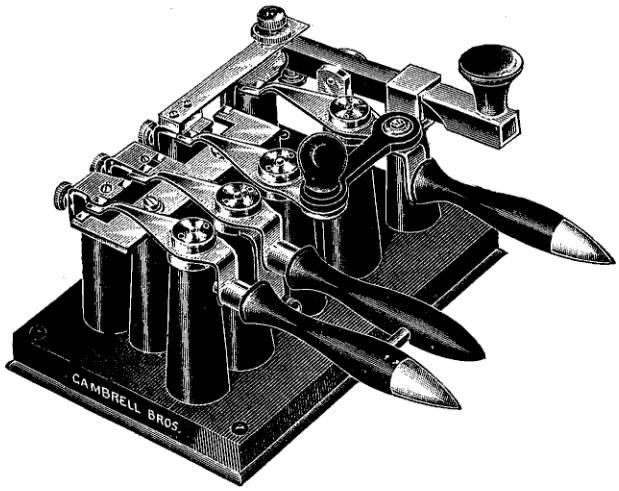


FIG. 11.

The distance between the contacts is so proportioned that the outer conductor is charged or discharged immediately

before the inner. The outer is charged directly from the battery, only the current through the inner conductor passing through the galvanometer. There is therefore no deflection on the galvanometer due to the outer conductor. The levers can be moved into any position without producing a deflection of the galvanometer when the outer is "free." When the connections are once made no change is necessary for either insulation, capacity, or loss of charge tests.

McCalla's Combined Shunt and Switch Key. (Fig. 12.)

For cable testing; designed with the view of reducing the number of keys, switches, &c. usually employed for cable testing to one only.

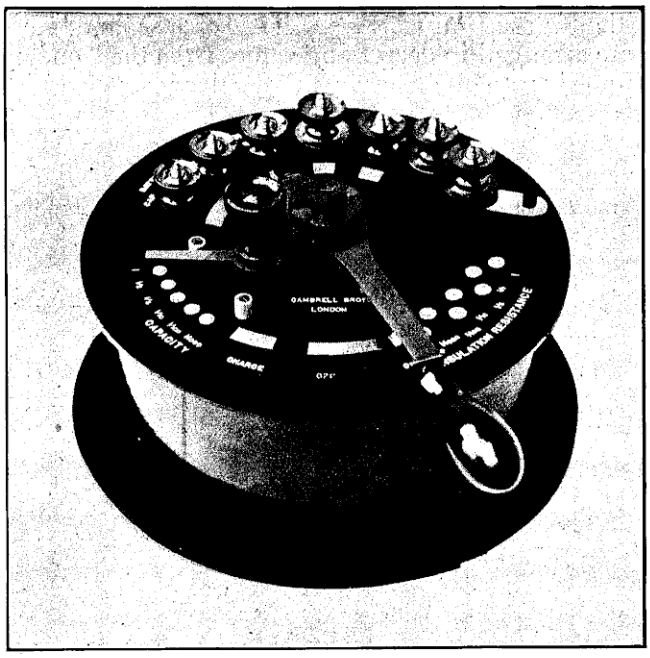


FIG. 12.

There is only one lever, by means of which both capacity and insulation tests are taken, and the galvanometer short

circuiting key is entirely done away with; the lever in the "off" position completely disconnecting one side of the galvanometer from the circuit, and connecting the cable under test to "earth."

When the connections are made to the terminals on the key, capacity tests are made by switching the lever to the left, and insulation tests by switching the lever to the right. With this key capacity tests may be taken either by measuring the discharge or by measuring the charge, by simply changing over the link shown between two of the back contact blocks.

For measuring insulation resistance the lever is switched to the "on" position, this putting the battery directly on to the cable, the galvanometer not being in the circuit; on switching the lever still further to the right the galvanometer is put into circuit, with a shunt corresponding to the value marked opposite the particular stud on which the lever rests; and, since these shunts are arranged in decreasing values from the "on" position, there is no danger of damaging the galvanometer with a large current due to a short circuit on the connections or cable, since the galvanometer is put into circuit with the largest shunt first.

The shunt is arranged on the Ayrton-Mather principle, and connections are made on to a small switch on the capacity side, so that the shunts may be used in taking capacities.

Davies' Long-Range Measuring Instrument. (Fig. 13.)

Permanent magnet moving coil type, with scale covering an arc of 220°. Particularly suitable as a laboratory instrument or for the purpose of calibration.

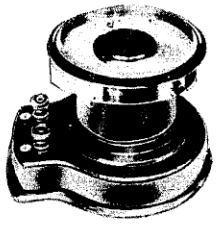


FIG. 13.

High Insulation Reversing Switch.

Particularly suitable for use in damp humid climates.

Paley-Yorke's Apparatus for Lantern Demonstration.
(Fig. 14.)

Ballistic Galvanometer, with direct reading scale. Can be used for condenser experiments, for electro-magnetic induction experiments, or for magnetic ballistic methods. Can also be used as an ordinary galvanometer.

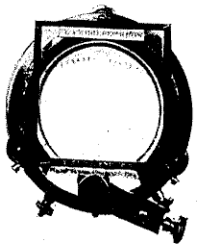


FIG. 14.

Magnet Sets.

Ewing Model.—Coils showing by means of iron filings lines of force in neighbourhood of single or parallel coils and solenoid.

Solenoid on Stand.

Lantern Electric Bell.

Lantern Electroscope.

Volta's Simple Cell and Voltameter.

Messrs. W. Gowlland, Ltd., *Moorland Road, Croydon.*

Sutcliffe Keratometer.

Laboratory Model for research work allowing of the immediate measurement of 19 different areas of the cornea. Fitted with right-angle eye-piece.

Sutcliffe Keratometer, 1910 *Model.* (Fig. 1.)

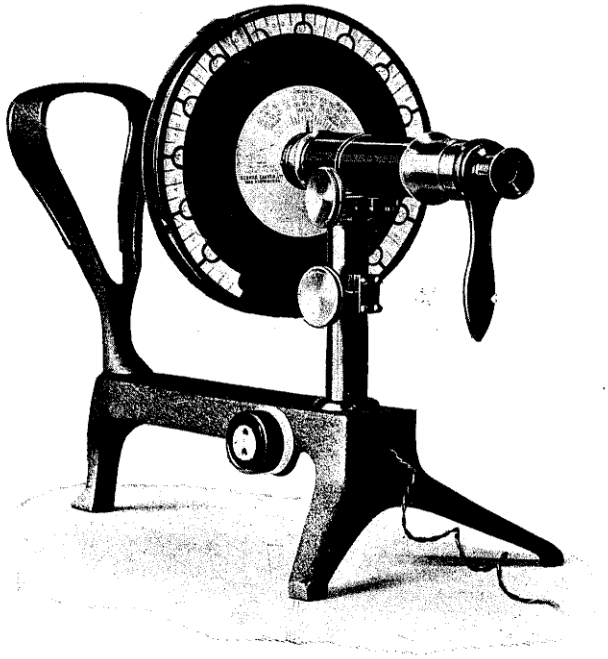


Fig. 1.

The unusual appearance of this instrument is largely due to constructional details carried out in order to avoid all visible mechanism, the operation of which may produce distraction and movement in the patient.

The ability of the instrument to take both first and secondary positions at one and the same time permits of the inclusion of a novel and ingenious differential gear, and does

away with all calculation on the part of the observer. It mechanically records the difference in the power in dioptres and the exact nature of the astigmatism. The dial plate also records the curvature in dioptres together with the radius of the cornea.

There is one continuous mire, the equivalent of the ordinary two mires ; the whole of the mire is utilised, and there are no confusing extra images, and as the mire is stamped out of one piece of metal, it is impossible for it to develop the common fault of mal-alignment. The original single image of the mire is trebled by the cylindrical prisms. Thus all the images are decentred diagonally in opposite directions, the first up and to the right, the second down and to the right, the third down and to the left. The slides cause the horizontal outside image to approach the corner stationary image, and in similar manner the vertical image moves downward. Although the decentration is oblique, the approximation is vertical and horizontal.

Steven's Phorometer.

The Steven's phorometer is fitted with two cells, each containing a 5° prism. The two are connected together by a small gear wheel, fitted between the two prism cells ; the frame containing these is pivoted on a fitting connected to the arm. A small milled head with back spring is provided for levelling the instrument, a level being fitted in the frame. Scales marked in gold on black are fitted around the cells, and read from centre each way from 0° to 10° the numbers representing the refracting angle of the prisms.

Phoro-Optometer.

This instrument is a combination of the revolving three cell gear driven trial frame ; the multiple and single red Maddox rod for each eye ; the Steven's phorometer, with spirit level, and a graduated adjustable near point test ; all so arranged as to be used separately or collectively as desired.

The adjustments for pupillary dimensions, cylinder axis, and prism powers, are all accurately and plainly graduated in gold on black and are larger than in the earlier models. They are fitted in friction tight bearings giving an ease and smoothness of movement seldom found.

McHardy Perimeter. (Fig. 2.)

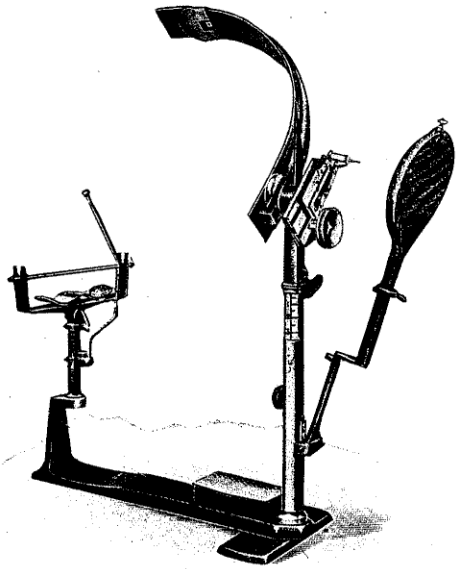


FIG. 2.

Geared for automatic registration on two scales of the "Angle of Strabismus" angle and field of fixation.

The quadrant rotates and can be locked in any meridian by turning a screw. By turning the milled head in front of the instrument, the travelling carriage and pointer are moved simultaneously, and by pressing the chart holder against the point, a permanent record is taken. The quadrant is divided into degrees and half degrees, enabling the instrument to be used to determine the angle of squint or the angle "α" accurately.

The objects consist of colours fitted in the travelling carriage on a circular wheel, having a diaphragm in front with apertures of a given diameter, enabling any colour to be used with any number of sizes of object. There is also a candle holder for light test.

The Bardsley Scotometer.

This is a miniature Bjernum's screen with a central fixation disc arranged so that the objects can be moved without distracting the patient's attention.

The New W.G. Trial Case and Sundries.

Each individual lens is tested and stamped at the National Physical Laboratory and conforms to the standards of the Optical Society.

The lenses are 15 mm. diameter and are mounted in a metal diaphragm. All spherical and cylindrical lenses from 0·12 to 20 dioptres are of uniform thickness. The lenses are plano-concave and plano-convex, and this enables an actual prescription with only two curved surfaces to be used in the trial frame. The maximum thickness does not exceed 3 mm. in the optical axis. All the dioptre markings are raised on the diaphragm in large figures, and around each cylindrical lens is engraved the standard notation. Every possible periscopic combination can be used in the trial frame.

The prisms have the base line raised on the diaphragm, and are supplied from ·25 to 8 prism dioptres.

W.G. Trial Case.

New W.G. Trial Lenses.

Several designs of Instrument Tables, including the New Rising Table (with cavity), for Ophthalmological Instruments.

Adjustable Table.

The table is made of iron, copper plated and bronzed with mottled finish lacquer; it has a positive vertical adjustment by rack and scroll, worked by the handle conveniently placed at the side.

Trial Frames, 42 different patterns.

Perfection Trial Frame.

This frame registers all measurements required to fit the patient's face. The two milled knobs on each end of the temple bar are connected to a right and left-handed screw, which moves

the compound cells to the required pupillary distance. The nose rest has a vertical and horizontal movement, which is divided for measurement. The front cell is arranged to take two lenses, making the frame very convenient for use; it is rotated for cylindrical lenses by the small milled heads at the side of frame, and is fitted with extension sides, and also straight sides.

Lang Trial Frame. (Fig. 3.)

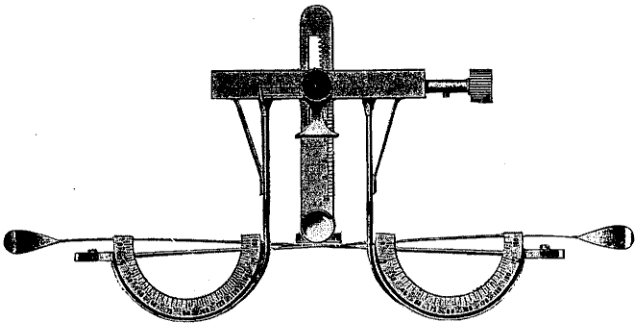


FIG. 3.

This trial frame is constructed from the design of Dr. Lang, and will be found convenient in use. It is strongly made, has rack adjustment for the bridge and screw adjustment in and out.

Opthalmoscopes, 54 various patterns.

Morton's Improved Magazine Ophthalmoscope. (Fig. 4.)

Concave Lenses: ·5, 1, 1·5, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20.

Convex Lenses: ·5, 1, 1·5, 2, 3, 4, 5, 6, 7, 8, 10, 12.

Lenses on Extra Disc: Concave, 10, 30; convex, 5, 20.

The ophthalmoscope here illustrated carries 29 separate lenses, enclosed in an endless groove, and propelled by a driving wheel. On the front of the instrument is an arrangement similar to the double nose piece of a microscope, revolving on a pivot and carrying a concave mirror at either end, one of 10 ins.

(25 cm.) focus for indirect examination and retinoscopy, the other of 3 ins. (7·5 cm.) focus, for direct examination. Other lenses for exceptional cases are provided on an extra disc. The numbers of the lenses are indicated on the disc in centre of engraving, and being fully exposed, the direction of rotation to bring any lens to the sight hole is at once apparent.

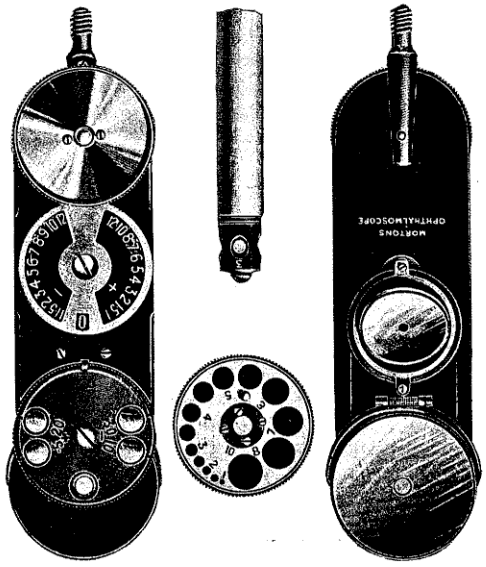


FIG. 4.

Paxton's Improved Ophthalmoscope.

Concave Lenses: ·5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

Convex Lenses: 1, 2, 3, 4, 5, 6, 8.

Extra Lenses on Segment: −20, −10, + 5, + 20.

The Paxton's improved opthalmoscope is a student's instrument, and consists of a wheel containing 19 lenses, with four extra lenses in segment, in front of instrument. It also has the revolving mirror fitting similar to the Morton's, with concave mirror and revolving angle mirror for direct examination.

Luminous Ophthalmoscopes.

Morton Inskeep Luminous Ophthalmoscope Patent. (Fig. 5.)

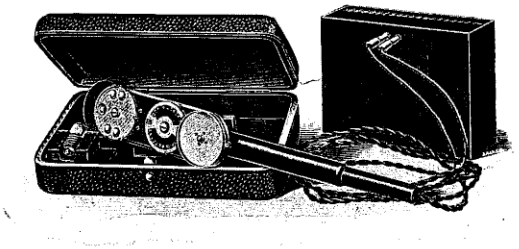


FIG. 5.

The arrangement of condensing lenses and lamps gives a better illumination than heretofore in luminous ophthalmoscopes. The form of mirror and aperture permit a good view of the fundus when seen through a smaller pupil than has been considered possible heretofore, and hence in those cases when a cyclopaegic is not indicated the instrument is an especially valuable ophthalmoscope.

The Inskeep Luminous Retinoscope. (Fig. 6.)

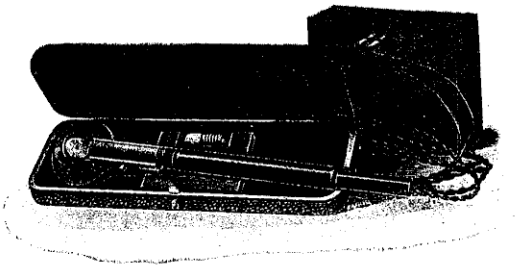


FIG. 6.

This is a compact instrument, the light being located in the handles as in the luminous ophthalmoscope. The mirror and aperture are sufficiently elongated in their greatest diameter to have the effect of a round mirror and aperture when in use. There are two condensing lenses, that next the mirror being fixed, and the other adjustable in the tube. By means of this adjustable lens, one is able to produce a light as from a concave or plane mirror at will.

Laryngoscopes, 19 *Varieties.*

Spectacle Frame Set.

The laryngoscope set illustrated above is a very complete set, containing a spectacle frame with ball and socket fitting, rubber nose rest, strong curl sides, $3\frac{1}{2}$ in. mirror with oval hole, three metal adjustable handles, six throat mirrors, Nos. 1–6, one uvula hook, one throat probe, one metal brush holder, three metal-mounted brushes, one set of three ear specula, one nasal speculum, in leather case.

Laryngoscope Head-band Set.

Laryngoscope set, containing head-band with ball and socket fitting and nose rests, $3\frac{1}{2}$ in. mirror with round hole, six throat mirrors, two metal adjustable handles, one probe, one brush holder, three metal-mounted brushes, in leather case.

Laryngeal Mirrors, &c.

Dental Mirrors.

Retinoscopes.

Amblyscope. (Fig. 7.)

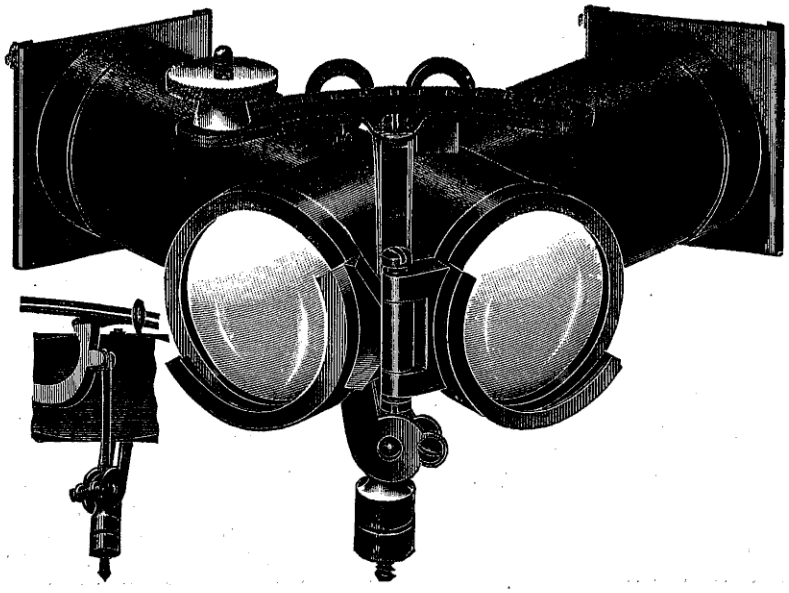


FIG. 7.

This instrument is used for the orthoptic treatment of squint. Two transparent pictures are placed at the ends of two tubes, each provided with a mirror and joined together by a hinge. By means of this construction the tubes may be brought together to suit a convergence of 60° or separated to suit a divergence of 30°. The eye-pieces have a focal length so that the reflected images appear at infinity. Dr. Black has added to the instrument an additional movement in the vertical direction, in order to obtain fusion when the lateral deviation is complicated by a vertical deviation. This vertical adjustment is effected by turning the milled head mounted on the shaft extending down from the hinge.

Model Eye.

C. Chambers Inskeep Improved.

In this improved form the inner tube slides in a cloth sleeve to insure smooth and easy adjustment. The posterior end, which carries a normal retina, is concave and of such a curvature that its centre is on the lens when the eye is adjusted to emmetropia.

Cornea and Skin Magnifier.

This achromatic magnifier will be found to give a flat field, the magnification being about 11 diameters; the optical system is a triplet, consisting of one crown and two flints, fitted in a nickel-plated folding mount.

Macnab Retinoscope.

In this instrument the mirror is made astigmatic, so that the illuminated area on the fundus is a band of light rather than an image of the lamp. The illumination, or the shadow, observed in the pupil is therefore more or less band shaped, and much more easily observed. By the rotation of the mirror the band of light on the fundus can be made to lie in the axis of the astigmatism when such is present; the appearance is then produced of a band of light on the face, and a narrow band of light and shadow ("the shadow") at right angles to it in the pupil. The movement is made along the line of the band on the face, which represents the meridian being tested; the action is that of a plane mirror. If the light on the face

and the shadow in the pupil be arranged at right angles to each other, and the handle of the mirror be held vertically, then a scale on the back of the instrument will indicate the axis which is being tested, that is, the axis of the astigmatism.

The Amber Glass Retinoscope.

The reflections from a mirror made of amber glass are very much less irritating to the eye under examination than when a clear glass mirror is used. When approaching the "point of reversal" the clear cut "illuminated area" is a decided advantage to the examiner.

Sutcliffe Bracket Trial Frame. (Figs. 8 and 9.)

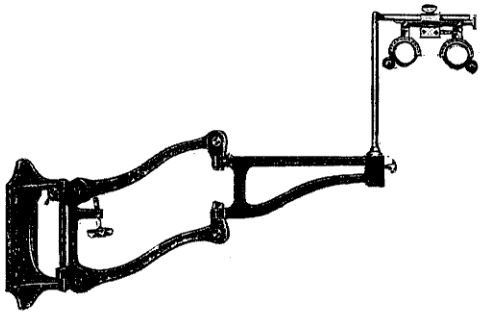


FIG. 8.

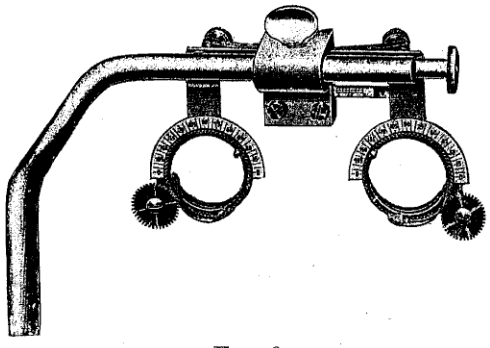


FIG. 9.

This Bracket Trial Frame has been designed to remove some of the objectionable features present in testing with an

ordinary frame, which has to be placed upon the face. With this frame the patient sits down to a table, or stands in front of the frame, and presses his temples against the rests provided for the purpose; the trial frame can then be adjusted for height and pupillary width, and locked in position. There is no obstruction in the way of placing the test lenses in the cells, and owing to the frame being locked there is no chance of the frame moving whilst inserting or taking out lenses.

Electrical Berger Loup and Head Bands.

Punctometers.

Optometer, nickel plated, with stand.

Illuminating Brackets.

This illuminating bracket is strongly made in brass, nickel-plated, fitted with double ball and socket joint, enabling the lamp and reflector to be placed in any position without clamping. It has a Universal wall joint, which allows the bracket to be raised, lowered, or swung back to the wall.

The reflector is fitted with a cover on which is fixed an iris diaphragm, graduated from 5 to 25 mm. The above bracket is fitted complete with an electric lamp.

Dr. Bishop-Harman's new Diaphragm Test.

New Colour Perception Lamp.

Electric Colour Perception Lamp.

This lamp is the improvement of the lantern described on p. 263 of "Colour Blindness and Colour Perception" (Kegan Paul & Co.) and enables the operator to make the test very quickly, while placing at his disposal a great many combinations of colours.

There are four wheels, three of which each contain yellow, pure green, standard green, blue, purple, red 1 and red 2, and the fourth ground glass, ribbed glass, neutral 1, neutral 2, neutral 3, neutral 4. In addition provision is made for extra modifying glasses to be put in front of the lamp if required.

Adam Hilger, Ltd., 75A, *Camden Road, London, N.W.*

Spectroscopic Apparatus of High Resolving Power.

Fabry and Perot Interferometer. (Fig. 1).

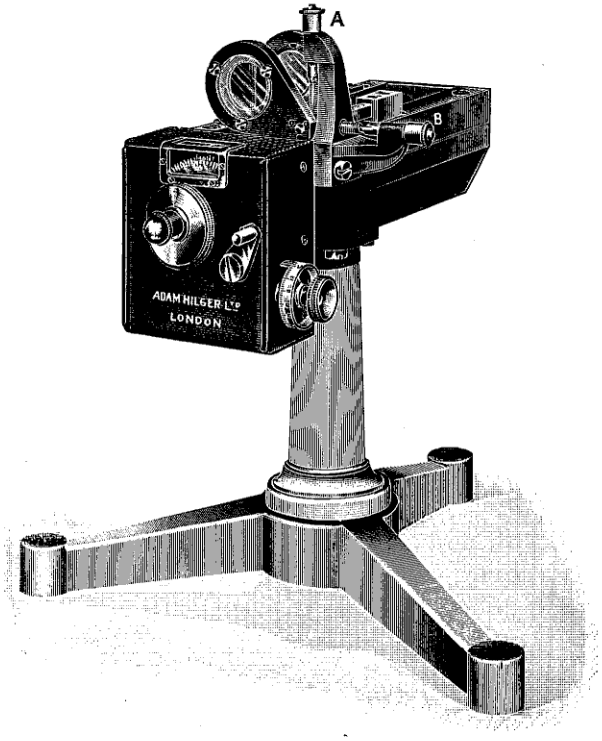


FIG. 1.

*Annal. Chim. Phys. (7), *12*, page 459 (1897).
,, (7), *16*, page 115 (1899).
,, (7), *16*, page 289 (1899).
Comptes Rendus, *130*, page 406 and page 492 (1900).
Journal de Physique (3), *9*, page 369 (1900).

* The bibliography has been chosen from the most important literature on the principles and methods involved in the instruments exhibited. Reference, if any, to the instruments of this firm is only incidental.

Annal. Chim. Phys. (7), *22*, page 564, (1901).
,, (7), *24*, page 119 (1901).
,, (7), *25*, page 98 (1902).
Comptes Rendus, *138*, page 676 (1904).
Annal. Chim. Phys. (8), *1*, page 5 (1904).
Comptes Rendus, *138*, page 854 (1904).
Journal de Physique, *3*, page 842 (1904).
,, *4*, page 245 (1905).
Comptes Rendus, *140*, pages 848, 1136 (1905).
,, *144*, page 1082 (1907).
Journal de Physique, March (1908).
,, June (1908).
Astrophys. Jour., *31*, 97, March (1910).

This apparatus is shown in Fig. 1. Screw, 1 mm. pitch, the thread being 120 mm. long. Motion of the carriage, 75 mm.

The divided head attached to the screw has 100 divisions, and one turn of the slow motion screw (whose head also is divided into a hundred parts) corresponds with one division on the main drumhead. Thus, one division on the drumhead of the slow-motion screw corresponds with $\frac{1}{10000}$ mm. (one ten thousandth of a millimetre).

The slides are very massive, and are worked *optically flat;* and this, combined with great care in mounting, produces the desired accuracy in maintaining the parallelism of the mirror when moved from one position to another.

The plates are silvered by cathodic deposition from freshly electrolytically deposited silver. With silver films deposited in this manner, the loss of light is less than with any other kind of reflecting film, and the necessary condition for sharply defined and bright intensity maxima is thus fulfilled. The plates are made slightly wedge-shaped in the usual manner, to avoid the secondary interference systems caused by reflections at the unsilvered outer surfaces.

The final adjustment of parallelism of the mirrors is obtained by the screws A and B, which cause alterations in the tensions of springs which are attached to one of the mirror mounts, this mirror mount being thus rotated through a very small angle about a vertical or horizontal axis as the case may be.

The Hilger Wave-length Spectrometer.

(*Constant Deviation Type*).

Pellin et Broca; Jour. de Physique (3), *8*, 314 (1899.)
Blakesley; Proc. Optical Convention, 1905, page 54.
Uhler; Phys. Review, vol. 29, No. 1, July 1909.

This is shown as modified for use with the following accessories, which are also exhibited. (The spectrometer is shown in Fig. 5, and is described below):—

(*a*) *Small Echelon* (Fig. 2).

As with all these three accessories, this is designed for use on any ordinary spectroscope, but it is specially suitable for use on the Hilger Wave-length Spectrometer described below:—

Number of plates, 12.
Thickness of plates, about $4\frac{1}{2}$ mm.
Width of step, 1 mm.
Effective aperture, 13 mm. square.
Resolving power, 45,000, for W.L., 5461.

The thickness of the plates and the optical properties of the glass are engraved on the mount.

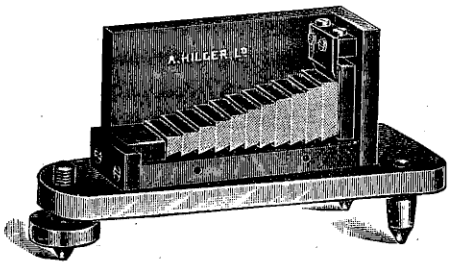


Fig. 2.

(*b*) *Lummer-Gehrcke Plate.* (Fig. 3.)

Deutsch. Phys. Gesell., Verh. *3*, 85 (1901).
Preuss. Akad. Wiss. Berlin Sitz. Ber., page 11 (1902).
Deutsch. Phys. Gesell. Verh., *4*, 14, 337 (1902).
Ann. d. Physik (4) *10*, 457 (1903).
Phys. Tech. Reichsanstalt Wiss. Abh., *4*, 63 (1904).
Deutsch. Phys. Gesell., Verh., *7*, 13, 236 (1905).
Preuss. Akad. Wiss. Berlin, Sitz. Ber., 50, 1037 (1905).
Deutsch. Phys. Gesell., Verh., *8*, 12, 209 (1906).
Ann. d. Physik, (4) *20*, 269 (1906).
Physik. Zeitschr., 7, 24, 905 (1906).
Deutsch. Phys. Gesell., Verh., 9, 4, 84 (1907).
Ann. d. Physik. (4), 23, 745 (1907).
Deutsch. Phys. Gesell., Verh., *9*, 19, 529 (1907).
,, ,, *10*, 10, 357 (1908).
,, ,, *10*, 12, 423 (1908).
,, ,, *11*, 6, 141 (1909).

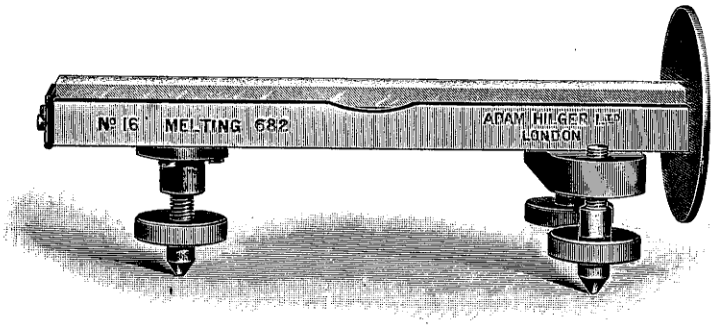


FIG. 3.

The mounting of this is illustrated in Fig. 3. Like the Echelon above, this can be used on any ordinary Spectroscope, or preferably on the modified form of Spectrometer described below :—

Length of plate, 130 mm.
Width of plate, 15 mm.
Thickness of plate, $4\frac{1}{2}$ mm.

The resolving power for W.L. 5461 is more than 200,000 (equal to that of a diffraction grating of 20,000 lines per inch, with 10 inches of ruling, in the first order spectrum).

In the plate shown, direct vision is secured by a modification in the form of prism cemented on the end of the plate from that originally described by Lummer and Gehrcke.

The thickness of the plate and optical properties of the glass of which it is made are engraved on the mount.

(For the theory of the Lummer-Gehrcke parallel plate, *see* Annalen der Physik, Band 10, 1903, p. 457.)

This was made from a plate of hard crown glass from the works of Messrs. Chance Bros. & Co., which was large enough to enable 12 strips to be cut from it. The method of testing the plate was essentially the same as for the large Echelon (*see* below), about the same order of accuracy being required.

(*c*) *Fabry & Perot Etalon* (Fig. 4).

