N° 8832 A.D. 1898

Date of Application, 15th Apr., 1898
Complete Specification Left, 14th Jan., 1899—Accepted, 15th Apr., 1899

PROVISIONAL SPECIFICATION.

Improvements in Electricity Meters.

I, Charles Edouard O'Keenan, of 168, Rue de Grenelle, Paris, France, Engineer, do hereby declare the nature of this invention to be as follows:—

This invention relates to electricity meters constructed and operating as I shall describe referring to the accompanying drawings.

Figure 1 is a front view and Figure 2 is a side view, both partly in section, and Figure 3 is a sectional plan of one form of meter according to my invention. Figure 4 is a perspective view of one of the coils of the electric motor.

The current to be measured passes from pole A to A¹ through a resistance B, which is as little inductive as possible, so that, in case of short circuiting in the installation, the current may not create a field which can affect the permanent magnet employed. The resistance should also be of metal the resistance of which is not affected by temperature. Thus the difference of potential at the extremities of the resistance is always proportional to the intensity of the current passing through it. From the posts A A¹ two copper wires C C¹ lead to the brushes D D¹ of a small magneto electric motor, having for its field a permanent magnet E within which is a stationary soft iron core G. The armature F is a cup carrying copper coils like those shewn in Figure 4 which are connected to the commutator. Owing to the stationary core G, the armature is not affected by hysteresis, and the cup being as little conductive as possible, it is not affected by Foucault currents. The axis of the armature is pivotted on a jewel in a lower bearing H and revolves in an upper bearing I of different metal; it has on it a worm or pinion J geared to a counter. The whole apparatus is fixed against a plate K of insulating material and enclosed in an air tight casing having a glass through which the dials of the counter can be seen.

The meter operates as follows:—

The current to be measured divides into two parts, the one passes through the resistance B, the other through the armature of the motor, which revolves with velocity increasing until its contra electro motive force equals the difference of potential at A and A¹. Thus a small amount of current passes through the motor, only enough to overcome friction and other resistances which should be as small as possible. Thus the velocity of the motor may be said to be proportional to the difference of potential, which is itself nearly proportional to the intensity of the whole current almost all of which traverses the resistance. Hence the apparatus constitutes a Coulomb meter, or an ampère-hour meter.

As little or no current passes through the armature, the effect of variations of resistance in the motor circuit may be neglected, whether these proceed from changes of temperature, friction of the brushes or other causes; the meter thus is independent of temperature.

If the direction of the current changes, the armature is reversed, so that at any time the counter indicates the algebraic sum of the currents that have traversed it. Thus the meter applies to constant and variable currents provided they are not changed in direction. For alternating currents it is inapplicable, since the algebraical sum would be nothing or nearly so.

[Price 8d.]

The power of the magnetic field is sufficient to annul the influence of external fields.

As there is a slight error of proportionality due to friction, this may be corrected in the following manner.

As shewn in Figure 5 between A^1 and D^1 is introduced a resistance P equivalent to that of the armature. From *q* between P and D^1 a fine wire passes through a resistance R to a third post A^{11} connected to the other terminal of the installation. The shunt current through this resistance is proportional to the difference of potential at the two terminals of the installation and is almost constant if the installation has constant tension. Part of this current passes through the resistance P, part through the armature.

The resistances P and R are so determined that the intensity through the armature balances the friction of the apparatus so that its proportionality is almost complete.

For currents of constant intensity the meter is applied by directing through it a current of potential taken at two suitable points of a resistance connected to the ends of the lamp circuit as indicated in Figure 6, and the meter shews the energy expended in the circuits.

The coils, instead of being on a cylinder may be on a disc as shewn in Figure 7, mounted between the poles of the magnet and a keeper as shewn in Figure 8, or between the magnet poles themselves as in Figure 9, an arrangement convenient for explanations that follow. Instead of coils, a split cup or disc may be used, or, for a unipolar machine, an undivided cup or disc, such a machine with cup being shewn in Figure 10. In this case the cup U has a conducting wire T revolving in mercury M, the circuit being A C M T U *u* A^1.

If, instead of a permanent magnet, a not saturated electromagnet in shunt with the terminals of the installation were employed the apparatus would act as a lamp hour meter. In this case if *f* be the inducing flux, *v* the angular velocity and I the intensity of the current $I = K\ f\ v$.

If *f* is proportional to the difference of potential at the two terminals of the installation, that is to say if the iron is not saturated, then $\frac{1}{E} = K^1 v = \frac{1}{R}$ or the angular velocity is proportional to the conductivity of the circuit or the number of lamps in operation. The direction of revolution of the apparatus is independent of the direction of the current, and it is therefore applicable for alternating currents.

If the unsaturated electromagnet is excited by the current to be measured, the velocity is constant, and the instrument is then an hour meter, or clock indicating merely the time of operating.

As shewn in Figure 11, the apparatus may be arranged as a Watt-hour meter. On the left is a permanent magnet *b* the flux $2\ f^1$ of which traverses the left part of the armature, on the right is the electromagnet with flux *f*, so the core which serves as armature to both magnets is traversed by flux $2\ f^1 + f$ not enough to saturate it. The flux which determines the contra electromotive force of the motor is $2 f^1 - f$.

The resistance of the winding of *a* is so adjusted that, at mean potential, the flux f^1 is equal to $2\ f$. If the potential increases say 1 *per cent.*, the flux *f* increases 1 *per cent.* and the quantity $2\ f^1 - f$ is lessened 1 *per cent.*, consequently the speed will increase 1 *per cent.*

Thus, for any given intensity, the velocity is almost proportional to the potential if it varies within narrow limits. The apparatus can therefore be employed as an energy meter where the tension varies little. For the permanent magnet may be substituted a saturated electromagnet.

In this form the apparatus may be used for alternating currents in which case the cores of the electromagnets should be divided into strips parallel to the lines of force.

For installations having constant intensity with variable potential, the potential current is passed through the internal resistance B Figure 1, while the intensity current excites the unsaturated electro-magnet opposite the permanent magnet.

The arrangements for adapting the disc armature to various conditions may be described as follow;—

1) For an ampère hour meter, Figure 12, the permanent magnet E serves as field. This does not apply to currents which have not constant direction.

2) For a lamp-hour meter, Figure 13, the field magnet is an unsaturated electro-magnet excited by a potential current. This may be used for all currents.

3) For an hour meter or clock, Figure 14, the field magnet is an unsaturated electro-magnet excited by the main current. This may be used for all currents. An hour meter or clock may also consist of the motor of the ordinary ampère-hour meter, connected to the terminals of a battery of constant voltage.

4) For a Watt-hour meter, Figure 15, the field consists of a preponderating permanent magnet and of an unsaturated electromagnet excited by a potential current in opposition to the permanent magnet the poles of the same name being towards the same face of the disc.

