(No Model.) 4 Sheets—Sheet 1.

J. J. WOOD.

ELECTRIC CURRENT INDICATOR.

No. 520,129. Patented May 22, 1894.

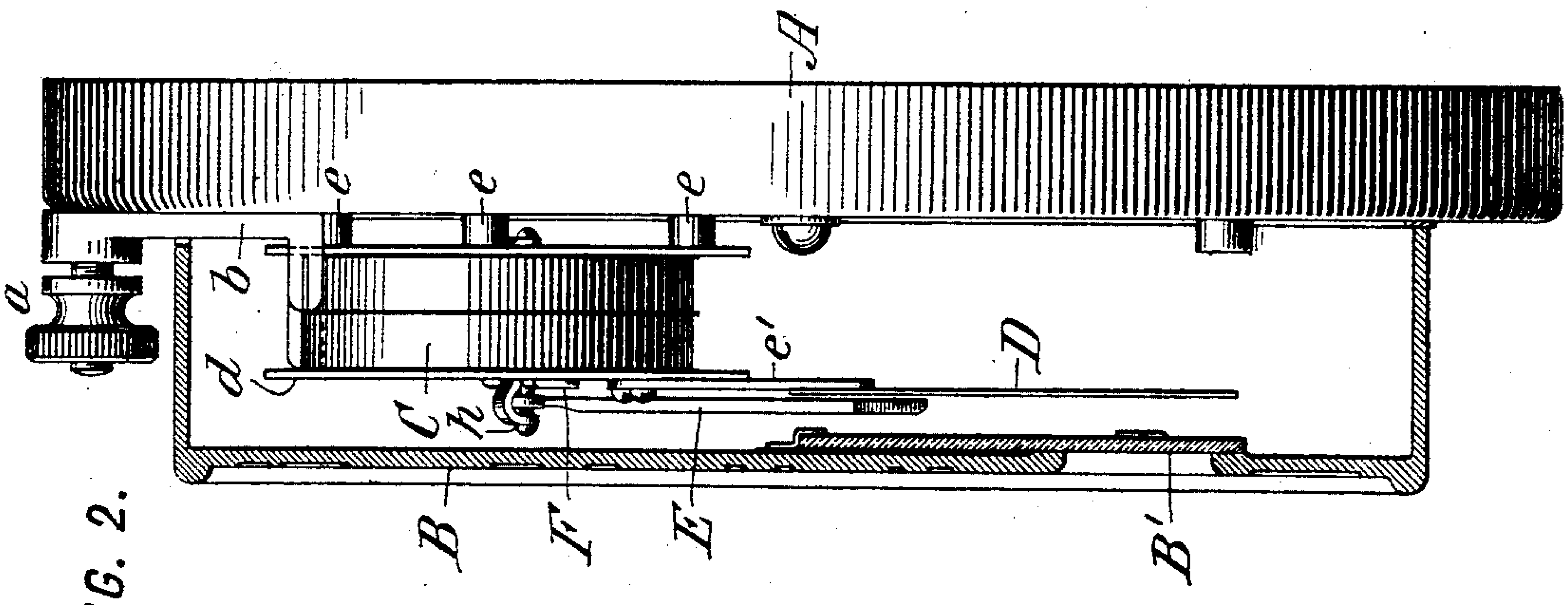

FIG. 2.

