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E. WESTON.

STANDARD TANGENT GALVANOMETER.

No. 389,274. Patented Sept. 11, 1888.

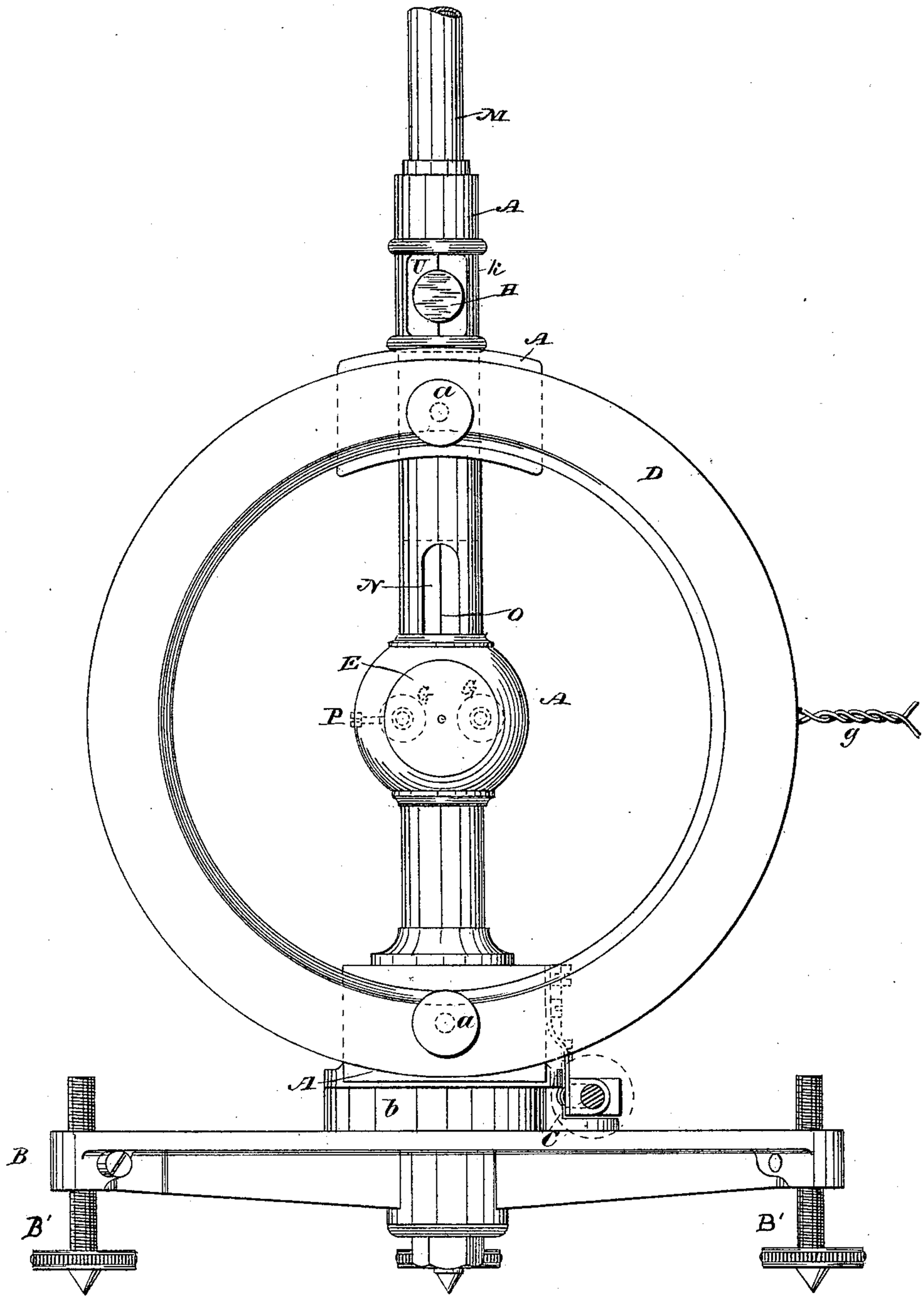

FIG. 1.

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Fig. 7.

