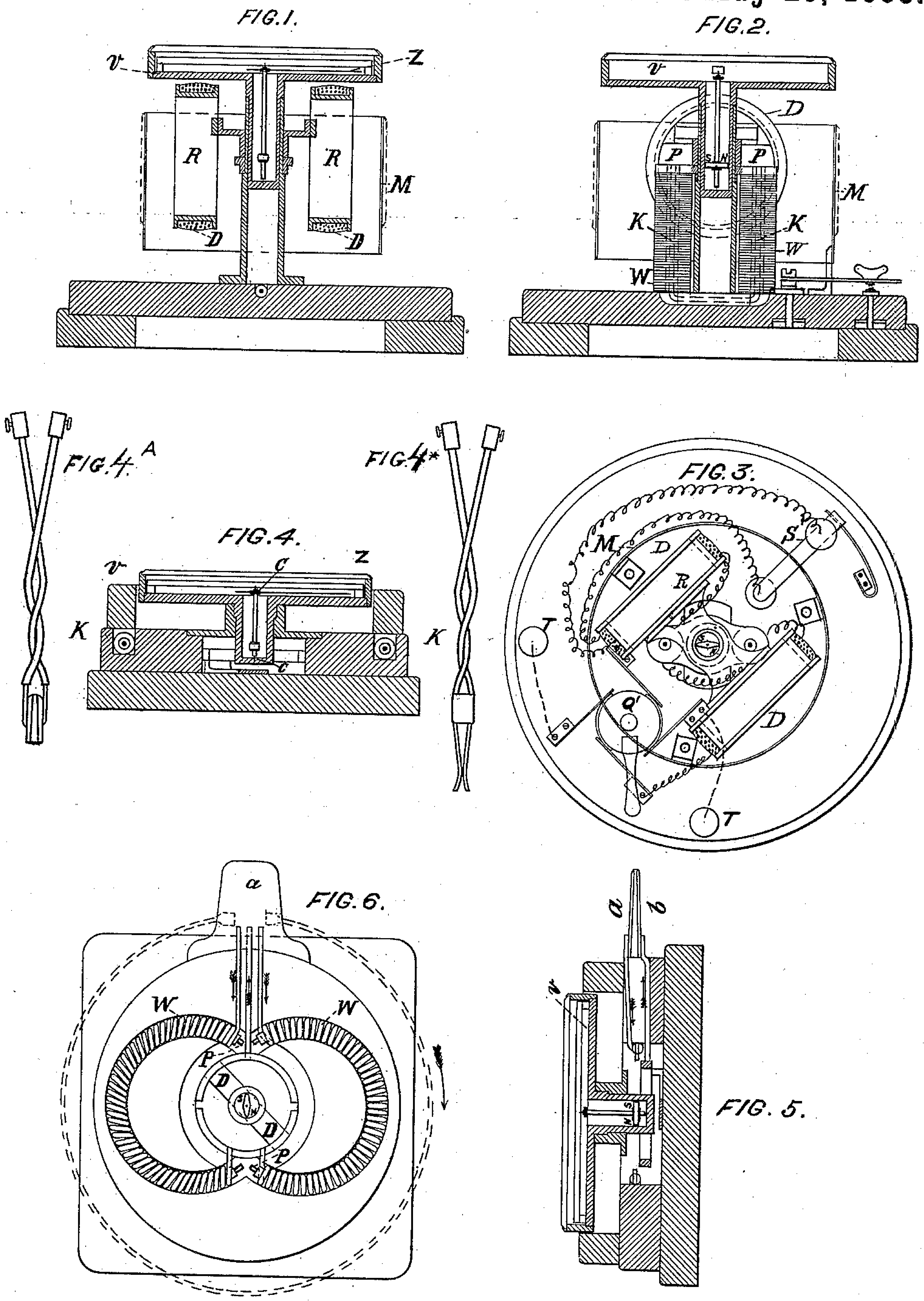
(No Model.)

