No. 845,656. PATENTED FEB. 26, 1907.

H. W. LEONARD.

ELECTRIC CIRCUIT CONTROLLER.

APPLICATION FILED APR. 6, 1906.

7 SHEETS—SHEET 1.

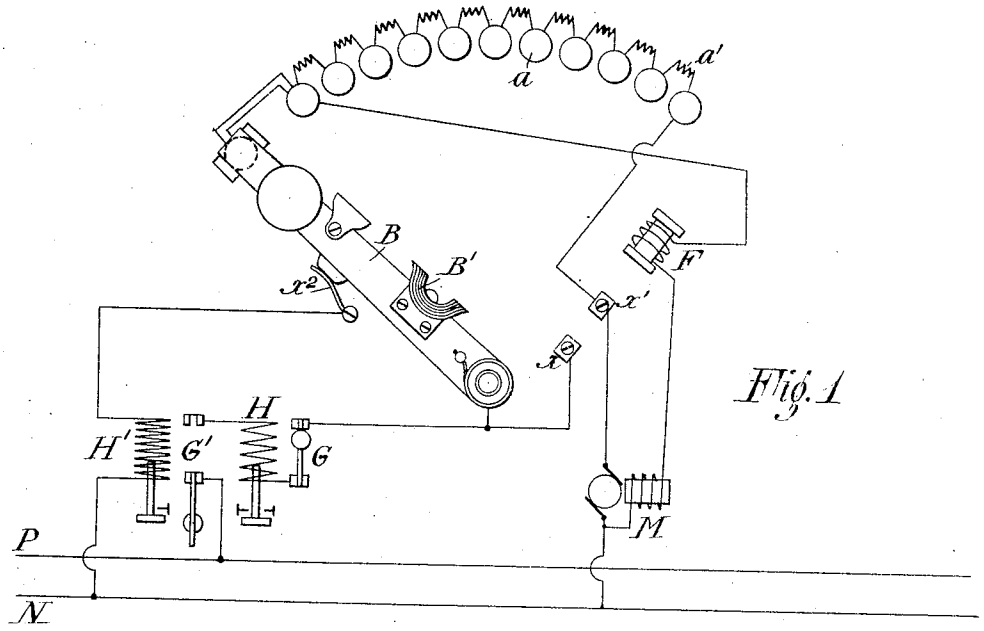

Fig. 1

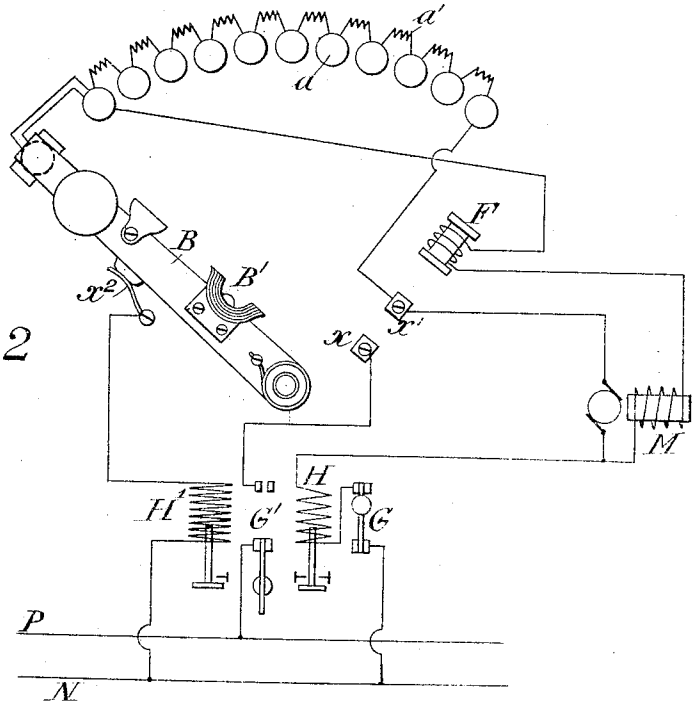

Fig. 2

Witnesses
L. K. Sager.
Geo. N. Kerr.

Inventor
H. Ward Leonard.
By his Attorney
C. Edwards.

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7 SHEETS—SHEET 2.