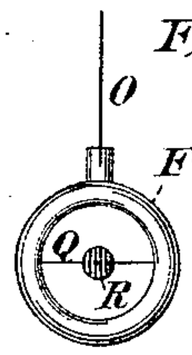


Fig. 8.

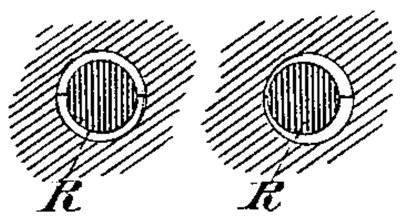
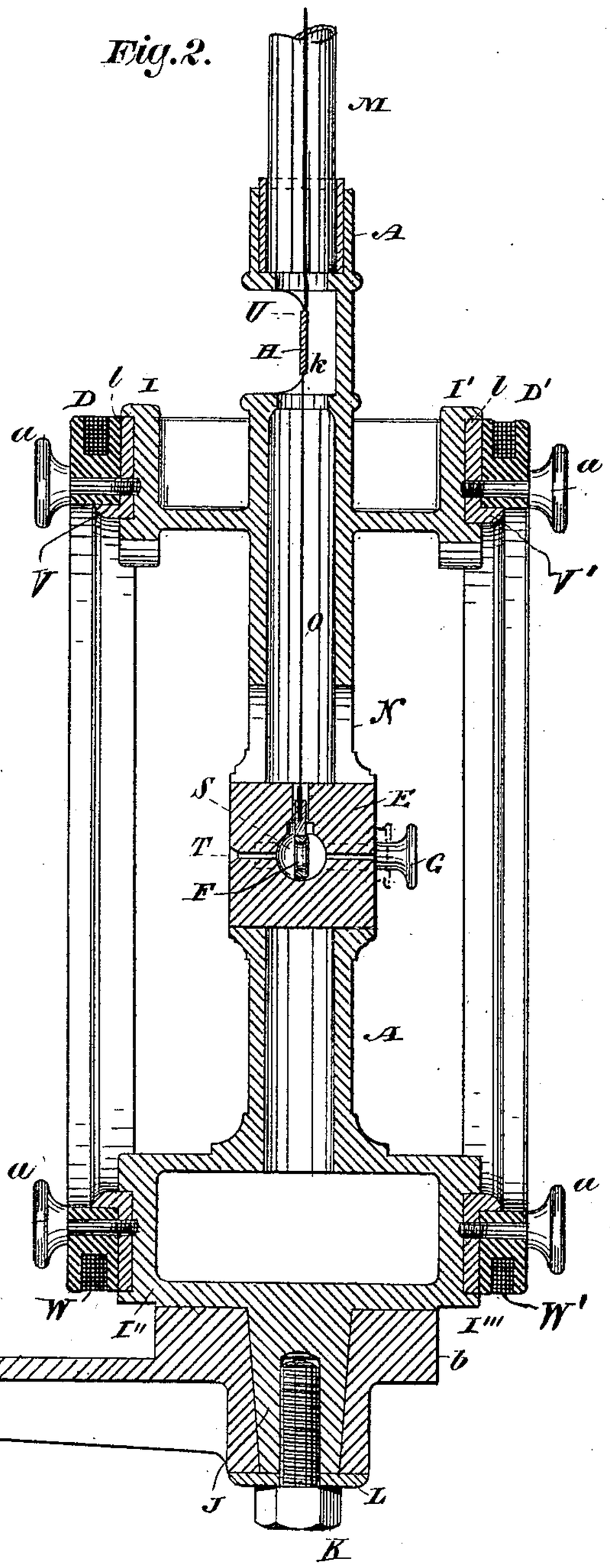


Fig. 2.



WITNESSES.
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STANDARD TANGENT GALVANOMETER.

No. 389,274. Patented Sept. 11, 1888.