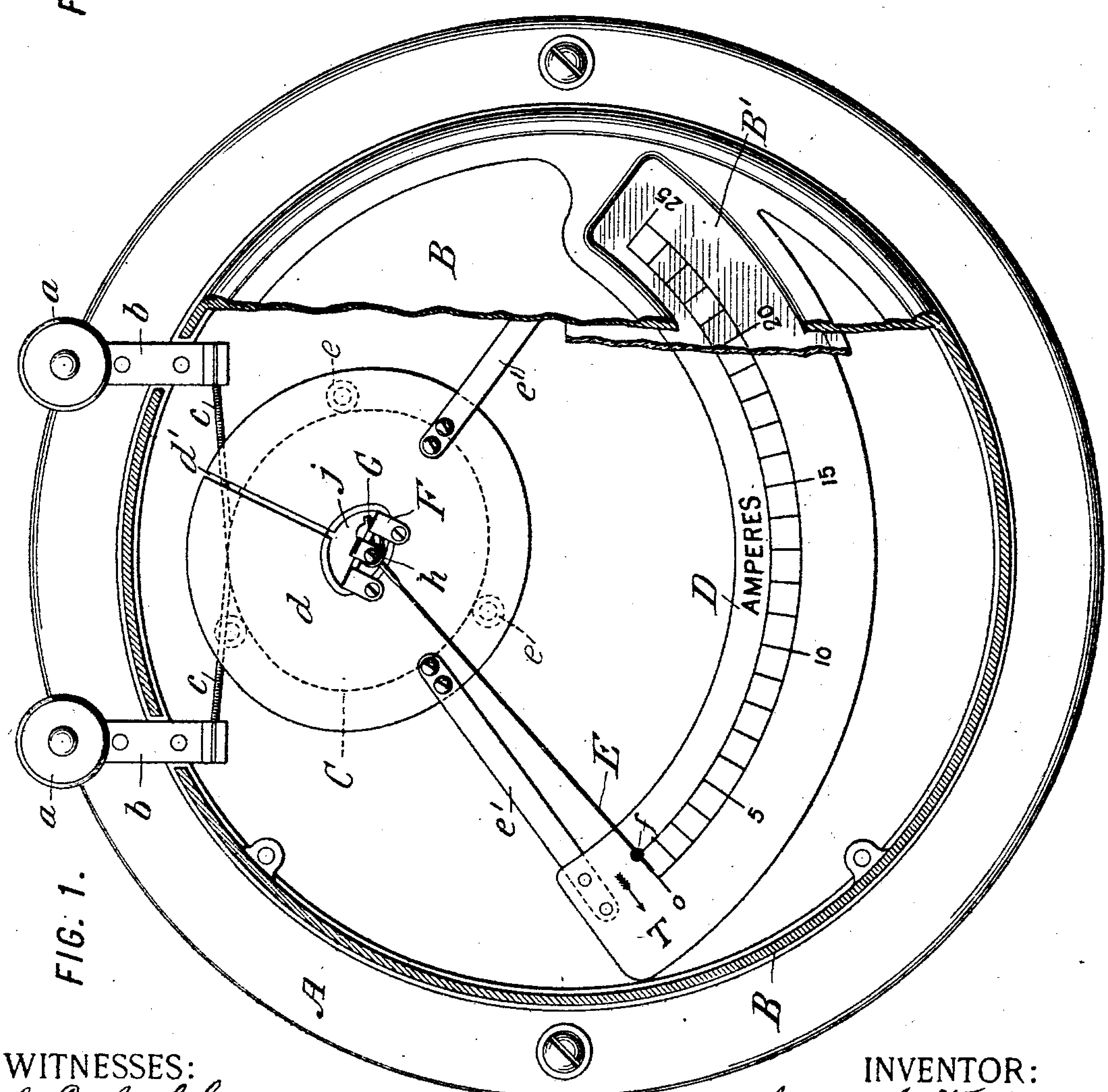

FIG. 1.

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ELECTRIC CURRENT INDICATOR.

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FIG. 3.

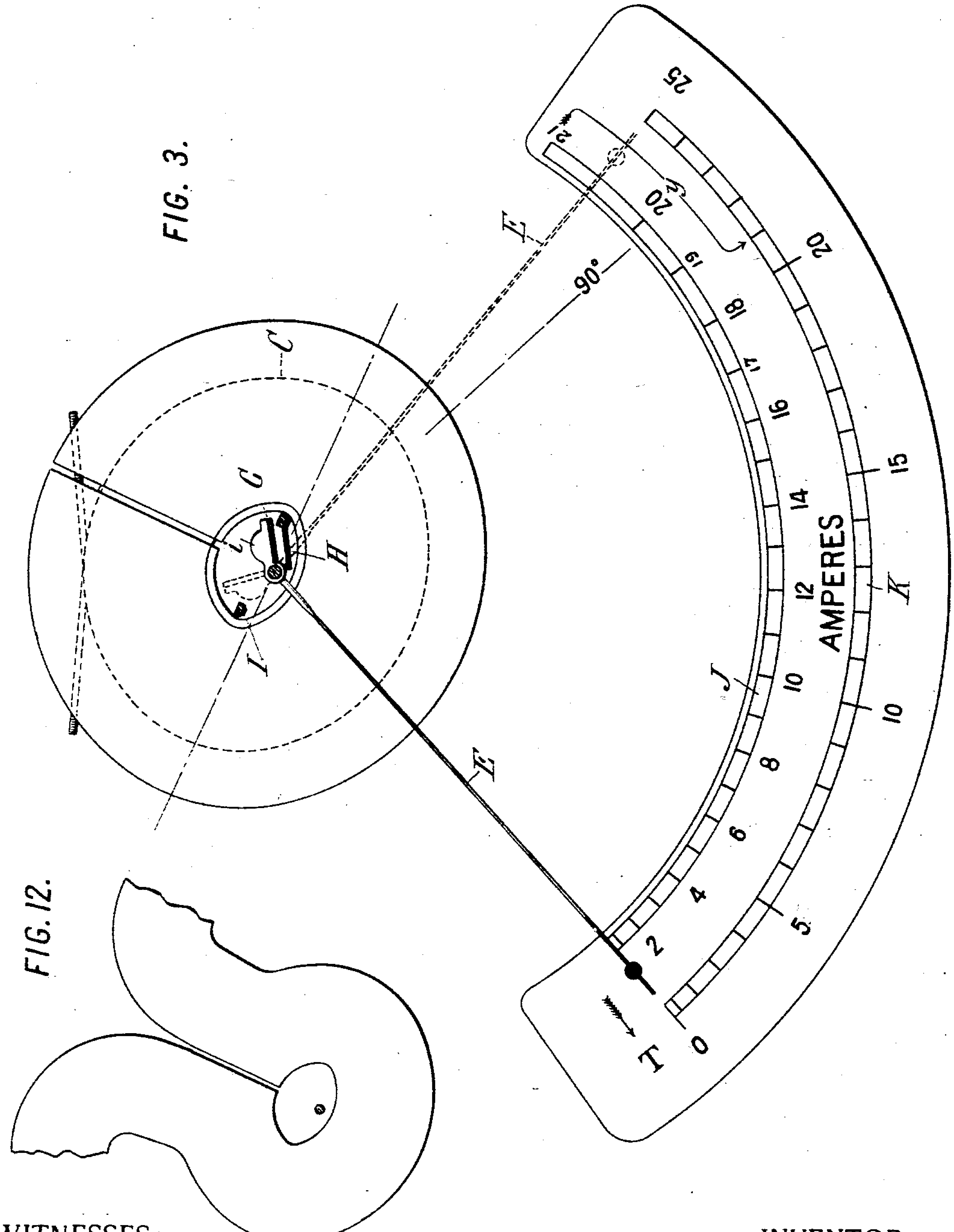

FIG. 12.

