No. 613,853. Patented Nov. 8, 1898.

W. H. CHAPMAN.

ELECTRIC REGULATOR.

(Application filed Mar. 24, 1898.)

(No Model.) 2 Sheets—Sheet 1.

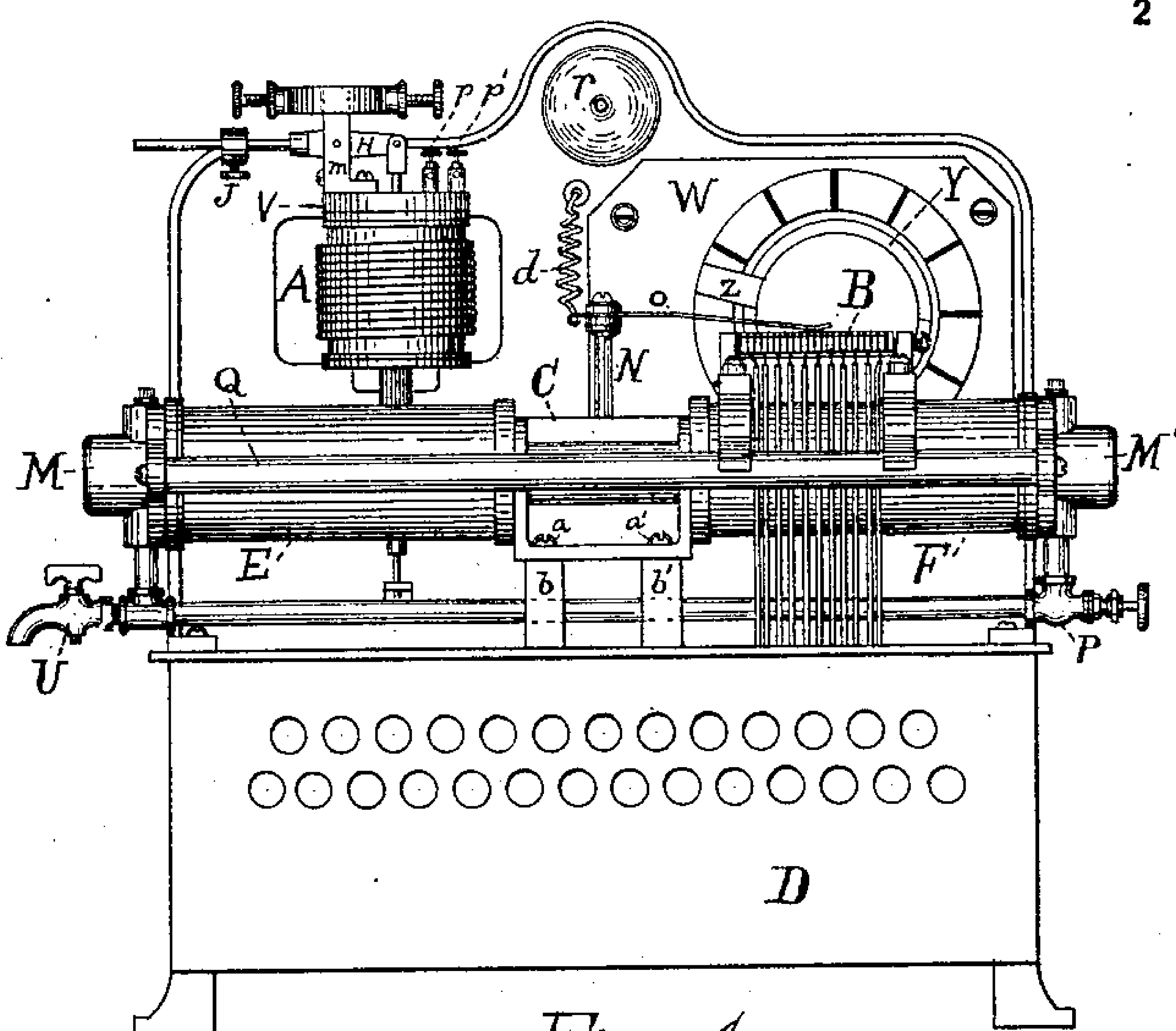

Fig. 1