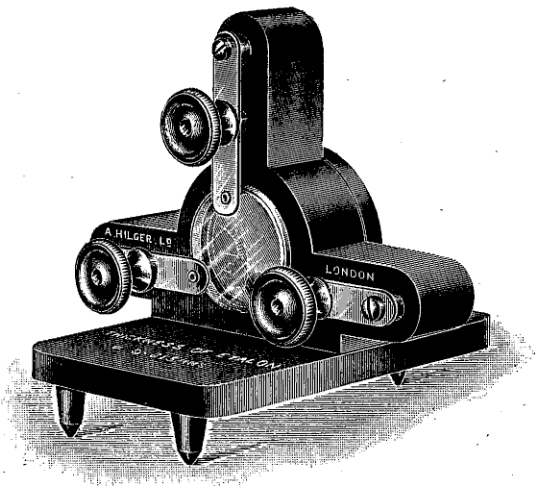


FIG. 4.

Zeeman; Konink. Akad. Wetensch. Amsterdam, Proc., 351 (1907), 440 (1908).

Zeeman; Archives Néerlandaises, 13, Nos. 3 and 4, page 260 (1908).

See also references under Fabry & Perot Interferometer above.

The Etalon, shown in (Fig. 4), is constructed with a distance piece consisting of a hollow cylinder of fused silica between the plates (as described by H. C. Rentschler, *Astrophysical Journal*, December, 1908).

The co-efficient expansion of fused silica being less than that of any other known material (0·000,000,59 per 1° C.—about one-seventeenth part of that of platinum) alterations due to changes of temperature can be entirely avoided.

The plates are silvered by cathodic deposition, as described under the " Fabry & Perot Interferometer " above.

The appearance seen in the eyepiece of the Spectroscope when the Etalon is in position and correctly adjusted is as follows :—

(1) The lines of the spectrum are visible in the same positions as they would occupy were the Etalon removed, but of course they are less bright.

(2) Each spectrum line is a diametrical strip of the ring system which would be produced by the Etalon if the field of view were filled with light of the W.L. of the line in question. The diameter of the ring system for each line can be measured by a micrometer eyepiece.

The distance between the plates is about 10 mm., this distance producing a convenient ring system for measurement.

The thickness of the Etalon correct to 0·005 mm. is, in each case, engraved on the mount.

For a method of working to obtain standard wave-lengths by comparison with lines of accurately known wave-lengths, *see* papers by Lord Rayleigh, Phil. Mag., Vol. 11, May 1906, p. 685; and Vol. 15, April 1908, p. 548.

Hilger Wave-length Spectrometer.

The modified form of Hilger Wavelength Spectrometer, designed for use with the above three accessories is shown in Fig. 5.

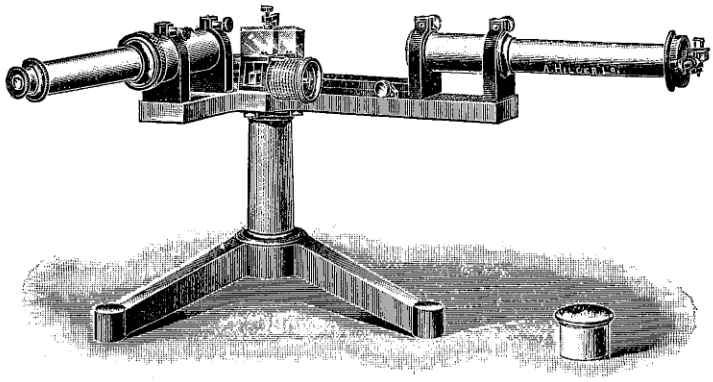


Fig. 5.

This now well-known form of spectrometer makes use of a prism first described by Pellin & Broca (Fig. 6). The prism may be considered as built up of two 30° prisms and one right-angled prism from the hypotenuse of which the light is internally reflected.

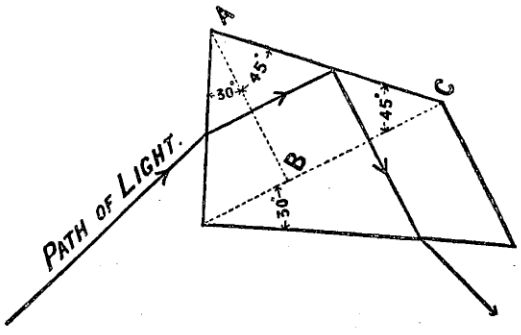


Fig. 6.

Such a prism is naturally suited for use on a fixed arm spectrometer, the only portion of the spectrometer which it is necessary to have movable being the table on which the prism stands.

This table is rotated by means of a fine steel screw, the point of which pushes against a projecting arm on the prism table. To the screw is fixed a drum (Fig. 7) on which the wave-lengths of the line under observation are read off direct as indicated by the index which runs in a helical slot.

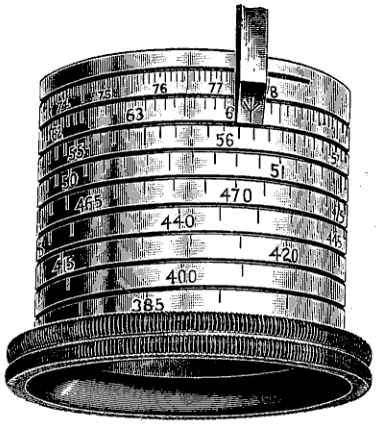


FIG. 7.

The object glasses are apochromatic triples, made from the calculations and measurements of refractive indices of J. W. Gifford, Esq. Clear aperture, 32 mm., equivalent focal length, 280 mm. The focussing of the telescope is by a helical motion, instead of the ordinary rack and pinion.

The accessories described above stand on a brass plate capable of slight rotation by means of a milled head screw; the arm carrying the collimator being specially extended to make room for this brass plate. This arrangement, together with a readily accessible levelling screw, provides the necessary adjustment for each of the accessories, each of which is in addition provided with screws for the levelling adjustment, for operation if it be desired to use them on the table of an ordinary spectrometer.

The slit of the collimator is made specially long for use with the Etalon. A second slit is attached to the main slit, the jaws of the two slits being at right angles to one another. This second slit can be rotated into or out of position as desired, and is necessary for use with the Echelon. The Echelon is mounted with the edges horizontal in the manner employed by Professor Michelson.

Michelson Echelon Diffraction Grating of 56 *plates*, the plates being 10 mm. thick. Resolving power for W.L. 5,461 = about 560,000.

Michelson ; Astrophysical Journal, 8, 37 (1895).
Blythswood and Marchant ; Phil. Mag., 49, 384 (1900).
Zeeman ; Archives Néerlandaises, 6, 320 (1901).
Laue ; Phys. Zeitschrift, 6, 283 (1905).
Galitzin ; Acad. Sci. St. Petersbourg, Bull., 5, 23, 67 (1905).
Janicki ; Ann. d. Physik, 19, 1, 36 (1906).
Hull ; Roy. Soc. Proc., A. 78, 80 (1906).
Hull ; Astrophys. Jour., 25, 1 (1907).
Galitzin : Acad. Sci. St. Petersbourg, Bull., 6, 159 (1907).
Galitzin ; Acad. Sci. St. Petersbourg, Bull., 8, 213 (1907).
Gmelin ; Phys. Zeitschr., 9, 212.
Stansfield ; Nature, 77, 98, and 222 ; 78, 8 (1908).
Nagaoka and Asmano ; Tôkyô Sûgaku-Buturigakkwai Kizi, 2nd Ser., Vol. 4, p. 21, 1908 ; and 2, 5, 2 (1909).

The glass of this Echelon was cut from a plate of light flint glass, 12 ins. (30 c.m.) diameter, from the works of Messrs. Schott.

The parallelism of the glass is such that the equivalent thickness (μ t) does not vary by $0 \cdot 05\lambda$ (one-millionth of an inch, 0·000025 mm.).

During the working, the plate was tested by observing the interference of light from a mercury vapour lamp reflected normally from the upper and lower surfaces. An auto-collimating method was used, a lens of 10 ins. (25 cm.) aperture enabling nearly all the surface to be seen at a glance. The convenience of this method was increased by arranging a system of mirrors so that, while testing, the surface of the glass could be marked out during actual observation.

It is found, however, that in the final stages examination of the plate by the older method from point to point gives more accurate results (*see* Michelson's original paper on the Echelon diffraction grating). Still greater accuracy is obtained by partially silvering the surfaces and observing the Fabry and Perot ring system obtained with transmitted light.

Hilger Wave-length Spectrometer, Constant Deviation Type, with Diffraction Grating. (Resolves the four doublets of the E group in the solar spectrum, and measures wave-lengths to 0·1 $\mu\mu$.)

This spectrometer (Fig. 8) has been designed to give a greater accuracy of wave-length measurements than is attainable with the prism form described above.

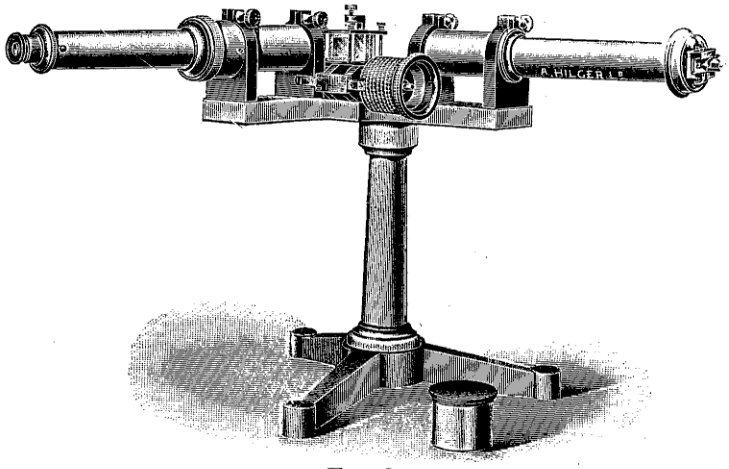


FIG. 8.

The diffraction grating, which is a carefully selected film replica by Thorp, of Manchester, of one of Rowland's metal diffraction gratings, is mounted on a right-angle prism from the hypotenuse of which the light is totally reflected. By this means one can pass through the spectrum by rotation of the table on which the prism stands. This table is rotated by means of a fine steel screw in the same manner as in the prism instrument above. To the screw is fixed a helical drum (*see* Fig. 9) on which the wave-lengths of the line under observation are read off direct as indicated by the index which runs in the

helical slot. This index is so arranged (*see* Fig. 9) that the readings can be taken as one sits at the eyepiece.

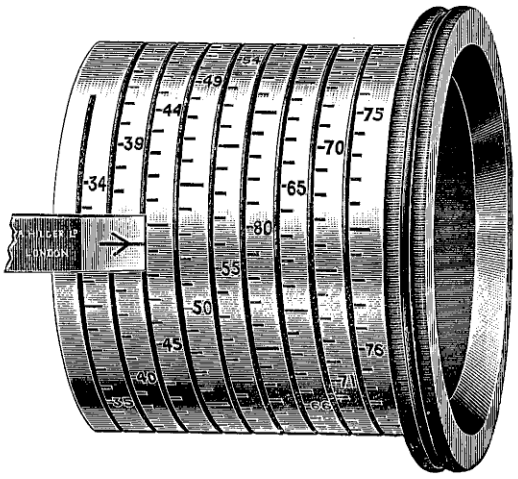


Fig. 9.

The telescope and collimator are both rigidly fixed to the cast-iron base, and the whole is screwed to a strong cast-iron tripod.

The object glasses are apochromatic triples, as in the prism instrument, and there is helical focussing motion to the telescope in place of the usual rack and pinion.

Quartz Spectrograph.

This spectrograph (Fig. 10) has lenses of 24 ins. (610 mm.) focus, the instrument giving a spectrum from W.L. 8,000 to W.L. 2,100 of about 200 mm. long. Size of plate, 10 × 4 ins.

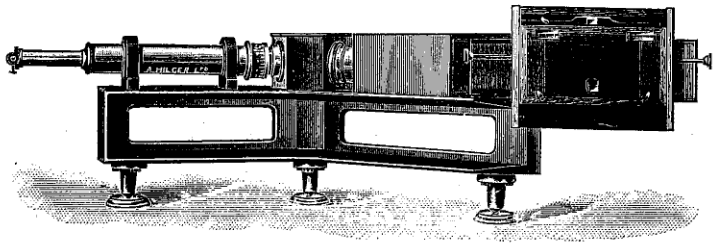


Fig. 10.

This spectrograph, with quartz prisms and lenses, has been very carefully designed with the following objects in view :—

(1) To be in permanent adjustment.

(2) To give the spectrum from W.L. 2,100 to W.L. 8,000 on one plate.

(3) To give good definition over the whole spectrum on the photographic plate.

The flat field in the above spectrograph is obtained by using a combination of quartz lenses for the camera, instead of the usual single lens.

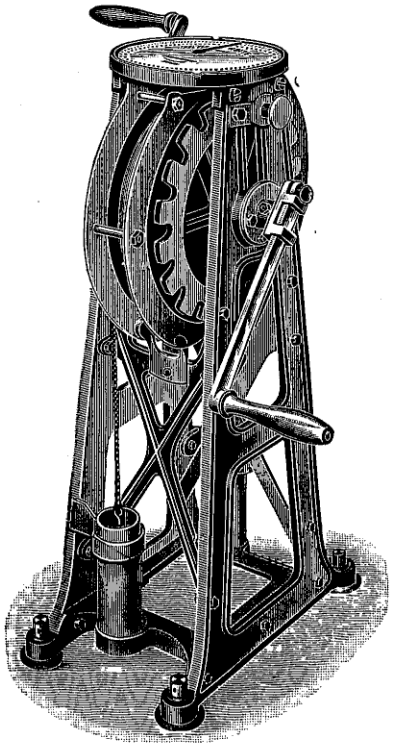
Specimen photographs taken on this instrument are exhibited.

Messrs. Kelvin and James White, Ltd., *Glasgow, Makers of Navigational and Electrical Instruments.*

I.—Navigational Instruments.

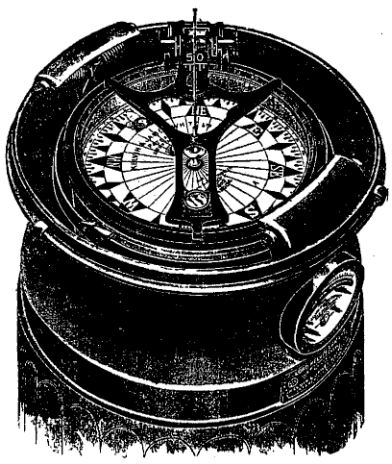
(1) *Lord Kelvin's Sounding Machine* is designed to enable flying soundings to be taken, without stopping or moderating the speed of the vessel. The line used is a 7-strand crucible steel galvanised wire, 300 fathoms in length. A dial is fixed to the side of the machine to indicate the length of line reeled out at each cast. The depth of water is found by two alternative methods. First, by means of a long glass tube closed at the top, the inside of which is coloured by a chemical preparation. This tube is protected by a brass sheath, which is lashed to the sinker. As the tube sinks, the sea water is forced up inside the tube against the column of air which it contains. The distance which the water is forced up inside the tube depends on the depth reached. When the tube is brought to the surface, a special scale, reading directly in fathoms, is used to measure the depth as shown by the marking on the tube. In the second method the pressure of the sea water acts upon a spring and piston arrangement termed a "Depth Recorder," which is fitted with a travelling marker, indicating the depth in fathoms.

(2) *Lord Kelvin's Sounding Machine, Admiralty Pattern, Mark IV.* (Fig. 1), as supplied to battleships and cruisers of the British Navy. The line used is a 7-strand crucible steel galvanised wire, 300 fathoms in length. It is designed principally for taking flying soundings from the fore-bridge, the line being carried over a spar rigged out from either side of the vessel. The depth of water may be obtained by either of the two methods described above, if desired; but a special feature of the Mark IV. machine, is that it indicates with a high degree of accuracy upon a large horizontal dial on top of the machine, the amount of line reeled out at each cast. Tables are prepared, for the different speeds of the vessel, to show, at the moment the lead touches the bottom, the depth of water according to length of wire out. To ensure that the line runs out uniformly, the drum is fitted with a groove upon which is hung a series of weights as in a rope-brake. This also prevents the wire over-running the sinker.



Sounding Machine. FIG. 1.

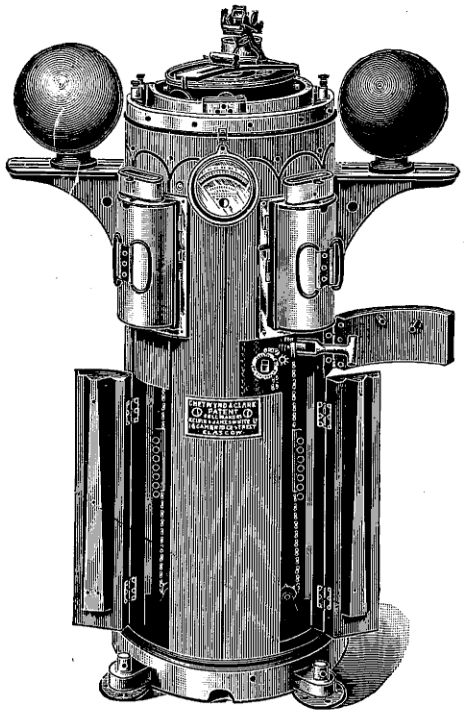
(3) *Lord Kelvin's Standard Compass* (Fig. 2).—In addition to the original light short needles, and extreme lightness of the card generally, the latest form of the compass comprises many improvements; among others, lighting entirely from underneath, azimuth mirror working freely upon, but secure against dislodgment from, the compass bowl, improved form of spring suspension with idle ring and gimbal ring, and rifle sights on helmet for taking quick approximate bearings.



Standard Compass. FIG. 2.

(4) *Chetwynd and Clark's Binnacle, Compass Bowl, Azimuth, and Steering Prism :*

Binnacle (Fig. 3).—The binnacle is built of wood tapering slightly from the base to the flange, fitted with four snugs to fasten down to the deck plates. Instead of the magnets being placed in fixed holes, they are carried horizontally on chains, running vertically over sprocket wheels carried by spindles, which are mounted within the binnacle, and driven by worm gearing, thus enabling the magnets to be placed at the exact positions required, and avoiding disturbance of the compass card caused by moving magnets from one hole to another. The worm pinions are actuated by means of a box spanner, so that the adjustment can be effected whilst the adjuster is watching the bearing.



Binnacle. FIG. 3.

The method of worm gearing makes any unintentional movement of the magnets impossible; but, as an additional safety arrangement, pawl wheels are fitted to the worm pinions, the pawls engaging in notches round the circumference of the wheels. On closing the "safety door" of the binnacle, two stops engage over the pawls and prevent them disengaging. Should the pawls not be engaged, the door will not close.

Liquid Compass (Fig. 4).—The compass bowl is made in two parts. The upper is a brass cylinder closed at the top and bottom by glass plates, forming a chamber containing the liquid (alcohol and water) in which the compass card is immersed. The lower part of the bowl is formed by a hemispherical glass vessel secured to the base of the upper part, the space between forming a hemispherical chamber, which is partially filled with castor oil for damping purposes. The upper (or verge) glass of the bowl is fitted so that its surface is slightly above the verge ring, to prevent spray and rain accumulating on the glass.

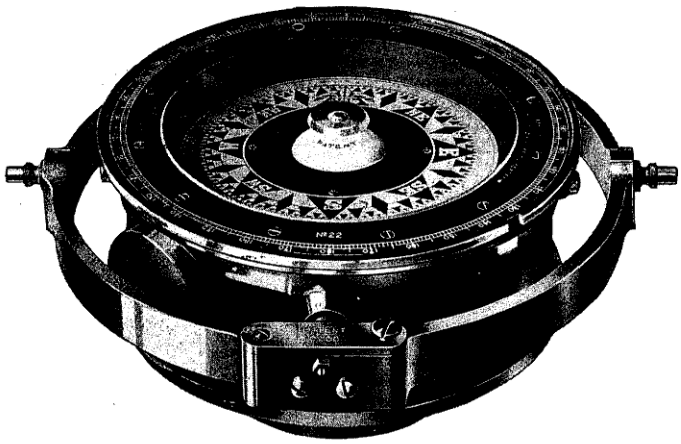


FIG. 4.

Two expansion chambers are fitted to obviate damage due to change of volume of the contained liquid caused by changes of temperature.

The "lubber's" point consists of a fine horizontal pointer in close proximity to the edge of the card.

The card pivot is supported by a brass cross-bar, secured to the lower edge of the brass portion of the bowl, so as not to be in contact with the glass bottom.

The card, fitted with a float, is attached to four needles (round bar magnets), each 8 cms. in length, and of total magnetic moment of 1,000 cgs. The diameter of the card is approximately three-quarters the internal diameter of the bowl.

Between all parts of the card and bowl there is a "cushion" of liquid of at least one inch in thickness. This "cushion" prevents the effects of shock, vibration, &c., being communicated to the compass card, and also obviates any disturbance of the card due to the annulus of liquid which, during altering course, is dragged round by the inner surface of the bowl.

The upper edge of the card is graduated in the usual manner; but there are two rows of graduation figures, the inner set painted upright, and coloured red; the outer set set, coloured black, are inverted, so that, when read in a prism, they are reflected to view upright.

Improved Azimuth Mirror for Standard Compass (Fig. 5).—The frame of the instrument is constructed so as to interrupt the view of the compass card as little as possible, and is supported on the verge ring only, there being no contact with the verge glass, and the frame clips over the edge of the verge ring, in such a way that it cannot be accidentally displaced, but is free to move in azimuth.

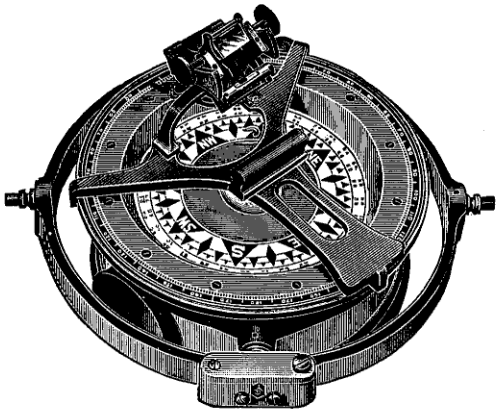


FIG. 5.

The spirit-level is fitted in such a position that the bubble is directly under the eye of the observer whilst taking an observation for bearing.

Shadow Pin.—The shadow pin is carried on a skeleton frame which clips on to the compass bowl, in a manner similar to the azimuth instrument, which it replaces. It is also fitted with a level.

Magnifying Prism for Steering Compass (Fig. 6.)—The prism, mounted in a glass-fronted case, is fitted to the compass glass by a watertight joint, so that no damp, spray, &c., can lodge between the prism and the verge glass. It is adjustable by a quadrant, so as to suit the heights of different steersmen.

The magnification gives the effect of steering with a card 24 inches in diameter, and thus small deviations from the course are readily detected. An advantage of the prism is that the "lubber's" point and card are reflected to view in a normal direction.

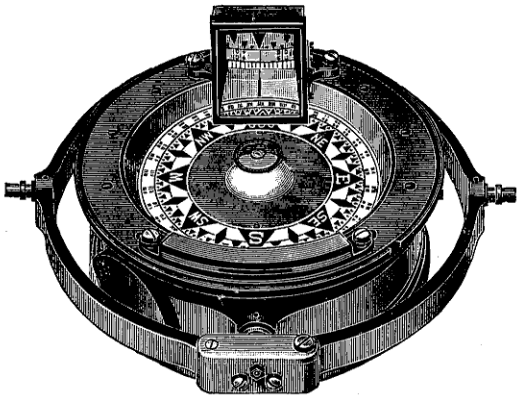


FIG. 6.

(5) *Submarine Steering Compass*, designed for surface navigation, is fitted on the outside of the hull. The binnacle and compass are of diminutive size; and the compass is fitted with an azimuth circle, and also a magnifying prism which shows a large image of the card at the "lubber's" line for steering, or at any point over which a bearing is being taken. The binnacle and compass can be readily shipped or unshipped after and before submersion.

(6) *Lord Kelvin's Deflector* provides a means of adjusting compasses when bearings of any kind are not available. It is designed upon the principle that there is no error in the compass when the directive force of the needles is the same with the ship's head on any four points, each two of which are opposite to the other two. By means of the deflector, the directive force is measured with the ship's head on any four points mutually at right angles. The directive force on these points is read successively upon the scale of the instrument and duly noted. The usual correctors are then applied so as to render the directive force equal on all points.

(7) *Lord Kelvin's Vertical Force Instrument* (Fig. 7), for comparing the vertical force on board ship with the vertical force on shore; to enable the vertical magnets in the binnacle to be adjusted to correct the heeling error.

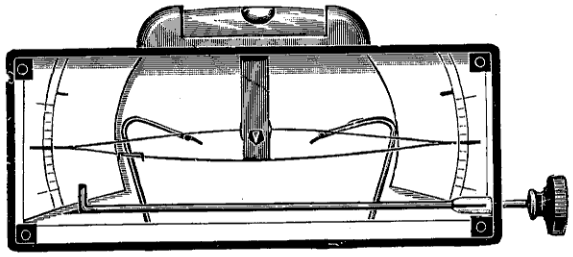


Fig. 7.

The balanced magnet consists of two slightly curved steel slips, having their ends rivetted together, with their convex sides outwards. The lower of these slips is graduated on its under side, and carries a sliding weight which is free to move from end to end. The other steel slip is attached to a knife-edged axle, which is supported on agate V-bearings.

The containing case has a glass front and a brass roof carrying a spirit level on its upper side. The bottom has a long glass window to allow the slider and its scale-reading to be seen when the instrument is held upside down, as is done for adjustment or verification.

Two blocks of high conductivity copper, shaped to be as near as possible to the ends of the magnet, are fixed at the ends of the case inside, so as to damp the vibrations of the needle; they carry two circular arcs, having divisions to show the level position of the magnet, and small deviations from it.

The brass back of the case carries two lifters, worked by two arms outside, so as to lift the magnet off its bearings when out of use, or when an adjustment of the sliding weight for the place of the ship is required. This adjustment is made by aid of a rake mounted in the bottom of the case, and the case does not need to be opened.

II.—Electrical Instruments.

(1) "*Kelvin*" *Moving Coil Instruments, S.R. Type.*—The instruments known as the S.R. (siphon recorder) type, work on the principle of Lord Kelvin's siphon recorder. They are made in *round*, *edgewise*, and *thistle* (Fig. 8) patterns of various sizes.

FIG. 8.

The main advantage of ammeters of this class is that heavy cable connections do not require to be carried to the instrument. The current to be measured is passed through a shunt, and a pair of flexible wires connect the potential terminals of the shunt to the instrument terminals.

The moving parts of the voltmeters are constructed on the same principle as the ammeters. The resistance wire has a negligible temperature coefficient and the instruments possess a high degree of accuracy.

(2) "*Kelvin*" *Cell Tester*, for testing the voltage of each cell in a battery. It is provided with a flexible and spike for connecting to the accumulator.

(3) "*Kelvin*" *Portable Paralleling Voltmeter.*—To enable paralleling of two or more machines to be accomplished with the least possible chance of producing alteration in the voltage. It is so constructed that when the bus bar voltage is equal to the dynamo voltage, the pointer of the instrument comes to zero. In practice it is usual to close one switch of the dynamo circuit, and to place the instrument across the terminals of the remaining switch, which is closed when the instrument indicates zero.

(4) "*Kelvin*" *Ampere Gauges* are suitable for either direct or alternating circuits. The solenoid carries the whole current and produces a very intense and uniform field; and a dash pot is provided to render the instrument dead-beat.

(5) "*Kelvin*" *S.R. Recorders* are constructed on the moving coil principle. A broad chart is employed which enables accurate readings to be taken. A 25 hour recording clock is fitted, and is so designed that the removal of the drum to put on a new chart, winds it up. It is thus impossible to forget to wind the clock. A release gear prevents over winding.

(6) "*Kelvin*" *Continuous Chart Recorder.*—A S.R. recorder is also shown fitted with a clock to give a continuous record on a chart for one week.

(7) *Feeder Logs* (Fig. 9).—A combination of a recording voltmeter, and a recording ammeter. It can be readily adapted for many tests, such as recording the load on the feeder, and also the voltage at the end of the feeder on the same chart.

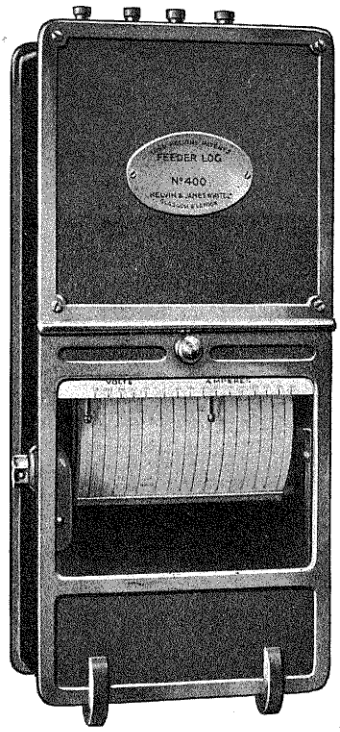


FIG. 9.

(8) "*Kelvin*" *Astatic Wattmeters, Horizontal Scale Pattern*, suitable for use on either continuous or alternating current circuits, are of the astatic electro-dynamometer type. A large non-inductive resistance is fitted in series with the moving coils, damping arrangements are provided to give any degree of dead-beatness.

By means of plugs, the coils can be connected in series, or in parallel, according to the range required.

These instruments are sensitive, and can be used on very low power factors.

(9) "*Kelvin*" *Insulation Testing Set* consists of a very sensitive galvanometer, fitted with controlling magnet, set of shunts, set of compensating resistances, with two-way switch. It is made in two forms, moving magnet type for ordinary testing, and moving coil type for use where stray fields abound. The readings of this instrument are unaffected by capacity effects in cable testing.

(10) "*Kelvin*" *Multicellular Voltmeters* (Fig. 10) are shown in two forms, the vertical scale pattern, and the horizontal scale, or portable pattern. They are operated by electrostatic forces, and are, therefore, unaffected by external magnetic fields.

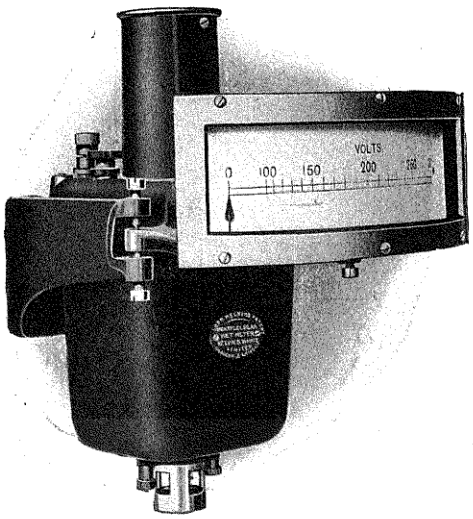


FIG. 10.

They read correctly on continuous or alternating current circuits, and are independent of wave form and frequency, and require practically no energy to operate them.

The range can be extended by means of a multiplier.

(11) "*Kelvin*" *High Tension Electrostatic Voltmeters* (Fig. 11).—The vertical electrostatic voltmeters essentially consist of two parallel vertical metal plates of peculiar shape. Into the space between them a movable vane supported on knife edges is attracted. This vane is fitted with a pointer at one end, and a support is provided at the other end, on which different weights are placed. The scale value of the instrument depends upon the weight used.

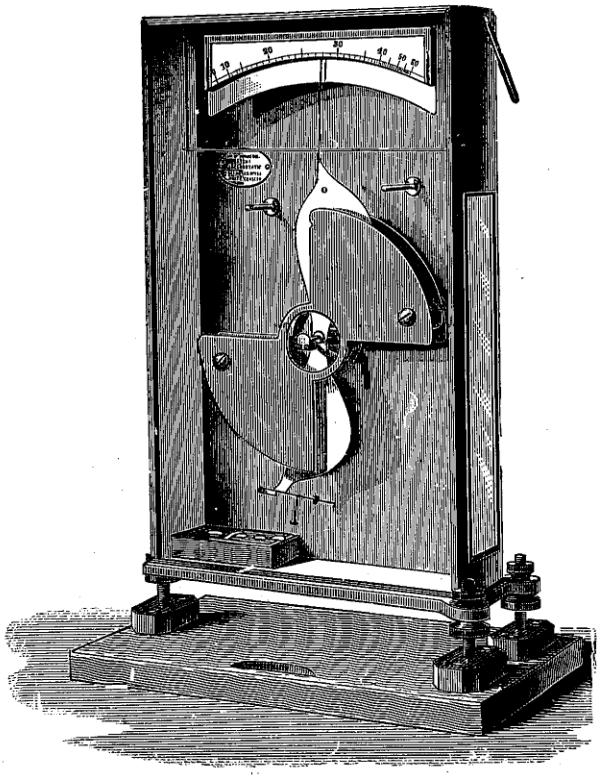


FIG. 11

(12) *Electrostatic Volt Balances* (Fig. 12) consist of an insulated metal plate, which attracts another metal plate carrying an arm, which travels over a graduated scale.