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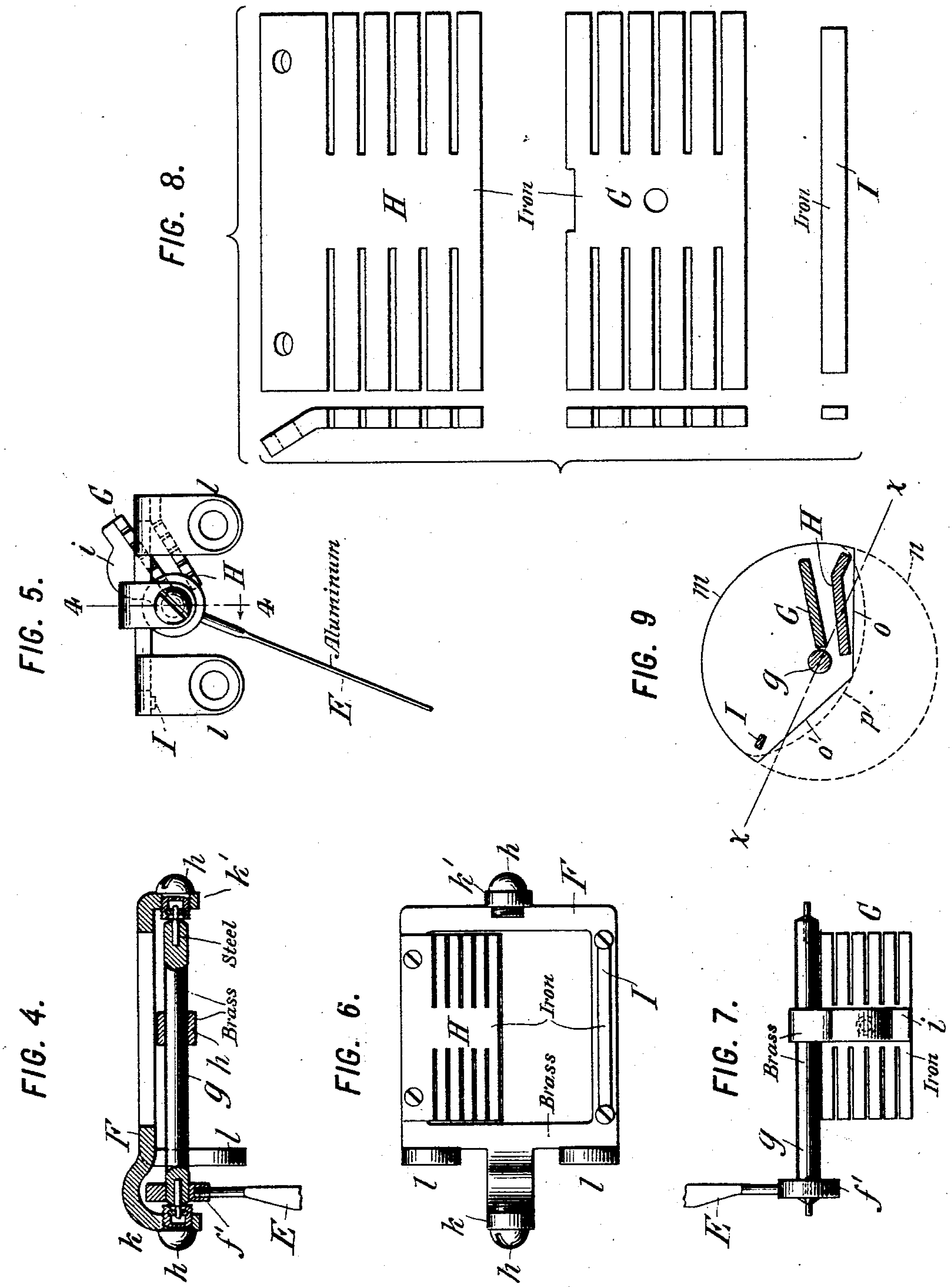
4 Sheets—Sheet 3.

J. J. WOOD.

ELECTRIC CURRENT INDICATOR.

No. 520,129. Patented May 22, 1894.



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(No Model.) 4 Sheets—Sheet 4.

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ELECTRIC CURRENT INDICATOR.

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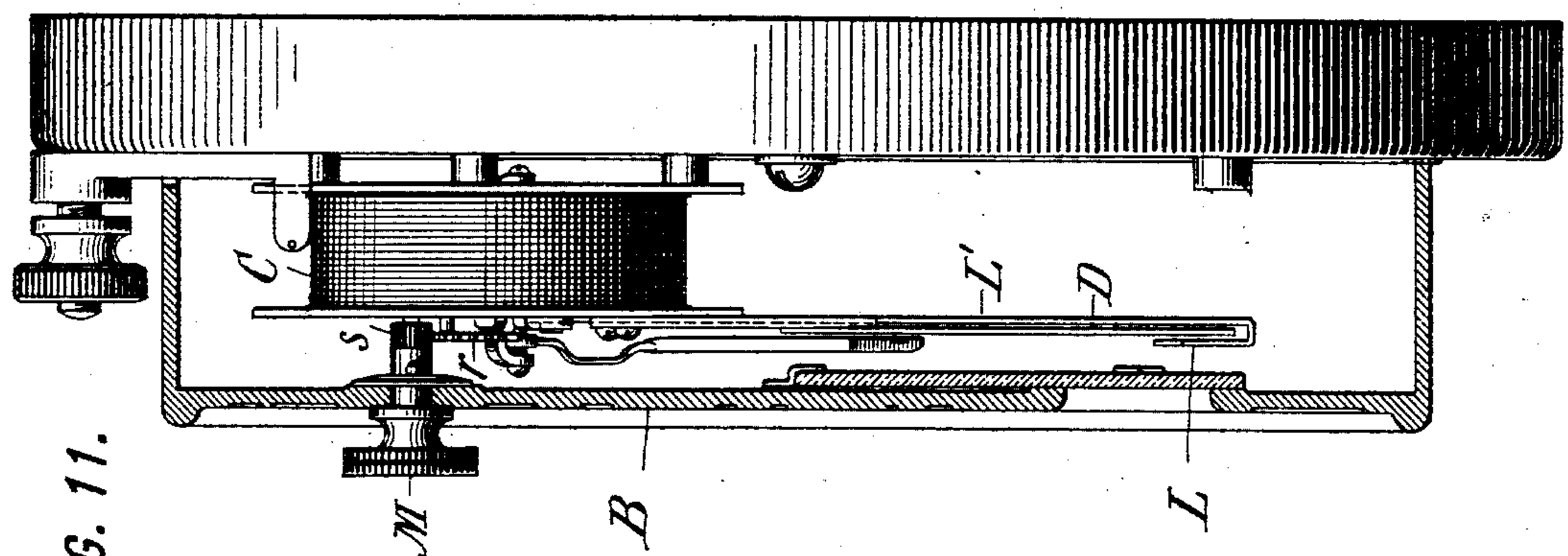

FIG. 11.

