(No Model.)

5 Sheets—Sheet 1.

T. DUNCAN.

ELECTRIC METER.

No. 604,459.

Patented May 24, 1898.

Fig. 1.

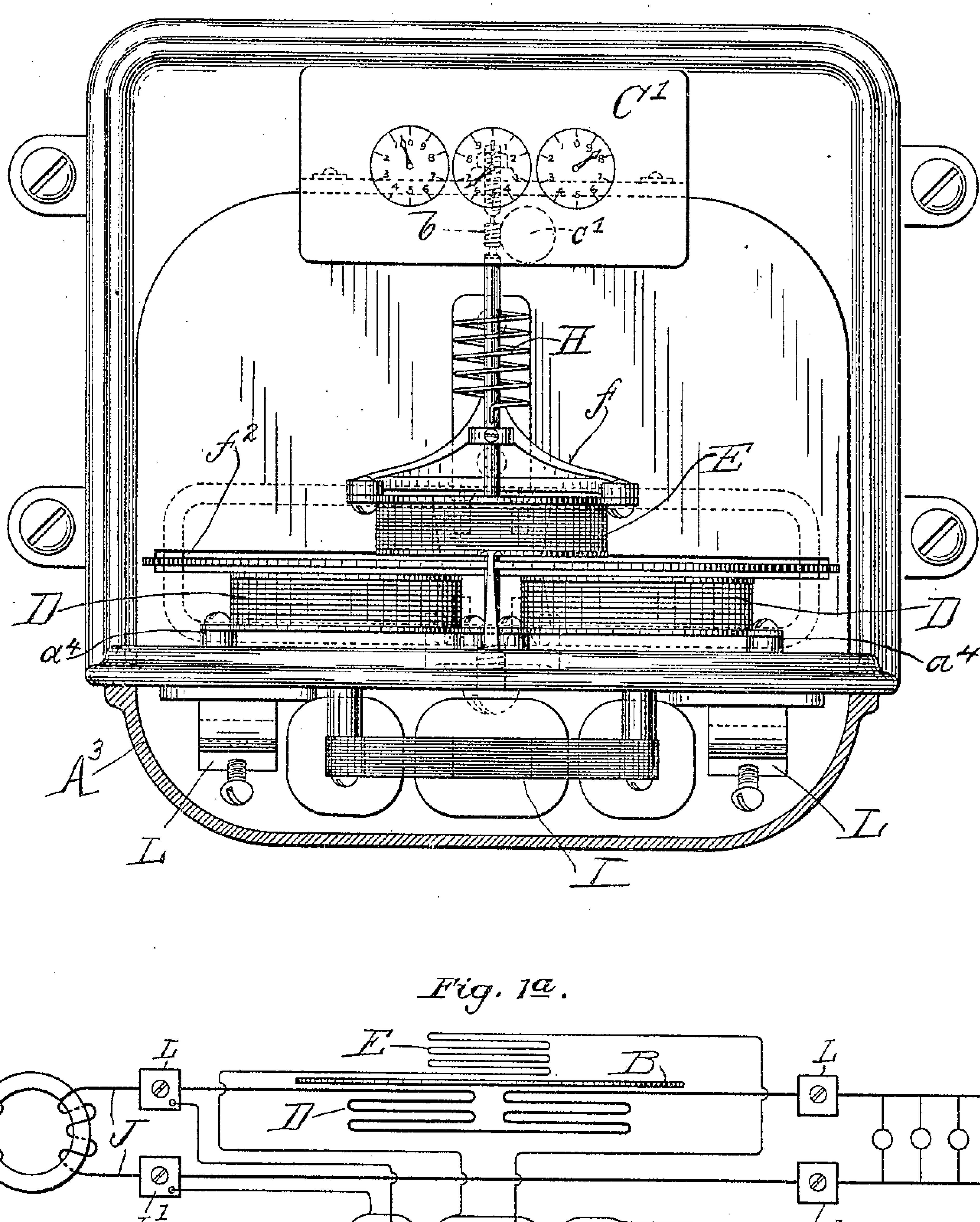
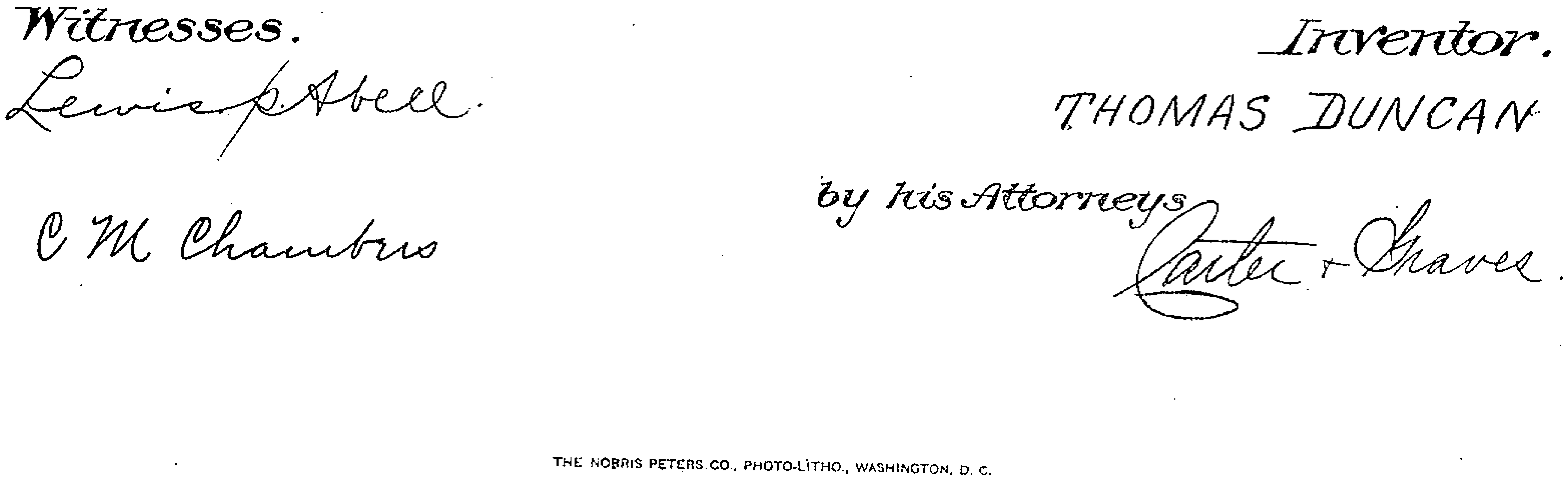


Fig. 1a.