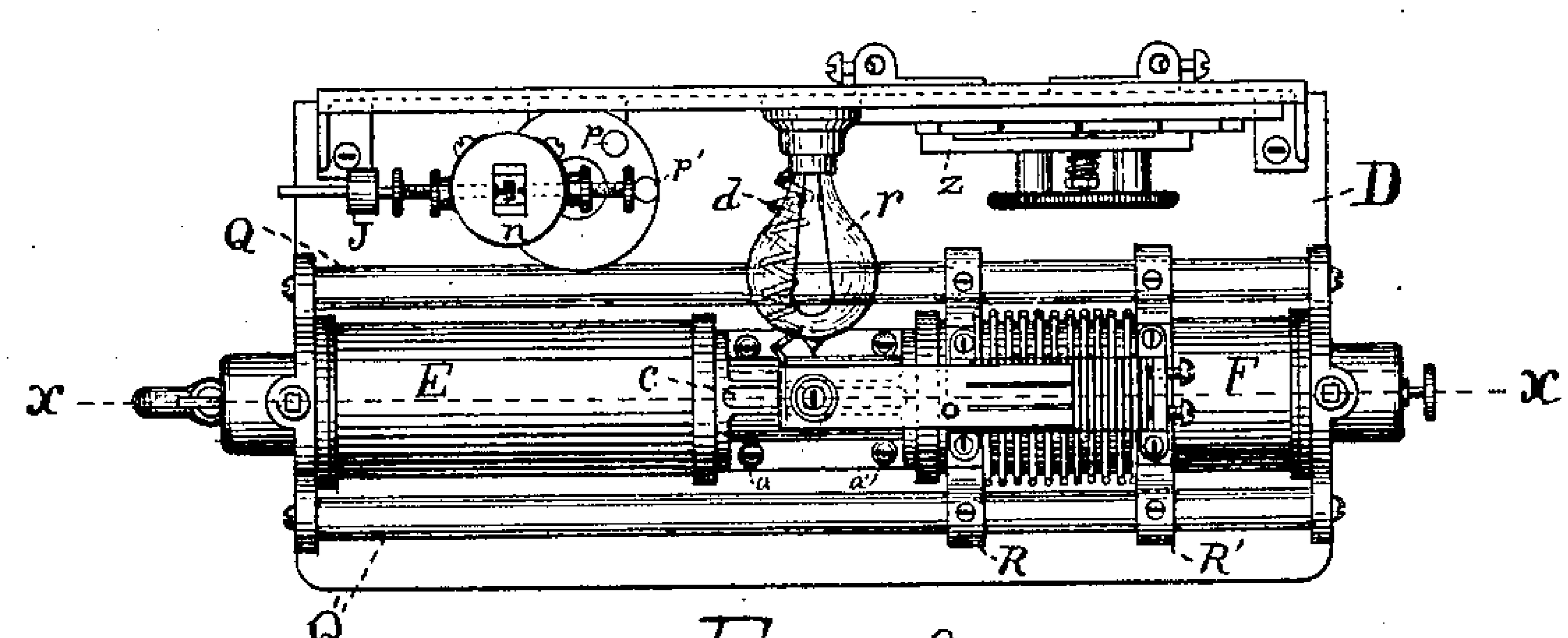

Fig. 2

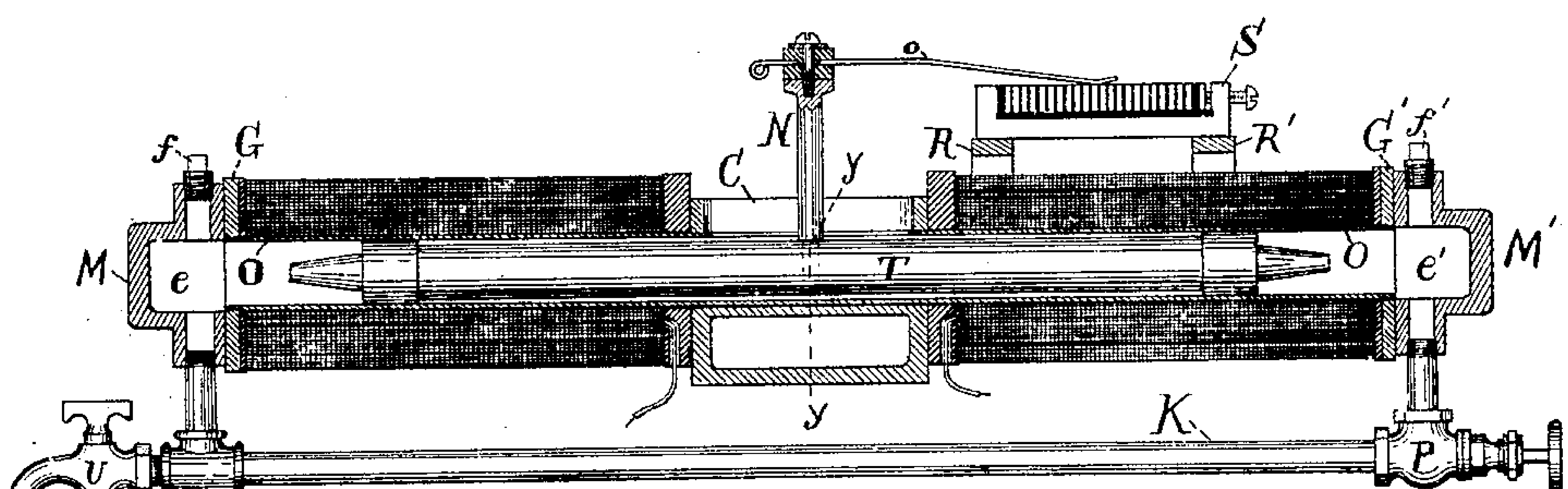

Fig. 3

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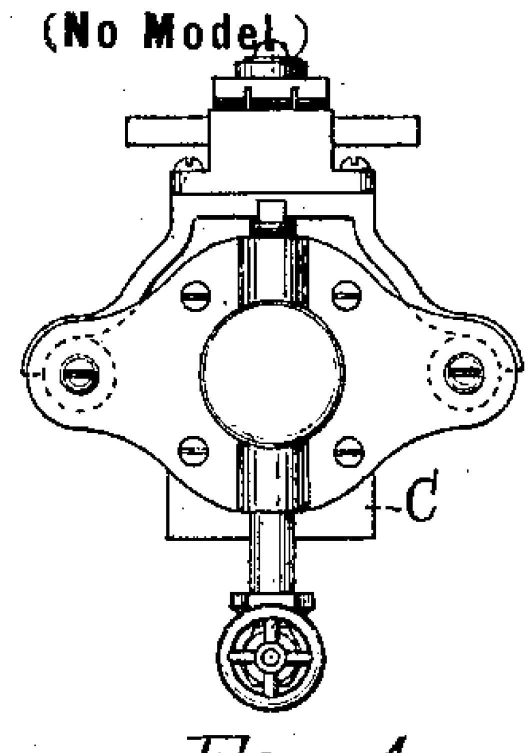