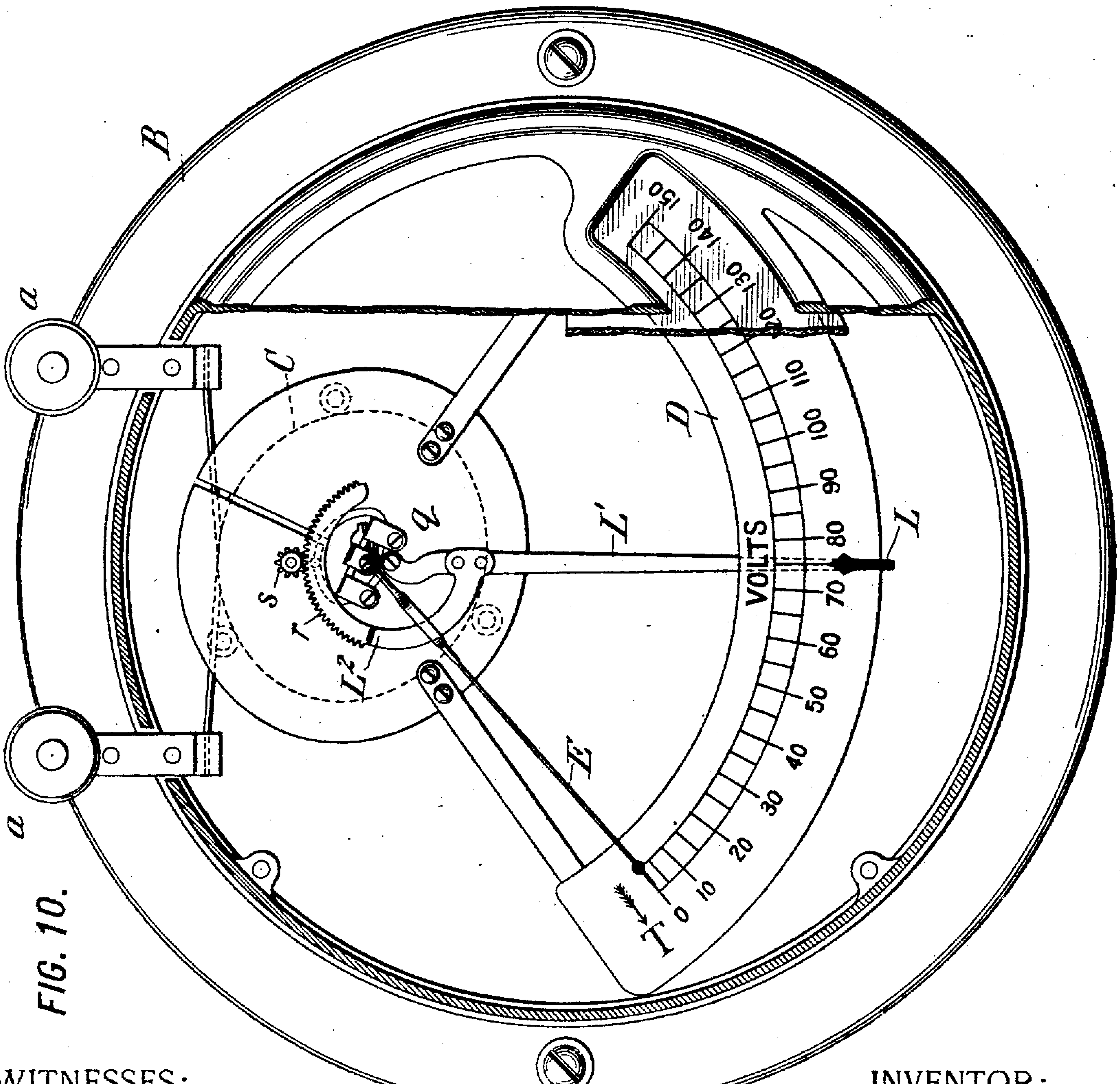

FIG. 10.

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UNITED STATES PATENT OFFICE.

JAMES J. WOOD, OF FORT WAYNE, INDIANA.

ELECTRIC-CURRENT INDICATOR.

SPECIFICATION forming part of Letters Patent No. 520,129, dated May 22, 1894.

Application filed February 6, 1894. Serial No. 499,257. (No model.)

To all whom it may concern:

Be it known that I, JAMES J. WOOD, a citizen of the United States, residing in Fort Wayne, in the county of Allen and State of Indiana, have invented certain new and useful Improvements in Electric-Current Indicators, of which the following is a specification.

This invention relates to instruments for measuring or indicating the quality or energy of electric currents and other analogous phenomena, such instruments being commonly constructed as ammeters or voltmeters so called. In the construction of such instruments both mechanical and electrical conditions require to be fulfilled in order to attain a practical degree of perfection. The moving parts should be very light in order that their inertia shall not carry them too far and cause them to vibrate before settling down to the required indication, and in order that the jar to which they are subjected during shipment will not injure them. The moving parts should be easily accessible and easily removable for repairs or readjustment, and this should be capable of accomplishment without disturbing the coils or any of the circuit connections. The movable parts should be brought to zero by the action of gravity, since the employment of a spring is undesirable because of the variations occurring in its tension by reason of changes in temperature. Finally, the construction should be such that the parts can be easily and cheaply made in large quantities, and so as to be interchangeable. The required electrical conditions are, that the magnetic reactions between the fixed and movable members should maintain a direct proportion relatively to the retractile force for each stated increase or decrease in electrical energy to be indicated, in order that the scale may have a uniform graduation. The magnetic properties should remain constant, in order that no need may arise for recalibrating the scale, and the residual or reminent magnetism must be so far suppressed that the instrument will indicate with the same accuracy when affected by successively increasing manifestations of electric energy, as when affected by successively decreasing manifestations, in order that the index shall for a given current point to the same position on the scale whether the preceding current affecting the instrument has been less or greater. It is also highly desirable for an ammeter that the same instrument shall be applicable for either direct or alternating currents.