Witnesses.

Lewis J. Abell.

C M Chambers

Inventor.

THOMAS DUNCAN

by his Attorneys Carter & Graves.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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ELECTRIC METER.

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Fig. 2.

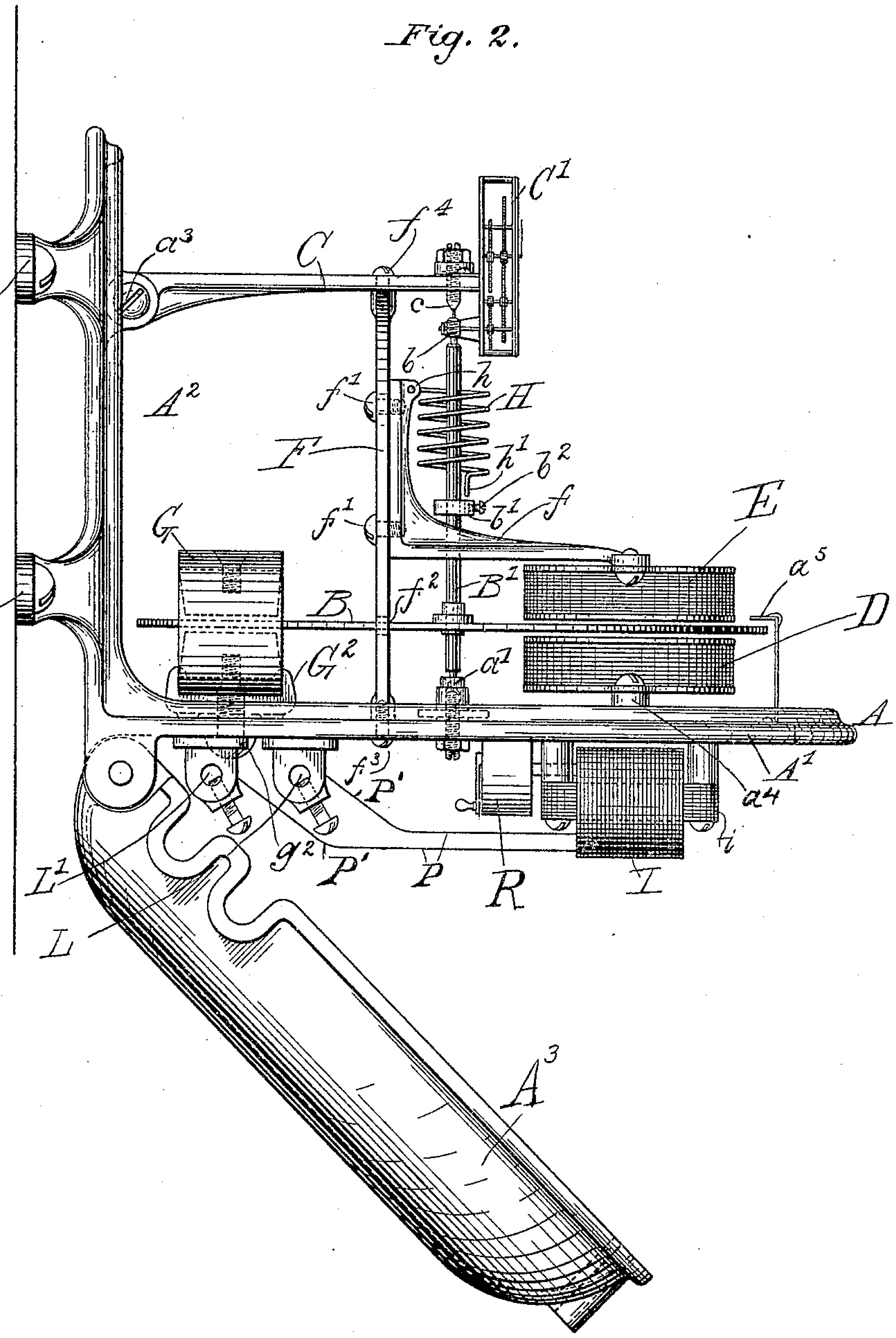

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Fig. 3.