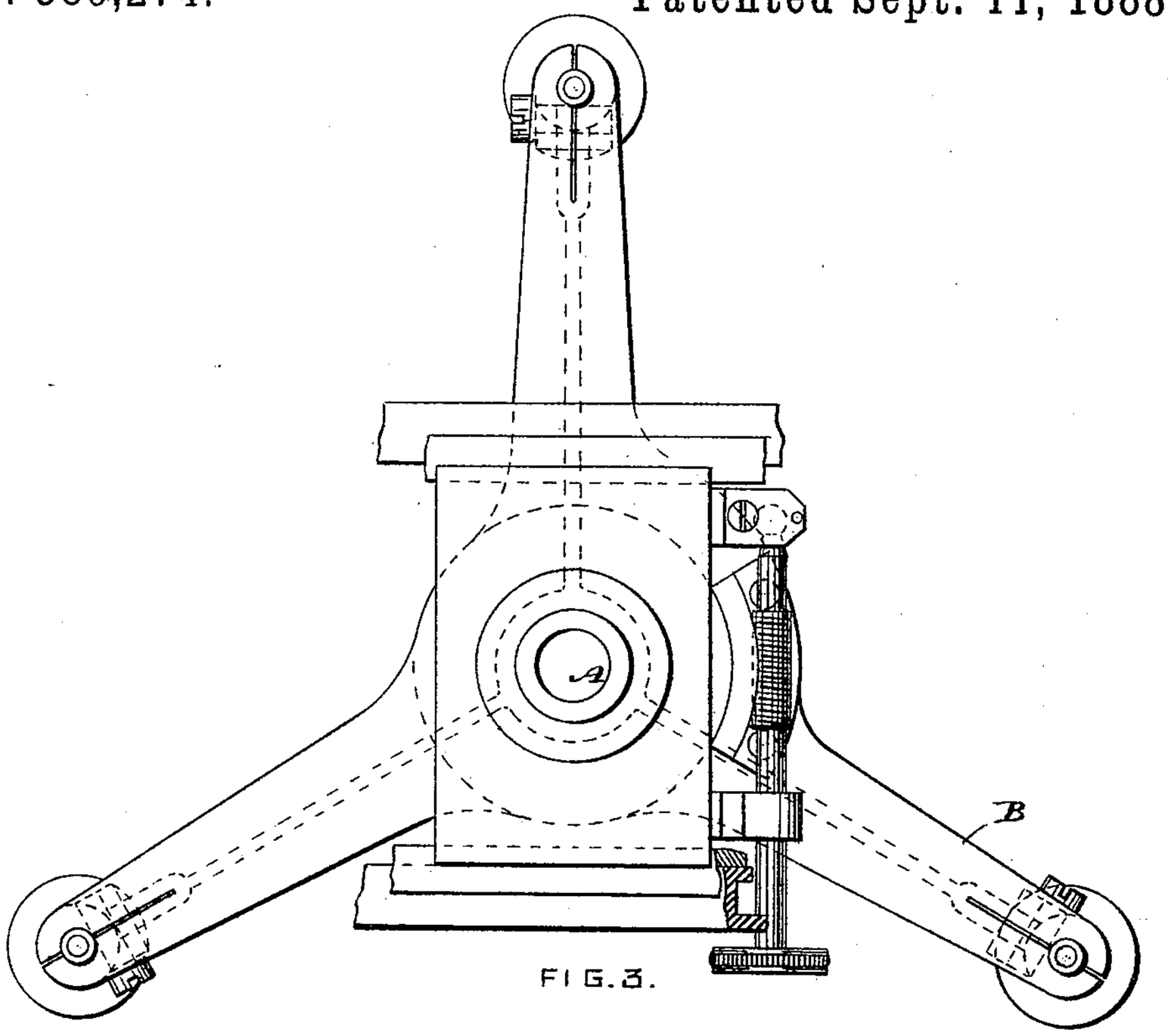

FIG. 3.