At mean potential the flux of the electromagnet is half that of the permanent magnet. This is not applicable to currents that change direction.

5) For an ampère-hour meter, Figure 16, the field consists of a saturated electro-magnet B excited by the potential current and a much weaker unsaturated electro-magnet C excited by the same current. When the potential varies, the greater variations of the second make up for the weaker variations of the former.

This is applicable for all currents.

6) For a Watt-hour-meter, the field like the former consists of a preponderating saturated electromagnet and an unsaturated electromagnet the flux of which, at mean potential, is a little greater than half that of the former, the slight excess making up for the small variations of the former when the potential varies.

7) Ampère-hour meter for change of price. If to the ampère hour meter described under 5) there is added a third magnet which is permanent but not preponderating, or an ampère hour meter which revolves always in the same direction but with different velocities according to the direction of the current, for in the one case the flux of the permanent magnet is added to the difference of flux of the electromagnets, and in the other case it is deducted, then the quantities of electricity are registered at different prices in the two cases, the supplying station determining the price of delivery by fixing the direction of the current This arrangement is applicable to every meter in which the induced current and the inducing field change direction with the current, on condition that the proportionality of the instrument is maintained when the relation between the field of the magnet and the resultant inducing field does not remain fixed. This condition excludes the application to apparatus having an inducing system which does not contain permanent magnets, such as in the Watt meter above described.

8) For a meter registering at different rates on the same dial, the consumption of several separate circuits taken at the two terminals of the same installation, as shewn in Figure 17, the + wires of the several circuits are connected to A^1, A^1_1, A^1_2, A^1_3 &c. points of the resistance. The rate registered in each case is proportional to the part of the resistance comprised between A and the point of connection. The meter registers the sum of all at a fixed rate. This arrangement is applicable to all the apparatus above described. When the apparatus 7) is employed the general rate registered can be modified at definite hours by changing the direction of the current.

9) For a meter for a distributing system with several wires a multiple meter is employed comprising as many induced and inducing organs as there are wires except one of the end wires. The induced organs are keyed on the same spindle, and the resistance for each wire is proportional to the difference between the voltage of this wire and the end one which does not pass through the instrument.

The following are other arrangements for making the meter a Watt-hour meter.

a) The apparatus, Figure 18, is the same as the ampère-hour meter except that the core of soft iron, instead of being cylindrical, has two grooves holding a coil of fine wire determining in the core an inverse flux partly opposing that of the permanent magnet.

b) For the resistance B may be taken a plate or wire of bismuth placed in the magnetic field due to an electromagnet in shunt with the tension of the net work, for, as is known, the resistance of bismuth increases with the field in which it is bathed, hence, for a given constant intensity, the difference of potential at the two ends of the bismuth increases with the magnetic field and consequently with the tension.

c) The Hall phenomen may be applied this, being little more than the previous arrangement with the advantage that can be obtained if a metal having no coefficient of temperature.

d) The induced organ may be raised or lowered out of the field of the magnet, to an extent proportional to the voltage by means of a solenoid or by the wire of a Cardew volt meter, or otherwise, so that the flux affecting this induced organ (armature) may be inversely proportional to the tension for a constant intensity given in the part traversed by the main intensity current.

e) The induced organ may be moved in the field of an electromagnet in the circuit of which there is a bismuth resistance influenced by another electromagnet also in shunt on the tension.

f) The contact position of the brushes may be varied by an electromagnet so as to increase or diminish the velocity proportionally to the voltage.

g) The induced organ being between the arms of a permanent magnet as in the ampére-hour meter, there may be placed in shunt on the tension of the net work, a solenoid with fine wire so as to attract an armature integral with a cone for varying speed, thus increasing or lessening the velocity transmitted from the armature proportionally to the voltage.

h) An electromagnet in shunt may work a bar of soft iron so as to shunt the magnetic field and make it vary in a manner inversely proportional to the voltage.

Dated this 15th day of April 1898.

ABEL & IMRAY,
Agents for the Applicant.

COMPLETE SPECIFICATION.

Improvements in Electricity Meters.

I, CHARLES EDOUARD O'KEENAN, of 168, Rue de Grenelle, Paris, France, Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to electricity meters constructed and operating as I shall describe referring to Sheets 1 and 2 of the drawings accompanying the Provisional Specification and to the sheet filed herewith.

Fig. 1 is a front view and Fig. 2 is a side view, both partly in section, and Fig. 3 is a sectional plan of one form of meter according to my invention. Fig. 4 is a perspective view of one of the coils of the electric motor.

The current to be measured passes from post A to A^1 through a resistance B, which is as little inductive as possible so that, in case of short circuiting in the installation, the current, may not create a field which can affect the permanent magnet employed. The resistance should also be of metal the resistance of which is not affected by temperature. Thus the difference of potential at the extremities of the resistance is always proportional to the intensity of the current passing through it. From the posts A A^1 two copper wires C C^1 lead to the brushes D D^1 of a small magneto electric motor, having for its field a permanent magnet E within which is a stationary soft iron core G. The armature F is a cup carrying copper coils like those shewn in Fig. 4 which are connected to the commutator.

Owing to the stationary core G, the armature is not affected by hysteresis, and the cup being as little conductive as possible, it is not affected, by Foucault currents. The axis of the armature is pivotted on a jewel in a lower bearing H and revolves in an upper bearing I of different metal; it has on it a worm or pinion J geared to a counter. The whole apparatus is fixed against a plate K of insulating material and enclosed in an air tight casing L having a glass through which the dials of the counter can be seen.

The meter operates as follows:—

The current to be measured divides into two parts, the one passes through the resistance B, the other through the armature of the motor, which revolves with velocity increasing until its contra electro motive force equals the difference of potential at A and A^1. Thus a small amount of current passes through the motor, only enough to overcome friction and other resistances which should be as small as possible. Thus the velocity of the motor may be said to be proportional to the difference of potential, which is itself nearly proportional to the intensity of the whole current almost all of which traverses the resistance. Hence the apparatus constitutes a Coulomb meter, or an ampère hour meter.

As little or nearly no current passes through the armature, the effect of variations of resistance in the motor circuit may be neglected, whether these proceed from changes of temperature, friction of the brushes or other causes; the meter thus is independent of temperature.

If the direction of the current changes, the armature is reversed, so that at any time the counter indicates the algebraic sum of the currents that have traversed it. Thus the meter applies to constant and variable currents provided they are not changed in direction. For alternating currents it is inapplicable, since the algebraical sum would be nothing or nearly so.

The power of the magnetic field is sufficient to annul the influence of external fields.

As there is a slight error of proportionality due to friction, this may be corrected in the following manner.

As shewn in Fig. 5 between post A^1 and brush D^1 is introduced a resistance P equivalent to that of the armature. From *q* between P and D^1 a fine wire passes through a resistance R to a third post A^{11} connected to the other terminal of the installation.