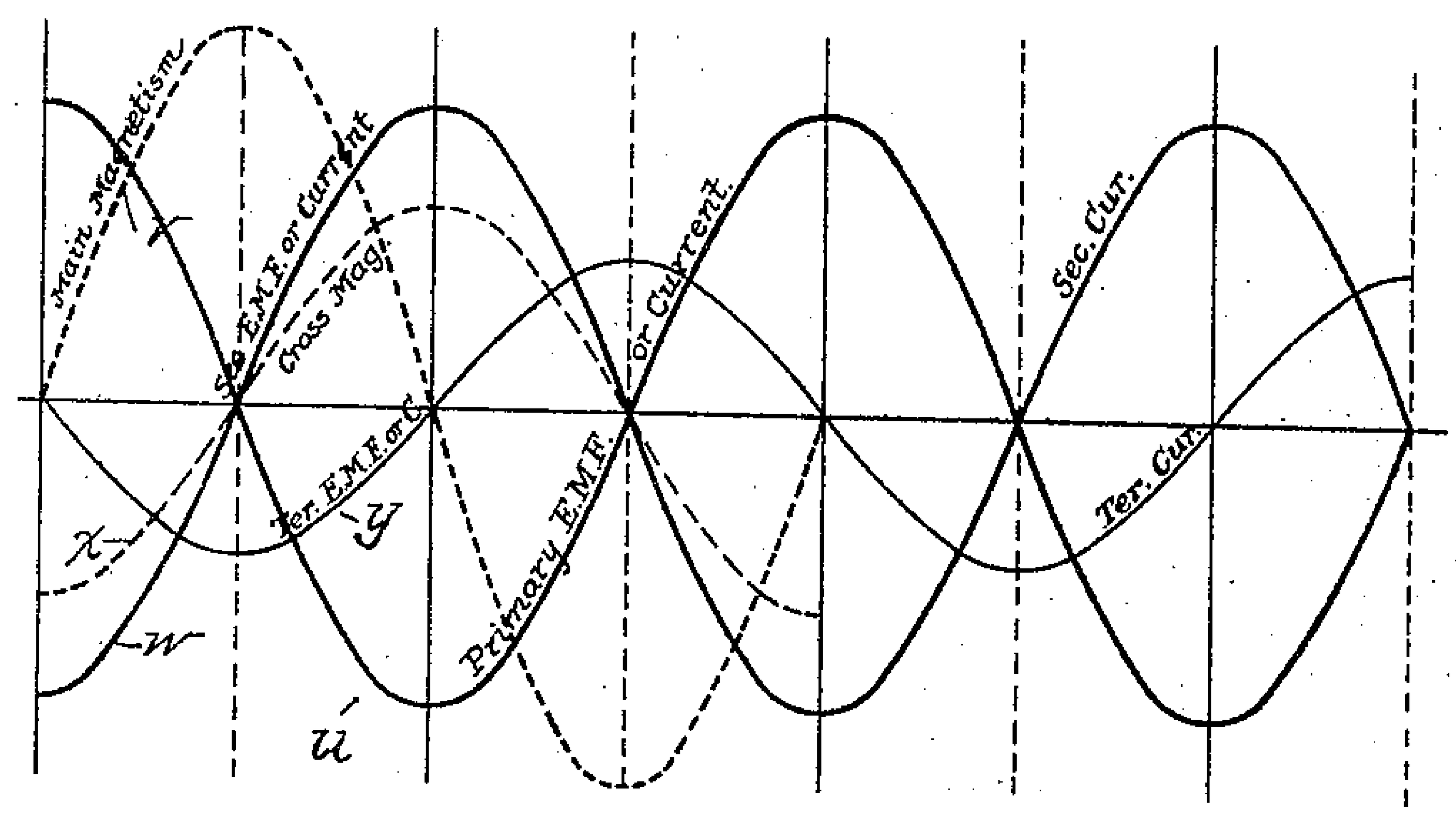
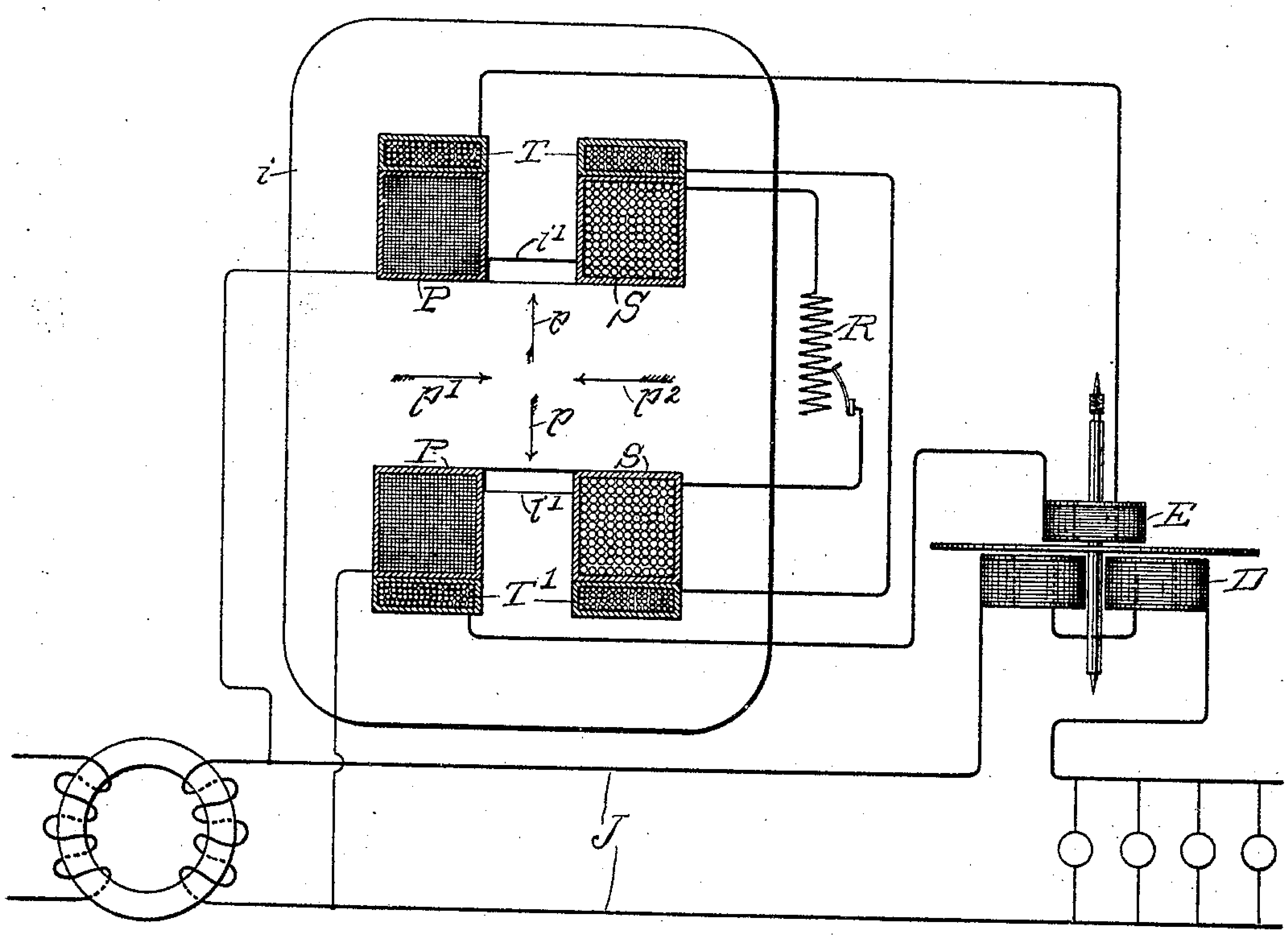


Fig. 4.



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ELECTRIC METER.

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Fig. 5.