R. E. B. CROMPTON & G. KAPP.

GALVANOMETER.

No. 383,444. Patented May 29, 1888.



Witnesses:
Percy White.
G. L. De Motte,

Inventors.
Rookes Evelyn, Bell, Crompton.
and
Gisbert Kapp,
By John J. Halsted & Son
their attys.

UNITED STATES PATENT OFFICE.

ROOKES EVELYN BELL CROMPTON AND GISBERT KAPP, OF CHELMSFORD, COUNTY OF ESSEX, ENGLAND.

GALVANOMETER.

SPECIFICATION forming part of Letters Patent No. 383,444, dated May 29, 1888.

Application filed September 27, 1884. Serial No. 144,135. (No model.) Patented in England April 13, 1883, No. 1,877, and September 18, 1883, No. 4,453; in France September 26, 1883, No. 157,743; in Belgium September 26, 1883, No. 62,717; and in Austria-Hungary December 24, 1883, No. 38,890, and No. 53,900.

To all whom it may concern:

Be it known that we, ROOKES EVELYN BELL CROMPTON and GISBERT KAPP, both subjects of the Queen of Great Britain and Ireland, residents of Chelmsford, in the county of Essex, England, in the United Kingdom of Great Britain and Ireland, have invented certain new and useful Improvements in Apparatus for Measuring Electric Currents and Electro-Motive Force, (for which we have obtained patents in the following countries—namely: in England, No. 1,877, dated April 13, 1883, and No. 4,453, dated September 18, 1883; in France, No. 157,743, dated September 26, 1883; in Belgium, No. 62,717, dated September 26, 1883, and in Austria-Hungary, No. 38,890 and No. 53,900, dated December 24, 1883,) of which the following is a specification.

Our invention consists in improvements in that class of apparatus for measuring electric currents and electro-motive force where the deflection of a magnetic needle, which needle is under the combined influence of a directing-magnet and one or more deflecting-coils, indicates the current. The magnets hitherto used in such apparatus were permanent steel magnets; but it is well known that the strength of such magnets, and therefore also their directing force upon the needle, is liable to variations brought about accidentally, and therefore such instruments must from time to time be recalibrated in order to obtain accurate measurements.

Our invention consists in substituting for these permanent steel magnets electro-magnets which are excited by the whole or by a part of the very current which is to be measured.

The directing force of an electro-magnet is the sum of the directing force due to the current circulating through its coils and of the directing force due to the iron core. The latter is, generally speaking, numerically much larger than the former. For weak currents it is nearly proportional to the current; but if the current be increased sufficiently a maximum is ultimately reached, beyond which the directing force of the soft-iron core cannot perceptibly be increased. This condition of the core is generally known as "magnetic saturation." We employ in our instruments electro-magnets with comparatively thin cores and obtain thereby that, with the weakest currents which it is desired to measure, the core becomes already nearly saturated. The directing power of the coils themselves is proportional to the current for all currents, but as it is, generally speaking, numerically smaller than the directing power of the saturated core, and, moreover, can be neutralized by a method hereinafter described, the total directing power will only slightly vary with the current. On the other hand, the deflecting power of the coils is, as in all galvanometers, strictly proportional to the current, and therefore the deflection of the needle will be a definite function of the current.

If the relation between the deflection of the needle and the current be once experimentally determined for various currents within the limits of the instrument, a scale or dial can be constructed, upon which, by means of a pointer rigidly attached to the needle, the current can be read off.

If it be desired to obtain instruments of very great accuracy and a convenient and even division of the dial, we eliminate or neutralize the directing power of the coils of the electro-magnet, so that only the directing power due to its core influences the needle. This elimination can be made in various ways, either by extending the core and poles of the electro-magnet toward the needle, so that the latter is well under the influence of the core, but not or only slightly under the influence of the winding, which lies at a greater distance from the needle, or we surround the needle with a separate balancing-coil traversed by the same or a proportionate part of the current which excites the electro-magnet, and we arrange this balancing-coil in such a way that its magnetic influence upon the needle is equal and opposite to the magnetic influence of the coils of the electro-magnet upon the needle, or we set the deflecting-coil at a certain angle to the line joining the poles of the electro-magnet. How this angle is found will be shown farther on.