The shunt current through this resistance is proportional to the difference of potential at the two terminals of the installation and is almost constant if the installation has constant tension. Part of this current passes through the resistance P, part through the armature.

The resistances P and R are so determined that the intensity through the armature balances the friction of the apparatus so that its proportionality is almost complete.

For currents of constant intensity the meter is applied by directing through it a current of potential taken at two suitable points of a resistance connected to the ends of the lamp circuit as indicated in Fig. 6, and the meter shews the energy expended in the circuits.

The coils, instead of being on a cylinder may be on a disc as shewn in Fig. 7, mounted between the poles of the magnet and a keeper as shewn in Fig. 8, or between the magnet poles themselves as in Fig. 9, an arrangement convenient for explanations that follow. Instead of coils, a split cup or disc may be used, or for a unipolar machine, an undivided cup or disc, such a machine with cup being shewn in Fig. 10. In this case the cup U has a conducting wire T revolving in mercury M, the circuit being A C M T U *u* A^1.

If, instead of a permanent magnet, a not saturated electromagnet in shunt with the terminals of the installation were employed, the apparatus would act as a lamp hour meter. In this case if f be the inducing flux, v the angular velocity and I the intensity of the current $I = K\ f\ v$.

If f is proportional to the difference of potential at the two terminals of the installation, that is to say if the iron is not saturated, then $\frac{I}{E} = K^1 v = \frac{I}{R}$ or the angular velocity is proportional to the conductivity of the circuit or the number of lamps in operation. The direction of revolution of the apparatus is independent of the direction of the current, and it is therefore applicable for alternating currents.

If the unsaturated electromagnet is excited, by the current to be measured, the velocity is constant, and the instrument is then an hour meter, or clock indicating merely the time of operating.

As shewn in Fig. 11, the apparatus may be arranged as a Watt-hour meter. On the left is a permanent magnet b the flux $2\ f^1$ of which traverses the left part of the armature, on the right is the electromagnet with flux f, so the core which serves as armature to both magnets is traversed by flux $2\ f^1 + f$ not enough to saturate it. The flux which determines the contra electromotive force of the motor is $2 f^1 - f$.

The resistance of the winding of a is so adjusted that, at mean potential, the flux f^1 is equal to f. If the potential increases say 1 *per cent.*, the flux f increases 1 *per cent.*, and the quantity $2\ f^1 - f$ is lessened 1 *per cent.* consequently the speed will increase 1 *per cent.*

Thus, for any given intensity, the velocity is almost proportional to the potential if it varies within narrow limits. The apparatus can therefore be employed as an energy meter where the tension varies little. For the permanent magnet may be substituted a saturated electromagnet.

In this form the apparatus may be used for alternating currents in which case the cores of the electromagnets should be divided into strips parallel to the lines of force.

For installations having constant intensity with variable potential, the potential current is passed through the internal resistance B Fig. 1, while the intensity current excites the unsaturated electro magnet opposite the permanent magnet.

The arrangements for adapting the disc armature to various conditions may be described as follows:—

(1). For an ampère hour meter Fig. 12, the permanent magnet E serves as field. This does not apply to currents which have not constant direction.

(2). For a lamp-hour meter, Fig. 13, the field magnet is an unsaturated electromagnet excited by a potential current. This may be used for all currents.

(3) For an hour meter or clock Fig. 14, the field magnet is an unsaturated electro magnet excited by the main current. This may be used for all currents. An hour meter or clock may also consist of the motor of the ordinary ampère-hour meter, connected to the terminals of a battery of constant voltage.

(4) For a Watt-hour meter, Fig. 15, the field consists of a preponderating permanent magnet and of an unsaturated electromagnet excited by a potential current in opposition to the permanent magnet the poles of the same name being towards the same face of the disc.

At mean potential the flux of the electromagnet is half that of the permanent magnet. This is not applicable to currents that change direction.

(5) For an ampère-hour meter, Fig. 16, the field consists of a saturated electromagnet B excited by the potential current and a much weaker unsaturated electromagnet C excited by the same current. When the potential varies the greater variations of the second make up for the weaker variations of the former.

This is applicable for all currents.

6.) For a Watt-hour-meter, the field like the former consists of a preponderating saturated electromagnet and an unsaturated electromagnet the flux of which, at mean potential, is a little greater than half that of the former, the slight excess making up for the small variations of the former when the potential varies.

7.) Ampère-hour meter for change of price. If to the ampère hour meter described under 5) there is added a third magnet which is permanent but not preponderating, or an ampère hour meter which revolves always in the same direction but with different velocities according to the direction of the current, for in the one case the flux of the permanent magnet is added to the difference of flux of the electromagnets, and in the other case it is deducted, then the quantities of electricity are registered at different prices in the two cases, the supplying station determining the price of delivery by fixing the direction of the current. This arrangement is applicable to every meter in which the induced current and the inducing field change direction with the current, on condition that the proportionality of the instrument is maintained when the relation between the field of the magnet and the resultant inducing field does not remain fixed. This condition excludes the application to apparatus having an inducing system which does not contain permanent magnets such as in the Watt meter above described.

8.) For a meter registering at different rates on the same dial, the consumption of several separate circuits taken at the two terminals of the same installation, as shewn in Fig. 17, the + wires of the several circuits are connected to A^1, A^1_1, A^1_2, A^1_3, &c. points of the resistance. The rate registered in each case is proportional to the part of the resistance comprised between A and the point of connection. The meter registers the sum of all at a fixed rate. This arrangement is applicable to all the apparatus above described. When the apparatus 7 is employed the general rate registered can be modified at definite hours by changing the direction of the current.

9.) For a meter for a distributing system with several wires a multiple meter is employed comprising as many induced and inducing organs as there are wires except one of the end wires. The induced organs are keyed on the same spindle, and the resistance for each wire is proportional to the difference between the voltage of this wire and the end one which does not pass through the instrument.

The following are other arrangements for making the meter a Watt-hour meter.

a) The apparatus, Fig. 18, is the same as the ampère-hour meter except that the core of soft iron, instead of being cylindrical, has two grooves holding a coil of fine wire determining in the core an inverse flux partly opposing that of the permanent magnet.

b.) For the resistance B may be taken as shewn in Fig. *b* a plate or wire of bismuth placed in the magnetic field due to an electromagnet in shunt with the tension of the net work, for, as is known, the resistance of bismuth increases with the field in which it is bathed, hence, for a given constant intensity, the difference of potential at the two ends of the bismuth increases with the magnetic field and consequently with the tension.

c.) Instead of bismuth another metal may be applied as shewn in Fig. *c* with the advantage that can be obtained if the metal has little coefficient of temperature.

d.) The induced organ may be raised or lowered out of the field of the magnet, to an extent proportional to the voltage by means of a solenoid as shewn in Fig. *d* or by the wire of a Cardew volt meter as shewn in Fig. d^1 or otherwise, so that the flux affecting this induced organ (armature) may be inversely proportional to the tension for a constant intensity given in the part traversed by the main intensity current.