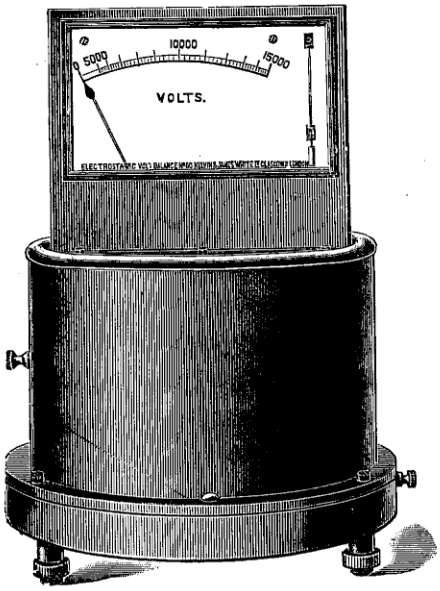


FIG. 12.

Both types of instruments are direct reading. They do not require transformers.

The small volt balance is shown fitted in a portable case.

(13) *Deka-Ampere Balance* (Fig. 13).—"Kelvin" balances are generally recognised as standards for current measurement. The instruments depend on the mutual forces between movable and fixed portions of an electric circuit. In most instances the movable and fixed coils consist of circular rings. The current is in opposite directions through the two movable rings, in order to annul disturbances due to local magnetic forces.

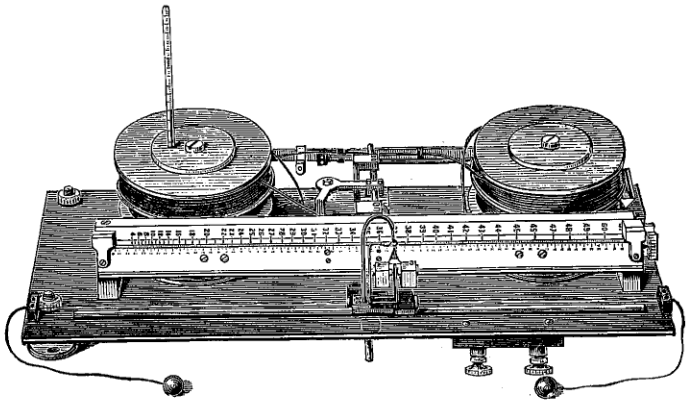


FIG. 13.

The balance arm is supported by two trunnions, and is hung by an elastic ligament of fine wire, through which the current passes into, and out of the movable ring, or rings.

The balancing is performed by means of a weight which slides on a graduated horizontal scale, and a receptacle is fixed at the right end of the balance to receive a counterpoise weight. For adjusting the zero, a small metal flag is provided.

To measure a current, the weight is slipped along the scale until the balance rests in equilibrium. The strength of the current is read off on the fixed scale for approximate measurements, and on the finely divided scale for greater accuracy.

These instruments are suitable for either direct, or alternating currents, at ordinary frequencies.

They are also made as watt balances, and a special instrument is designed, called the composite balance, which can be used as an ampere balance, a watt balance, or a volt balance.

For extremely accurate work, an instrument is made suitable for measuring one definite current only, such as 10 amperes; no other current can be measured on this instrument. It is called the Board of Trade Standard Pattern. The principle, however, is the same as the ordinary "Kelvin" balance.

(14) "*Kelvin*" *Portable Combined Voltmeter and Ammeter* consists of a sensitive milli-voltmeter of the moving coil type, fitted in a polished wood box.

The range of the instrument on the volt-meter side is from 0·001 to 600 volts, and on the ampere side from 0·01 to 750 amperes or more. The scale is graduated into 150 divisions, and a knife edge pointer with parallax mirror is provided. There are no live parts exposed on the instruments, so that it is impossible to short circuit any of the connections.

The terminals of the current shunts, are so designed as to facilitate connecting up for temporary use. Almost any size of cable can be securely clamped in the terminals.

The instrument can be used for conductivity or low resistance measurements, and also for insulation tests, as well as for the ordinary ammeter and voltmeter tests.

The Morgan Crucible Company, Ltd., *Battersea, London, S.W.*

Morganite Brushes for Dynamos and Motors.

These differ from other brushes in their composition and construction. The material is the purest plumbago, and in the process of manufacture is *not* subjected to a high temperature. The brush is made in layers in such a way that the conductivity in the direction of the external circuit is very much higher than that of the ordinary carbon brush, while the cross resistance may be seven or eight times greater than the longitudinal resistance.

For special cases of difficult commutation the brushes can be built up to meet requirements with a material of high resistance on one side and low resistance on the other, thus assisting the reversal of the current in the short-circuited coil and facilitating the sparkless collection of the current. These brushes are described as link-three type.

As the material is not subjected to a high temperature in course of manufacture it is possible to embed metal tops and flexibles in the brushes in the process of manufacture, and thus provide an excellent electrical connection.

The flexible, after being drawn through the filleted holes in the metal top, is spread out and pressed into intimate contact with the metal top through the medium of a thin sheet of copper. The electrical connection is made perfect by the great pressure employed in the manufacture of the brush. The absence of solder ensures immunity from the trouble which arises when the solder runs out of an overheated brush.

Careful tests have been made to ascertain the voltage drop at the junction of the flexible and metal top, and the results show that the method adopted of connecting the flexible to the brush is superior to any other method.

Whenever possible it is preferred to fit metal tops to the brushes, so as to ensure that all layers are connected together and the current drawn uniformly from the whole surface of the brush.

The following table gives particulars of the principal types of Morganite brushes and their spheres of use :—

Type.	Normal current density. amps. per sq. cm.	Sphere of use.
Morganite :		
Link-one - -	9·5	Suitable for dynamos and motors of all voltages which are not working under specially adverse conditions.
Link-two - -	9·5	General properties similar to Link-one, but mechanically stronger.
Link-three - -	9·5	This type of brush is composed of strata of varying conductivity, and is suited for machines offering special commutating difficulties.
Hard-Morganite :		
Link-one/289 -	15·5	Harder and tougher than Link-one. Specially suited to machines of low voltage and slip rings.
Link-two/24 -	12·5	Harder and tougher than Link-two. Recommended for use on steel slip rings.
Copper-Morganite :		
Link-two/538 -	25	Very high conductivity and good lubricating qualities. This brush can replace copper gauze on D.C. machines and is suitable for slip rings where extra high current densities are employed.

Battersea Carbon Brushes.

These are made from the best materials, obtained from the maker's own mines. A special feature is the method by which flexible leads are fixed in brushes of this description.

The brush is drilled at any desired point to the depth of about $\frac{1}{2}$ in. The flexible after being splayed out at the end is inserted in the hole and held firmly in position by means of a pure metallic powder compressed by a new method.

The principal grades and their spheres of use are as follows :—

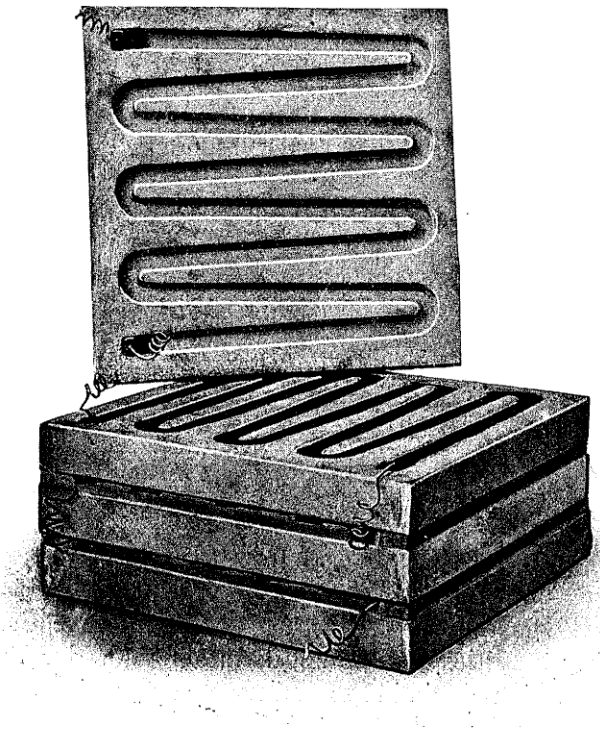
Type.	Normal current density. amps. per sq. cm.	Sphere of Use.
Battersea Carbon Brushes :		
Link-A. - -	6·5	Medium hard brush with good lubricating qualities ; for all standard voltages, but specially adapted to machines from 0·200 volts.
Link-B. - -	8	Graphitic brush, medium soft, having low co-efficient of friction. Suitable for low voltage generators and boosters, also for traction motors with mica grooved out.
Link-C. - -	5·5	Standard hard brush for machines of about 500 volts. Suitable for traction motors working under normal conditions.

Battersea Carbon Turbine Gland Rings.

These rings are mechanically very strong, have the highest lubricating qualities, and do not disintegrate under the severe conditions which obtain in the modern steam turbine. Extensive practical tests have been carried out with Battersea carbon rings for this work, and it is found that with a suitably-designed gland the rings may be arranged so that they just bear upon the shaft, and thus make a practically steam-tight joint without wearing themselves to any appreciable extent, and causing absolutely no wear of the shaft.

Battersea Type Lightning Arrester Resistances and Over-pressure Discharge Apparatus.

These replace liquid and carbon rod resistances, and consist of slabs of highly insulating fireproof material, in the top surfaces of which are grooves as shown in the accompanying illustration of a standard slab measuring 30 cms. × 30 cms. × 4 cms.



These grooves are filled with a special grade of carbon-resistance powder, and are so spaced that the greatest thickness of insulation is provided where the greatest difference of potential occurs. The terminals consist of carbon blocks with copper flexibles embedded in them. The resistance can be altered by varying the depth and the quality of the carbon powder.

Following are the results of two recent tests :—

With 6,000 volts across one standard slab (powder $\frac{1}{2}$ in. in depth) for a period of 7 minutes, the current rose to a maximum of 1·9 amps., falling gradually to 1·35 amps.

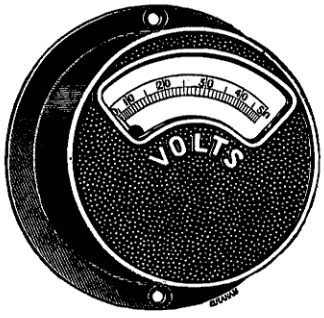
With 10,000 volts on the same standard slab for 1 minute, the maximum current was 2·4 amps., reducing down to 1·8.

Resistances of similar description are made for earthing the neutral point on high-tension systems. These are capable of absorbing a very large amount of power when a fault occurs.

Nalder Bros., and Thompson, Ltd., 34, *Queen Street, London, E.C., and Kingsland Green, Dalston, London, N.E.*

Electrical Instruments.

"*Soft-Iron*" *Ammeters and Voltmeters for Continuous and Alternating Current* (Fig. 1).—These instruments are made in a large variety of styles and sizes. In *round cases*, equivalent to dials of a diameter of 3 ins., 5 ins., 6 ins., and 8 ins., also *sector patterns* with scale lengths of 5 ins., 7 ins., 9 ins., and 12 ins., with either plain or illuminated dials; and edgewise pattern with 5 in., 8 in., and 12 in. scales. The last size can be made with illuminated dial.



Dead-beat soft iron Instrument, 3 in. dial. FIG. 1.

The cases are of black enamelled iron, with nickel or copper finish, or, in 6 ins. and 9 ins. dials, with brass cases.

In all cases the scales are of white enamelled metal.

In the case of ammeters a practically even scale is obtained from $\frac{1}{10}$ of the full load current upwards, in voltmeters the scale is opened at the working point and reads from $\frac{1}{2}$ of the top scale reading.

The usual controlling force is "gravity," but the instruments are fitted with "spring control" for marine, locomotive or portable use.

The instruments work on the principle of the repulsion of two similarly magnetised pieces of soft iron, the one being fixed, and the other carrying the pointer being free to move.

The moving system is pivotted and carried in jewelled centres. The instruments are fitted with air damping to render them "Dead Beat," and a soft iron screen to protect them from errors due to "stray fields" or possible magnetisation of the iron case.

For alternating currents the movement is constructed of laminated iron. For continuous current work the iron is treated so as to be practically free from "Hysteresis error."

In *ammeters* the consumption of power is negligible, and there is no temperature error; in voltmeters the consumption of power is reduced to 6 watts, and the temperature error is very small.

Moving Coil Instruments.—These instruments are constructed on the d'Arsonval principle.

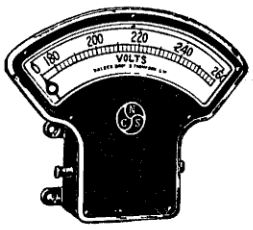
The magnets are treated so as to ensure permanence and a high figure of merit.

The instruments are dead beat, and free from stray field errors.

In the case of voltmeters the scales may be "set up"; thus, for example, an instrument for a circuit of 100 volts would read from 80 to 120 volts; more open scales are not recommended.

As in the "soft-iron" instruments, the cases are usually of black enamelled iron, with nickel or copper relief, and are made in a very large number of types and sizes.

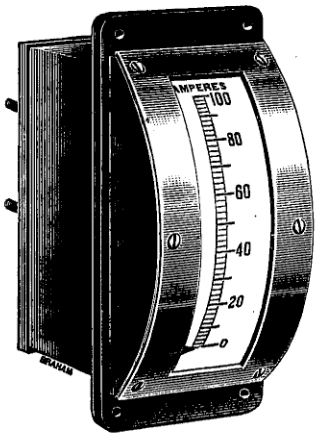
The *round type* in 5 in., 6 in., 8 in., and 11 in. dials.



Sector type Voltmeter. FIG. 2.

The *sector type* in 5 in., 7 in., 9 in., and 12 in. scales (Fig. 2), and a special type with scale lengths of 17 ins. and 21 ins.; these can be had with plain or illuminated dials (the 5 in. size is made in plain dial only).

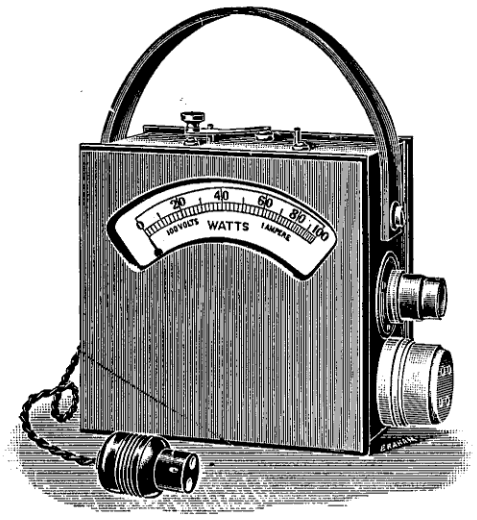
Edgewise type with scale lengths of 5 ins., 8 ins., and 12 ins.; the latter is made with an illuminated dial. (Fig. 3.)



Edgewise Instrument Flanged Type, 5 in. Scale. FIG. 3.

Wattmeters.—These are of two types, the *moving-coil type (Drysdale's Patent)*, and the dynamometer type. The former consists of a moving coil of the "Ayrton-Mather" pattern moving in a magnetic field. The moving coil is connected to the pressure circuit with non-inductive resistance in series, and the current or series windings being wound on soft-iron stampings produce the required field. This type of wattmeter gives accurate results, especially with alternating currents; it possesses the advantage of accuracy on circuits of low power factor. It is dead beat being fitted with air-damping. The instrument is mounted in round cases, 8 ins. in diameter, and finished copper or nickel.

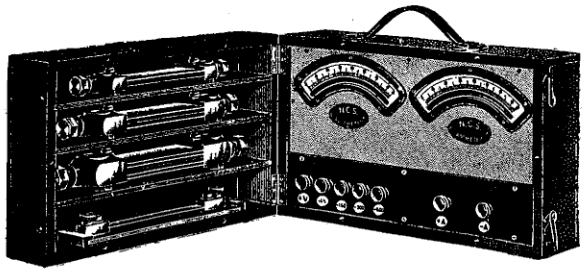
Dynamometer Type.—This type consists of a fixed and moving coil, the former carrying the current and the latter being connected in the pressure circuit; it is also fitted with air damping.



Lamp Testing Wattmeter. FIG. 4.

This type of instrument is equally suitable for continuous or alternating current. It is independent of periodicity or wave form errors, and lends itself very conveniently to be fitted in portable cases. An example of this is seen in the *Lamp Testing Wattmeter*, an instrument arranged with a view to the easy determination of the power consumed by incandescent lamps. A lamp-holder and fuse are fitted to the case, and the power consumed read directly from the scale in watts. These instruments are generally arranged for two voltages, and read up to about 100 watts at the higher voltage.

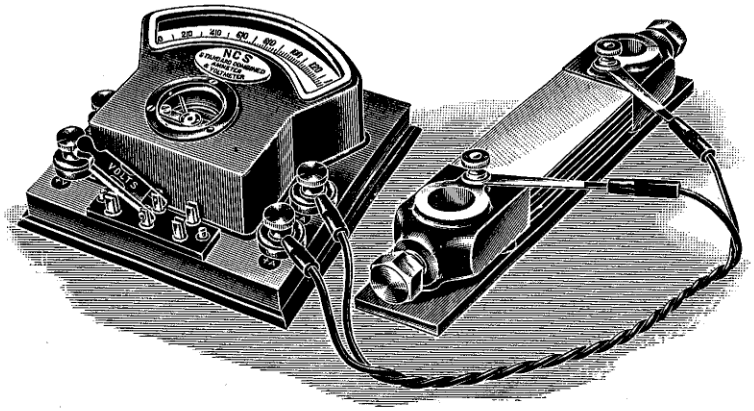
Portable Instruments (Fig. 5).—The soft iron and dynamometer types for continuous and alternating currents, and the moving coil type for continuous currents only, are arranged in leather-covered cases or in teak cases with removable fronts, and in the case of the moving coil types they are fitted with parallax mirrors.



Combined Ammeter and Voltmeter, moving coil Type. FIG. 5.

Combined ammeter and voltmeter set covering a wide range of voltage and current and mounted in a convenient leather-covered case ; this set consists of two movements mounted side by side.

Portable Standard Instruments (Fig. 6).—Portable standard moving coil testing set (*a*) " plain," (*b*) " shielded " type. These



Portable Standard Instrument, plain Type. FIG. 6.

are very accurate and convenient sets, they consist of a moving-coil instrument fitted with a change-over switch, with mirror scale and a set of shunts covering a wide range of currents and extra resistances for the volt ranges. The shielded type is for use in places where there are strong stray fields.

Portable Cell-tester (Figs. 7 and 8).—Of the moving-coil type, complete with spear. This is a convenient instrument for taking quickly the voltage of accumulators; it is arranged to read 3 volts on each side of a centre zero. It is light and dead-beat.

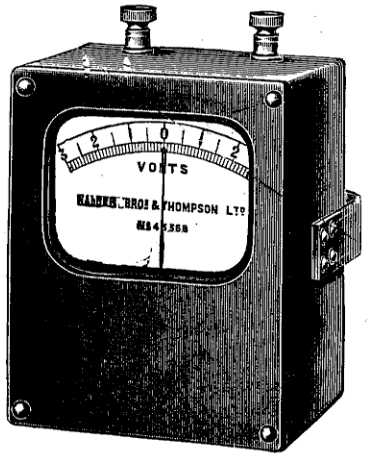
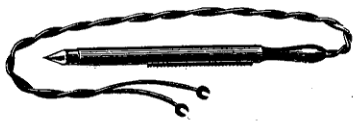
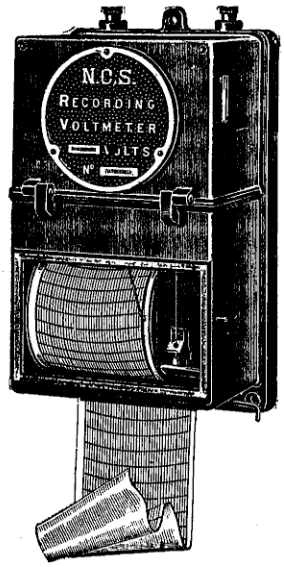


FIG. 7.



Portable Cell Tester. FIG. 8.

Recording Instruments (Fig. 9).—(*a*) Moving-coil type for continuous currents; (*b*) soft-iron type ammeters for alternating currents; and (*c*) dynamometer-type voltmeters for alternating currents. These instruments are arranged either to give a 24-hour record on a single sheet with a paper speed of about 13 mm. per hour; or in the continuous record pattern giving one month's record in one length with a paper speed of 25 mm. per hour. The cases are generally of enamelled cast iron, arranged with a view to convenience in replacing the chart; the pens are simple and reliable.

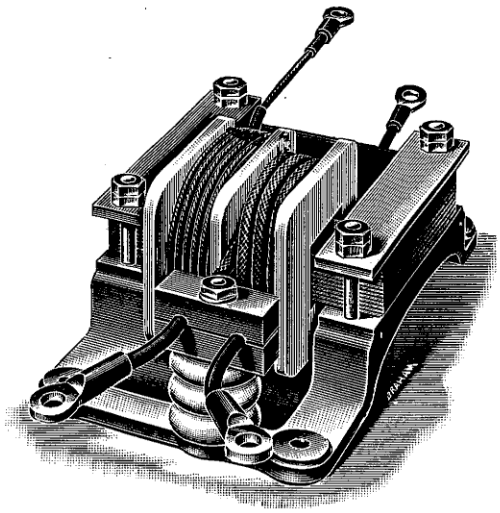


Moving Coil Recording Voltmeter. FIG. 9.

Recording voltmeter suitable for recording the voltage of a three-phase supply—

(*a*) Switchboard type.
(*b*) Portable type.

Instrument Transformers (Fig. 10). — Instrument transformers designed with a view to constancy of ratio and a minimum of phase displacement. Series transformers suitable for circuits of 10,000 volts pressure and currents up to 5,000 amperes. These are of two types, a large type suitable for use with wattmeters, induction ammeters, relays, &c., and a smaller type for use with soft iron or dynamometer ammeters alone. Pressure transformers both of the open and oil-cooled types suitable for voltmeters, wattmeters, &c., these are made for pressures up to 20,000 volts. The secondaries of the series transformers are generally wound for 5 amperes and the secondaries of the pressure transformers for 110 volts, normal.

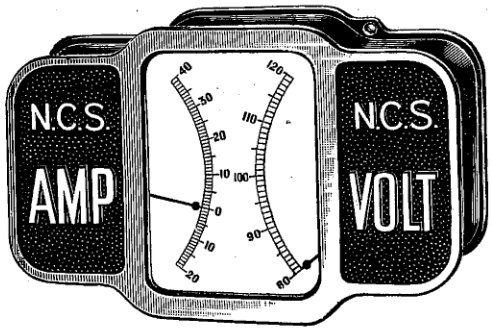


Series Transformer. FIG. 10.

Electrostatic Voltmeters (*Ayrton-Mather Type*).—Where it is desirable to measure high voltages directly electrostatic voltmeters must be used, they possess advantages such as absolute immunity from errors due to wave-form and periodicity, they have no temperature error and consume no power.

The movement is of aluminium and extremely light; electromagnetic damping is provided so that the instrument is dead-beat. The voltmeters have a large factor of safety, and will stand at least double the working pressure. They are protected by an internal spark-gap from sudden and excessive rises of pressure. The cases are generally of black enamelled iron with nickel or copper finish.

Motor Car Instrument (Fig. 11).—Double moving-coil instrument suitable for mounting on the "dashboard" of electric cars. It consists of an ammeter and voltmeter in one case; it is light, strong, and dead-beat.



Motor Car Instrument. FIG. 11.

"*Admiralty*" *Gauge* (Fig. 12).—Water-tight soft-iron ammeter or gauge designed for and used by the British Admiralty on battleships and for ship work generally. They are of very strong design, fitted with spring control and air-damped. The gunmetal-made case is in two parts, each being independently watertight, containing respectively the movement and the terminals.

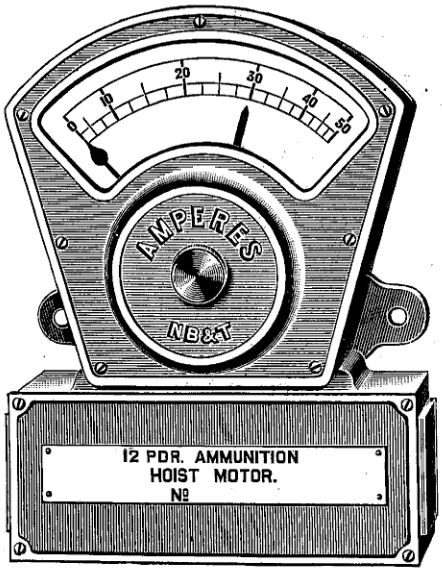


FIG. 12.

Automatic Accumulator Charging-switch (Figs. 13 and 14).—For the purpose of rendering the charging of a battery of accumulators a purely automatic process.

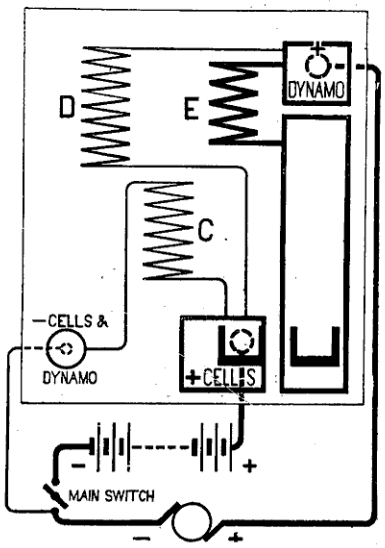


FIG. 13.

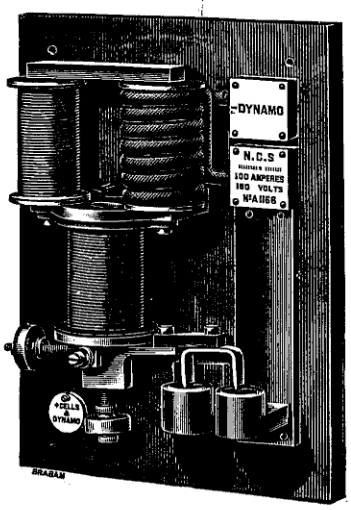


FIG. 14.

The " Crawley " type. Three coils are employed, a high-resistance coil C is connected across the cells and permanently magnetises a soft-iron bar attached at right angles to the " dipper " bar.

The coil D or differential coil is connected between the cells and the dynamo, and if the voltage of the latter exceeds the cell voltage, it repels the soft iron bar and closes the circuit; the series coil E holds this bar in position as long as any current is passing, but releases it when the current falls to zero; at the moment of closing the difference coil D is short-circuited. This switch is suitable for circuits up to 500 volts and 500 amperes. It is mounted on a slate or marble panel.

The *Midget* pattern (Figs. 15 and 16), a smaller switch, suitable for voltages up to 80 volts, and currents up to 50 amperes makes it suitable for low voltage installations for metal filament lamps. It differs from the Crawley type in that it possesses a permanent magnet to induce the magnetism in the soft iron bar attached to the dipper bar instead of a coil connected across the cells; in other respects the principle is the same. It is of the enclosed type, the mercury cups and terminals being fitted to the front of the case.

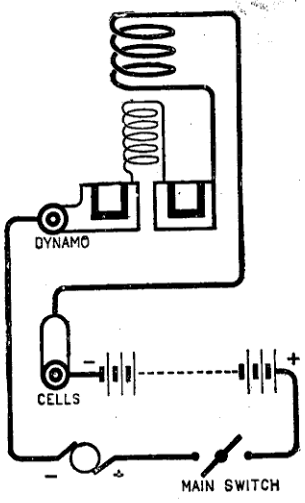


FIG. 15.

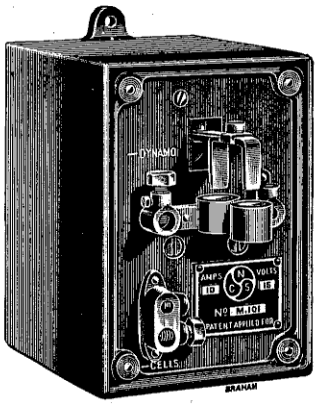
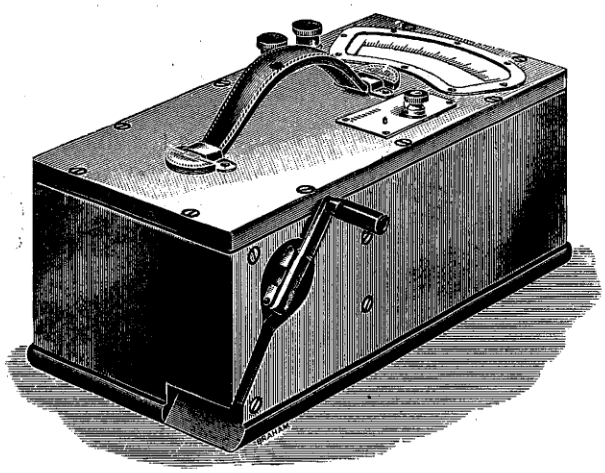


FIG. 16.

Insulation Testing-Set "the Ohmer" (Cox's Patent.)—Consists of an ohmmeter and generator mounted in one case. The ohmmeter is of the electrostatic type, and is thus independent of external fields, the moving system consists of a number of parallel vanes of mica coated with aluminium, giving great rigidity and lightness. These move into a series of fixed vanes or "inductors," on the principle of an electrostatic voltmeter. Electro-magnetic damping is provided, rendering the instrument dead-beat.



Ohmer Insulation Testing Set. FIG. 17.

The generator is compact and runs on roller bearings, and is fitted with a "free wheel clutch," so that it cannot be suddenly stopped by stopping the handle; carbon brushes are fitted which are easily replaceable, and the wear of the commutator is inappreciable. The generators are wound to give two standard pressures of either 500 or 1,000 volts. The ohmmeter is arranged to read to 20, 50, or 100 megohms; the 1,000 volt set is only made in the two last ranges. A special modification is a set giving both 500 and 1,000 volts, a vibrating reed attachment being fitted to indicate which voltage the generator is producing; the higher voltage is obtained by turning the handle at a higher speed; by this means the advantages of two generators are obtained with one. The set weighs about 6½ kilos complete. In connection with this an adjustable liquid resistance is made by which the range of the instrument may be increased to 500 or 1,000 megohms.

The "Telethermometer" (Figs. 18 and 19).—This is an apparatus for indicating accurately the temperature in a "cold store," or any place where access is difficult, such as tanks of liquid, &c. It consists essentially of two parts, an indicating

instrument, and a coil of wire mounted in a sealed metal tube, which is installed in the chamber or vessel, the temperature of which it is desired to ascertain.

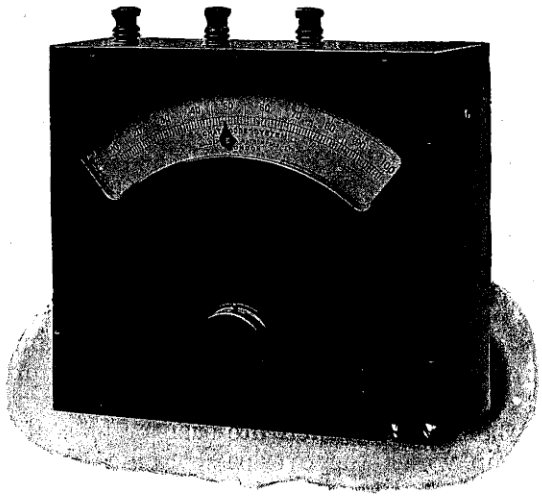


FIG. 18.

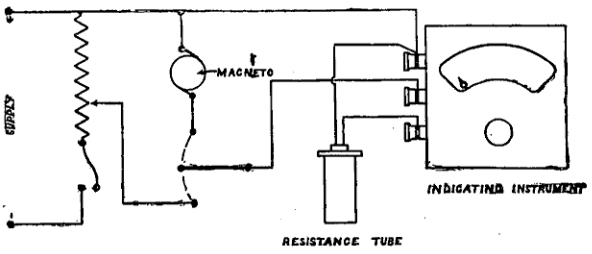


FIG. 19.

The apparatus is constructed on the principle of the "Wheatstone Bridge." Three resistances of the bridge are fixed in the case of the indicating instrument, and the fourth is in the sealed tube, and constitutes the thermometer. The indicator consists of a moving coil ohmmeter, with two coils mounted at right angles on one spindle; these two coils are connected across opposite corners of the "bridge," one coil constituting the "control coil," and one the "deflecting coil." The instrument is very quick in action and is dead-beat. The

four arms of the Bridge have about 800 ohms resistance; the three arms in the instrument case are wound with "eureka" or constantan having practically no temperature coefficient, and the fourth arm or thermometer coil of nickel or copper. The scale is marked in degrees Centigrade or Fahrenheit, and for cold storage work ranges from about 10° Fahr. (−15° C.) to say 100° Fahr. (40° C.); these ranges, however, can be considerably modified. A continuous current at about 30 volts is required to work the apparatus, this can be obtained either from a small hand generator, or from the mains by use of a resistance.