My present invention provides a new construction of ammeter or voltmeter designed to realize the conditions stated. In its construction I employ a coil of one or more turns as the electrical conditions may require, and within the opening in this coil I mount a movable armature of soft iron which is so pivoted that it may swing to different positions within the coil opening, a light pointer arm or index being connected to this armature so as to swing over a scale as the armature moves to different positions. The instrument is preferably so placed that the pivotal axis of the armature is horizontal, and the armature and pointer are made to partially counterbalance each other in such manner that they will gravitate to the initial or zero position, and gravitation will resist their displacement therefrom. Within the coil and adjacent to the initial position of the armature, is placed a fixed repellent magnet of soft iron, so that when this magnet and the armature are both magnetized by the same current in the coil, their polarization will be of like sign, and they will mutually repel each other, so that the armature is forced to recede from the fixed magnet, its recession being opposed by the retractile force of gravitation. To increase the effect, one side of the coil is flattened by being brought in close to the pivotal axis, so that the magnetic axis of the coil becomes eccentric to the pivotal axis, and the flattened side of the coil exerts a preponderating attraction for the armature. The fixed magnet and armature being inclosed within the coil, and hence not readily accessible, are mounted on a frame which projects into the coil and forms the stationary mounting for the fixed magnet and the pivotal mounting for the armature. This frame has flanges overlying one face of the coil and fastened thereto by screws, so that the entire frame may be readily removed, carrying with it all the mechanical parts to which complete access can thus be gained for inspection or adjustment. To reduce the reminent magnetism to the minimum, the armature and fixed magnet are made as fish-bone magnets, that is, they are thin plates of iron deeply slotted from opposite edges to subdivide them into minute magnetic bars. As thus constructed the instrument is found to possess all of the required conditions except that the scale is not uniform, the graduations being spaced wider apart as the scale ascends. To overcome this objection, my invention introduces a new and important feature in instruments of this class, namely, an additional repellent magnet, much smaller than the main stationary magnet, placed within the coil on the opposite side of the armature from the main stationary magnet, the effect of which is to exert a counter repulsion against the armature, increasing as the armature becomes more remote from its zero position, and consequently reducing the extent of movement of the armature in response to the higher manifestations of energy in the coil, and hence consequently serving as it were to crowd together the scale graduations toward the upper end of the scale so as to bring them to the same spacing that prevails over the lower portion of the scale. By this means the scale is brought to almost absolute uniformity of graduation. This smaller or scale correcting magnet I will call the compensating magnet, while the main repellent magnet I will call the main magnet.

My invention also involves other features or details of construction as will be hereinafter set forth.

Figure 1 of the accompanying drawings is a front view of an ammeter constructed according to my invention, the front of the case being partly broken away to show the interior construction. Fig. 2 is a side elevation of the ammeter, the case being in vertical midsection. Fig. 3 is a diagrammatic view on a larger scale showing only the essential parts, the iron magnets, armature and supporting frame within the coil being shown in section. Figs. 4 to 7 show on a larger scale and in detail, the construction of the movable armature, the main and compensating magnets, and their supporting frame and pivotal connections, Fig. 4 being a longitudinal mid-section on the line 4—4 in Fig. 5, Fig. 5 being a front end elevation, Fig. 6 a face view of the frame and stationary magnets from underneath, and Fig. 7 a face view of the armature and its pivot support. Fig. 8 includes face and edge views of the two iron magnets and the iron armature. Fig. 9 is a diagrammatic section corresponding to part of Fig. 3. Figs. 10 and 11 show a voltmeter constructed according to my invention, Fig. 10 being a front elevation partly broken away in the same manner as in Fig. 1, and Fig. 11 being a side elevation with the case in section in the same manner as Fig. 2. Fig. 12 is a front view showing a modification of the coil.

Referring to Figs. 1 and 2, let A designate an insulating base plate of wood, slate, marble or other material upon which the several parts are mounted, and B an inclosing case fastened against the front of said base.

C is a coil of wire or tape of any suitable conductor, in one or more convolutions according to the volume of current which the instrument is to receive and measure. The terminals *c c* of this coil are shown as joined to metal plates *b b* fitted with binding posts *a a* by which to join the circuit wires. The coil is shown as wound upon a spool or supporting frame *d*, which may be of brass, and which in turn is supported on the base B by means of three posts *e e* with fastening screws. In order to prevent currents being generated in the spool and consequent heating when alternating currents are employed, the spool *d* is slotted radially at one side as shown at *d'*.

The case B is formed with an arc-shaped scale opening B', preferably protected by glass, and behind this opening is a scale plate D on which are marked scale graduations which are visible through the opening. The plate D is supported preferably from the spool *g* of the coil by means of arms *e' e'*. Over the scale moves the end of a pointer or index E, pivoted at the center of the scale, and which consists preferably of an arm of aluminium in order to be extremely light and sensitive. To render the position of this index or pointer clearly visible without too close inspection, it carries a blackened disk *f*.

The index arm E is mounted as shown in Fig. 4 on a hub *f'* fixed on a spindle *g* which is delicately pivoted at its ends in jeweled pivot supports or bearings *h h*, as shown in Fig. 4. On this spindle *g* is fixed a radial arm *i*, and to this arm is fastened a movable iron armature G, as shown in Fig. 7. The index arm E and the armature G are consequently mounted to swing or oscillate around the pivotal axis of the spindle *g*. The armature swings thus in an opening *j* within the coil C, this opening being bounded by the inner part or barrel of the spool *d*. The coil opening is amply large to permit the armature to swing through from ninety degrees to one hundred and twenty degrees or more as may be desired. Within the same coil opening, and on the side thereof adjacent to the zero position of the armature, is mounted a stationary repellent magnet H. On the opposite side of the armature, and near the position assumed by it when it has been repelled over, remote from the zero position, is a much smaller magnet I, their relative positions being shown in Fig. 3. To distinguish the two stationary magnets, the larger one H will be called the main magnet, and the smaller one I the compensating magnet. In order to support these magnets, and also to support the pivotal bearings *h h*, I provide a frame F, shown best in Figs. 4, 5 and 6, the magnet H being fastened against one side of this frame, and the magnet I against the opposite side, while the armature is mounted to swing through the opening of the frame, its bearings h being held by turned in arms k k'. Thus both the stationary and movable magnetic parts are all mounted on this frame. The frame is inserted into the coil opening, and is fastened by screws passing through ears or flanges l l on the frame into the spool of the coil. As these two fastening screws enter the front of the spool, as shown in Fig. 1, the removal of these two screws, which are easily accessible upon taking off the case B, permits the entire frame F and the magnetic parts carried by it, including the arm E, to be removed bodily for examination or adjustment. Their removal is thus effected without disturbing any of the electric connections, and without disturbing the pivotal mounting of the armature and index.