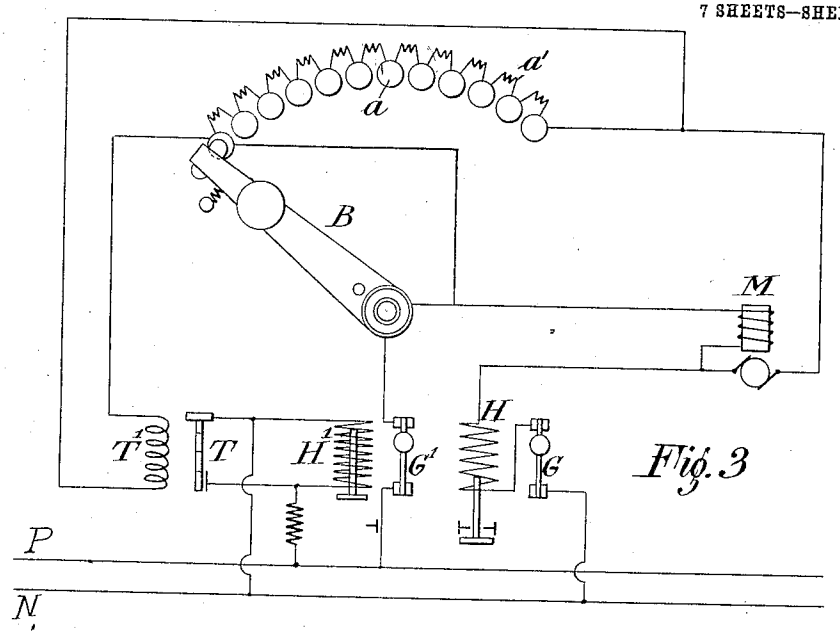

Fig. 3

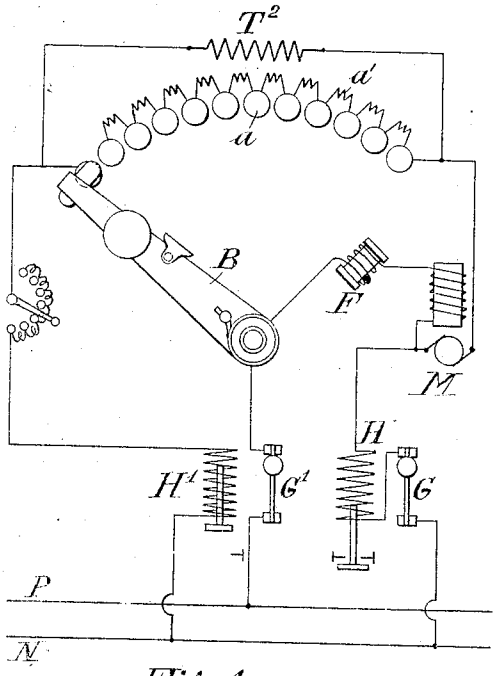

Fig. 4

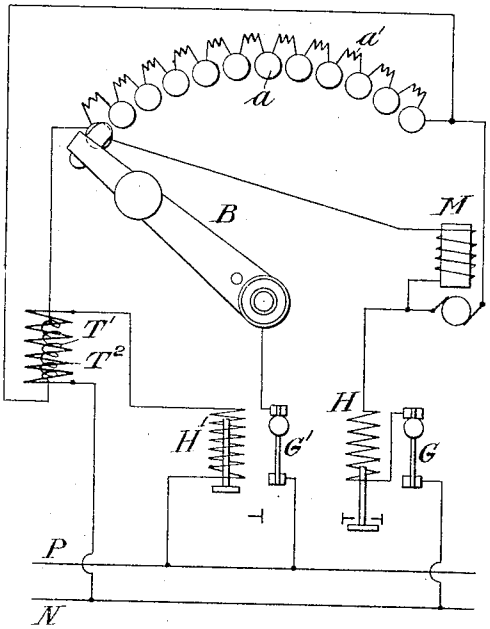

Fig. 5

Witnesses
L. K. Suger.
Geo. N. Kern.

H. Ward Leonard Inventor
By his Attorney C. W. Edwards

No. 845,656. PATENTED FEB. 26, 1907.

H. W. LEONARD.

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7 SHEETS—SHEET 3.