Fig. 4

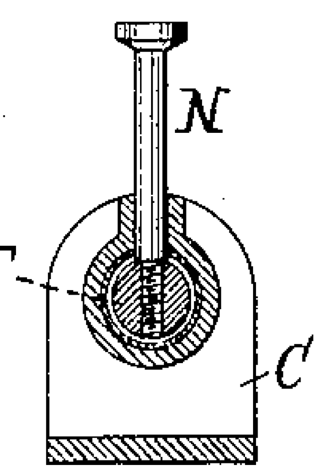

Fig. 5

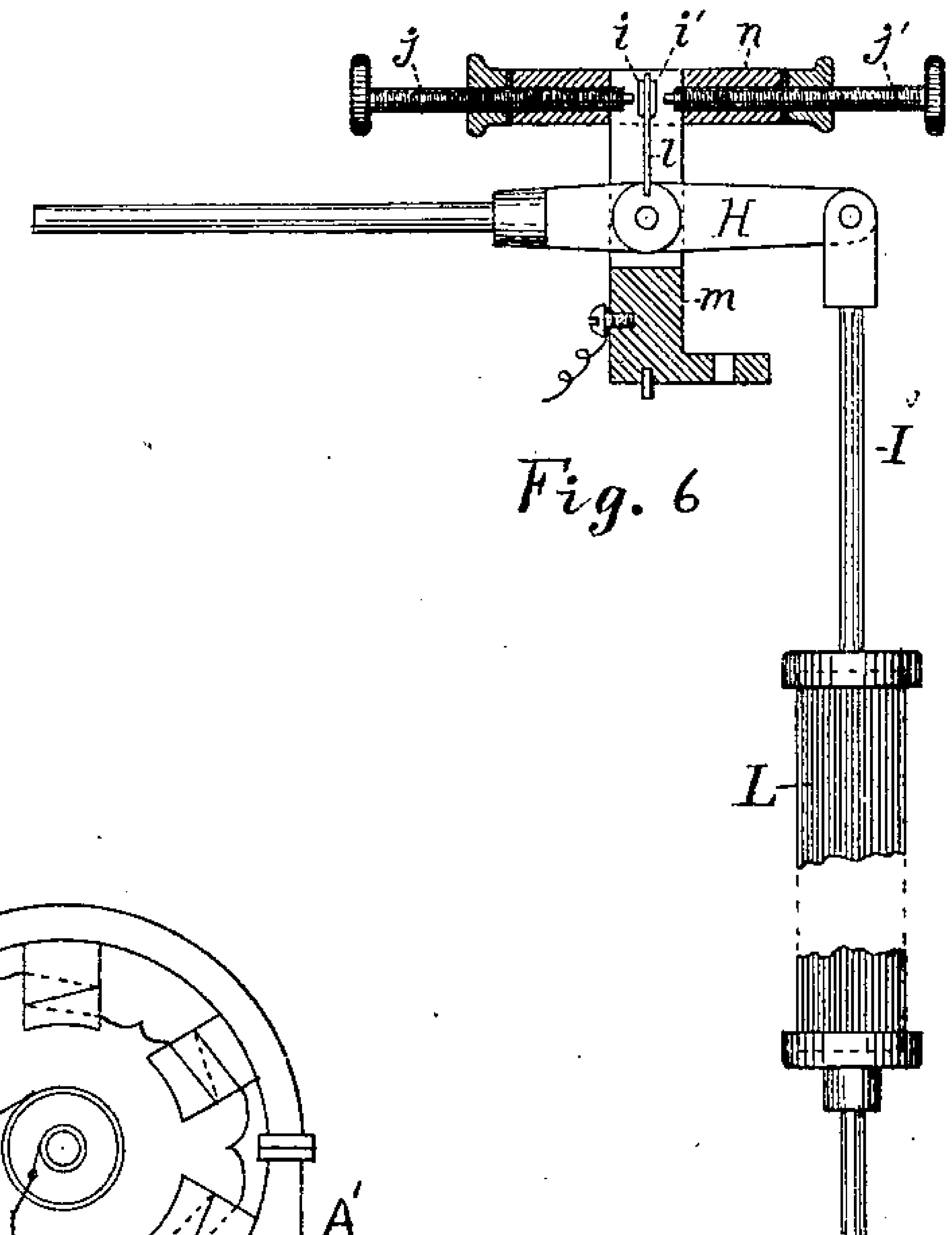

Fig. 6

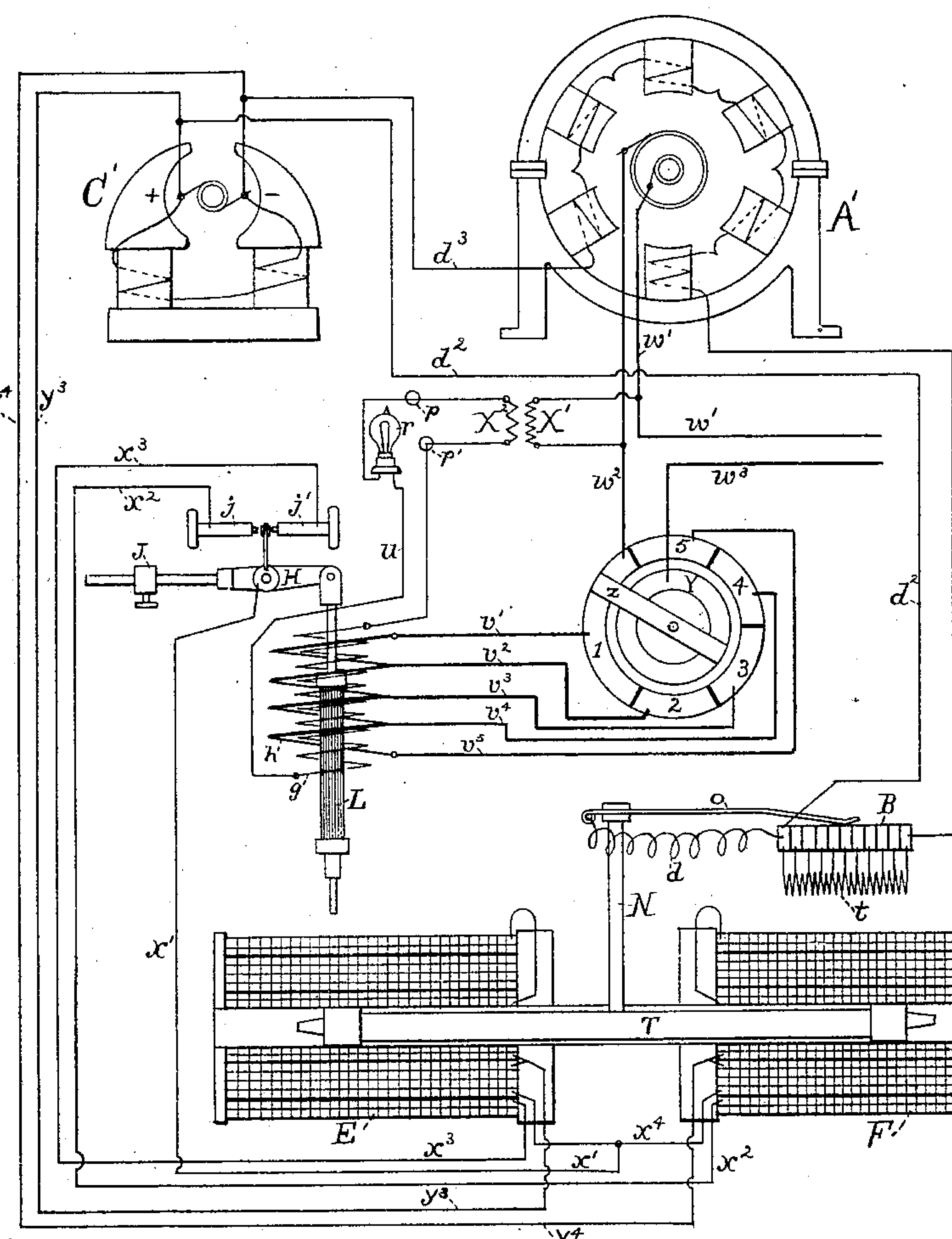

Fig. 7

Witnesses.
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UNITED STATES PATENT OFFICE.

WILLIAM H. CHAPMAN, OF PORTLAND, MAINE, ASSIGNOR TO THE BELKNAP MOTOR COMPANY, OF SAME PLACE.

ELECTRIC REGULATOR.

SPECIFICATION forming part of Letters Patent No. 613,853, dated November 8, 1898.

Application filed March 24, 1898. Serial No. 675,051. (No model.)

To all whom it may concern:

Be it known that I, WILLIAM H. CHAPMAN, a citizen of the United States, residing at Portland, in the county of Cumberland and State of Maine, have invented a new and useful Improvement in Electric Regulators, of which the following is a specification.

My invention relates to electric regulators in which a rheostat is operated automatically by magnetic power for the purpose of maintaining either a constant voltage or a constant current at some point in a given electrical circuit. It is designed as an improvement on the electric regulator for dynamos shown and described in Letters Patent No. 599,892, issued to me March 1, 1898.

The objects of my invention are to provide a more direct application of the power of the working solenoid to the contact-slider of the rheostat and to arrange a retarding device that may be adjusted while the regulator is doing service. I attain these objects by the mechanism shown in the accompanying drawings, in which—