Having now particularly described and ascertained the nature of this invention and in what manner the same is to be performed, I declare that what I claim is:—

1. An ampère-hour meter consisting essentially of a small magneto electric motor, the induced organ of which, connected in shunt to the ends of a fixed resistance traversed by the current measured, has no movable iron and operates as described without any brake.

2. A lamp-hour meter consisting of a small dynamo electric motor connected as the former, the inducing field of which supplied in shunt from the ends of the subscribers circuit contains no saturated iron, and is proportional to the potential.

3. An hour meter or clock constructed as the former apparatus except that the field containing no saturated iron, is excited by the main current.

4. A Watt-hour meter constructed as in Claim 1 except that the motor has two inductors placed opposite in the commutation diameter of the induced organ, the one being a permanent magnet, the other an unsaturated electro-magnet excited by a potential current, and the flux of the permanent magnet being double that of the electro magnet to the mean potential for which the meter is constructed.

5. An ampère-hour meter, arranged as in Claim 1 except that the motor has two opposite inductors, the chief inductor being a saturated electro magnet excited by a potential current, the other being a weaker unsaturated compensating electro-magnet excited by the same current and so constructed that the variations of its flux compensate those of the flux of the other when the potential varies.

6. A Watt-hour meter like the preceding meter except that the unsaturated electro-magnet is reinforced until its flux is a little greater than half the flux of the saturated electro-magnet, this slight excess compensating the slight variations of the latter.

7. An ampère-hour meter for change of price, obtained by adding as described a permanent magnet, this system being applicable to every motor meter, in which the current changes direction, simultaneously in the inducing and the induced organs and the proportionality of which is not altered when the proportion of the flux of the magnet to the inducing flux changes and in which the current stops in the induced organ when the consumption ceases.

8. A meter registering at two different rates on the same dial the consumption of several separate circuits, taken at the extremities of one installation as described.

9. A distribution meter for several wires, as described.

10. A distribution meter for variable intensity, under constant potential as described.

11. In the above apparatus the use of a non-inductive resistance B, independent of variations of temperature.

12. In the said apparatus the use of a frame of the induced organ slightly or not at all conducting, so as to prevent generation of Foucault currents.

13. In the said apparatus the use of a shunt potential current to overcome friction, as described.

14. The various expedients, indicated under the heads *a* to *d* inclusive, for transforming into a Watt-hour-meter the ampère meter first described.

Dated this 13th day of January 1899.

ABEL & IMRAY,
Agents for the Applicant.

Redhill: Printed for Her Majesty's Stationery Office, by Malcomson & Co., Ltd.—1899

[This Drawing is a reproduction of the Original on a reduced scale]

FIG. 1.

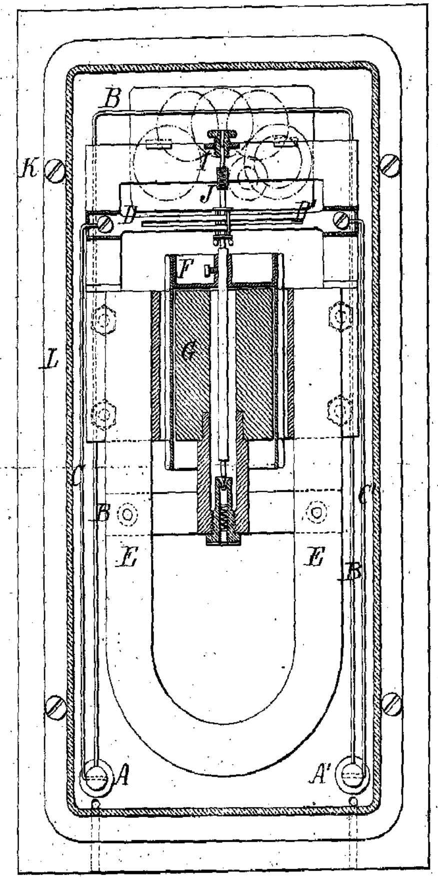


FIG. 2.

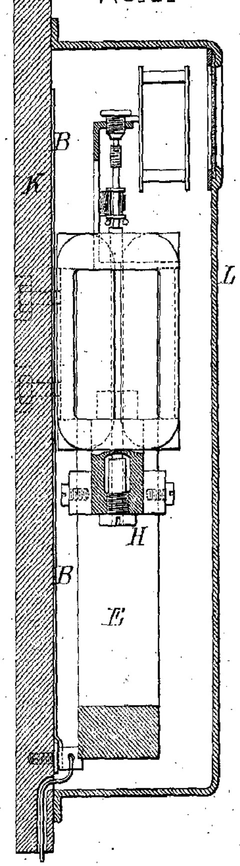


FIG. 3.

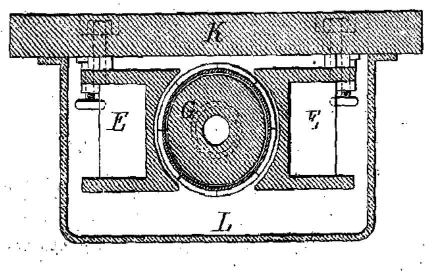
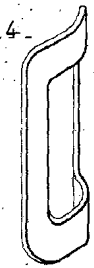


FIG. 4.



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O'KEENAN'S PROVISIONAL SPECIFICATION.