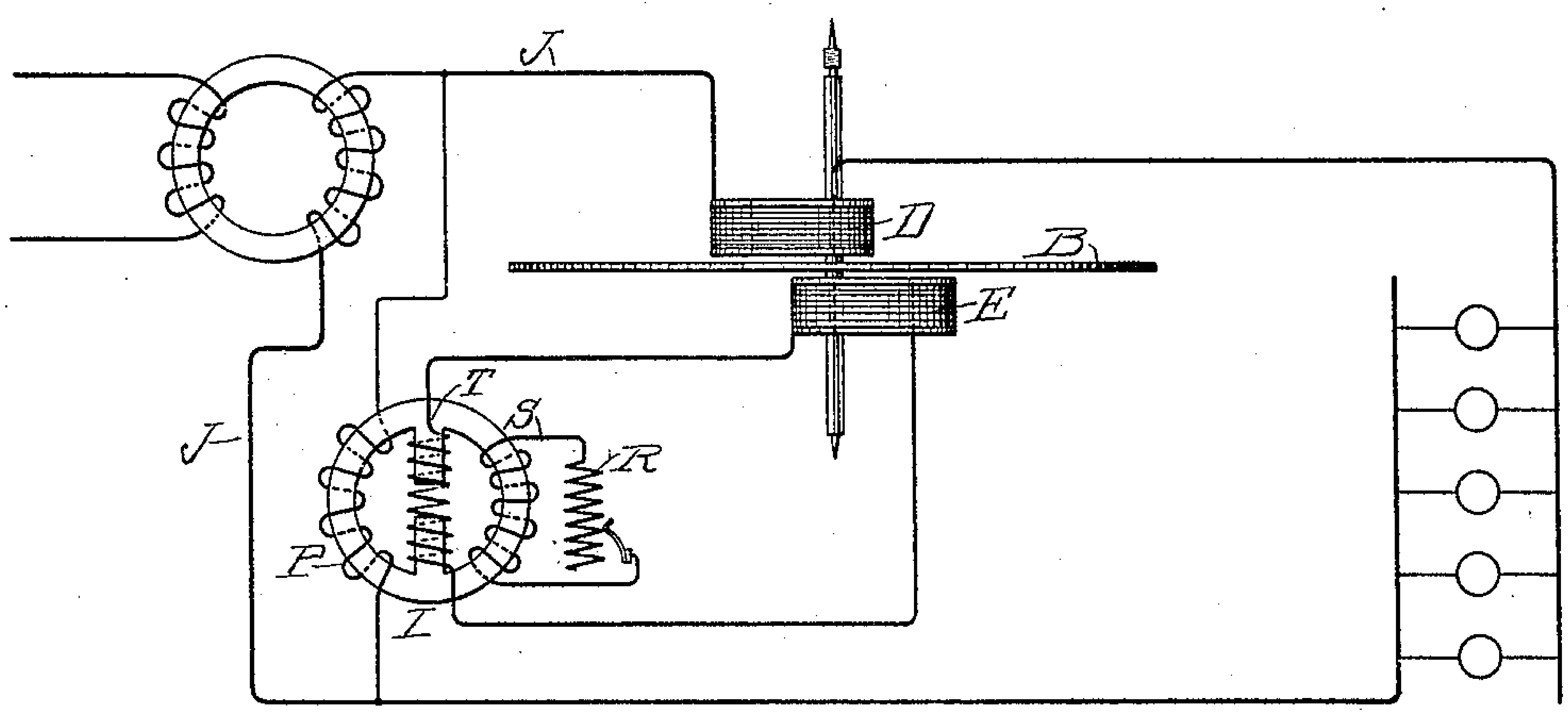

Fig. 6.

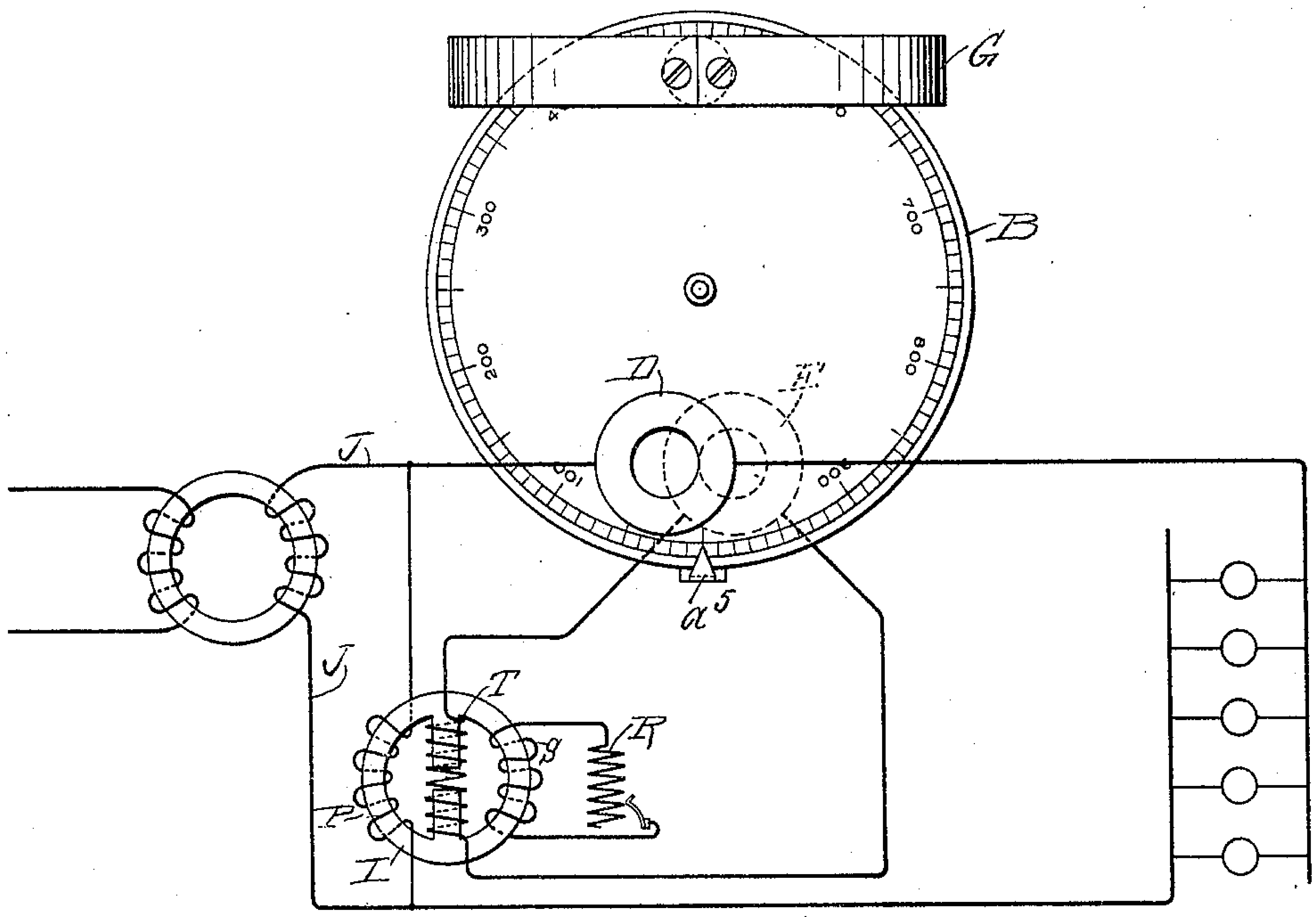

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Fig. 7.