Figure 1 is a front elevation of the complete regulator. Fig. 2 is a plan view of the same. Fig. 3 is a vertical cross-section of the working solenoid on the line *x x* of Fig. 2, and is drawn to a somewhat larger scale. Fig. 4 is an end elevation of the working solenoid. Fig. 5 is a vertical cross-section of the middle portion of the working solenoid on the line *y y* of Fig. 3. Fig. 6 is a detail view, partly in cross-section, showing the contact-points and parts mechanically connected therewith which control the energy of the working solenoid, and is drawn to a large scale. Fig. 7 is a diagram showing the complete electrical connections of the various parts of the regulator with each other and with an alternating-current-generating system which it is arranged to regulate.

D is a cast-iron box having holes in its sides for ventilation. The back of the box extends above the cover to provide support for the solenoid A and other parts of the regulator. Inside of the box is a set of resistance-coils (represented at *t* in the diagram Fig. 7) connected in continuous series with each other and having their terminals connected in the usual manner of rheostats with a series of insulated copper segments B. On the cover of the box D are upwardly-projecting lugs *b* *b'*, which support the working solenoid. The working solenoid consists of two differentially-wound coils E and F, one mounted on each end of a brass tube O, and a soft-iron core T, arranged to move longitudinally within the tube. The end portions of the core T are fitted to the tube nicely, like a piston to a cylinder. The extreme ends of the core T, however, are turned to a cone shape, as experience has proved that that form gives a more even magnetic force throughout the range of movement of the core than plain blunt ends would do. The length of the core T is made somewhat less than the whole distance through the two coils E and F.

At the middle part of the tube O and inclosing it tightly is a brass casting C, having on its lower side a plain surface, which rests on the lugs *b* *b'*, to which it is secured by screws *a* *a'*. The casting C has on its upper side a longitudinal slot *c*, which coincides with a slot cut through the tube O. At the middle portion of the core T is attached the bar N, which passes upward through the slot *c*, along which it can move freely. Attached to the upper end of the bar N, but insulated therefrom, is the contact brush or slider *o*. The contact-slider *o* is arranged to move over the surface of the series of segments B. A wire *d* connects the slider *o* with the segment of the series which is situated at the extreme left, and the slider serves to short-circuit more or less of the resistance-coils connected with the segments, according to the position of the slider along the series of segments.