To make our invention clearly understood we annex a sheet of drawings.

Figure 1 is a sectional front elevation, Fig. 2 a sectional side elevation, and Fig. 3 a plan, of one form of our instrument.

In the figures, K K' is the core of the electro-magnet. P P are its poles. W W are the coils exciting the core, and D D are the deflecting-coils wound upon frames R R, which, for the convenience of access to the magnetic needle N S, are arranged on both sides of it. If a current be sent in the proper direction through the various coils of the instrument, the electro-magnet will tend to keep the needle in its zero position, as shown in the drawings, while the deflecting-coils D D will tend to set the needle at a right angle to their plane. In consequence of this the needle will set at a certain angle to its zero position, and this angle stands in a definite relation to the current. It must be remarked that the magnetic moment of the needle N S has, as in all galvanometers, no influence upon the angle of deflection. A needle made of soft iron could also be employed; but we prefer a magnetized steel needle, because it points with more accuracy to zero when no current is passing, and because its deflection to one or the other side of the dial indicates the direction of the current.

Fig. 4 is a sectional front elevation, Figs. 4^A and 4* details, Fig. 5 a sectional side elevation, and Fig. 6 a plan, of another form of our instrument which is intended for the measurement of rather stronger currents than the instrument above described.

N S is a magnetized steel needle pivoted in centers C C, as shown in the drawings, Fig. 4; or, instead of one single needle, we can employ two needles placed parallel side by side, their similar poles pointing the same way, and suspended, in the fashion of compass-needles, upon a point, around which they are free to revolve in a horizontal plane. This arrangement is, however, not shown in the drawings, being a well-known and understood method of supporting magnetic needles. The electro-magnet consists of a soft-iron core bent in double-horseshoe form, the pole-pieces P P of which are slightly bent inward, as shown.

The current enters at the flat copper terminal *a* and splits, as shown by the arrows, into two halves, which traverse the two horseshoes of the electro-magnet W W. Instead of a complete deflecting-coil, we use in this case a single conductor, D D, which carries the current under the needle or needles back to the other flat copper terminal, *b*. The two cables, which connect the instrument with the circuit, are joined onto these terminals *a* and *b*. The joint can be best made either by spring-contacts or by soldering the single strands of the cables in a fan-like shape onto these terminals. To avoid any disturbing influence from the current in these cables upon the needle, we twist them together.

It will be seen that the deflecting-conductor D D in Fig. 6 and the deflecting-coils D D in Fig. 3 are not shown parallel with the zero position of the needles, although for convenience in drawing we have in the elevations shown them so, but turned by a certain angle in the sense of their deflection. The object of this arrangement is the elimination of the directing force exerted by the coils of the electro-magnet themselves upon the needle. To find this angle we proceed as follows: We place the instrument in such a position that upon removal of the core from the electro-magnet the needle sets at a right angle to its zero position if it is solely under the influence of the horizontal component of terrestial magnetism. If we now send a current through the instrument, we find that the needle will deflect from its position in the magnetic meridian; but that this deflection can be eliminated by swiveling the conductor D or the coils D D into the new angular position shown in the drawings. If the conductor be fixed in that position, the resultant force due to the directing force from the coils W and to the deflecting force of the conductor D or coils D D acts at a right angle to the zero position of the needle; or, in other words, the angular displacement of the conductor D or coils D D from the zero-line P P has the effect of exactly balancing the directing force of the coils W W. If we now replace the iron core of the electro-magnet, the needle will only be influenced by that part of the directing force which emanates from the core, and which is, as shown above, nearly a constant.