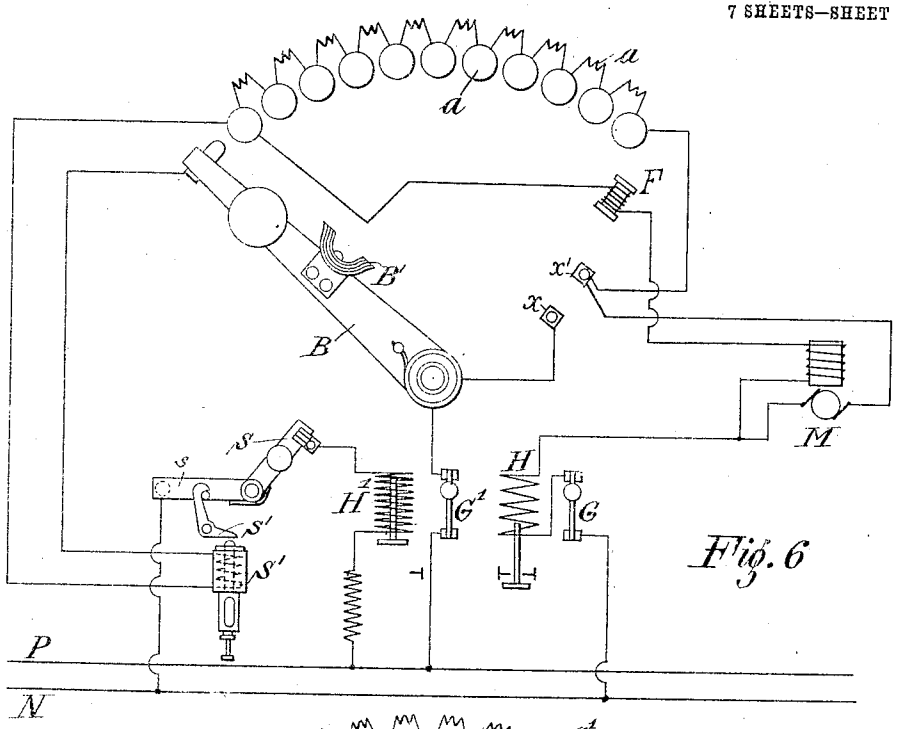

Fig. 6

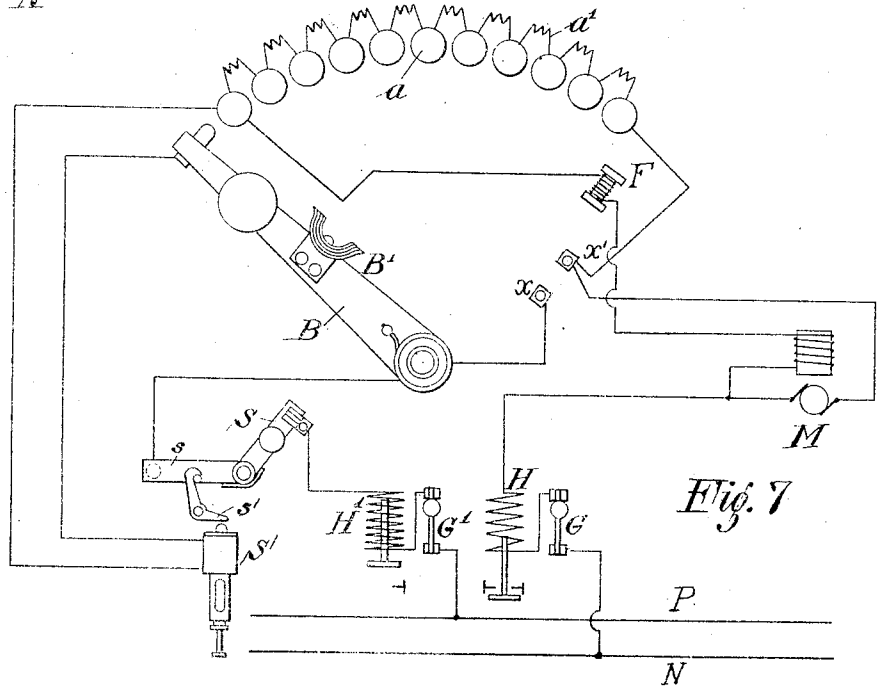

Fig. 7

Witnesses
L. K. Sager.
Geo. H. Kerr

Inventor
H. Ward Leonard
By his Attorney
C. V. Edwards

No. 845,656. PATENTED FEB. 26, 1907.

H. W. LEONARD.

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7 SHEETS—SHEET 4.

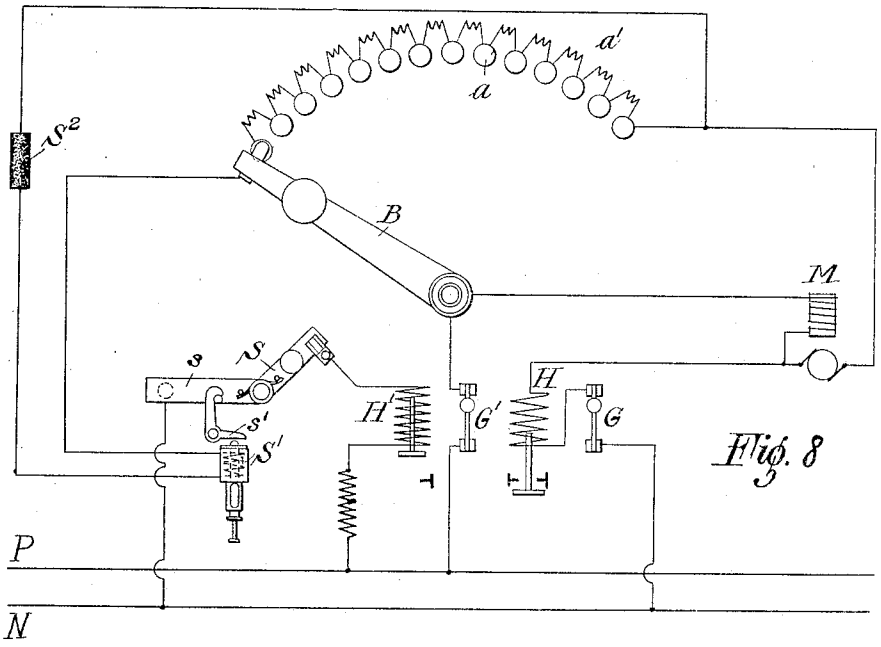


Fig. 8

Fig. 9

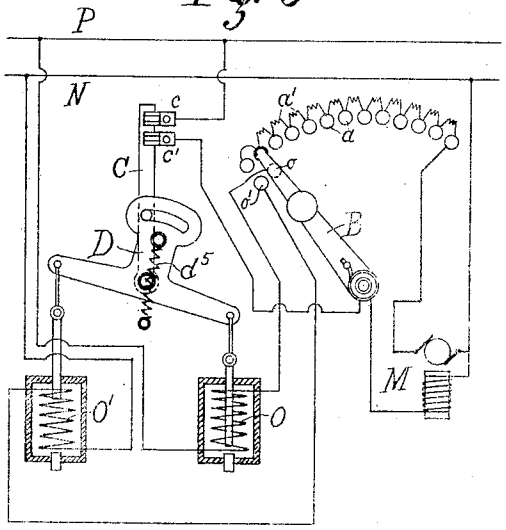
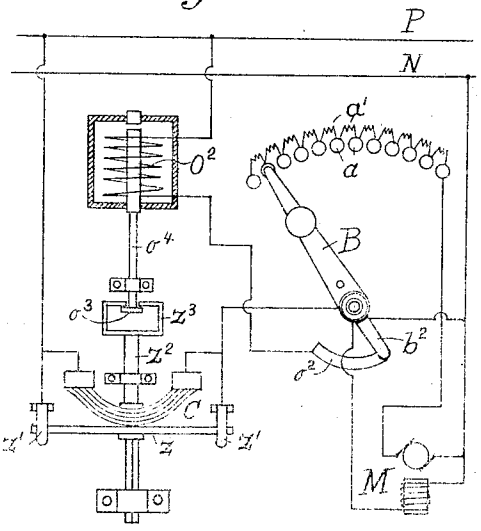


Fig. 10



Witnesses
L. K. Sager.
Geo. N. Kerr.

H. Ward Leonard Inventor
By his Attorney
C. W. Edwards

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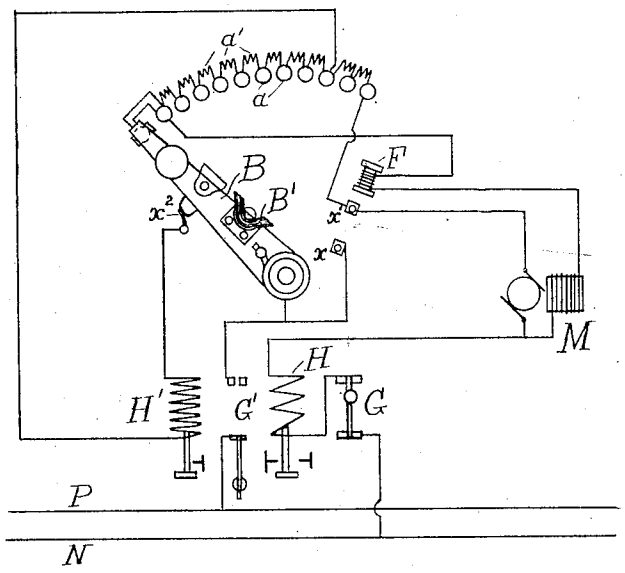
7 SHEETS—SHEET 5.