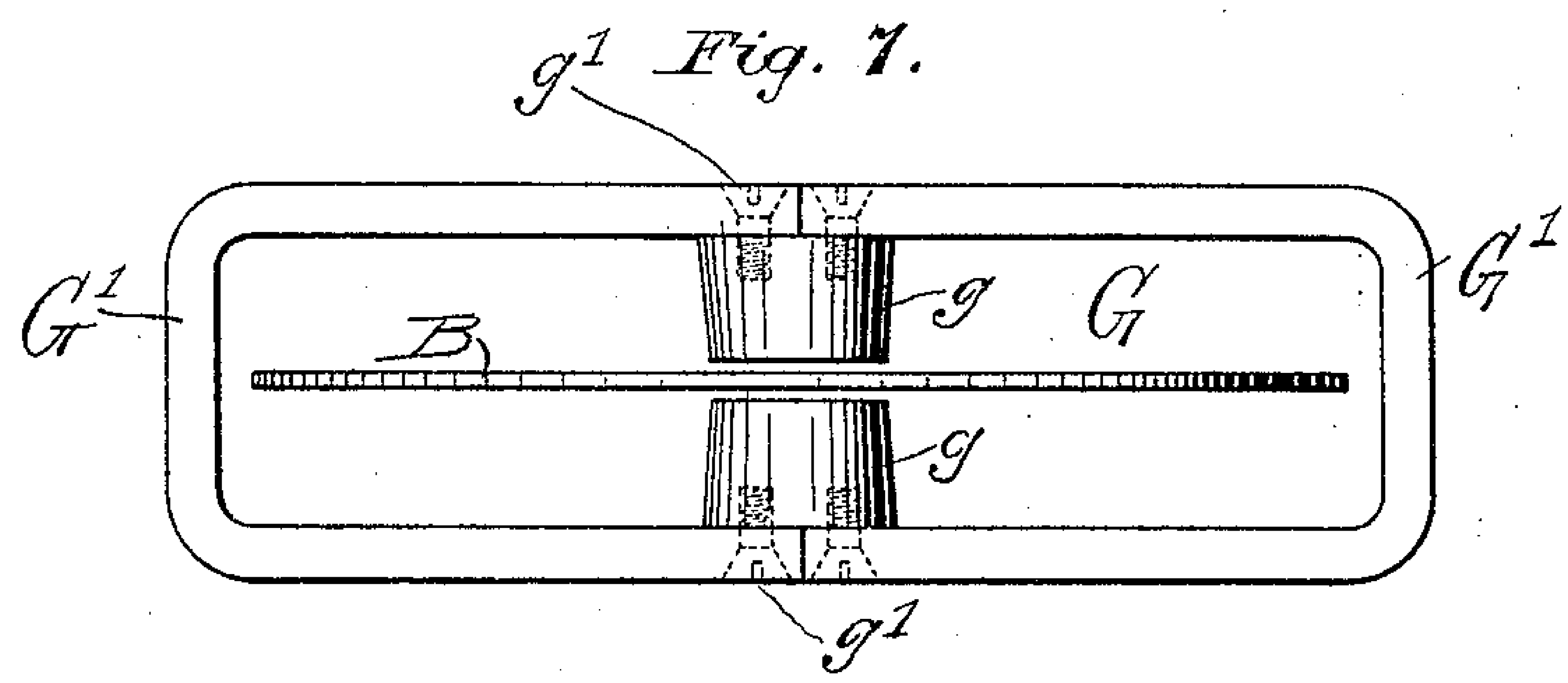
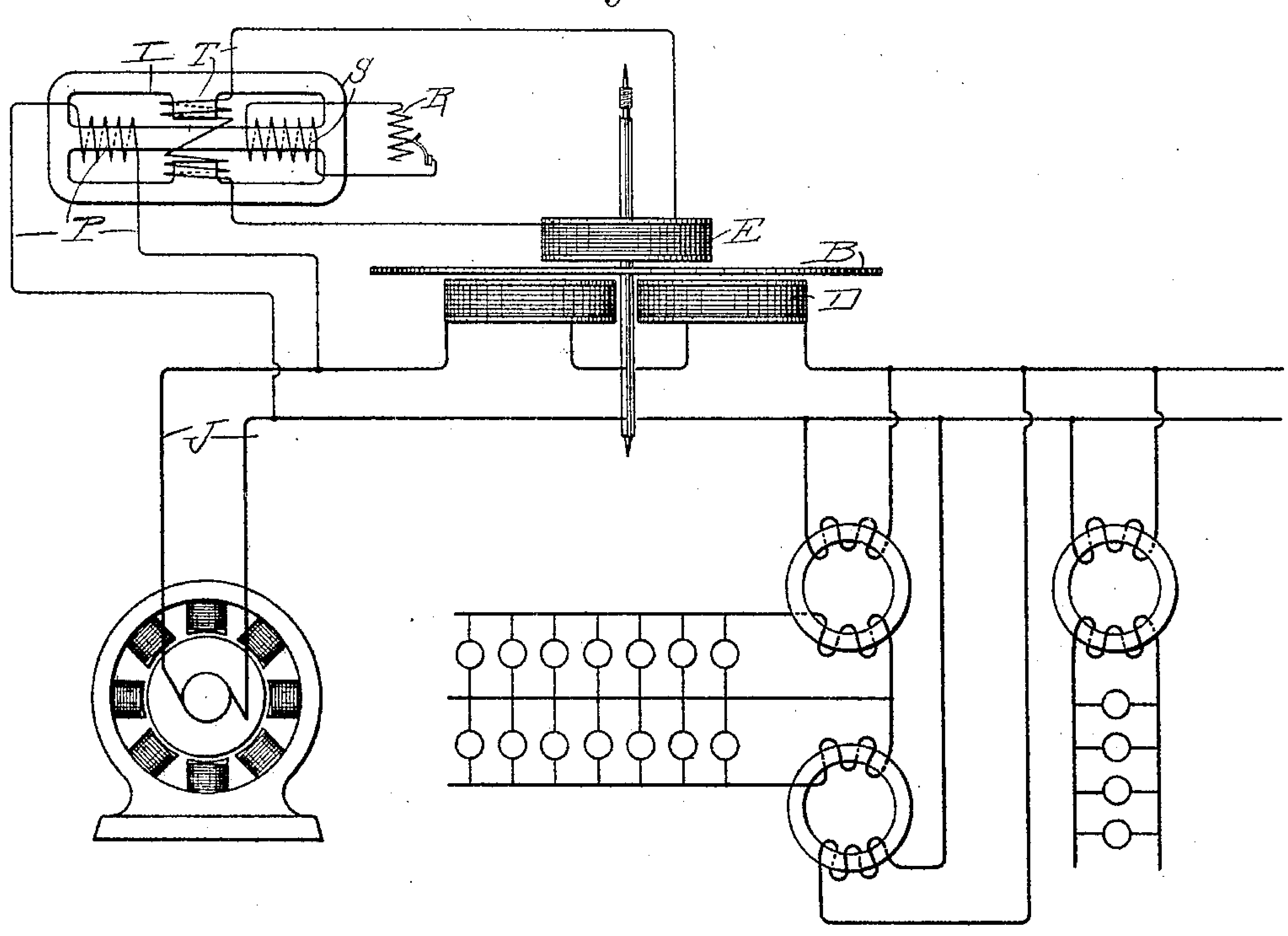


Fig. 8.