The coils E and F are wound in a manner that constitutes a double differential solenoid which is substantially the same in its construction, connections, and operation as the differential solenoid described in the Letters Patent, No. 599,892, issued to me March 1, 1898, and it therefore does not need a detailed description in this specification. The characters used in this specification to designate the wires leading from the various parts of this differential solenoid are purposely made the same as those used in the Letters Patent referred to to designate corresponding wires, so as to facilitate comparison of the two with each other. At each end of the differential solenoid is a brass flange G G′, into which the tube O is secured.

M M′ are cast-iron end plates secured by screws to the flanges G G′, with which they make an oil-tight joint. Each end plate has in it a chamber *e e′*, which has an opening upward, in which are the pipe-plugs *f f′*, and an opening downward connecting with the pipe K, which leads from one end to the other of the solenoid and provides a passage for oil or other liquid which is used to fill up the chambers *e e′*, tube O, and the connecting-pipes. At one end of the pipe K is an ordinary valve P, such as used by steam-fitters, and serves to adjust the freedom of flow of liquid from one end to the other. At the other end of the pipe K is a drain-cock U, which is ordinarily kept closed, but is used whenever it is desired to remove the liquid.

Q and Q′ are iron rods extending from one end plate to the other and serving to improve the magnetic circuit of the solenoid.

R R′ are two brass pieces which span across over the coil F from one rod Q to the other rod Q′, to which they are secured. Onto the pieces R R′ is secured the cast-iron shoe S, which serves as a frame for containing and clamping the series of segments B, the segments being insulated from the shoe by fiber or mica.

A is a solenoid secured to the upwardly-extended back of the box D. This solenoid is composed of two distinct windings *g* and *h*, Fig. 7.

g is a winding of many turns of fine wire, and *h* are a few turns of a comparatively large wire. The winding *g* has one end connected by wire *u* to one terminal of an incandescent lamp *r*, which is used as a non-inductive resistance, and the other end of the winding *g* is connected with a terminal post *p′* on top of the solenoid A. The other terminal of the lamp *r* is connected to the other binding-post *p* on top of the solenoid A. The winding *h* has its two ends and each successive convolution connected, as shown in Fig. 7, with a series of metallic segments arranged in a circle, the number of which varies with the number of turns of wire used in the winding *h*. In Fig. 7, *h* is represented as having four convolutions, and there are five segments, to which these are connected. One end of the winding *h* is connected by wire *v′* to segment 1 and the other end of the winding by wire v^5 to segment 5, and the intermediate convolutions are connected by wires v^2 v^3 v^4 to segments 2, 3, and 4, respectively. The series of segments 1 2 3 4, &c., is mounted on a piece of slate, (shown at W, Fig. 1,) by which they are insulated. Concentric with the circular series of segments is a metallic ring Y, also mounted on the slate W.

z is a metallic bar pivoted at the center of the ring Y and serving to connect the ring Y with any one of the series of segments onto which it may be placed. The series of segments 1 2 3 4, &c., together with the ring Y and bar *z*, constitute what is known as a "compounding" switch, whose purpose is the introduction of more or less of the turns of wire on a coil into a generator-circuit.

On the top of the solenoid A is the fiber disk V, on which is mounted the forked brass piece *m*. In the piece *m* the lever H is pivoted. At one end the lever H has the connecting-rod I pivoted to it, and the rod I supports the iron core L of the solenoid A. The upper end of this core is preferably located about two-thirds way through the solenoid from bottom to top. On the other end of the lever H is the weight J, which is adjustable to different distances from the center or fulcrum of the lever H and serves to adjust the balance between the two opposing forces that act on the iron core L—namely, the force of gravity tending downward and the magnetic pull of the solenoid tending upward. Attached to the lever H and projecting radially upward from its fulcrum is the strip of heavy sheet-brass *l*, having at its upper end two platinum contact-pieces *i* and *i′*, one on each side. *j* and *j′* are platinum-tipped screws placed one each side of the piece *l* and arranged to make contact with the platinum contact-pieces *i* and *i′* as the lever H is tilted one way or the other. The screws *j j′* are supported and insulated by the circular-shaped piece of fiber *n*, attached to the upper end of the brass piece *m*.