The spindle g is of brass or other non-magnetic metal so that it can have no residual magnetism, and to avoid being heated by alternating currents. In order to properly pivot it it has holes bored into its opposite ends in which small hardened steel pins are driven, these pins constituting the pivotal journals, as shown in Fig. 4. The ends of these journals enter into bearing sockets formed in jewels which are held within the bearings h, these bearings being constructed as screws to screw into the openings in the turned-up ears k and k', as clearly shown. The arm h and hub f' are pressed onto the brass spindle g, or otherwise fixedly attached, and to make room for the hub f to turn freely, the frame F has its arm k swelled or rounded around this hub, as shown in Fig. 4. The index arm E is made of round aluminium wire screwing into a threaded socket in the hub f', this wire being flattened as shown.

The fixed magnets H and I, and the removable magnet or armature G, are all made of soft iron, being punched from annealed sheet iron. The magnets G and H are made as fishbone magnets, that is, they are partially subdivided by being slotted from opposite edges, as shown, in order to efface their residual magnetism in the well known manner. The relative proportions of the three magnets are shown in the magnified view, Fig. 8, these being the proportions which have thus far been found to give the best results, although my invention admits of the proportions being varied to suit any requirements which may be determined by experiment.

The mechanical construction thus described admits of the parts being easily and cheaply made and assembled, the pivotal adjustment of the armature being effected while it is exposed and accessible and before the parts are introduced into the coil opening. The armature by swinging in the opening of the frame F, utilizes the opposite sides of the frame opening as stops to limit its motion. Thus in its zero position it approaches closely to one margin of the frame, as shown in Fig. 5, this portion of the frame serving to prevent the armature from moving too close to the magnet H, as if they were to approach too closely, the magnetic effect would be reversed and they would tend to stay together instead of to repel each other.

It will be observed that when at rest or in the zero position, the armature G extends to the right of the pivotal axis while the index arm E projects to the left, so that they tend to counterpoise each other. To give the armature sufficient weight to properly counterpoise the long index arm without adding too greatly to the mass of iron, the brass arm i is thickened as shown in Fig. 5 to make it a sufficient counterweight. When in the normal or zero position, the center of gravity of the armature spindle and arm, that is to say, of the movable system of the instrument, is directly beneath the pivotal axis, so that the parts tend by gravity to return to this position when displaced therefrom. In this position of the armature, the magnet H should be close to it, and to this end the frame F is tilted to the angle shown in Figs. 1 and 3.

Heretofore in instruments of this character the pivotal axis of the armature has been concentric with the axial center of the coil, so that the armature was actuated solely by repulsion from the fixed magnet, and the only influence of the current in the coil upon the armature was to magnetize it equally with the fixed magnet, and thereby set up a mutual repulsion, causing the armature to swing more or less away from the fixed magnet. The movement of the armature did not alter its relations with the coil, since it swung always around the center of the coil and could not approach to or recede from the coil, and consequently the magnetic lines of force emanating from it would inclose the coil only to the same extent, whatever its position or degree of magnetization. According to my invention I so construct and mount the coil and armature respectively that the armature shall be pivoted eccentrically to the magnetic axis of the coil, and as the current in the coil increases in strength and the armature is thereby repelled farther from the fixed magnet H, it changes continually its relation to the magnetic axis of the coil, and reaches a position where as it becomes more remote from the fixed magnet H, it approaches closer and closer to the coil, so that by reason of the well known tendency of a magnet to draw toward an electric current flowing at right angles to it so as to contract the lines of force that it throws around the current, the armature is attracted by the coil, in co-operation with the repulsive effect of the fixed magnet, and is thereby moved farther than it would be moved by repulsion of the fixed magnet alone. To accomplish this result, one side or half of the coil is drawn in as close as is practicable to the pivotal axis of the armature, in the manner shown in Figs. 3 and 9. One half or thereabout of the coil opening j is concentric with the pivotal axis, as shown by the arc m (Fig. 9), in order that the armature may have free concentric swing within this portion. If the coil opening were continued concentric with the pivotal axis, it would follow the dotted line n (Fig. 9). An inclined diametrical line $x\,x$ is drawn through the pivotal axis, and (approximately stated) that portion of the coil opening on one side of this line is concentric as shown at m, while on the other side of this line the coil opening is contracted or drawn in toward the axis as far as the mechanical construction will admit, that is, it will be drawn in close against the magnet H toward one side, as shown by the line o, and correspondingly on the other side as shown by the line o' (Fig. 9). To suppress the angles between the lines m, o, o', m, and produce a shape for the barrel of the spool over which the wire of the coil can be practicably wound, the outline is made curved with rounded corners, as shown by the dotted outline p in Fig. 9, and as shown in full lines in Fig. 3.