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UNITED STATES PATENT OFFICE.

THOMAS DUNCAN, OF FORT WAYNE, INDIANA.

ELECTRIC METER.

SPECIFICATION forming part of Letters Patent No. 604,459, dated May 24, 1898.

Application filed March 20, 1897. Serial No. 628,396. (No model.)

To all whom it may concern:

Be it known that I, THOMAS DUNCAN, of Fort Wayne, in the county of Allen and State of Indiana, have invented certain new and useful Improvements in Electric Meters, of which the following is a specification.

My invention relates more particularly to that type of alternating-current meters known as "induction motor-meters" and operating by the inductive action of two magnetic fields of differing phase upon a closed secondary or armature. Some of its features are, however, also adapted for use in electric meters of other types.

Among the objects of the invention are to provide an improved form of meter which will be accurate under all conditions of service and under inductive as well as non-inductive loads, to provide a construction that may be changed at will from an integrating to an indicating meter, or vice versa, in a moment's time and without material alteration of its parts, and to provide certain other features of improvement, all as hereinafter set forth, and more particularly pointed out in the appended claims.

In the accompanying drawings, Figure 1 is a front elevation, partly in section, of a meter constructed in accordance with my improvements. Fig. 1ª is a diagrammatic view of the connections thereof. Fig. 2 is a side elevation of the meter. Fig. 3 is a diagram illustrating the relative oscillations of magnetism, current, and electromotive force involved in the operation of the phase-transformer. Fig. 4 is an exaggerated diagrammatic view showing an alternate form of phase-transformer. Figs. 5 and 6 are diagrammatic views, in elevation and plan, respectively, showing certain details of the meter and a further alternate form of transformer. Fig. 7 is a detail of an improved form of magnetic drag. Fig. 8 is a diagrammatic view showing the meter connected directly in the main circuit from the dynamo.

In said drawings, A designates a supporting frame or bracket ordinarily made of cast-iron and comprising, as herein shown, a horizontal base-plate A′ and an upright back plate A^2, having lateral lugs a, through which screws may be passed to secure the meter in place.

B designates a revoluble disk or armature of aluminium or other suitable material carried by a spindle B′, to which it is rigidly fastened. The lower end of the spindle is stepped in a suitable bearing a' on the base-plate, and its upper end is detachably engaged by a bearing c in the outer end of an arm C, which latter is pivoted to the back plate A^2 at a^3 in such manner that it may be swung up to release the spindle and permit the removal of the armature. A worm b on the upper end of the spindle engages the worm-wheel c' of a registering-train C′, conveniently carried by the arm C, and thus registers the movement of the armature in a manner well understood.

D and E designate, respectively, the series and volt coils, by the inductive action of which the armature is rotated. The volt-coil is herein shown as placed closely superjacent to the disk B, near the front edge of the latter. The series coil or coils are on the opposite side of the disk from the volt-coil—*i. e.*, are just beneath the disk—in the arrangement herein shown and are located eccentrically to the volt-coil.

As shown in Figs. 1 and 2, the series coils are two in number and are connected in series and located on opposite sides of the axis of the volt-coil. (In Figs. 5 and 6 only a single series coil is shown.) The series coils are supported by lugs a^4 of the base-plate, while the volt-coil is in this instance carried by a bifurcated bracket f, which is secured by screws f' to an upright partition F. The latter extends transversely across the meter just back of the spindle B′ and is provided with a horizontal slot f^2, through which the disk B rotates freely. Said partition is secured by screws f^3 to the base-plate and at its upper edge is steadied by and at the same time forms a rest and additional support for the pivoted arm C. A screw f^4 passes through the arm into the partition and is first removed when the arm is to be swung up to release the spindle. The essential function of the partition F, however, is as a shield to prevent disturbance between the fields of force of the coils D and E and a Foucault or magnetic drag G, provided to exert a retarding action on the armature directly proportional to the speed of the armature in a manner well understood. Any suitable form of magnetic drag may be used for this purpose; but the peculiar construction of permanent magnets herein shown constitutes one feature of the present improvement. It comprises two horseshoe-sections G′, arranged end to end in the form of a continuous loop with like poles in proximity. Soft-iron pole-pieces g are secured to both sections at their opposite points of juncture by screws g' and serve to unite the sections into substantially a single continuous structure. The space between the proximate ends of the pole-pieces is wide enough to permit the armature B to rotate freely between them, and the magnet is held in proper position relatively to the armature by any suitable clamps G^2, secured to the base by a screw g^2 and made to permit the magnet to be adjusted toward or from the axis of the armature to vary the drag in standardizing. The form of magnet thus described is easily and cheaply made and very effective for the purpose intended. The partition F is made of soft iron or steel and being directly between the drag and the coils and both above and below the armature serves as a shield to prevent the flux from the coils from affecting the drag or being effected thereby.