Circuit Breakers (Fig. 20).—Of various types; maximum, minimum, and reverse current, and various combinations maximum and reverse current and maximum and no volt.

The loose or free handle type is fitted with laminated contacts working at a low current density. The circuit cannot be closed if the short or overload is still on. The breaks are in all cases made on carbon blocks, which are easily replaceable. A time-limit device, in which the overload produces a release of the circuit breaker in a time inversely proportional to the amount of over-load, and a magnetic blow out can be provided.

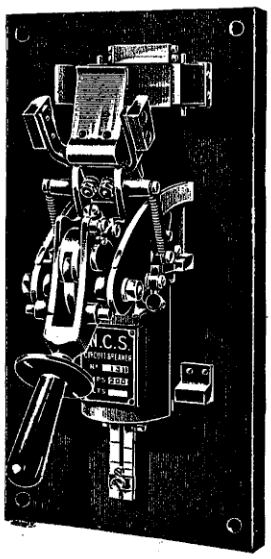


FIG. 20.

N.C.S. Limiter (Fig. 21).—The object of this instrument is to limit the current, that a consumer may take to a predetermined value ; if this value is exceeded the "Limiter" introduces a resistance into the lighting circuit, and causes the lamps to flicker. The instrument is built on the thermal principle, and the current is carried through a steel wire which expands by the heat and opens a contact which is held in position by a spring. The breaking of this contact introduces a resistance in the lighting circuit, thus dimming the lights.

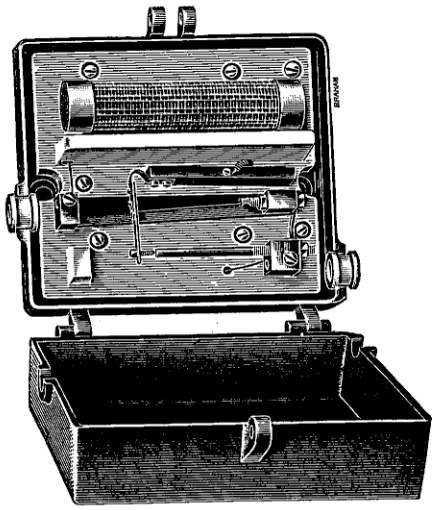


FIG. 21.

This reduction of the main current allows the steel wire to cool again, with the result that the circuit is restored to its original condition, and the operation is rapidly repeated. A condenser is put across the break, so that the sparking is reduced to a minimum, and the whole apparatus in enclosed in an iron case. These limiters are for use in connection with Messrs. Handcock and Dykes' scheme of charging for electrical energy (*see* Journal of the Institution of Electrical Engineers, 1908, p. 345 ; 1910, p. 67). The limiter is in use at Harrogate and other places.

Negretti and Zambra, *Holborn Viaduct, London.*

Standard Meteorological Instruments.

Standard "Fortin" Barometer, with tube ·6 in. internal diameter, with square frame and square cistern.

Standard Barometer, as originally designed by Newman; of strong construction, with an iron cistern in order to support the great weight of mercury, and yet on the "Fortin" principle, with tube ·6 in. internal diameter.

Standard Thermometer, of the highest accuracy.

Standard Thermometer, mounted with opal scale; oak frame.

Standard Thermometer, "Reference" type, as used by the Meteorological Office, for use in H.M. Navy, &c.

Standard Maximum Thermometer, Negretti and Zambra's original patent.

Standard Minimum Thermometer, to match the above.

Terrestrial Radiation Thermometer, with special sensitive bulb in the shape of a link.

Solar Radiation Thermometer, with blackened bulb in vacuum sheath, with a new type of gauge for indicating the state of the vacuum.

Negretti and Zambra's Mercurial Minimum Thermometer.

Standard Hygrometer, with wet and dry bulb thermometers.

A Model Set, one quarter natural size, showing a complete set of instruments in position, as used in a Climatological Station of Great Britain.

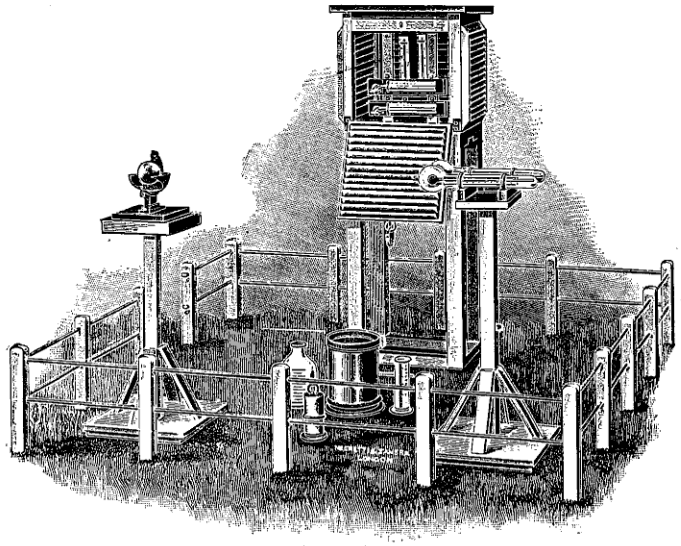


FIG. 1.

A Special Pocket Boiling Point Apparatus, consisting of the apparatus proper, four thermometers, and two small tanks containing a supply of spirit and water respectively. All fitted into a neat case measuring 7 in. × 4 in. × 4 in. (18 × 10 × 10 cm.). An important feature of this apparatus is that the construction is such that an observation may be taken whilst the instrument is remaining in its case.

Anemometer, "*Robinson*" *type*, with two dials.

Sunshine Recorder, the well-known "Campbell-Stokes" pattern, with adjustable arc making the instrument universal.

Sunshine Recorder, "*Jordan*," with twin cylinders.

Sunshine Recorder, "*Jordan*," simple type, with single cylinder.

Rain Gauge, with special arrangement to melt snow. The gauge has a graduated glass bottle to show roughly the quantity, and a rain gauge measure with a sub-division to ·001 in. or ·05 mm.

The "Hyetograph" New Recording Rain Gauge, constructed under Halliwell's patent.

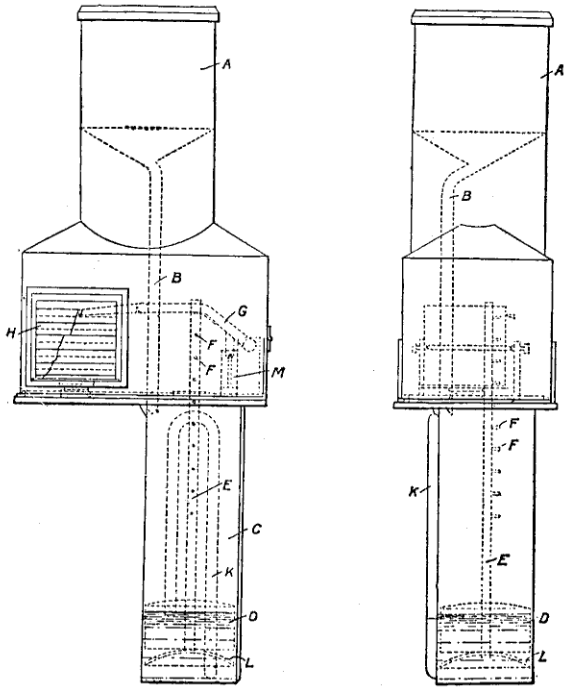


FIG. 2.

An automatic mechanical syphon, which can be trusted not to go out of order, involves an expense in construction which could not be incurred in a gauge of low price, and for this reason a mechanical device affecting the pen only is substituted. This device enables an open scale of $\frac{1}{2}$ in., or 15 mm., of rainfall to be recorded on a chart measuring about 3 ins., or 75 mm., in height.

As long as rain continues to fall the float D rises up to the maximum capacity of $4\frac{1}{4}$ ins., or 120 mm. On a spindle E, rising from the float D, are a number of projecting pins FF, which engage successively with a projection on the lever G, which lever is so pivoted that when the pen reaches the top of

the chart the lever disengages with the pin and falls by its own weight on to the next lower pin, which is so placed to allow the pen to fall to zero on the chart. The float, therefore, continually ascends during rainfall, but at each successive $\frac{1}{2}$ in. (or 15 mm.) of rain, the pen descends to zero, and recommences its upward movement.

As no automatic syphon is used, the rain collects in the float chamber until it is removed. The float cylinder is constructed of sufficient size to allow an accumulation of over 4 ins. (or 120 mm.) of rainfall. In order to remove the water, the Hyetograph is fitted with a specially designed syphon K, which is started by hand.

The instrument is built on a cast-iron plate protected from rust by a special galvanising process. On the plate and underneath is bolted the copper float chamber C, with its accompanying syphon tube K. The float D is of copper. The clockwork cylinder H is also bolted on to the upper part of the iron-base plate, and the whole of the working parts are protected by a galvanised iron cover A, hinged at the side, having an observation window.

The case allows of the circulation of a current of warm air to melt snow as it falls intc the funnel. A night-light or small spirit lamp will give the necessary heat.

Standard Recording Rain Gauge, constructed under Halliwell's patent. (Fig. 3.) The rain from a standard deep-rimmed copper receiver passes through a wide pipe to a cylinder, in which is a float bearing a vertical rod that raises or lowers a sliding anti-friction pen arrangement. As water accumulates in the cylinder the float and pen rise, the latter recording continuously, in ink, on a non-stretching waterproof chart. Shortly before the pen arrives at the top of the chart, a curved strip of metal attached to the float-rod begins to bear against the knob of a weight on a sensitively-poised arm, which falls suddenly at the right moment, striking a catch-lever, which releases a suspended very wide-bore syphon. A full bore discharge is instantly occasioned, the pen descending to zero in five seconds. A special arrangement enables the syphon to be automatically re-set.

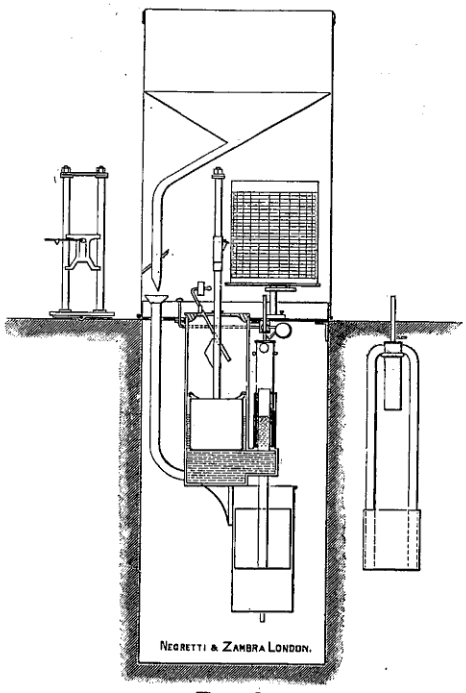


FIG. 3.

With these arrangements no "trickling" can possibly occur; and a faithful and distinct record is furnished by the gauge of either the heaviest tropical downpour, or a wet fog or misty drizzle. The instrument is free from frictional effects; the scale is uniform throughout; and the rain and time divisions on the chart are rectangular.

The gauge has either an 11 in. funnel, (279 mm.) with a drum making one revolution in 24 hours, or an 8 in., (200 mm.) funnel, with drum making one revolution in seven days.

**Electrical Self-recording Rain Gauge* has the tilting mechanism placed out of doors and connected electrically with the recording mechanism placed indoors, obviating the inconvenience of going out of doors to change the chart, and permitting the progress of a storm to be watched in comfort.

* This instrument will be recording during the Exhibition.

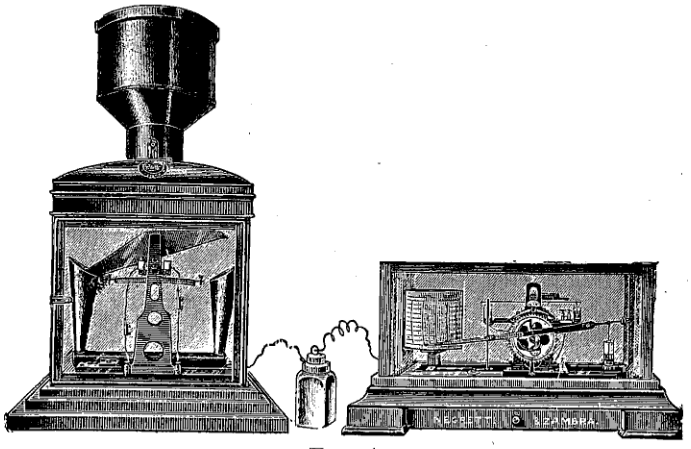


FIG. 4.

The gauge complete consists of—

The transmitter.
The recorder.
A length of double wire.
A primary battery.

The transmitter is constructed on the principle of a tilting bucket divided into two equal parts, which tips over when 0·01 in., or 1 mm., of rain has fallen, and which, in tipping, closes an electric circuit by dipping platinum wires into mercury.

The recorder is constructed on the principle of an escapement motion attached to a helix, which raises the lever arm and pen by steps of 0·01 in., or 1 mm., until 1 in., or 25 mm., of rain has fallen, when the pen descends to zero. The escapement is set in motion by the attraction of an armature to an electro-magnet, the circuit of the magnet having been closed by the contacts on the transmitter.

The battery consists of four Leclanché cells packed in a wood box.

The transmitter is fitted in a polished copper case, with 8 in., or 20 cm., brass rim. The recorder in a frame of oak or mahogany with a drawer for charts, and bevelled plate glass on all sides and top. It is complete with pen, ink, and 50 charts.

**Electrical Recording Anemometer (Lowne's Patent).*—An important point in anemometry is situation. The great advantage of this instrument is that the transmitter can be placed at a high spot, and connected up in simple manner with the recording mechanism in a room. One has therefore the advantage of correct exposure combined with comfort in observing.

Recording anemometers may be classed under two headings based respectively on the principles of the pressure tube or of the hemispherical cups invented by Dr. Robinson. The latter is the principle adopted in Negretti and Zambra's electrical recording anemometer. A 3-wire cable connects the two parts of the instrument.

In order that the curve on the chart may be free from steps, 10 contacts are made to 1 mile or 5 contacts to 1 kilometer.

To prevent rapid running down of the batteries the duration of each contact is automatically reduced to a fixed short interval, irrespective of the speed of the cup.

The transmitter (Fig. 5) consists of a cast-iron chamber and pillar, surmounted by the well-known Robinson's cups. In the chamber is arranged the contact-making apparatus.

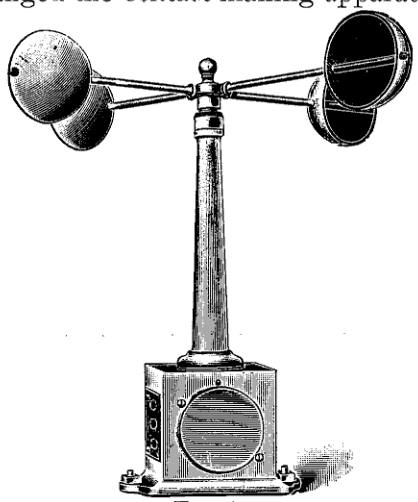


FIG. 5.

The total height is 17 in. (43 cm.)
,, weight is 7½ lbs. (3½ kg.)
Measurement over cups, 17 in. (43 cm.)

* This instrument will be recording during the Exhibition.

The recorder (Fig. 6) is constructed on the basis of a helix, which raises the lever arm and pen by steps of 1/10th mile up to 100 miles, or 1/5 km. up to 200 km., when the pen descends to zero. The helix is moved by a chain of gear wheels and mechanism actuated by the attraction of an armature of an electro-magnet, the impulses being received from the transmitter.

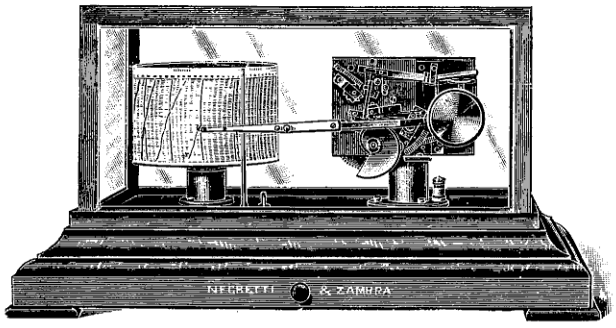


FIG. 6.

The battery consists of three or four Leclanché cells, fitted into a box.

The electrical recording anemometer consists of transmitter, and recorder, and is complete with battery, pen, ink, and 50 charts.

Electrical Wind Vane, Lowne's Patent.

The apparatus consists of a rotating vane and a dial electrically connected together. Three or four Leclanché cells provide the motive power. The dial, which resembles a clock face, and which may be placed in any desired position, is marked with the eight cardinal points of the compass. It is made in sizes up to 17 in. (43 cm.). The pointer of the dial moves round as the direction of the wind alters. As in the electrical anemometer a necessary part of the design is an arrangement to allow only a momentary electrical current to flow, in whatever position the vane may come to rest.

---

* This instrument will be recording during the Exhibition.

Deep Sea Thermometers, the claims for which are :—

(1) No liquid but mercury, no getting out of adjustment, and no care necessary in packing.

(2) No indices to depend upon ; the column of mercury is its own index.

(3) The thermometer takes the temperature only at the spot where it is reversed.

The construction of the thermometer is shown in Fig 7. ıere is a minute contraction of the bore at (A), upon the shape d fineness of which depends the successful action of the ɜtrument.

FIG. 7

Below this is constructed a small reservoir (B), and at the bottom of the tube is blown a small cavity (C), which permits of the expansion of the mercury when the thermometer is being carried with the bulb downwards.

When the thermometer is in use, it is placed with the bulb downwards, and the mercury rises and falls in precisely the same way as in an ordinary thermometer. When the moment arrives at which it is desired to take the temperature, the thermometer is reversed, the bulb then coming uppermost. The mercury column at this moment parts at (A), and falls by its own weight to the bottom of the tube indicating on the graduated scale which reads upwards from (C) the temperature at the moment of reversal. Any mercury which is forced past the contraction (A), between the time of reversal and the moment of observation, either remains there through capillarity or falls into the reservoir (B). As an additional precaution the thermometers are now constructed with another fine contraction in the bore at (D).

To protect the thermometer against pressure, it is placed entirely in a hermetically sealed shield of glass. The shield must be strong, but need not be exhausted of air.

To counteract sluggishness some mercury is introduced in the portion of the shield surrounding the bulb, and confined there by a partition cemented in the shield around the neck of the thermometer bulb. This mercury acts as a carrier of heat from the exterior of the shield to the bulb of the thermometer.

A very simple and efficient method for reversing the thermometer, where the depths are not too great is a hollow wooden frame loaded with shot free to move from end to end, and sufficient to render the instrument just vertically buoyant in sea water. A cord is rove through the hole in the frame nearest the bulb, and the instrument is fastened by this cord to the sounding line. The thermometer will descend with the bulb downwards, but upon being pulled up, owing to the resistance through the water and consequent displacement of the centre of gravity, the instrument will turn over and come up bulb uppermost.

In sounding to great depths an accidental check upon the line may make the thermometer turn over and register.

An improvement, due to suggestions kindly furnished in 1881 to Negretti and Zambra by the late Admiral, then Commander, Magnaghi, of the Royal Italian Navy, avoids this defect.

The apparatus will be best understood by reference to the accompanying figure. (Fig. 8.) A is a metallic frame in which the case B, containing the thermometer, is pivoted upon an axis H, but not balanced upon it. C is a screw-fan attached to a spindle, one end of which works in a socket D, and on the other end is formed the thread of a screw E, about half an inch long, and just above it is a small pin or stop F on the spindle.

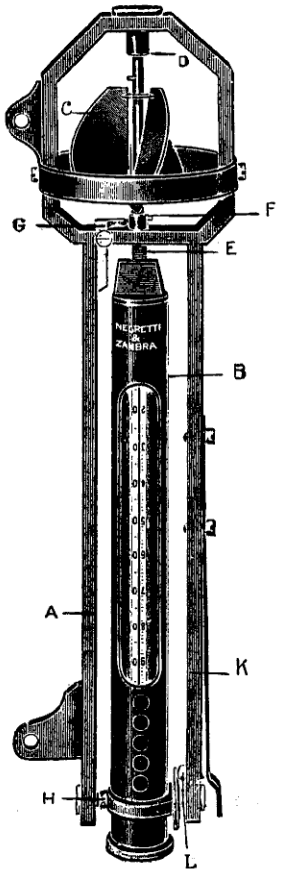


FIG. 8.

G is a sliding top piece against which the pin F impinges when the thermometer is adjusted for use. The screw E works into the end of the case B the length of play to which it is adjusted. The number of turns of the screw into the case is regulated by means of the pin and stop-piece. The thermometer in its case is held in position by the screw E, and descends into the sea in this position, the fan C not acting during the descent because it is checked by the stop F. When ascent commences the fan revolves, raises the screw E, and releases the thermometer, which then turns over owing to the axis H being below the centre of gravity of the case B as adjusted for the descent, and registers the temperature at that spot. Each revolution of the fan represents about 10 feet of movement through the water upwards, so that the whole play of the screw requires 70 or 80 feet ascent; therefore the space through which the thermometer should pass before turning over must be regulated at starting. If the instrument ascends a few feet by reason of a stoppage of the line while attaching other thermometers, or through the heave of the sea, the subsequent descent will cause the fan to carry back the stop to its initial position, and such stoppages may occur any number of times provided the line is not made to ascend through the space necessary to cause the fan to release the thermometer. When the hauling-in has caused the turnover of the thermometer the lateral spring K forces the pin L into a slot in the case B and clamps it until it is received on board so that no change of position can occur in the rest of the ascent from any cause. The case B is cut open to expose the scale of the thermometer, and is also perforated to allow the free entry of the water.

In 1884, Dr. H. R. Mill invented a type of frame for reversing the Negretti and Zambra Deep Sea Thermometer which was

adopted by the Scottish Fishery Board, and in consequence is frequently known as the " Scottish " pattern. (Fig. 9.)

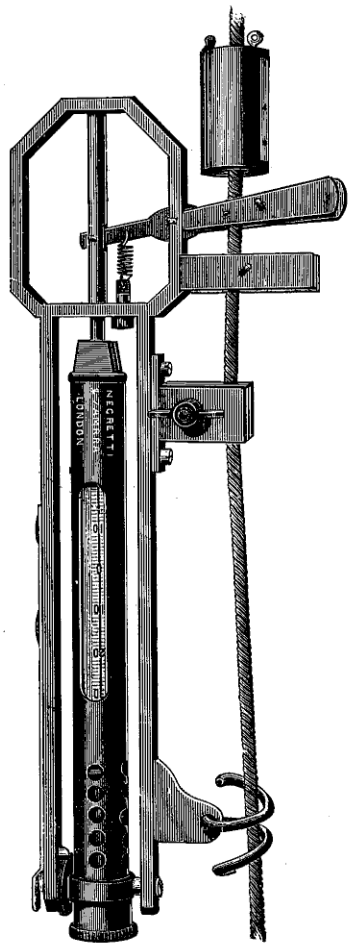


Fig. 9.

This pattern is somewhat similar to the foregoing, but the release of the frame is effected by a lever instead of a screw fan. The lever is depressed by means of a substantial weight, some-

times called a "messenger," which when loosed from the ship, travels down the sounding line, and striking the longer end of the lever, effects the reversal of the thermometer.

NOTE.—All Negretti and Zambra's Deep Sea Thermometers are guaranteed to withstand a pressure of 450 atmospheres, or 3-tons pressure per square inch, and may be tested by the National Physical Laboratory for this pressure, and also for corrections to be applied to the scale readings.

Aneroid Barometers.

An assortment of aneroid barometers, showing the watch, pocket, surveying, and yacht sizes, including—

(*a*) *The "Whiteside-Cook" Aneroid*, facilitating the observation of altitudes, &c.

(*b*) *Surveying Aneroid*, with vernier, graduated to 2,000 metres and reading to 1 metre.

(*c*) *Aneroid Barometer*, with 12 in. dial, of the best construction, showing partly the mechanism.

**Barograph and Thermograph*, of the best construction and finish.

Thermometers.

A Set of Clinical Thermometers, without scale error, all having Kew certificates of the National Physical Laboratory.

Surveying Instruments.

6 *in. Tacheometer*, of the very strongest construction and highest accuracy.

3 *in. Theodolite*, constructed entirely of aluminium, with the exception only of the centres.

Pocket Surveying Instruments, including—

(*a*) *The Theodolette*, &c.

(*b*) *The Brunton-Pearse Mine Transit* is an alt-azimuth, for taking horizontal and vertical angles, and also for use as a clinometer.

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* These instruments will be recording during the Exhibition.

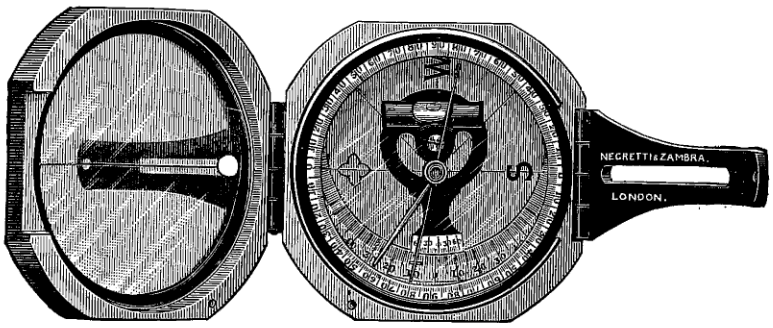


FIG. 10.

Its chief features may be summarised as follows:—

1. It enables the surveyor, by means of a mirror, to observe the compass needle simultaneously with taking the sights above or below the horizontal.
2. There is no necessity for a staff or tripod, or for a second observer.
3. Great convenience in taking vertical angles.
4. Use as an ordinary clinometer.
5. It is constructed of magnalium weight, 10 oz. (280 grammes), and of such a size and form, 3 in. by $1\frac{1}{8}$ in. (76 by 30 mm.), as to go conveniently into the pocket.
6. The needle being of the bar form, is much steadier and more accurate than with a ring or card attached.
7. The graduated horizontal circle is furnished with a screw to admit of adjustment for magnetic deviation at place of use.

Drawing Instruments.

A set of the best English made drawing instruments, in case.

Nautical.

A Nautical Sextant of great rigidity and strength known as the "Pillar" pattern, on a tripod stand, with every possible adjustment.

Telescopes.

A display of telescopes, comprising models for midshipmen, Officers of the Watch, Marine, Navy, Yachting, Army, Astronomy, Deer-stalking, &c.

Binoculars.

Binoculars of brass or aluminium.

Binoculars of the "prism" type, with patent rack-work movement working on the principle of a differential thread.

"*Minim*" is a prism binocular with a magnification of 8 diameters, about three-quarters the size and two-thirds the weight of an average prism binocular of the same power. (Fig. 11.) To secure this compactness in conjunction with high power, the lenses and prisms must be small, and in consequence the light-transmitting power, under certain circumstances, is rather less than in binoculars fitted with large object glasses. We emphasize "under certain circumstances," because when used at night, twilight, or on a very dull day, the large object glasses may give better results. On the other hand, on an average bright day the "*Minim*" will be practically equally satisfactory.

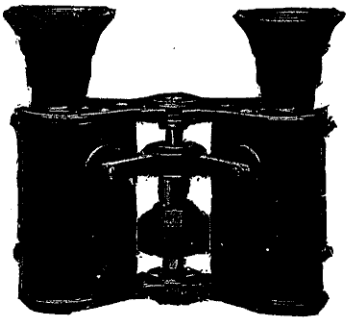


FIG. 11.

The advantage of compactness need not be set forth here, but it is much easier to hold the "Minim" steady in the hand than larger instruments, an all important matter with a power of + 8.

Special attention is drawn to the well-designed rackwork adjustment; the principle is that of a differential screw, giving a smooth motion, which can be worked by one finger. Being unaffected by the continual wear and tear, it does not give rise to any slackness. One eyepiece is separately adjustable for unequal vision, and the bodies are hinged for interpupillary distance.

The "*Minim*" is constructed of a special light metal alloy, well japanned; and the bodies are covered with dark green Russia leather. It is supplied with a small sling strap to carry the glass round the neck when not in use.

Compasses.

An assortment of night marching, touring, luminous, and pocket compasses.

Microscope.

A Microscope of the highest accuracy and finish.

Sun Dial.

The "Helio-Chronometer," an instrument for giving the correct local mean time to the fraction of a minute.

By means of an accurately shaped cam, automatic correction is made for the "Equation of Time." This is done by setting the rotating part of the instrument to indicate the day of the year on which the observation is being made.

Robt. W. Paul, *New Southgate, London, N., and 33, Leicester Square, London, W.C.*

Unipivot Galvanometers and Measuring Instruments.

A series of moving coil portable instruments of unique design, by which a sensitivity is attained exceeding by some hundreds of times that of similar instruments of ordinary construction. They are characterised by the use of only one pivot, which supports the moving system (Fig. 1).

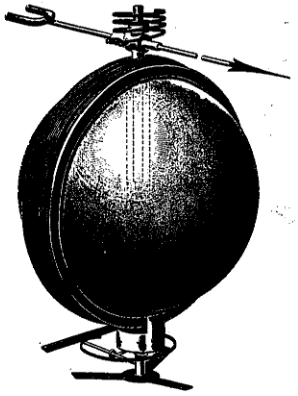


Fig. 1.

The spherical iron core between the poles of the permanent magnet has a hole down to its centre, at which is a jewelled cup in which the pivot, fixed on a short vertical axis, rests. The moving part is thus supported at its centre of gravity, so that the levelling is of little importance.

The use of only one pivot reduces the friction so much that portable instruments reading to less than one-millionth of an ampere are available.

A working model, four times the actual size of the instruments, is shown.

A number of these instruments are shown adapted for special purposes, their unusual sensitivity enabling measurements to be made with a portable instrument which were previously impossible.

They have an arrangement for lifting and clamping the moving coil, and for adjusting the zero. The magnet and moving coil are well insulated from the case, and scales may have the zero at the centre or end.

They are especially useful for accurately measuring small voltages, and so may be used as ammeters for currents up to very large values in combination with small and inexpensive shunts.

Pattern A.—Horizontal: (Fig. 2.)

Brass case 4 ins. (100 mm.) diameter, coil automatically lifted off pivot by lifting the instrument.

Full scale deflection for 0·0001 ampere, 50 ohms resistance.

Full scale deflecting for 0·0015 volt, 5 ohms resistance.

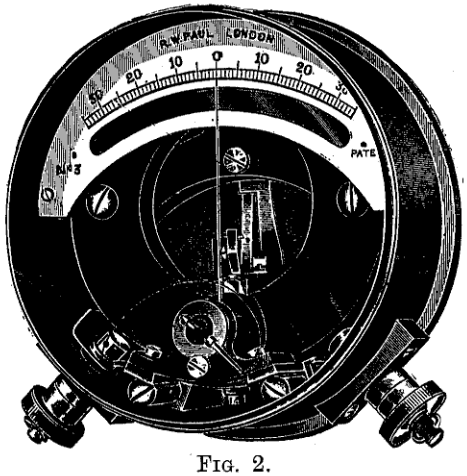


FIG. 2.

Pattern H.—Horizontal. For general work, Wheatstone Bridge, milliammeter, and for measuring high frequency currents with thermo-junction.

Pattern J.—Vertical. To fix on a wall plate, of which several may be placed in convenient positions; suitable for thermo-electric pyrometer indicator.

Pattern K.—Square Horizontal. For laboratory work; and as a universal measuring instrument.

Pattern L. (Fig. 3).—Portable, with removable hinged lid and strap handle.

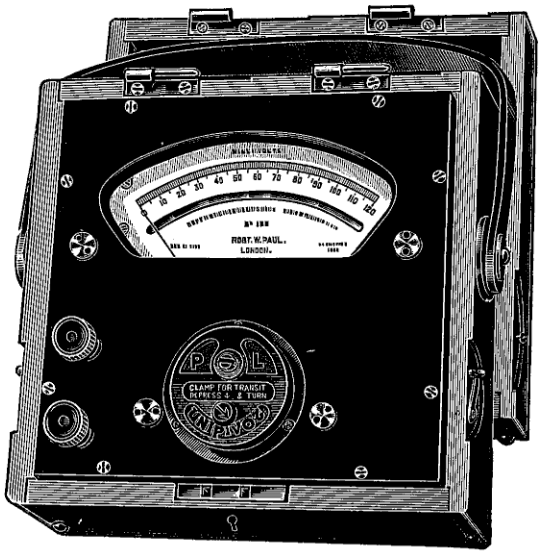


FIG. 3.