Bearing in mind that the center of gravity when the armature is in the zero position is directly beneath the pivotal axis, then as the armature is repelled from this position the center of gravity swings upwardly to the right in Fig. 3, so that it acts with continually increasing leverage until the armature has traveled ninety degrees from its zero position, and after that with a decreasing leverage. By reason of this increasing leverage, the retracting force resisting the movement of the armature increases as the armature recedes from its zero position, or in other words, as the index ascends the scale, so that if the magnetic repulsions were in direct proportion to the successive increments of electrical energy, the armature and index would execute successively smaller movements with each uniform increment of current, so that the scale graduations would become relatively closer until the index had moved over ninety degrees. And as in fact the magnetic repulsion of the armature and fixed magnet acts to continually decreasing advantage as the armature and fixed magnet become farther apart, there is from this cause an added tendency to crowd the scale graduations together as the index ascends the scale. These two causes, however, are counteracted by the construction of the coil to approach more closely to the armature center on one side than on the other, so that as the retractile or opposing force acts with increasing advantage, and the repulsive force acts to decreasing advantage, the direct attractive effect of the coil upon the armature comes into play to accelerate or enhance the movement of the armature, and thereby keep the scale graduations from closing together as the scale is read up. In practice it is found, however, that such an adjustment of the coil in this respect, and in the absence of the magnet I, produces a fault of opposite effect, that it causes the scale graduations to become disproportionately widely spaced toward the upper part of the scale, and especially after the ninety degree movement has been exceeded. This is shown in Fig. 3, where the upper scale J was calibrated before introducing the scale correcting magnet I. It will be seen that this scale has its graduations spaced gradually wider apart as the scale is read up, the widening, however, not being serious until past the graduation mark 16, that is to say, until closely approaching the ninety degree point, and that after passing the ninety degree point at 20, the next step from 20 to 21 is spaced relatively much wider even than those between 16 and 20. To overcome this objection I introduce the slight counter repulsion derivable from the magnet I, which is placed within the coil on the opposite side of the armature to the magnet H. The effect of this counter repulsion is shown by comparing the scale J in Fig. 3 with the scale K which was calibrated on the same instrument after introducing the magnet I. This minute magnet has so crowded the upper portion of the scale together as to bring the graduation 21 in to the extent indicated by the arrow y, thereby enabling the scale to read several degrees higher, and what is most important and desirable, enabling me to attain a scale of almost ideally uniform graduation. The magnet I is of much smaller mass than either the armature G or maximum magnet H, as shown in Fig. 8. Being placed within the coil it is subjected to the same magnetizing effect as the magnets G and H, and has the same polarity, so that it tends to repel them, its repulsive effect, however, being but slightly apparent in the lower portion of the scale, and increasing toward the upper portion of the scale, having thus the ratio required to correct the inequality existing in the scale before this magnet was introduced. Thus by this simple combination of expedients, I have succeeded in producing an instrument in which the liability to error due to the use of a spring as the retracting force is overcome, and in which at the same time the scale ascends by equal steps for equal increments of energy to be measured. This statement is subject only to the exception that at the lower end of the scale the first one, two or more graduations are spaced unduly close together, as is the case with all instruments of this character, due as is believed to the portion of energy that is wasted in forcing magnetic lines across the air space between the relatively reacting magnets G and H, so that the initial movement of the armature is disproportionately small. In Fig. 3, all graduations beyond that for two ampères are free from this defect.

Another and even more important advantage of the introduction of the compensating magnet I, is that it practically overcomes the defect heretofore inherent in all instruments of this character used with continuous currents employing iron in their movable system, that for like currents the index points to different positions on the scale when reading up the scale than it does when reading down the scale. This defect is believed to be due to the effect of residual magnetism in the iron magnets, which, having been magnetized by a greater current, retain a portion of this magnetism when the current is reduced to a lesser amount, so that they then present a greater intensity of magnetism than this lesser current of itself would have produced. In consequence of this error it has been found necessary heretofore, in order to secure a correct reading whenever the index is descending the scale, to momentarily interrupt the circuit through the instrument, and thereby demagnetize the magnets. The introduction of the compensating magnet I is found in practice to entirely correct the error referred to, and so renders it unnecessary to interrupt the circuit. This result is believed to be due to the fact that the compensating magnet retains itself the same proportionate degree of residual magnetism as the magnets G and H, and by acting in the contrary direction its residual magnetism opposes itself against their residual magnetism, so that while their residual magnetism tends to cause the index to remain higher up on the scale than it should, the residual magnetism of the compensating magnet exerts the contrary effect, thereby pushing the armature back until the index is brought to the proper position on the scale. Although the compensating magnet has a mass much less than the magnets G and H, yet their action takes place against the retracting effect of gravitation, while the action of the compensating magnet is assisted by gravitation, so that its effect under the influence of residual magnetism in this respect is much greater in proportion to its mass than theirs.

The scale at the left of zero is marked with an arrow and the letter "T," meaning "test." This is in order that it may be determined at any time whether the index arm has become bent. The movement of the armature G is limited by a positive stop when it strikes the frame F, and by pressing the armature down against this stop, the index is carried to the left of zero and should be brought to T. If it does not coincide with T, it should be bent until it does. The instrument should be leveled by adjustment until the weight of the index brings it to zero with the current turned off. This means for "test" adjustment is claimed in my Patent No. 452,354, dated October 8, 1889.

The construction of the voltmeter shown in Figs. 10 and 11 provides essentially the same features as already described, with the addition of a further element of my invention. It is of course understood that for a voltmeter the coil requires to be wound with fine wire. The construction of the magnetic elements is precisely the same as that already described, the only essential differences being in the coil winding and the scale graduation, the scale being graduated for volts form some known standard. It is usual and desirable in voltmeters which are used upon a circuit on which a certain normal potential is sought to be maintained, to provide a pointer which can be set to indicate the normal voltage that it is desired to maintain, so that at a glance any deviation of the index E from this voltage can be detected. This pointer has heretofore been constructed as a hand lying over the face of the scale beneath the index, and pointing like the index, downwardly. I construct it to point in the contrary direction or upwardly, so that at the correct voltage the index and pointer will stand facing each other or point to point, it being easier to detect any variation of the index from the correct position when the two are thus arranged than when the index lies over the pointer. The pointer in these figures is lettered L, and consists of the upturned end of an arm L', which is pivoted at q on a screw fastened to the spool at a point as near as is practicable to the pivotal axis of the armature. In order to turn the arm L' to different positions for setting the pointer L, an arc-shaped arm L^2 is fixed to it and is curved around concentrically with its pivotal axis and formed with gear teeth r constituting a toothed sector, with which meshes a pinion s formed on the inner end of a stem passing through a hole in the inclosing case B, and having formed on its outer end a knob M by which to turn it. By turning this knob M the pointer L can be propelled to any desired position on the scale, and because of the friction attending the movement of the knob and gearing, it will retain any position at which it is set. The arm L^2 passes beneath or back of the index E, the latter being bowed upwardly to bridge over the arm.