Precisely the same explanation applies to the case when we use a double needle suspended compass fashion, instead of the single needle pivoted in centers, as shown in the drawings.

In calibrating our instruments we place them so that the line P P lies in the magnetic meridian, and so that the earth's directing force is added to the directing force of the electro-magnet. We determine the divisions of the scale or dial *v* empirically by comparing each instrument with a correctly-calibrated standard instrument. If it is desired to measure very large currents, we add to our instruments a shunt-coil of a very small but known resistance, (preferably one-ninth of the resistance of the instrument,) and we connect this coil with the terminals of the instrument, so that a proportionate part of the current is shunted through this by-pass coil. In making it detachable the same instrument can serve for reading strong and weak currents with equal accuracy. Care must be taken that the current in the by-pass coil does not influence the needle.

Our instrument, and more especially the form shown in Figs. 1, 2, and 3, can also be used for the measurement of electro-motive force. In this case we wind the electro-magnet and deflecting-coils with a large number of turns of fine wire having a considerable resistance. We join up this instrument direct to the points the electro-motive force between which is to be measured. In the first instance this instrument measures, therefore, the small current which is flowing through it under that electro-motive force; but as by ohms law the current is proportional to the electro-motive force the instrument measures also indirectly the latter, and in calibrating it, which is done by comparison with a standard instrument, we determine the divisions of the dial *v* directly in volts.

Z is the pointer sweeping over the dial *v*.

If it be desired to measure larger electromotive forces than can be safely applied to the instrument without heating the coils unduly, we insert into the circuit of the instrument a resistance preferably nine times as great as that of the instrument proper, and we arrange the resistance so that it can be short-circuited by a key if low electro-motive forces are to be measured. In this manner the same instrument can serve to measure high and low electro-motive forces with an equal degree of accuracy. This resistance is shown at M in Figs. 1, 2, and 3. In the accompanying drawings, Fig. 3, this key is shown at S′, and at Q′ a commutator is inserted by which the direction of the current through the instrument can be reversed. We arrange the connections between this commutator and the coils of the instrument in such a way that when the instrument is in use then the handle on the commutator must be turned toward the positive of the two terminals T T, in order that the sweep of the pointer may be over the graduated portion of the dial. In this manner the instrument can be used to find which is the positive terminal.

If it be desired to construct instruments for the measurement of currents which, although varying as regards their intensity, are always flowing under a constant electro-motive force—as, for instance, the currents obtained from a self-regulating dynamo-machine—we excite the electro-magnet of our instruments by a very small portion of the current to be measured, which small portion we take direct from the positive to the negative lead through the electro-magnet, which is wound with fine high-resistance wire, while the main current is made to pass through the deflecting-coils D D or an equivalent device.

Having now described our said invention, we wish it to be understood that we do not limit ourselves to the particular forms shown by way of example in the accompanying drawings; but what we claim as our invention is—

1. In an instrument for measuring electro-motive force or current, an electro-magnet or electro-magnets having the core or cores small enough to be easily saturated, excited by all or part of the current to be measured, supplying the controlling-field instead of the permanent magnet hitherto employed, in combination with a deflecting-coil or its equivalent, and a steel or soft-iron needle free to take up a portion depending on the relative strengths of the controlling and deflecting fields, substantially as described.

2. In an instrument for measuring electro-motive force or current, the combination of the controlling electro-magnet or electro-magnets having a core or cores small enough to be easily saturated, with poles extended beyond the exciting coil or coils toward the needle, so as to minimize the direct action of the magnetizing coil or coils upon the needle, substantially as set forth.

In testimony that we claim the foregoing as our invention we have signed our names, in the presence of two witnesses, this 21st day of May, 1884.

ROOKES EVELYN BELL CROMPTON.
GISBERT KAPP.

Witnesses:
JOHN DEAN,
JOHN WATT,
Both of 17 *Gracechurch Street, London.*