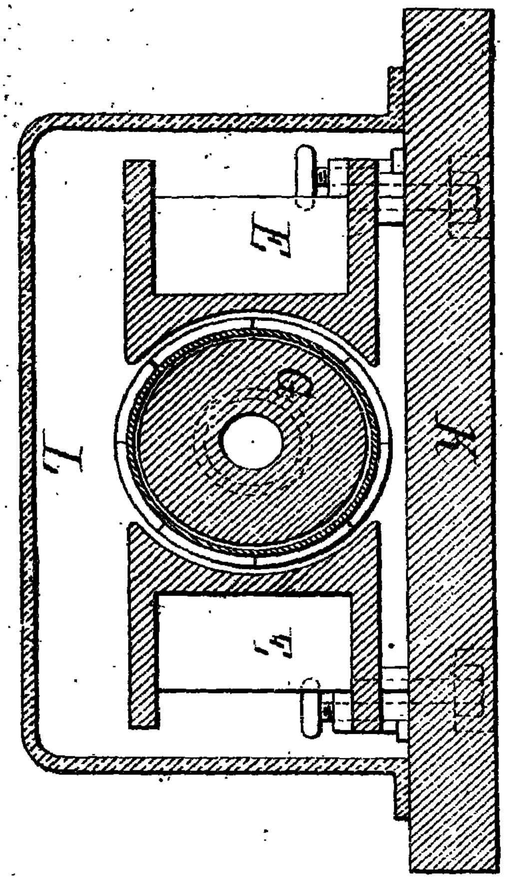


FIG_3_

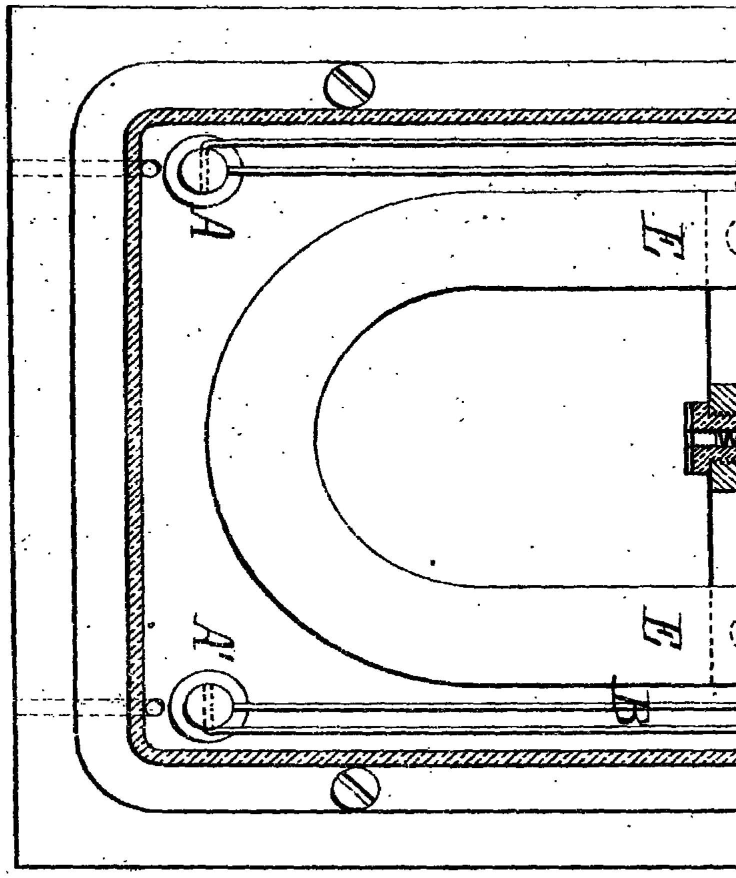
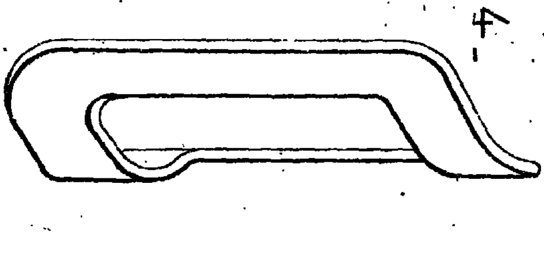
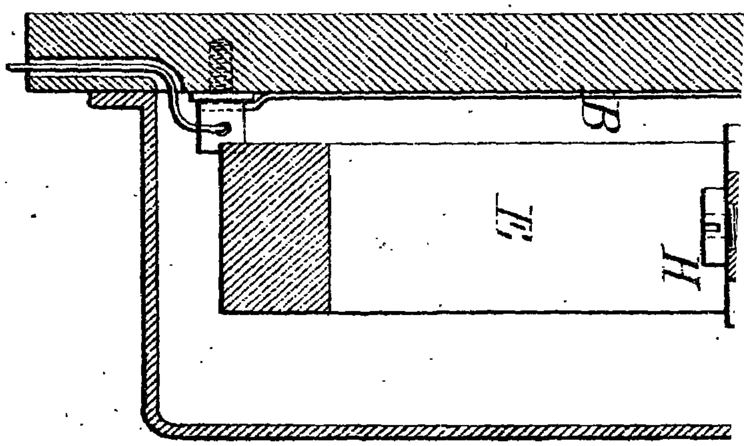


FIG_4_





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(2 SHEETS)
SHEET 1.