I have spoken of the coil C being essentially of one or more convolutions as the electrical conditions may require. For example, for a very heavy current a coil of one convolution might be made of a single piece of massive copper, in substantially the shape shown in Fig. 12, its ends being connected to the outside line in any suitable way. In this case no spool will be used, and the frame F will be fastened to the copper casting constituting the coil.

My invention may be modified in certain respects without departing from its essential features. For example, the frame F may be fastened otherwise than to the spool or coil, as shown, it being only practically necessary that its fastening shall be exterior and easily accessible. The compensating magnet I need not necessarily be arranged within or wholly within the coil, as any other arrangement by which the same effect of compensation is realized would be equivalent. The compensating magnet need not be stationary, as it might be mounted to move either with the armature or independently thereof, provided only that it be so mounted, arranged or proportioned as to exert the same compensating action or counter repulsion that I have herein described. The magnets G, H and I need not necessarily be made of soft iron, for soft steel will answer, or any magnetizable substance which will lose its magnetism upon the cessation of the magnetizing current.

I claim as my invention the following-defined novel features, substantially as hereinbefore specified, namely:

1. In an instrument for electrical measuring the combination of a coil, a magnetic armature movable within said coil, and tending to come to rest at a certain position, a main magnet fixed within the coil adjacent to that position to repel the armature therefrom when excited by a current in said coil, and a compensating magnet arranged to exert a counter-repulsion as the armature is remotely repelled from the main magnet, whereby to resist a tendency to disproportional movement of the armature as the current increases.

2. In an instrument for electrical measuring the combination of a coil, a magnetic armature pivoted to move within said coil, having an index connected to it, and mounted to gravitate to a position of rest, a main magnet fixed within the coil adjacent to that position to repel the armature therefrom against gravitation when excited by a current in said coil, and a compensating magnet arranged to exert a counter-repulsion as the armature is remotely repelled from the main magnet, whereby to resist a tendency to disproportional movement of the armature as the current increases.

3. In an instrument for electrical measuring the combination of a coil, a magnetic armature movable within said coil, pivoted on an axis eccentric to the magnetic center thereof so that one side of the coil exerts an attraction for it preponderating over the other, and increasing with its movement from the zero position, a main magnet fixed within said coil adjacent to said position to repel the armature therefrom when excited by a current in said coil, and a compensating magnet arranged within said coil to exert a counter repulsion partially counteracting the increasing attraction of the coil as the armature recedes from the main magnet.

4. In an instrument for electrical measuring the combination of a coil with a large opening, said coil wound on one side of its diameter concentrically of a given axis and on the opposite side eccentrically thereto and drawn toward said diameter so that the opening is somewhat flattened on that side, an armature movable within said coil and pivoted coincidently with said axis and hence eccentrically to the coil, so that the flattened side of the coil exerts a preponderating attraction for the armature, and a main magnet fixed within said coil adjacent to said position, to repel the armature therefrom when excited by a current in said coil, and a compensating magnet fixed within said coil on the opposite side of the armature to exert a counter-repulsion against it partially counteracting the increasing attraction of the coil as the armature recedes from the main magnet.

5. In an instrument for electrical measuring the combination with a coil, a magnetic armature pivoted to move within it, and a stationary main magnet within it, of a detachable frame projecting within the coil forming pivotal bearings for said armature and fastened exteriorly to the coil, whereby said frame may be detached and removed carrying the armature with it, without disturbing the armature pivots or any of the electrical connections.

6. In an instrument for electrical measuring the combination with a coil, a magnetic armature pivoted to move within it, and a stationary main magnet within it, of a detachable frame projecting within the coil forming pivotal bearings for said armature and carrying said stationary magnet, and fastened exteriorly to the coil, whereby said frame may be detached and removed carrying with it the stationary magnet and armature, without disturbing their relative arrangement or the pivotal bearings of the armature.

7. In an instrument for electrical measuring the combination of a coil, a frame F entering the opening in said coil, having flanges *l* for fastening it exteriorly to the coil, and formed with ears *k k'* supporting pivotal bearings *h h*, a stationary magnet H fixed to one side of such frame, a movable armature G, a spindle *g* carrying said armature and pivoted in said pivotal bearings, and an index arm E attached to said spindle.

8. In an instrument for electrical measuring, the combination of a coil, a frame F entering the opening in said coil, having a central opening and formed with means for fastening it to said coil, and with ears *k k'* supporting pivotal bearings *h h*, a stationary magnet H fastened to one margin of said frame and projecting toward the middle thereof, a spindle *g* hung between said pivotal bearings, and an armature G mounted on said spindle and arranged to swing in said opening in the frame, so that the opposite sides of said opening may form stops to limit the movement of the armature.

9. In an instrument for electrical measuring, the combination of a coil, a magnetic armature pivoted to move within said coil, a spindle *g* for said armature made of non-magnetic material and having steel pivot pins inserted in its opposite ends, and pivotal bearings in which said pivots turn.

10. In a voltmeter or other instrument for electrical measuring, the combination with an exciting coil, a scale-plate, an index arm traversing said scale-plate, and a movable armature connected thereto for moving said index, of an adjustable stationary pointer L projecting inwardly across the face of said scale-plate from the outer side thereof, and a pivoted pointer arm L' carrying said pointer and extending behind the scale-plate.

11. In a voltmeter or other instrument for electrical measuring, the combination with an exciting coil, a scale-plate, an index arm trav-

ersing said scale-plate, and a movable armature connected thereto for moving said index, of an adjustable stationary pointer L, a pivoted arm L′ carrying said pointer, a curved arm L^2 branching therefrom and formed with segmental teeth r, and a pinion s meshing therewith connected to an actuating knob M for adjusting said pointer.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

JAMES J. WOOD.

Witnesses:
ARTHUR C. FRASER,
GEORGE H. FRASER.