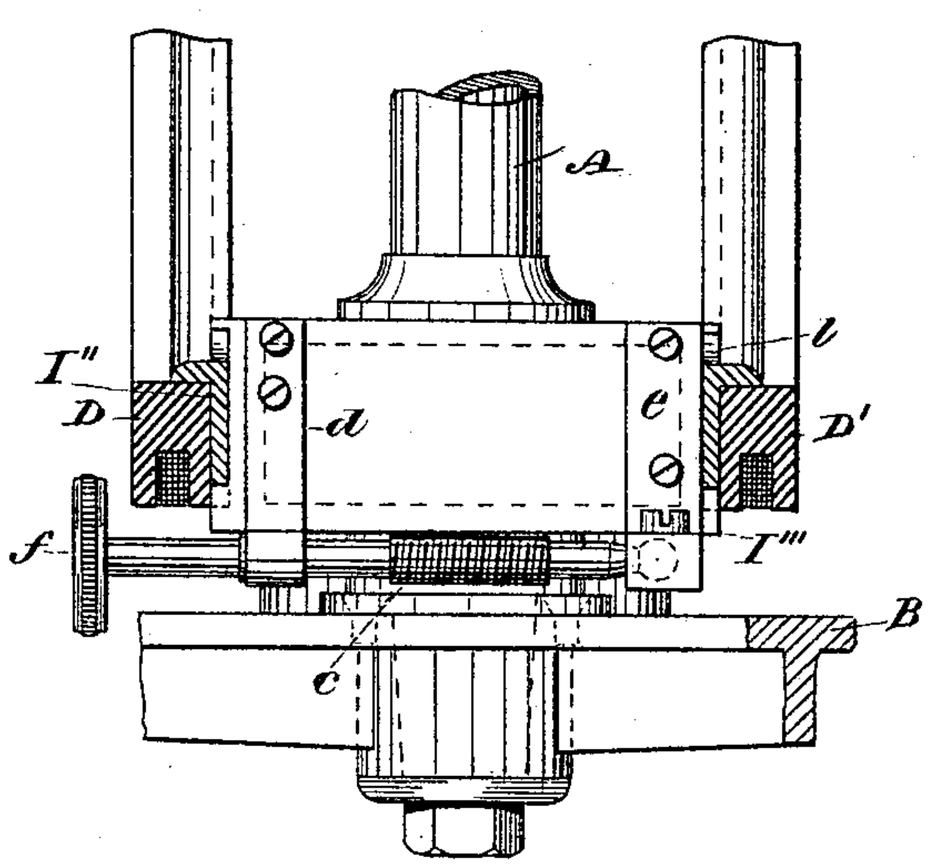

FIG. 4.

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STANDARD TANGENT GALVANOMETER.

No. 389,274. Patented Sept. 11, 1888.

Fig. 6.

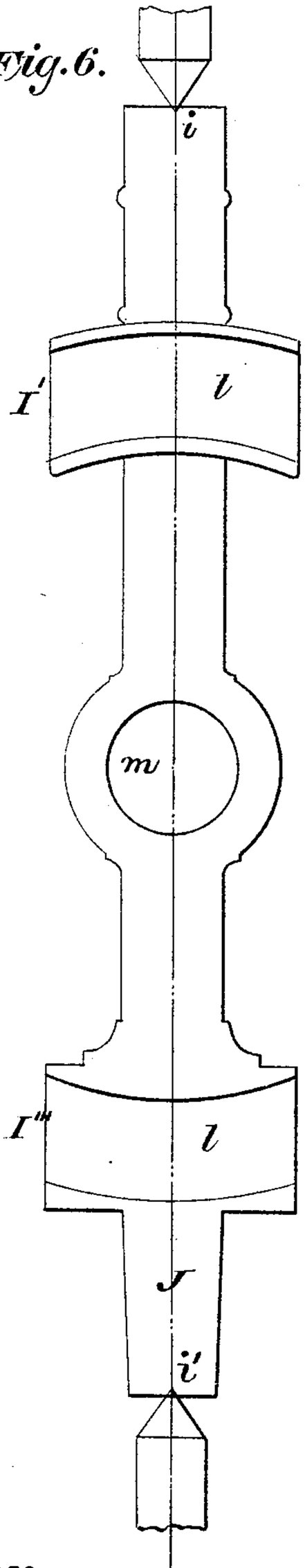
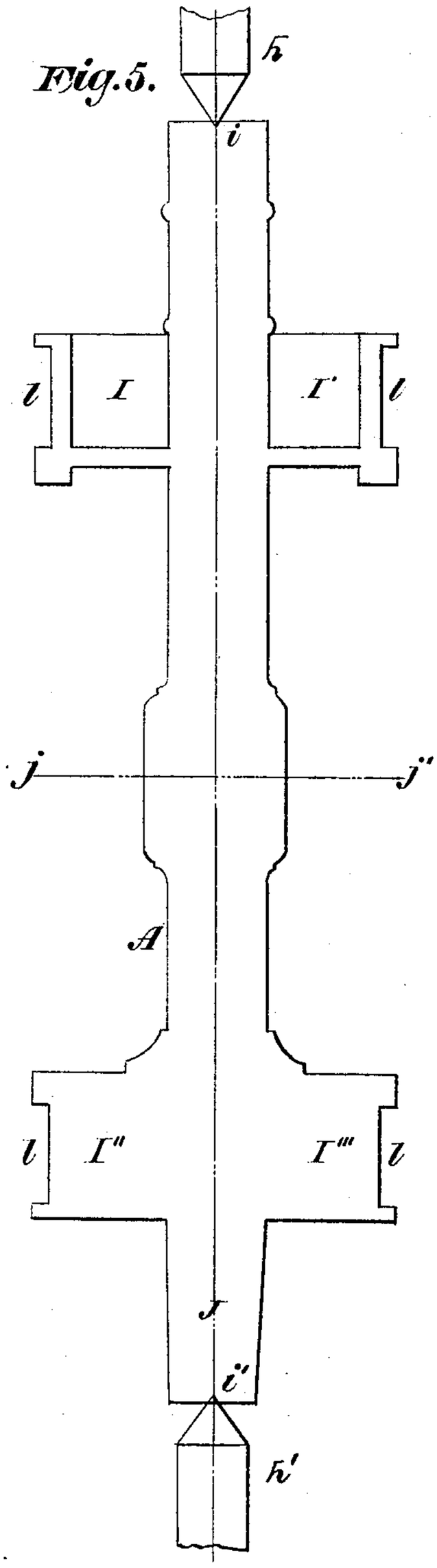