Sector Unipivot Instruments. (Fig. 4.)

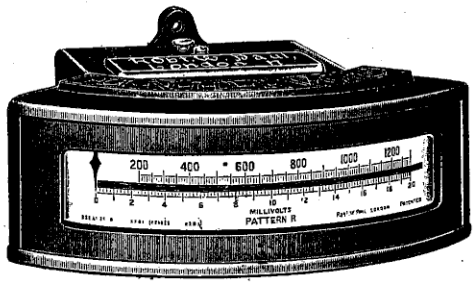


FIG. 4.

The working parts of these instruments are larger than those of the previous ones (Fig. 5). The scales are 175 mm. in length, and full deflection is produced by 0·000024 amps.

for the high resistance, and 0·0024 volt for the low resistance type.

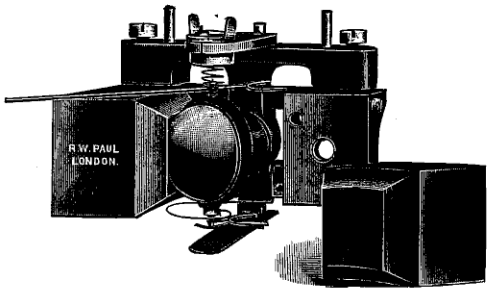


Fig. 5.

Pattern R.—Vertical:—Suitable for workshop use and pyrometry, and as a high resistance milli-voltmeter.

Horizontal Type.—For laboratory work, will read one ten-millionth of an ampere.

Interchangeable Portable Standard Shunts. (Figs. 6, 7).

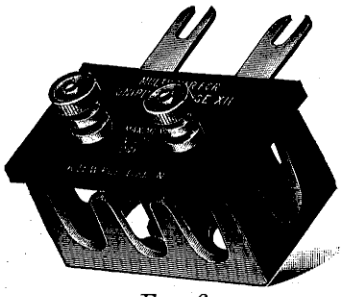


Fig. 6.

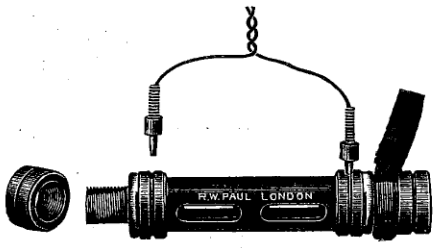


Fig. 7.

For use in measuring currents and low resistances. Constructed of manganin, the larger ones in the form of thin ventilated tubes with novel screwed ends adapted to take thimbles, wires or rod. With multi-range single pivot instruments each can measure currents one thousandth of the maximum.

12	amperes	0·01 ohm
to 600	„	0·0002 ohm.

Interchangeable Voltage Multipliers.

These are arranged to suit the same instruments as above. Up to 240 volts, or higher.

Unipivot Testing Sets.

Pattern O. (Fig. 8.)—A self-contained portable set for all direct current measurements.

Voltage ranges, 0·02 to 2·4; 0·1 to 12; 1 to 120; 10 to 600, &c.

Insulation resistance, 0·01 up to 600 megohms.

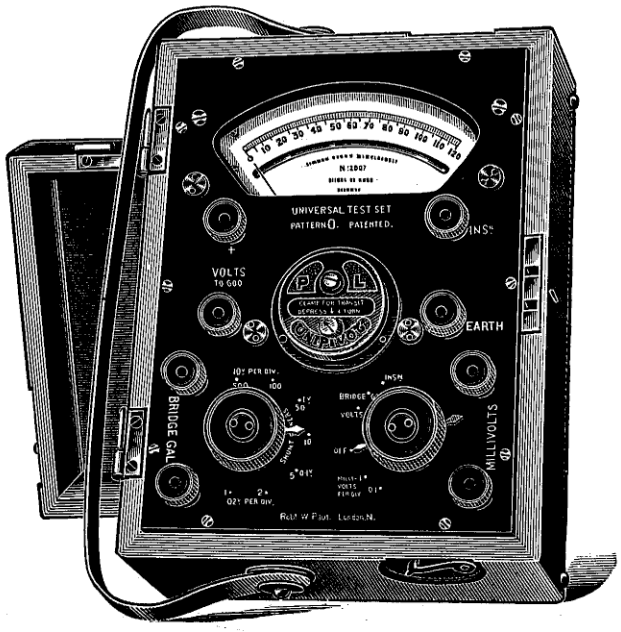


FIG. 8.

Currents, one-millionth ampere to 120 amperes or higher.

Low resistances, by connection in series with one of the shunts included.

Measurement of rail bond resistance by special two-way switch.

Measurement of furnace temperatures to 600° and 1200° by standardised thermocouples.

Inexpensive accessories are supplied to extend the range of measurement. A tripod stand is fitted for out-door use in fault localising.

Pattern U.—A larger instrument working on the same principle, fitted with dial illumination for night work, and measuring to 3,000 megohms. The necessary additional apparatus for bridge measurements can be fitted to these sets.

Unipivot Reflecting Galvanometer. (Fig. 9.)

This is a portable instrument which may be fixed to a wall, if required, and it does not require to be accurately levelled. It is ready for use on unclamping the fixed coil. It has a quick time of swing. With a period of $1\frac{1}{2}$ seconds and a resistance of 200 ohms, it has a sensitivity of 25 mm. at 1 M. for 1 micro-ampere.

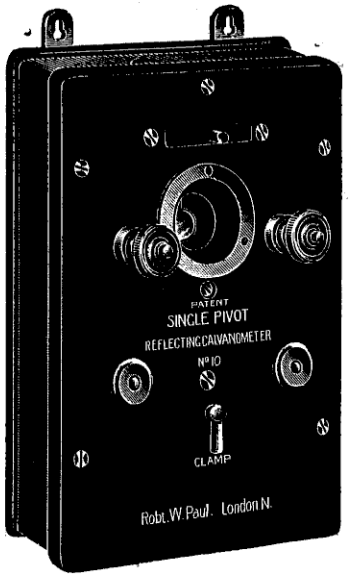


FIG. 9.

Unipivot Dynamometer. (Fig. 10.)

The dynamometer is constructed with a small coil, pivoted in the same fashion as that of the direct current instruments, closely surrounded by two fixed coils and turning in a spherical space at their centre. It gives a full scale deflection for 0·005 ampere or 0·5 volt, and it may also be used as a wattmeter, being particularly adapted for measuring the consumption of metallic filament lamps. The coil is removed from its pivot when required. As the great sensitivity allows a large resistance to be used in series with the voltage circuit, it is capable of accurate use as a quadrature detector, and in all cases where small amounts of power are to be measured.

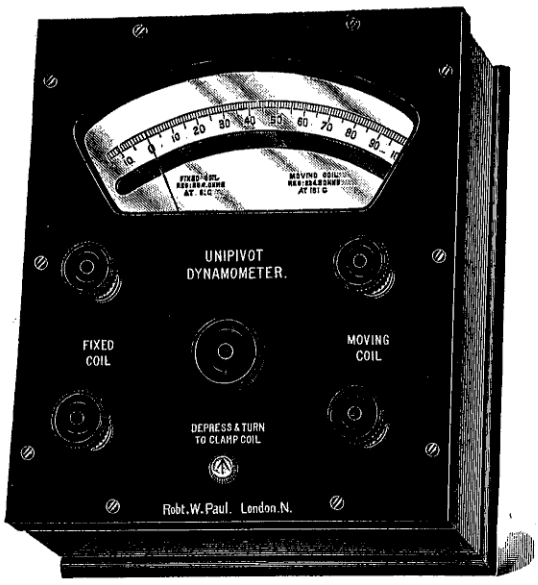


FIG. 10.

Thermo-Junctions of Platinum, Platinum-Iridium.

Thermo-junction wires of platinum and platinum-iridium, standardised for resistance so as to be interchangeable, are threaded through porcelain tubes with two longitudinal holes.

As furnace pyrometers for temperatures up to 1,200°, the junction is contained in a quartz tube. The whole is protected by a steel tube, which is easily replaced.

Pyrometer Thermo-Junction Cold Box and Supplementary Water-cooled Junction. (Fig. 11.)

In order to measure accurately the temperature by means of thermo-junctions it is necessary to know accurately the temperature of the "cold" junction. This apparatus is designed to be a convenient form of cold junction, the temperature of which can be measured by a thermometer.

By means of the supplementary water-cooled attachment the cold junction, which is then automatically transferred to the attachment, can be more accurately maintained at a known temperature. Arrangements are made for circulating water for this purpose.

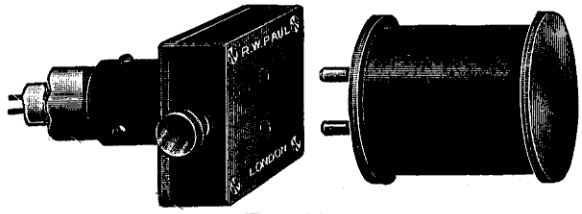


FIG. 11.

Temperature Measurement by Electrical Resistance Method. (Fig. 12.)

("Electrician," London, December 1908.)

FIG. 12.

The Harris direct reading resistance thermometer works on the principle of the ohm-meter. It is independent of the battery power and does not require a balancing galvanometer as in

bridge methods. It is direct reading with ranges $-200°$ to $0°$, $0°$ to $200°$, $200°$ to $400°$, &c., up to 1,200°, on the one instrument.

A deflection of 90 angular degrees is produced by $200°$ of temperature with a platinum thermometer of 1 ohm fundamental interval. The accuracy can be easily checked by immersing the thermometer in ice and steam. At the National Physical Laboratory the error up the 1,200° has been found not to exceed $\frac{1}{1000}$. The instrument can be calibrated in platinum degrees for use with any make of platinum thermometers.

Platinum Resistance Thermometers.

The platinum is in the form of flat strip to minimise the effect of heating by the measuring current. The mounting depends on the temperature to be measured. They are made of 1 ohm "fundamental interval," that is the change in resistance from 0° to 100° C. is 1 ohm. The total resistance at 0° is made 3 ohms by the addition of a small resistance without temperature co-efficient. In this way all thermometers are interchangeable for use with the Direct Reading Indicator or any other piece of apparatus. Compensating leads are provided in the usual way.

Drysdale Standard Resistance Coil, 1 ohm. (Fig. 13.)

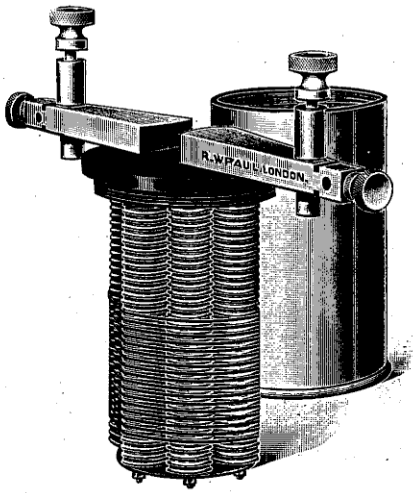


FIG. 13.

Coils of this type are compensated for temperature by the method suggested by Dr. Drysdale (British Association Report, 1907). The temperature coefficient does not exceed one or two millionths of an ohm. They may be used for comparatively large currents without loss of precision.

Standard Wheatstone Bridge. (Fig. 14.)

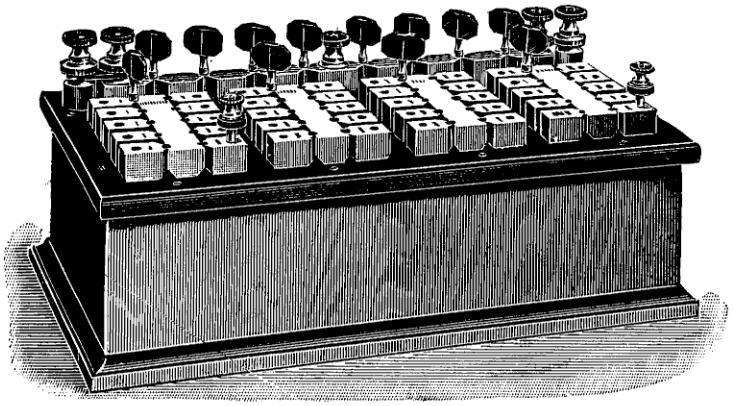


Fig. 14.

Plug decade form. Resistance coils 1 to 11,100, and four pairs of ratio coils.

Decade Resistance Box. (Fig. 15.)

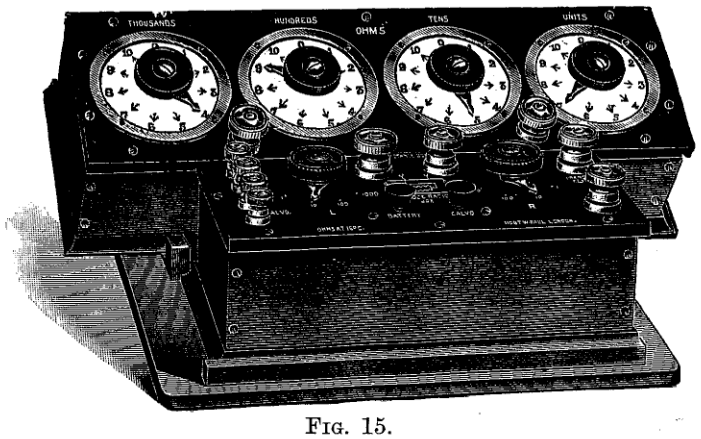


Fig. 15.

Rotating Dial form with enclosed brush contacts.

Wheatstone Bridge addition to above, with four pairs of ratio resistances and battery and galvanometer keys. The whole on inclined stand.

Three-Dial Portable Bridge.

This bridge is fitted with internal switch contacts, there being ten coils to each dial. The values of the coils are clearly legible, and a novel spring stop locates the switch brush on its contacts. It has resistance coils 1 to 1,110 ohms. The ratio switches give four values and also a zero position in each arm of the bridge, so as to render it suitable for fault localising. Each of the keys has a locking device. The terminals are designed to clamp stranded conductors, fine wires, or thimbles with equal certainty.

Paul-Harris Test Wire. (Fig. 16.)

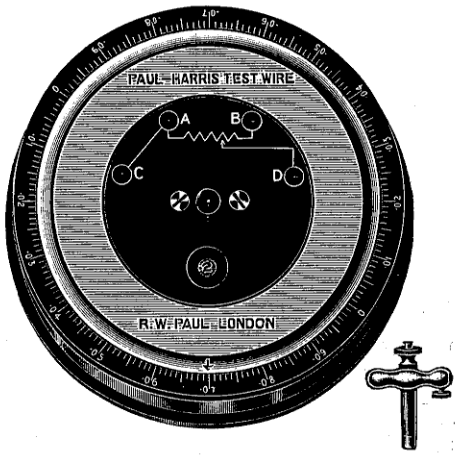


FIG. 16.

Available for use as—

(1) Metre slide wire bridge.
(2) Potential divider.
(3) Fault localising bridge.
(4) Regulating resistance.

A resistance wire, usually 1 ohm, which will carry $2\frac{1}{2}$ amperes, is coiled in five spiral turns round a drum. A sliding contact actuated by a screw of the same pitch forms the intermediate

connection, and the position is read to 0·001 of the length of the wire. By additional resistances it forms a complete bridge, reading directly 0·02 to 2 ohms. It is fitted with detachable cone terminals. A feature of the instrument is that the dimensions are not increased by operating the contact.

Carbonised Cloth Compression Rheostat. (Fig. 17.)

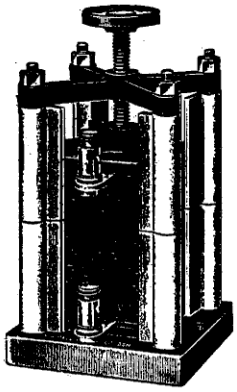


FIG. 17.

Capacity :—6 amperes, 0·15 to 3·5 ohms. Other sizes up to 10 amperes are made.

Carbon Plate Compression Rheostat. (Fig. 18.)

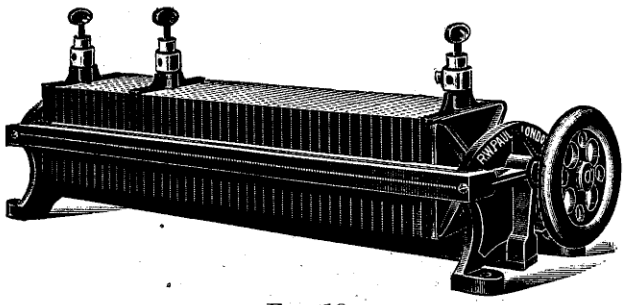


FIG. 18.

Capacity :—20 amperes, 0·03 to 2·5 ohms.

By intermediate terminal plates the larger sizes may be used in two or more sections in parallel up to 200 amperes.

Fine Adjustment Rheostat. (Fig. 19.)

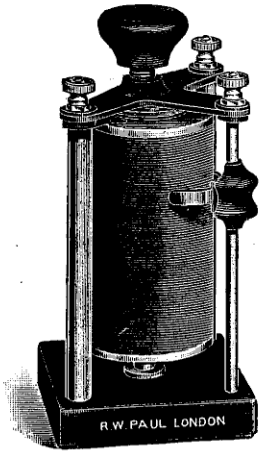


FIG. 19.

A slider moves on a spiral of resistance wire, and a fine adjustment is provided by rotating the cylinder carrying the resistance wire.

Capacity :—16 ohms, 4 amperes. Other resistances as required.

Moving Coil Galvanometer. (Fig. 20.)

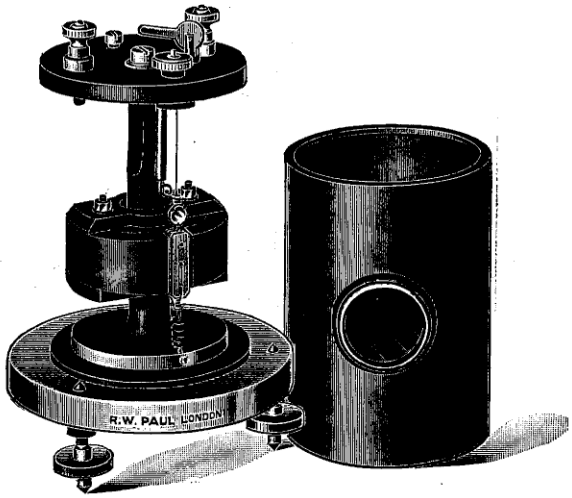


FIG. 20.

Of simple construction for general use, with outside clamping arrangement and separate coils of different resistances and for aperiodic or ballistic work.

Resistance, ohms - - -	5	1,400	175
Periodic time, secs. - - -	4	4	5
Deflection per micro amp. mm. at 1 M.	15	350	—
,, ,, micro volt ,,	3	—	—
,, ,, micro coulomb ,,	—	—	250

Ayrton-Mather Moving Coil Galvanometer. (Fig. 21.)

Moving coil of small moment of inertia enclosed in a tube of silver for general work, and of ivory for ballistic work, which support the coil and render them easily interchangeable.

Resistance.	D.	S.
3 ohms.	9	18
325 ,,	60	170
1,000 ,,	75	220

D. = Deflection in millimetre per micro-ampere at 1 M. Period, 3 seconds.

S. = Swing in millimetre per micro-coulomb at 1 M. Period, 5 seconds.*

Translucent Scale.—The illumination is by a four-volt. lamp with adjustable mounting.

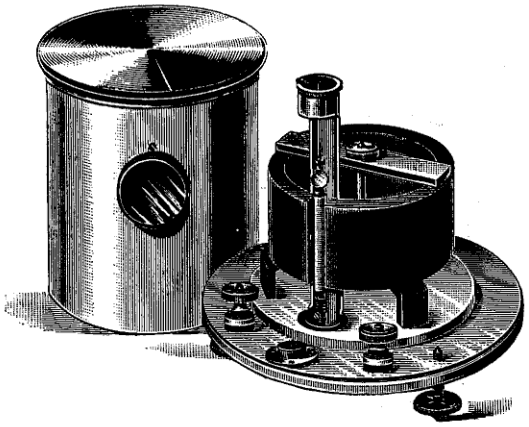


FIG. 21.

* This may be increased to 10 seconds by additional weights.

Universal Galvanometer Shunts. (Fig. 22.)

The shunting power of these resistances is independent of the galvanometer resistance so that no adjustment is required to suit any particular galvanometer.

It is advisable to have the total resistance of the shunt about 10 times that of the galvanometer.

Large Pattern.—21 shunt powers, resistance 100,000 ohms., also adaptable for 10,000 and 1,000 ohms.

Small Pattern.—7 shunt powers, resistances as above; and provided with short circuiting key.

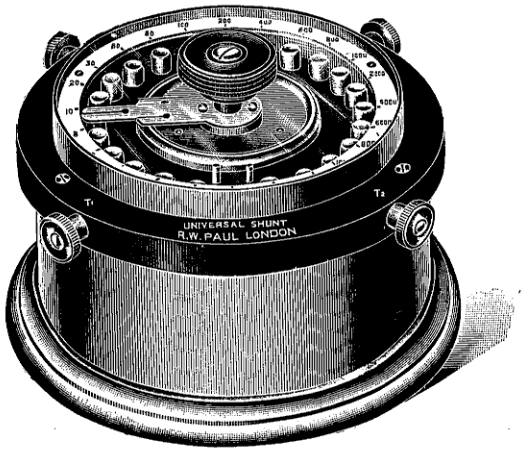


FIG. 22.

Standard Condenser with Mica Insulation.

Sub-divided Paraffin Paper Condenser.

10 of 0·1 Micro-farad.
10 of 1·0 ,,

Two Portable H Pattern Cadmium Cells giving an E.M.F. of 1·018 *volts. at* 15° *C.*

The temperature co-efficient 0·004 per cent. per degree centigrade is quite negligible for ordinary purposes. The case is designed to prevent accidental overturning.

Duddell-Mather Standard Wattmeter and Anti-Capacity Gauze Resistance. (Fig. 23.)

These instruments have been designed for the measurement of power in alternating circuits to the highest attainable accuracy. They are designed so as to be as accurate as possible on very low power factors.

This is accomplished by the absence of all unnecessary metal, by the stranding of the conductors, and by the astaticism of the wattmeter.

It is further direct reading and by having the current circuit in 10 sections which may be put in series or parallel each type has a large range of currents over which accurate measurements may be made.

The reading is obtained by balancing the electrical torque on the moving coil by the action of a spiral spring actuated by the disc on the top, divided into 500 parts.

At high power factors $\frac{1}{100}$ ampere is used in the pressure circuit, but at low power factors this may be increased 10 times, so that full deflection (one turn of the disc) may be obtained for a power factor of $\frac{1}{10}$.

A very valuable feature is the rapid determination of the error caused by the self-induction of the moving coil, which

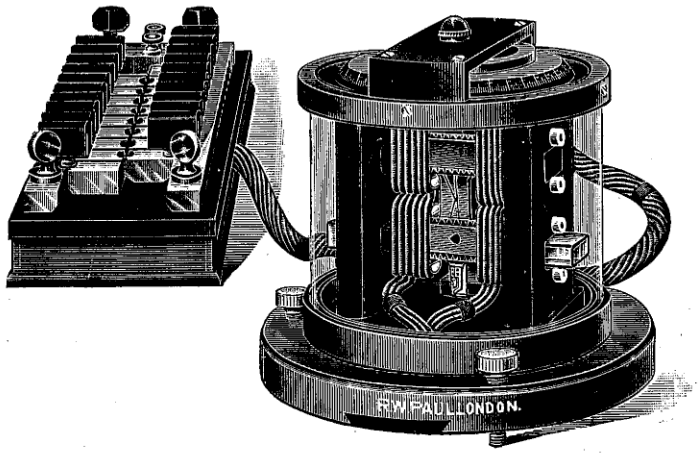


FIG. 23.

becomes appreciable at very low power factors. This consists of an additional coil with self-induction equal to that of the voltage circuit of the instrument—5·7 millihenry—which can be put in circuit by a switch without altering the resistance.

By subtracting the difference in the reading thereby caused from the original reading, the instrumental error from this cause is eliminated.

The instrument shown has 10 circuits, each carrying 10 amperes. It is made in other forms for 1 ampere and 0·1 ampere, and also with insulation for operation at 10,000 volts. The Duddell-Mather sub-divided gauze resistance box, with negligible inductance and capacity, is constructed of resistance wire, silk-covered and woven with silk threads into a continuous fabric about 20 cm. wide, and of any length, according to the resistance required. It is then mounted on insulators, and connections brought out to terminals, as required. (Fig. 24).

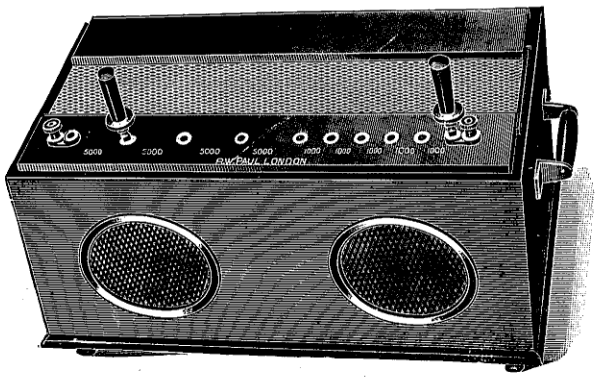


FIG. 24.

This example shown is arranged for use with the wattmeter, and has resistances suitable for 125 and 250 volts, which will carry 0·01 and 0·1 ampere, and an additional coil of 5·7 millihenry for use, as mentioned above, in obtaining the correction for the inductance of the voltage coil of the wattmeter. These instruments have been constructed with oil insulation for pressures up to 25,000 volts.

Ayrton-Mather Electrostatic Voltmeters.

Laboratory pattern specially sensitive for low continuous or alternating potentials. (Fig. 25.)

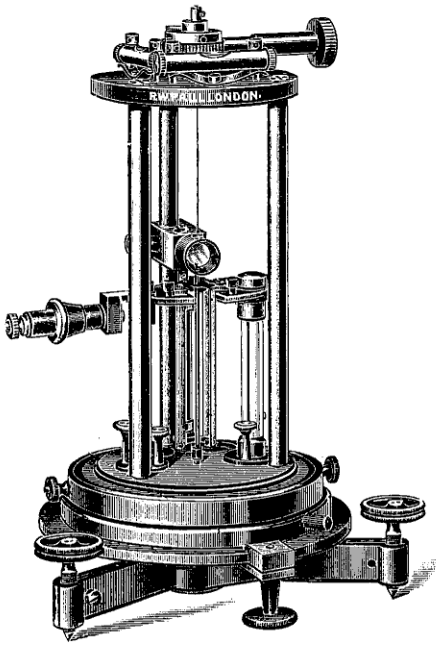


FIG. 25.

The deflecting part N and the inductors I are made of aluminium, and great care is taken to diminish the contact difference of potential. (Fig. 26.)

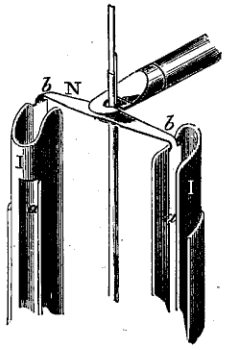


FIG. 26.

A clamp permits the instrument to be transported. The inductors are mounted on glass pillars, and protection from outside electrostatic influences is ensured. The instrument shown has a range of 1·5 to 11 volts, with a period of 9 seconds. It is also made with ranges up to 7 and 30 volts, with periods of 13 and 3·6 seconds.

Ayrton-Mather Electrostatic Voltmeter, Zero Pattern. (Fig. 27.)

The torque produced by the potential on the instrument, alternating or continuous, is balanced by the torsion of the suspension as in a Siemens electrodynamometer, and the torsion of the head, which is divided into 360 parts, is proportional to the square of the voltage.

The instrument is portable and reads up to about 60 volts.

Both the above instruments are particularly adapted for measuring alternating currents by connecting them to the ends of a known resistance carrying the current.

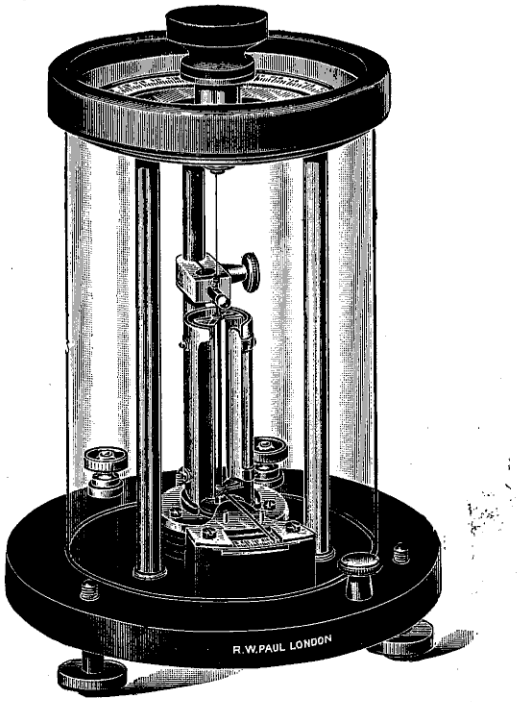


Fig. 27.

Sumpner Reflecting Electro-Dynamometer. (Fig. 28.)

An instrument of a moving coil type, designed for use with alternating currents.

The laminated electro-magnet has two fine wire coils, A, B, of 2,000 turns wound upon it, each of which will take 100 volts, and a third coil, C, of 200 turns, for use with lower voltages. The flux, produced by these coils in the space occupied by the moving coil is proportional to the voltage applied and in quadrature with it.

The moving coil is fed from the same source or off one of the other coils through a condenser, thus producing a quadrature current flux, at 180° phase displacement from the magnet flux, so that the deflection is proportional to the square of the voltage multiplied by the capacity of the condenser. If the low

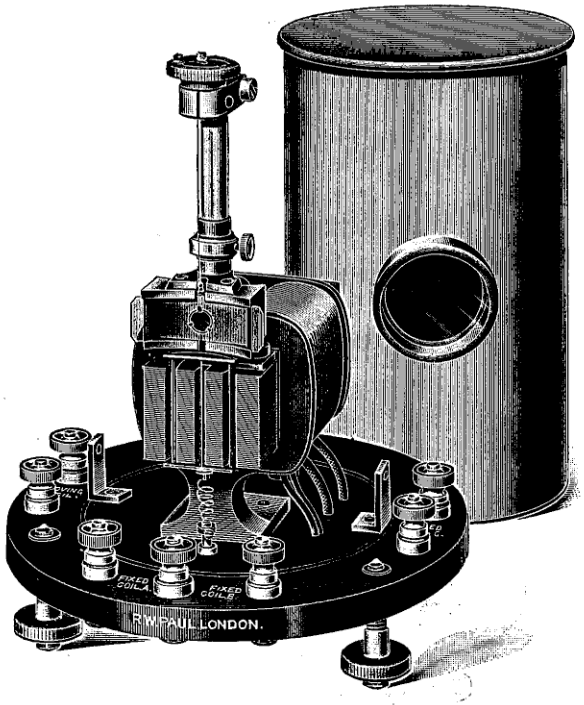


FIG. 28.

voltage coil be used, the voltage for the condenser circuit may be transformed up by using the fine wire coils to supply it.

For example—

		Capacity. mfds.	Volts. for 10 mm.
Volts on C	Condenser on AB	5	0·005
C	C	2·5	0·031
AB	AB	1	0·22
AB	C	0·1	3·1

The sensitivity may be increased by connecting the magnet coils to a separate source of supply at 100 or 200 volts. By this means less than one micro-volt may be detected.

The application of the instrument to the measurement of large and small capacities down to 0·00005 mfd. will be understood from the above. It may be used for such purposes as determining the effective resistance of a conductor placed in series with a similar resistance of known properties.

By means of series quadrature transformers it may be used as a wattmeter, and it will measure very small powers when used in this manner.

Cohen's Interrupter. (Fig. 29.)

("Phil. Mag.," Sept. 1908.)

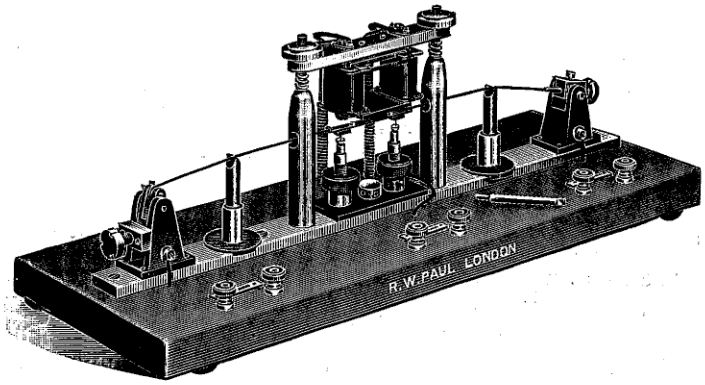


FIG. 29.