Fig. 11



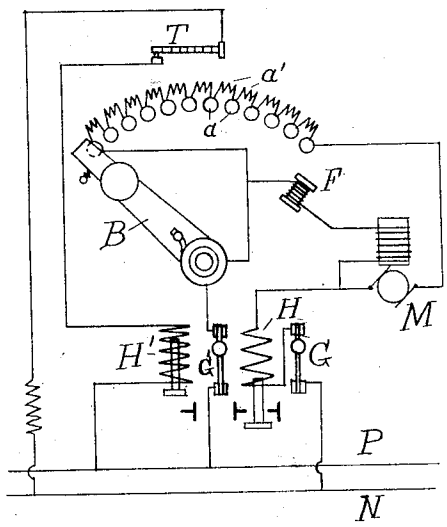


Fig. 12

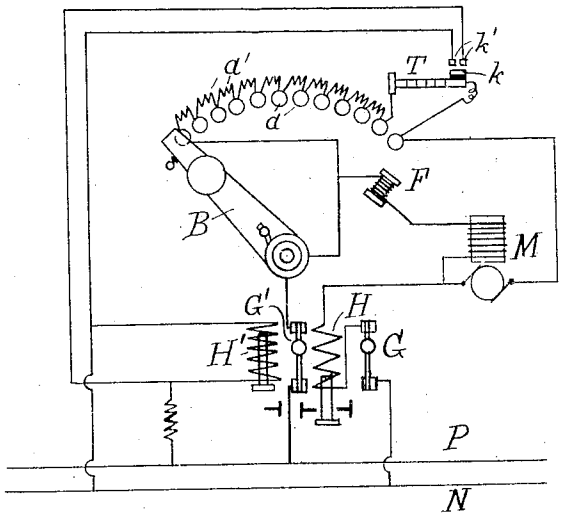


Fig. 13

WITNESSES:

L. K. Sager.

Geo. N. Kerr.

INVENTOR

H. Ward Leonard

BY

C. W. Edwards

ATTORNEY

No. 845,656. PATENTED FEB. 26, 1907.

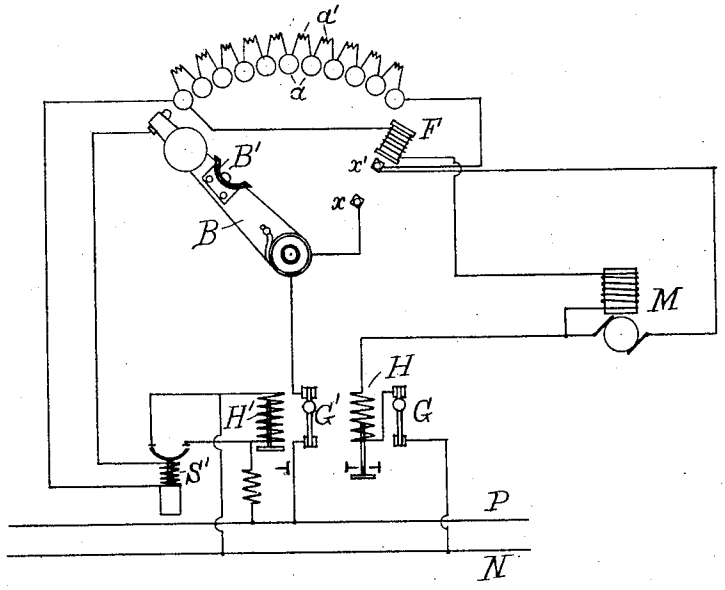
H. W. LEONARD.

ELECTRIC CIRCUIT CONTROLLER.

APPLICATION FILED APR. 6, 1906.

7 SHEETS—SHEET 6.

Fig. 14



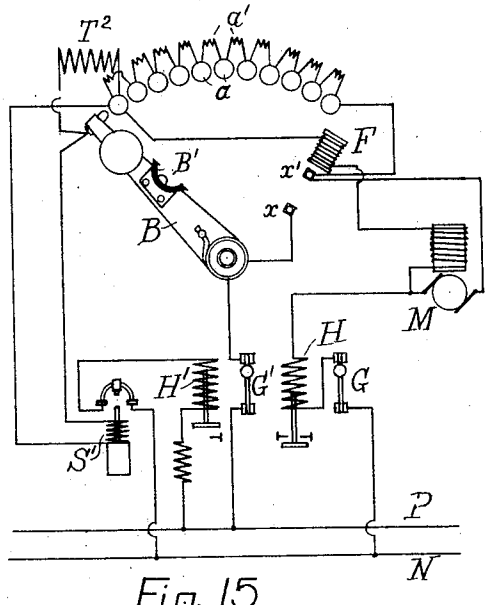


Fig. 15

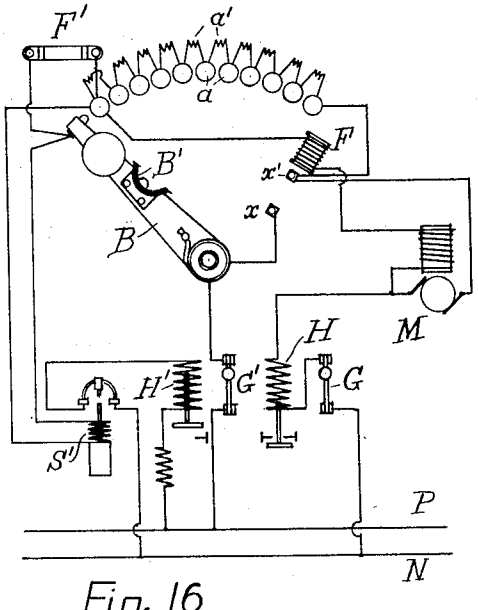


Fig. 16

WITNESSES:

L. K. Sager.

Geo. N. Kerr.