Fig. 5.



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UNITED STATES PATENT OFFICE.

EDWARD WESTON, OF NEWARK, NEW JERSEY.

STANDARD TANGENT-GALVANOMETER.

SPECIFICATION forming part of Letters Patent No. 389,274, dated September 11, 1888.

Application filed May 10, 1888. Serial No. 273,517. (No model.)

To all whom it may concern:

Be it known that I, EDWARD WESTON, of Newark, Essex county, New Jersey, have invented a new and useful Improvement in Tangent-Galvanometers, of which the following is a specification.

The ordinary form of tangent-galvanometer consists, essentially, of a coil of wire wound in a groove in the circumference of a circular ring, in the center of which ring the magnetic needle is placed. In order that the magnetic influence of the current on the needle may be the same at whatever angle the needle may assume, the length of said needle must be very small compared with the diameter of the coil, and the position of the needle must be such that its central point is at the axis of and also in the same plane with the single coil. It has been found that the error due to the magnetic needle not being infinitely short may be obviated by suspending the needle, not at the center of the coil, but at a point on the axis thereof at a distance from the center equal to one-half the radius of the coil, and it has further been determined that the error due to the center of the needle not being truly at the point above indicated may be eliminated by arranging a second coil similar to the first at equal distance on the other side of the magnet. In that my hereinafter-described instrument embodies two coils disposed at equal distances on each side of the magnet which is located on the axial line joining the centers of said coils, it may be regarded as of the general type of apparatus last above noted. Galvanometers of this description, however, when intended for exact electrical measurements have been found difficult and expensive to manufacture and wanting in accuracy. Leaving the question of greatly increased and, for general usage, prohibitive cost aside, it by no means follows that the multiplication of delicate parts and adjusting mechanism, as is frequently done, results in increased certainty in the indications of the instrument. Error in one adjusting device may easily affect the operation of a second, and this of a third, and so on, or mutual interaction, so to speak, of disturbing causes may introduce uncertainty throughout the whole chain, so that the mere operation of putting an instrument into condition for use may easily result in a long and tedious series of trials for relative adjustments, terminating only when a real or more often assumed condition of equilibrium of the opposing forces is attained, and this even then may be subject to unknown inaccuracy dependent upon the "personal equation" of the observer or adjuster.