For producing small alternating currents suitable for the measurement of small inductances and capacities.

An electrically driven vibrating wire has a frequency of 20 to 500. By the addition of an extra oscillating circuit of variable inductance and capacity an alternating current with any frequency up to 3,000 may be obtained. By the use of two oscillating circuits continuous waves may be produced.

Portable Alternating and Direct Current Galvanometer.

(Fig. 30.)

(Institution of Elect. Engineers, May 1907.)

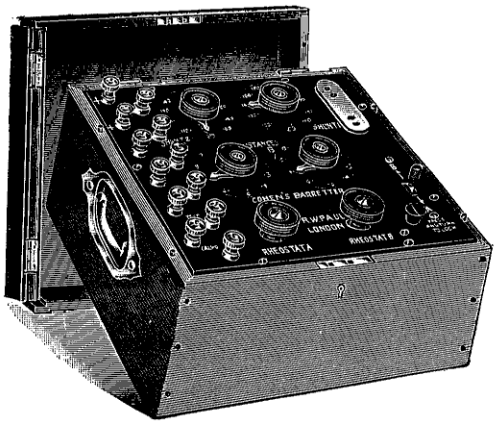


FIG. 30.

For high frequency currents from 5 micro amperes, and for direct currents from 0·1 micro ampere.

The indications of the instrument depend on a "baretter," constructed of a fine filament of carbon in vacuo through which the alternating current passes. This raises the temperature of the filament and decreases its resistance, which change is indicated by the alteration of a superposed continuous current which passes through the galvanometer.

Inductances, galvanometer and shunts, and potential divider with dummy baretter to compensate for change of air temperature, form part of the arrangement. (Fig. 31.) A similar set for use with an external galvanometer is shown.

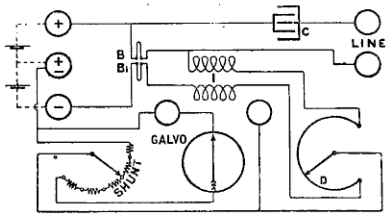


FIG. 31.

Irwin's Hot Wire Oscillograph. (Fig. 32.)

(Journal, Institution of Electrical Engineers, Vol. 39, p. 617.)

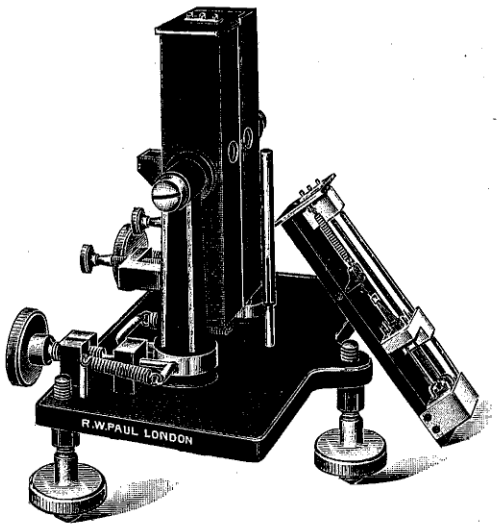


FIG. 32.

In this instrument the natural frequency is about 6,000, even with a large mirror. The damping, which is electrical, is independent of temperature and the mirror is not immersed in

oil. The damping may be reduced or entirely removed so that high harmonics may be shown.

The ingenious principle on which this instrument is founded is shown in the diagram. (Fig. 33.)

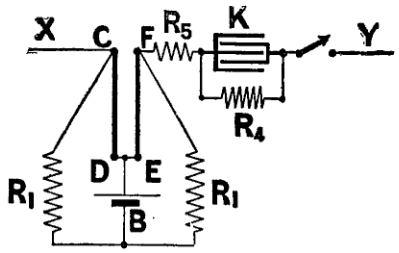


FIG. 33.

Two thin wires of about 7 ohms each are traversed by a current of about 0·4 ampere from a battery B through equal resistances R_1. Superposed on this current, an alternating current of about 0·3 ampere passes from C to F, so as to reduce the current in one side and increase it in the other. By putting a tension on the wires at their centre, in a direction normal to their length, the differential extension of the wires due to temperature change produces a deflection of a small mirror fixed to the centres of the two wires. The wires are immersed nearly up to the mirror in oil.

The special feature of the instrument is the condenser K and the resistance R_4 in the circuit. These compensate for the thermal lag in the instrument.

Another resistance, R_5, governs the damping, and is variable or removable.

The outfit consists of—

A double oscillograph, indicating simultaneously two wave forms.

A condenser and resistance, K·R_4, suitable for 250 volts.

A damping resistance, R_5, adjustable from 10 to 500 ohms.

Inductive shunt for current waves, three ranges, 2 to 25 amperes. (Fig. 34. S. R. P.)

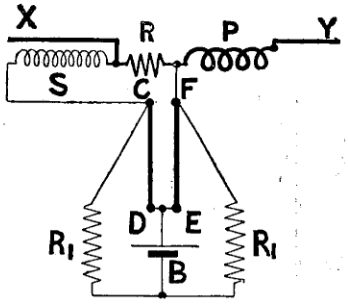


Fig. 34.

Instantaneous camera with eight plate carriers and trigger arrangement, for projecting the plate at a suitable velocity at right angles to the direction of motion of the spot of light.

Campbell Variable Mutual Induction Standard. (Fig. 35.)

("Phil. Mag.," Jan. 1908; also "Electrician," Feb. 1908.)

This instrument provides direct reading inductances from 0·0002 up to 11 millihenries.

The handle and pointer read from − 2 up to 102 microhenries, and there are 10 additional coils of 100 microhenries.

By a further multiplying arrangement these values are increased 10 times. The scale is most open at the lower values, thus diminishing the percentage error. Mutual inductances are preferable to self-inductances for small measurements, as their value is more easily calculated, and they can be reduced to zero and made negative.

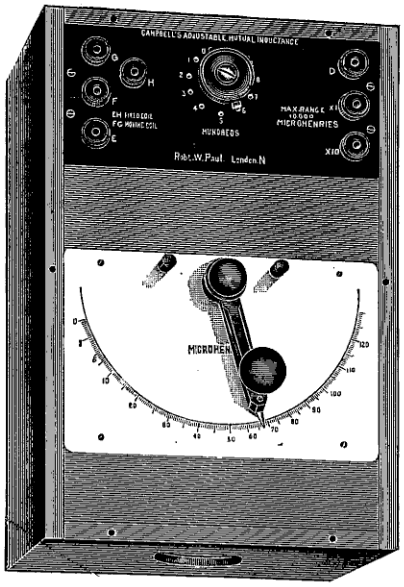


FIG. 35.

Microphone Hummer. (Fig. 36.)

This provides a convenient source of small alternating current of known high frequency and consists of a bar of steel resting on its nodal points. It is kept in continuous vibration by a battery and a microphone shunted by a condenser; a pulsating current in an electro-magnet placed near the centre of the bar is thus produced.

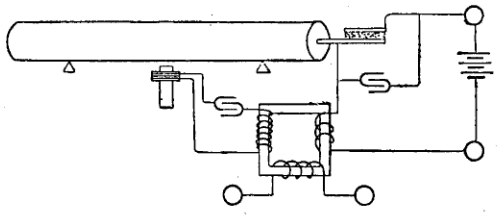


FIG. 36.

The magnet is supplied through a transformer, which also supplies current to the outside circuit.

The frequency depends on the dimensions of the steel bar, and may be conveniently 1,000, 2,000, or 3,000.

It is especially suitable for use with telephonic detectors, which should have their natural period identical with that of the bar. A telephone so adjusted is shown.

Campbell's Vibration Galvanometer. (Fig. 37.)

("Phil. Mag.," Oct. 1907.)

An interesting example of a type of instrument which has been perfected owing to the demands for accuracy required in the measurements associated with telephonic and wireless apparatus. It is especially useful in the measurement by null methods of small inductances and capacities, replacing the telephone for many purposes, and, owing to its superior sensitivity it enables much greater accuracy to be attained.

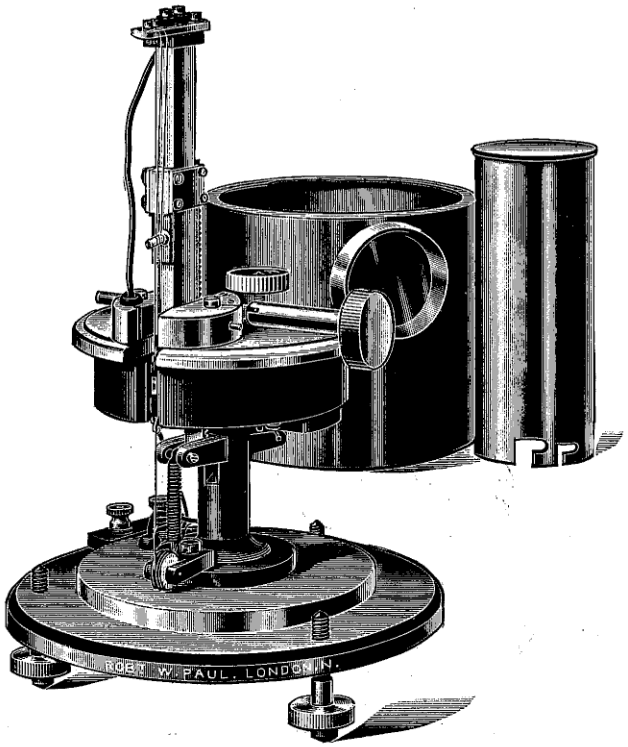


FIG. 37.

The instrument is "tuned" to have a natural period of vibration equal to that of the current in the circuit under test, and its sensitivity is dependent on the accuracy of tuning. It does not respond to other frequencies, and if other than a sine wave is used, it only takes account of the frequency to which it is tuned, so that the circuit may be considered to be traversed by a pure sine wave of this frequency.

It is of the moving coil type, with permanent or electromagnet, and, by altering the tension on the suspension, the instrument can be adjusted to resonate to any frequency, from 50 to 1,000, without removing the case.

An alternator, tuning fork, vibrating wire, or, for higher frequencies, a microphone hummer may be used as a source of supply.

With an effective resistance of 60 ohms at 100 cycles per second, the sensitivity is about 5 mm. at 1 M. for 1 micro-ampere.

Non-Inductive Decade Resistance Box. (Fig. 38.)

For accurate alternating current measurements the inductance and capacity must be reduced to the lowest possible.

In this box the higher resistances are woven wire gauze, and the lower resistances are of special construction.

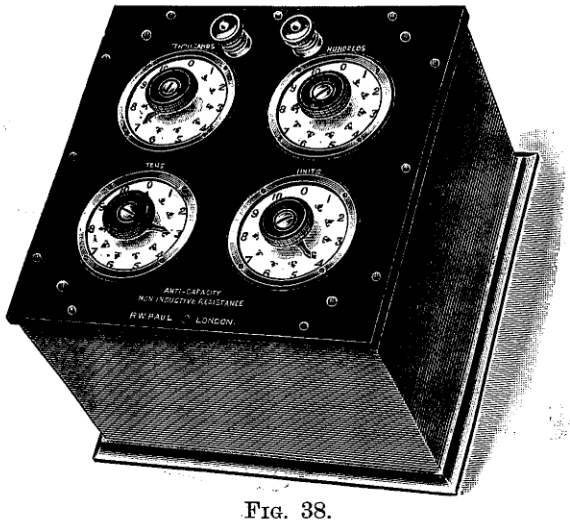


FIG. 38.

Universal Testing Key. (Fig. 39.)

A double key with upper and lower contacts, and an intermediate insulating position brought into action by ebonite cams.

The ebonite pillars are in pairs, so that there is no chance of working loose, and the key gives a rubbing action on the platinum contacts.

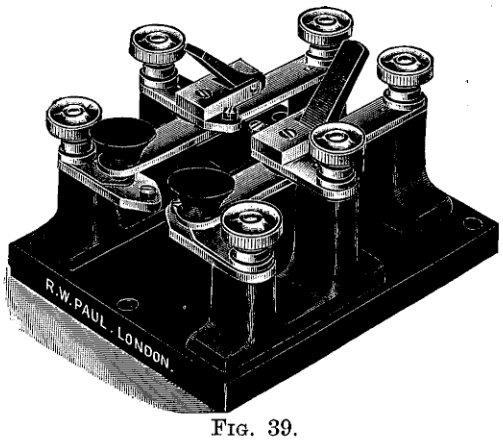


FIG. 39.

High Insulation Switch. (Fig. 40.)

A more convenient form than plug switches. The spring contacts are adjustable as to pressure by the central screw. The contacts can be easily cleaned, and have very low resistance. The central axis does not form a part of the circuit.

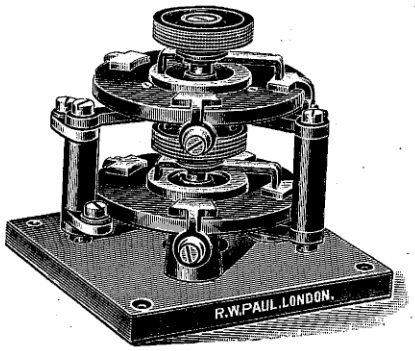


FIG. 40.

High Insulation Change-over or Reversing Switch. (Fig. 41.)

This compact switch is designed for use in fault localising tests for reversing the current, and as a double-pole change-over switch. The three positions of the switch are located by spring stops.

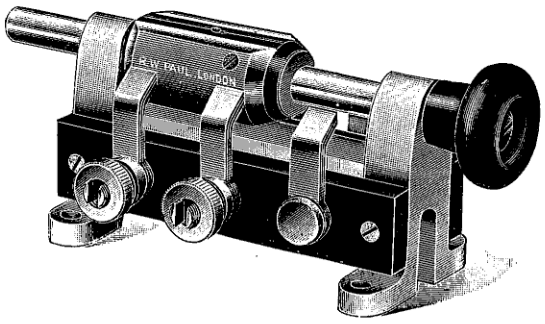


Fig. 41.

J. Pillischer, 88, *New Bond Street, London, W.*

Clinical Thermometers "Inaltérables."

These thermometers are constructed of a glass of such quality that any change of the reading due to the age of the thermometer is inappreciable.

The front of the thermometer is shaped so as to give a highly magnified image of the mercury column. To facilitate the reading a small parallelogram is engraved on the glass, and when, by rotating the thermometer, the mercury is seen in the centre of this, the image of it appears highly magnified.

Clinical Thermometers "Automatiques Inaltérables." (Fig. 1.)

This type possesses the same features as the previous one, but in addition it has a special arrangement for "setting" the mercury after taking a reading. Instead of shaking the thermometer somewhat violently, as is usually required, quite a different method is provided.

The end of the thermometer is formed into a second flat bulb which also contains mercury. To set the thermometer, this bulb is pressed between thumb and finger, and it is capable of being so compressed as to allow mercury to be forced along the thermometer tube sufficiently far as to push the registering thread back into the ordinary bulb, a small quantity of gas being left to act as a cushion between the two quantities of mercury to prevent their joining.

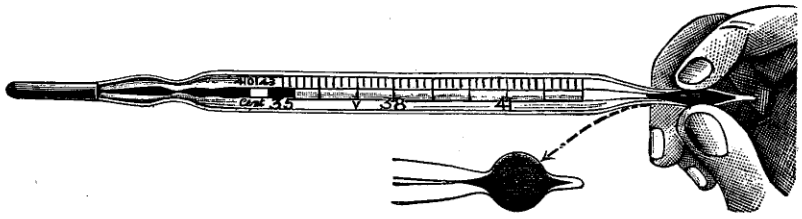


FIG. 1.

" Kosmos " Microscope.

Large stand of new form designed with a view to steadiness and accuracy of adjustments, especially adapted for bacteriological and biological work.

It has a graduated draw tube, a rack and pinion coarse adjustment and micrometer fine adjustment.

Mechanical stage and rotating plate with spring clamps. Substage with centering screws, iris diaphragm, parallel diaphragm with rack and pinion adjustment, adaptable for oblique illumination. Abbe condenser 1·40 N.A., and plane and concave mirrors adjustable in all directions.

Representative exhibit of astronomical, meteorological, surveying, and ophthalmic instruments. Among the latter are apparatus made to the designs of Juler, Dr. Lindsay Johnson, Morton, and Sir John Tweedy.

The Reflector Syndicate, *Grosvenor Mansions, Victoria Street, London, S.W.*

The exhibit consists of a collection of reflectors used chiefly for searchlight and other projection work. These are optically worked of either metal or glass, the special new feature being the deposition of gold on glass to form a parabolic gold mirror.

Light reflected from a gold coloured reflector is found to illuminate a distant object more clearly and to be more effective in thick and foggy weather. The probable reason for this is that the beam from a gold reflector contains a very high percentage of red and yellow rays which are least absorbed by the atmosphere. Another advantage of a gold mirror is the absence of white halos, and consequent deep shadows of objects close to the source of light. In other words, there is a softer and more even illumination of fore and back ground, and it is easier to distinguish colours such as a grey torpedo boat on a grey sea with a grey sky. Lastly, the gold is unaffected by chemical or climatic conditions.

A 24 in. diameter combination mirror is also shown, having gold and silver radial bands. The object is to combine the penetrative effect of the gold mirror with the dazzling effect of the white light.

A 24 in. metallic mirror is shown ; this has been electrolytically deposited on a silvered glass former. A structureless metallic mirror is thus obtained. These mirrors are afterwards coated with a deposit of palladium, which is very hard and does not tarnish. This particular mirror has been pierced with rifle shots.

A copper parabolic locomotive headlight for an American railroad is shown. This has also been electrolytically deposited.

Various samples of translucent and non-transparent glass are shown. The gold is chemically deposited on the glass, and viewed translucently has a delicate greenish tint, but the deposit is so fine as to give a gold mirror effect by reflected light.

Surface reflecting gold mirrors are also shown. The gold being deposited in a hard condition to permit of reasonable handling without damage to the surface.

Non-tarnishable palladium deposits on metallic mirrors as used for signal semaphore work.

Special Processes.

Samples of the deposition of copper on glass.

Samples of the deposition of palladium on glass. This process is being tried instead of silver for telescope and other astronomical reflectors. The surface is both hard and practically untarnishable. This deposit has also been satisfactorily tried on sextant and range-finding mirrors.

Messrs. W. F. Stanley & Co., Ltd., *Great Turnstile, Holborn, London, England.*

The special features of the instruments exhibited are the rigidity of the frames of the instruments, the machining, wherever possible, of combinations of parts from one casting or piece of metal,* and that the instruments are designed, as far as possible, for the particular work for which they are intended to be used.

The following are some of the instruments exhibited :—

1. *Large Geodetic Theodolite.* (Fig. 1.)

The uprights and centre are in one casting. The mechanical stage actuated by means of fine motion screws can readily be adjusted over any desired spot. The sliding movement being above the levelling screws, a lateral adjustment can be made without the necessity of re-levelling. The theodolite is fitted with micrometers in the place of verniers, it being estimated that the accuracy of reading obtained is about four times greater than with verniers. The theodolite is fitted with illuminated axis, spirit level, diagonal eyepiece, &c.

* As illustrating the large reduction in the number of parts of a modern theodolite as compared with an earlier model, it may be mentioned that the former now consists of 102 pieces, whereas the latter used to consist of 226 pieces.

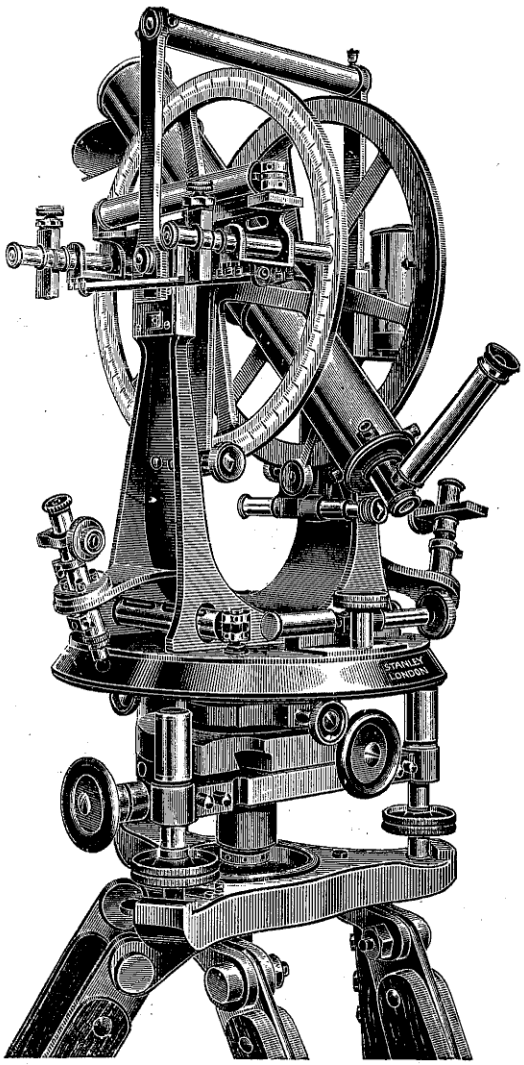


FIG. 1.

2. *Tacheometrical Theodolite with High Power Telescope.*
(Fig. 2.)

The increasing demand for high-power telescopes for tacheometrical work has necessitated the introduction of extended telescopes with larger object glasses. The "trumpet" extension is made of aluminium and, therefore, requires little balancing.

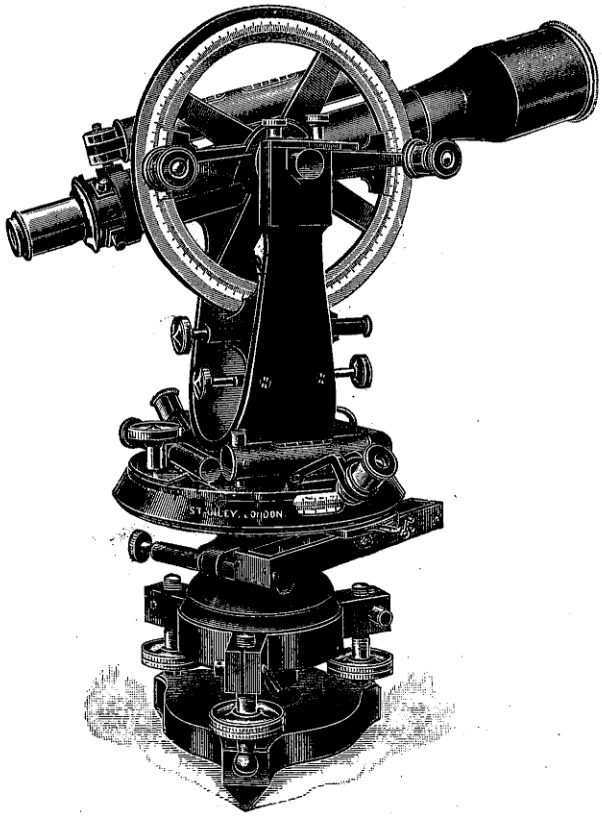


FIG. 2.

3. *Quick-Setting Theodolite.* (Fig. 3.)

This instrument is fitted with an improved form of ball joint, which gives all the advantages of the Hoffmann head combined with the tribrach system. By its use, the theodolite can be set up quickly; the arrangement also allows of a great range of adjustment, so that the instrument may be used on very uneven ground. It can be easily set up approximately level, and the parallel screws then used for a final adjustment.

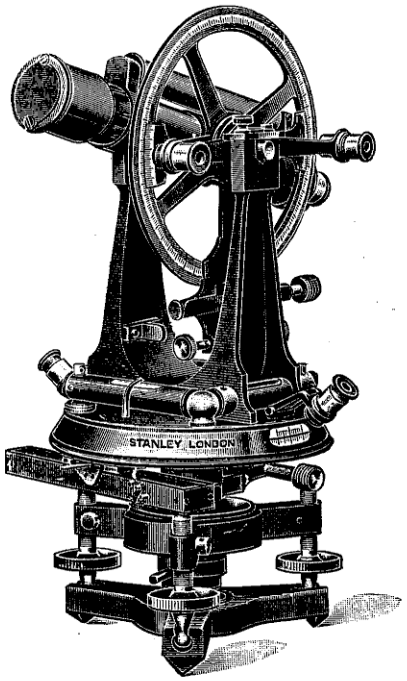


FIG. 3.

The Solar Attachment. (Fig. 4.)

The solar attachment enables the surveyor to establish the true meridian, to determine the correct latitude, and to obtain the true time nearly. It consists of the polar axis, which is fixed in the centre of the transverse axis of the telescope perpen-

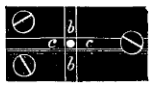
dicularly to its optical axis. The transit theodolite is particularly suitable for forming a base for the solar attachment, as it contains many of the necessary parts, as follows :—

Suitable levelling adjustment.

Divided horizontal limb, with clamp and fine adjustments, which, when levelled, moves in the plane of the horizon.

A good telescope, with vertical divided circle and clamp, and fine adjustment, which moves in the plane of the meridian.

The declination arc, which revolves upon and around the polar axis, carries the hour circle, which reads to a fixed index, and also an arm centred to move radially over the declination arc. This arm carries a vernier, reading to divisions upon the declination arc, and has a clamp and fine adjustment, and also two bracket pieces, one at either end ; each bracket piece carries a lens and a little silver plate, either lens throwing the sun's image upon the silver plate of the opposite bracket. Upon the silver plates four lines are drawn : two vertical and two horizontal, and are so spaced that the square formed by their intersection just includes the image of the sun thrown from the solar lens opposite to it. The vertical lines are called the hour lines, as the image of the sun is kept or brought between them for ascertaining or setting time, and the horizontal lines are called the equatorial lines, as the image of the sun is kept between them only when the polar axis is placed in the plane of the meridian. The figure below illustrates the silver



reflector or solar screen with the image of the sun in the square, b.b. being the hour lines and c.c. the equatorial lines.

The whole of this apparatus revolving upon the polar axis is provided with a clamp and tangent for fine adjustment, which assists greatly in setting the instrument, this being a refinement no other make of solar attachment is provided with.

The solar attachment possesses important advantages over the magnetic needle when used for surveys, as lines can be run and angles measured without regard to the diurnal variation or

the effect of local attraction, and the bearings being taken from the true meridian remain unchanged for all time.

To use the instrument for this purpose, the theodolite is first set up as for ordinary surveying, the latitude of the place where the instrument is being used being set off on the ordinary vertical arc of theodolite, and the declination for the given day

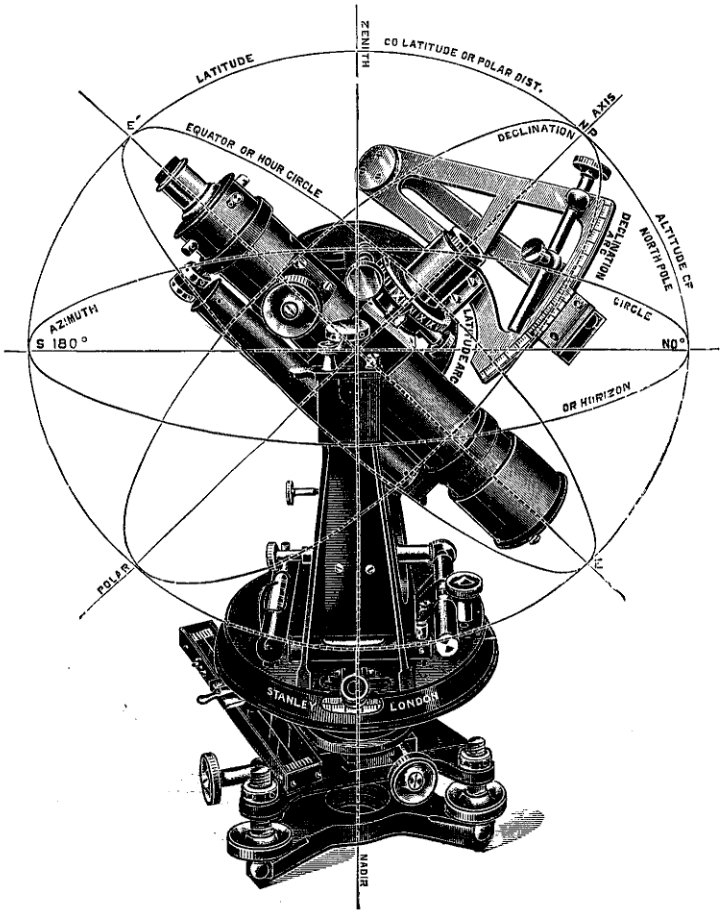


FIG. 4.

and hour upon the declination arc. The horizontal limb of the theodolite is then clamped at zero, and the telescope pointed approximately north by the compass, having previously unclamped the lower clamp so that the horizontal arm revolves with the telescope. The solar lens on the arm of declination arc is now pointed towards the sun, and then by taking the declination arc in one hand and the horizontal limb of the theodolite in the other, these are moved slightly backwards and forwards, at the same time observing the sun's image on the silver plate and solar screen. The horizontal plates of the theodolite are moved until the position is found in which the revolving arm of the solar attachment will revolve keeping the sun's image between the equatorial lines upon the solar screen the whole of their length. When this is found, the telescope is then in the true meridian, as is also the zero of the horizontal limb.

When the solar attachment is accurately adjusted as above, the image of the sun cannot be brought between the equatorial lines until the polar axis is placed in the plane of the meridian of the place, and in a position parallel with the axis of the earth. The slightest deviation from this position is detected by the instrument.

From the position of the sun in the solar system is thus obtained a direction absolutely unchangeable, from which to run lines or measure horizontal angles with a minuteness and accuracy unattainable with the best magnetic compass, and unaffected by extraneous attraction of any kind, and the more perfect horizon obtained with a theodolite as a base, and the use of the telescope in place of sights renders the solar theodolite far more accurate than the ordinary solar compass.

If a magnifier is used to observe the sun's image upon the solar screen, an error of twenty seconds in the direction of the true meridian can be easily detected.

By means of the solar attachment, also, the latitude and mean time at any point may be readily and accurately obtained.

4. *Tunnelling Theodolite.* (Fig. 5.)

This theodolite is specially made for underground work. It is constructed as compactly as possible, allowing the telescope to transit. The vertical axis is made hollow, so that an angle of about 10° may be read directly below the vertical. This is useful in transferring lines from the surface of the ground to a point at the foot of a shaft, and also for plumbing. The hollow centre is supported upon a sliding fitting so that it may be displaced 30 mm. about the centre of the tripod, and clamped to its position.

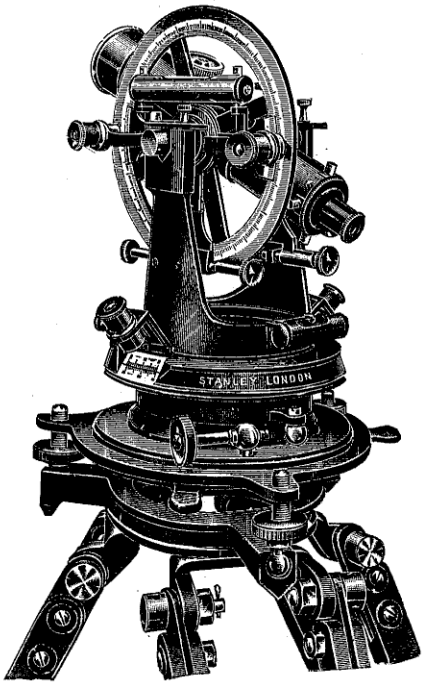


FIG. 5.

5. *Stanley's Dunbar-Scott Auxiliary Top and Side Telescope.* (Figs. 6 and 7.)

A useful attachment to a theodolite for mine surveying work. The particular feature is the interchangeability of the auxiliary telescope, which can be quickly placed in either the top or side positions illustrated. The auxiliary telescope is fitted with a centre that may be screwed to the threaded extension of either the transverse axis or the vertical pillars of the main telescope. In either position it can be ranged quickly

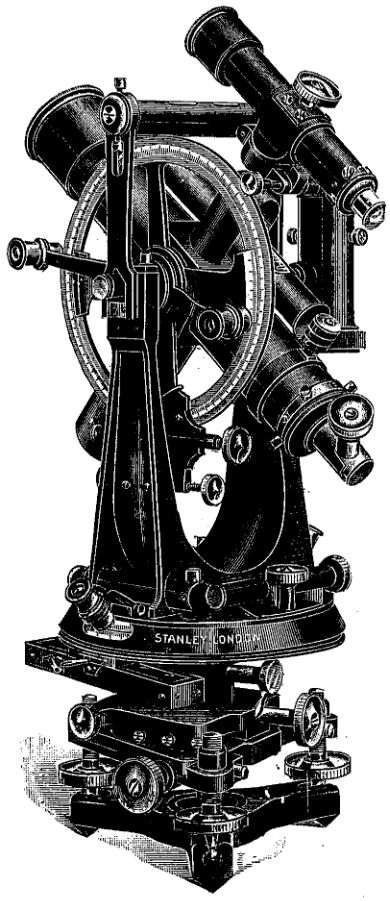


FIG. 6. Telescope on top.