A principal feature of the present improvement and one of great practical value consists in a provision whereby the meter may be changed at will from an indicating to an integrating instrument, or vice versa, as follows: H designates a light spring arranged between a part of or upon or rotating with the armature and a stationary part of the frame and also arranged to be instantly connected or disconnected, as desired. In an approved form, and as herein illustrated, said spring is of helical shape and conveniently coiled around the spindle, with one end secured at h to the framework and with its other end h' adapted to be inserted in an aperture in a collar b', fixed on the spindle B′ to rotate therewith, a clamping-screw b^2 serving, if necessary, to fasten the end of the spring in said aperture. When the spring is disconnected from the collar, the armature is free to rotate as usual, and its movement is recorded by the registering-frame. If, however, the end of the spring is engaged with the collar, the armature will be brought to rest as soon as the tension of the spring is equal to the torque produced by the inductive action of the coils on the armature, and the amount of the movement of the armature from the position at which it will be naturally held by the spring when no current is passing to the position which it will assume when the current is turned on will obviously measure the torque of the meter and be proportional to the energy being consumed in the circuit. The edge of the armature-disk is graduated, as shown in Fig. 6, and a fixed pointer a^5 on the base is arranged to point to the zero of the scale when the spring is connected and the meter is idle. When the current is turned on, this pointer will then indicate on the scale the amount of energy being consumed in the circuit at each particular moment, the scale being graduated either to watts or horse-power or other units, as desired. With this construction if it is desired, for example, to determine the actual number of watts per lamp being consumed by the particular set of lamps on the circuit it is only necessary to insert the end h' of the spring in the apertured collar b', note the indication of the pointer on the graduated edge of the disk when the armature comes to rest, and divide the total number of watts thus indicated by the number of lamps in use, or the load on a motor at any given moment may be determined with substantial accuracy by indicating the energy supplied to the motor in the same manner as above described and multiplying by the efficiency factor of the motor. To connect the spring and take the reading, need occupy but a moment, and if the spring is then immediately disconnected again the registration will proceed as before, and the interruption need have been so slight as to practically not affect the accuracy of the totals. The instrument is thus fully available in both of its capacities and fills a want long felt by central-station men and other distributers and users of electrical energy. It will be obvious that the features of construction thus described and which render the meter capable of use either as an indicating or integrating instrument are not special to induction-motor meters or to wattmeters more than current-meters; but will operate equally well in connection with any form of meter having an armature or rotary part the actuating torque upon which may be measured by the extent of movement it will produce in opposition to an increasing resistance. It will also be obvious that such variable resistance might in some cases be exerted by an agency other than a spring or by a spring differently applied and arranged to be differently connected and disconnected than as herein shown, and any construction within the broad statement thus made will be understood to be included within the present invention.

In common with other alternating-current wattmeters of the induction-motor type that herein illustrated depends for its actuating torque upon the inductive action upon the armature of the resultant shifting field produced by the combined action of the series and volt coils as energized by currents which differ in phase. Such difference in phase is commonly effected by advancing or retarding the current in the volt or shunt coil with respect to the impressed electromotive force of the work-circuit. In order that the meter may be accurate under changing conditions of load-inductants, it is necessary that such phase displacement in the volt-coil shall be approximately ninety degrees, this because the energy consumed in the work-circuit equals the product of the current, the electromotive force, and the cosine of the angle of lag of the work-current, while the torque of the meter is proportional to the product of the current, the electromotive force, and the sine of the angle of phase displacement between the currents in the volt and series coils. When the phase displacement between the electromotive force of the work-circuit and the current in the volt-coil is ninety degrees, the two angles of the equations are complementary, and the sine of the one always equals the cosine of the other, in consequence of which the torque of the meter will always vary in exact proportion to the energy being consumed in the work-circuit, no matter how much the current in the latter may lag by reason of the self-inductance of the load. A further feature of my present improvements therefore consists in the combinations and arrangements whereby a phase displacement of substantially ninety degrees may be secured in the volt-coil circuit and involve the use of a transformer I, constructed after the manner set forth in the patent to Hunting, granted June 25, 1895, No. 541,615, and connected in circuit in the manner more particularly shown in Fig. 8 of said patent. The construction and operation of such transformer are well explained in Hunting's specification, substantially as follows, the wording being herein altered to correspond with Fig. 4 of the present drawings and with the reference-letters thereon.

The magnetic core i of the transformer is laminated or built up of separate layers of soft-iron punchings in the usual manner, any suitable subdivision of the punchings for assembling the parts being resorted to and the core being formed with preferably two openings or slots, in which the primary and secondary coils may be wound. So far as the core and the primary and secondary coils are concerned the transformer does not differ necessarily from those now commonly constructed, except that the primary and secondary coils instead of being wound the one over the other, as usual, are wound in opposite ends of the slots or openings. Thus in Fig. 4 the primary coil is wound in the spaces P and the secondary coil in the spaces S, each filling the spaces from the end of the slot nearly to the middle thereof. By reason of this arrangement consequent magnetic poles are formed, which are strongest in the positions denoted by the arrows p p—that is to say, between the coils P and S—their strength gradually diminishing toward each end of the slot. The formation of these consequent poles is due to the opposition of the magnetization induced by the primary current to that induced by the secondary current. Thus the primary coil tends to project lines of force through the core in the direction of the arrow p', while the secondary coil tends to project lines of force through the core in the opposite direction, as denoted by the arrow p^2, and these opposing forces result in the diversion of lines of force in the direction of the arrows p at the consequent poles. These diverted lines of force are projected across the gaps or slots and constitute a magnetic leakage, the extent of which will be determined by the particular proportions given to the transformer. These lines of magnetic leakage occur in oscillations of like frequency to those of the primary and secondary current, and are capable of generating alternating currents in any coil which may be arranged to inclose them. One such coil is wound in the spaces T T and another in the spaces T' T', both coils being in planes perpendicular to the planes of the primary and secondary coils. These coils T T' may be designated "tertiary" coils and are herein shown as connected in series with each other, although they may be otherwise connected, if desired. For reducing the magnetic resistance of the path of the cross-magnetic field and to gather in the lines as close as possible the core is further shown as provided with lugs i', which project into the coils T T' and direct as many lines as possible through the inner convolutions of the coil.

In applying the construction thus described to the meter under consideration the primary coil of the transformer is connected in shunt between the main leads J of the work-circuit, while its secondary coil is connected in an independent circuit containing a resistance R, preferably non-inductive and made adjustable, as indicated. The tertiary circuit of the transformer is connected with the volt-coil of the meter, and the current induced in said tertiary circuit and volt-coil will differ in phase from that in the primary or shunt circuit by approximately ninety degrees for reasons which will be made apparent by a consideration of the diagram shown in Fig. 3. In said figure the line u is a graphical representation of the oscillations of electromotive force in the work-circuit and consequently in the shunt-circuit and primary of the transformer. The current in the shunt-circuit will be in step with its electromotive force and may be represented by the same line. The magnetic oscillations induced in the transformer-core by the primary current are represented by the line v and the electromotive force set up thereby in the secondary coil by the line w. The latter line may also stand for the secondary current, since, as before stated, the load or resistance R in the secondary circuit is non-inductive. Inasmuch as the greatest electromotive force is generated when the rate of change in the number of magnetic lines is greatest, and vice versa, the line u is displaced by a quarter-period or ninety degrees from the line v, and the line w is displaced the same amount from the line v, and consequently by a half-period or one hundred and eighty degrees from the line u, the primary and secondary currents being thus exactly opposite in phase. The magnetic leakage or cross-magnetism which induces the tertiary current being the resultant of the mutually-opposing magnetizing actions of the primary and secondary currents is greatest when they are greatest and least when they are least.