FIG_1_

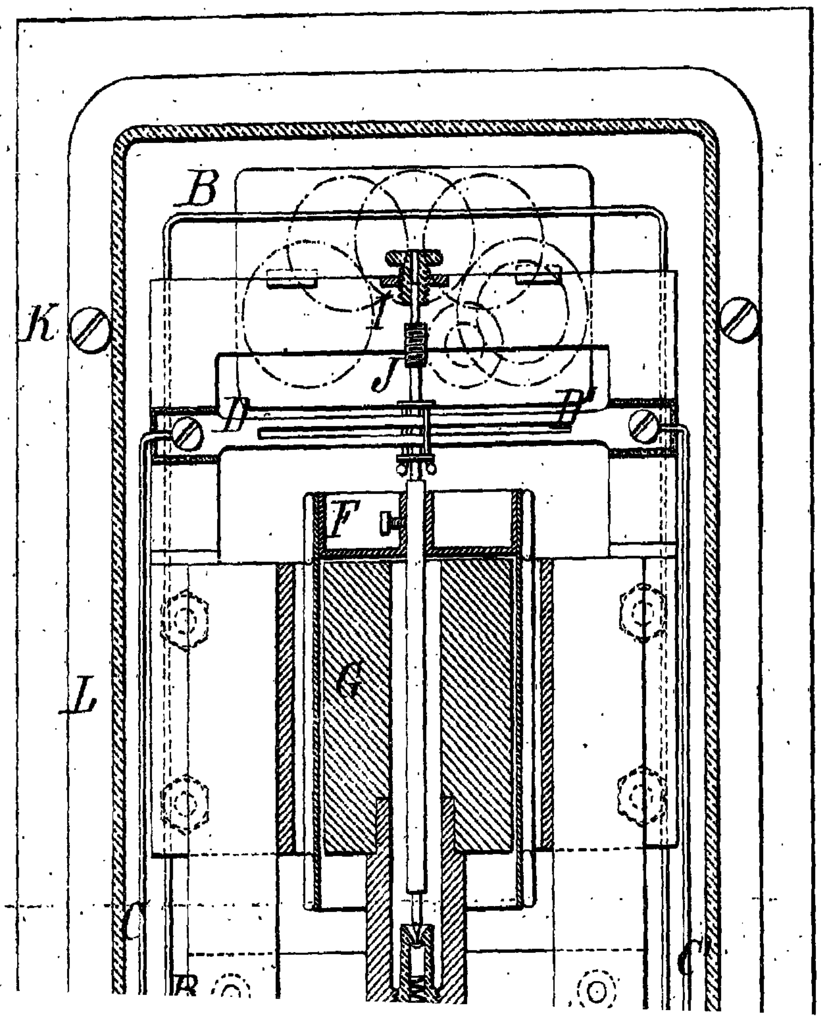
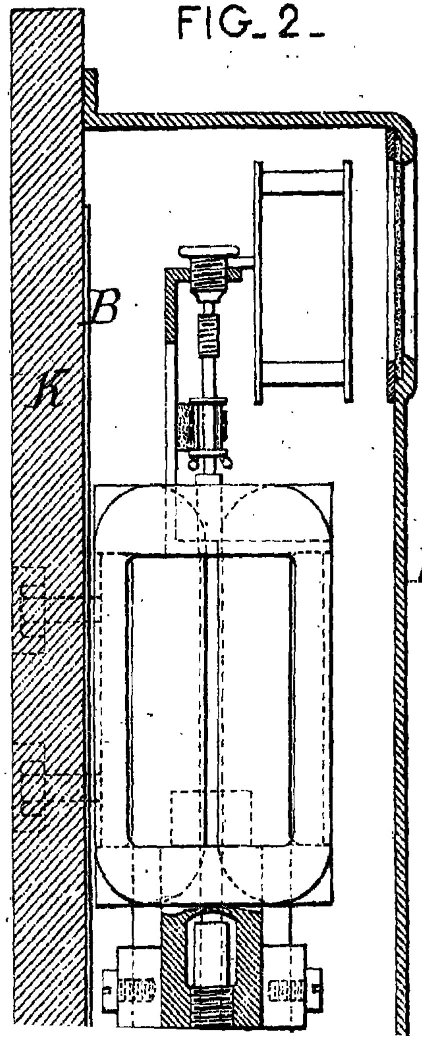
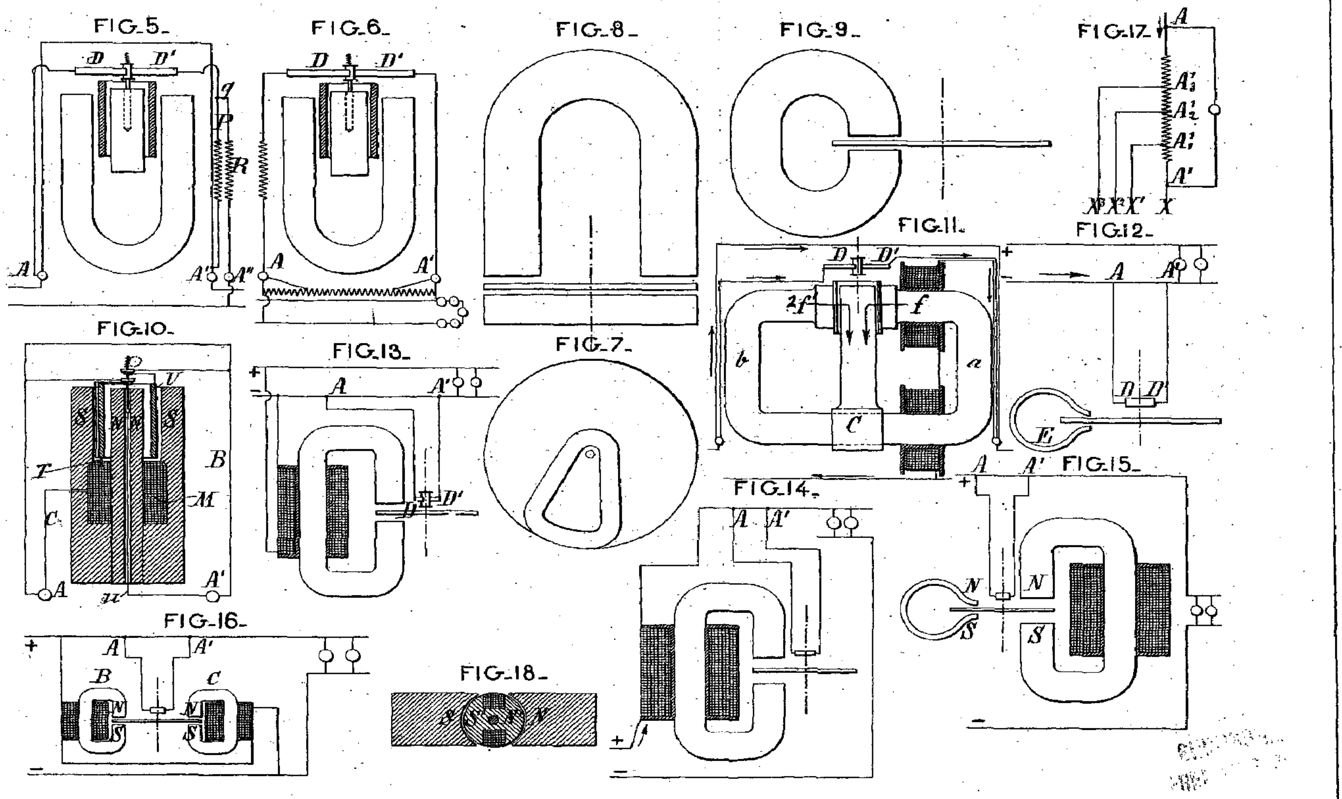


FIG_2_



Malby & Sons, Photo-Litho.



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Malby & Sons, Photo-Litho.