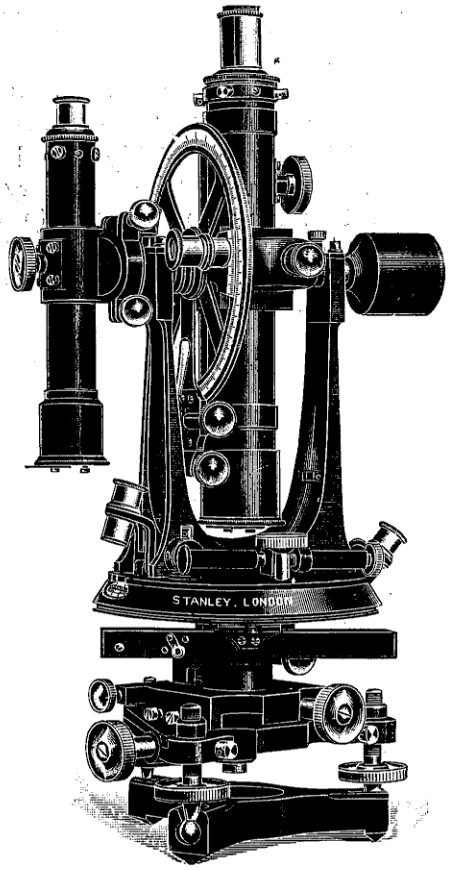


FIG. 7. Telescope at side.

into alignment with the main telescope by two opposing screws. The diaphragm has one web only, so placed that it is vertical when on the top and horizontal when at the side. The observation of steep horizontal angles is made with the auxiliary on the top, and of precipitous vertical angles with the auxiliary on the side. A counter-balance is provided, so that there is no strain upon the instrument.

6. *New Engineer's Dumpy Level.* (Fig. 8.)

In this level the centre is cast in one piece with, and directly upon, the telescope body and object end. The cast telescope body is cored out to a suitable thickness, so that, although of much greater strength and rigidity, it does not weigh as much as the old form of tubular body with its mounting. With a comparatively small amount of care the instrument should remain in adjustment for a lifetime. The pinion is fitted to the side of the outer cast body. The level is fitted with clamp and tangent adjustment, tribrach levelling, and locking plate.

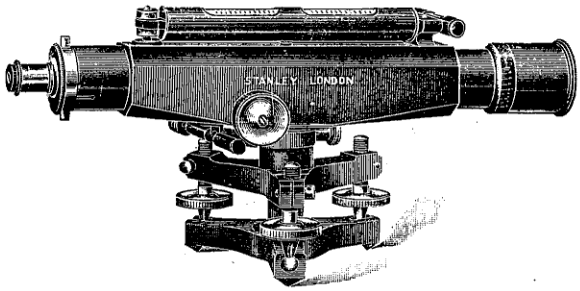


FIG. 8.

7. *Quick-setting-up Level.* (Fig. 9.)

This level is fitted with a similar ball joint arrangement to that fitted to the quick-setting theodolite (*see* Fig. 3), enabling the instrument to be levelled rapidly when working over rough ground.

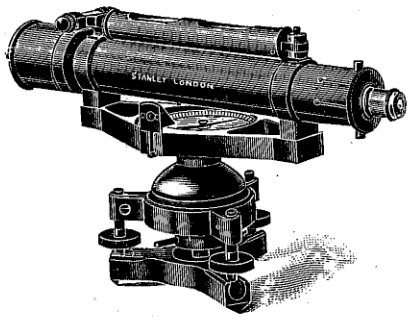


FIG. 9.

8. *Pocket Mine Transit.* (Fig. 10.)

This instrument is an alt-azimuth for taking horizontal and vertical angles and for use as a clinometer. By means of a mirror the observer can take readings of the compass needle simultaneously with sights above and below the horizontal. A screw adjustment is fitted to the horizontal circle in order that it may be adjusted to the magnetic deviation of the locality.

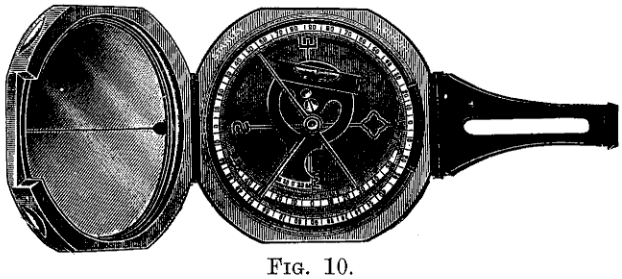


Fig. 10.

9. *Combined Mining Dial, Level, and Theodolite.* (Fig. 11.)

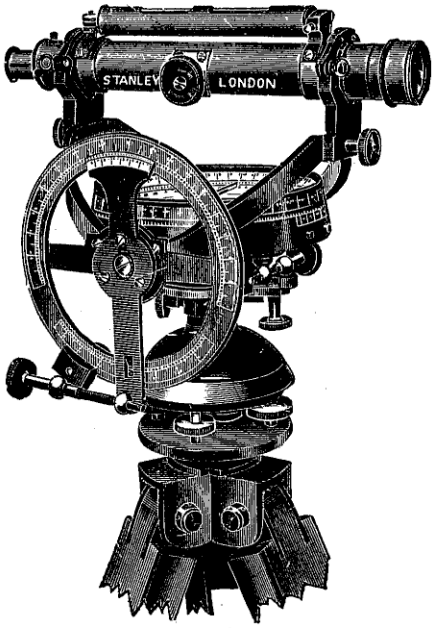


Fig. 11.

The chief feature of this instrument is the fact that the frame supporting the telescope is cranked so that the telescope can be moved through 90° either side of the vertical, thus enabling a bearing to be taken of any object upon the surface from the top of the shaft and a line sighted at the bottom of the shaft in the same vertical plane with it, without changing the horizontal adjustment of the instrument. The vertical arc is divided to read single minutes. The telescope is fitted with stadia points for reading distances without the use of a chain.

10. *Combined Altitude Instrument and Prismatic Compass.* (Fig. 12.)

With this instrument altitudes, levels, horizontal angles, compass bearings, and rise and fall of any surface in degrees or millimetres per metre can be obtained. The diameters of the compass dial and altitude circle are 63 mm., both being divided into half degrees. The altitude circle has also a scale of rise and fall in inches per yard or millimetres per metre.

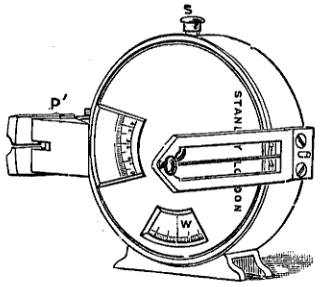


FIG. 12.

11. *Improved Sight or Surveying Compass and Clinometer.* (Fig. 13.)

This instrument is fitted with simple and yet efficient sights. To convert the instrument from a surveying compass into a clinometer for taking vertical angles or levels it is only necessary to move the sights through 90°, when both sights and compass can be used for levels or inclination.

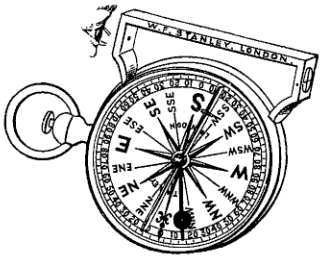


FIG. 13.

12. *Prismatic Compasses.* (Fig. 14.)

Of various sizes, ranging from 60 mm. to 150 mm. in diameter. They are fitted with sapphire centres, aluminium compass rings, &c.

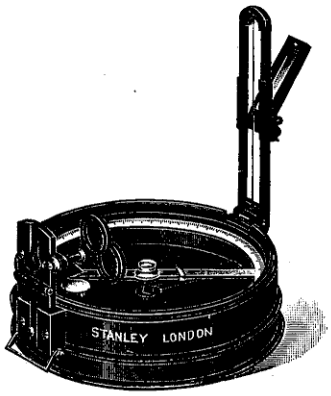


FIG. 14.

13. *Aneroid Barometers.* (Fig. 15.)

These instruments have been specially designed for accuracy of reading, the end of the aneroid hand carrying a small silvered plate on which a line is engraved, this line being in the same plane as the divisions on the dial. These aneroids are adjusted so as to indicate clearly a difference in altitude of one metre.

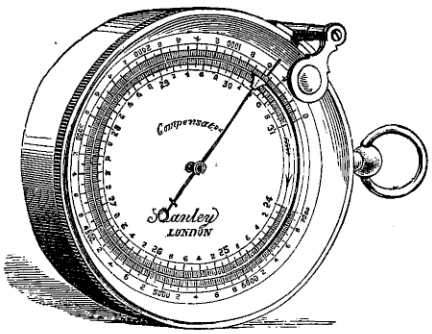


FIG. 15.

14. *Sextants.* (Fig. 16.)

Of the type used on H.M.S. Training Vessel "Britannia." 165 mm. arm divided on silver to 120° of arc, reading by means of vernier to 10 seconds.

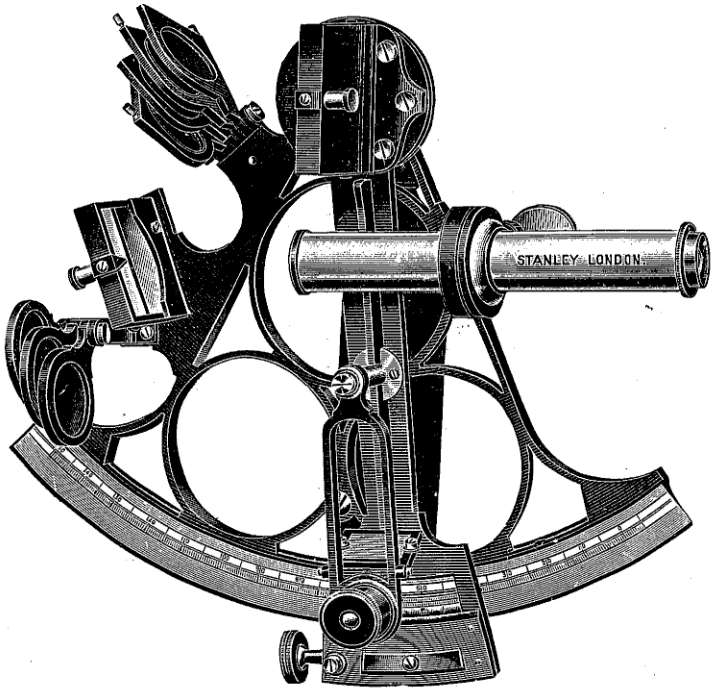


FIG. 16.

N 2

15. *Portable Ventilation Anemometer.* (Fig. 17.)

In this small fan type of anemometer the registering apparatus is placed in a separate chamber on the same plane as the fan in order that there may be no obstruction to the passage of the air past the fan. The instrument records in metres the quantity of air that has passed through the fan. A table of corrections is always supplied with these instruments.

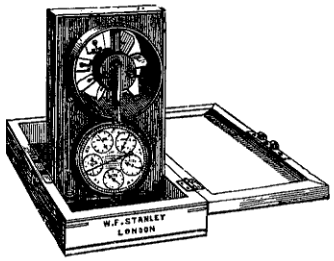


FIG. 17.

16. *Eidograph.* (Fig. 18.)

Although this instrument was invented by Prof. Willis so long ago as 1821, it is not extensively used. Its range of working power is somewhat limited, since it is not really effective for making a reduction beyond one-third of the original size. Within these limits, however, it reduces conveniently and exactly and in any proportion. The point of support is a pin supported by a heavy foot, the whole instrument being free to move round this pin. A socket which accurately fits the pin slides upon the centre beam of the instrument, at any part of which it can be clamped. Under the ends of the beam are placed a pair of equal wheels connected by two steel bands, the tension of which can be adjusted. Under each of these wheels is a box, through which one of the arms of the instrument slides and can be clamped where required. These arms are graduated, and one of them carries a tracing point and the other a pencil. The tracing point being moved over any drawing, the pencil point makes a copy of the drawing in the proportion for which the instrument has been set.

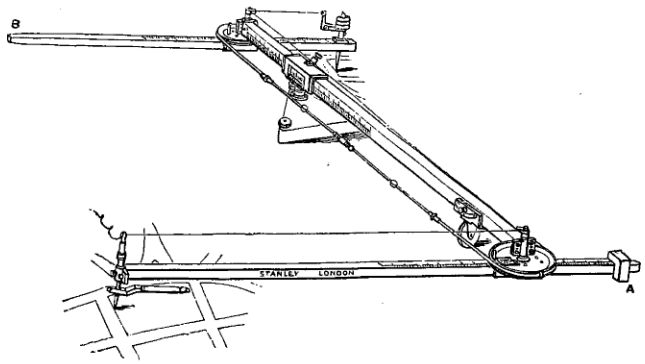


FIG. 18.

17. *Prof. Fuller's Calculating Slide Rule.* (Fig. 19.)

This is a spiral slide rule equal to a slide rule 25 metres long; it consists of a cylinder on which a printed scale is placed, the divisions being arranged spirally round the cylinder. This cylinder slides on a tube, upon which it can also be turned, and in this way brought to any position in relation to a pointer fixed to one end of the tube. Another pointer is carried by a smaller tube, which slides and turns in the tube on which the cylinder is carried. The rule will give logarithms, multiplication, division, proportion, &c., to four or five figures.

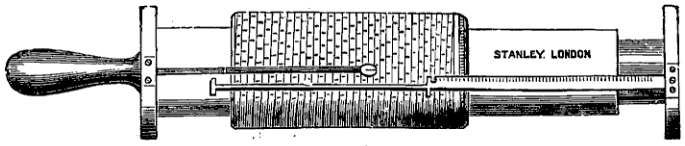


FIG. 19.

Drawing Instruments.

A large variety of drawing instruments of every kind are exhibited.

J. H. Steward, 406, *Strand, and* 457, *West Strand, London, England. Established* 1852.

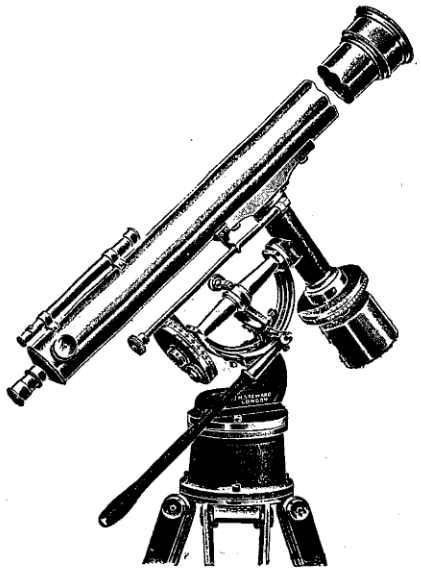
1. *Astronomical Refracting Telescope.*

Equatorially mounted on cast-iron pedestal. Telescope of brass. Object-glass, 75 mm. aperture ; 107 cm. focal length. Two astronomical eyepieces with tinted glass heads for solar observations. Rackwork focussing adjustment. Supplementary Star Finding Telescope.—Equatorial mounting, with polar altitude adjustable from 0° to 70°. Right ascension and declination circles, 10 cm. diameter, reading by verniers to 20 seconds and 5 minutes respectively. Levelling circle to right ascension, with rack and pinion adjustment.

The telescope is driven by clockwork, and can also be driven by a handle with Hook's joint from the eye end. Levelling screws are fitted to the base of the metal head, and there are a few degrees of adjustment in azimuth.

2. *Astronomical Refracting Telescope.*

As described above. Mounted on an oak tripod, and driven entirely by hand from the eye end (Fig. 1). A wooden case is supplied to contain the telescope and eyepieces.



Astronomical Telescope on Oak Tripod. FIG. 1.

3. *The "Lord Bury" Hand Telescope.*

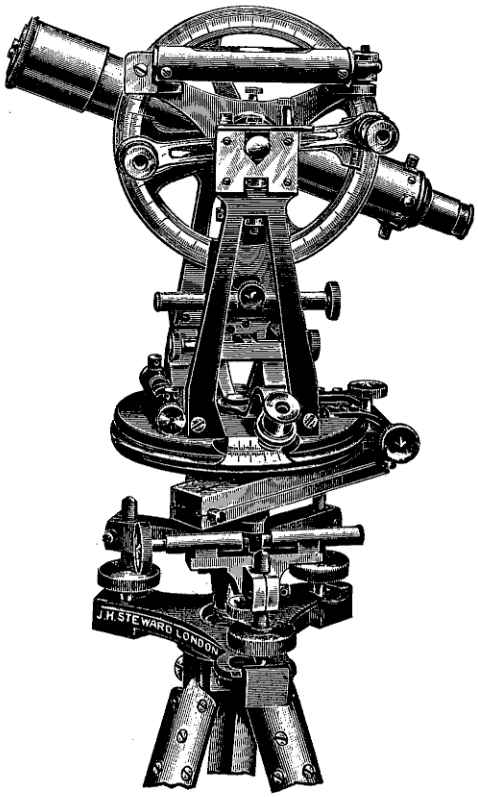
Especially suitable for sportsmen and military men. Three draw tubes and bronzed brass mounts. Length when fully extended 79 cm., and when closed 27 cm. Object-glass, 4 cm. diameter, protected by a sliding shade and metal cap. Adjustable eyepiece, by means of which the magnifying power can be varied from 25 to 35 diameters. The advantage of this adjustment is that the power can be so regulated that the telescope will perform to the best advantage in the atmosphere prevailing at the time. A leather case with shoulder strap is provided with the telescope.

4. *Marine Telescopes.*

Of wide angular field. One draw tube for focussing; the object-glass is protected from sun or rain by a metal shade. Nickel-plated mounts. Metal body covered with leather.

5. *Transit Theodolite.* (Fig. 2.)

Horizontal and vertical circles 15 cm. in diameter and divided on solid silver. Opposite verniers to both circles reading to 20 seconds. The horizontal circle is completely covered and protected by a top plate with the exception of the sections opposite the verniers. Slow motions with tangent screws and clamps are fitted to vertical and horizontal circles, and a third slow motion with tangent screw and clamp is attached to the pedestal. The tangent screws of slow motions work against reaction springs. The telescope reverses in its standards and transits. A trough compass is fitted to the under side of horizontal limb and is detachable. The principal spirit level is attached to the vernier arm of the vertical circle, and two spirit levels at right angles are attached to the horizontal limb. Levelling head with three screws and locking plate. Centering head to tripod, which is fitted with adjustable legs.



Transit Theodolite. FIG. 2.

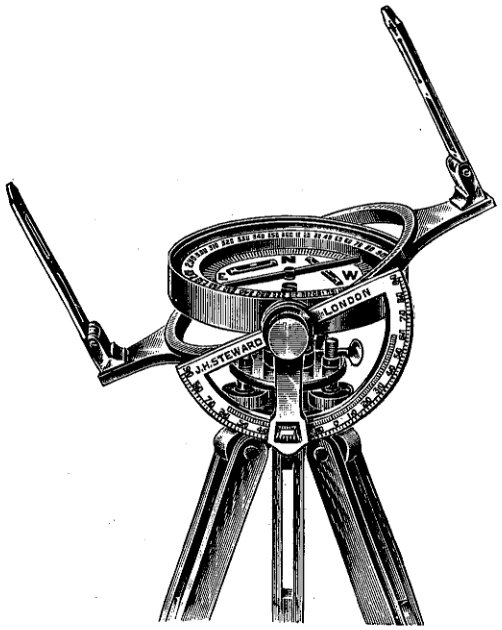
6. *Engineer's Dumpy Level.*

With high and low power inverting eyepieces, cross bubble, compass with graduated floating ring and reading microscope, three levelling screws, and locking plate.

7. *Hedley-Steward Miner's Dial.* (Fig. 3.)

With telescope for surface surveying and double sights for underground work. The telescope is reversible in its standards and can be entirely removed and replaced by the double sights. The swinging frame enables inclines and compass bearings to

be taken simultaneously. The horizontal circle reads to three minutes by vernier and has a concealed rack adjustment for rapid dialling. The swinging frame and bottom plates can be locked at 360° for converting the instrument to a plain dial. Vertical arc attached below the level of compass and reading to half degrees. Metal head with parallel plates and four levelling screws, and clamp to horizontal motion.



Hedley Steward Miners' Dial with Double Sights. FIG. 3.

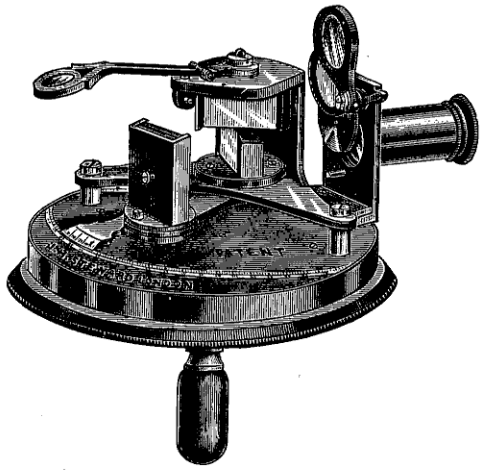
8. *Wide Angle Pocket Sextant.* (Fig. 4.)

Designed by Mr. John Blakesley, for measuring angles from 0° to 180°, and without error from parallax. The arc, which has a radius of 64 mm. is divided on solid silver and reads by vernier to one minute. The sextant is fitted with an erecting telescope and with a plain aperture sight and tinted glasses. It is furnished also with two index mirrors, mounted on a common vertical axis, the upper mirror being fixed, and the lower one attached to, and moving with the vernier arm by rack and pinion adjustment. The horizon mirror which is

common to the two index mirrors, and the sighting telescope are mounted on an arm, which moves about the same axis as that of the lower index mirror. Thus the horizon mirror in all positions reflects the axis of the index mirror to the eye. If the horizon mirror is placed as far towards the zero end of the scale as it will go, this position will be found convenient for observing all angles up to about 70°, the rays from both objects passing to one side of the horizon mirror. For greater angles, the horizon mirror is turned through an angle less by about 20° than that estimated for the new angle, so that it avoids the paths of the observed rays, which now pass on different sides of the horizon mirror.

Each line of vision is reflected from its own index mirror and the horizon mirror, and the divergence of the lines of vision is measured by the angle between the two index mirrors. With this instrument the parallax possible is negligibly small.

The instrument is useful for use in open country and for roughly taking altitudes.

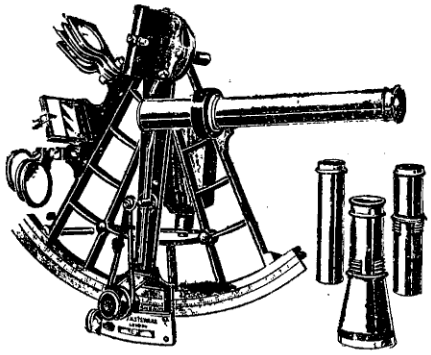


Wide Angle Pocket Sextant. Fig. 4.

9. *Nautical Sextant.* (Fig. 5.)

Brazed metal frame of triangle pattern giving increased rigidity. Arc 185 mm. radius divided on silver and reading by vernier to 10 seconds. Star telescope. Inverting telescope

with high and low power eyepieces. Tinted shades for eyepieces and to index and horizon mirrors.



Nautical Sextant. FIG. 5.

10. *The Steward Pocket Surveying Telemeter.* (Fig. 6.)

This instrument is especially useful when a preliminary survey has to be made in a short space of time. The telemeter is designed to measure the two angles at the extremities of a base of definite length, forming a triangle with the object of which the range is required. The range is read directly on the graduated scale in terms of units of the base, so that any system of measurement may be employed. By making the unit of measurement either short or long, distances of any length can be determined. The scale of distances is computed for a normal base of 20 units, and is figured at every tenth division from 200 to 1,000, each division representing 10 units of distance. The accuracy of the indications is assured by empirically graduating each instrument. The proportion that the base bears to the distance decreases from $\frac{1}{10}$ to $\frac{1}{50}$, as the range

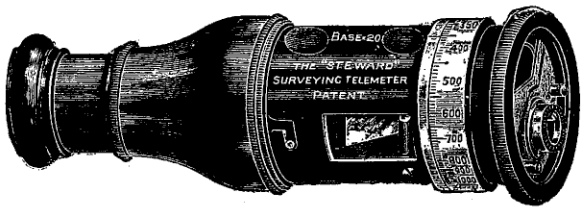


FIG. 6.

increases. In certain operations it may be convenient to employ a base of constant ratio to the distance, and the telemeter is adapted for this system of measurement.

The telemeter is provided with a telescope of moderate power, and the mechanical construction is so designed that it cannot easily become deranged.

The size of the telemeter is 107 × 37 mm. and it is manipulated by one observer.

11. *The "Steward" Hypsometric Aneroid.* (Fig. 7.)

FIG. 7.

This instrument has been designed to overcome the objection to the ordinary type of aneroid, in which an altitude scale is attached, that the zero of the altitude scale cannot be shifted relatively to the barometric scale without introducing an error. In this aneroid, by means of a compensation arrangement, the barometric scale expands as the pressure decreases, and thus the altitude scale, which is divided into equal divisions to the left for "ascents" and to the right for "descents," can be shifted relatively to the barometric scale. The graduations in the

altitude scale are so arranged that with a scale extending up to 3,000 metres, differences as small as two metres can be read without the use of a vernier. The aneroid is read and set without removing it from its case, and the altitude scale automatically locks so that it cannot get shifted during transit. A small swing thermometer, for ascertaining the air temperature, is carried in the pocket at the back of the case. The altitude scale of the aneroid being computed for the weight of air at a given temperature which is noted on the dial of the instrument, a simple correction should be made, when the temperature at the time of observation differs from this value ; printed instructions for doing this are attached to the leather case. The diameter of the dial is 82 mm. which admits of an open scale.

12. *Barograph.*

A self-recording aneroid barometer, giving a continuous record of atmospheric pressure. The instrument consists of an aneroid movement, which is multiplied by a system of levers, and communicated to the pen which traces an ink line on the chart.

13. *Luminous Magnetic Compasses.* (Fig. 8.)

These compasses have been designed more particularly for military purposes. The dials and direction pointers are coated with a preparation, which on exposure to a bright light becomes luminous. The luminosity is retained for some hours, and is sufficiently brilliant to enable a person to march on a bearing at night time, and at the same time is not brilliant enough to betray his position. The mechanical construction permits bearings to be observed by day or night. Two sights are sometimes attached to the compass and serve for taking bearings, and for rapid field sketching. Fig. 9 illustrates a luminous magnetic compass fitted with a prismatic back-sight and a line fore-sight.

Luminous Prismatic Compass. FIG. 8.

14. *Artillery Clinometer.*

For rapidly measuring angles of sight for field artillery. The instrument is made to fit on to a tripod, and consists of a telescope, with a magnifying power of 6, and an angular field of 5 degrees, on the upper surface of which a clinometer and level are attached. The scales representing the angles of depression and elevation read to one minute on a graduated head.

15. *The "Steward" Reflecting Level and Clinometer.*

On Abney's principle. Arc divided to degrees and reading by vernier to 10 minutes. Supplemental scale giving ratio to horizontal of rise or fall of gradient. Quick motion and slow motion by tangent screw.

16. *Heliograph.* (Fig. 9.)

For telegraphing messages on the Morse system by intermittently flashing the sun's rays. The flashes can be seen a distance of 110 kilometres.

The signalling mirror is mounted in a metal frame furnished with trunions which rest in bearings on the supporting arms. By means of suitable mechanism a slow motion in a vertical or horizontal direction can be communicated to the mirror so as to counteract the apparent motion of the sun in azimuth and in altitude. A sending key, by means of which motion is imparted to the mirror, is connected to a vertical rod which is attached to the rim of the mirror. A sighting vane is supplied for use when the sun is in the same direction as the distant station. When the sun and the distant station are in opposite directions a duplex mirror is substituted for the sighting vane. Figure 10 illustrates the heliograph with the duplex mirror in use, the sighting vane being shown separately underneath. The heliograph is mounted on a firm mahogany tripod, and when dismounted, it packs into a leather case with shoulder strap and this also contains spare mirrors and spare parts, and tools. The tripod is carried separately slung across the shoulders. The mirrors are 125 mm. in diameter.

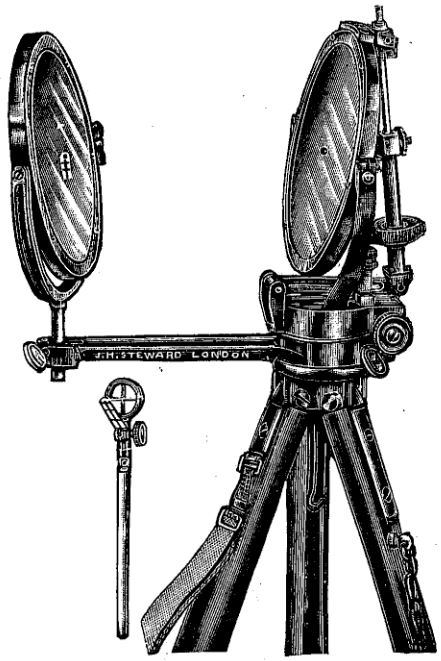


FIG. 9.

17. *Refractometers for Solids and Liquids.*

These instruments have been designed by Dr. G. F. Herbert Smith, M.A., D.Sc., of the British Museum, for the identification of substances by a measurement of their refractive indices, on the principle of total-reflexion. In the yellow light of a sodium flame the boundary between the light and dark fields is sharply defined. Two types :—

(1) *Refractometer for Solids.* (Fig. 10).—The solid, *e.g.*, a faceted gem stone, should have at least one flat surface, and is placed on the glass. The range extends from 1·300 to 1·795, the second decimal place being read direct from the scale, and the third by estimation. No calculation is required. A drop of methylene iodide removes the air-film under the gem. By rotating a doubly refractive stone, so that one flat surface remains in contact with the glass of the refractometer the amount of double refraction may be measured. The light enters from below. Gem-stones may be identified with unfailing certainty and there is no necessity to remove them from their setting.

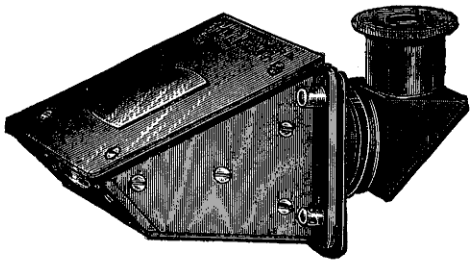


FIG. 10.

(2) *Refractometers for Liquids.*—Liquids require a refractometer of higher refinement than solids. In these instruments the scale reads directly to the third place of decimals, and the fourth is found by estimation. The range is selected to suit various classes of liquids. The temperature is controlled by a water jacket to which a small thermometer is attached. The thickness of the liquid-film is controlled by a screw to secure the best definition of the shadow-edge. With white light the shadow-edges are coloured, but their definition may be much improved by the introduction of the red glass disc.

18. *Davenport-Steward Electric Arc Lamp.*

For projection lanterns, cinematograph, and photomicrography. It can be used on any current, continuous or alternating. It will work with small carbons on a 7 to 10 ampere current; or, with larger carbons, up to 15 to 20 amperes. A special feature is the mechanical adjustment to the top carbon holder facilitating a quick adjustment of the crater when the position of the lamp, or the nature of the current, is varied.

James Swift and Son, 81, *Tottenham Court Road, London, W.*

Paragon Microscope.

This is a large binocular microscope, with complete mechanical adjustments. As the usual form of knuckle axis-joint is not used, the centre of gravity does not change when the instrument is swung from the vertical to the horizontal position. The graduation of the circular stage is carried to 5′, while the cross movements of its mechanical adjustments are divided to read to 0·01 in. (0·25 mm.). The fine adjustment is graduated to read to 0·0001 in. (0·0025 mm.), and is operated by two milled heads, one on either side of the limb. The Centering Substage is actuated by a rack and pinion motion, and carries an achromatic condenser, N.A. 1·0, iris diaphragm, polariser, mica undulation film, and a red and a blue selenite in rotating geared cells. All these accessories may be used separately, or together, or can be swung out of the optic axis. An analyser is mounted in the body of the microscope, immediately above the binocular prism, and works with the polariser.

Dick Mineralogical Microscopes.

This type of mineralogical microscope differs from all other patterns in having a fixed stage and simultaneously rotating prisms, so that, instead of turning the object between stationary prisms, the polariser, analyser and ocular are made to revolve together about the optic axis. By this arrangement the spider lines in the ocular turn on the object which remains stationary, so that the most minute specimen is maintained in position through an entire revolution. Thus the necessity of delicate centering adjustments, to secure absolute concentricity of rotation, is altogether obviated. Both polariser and analyser rotate independently in their divided fittings, and click when they are crossed. A divided circle revolves with the prisms to indicate the angle of rotation. Two focussing Bertrand lenses are fitted through the optical tube, while dustproof slots are provided for the reception of compensators. The various models exhibited differ chiefly in the arrangement of the substage convergent systems.