INVENTOR

H. Ward Leonard

BY

C. W. Edwards

ATTORNEY

No. 845,656. PATENTED FEB. 26, 1907

H. W. LEONARD.

ELECTRIC CIRCUIT CONTROLLER.

APPLICATION FILED APR. 6, 1906.

7 SHEETS—SHEET 7.

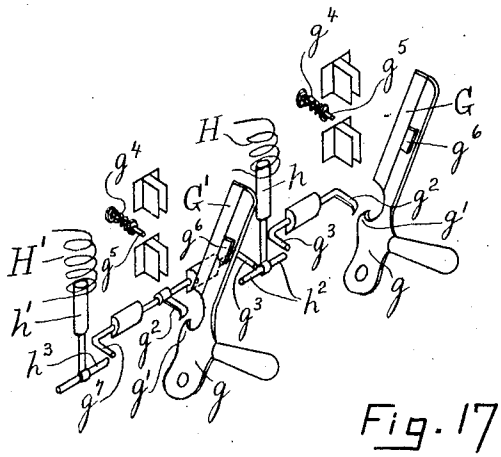


Fig. 17

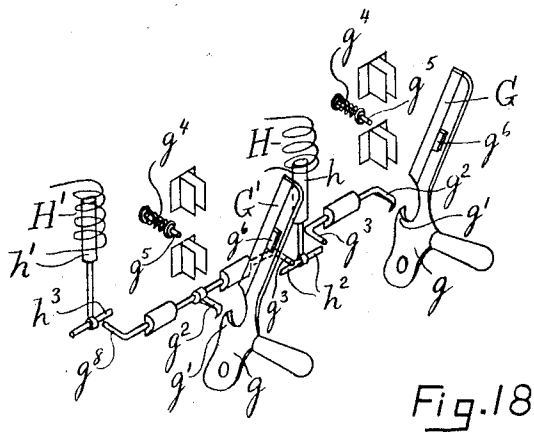


Fig. 18

WITNESSES:

L. K. Sager.

Geo. H. Fern

INVENTOR

H. Ward Leonard

BY

C. W. Edwards

ATTORNEY

UNITED STATES PATENT OFFICE.

HARRY WARD LEONARD, OF BRONXVILLE, NEW YORK.

ELECTRIC-CIRCUIT CONTROLLER.

No. 845,656. Specification of Letters Patent. Patented Feb. 26, 1907.

Original application filed December 20, 1904, Serial No. 237,653. Divided and this application filed April 6, 1906. Serial No 310,197.

To all whom it may concern:

Be it known that I, HARRY WARD LEONARD, a citizen of the United States, residing at Bronxville, in the county of Westchester and State of New York, have invented certain new and useful Improvements in Electric-Circuit Controllers, of which the following is a full, clear, and exact specification.

This application is a division of my pending application filed November 30, 1901, renewed December 20, 1904, Serial No. 237,653, granted April 10, 1906, No. 817,719, and relates generally to controlling-switches, and has a particular application to motor-starting rheostats or rheostats employed with electric motors or other electrical translating devices in which the resistance is employed not for regulating the energy supplied to the motor or other translating device, but mainly for gradually raising the energy at the terminals of the translating device to the full electromotive force.

My invention is also of importance where regulating resistances are used and to prevent their improper operation.

I have found in practice that such rheostats are frequently damaged by holding or permitting the contact-lever to remain on the initial or starting contact or contacts near the same with all the resistance of the rheostat or a considerable portion thereof in circuit. I have also found that operators frequently close the circuit at the initial or starting contact of the rheostat and then return the lever to the idle position, thus drawing an arc at the initial contact. This also damages the rheostat. I have also found that operators sometimes close the main circuit when the resistance-controlling device, which might be used as a regulator, is in an intermediate position. This of course allows an excessive and damaging flow of current.

The main object of my invention is to devise a starting rheostat or controller or to provide the present type of starting-rheostats with a controlling device which will prevent this improper handling of such rheostats. I have devised many ways for carrying out this object both mechanically and electrically.

The full-torque current is the current which the motor takes when developing its full-rated horse-power. In starting any motor it becomes necessary to produce a torque larger than that due to the full-torque current, because the motor and the load have to be accelerated and during the period of acceleration a larger current will be required than that necessary after the motor has been accelerated to full speed. In the manufacture of motor-starting rheostats it is common practice to have such a resistance in the rheostat that the current which will flow when the motor is at rest and the first contact is made at the rheostat will be fifty per cent. larger than the current taken by the motor when producing its normal full torque. In other words, this starting accelerating-current is fifty per cent. larger than the full-torque current—that is, it is one hundred and fifty per cent. of the full-torque current.

In order to prevent the burning at the initial contact of the rheostat, due to the closing of the circuit upon insufficient surface or due to the backward movement of the contact-lever after making the first contact, which results in the formation of an arc, due to the full electromotive force and one hundred and fifty per cent. of the full-torque current, (when the motor has no counter electromotive force,) the rheostat should be provided with an auxiliary switch by which the circuit is quickly closed upon an ample surface, and which switch will open the circuit with a snap action when the contact-lever is returned to the initial position. This auxiliary switch should be beyond direct hand control in opening and may be mechanically or electrically controlled by the rheostat contact-lever or controlling-switch.

In one form the rheostat contact-lever may be arranged to start a spring-actuated auxiliary switch which closes or opens with a snap action when the rheostat contact-lever is moved forward or backward at the starting position. In some instances this switch may be a small one which either opens or closes another circuit and thereby energizes a large quick-acting circuit-breaker. In such an arrangement the small switch need not be quick acting if it opens or closes the circuit to the coil of an automatic circuit-breaker whose current is very small—as, for instance, in the case of a winding connected with the full electromotive force, with or without resistance, in series therewith. In other arrangements the auxiliary switch may be of various forms, preferably a spring-actuated electrically-controlled switch of the automatic circuit-breaker type, the action of which is controlled by the variations in or the opening or closure of a circuit controlled by

the position of the rheostat-lever. In order to obtain quick action of the auxiliary switch at the time of making or breaking contact, it is important to suddenly apply a force or suddenly make a force effective at its full value to control its movement, and in carrying my invention into practice this may be accomplished by using a mechanical hammer-blow device, a tripping device so as to cause a spring or gravity to act suddenly and at its full force, or by the energization or deënergization of a magnet to give the resulting quick action to the switch moved thereby.