My invention consists in a standard absolute galvanometer, accurate primarily and necessarily by reason of its construction. I make it, in other words, so that by reason of its construction its coils when placed on the instrument in their stationary position and on opposite sides of the central standard shall be relatively parallel with their centers equidistant from the longitudinal axis of said standard, and disposed on a line intersecting said longitudinal axis at right angles. Within this standard I support the magnet. It is necessary, then, simply to adjust the movable magnet, so that its center will be at the point of intersection already permanently and exactly established. Therefore this is an instrument in which the proper position of the magnet with reference to the coils, and vice versa, is once for all fixed, not by relative adjustments of magnet and coils, but by the absolute relation and positions of the parts of the rigid structure, whereby said magnet and coils are held and supported. The position of the coils with reference to the magnet is invariable. The point which the magnet center should occupy with reference to the coils is fixed and invariable. It remains, then, to move the movable magnet so that its center will be in that position, or to allow it to take that position naturally, as by the action of gravity upon it. Consequently, in order to render my instrument ready for immediate operation, the coils being secured in place, I have merely to observe that the magnet is rightly located, and then I can proceed to make absolute electrical measurements with an accuracy not attainable, if at all, other than by the use of the most complicated and delicate adjustments. I also secure certain other features of benefit, whereby a great range of measurement covering very large and very small currents is obtained, and whereby the manipulation of the instrument is simplified. I also simplify the details of the construction, whereby the necessity for highly-skilled labor in the manufacture is obviated, the number of parts lessened, and the

general structure rendered strong and compact.

In the accompanying drawings, Figure 1 is a front elevation of my galvanometer. Fig. 2 is a vertical section of the same. Fig. 3 is a plan view of the base. Fig. 4 is a side elevation and partial section of the lower part of the instrument, showing the device for rotating the standard. Figs. 5 and 6 illustrate the mode of producing the standard and supports for the coils on a single pair of centers. Figs. 7 and 8 illustrate, respectively, the magnet and its relation to the sight-hole T during adjustment.

Similar letters of reference indicate like parts.

A is the central hollow supporting column or standard, having at its lower portion a tapering extension, J, which is received in a correspondingly-formed opening in the center of the tripod-base B. By means of the screw K and washer L the extension J is drawn into the tapering opening in the base B, and in this way the standard is centrally pivoted to the base. The base B is provided with leveling-screws B′, of the usual construction, located at the ends of the tripod-arms.

The standard A is enlarged at its middle portion, and is there bored transversely at *m*, Fig. 6, to receive the cylindrical block E, of copper or other diamagnetic metal, which constitutes a dampening device and prevents undue oscillation of the needle F, which is suspended in a central spherical cavity, S, in said block. The block E is divided transversely into halves and the parts are inserted into the bore of the enlargement of the standard A from opposite sides, and are connected together by screws G, Figs. 1 and 2. After the block is adjusted in the bore it is secured in place by the set-screw P, dotted lines, Fig. 1.

The needle or magnet F, as here shown, is of ring shape, as shown in detail in Fig. 7. Extending diametrically across it is a fine wire bar, Q, which exactly at its middle point, and hence at the center of the ring, carries a small circular disk, R. When the magnet is suspended in the chamber or cavity S in block E, this disk R comes directly in line with a sight-hole, T, so that if the disk is accurately centered then a true circle of light will appear around it on looking through the sight-hole, as indicated on the left of Fig. 8, whereas if it be not properly centered, then the eccentricity will be obvious by the irregular breadth of the light annulus, as shown on the right of Fig. 8.

The particular construction and form of the magnet F, its arrangement in combination with the block E, the mode of adjusting said magnet, and also the device for attaching it to its suspension-rod, as herein shown, are all disclaimed by me in this application for the reason that they are fully described and claimed in another application for Letters Patent, Serial No. 273,518, filed by me simultaneously herewith.

Resting in a socket in the upper end of standard A is a vertical glass tube, M, at the upper extremity of which (not shown) is any suitable support, whereto is attached a silk or other fiber, which extends down through said tube and into the standard A, and carries a mirror, H. This mirror is seen through an opening, U, in the side of a chamber or compartment, *k*, in standard A. It will be observed that I do not cover the opening U with glass, as is commonly done, in order to protect the mirror from possible air-currents. I find that it is better to leave the face of the mirror exposed, for the reason that the refraction of the glass shields, often an unknown quantity, is apt to impair the accuracy of the reflected image. Depending from the mirror H is a thin aluminium rod, O, which is connected to and supports the magnet F. Mirror H and magnet F stand in the same vertical plane, which, when no current traverses the coil, is parallel to the vertical planes passing through said coils.