Dick Mineralogical Microscope, No. 427. (Fig. 1.)

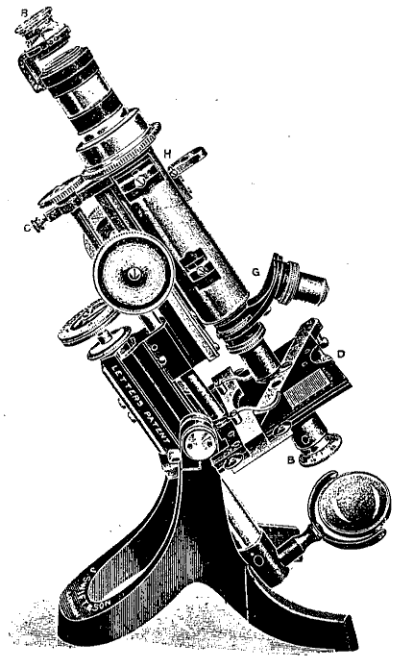


FIG. 1.

This instrument is as described above. It is fitted with an uncorrected high power convergent system, mounted immediately above the polariser. The hemispherical top lens of this system may be removed by the action of a slide running through the stage. In this model the fine adjustment reads to 0·001 mm.

Large Model Dick Mineralogical Microscope, No. 433.

This instrument is similar to the preceding, but is larger in all dimensions. The fine adjustment reads to 0·0002 mm. It is fitted with an achromatic convergent system, N.A. 1·0., dry, and N.A. 1·2, immersed. The lenses of the system are set in a mount which allows of their being raised or lowered for focussing by means of an original mechanical arrangement.

Immediately below the optical system is an iris diaphragm which is of great use for differentiating certain objects. The polariser is mounted independently, so that it can be swung out of the optic axis.

Improved Dick Mineralogical Microscope, No. 437. (Fig. 2.)

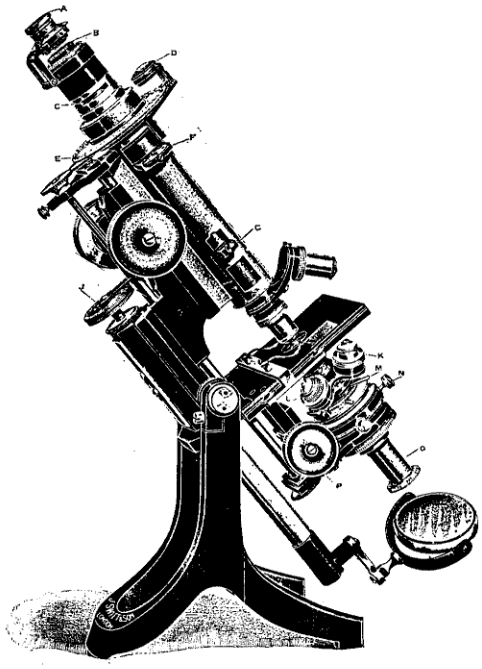


Fig. 2.

This model is similar in size and general construction to the preceding, but it is provided with a rack and pinion focussing and centering substage. This substage carries a triple revolver for taking three different condensers, an iris diaphragm and rotating throw-out, cell for stops, &c.

Petros Mineralogical Microscope. (Fig. 3.)

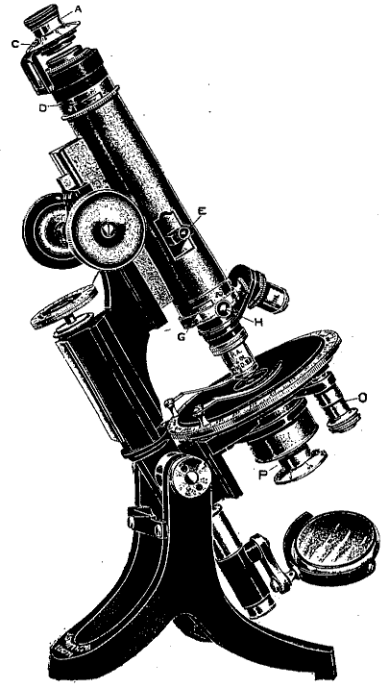


FIG. 3.

The coarse adjustment is by spiral rack and pinion. The milled head of the fine adjustment is divided to read to 0·01 mm. The stage rotation reads against a vernier to 5′. Dustproof slots for the reception of compensators are provided through the optical tube immediately above the nosepiece, and through the cross-webbed ocular. The analyser is fitted over the ocular as in the " Dick " instruments. The prism is of the Glan-Thompson type with an aperture of 30°. The degree of rotation is read from a divided circle which clicks at zero. The whole of this apparatus can be swung aside out of the optic axis. A convergent system, of which the top hemispherical lens can be removed, is mounted with an iris diaphragm on a lateral screw focussing adjustment. When brought down to the lowest point, the convergent system and

iris diaphragm can be swung out of the optic axis. The polariser is mounted independently on a swing-out arm. The lower flange of its mount is divided and clicks at zero. A centering nosepiece of very rigid design is fitted. Sliding through the optical tube is a focussing Bertrand lens.

Survey Mineralogical Microscope. (Fig. 4.)

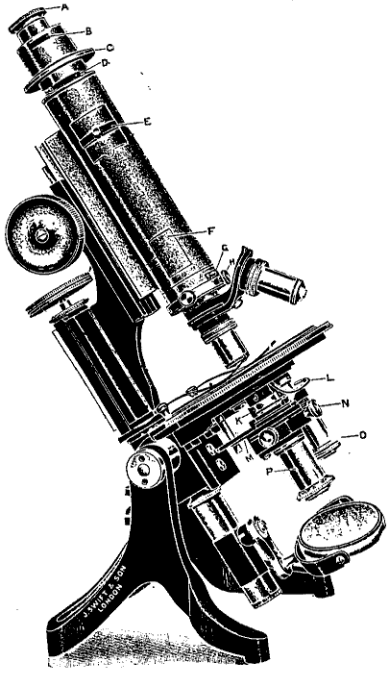


Fig. 4.

The coarse adjustment is by spiral rack and pinion. The fine adjustment milled head is divided to read to 0·01 mm. The stage rotation reads against a vernier to 5′. Dustproof slots for the reception of compensators are provided immediately above the nosepiece, through the cross-webbed ocular and through the mounting of the top analyser. Both analyser prisms are of the Glan-Thompson type, having an aperture of 30°. Through the optical tube is fitted a focussing Bertrand

lens. The centering nosepiece of this instrument is designed so as to be very steady. Below the stage is an achromatic convergent system, N.A. 1·0, mounted in an iris diaphragm provided with a rotating swing-out cell for carrying gypsum plates, oblique light stops, &c. The convergent system and diaphragm have centering screws. The hemispherical lens of the convergent system can be slipped out of the optic axis when light of less convergence is required. The polariser, which is a large Nicol prism, is mounted independently on an eccentric arm. It is divided on the lower edge of its rotating mount. The whole of the substage apparatus can be swung out of the optic axis, and is focussed by means of a quick-acting lateral screw.

Small Stage Goniometer. (Fig. 5.)

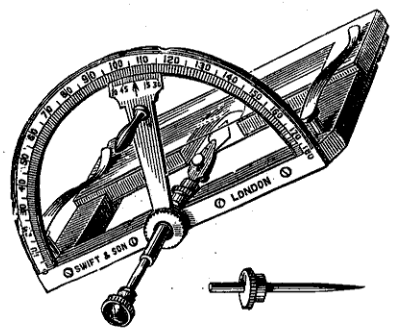


FIG. 5.

This instrument is clamped on the stage of a mineralogical miscroscope for determining the separation of the optic axes of bi-axial crystals, &c. It consists, essentially, of a pair of forceps or a needle point attached to a vernier, reading to 5′, which moves round a divided semi-circle. The small mineral section, or cleaving, is held either in the forceps or with a touch of wax on the needle point. The forceps and point are interchangeable. The instrument is so constructed that the readings may be made with the mineral either dry or immersed.

Large Stage Goniometer. (Fig. 6.)

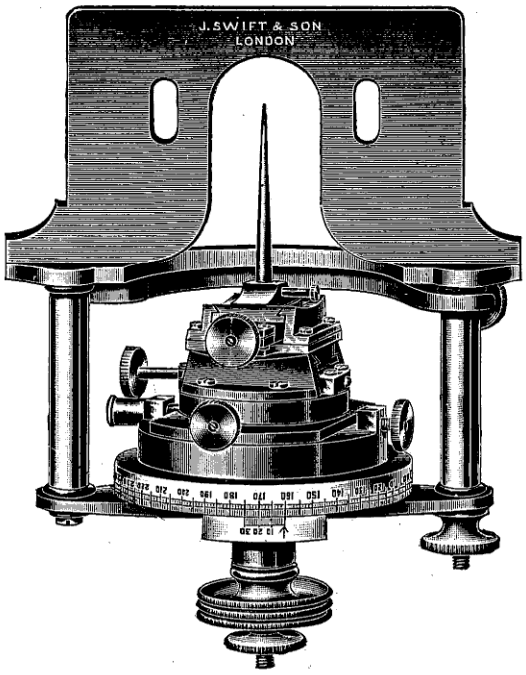


FIG. 6.

This Goniometer is clamped by two screws to the stage of any of the "Dick" mineralogical microscopes. By means of complete centering adjustments in three directions, a small crystal, set on the end of the steel pin, can be bought to coincide with the turning axis, and adjusted so that one of its edges is parallel to this while it remains under observation. The instrument is specially designed with a view to great rigidity and delicacy of adjustment so that it may be used with the highest powers. The divided circle reads by a vernier to 1′. All the movements can be clamped after adjustment.

Jackson-Blount Metallurgical Microscope. (Fig. 7.)

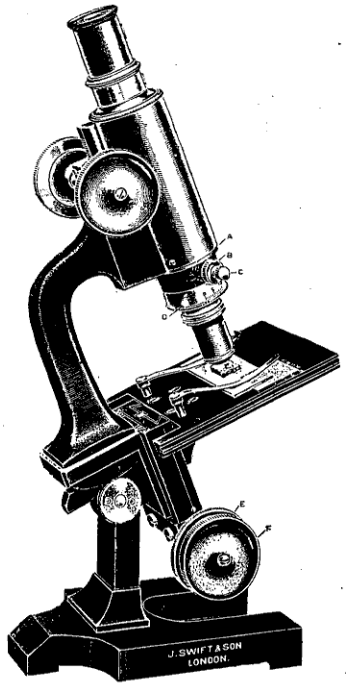


Fig. 7.

In this instrument a rack and pinion motion is fitted both to the optical tube and the stage. In addition to this, the stage is provided with a fine adjustment. The illuminator is of new design. The reflector consists of a plate of plane-parallel glass adjustable in all azimuths. Provision is made for inserting central stops in order to eliminate ghost images, haziness, &c. An iris diaphragm is mounted above the reflector for cutting off stray reflections and increasing the apparent depth of focus when photographing somewhat uneven surfaces.

Workshop Metallurgical Microscope. (Fig. 8.) (Designed by J. E. Stead, Esq., F.R.S.)

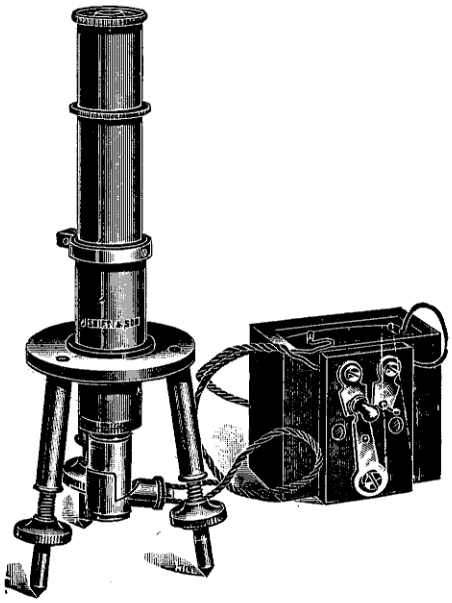


Fig. 8.

This instrument was constructed for the convenience of engineers, iron and steel founders, and other workers in metal, who occasionally require in their workshops the use of a compound microscope of the most simple form. The legs of the tripod may be lengthened or shortened, by rotating the milled heads on them, in order to compensate for any unevenness of the surface under examination. A silvered reflector is placed in a slit in the objective to which a small electric lamp is attached. When the current from a small 4-volt portable battery is switched on, the object is brilliantly illuminated.

Microscopes for General Investigation.

The four instruments exhibited are selected from a series which has been specially designed to render them suitable for all branches of Technical and Research Microscopy. The upper parts (limb, body-tubes, coarse and fine adjustments, &c.), are identical. They differ only in the type of base, the form of stage and the arrangement of the substage apparatus.

"*The Discovery*" (Fig. 9).—This instrument is fitted with $\frac{2}{3}$-in. N.A. 0·28, and $\frac{1}{6}$ in. N.A. 0·85, objectives, double nose-piece, two oculars and iris diaphragm. Magnifications 60 to 400 diameters. As arranged the instrument is specially serviceable for the study of Histology, Biology, &c.

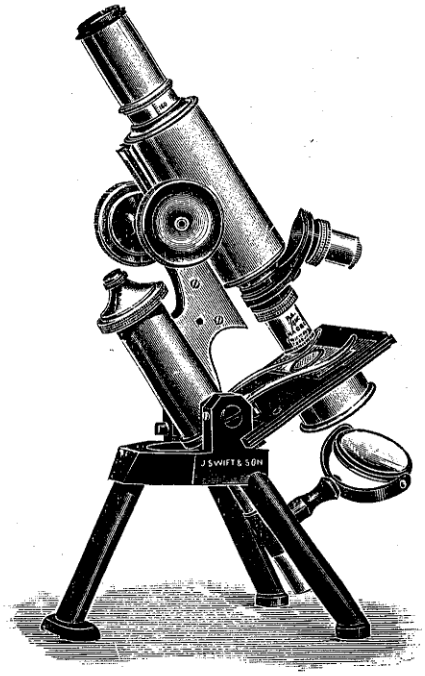


Fig. 9.

"*The Continental A*" (Fig. 10).—This instrument follows the lines of the Continental type of stand throughout, but has a larger stage, optical tube, &c., than is usual. It is fitted complete

for bacteriological research with $\frac{2}{3}$ in. N.A. 0·28, $\frac{1}{6}$ in. N.A. 0·85, oil immersion $\frac{1}{12}$ in., N.A. 1·30, objectives, triple nosepiece, lateral screw focussing Abbe condenser with iris diaphragm and stop carrier, and two oculars.

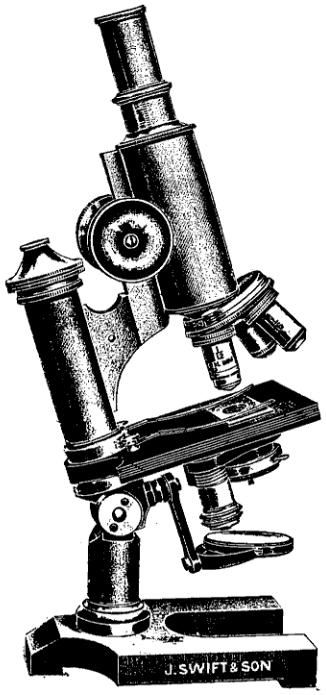


FIG. 10.

"*Research Microscope*" (Fig. 11).—In this microscope the mechanical stage is built as an integral part of the instrument. The horizontal rectangular motion is effected by a multi-thread screw, the vertical by a fine rack and pinion; both movements are graduated to read to 0·1 mm. The top of the stage can be entirely cleared to allow of the free use of a Petrie dish. In place of the uncorrected Abbe illuminator, an achromatic condenser, N.A. 1·0, is fitted, mounted together with an iris diaphragm and stop carrier in a rackwork focussing and centering substage. The other equipment is the same as with

the preceding model, except that the $\frac{1}{6}$ in. N.A. 0·85, objective is replaced by a $\frac{1}{8}$ in., N.A. 0·92; the instrument being thereby fitted for use in a brewing laboratory.

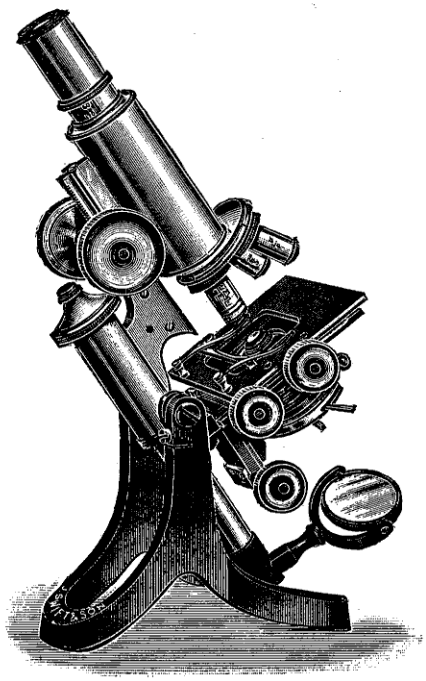


FIG. 11.

"*I.M.S. Microscope*" (Fig. 12).—The mechanical stage of this instrument, which is permanently built into it, is constructed so as to allow of the complete examination of a blood film covering the whole of a 76 × 25 mm. slip. The horizontal movement can be detached from the main stage, thus leaving the latter clear for the free use of a Petrie dish. The optical equipment is the same as with the "Continental A" model, except that the Abbe condenser is mounted in a rackwork focussing substage which allows of its being swung out of the optic axis.

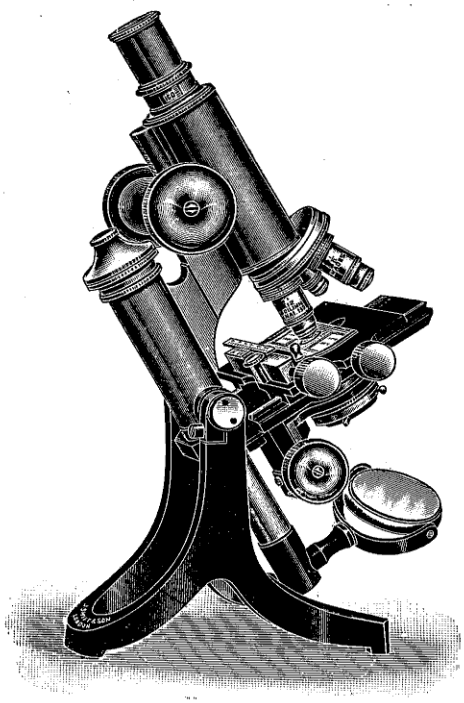


FIG. 12.

Stephenson Binocular Microscope. (Fig. 13.)

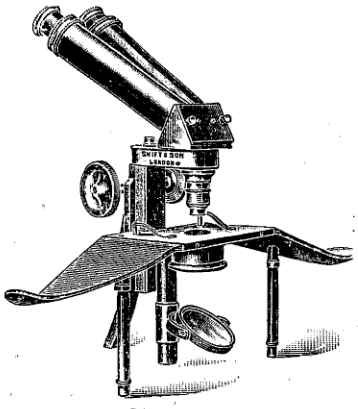


FIG. 13.

This microscope is intended for the most delicate dissection, for marine and other biological study, the arrangement of diatoms, &c. It is specially suited for these branches of biology as it gives an erect image with a most marked stereoscopic effect. Sufficient focussing adjustment is provided to allow of the use of a 5 in. (127 mm.) objective.

Portable Clinical and Zoological Microscope. (Fig. 14.)

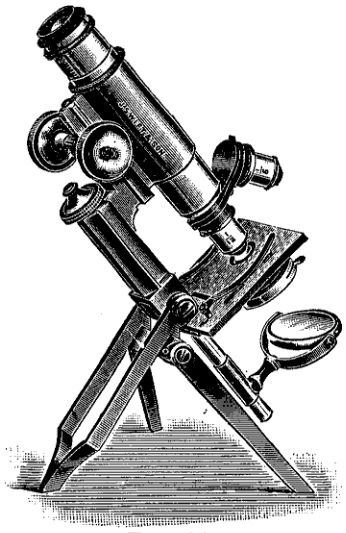


FIG. 14.

This instrument has a rack and pinion coarse, and micrometer screw fine, adjustment, focussing and centering Abbe condenser and iris diaphragm, double nosepiece, two objectives and ocular. It can be packed, together with glass bottle, forceps, scalpel and pipette, in a leather case measuring 9 ins. × $3\frac{1}{4}$ ins. × 3 ins. (230 mm. × 80 mm. × 75 mm.).

Apochromatic Objectives.

Focal Length.	N.A.
3 mm.	1·30
3 mm.	1·35
2 mm.	1·35
2 mm.	1·40

Achromatic Objectives.

Focal Length.		N.A.
4 inches	102 mm.	0·09
3 ,,	76 ,,	0·12
2 ,,	51 ,,	0·17
1½ ,,	37 ,,	0·20
1 inch	25 ,,	0·25
1 ,,	25 ,,	0·30
⅔ ,,	17 ,,	0·28
⅔ ,,	17 ,,	0·30
½ ,,	13 ,,	0·50
¼ ,,	6 ,,	0·80
¼ ,,	6 ,,	0·88
⅙ ,,	4 ,,	0·9
⅙ ,,	4 ,,	0·85
⅛ ,,	3 ,,	0·92
⅛ ,,	3 ,,	0·97

Oil Immersion :—

⅛ inch	3·2 mm.	1·26
1/10 ,,	2·5 ,,	1·26
1/12 ,,	2·1 ,,	1·30
1/16 ,,	1·6 ,,	1·30
1/20 ,,	1·3 ,,	1·30

Compensating Oculars.

For 160 *mm. Tube :—*

× 2, × 4, × 6, × 8, × 12, × 18.

For 250 *mm. Tube :—*

× 4, × 6, × 8, × 12, × 18, × 24, × 28

Huyghenian Oculars.

× 3, × 4, × 5·5, × 7, × 9.

Projection Oculars.

× 2, × 4.

Microscope Lamps.

Nelson-Dallinger Lamp.

This oil lamp has a metal chimney. The flame can be turned edge or flat on. Complete mechanical adjustments are provided for moving the lamp in the vertical and horizontal planes. An aplanatic bull's-eye is attached on an adjustable arm.

Simple Lamp with Low Reservoir.

This is a very convenient lamp for general work, owing to the very low position to which the flame can be brought.

Nernst Electric Lamp.

This lamp is fitted with a $\frac{1}{4}$ ampere Nernst filament. It can be brought very low and be worked in any position. It has an aplanatic bull's-eye with focussing and centering movements, and a large holder for light filters. Both bull's-eye and holder can be swung aside.

The Synchronome Company, 32 *and* 34, *Clerkenwell Road, London, E.C., F. Hope-Jones, M.I.E.E., Inventor.*

(Journ. Institution of Electrical Engineers, Feb. 1910.)

The "Synchronome" Electric Time System.

This system provides the time service in the British Section.

The master clock is an electrically driven pendulum which will operate any number of electrical impulse dials.

The pendulum is combined with a simple switch in such a manner that both the *time-keeping* and *switching* functions are performed automatically.

Each dial has only a "one-wheel" movement behind it, yet this simple mechanism secures uniform and accurate time-keeping without winding-up or any other attention.

The switch is shown in Fig. 1, and consists of two moving parts: (1) the right-angled lever G centred at F and normally

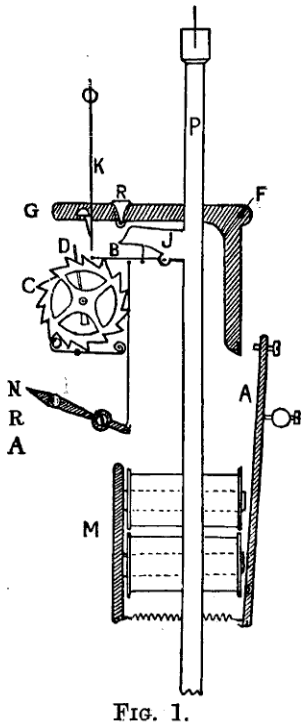


FIG. 1.

supported on spring catch K. Once every half-minute the lever is let down (in the act of giving an impulse to the pendulum P) upon the armature A. Current from any available source then passes through the series circuit of dials and the magnet M, which attracts the armature A and throws up the lever G on to its catch again.

The pendulum releases the switch by means of the 15-toothed wheel C which carries a vane D engaging with the catch K at each revolution. The hook B pivoted upon the pendulum P turns this wheel once every 30 seconds. At the moment of its release the little roller R on the gravity arm G is just above the curved end of the pallet J, down which it runs, giving an impulse to the pendulum at the moment when it passes through its zero or central position. Thus the pendulum is free at all times except in the middle of its swing; not only is the escapement detached, but it operates while the pendulum is passing its equilibrium position, thus approximating to the conditions necessary for isochonism.

The shape of the impulse surface of the pallet J is such as to yield an impulse, beginning with extreme gentleness, increasing to a maximum at the centre of the pendulum's swing, and diminishing in identical ratio. The switch cannot stop in closed circuit. The dials can be readily set to time by merely removing the lever from normal to retard or accelerate.

Battery warning.—A valuable feature of the system is the automatic warning of impending failure of the battery long before such failure can cause any irregularity in the working of the time circuit. When the current is insufficient to enable the magnet M to replace the gravity lever G the pendulum on its return swing to the left finds the gravity lever in its path and assists the magnet to raise it, thus prolonging the duration of the contact to a full second, which is clearly noticeable on every dial. The electrical contact, occurring at each half-minute precisely, is the only contact in the system, and it is a very perfect one. The whole of the energy required to keep the pendulum swinging being transmitted through its surfaces.

It is so designed that at each operation it transmits to all the dials sufficient current to propel them. By a novel application of the phenomenon of self-induction, it becomes impossible for the switch to operate without doing so.

The impulses from the controlling clock pass through the electro-magnet of each dial movement every half-minute. This dial movement is shown in Fig. 2 in which A is a wheel having 120 rectangular teeth rigidly connected with the minute hand. B is an electro-magnet with armature C and lever D carrying the pawl E at its end. F is a flat steel spring. The original and important feature in this movement is the perfect escapement lock of the wheel achieved by the backstop lever G carrying a fixed stop I, and the momentum stop H against which the driving click E comes to rest. The dials are almost noiseless in action and a perfectly silent movement can be put in whenever required.

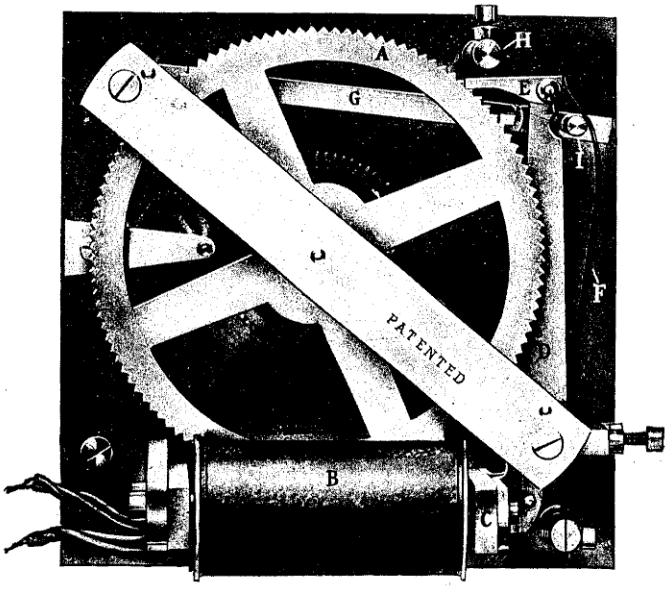


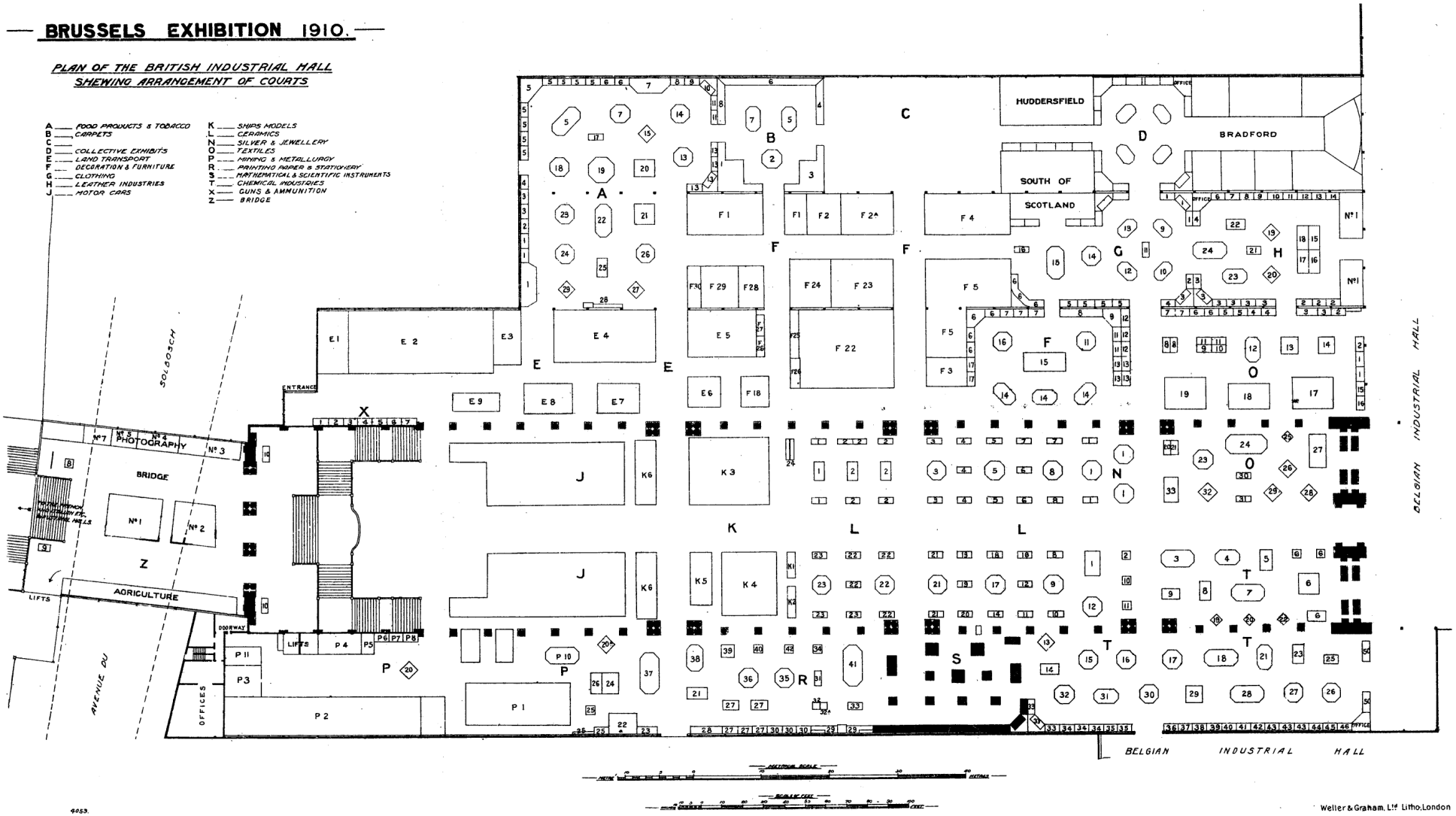
FIG. 2.

LIST OF EXHIBITORS

BRUSSELS EXHIBITION 1910.

PLAN OF THE BRITISH INDUSTRIAL HALL SHEWING ARRANGEMENT OF COURTS

A ___ FOOD PRODUCTS & TOBACCO
B ___ CARPETS
C ___
D ___ COLLECTIVE EXHIBITS
E ___ LAND TRANSPORT
F ___ DECORATION & FURNITURE
G ___ CLOTHING
H ___ LEATHER INDUSTRIES
J ___ MOTOR CARS
K ___ SHIPS MODELS
L ___ CERAMICS
N ___ SILVER & JEWELLERY
O ___ TEXTILES
P ___ MINING & METALLURGY
R ___ PRINTING PAPER & STATIONERY
S ___ MATHEMATICAL & SCIENTIFIC INSTRUMENTS
T ___ CHEMICAL INDUSTRIES
X ___ GUNS & AMMUNITION
Z ___ BRIDGE



4253.

Weller & Graham, Ltd Litho, London

LIST OF EXHIBITORS.

The exhibits referred to in this catalogue are those comprised in section S. (coloured) on the plan opposite, on which the numbers correspond to the positions of the exhibitors in the list below.