In my original application I have disclosed two forms of my invention in which the auxiliary switch is mechanically controlled. The present application relates more particularly to forms in which the control of the auxiliary switch is by electrical means.

My invention includes various other improvements and advantages, which will be understood from the following description and accompanying drawings.

In the accompanying drawings, Figure 1 is a diagrammatic view of one form of my invention. Figs. 2, 3, 4, and 5 are similar views of a modified forms of Fig. 1. Figs. 6, 7, and 8 are diagrammatic views of a modified form in which the initial movement of the rheostat-lever controls a loop-circuit containing a solenoid which in turn controls one coil of a circuit-breaker employed with the rheostat. Figs. 9 and 10 are diagrammatic illustrations of an arrangement in which the auxiliary switch is electromechanically operated. Figs. 11 to 16 are diagrammatic views of modifications, and Figs. 17 and 18 are perspective views indicating the construction of certain parts.

Referring to Figs. 1 and 2, there is mounted on a suitable base (not shown) a series of contacts a, to which the sections of the resistance a' are connected. This resistance, it will be understood, is arranged in any suitable manner beneath the base or within a casing, and the sections of resistance will be insulated from each other and in some instances provided with means for absorbing the local energy developed therein. B is a switch in the form of a rheostat contact-lever pivoted on the base. In this form of my invention the movement of the rheostat-lever B controls a coil which actuates a plunger to trip a spring-actuated switch, and which switch may be one element of a double-pole circuit-breaker.

The auxiliary switch of Figs. 1 and 2 is an automatic circuit-breaker of the type shown in the patent to Leonard and Ball, No. 705,102, granted July 22, 1902. In Fig. 1, G and G′ are independently-movable switches coöperating with stationary contacts, between which is connected an overload-coil H, said switches and coil being connected in series between conductor P and the contact-lever B. The contact-lever carries a switch B′ of the leaf-contact type, which bridges two stationary contacts x and x' when the lever is in the final position. Contact x is connected by a wire with the upper contact of switch G, and contact x' is connected by a wire with the final contact a of the resistance, so that while lever B is at the initial or any intermediate point the circuit to the armature of motor M from switch G will be through lever B and resistance a' to contact x', the motor-armature being connected between the latter contact and conductor N. The field of M is connected in series with underload-magnet F between the initial contact a and conductor N, the field and armature windings being in shunt relation.

It will be seen that when lever B is in the final position the armature-circuit of the motor will be through switch B′, which makes very intimate contact at x and x', the resistance being shunted out of the armature-circuit. With motor-starting rheostats it has been customary to provide spring-contact clips for the rheostat-lever at the final position, as shown in Fig. 2 of my original application, to afford good contact and prevent heating, which would happen if a contact-button were employed for the final contact. With those spring-clip contacts, however, I have found it necessary to employ a hammer-blow device for the contact-lever to start the same when an automatic release is provided to control the circuit. With a leaf-contact switch, as shown in Figs. 1 and 2, a hammer-blow device is not necessary. The spring-brush affords good contact and no undue heating occurs, and when the automatic release responds to abnormal conditions in the circuit the action of the leaf-contact assists the spring of the contact-lever to return it to the starting position. Switch G′ in this form serves as the auxiliary switch, and its opening movement in response to the backward movement of the contact-lever at the initial position is controlled by fine-wire coil H′, which is connected between conductor N and a stationary spring-contact x^2, which makes contact with lever B while in the initial position. The effect of this connection is to cause coil H′ to become energized and actuate its core or plunger, which when raised trips the catch which holds switch G′ closed and allows that switch to open, thus opening the circuit to the rheostat and motor. By reference to Fig. 1 it will be seen that so long as contact-lever B remains in the position shown, or whenever the lever is returned to that position, the high-resistance winding H′ will be energized by the full electromotive force, and switch G′ will be opened. In operating the controller switch G is first closed, and then G′ is closed immediately

after the initial movement of lever B, which breaks the connection at contact x^2, or switch G′ is closed before lever B is moved and held until the latter is moved to the first resistance-contact a, or switch G is first closed, then lever B is moved to the first resistance-contact, breaking contact at x^2, and then switch G′ is closed. If the operator returns lever B after the initial movement, the circuit will immediately be opened at switch G′ with a quick snap action, thus preventing the drawing of an arc. In Figs. 1 and 2 the first resistance-contact a is connected by a wire with the initial contact, so that the circuit is never opened at the rheostat, but the resistance can never remain in circuit while the lever is in its initial position. In this form lever B is provided with the usual retracting-spring for returning it to the starting or initial position. It will be noticed that in Fig. 1 switches G and G′ are located in the same side of the circuit, while in Fig. 2 they are in opposite sides of the circuit, thus providing a double-pole switch. This is the only difference between Figs. 1 and 2. In each of the different figures when the plunger of coil H is raised the latches holding switches G and G′ will both be tripped, as is customary in double-pole circuit-breakers and as in the Leonard and Ball patent above referred to. The construction of a suitable automatic switch is indicated in Fig. 17. Here each switch G G′ is shown as carried by the pivoted part g and each part having a handle for manual closing. Each part g has a projection g', adapted to be engaged by a latch g^2 for holding the switch in a closed position. The latches g^2 of both switches are controlled by the coil H and its core h. When the core is raised, due to the large current passing in coil H, both latches will be tripped by reason of the cross-piece h^2 engaging the extensions g^3 g^3, connected to the latches. The switches will then be opened, as by the force of springs g^4 and the rods g^5, since the latter are drawn outward by the tension of the springs, and which rods engage the surfaces g^6 on the switches. When the current in coil H′ causes its core h' to be raised, its cross-piece h^3 will engage the extension g^7, which latter is connected to the latch g^2 of switch G′. The switch G′ will therefore be opened by the passing of current in coil H′.