FIG_5_

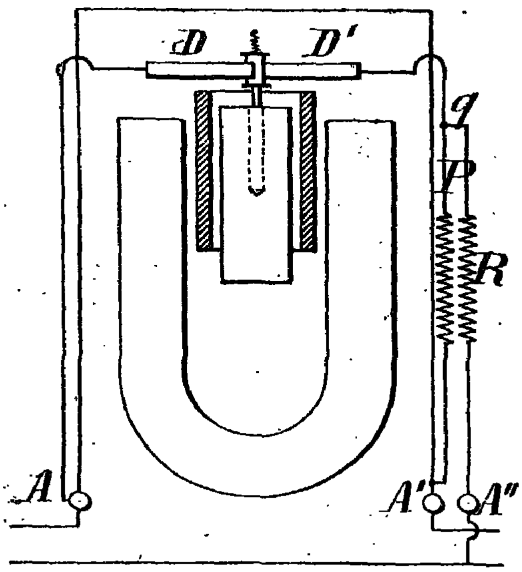


FIG_6_

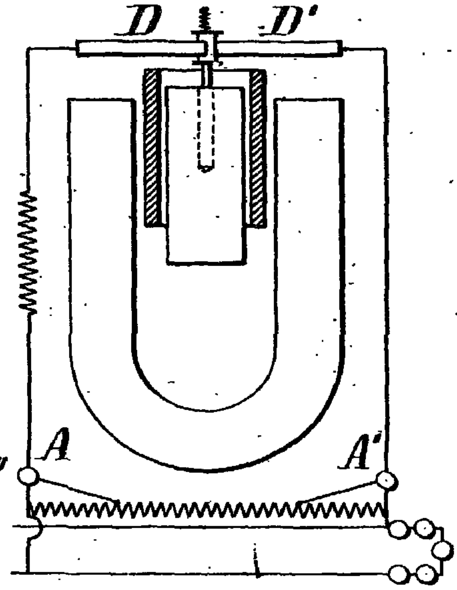


FIG_8_

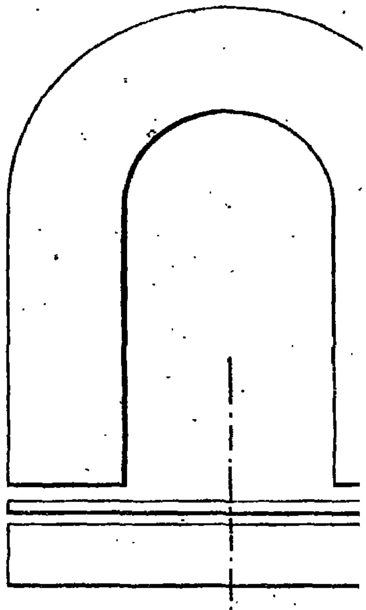


FIG_10_

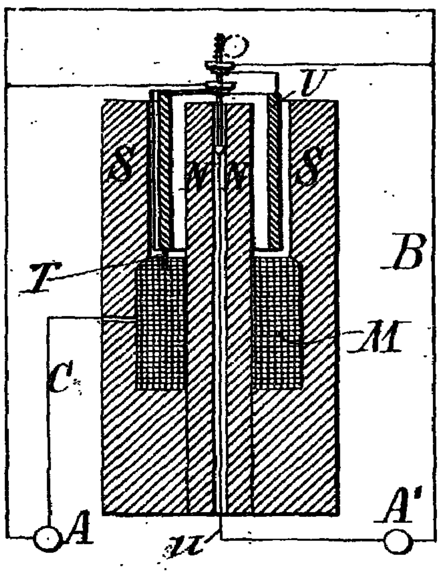


FIG_13_

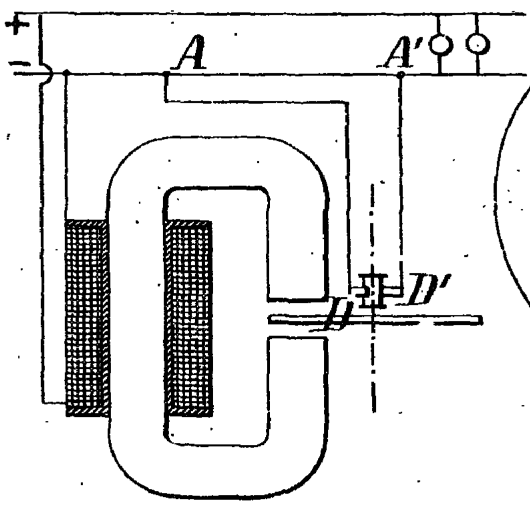
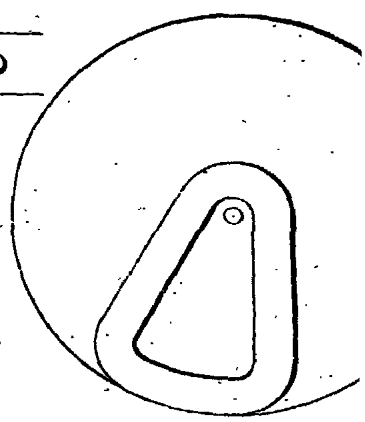


FIG_7_



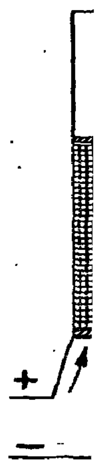


FIG_16_

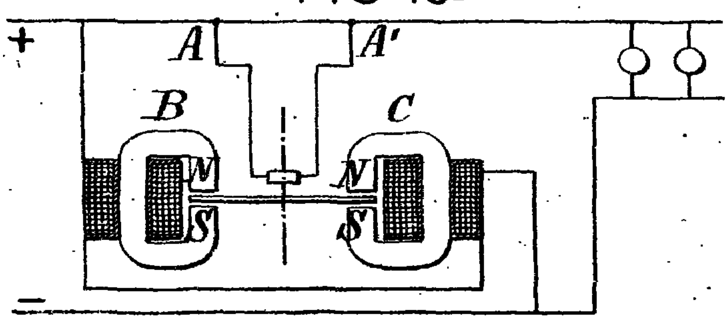


FIG_18_

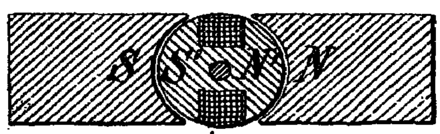


FIG. 9.

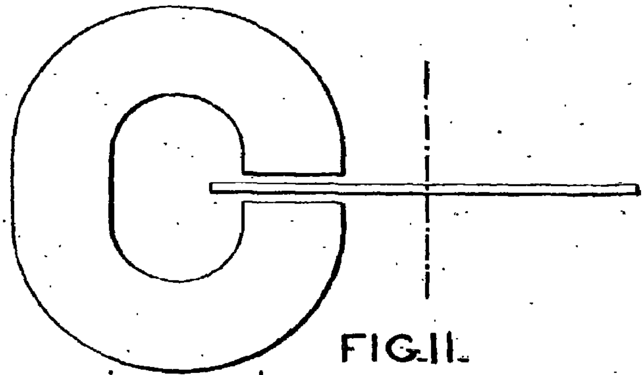


FIG. 17.

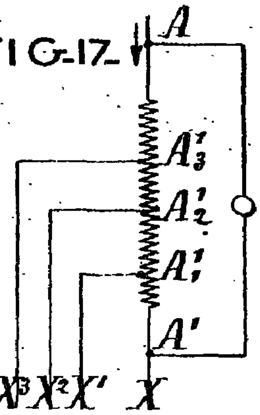


FIG. 11.

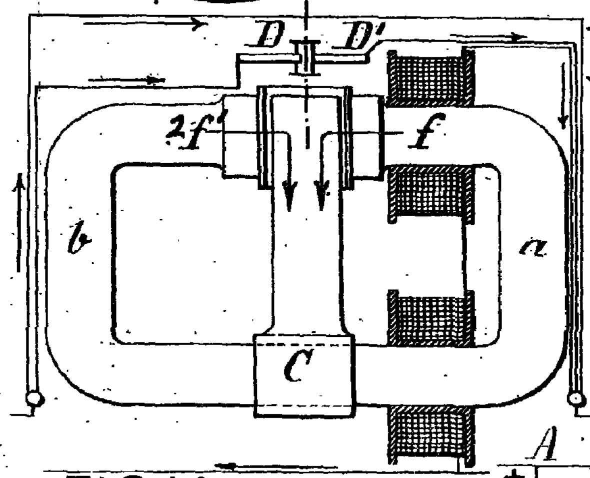
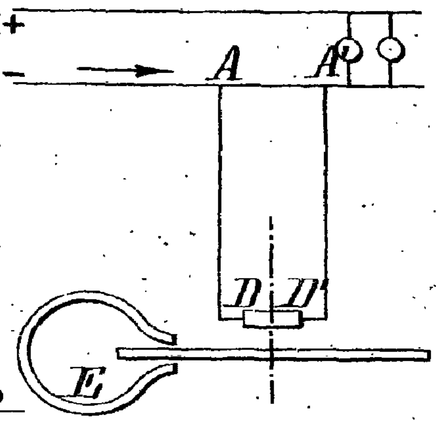


FIG. 12.