Referring to Fig. 7, A′ is an alternating-current generator whose voltage is to be controlled. C′ is the direct-current exciter which supplies current to charge the field-magnets of the generator A′. X′ is the primary coil of a transformer, and X^2 is the secondary coil of the transformer. One end of the field-magnet wire of the generator is connected by wire d^4 to one end of the series of resistance-coils *t*, and the other end of the field-magnet wire of the generator is connected by wire d^3 to one terminal of the exciter. The other terminal of the exciter is connected by wire d^2 with the other end of the set of resistance-coils *t*. Thus the circuit through which the field-magnet of the generator is charged includes in it the resistance-coils *t*, or such portion of them as are not short-circuited by the brush *o*. The two terminals of the secondary coil X^2 are connected with the two binding-posts *p p′*, which are the terminals of the circuit composed of the fine winding *g* and the lamp *r*. The two terminals of the exciter are connected also to the wires y^3 and y^4, which represent the terminals of the differential solenoid E F.

w′ and w^2 are the wires leading from the terminals of the alternating generator. One of these wires, w^2, goes directly to the compounding-switch and is connected to segment 1. The ring Y has the wire W^3 leading from it, and the two wires W′ and W^3 are the line-wires which lead to the devices to be operated by the generator. The connection having been made as shown and described, the operation of the mechanism may be explained as follows: Suppose the generator and its exciter to be running under normal conditions and that the voltage of the generator, and consequently the voltage of the transformer secondary, is at its normal amount. The alternating current that is then flowing through the fine winding g of the solenoid A has a certain lifting force on the core L. The weight J is then moved along on the lever H until its counterbalancing force, together with the normal lifting force of the core L, will just balance the lever H in a horizontal position and keep the platinum contacts $i\ i'$ clear of the screws $j\ j'$ on both sides. This being the case, a current passes from the exciter by wire y^3 through one half of the wire on each of the coils E and F and back to the exciter by the wire y^4. The pull of both coils being equal, the core T remains stationary. But now suppose the voltage of the generator by reason of increase of speed has risen to a higher value. This causes a greater current through the winding g. The core L is then acted upon by greater force, destroying the balance of the lever H and bringing the contact-piece i in contact with the screw j. Currents then flow through both halves of the coil F and through only one half of the coil E. The two halves of F neutralize each other and the core T is pulled toward E and the slider o is moved over the segments toward the left, introducing more resistance into the field-magnet circuit of the alternator. The rapidity of the movement is checked by the pressure of the oil against the core T, for the core T can only move as fast as it is able to displace the oil in front of it and force it through the pipe K to the other end, and the rapidity of the flow through this pipe may be controlled by setting the valve P more or less widely open.

The field-magnets of all electrical generators take some appreciable time to change their degree of excitation, some requiring much more time than others, and this arrangement of pipe and valve enables a quick and accurate adjustment to be made of the rapidity of the introduction of resistance into the field-magnet circuit to the rapidity with which the field-magnet is observed to respond to the change. Now suppose the voltage of the generator falls to a lower value by reason of diminished speed. The core L is then pulled up with less force, the lever H is unbalanced the other way, and contact is made between the contact-pieces i' and screw j'. In this case currents will flow through both halves of the coil E and through only one half of the coil F. The two halves of E then neutralize each other and the core T is pulled toward F and the contact-slider o moves toward the right and cuts out resistance from the field-magnet circuit until the voltage is again brought to the normal and the lever H balanced, when the core T will come to a standstill again.

It will be seen that the action of the apparatus, as above described, is to maintain a constant voltage at the terminals of the generator; but in practice it is sometimes desirable to maintain the constant voltage not at the terminals of the generator, but at some distant point on the line-wires. When there is considerable current being supplied to the lines by the generator, the loss of voltage on the lines may be considerable, and it is therefore often desirable to raise the voltage at the generator a little in proportion to the load on the line-wires. To accomplish this automatically is the object of the coarse winding h, in which the main current is caused to flow in a direction opposite to the current in the fine winding g, thus neutralizing a portion of the effect of the winding h on the core L and necessitating a higher voltage to balance the lever H when the lines are loaded. This arrangement is known as a "compound winding," and the amount of compounding effect is proportional to the number of turns of the coarse wire that are introduced into the main circuit. The purpose of the compounding-switch is to adjust the compounding effect by introducing more or less of the turns of the coarse winding h into the main circuit. When the bar z is located, as in the diagram Fig. 7, on segment 1, there is no compound effect, because the main current entering by segment 1 passes through the bar z and ring Y to the line-wire W^3 without going through a single convolution of the winding h. If, however, the bar z is located on segment 5, the main current will have to pass through all the convolutions of the winding h to get to the line W^3 and in so doing produces the maximum compounding effect, and different successive degrees of compound effect may be obtained by placing the bar z on segments intermediate between 1 and 5.