Instead of connecting coil H′ directly to conductor N it might in some cases be connected to an intermediate point in the circuit, which would give sufficiently high voltage to operate the plunger of coil H′. Fig. 11 illustrates one such modification, being similar to Fig. 2, except that one end of coil H′ is connected to a point in the series of resistances. In this case the coil depends for its operation upon the drop in electromotive force on a portion of the resistance.

Referring now to Fig. 3, it will be seen that switches G G′ and coil H are connected in circuit in the same manner as in Fig. 2; but high-resistance coil H′ is connected across circuit P N in series with a high resistance. A thermostatic switch T is connected across the terminals of coil H′, so that when contact is made at the platinum points coil H′ will be short-circuited and its core or plunger will drop, tripping the latch which holds switch G′ and permitting its spring to throw it open. To actuate thermal strip T, I provide a small electric heater T′, which may be a pottery tube having a resistance wound thereon, as shown in my Patent No. 691,949, granted January 28, 1902. This heater is connected around all or part of the resistance of the rheostat, as shown, and it will be seen that since the heater when lever B remains on the initial rheostat contact will be in the armature-circuit of the motor M across the line P N its temperature will rise rapidly, causing thermal-switch T to short-circuit coil H′ and open the circuit between the rheostat-lever B and conductor P.

In operating the controller of Fig. 3 the operator first closes switches G and G′ and will see that the core or plunger of fine-wire coil H′ is raised into the coil. The closure of switches G and G′ gives a full field to motor M and closes the armature-circuit through the entire resistance of the rheostat. The drop on the resistance a' causes heater T′ to heat up, and if lever B is allowed to remain in the initial position the heat of T′ will in a predeterminable time cause the thermostatic switch T to close the shunt around coil H′, thus demagnetizing that coil, whereupon its core drops and trips the latch which holds switch G′ closed. The movement of switch G′ through its actuating-spring opens the circuit to the motor and rheostat. An overload-current will cause the coil H to raise its core and trip the latches holding both switches. If an abnormally low or no voltage condition exists, coil H′ will be too weak to hold its core, and switch G′ will be opened. An arrangement of the parts for such an operation of switches G G′ is indicated in Fig. 18, which is similar to Fig. 17, except that the parts are so arranged that the falling of core h' causes the opening of switch G′ instead of the raising of core h'. The cross-piece h^3 of core h' in falling will engage the extension g^8, connected to latch g^2, and cause the latch to be moved, so that the switch G′ will be opened.

Various arrangements might be devised for heating the switch T when current flows through the resistance, and the switch T might cause the coil H′ to be deënergized in other ways. In Fig. 12 I have shown switch T in proximity to a part of the resistance a', which resistance will serve to heat the switch if the arm B is held in position on the resistance-contacts an objectionable length of

time. In this figure the switch T is shown in series with coil H′ and is adapted to open the circuit of this coil when heated instead of shunting the same, as in the case of Fig. 3.

Another modification is shown in Fig. 13, in which the thermostatic controlling-switch T is connected in series with resistance a' and heated by the current passing through a', and if this resistance or any part thereof is kept in circuit an improper length of time it will cause the thermostatic switch T to be heated to such a degree that it will move and force the insulated conductor k to engage the contacts k' and short-circuit coil H′. The coil H′ is thus demagnetized, and the dropping of its core will cause the main circuit to be opened at switch G′. When the resistance-controlling arm is in final position, the thermostatic switch is cut out of circuit.

Instead of a thermal strip T for controlling the action of coil H′ a resistance T^2, of iron, nickel, or other material having a high temperature coefficient, might be connected in series with coil H′ across the line, as shown in Fig. 4. In the arrangement of this figure the circuit through coil H′ is closed by the closing of switch G′, and when the rheostat-lever B is moved to engage the initial resistance contact the motor will start and begin to accelerate. After being held there a proper length of time the lever will be moved along the starting resistance contacts, thereby disconnecting the initial resistance contact from the first contact which originally actuated coil H′, and this coil is then placed in series with the resistance T^2. If the rheostat-arm B is left for an improper length of time on the starting resistance contacts, the magnetism of coil H′, due to the gradual increase in resistance of T^2 on account of being heated by resistance a' in close proximity to it, would gradually become less as the time interval increased, and in a predeterminable time the core or plunger of that coil would drop and trip the catch which holds switch G′ closed, whereupon that switch would open.

Another modification of this idea is shown in Fig. 5, in which a resistance T′, which may be mounted on a pottery-tube, as in Fig. 5, is placed inside of a second pottery-tube carrying a resistance T^2, of iron, nickel, or other material having a high temperature coefficient. In this arrangement coil H′ and resistance T^2 are connected in series across the line, and heater T′ is connected in a shunt around the resistance a' of the rheostat, as in Fig. 3 and for the same purpose. Instead of separating, the resistance T′ and T^2 they might be arranged upon the same support and suitably insulated. To predetermine the time interval at which the condition of coils T′ and T^2 would cause the coil H′ to release its plunger, an adjustable resistance might be provided for heater T′, or when the windings of T′ and T^2 are on separate supports the distance between them or the relative positions of one within the other might be varied to vary the heating effect of T′ upon T^2. Various other ways of regulating the action of T′ and T^2 and H′ in the arrangement of Figs. 3, 4, and 5 might be devised without departing from the main feature of my invention.

In Figs. 6 and 7 the coil H′ is controlled by an automatic switch. In Fig. 6 this coil is connected across the circuit in series with the automatic switch and a resistance, while in Fig. 7 the coil and automtic switch are connected in series with the rheostat. The automatic switch is preferably a double-arm switch S and s, pivoted on a common pivot and provided with a spring tending to throw them toward each other. Switch S makes contact with a spring-clip connected with coil H′ and which clip holds it in position, while arm s makes contact with a button connected to conductor N. This arm is held by a latch s', which is tripped by the action of the core or plunger of coil S′. Arm s is not provided with an operating-handle and is arranged to be moved onto its contact by arm S. The coil S′ for controlling this switch is connected across the first resistance contact of the rheostat and a blind initial rheostat-contact.