Upon the standard A are supports or brackets I I″ I′ I‴, which preferably are made integral with the said standard. On the opposite faces of these brackets are curved grooves *l* cut in true arcs of a circle, and receiving the metal-flanged rings V V′. Resting against the rings V V′ are the rings D D′, which are made of ebonite or other insulating material, and which constitute the spools or bobbins for the coils W W′. The rings V V′ and D D′ are clamped to the brackets I I′ by means of set-screws *a*, which pass through said rings and enter said brackets. At the center of the base B is an upwardly-projecting circular boss, *b*, upon one side of which is formed a toothed segment, *c*, Figs. 1 and 3. Secured to one side of the bracket I″ I‴ is a collar, *d*, and end bearing, *e*, for the worm screw *f*. The thread on screw *f* engages with the toothed segment *c*, and hence, by rotating said screw, said screw moves over the said segment, and thus rotates the standard A on its vertical axis, the extension J turning in its socket in the base B. Above the enlargement on standard A, and on opposite sides of said standard, are slots N, through which the rod O may be seen. The coil-terminals are shown at *g*, Fig. 1.

Referring to Figs. 5 and 6, I will now explain my mode of manufacture, whereby I secure a construction which insures the accuracy of the instrument, as already set forth. In Fig. 5 is shown the blank for the standard A disposed between the lathe centers *h h′*. When the standard is turned in the lathe to the desired form, obviously the line *i i′*, extending between said lathe-centers, is the longitudinal axis or center line of the standard, and in this way this line is very simply fixed. The standard is then applied to the face-plate of the lathe, as indicated in Fig. 6, and is centered thereon. The face-plate then being rotated, the grooves *l* in the brackets I I′ I″ I‴ are formed, and the bottoms of the said grooves, respectively in brackets I I′ and in brackets I″ I‴, are made equidistant from the axis *i i′*; or, in other

words, the grooves *l* are in arcs of circles struck from centers equidistant from the longitudinal axis *i i'* and located upon line *j j'* at right angles to and intersecting said axis. The grooves *l*, as already stated, conform to the curves of the circles of the spools D D' of the coils. Therefore, when said coils are fixed in said grooves, it will follow necessarily, first, that the said coils will stand in parallel planes and on opposite sides of the standard; second, that the centers of said coils will be equidistant from the longitudinal axis of said standard. It follows, then, that the point of intersection of the line *j j'* and the axis *i i'* will be the true position for the magnet. While the standard is centered upon the face-plate the cylindrical bore *m*, into which the block E enters, is also turned. If, now, the line *j j'* be the axis of the bore *m* and also of the sight-orifice T in the block E, which fits said bore, it follows that when the block is in place therein and the center of the magnet becomes symmetrically adjusted with reference to said sight-orifice, as already described, then said magnet center will be accurately at said point of intersection of axis *i i'* and line *j j'*, and thus the exact relative positions of coils and the magnet become established. It will be apparent, therefore, that the precise point for the location of the needle center is thus made fixed definite and inalterable by the actual construction employed. In operation the base B is leveled by means of the screws B', and the aluminium rod O is observed through the slots N until it appears to have assumed, as nearly as can be approximated, a true vertical in the standard axis. Then on looking through the sight-hole T the adjustment can be more accurately continued until a ring of light of even breadth appears around the magnet-disk. This done the magnet is accurately centered and the instrument is ready for use. The current traversing the coils influences a magnet in a way that is well understood and therefore need not here be described. The mirror H, moving simultaneously with the magnet, may reflect a reading from a scale disposed in suitable proximity, or reflect a beam of light upon a marked scale, by which means the extent of its angular displacement can be determined.

In my present application I do not describe any particular arrangement or construction of scale, for the reason that various dispositions therefor are well known and may be adapted to use in connection with the present instrument by any competent electrical workman or other person skilled in the art. The adjusting-screw allows of the standard A being rotated on its vertical axis, as already described, and in this way the coils may be set with reference to the magnetic meridian.