It may therefore be represented by the line x, and the electromotive force and current induced thereby in the tertiary or volt coil circuit may be represented by the line y, which for the same reasons above stated in connection with the relation of the lines u, v, and w is displaced by ninety degrees from the line x and from the lines u and w as well. The volt-coil current is thus displaced from the electromotive force of the work-circuit by the ninety degrees desired, and the torque of the meter will therefore vary accurately in proportion to the true energy consumed in the work-circuit in accordance with the reasons hereinbefore stated.

It will be understood, as is also further explained in said patent to Hunting, that the shape of the transformer-core and the location of the coils thereon may be widely varied with the same essential result in the operation of the device. Thus, for example, in the form of meter shown in Figs. 1 and 2 the coils are wound upon such a core as is shown diagrammatically in Figs. 5 and 6, while that in Fig. 8 is similar to the construction more particularly detailed in Fig. 4. So far also as the means described of securing the phase displacement between the current in the series of volt-coils is concerned the armature of the meter may obviously be of other than disk form and still be capable of accurate operation under the inductive influence of said coils. The adjustable resistance R is useful in varying the speed in calibrating by varying that factor of the torque representing the inductive action of the volt-coil.

Meters constructed in accordance with these improvements may be used to measure the energy consumed either in the secondary circuit derived from the ordinary series transformer K, as in Figs. 1^a, 4, 5, and 6, or in the main circuit from the dynamo, as in Fig. 8, it being obviously immaterial, so far as the meter is concerned, just how the circuits are arranged or what the energy-consuming devices consist of. In connecting the meter in circuit the wires from the service-transformer will lead up to binding-posts L and L′ at one side and lead off from similar binding-posts on the other side. The series coils are connected in series between the front binding-posts L L, while the rear binding-posts are connected with each other to complete the circuit. The terminals P′ P′ of the primary transformer-coil are connected to the front and rear binding-posts L and L′, so as to place the said primary coil in shunt with the work-circuit, and the resistance R, which is connected in the secondary circuit, is herein shown as conveniently located immediately behind the transformer beneath the base-plate A′, as shown in Fig. 2. The terminals of the tertiary coil of the transformer are carried upwardly along the edges of the shield F, past the ends of the slots f^2 thereof, and thence along the bracket f to the volt-coil. A hinged cover-plate A^3 is shown as provided on the transformer and connections on the under side of said base-plate and when raised is designed to be locked in place by any suitable device. (Not herein shown.) The upper portion of the meter may be inclosed by protecting-casing of the usual form, having a glazed opening through which the register-dials may be observed, and this cover may either be locked in place or left removable to permit the use of the meter as an indicating instrument, according to the service for which it is used.

It will of course be understood that the invention is not necessarily confined to the particular details of construction illustrated, as these may be varied through a wide range without departing from the broad spirit of the features of invention embodied therein.

I claim as my invention—

1. The combination with an electric circuit, of an electric meter for measuring the energy of said circuit, provided with a rotating armature, field-coils connected in series in said circuit, volt-coils coöperating with said field-coils to set up a shifting magnetic field to actuate the armature, a transformer having a primary coil in shunt across said circuit, and a closed-circuit secondary coil between which and the primary coil a consequent magnetic field is set up, and a tertiary coil wound to inclose the lines of said magnetic field, and connected with series with the volt-coil, substantially as described.

2. An induction motor-meter provided with an armature, coils acting inductively on the armature, a magnetic drag also acting on the armature, and a shield of conducting material inserted between the coils and drag.

3. An induction motor-meter provided with an armature, coils acting inductively on the armature, a magnetic drag also acting on the armature, and a shield of conducting material embracing the armature between the coils and drag.

4. An induction motor-meter provided with a disk armature, coils acting inductively on the armature, a magnetic drag also acting on the armature, and a shield of conducting material embracing the disk between the coils and drag.

5. An induction motor-meter provided with an armature, coils acting inductively on the armature, a magnetic drag also acting on the armature and shield of conducting material inserted between the coils and drag, said shield being slotted to permit the free rotation of the armature therethrough.

6. A meter provided with a disk armature, coils acting inductively on the armature, a magnetic drag also acting on the armature, a shield of conducting material arranged between the coils and drag and a slot in said shield through which the disk is free to rotate.

7. The combination with the meter-frame, of the armature mounted on its spindle, a bearing on the frame for one end of said spindle, a pivotal arm having a bearing for

the other end of said spindle, coils acting inductively on the armature, a magnetic drag also acting on said armature, a shield of conducting material secured to the frame between the coils and drag and forming a support for the pivotal arm, and a slot in said shield through which the armature rotates.

8. An electric meter provided with a rotative part, means for exerting a torque on said part, registering or recording devices therefor, an increasing resistance detachably applicable to said part, and means for measuring the movement of said parts in opposition to said resistance.

9. An electric meter provided with a rotative part, means for exerting a torque on said part, registering or recording devices therefor, a spring detachably applicable to said part, and means for measuring the movement of said part in opposition to the spring.

10. A meter provided with a rotative part, means for exerting a torque on said part, registering or recording devices therefor, a coiled spring detachably applicable between the rotating part and a stationary part, and means for measuring the movement of the part in opposition to said spring.

11. A meter provided with an armature, means for exerting a rotary torque on said armature, registering or recording devices therefor, a spring coiled about the armature-spindle and secured to a fixed part on the meter-frame, and detachable connections between the free end of the spring and the spindle.

12. An electric meter provided with an armature, coils acting inductively on said armature, a spring detachably applicable between the armature and a stationary part, and means for measuring the movement of the armature in opposition to said spring.

13. An electric meter provided with a rotating armature, registering or recording devices, a spring detachably applicable between the armature and a stationary part on the meter-frame, a graduated scale on the armature and a stationary pointer or mark for measuring on the scale the movement of the armature in opposition to said spring.

14. A magnetic drag for electric meters and the like, comprising two horseshoe sections arranged with their ends in proximity, and insetting pole-pieces secured to the ends of the sections at their points of juncture.

In testimony that I claim the foregoing as my invention I affix my signature, in presence of two subscribing witnesses, this 15th day of March, A. D. 1897.

THOMAS DUNCAN.

Witnesses:

ARTHUR L. HADLEY,
MARTIN C. GRASS.