In some cases it is desirable to secure a constant current in the main lines irrespective of the voltage for such purposes as the running of a series of incandescent lamps or a series of arc-lamps. In this case the fine winding g is disconnected or left off entirely and a considerable number of convolutions are used in the coarse winding h. The lever H will then be balanced only when a definite predetermined current is passing in the main circuit, and the definite current at which it will balance may be set by the weight J or by a change of the number of turns of winding on the solenoid A that are in the main circuit.

The great advantage of my apparatus, as above described, consists in the directness of application of the power of the working solenoid to the work of moving the resistance contact-slider and also in the facility of adjustment of the retarding device. The solenoid being placed in a horizontal position, there is no necessity for a counterbalancing weight and lever-arm, as is the case in that form of apparatus where the solenoid is vertical, and so the friction of pivots and the momentum of dead-weights are done away with, and the only friction is that of the core T along the inside of the tube and of the slider *o* along the surface of the segments; but since any pressure that the slider *o* has on the surface of the segments relieves to just that extent the weight of the core T, bearing down on the lower side of the tube, the friction due to the weight of the core is largely transferred to the slider, where it is useful and necessary in maintaining more perfect contact, and the total friction is reduced to the minimum, and it is found in practice to require a much less expenditure of energy to operate the working solenoid in my present form of apparatus than in the form hitherto employed on account of its simplicity and directness of application. The oil also, in which the core T is practically immersed, reduces the friction at the same time that it furnishes the means of retardation.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. The combination of a solenoid mounted on a tube or cylinder containing a liquid, an iron core fitted as a piston inside of said tube or cylinder and arranged to be moved by the magnetic pull of said solenoid, a passage-way for the movement of said liquid from one end to the other of said cylinder, a valve to regulate the rapidity of flow of said liquid and a rheostat having its contact-slider operatively connected to said iron core.

2. In an electric regulator the combination of a solenoid having a differential winding mounted on a tube or cylinder and having its magnetic core fitted as a piston to said cylinder, a passage-way leading from one end to the other of said cylinder, and means for closing said passage-way to a greater or less degree.

3. Two differentially-wound coils mounted on a tube or cylinder, an iron core arranged to be moved inside of said cylinder by the magnetic force of said coils, and fitted to act as a piston inside of said cylinder, a passage-way leading from one end of said cylinder to the other, a valve in said passage-way, and a rheostat whose contact-slider is operatively connected to said iron core.

4. Two differentially-wound coils of wire mounted on a closed tube or cylinder having its axis in a horizontal position and containing a liquid, an iron core arranged to be moved along the axis of said cylinder and having its periphery fitted to said cylinder to act as a piston, a passage-way leading from one end of said cylinder to the other, means for closing said passage-way to a greater or less degree, a rheostat whose contact-segments are arranged in a horizontal straight line parallel to the axis of said cylinder and whose contact-slider is operatively connected to said core.

5. In combination with an electrical generator, a differentially-wound solenoid mounted on a tube or cylinder and having its movable magnetic core fitted to act as a piston in said cylinder, a passage-way leading from one end of said cylinder to the other, means for closing said passage-way more or less, a rheostat operatively connected to said core, contact-points controlling the current admitted to said differential solenoid, and a solenoid for operating said contact-points having a winding connected into the main supply-circuit of said electrical generator.

6. In combination with an electrical generator, a differentially-wound solenoid mounted on a tube or cylinder and having its movable magnetic core fitted to act as a piston in said cylinder, a passage-way leading from one end of said cylinder to the other, means for closing said passage-way more or less, a rheostat operatively connected to said core, contact-points controlling the current admitted to said differential solenoid, a solenoid for operating said contact-points having a winding connected into the main supply-circuit of said electrical generator and a switch for varying the number of convolutions of said winding contained in the said main supply-circuit.

7. In combination with an electrical generator, a differentially-wound solenoid mounted on a tube or cylinder and having its movable iron core fitted to act as a piston in said cylinder, a passage-way leading from one end of said cylinder to the other, means for closing said passage-way more or less, a rheostat operatively connected to said core, contact-points controlling the current admitted to said differential solenoid, a solenoid for operating said contact-points having one winding connected into a circuit shunted from said generator-terminals and another winding connected into the main circuit of said generator.

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