The coil rings D are secured in stationary position to the supports, and may be permanently so fastened, if desired. It is preferable, however, to provide several coils varying in effect upon the magnet, and to this end the turns of the conductors, respectively, on said coils may vary from the single turn of a large conductor to many turns of a small conductor. These coils are all to be applied to bobbins or spools of like shape and dimensions, and hence all made interchangeable with reference to the supports I I', &c. I provide, also, pairs of coils, the conductor forming one coil of the pair being so arranged or constructed as compared with the conductor forming the other coil that the effect of both jointly upon the needle will depend upon the ratio existing between the said conductors, and this ratio I mark in suitable characters upon the pairs of coils themselves.

Inasmuch as the position of the coils with reference to the magnet center is made fixed and invariable, it follows that the constant of the instrument may once for all be determined for each coil. Referring to the well-known expression for the constant

$$\left(\frac{a}{2\pi}\right)$$

for a single coil, in which *a* is the distance of the coil from the magnet-center, it is obvious that in the present instrument this distance is once for all fixed; hence it is necessary simply to divide this constant by the number of turns of the coil to determine the constant of the instrument for any particular coil of more than one turn. The quotient multiplied by the tangent of the angle of deviation of the magnet and by the strength of the earth's magnetism at the place where used gives the measurement of the current in absolute electro-magnetic units.

I claim—

1. In a galvanometer, a hollow standard, a vibrating magnet therein, fixed supports integrally formed of said standard and upon opposite sides thereof, coils received by said supports and held in parallel planes, and means for securing said coils to said supports, substantially as described.

2. In a galvanometer, a hollow standard, a vibrating magnet therein, two parallel stationary coils fixed upon opposite sides of said standard, and means for adjusting the center of said magnet into coincidence with a line joining the centers of said coils, substantially as described.

3. In a galvanometer, a vertical hollow standard, a magnet suspended therein, and two stationary parallel coils fixed upon opposite sides of said standard, the center of said magnet coinciding with the point of intersection of the vertical axis of said standard, and in line with the centers of said coils, substantially as described.

4. In a galvanometer, a central hollow standard, a vibrating magnet therein, ring-supports on opposite sides thereof, coils, and means for securing said coils to said ring-supports, the arcs of said ring-supports being struck from centers located on a line intersecting and at right angles to the longitudinal axis of the standard, substantially as described.

5. In a galvanometer, a vertical hollow stand-

ard, a block of diamagnetic metal containing a central chamber and supported in said standard, a magnet suspended from the upper part of said standard and within said central chamber, and two stationary coils, respectively supported upon and on opposite sides of said standard in parallel planes, substantially as described.

6. In a galvanometer containing a vertical hollow standard and a magnet suspended therein, an open chamber in said standard and a mirror connected to and partaking of the motion of said magnet arranged within said chamber, substantially as described.

7. In combination with a galvanometer containing vibrating magnet, coils, supports, and a means for securing said coils to said supports, two or more coils of different inductive capacities interchangeably adapted to said supports, substantially as described.

8. In combination with a galvanometer containing a vibrating needle, coil, supports, and a means for attaching coils to said supports, two coils of different inductive capacities interchangeably adapted to said supports and marked with characters indicating the ratio of their respective capacities, substantially as described.

9. The combination, in a galvanometer containing a vibrating magnet and coils disposed on opposite sides thereof, of the hollow standard A, receiving the magnet, and provided with supports I I′, for the coils, substantially as described.

10. The combination, in a galvanometer containing a vibrating magnet and coils disposed on opposite sides thereof, of the hollow standard A, provided on opposite sides with fixed supports I I′, having curved grooves for the reception of the coils, the arcs of the curves of said grooves being struck from centers equidistantly located from the longitudinal axis *i i′* of said standard and upon a line, *j j′*, intersecting and at right angles to said longitudinal axis, substantially as described.

11. The combination of the hollow standard A, vibrating magnet therein, supports I I′ I″ I‴, rings C, coils D, and clamping screws *a*, substantially as described.

12. The combination of the standard A, having the conical extension J, base B, washer L, and screw-bolt K, substantially as described.

13. The combination of the standard A, supports I″ I‴ thereon, worm-screw *f*, and supports *d e* therefor, with the base B, having boss *b*, and toothed segment *c* on said boss, substantially as described.

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