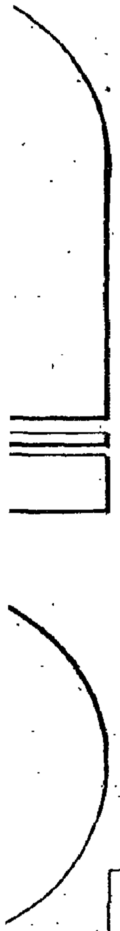


FIG. 14.

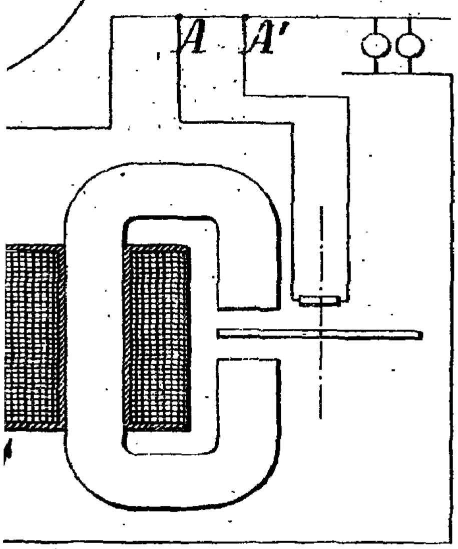


FIG. 15.

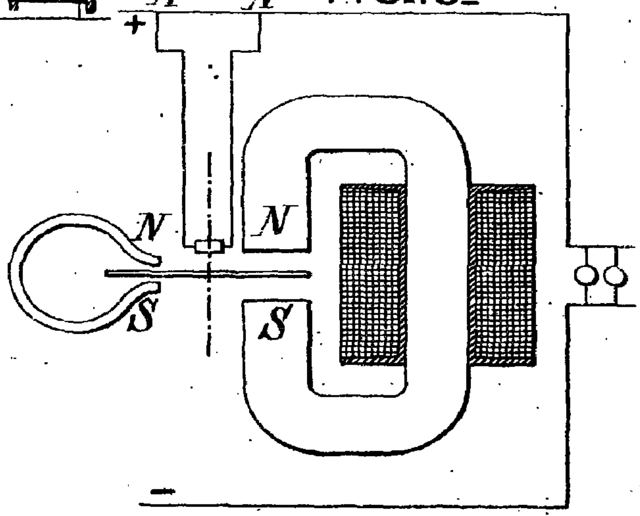


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FIG. b.

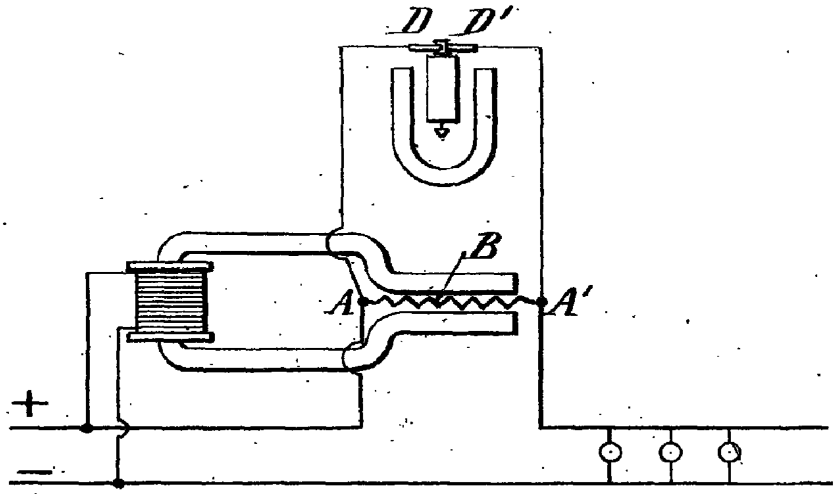


FIG. c.

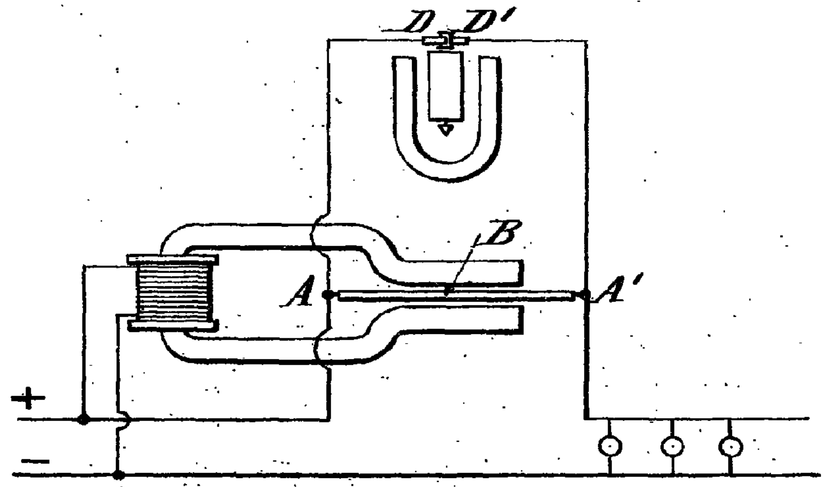


FIG. d.

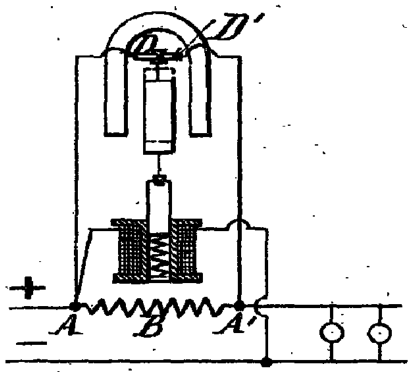
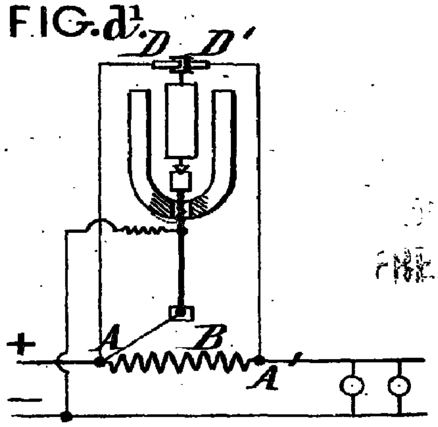


FIG. d¹.



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