It will be noted that the starter of Figs. 6 and 7 has no open-circuit point. To start the motor or other translating device, the operator first closes the switch G, then switch-arms S and s are closed, and then the operator holds down the plunger of coil S′ and closes switch G′. It will be seen that when this is done the circuit connections will be as indicated, that coil S′ is energized, and that if the operator permits lever B to remain on the initial or blind contact and lets go of the plunger or coil S′ that plunger will release switch-arm s and open the circuit of coil H′, which in turn will drop its plunger and effect the opening of switch G′ and the circuit to the rheostat and translating device. If the operator moves lever B to its final position, as he should do, it will be seen that the circuit to coil S′ is opened the instant lever B leaves the initial contact and that switch-arm s will remain locked until lever B is returned to its initial position, whereupon coil S′ becoming energized will act as above stated. After lever B is moved from its initial position the rheostat and translating device will be protected against abnormal conditions in the circuit by switches G and G′

Instead of connecting the auxiliary switch of Figs. 6 and 7 as shown it might be arranged to close a normally open shunt around coil H′. This is shown in Fig. 14. When current passes through the coil S′, its core is raised and the switch carried thereby closes the shunt around coil H′. Its core then drops and opens G′.

The switch and coil might be arranged as a time-switch by placing an iron or nickel resistance between the initial and first resistance contacts of the rheostat, so that coil S′ will be connected as a shunt to an initial resistance step of variable resistance, which in this case would act automatically to increase its resistance due to its high temperature coefficient and send an increasing current through coil S′. This is illustrated in Fig. 15, the resistance T^2 having a high temperature coefficient. When predeterminable current passes through coil S′ and raises its core, the switch in circuit of H′ is opened.

Instead of such a resistance a time-fuse might be employed, which when fused would cause the current to flow through S′. This modification is shown in Fig. 16, in which the time-fuse is indicated at F′ between the first two contacts and is fused after carrying the starting-current a predetermined length of time.

A still further modification is shown in Fig. 8, where coil S′ is connected as a shunt on the entire or part of rheostat resistance a' in series with a carbon resistance S^2 or other material of negative temperature coefficient. In such an arrangement when the carbon becomes heated a greater current will flow in the shunt and actuate coil S′ to release its switch and open or close a circuit, as above explained, to control coil H′, which may be connected in either of the ways suggested.

In Fig. 9 I have shown an electromechanically-operated auxiliary switch the action of which is governed by the movements of the rheostat-lever at its starting positions. C is a pivoted knife-switch blade; $c\ c'$, contact-jaws, as in Figs. 1 and 2 of my original application. D is the actuating-hammer, which in this instance is started by solenoids O and O′, whose cores are connected to the arms of the hammer, and d^5 is the spring for throwing the hammer after it passes the center of equilibrium, although in this arrangement the spring might be dispensed with, since the movement of the cores will be very rapid and move with increasing speed. The circuit connections are from conductor P to switch C, to lever B, resistance a' and motor M to conductor N, the field of M being in a shunt from lever B around the resistance and motor-armature. Coils O and O′ are connected in shunt relation between contacts o and o' and conductors P and N. Contacts o' and o are located adjacent to the first and second rheostat-contacts a, respectively, so that in the initial position lever B will bridge the first contact a and contact o' and in the second position contact o and the second contact a will be bridged. The effect of this is to connect either coil O′ or O in circuit, and, as shown, coil O is in circuit and its core is drawn down and hammer D is tilted to the right, closing switch C. If lever B is returned to its initial position, coil O will be cut out and coil O′ cut in, thus actuating the core of the latter to throw the hammer to the left and open switch C. When lever B is moved to its final position, both coils will be cut out of circuit and spring d^5 will hold switch C in position. A modification of this arrangement is shown in Fig. 10. Here only one coil O^2 is employed, and this coil is connected between conductor P and a contact o^2, with which the insulated short arm b^2 of lever B makes contact when in contact with any of the rheostat-contacts a from the second to the final contacts, but not when in contact with the initial contact. Switch C (shown as a brush-switch) is provided with a rod z, which breaks the arc on carbon contacts z'. This switch is mounted on a vertically-sliding rod z^2, provided at its upper end with a stirrup z^3, within which works a foot o^3, secured to the lower end of rod o^4, projecting from the core or plunger of coil O^2. The vertically-sliding rods z^2 and o^4 work in suitable guides, and the lower end of rod z^2 is rectangular and works in a correspondingly-shaped bearing to hold switch C in alinement with its stationary contacts.

As shown in Fig. 10, the rheostat-lever B is in its second position, and the circuit to coil O^2 is closed and its core is drawn up and switch C is closed. If now the operator returns lever B to the initial position, coil O^2 will become demagnetized and its plunger will drop, striking a blow to the stirrup, the force of which and the tension of the brush-switch will drive the switch downward and open the circuit to the rheostat and motor. When the lever B is moved forward, closing the circuit again at contact o^2, the plunger of coil O^2 will rise, and through the engagement of foot o^3 and stirrup z^3 switch C will be closed.

It will be noted that I have indicated a motor M in the drawings having a shunt-field-winding and that the supply-circuit to both the armature and shunt-winding is opened by means of the automatic switch in the main circuit; also, that when the circuit is opened the armature and field are closed on themselves, giving a closed circuit for the field discharge.

Where I have referred to "controlling means" in the claims, it will be understood that this includes indirect as well as direct control.

It is evident that my invention may be embodied in various forms of construction and that I am not limited in the scope thereof except as indicated in the following claims.

Having thus described my invention, I declare that what I claim as new, and desire to secure by Letters Patent, is—

1. The combination of a rheostat having a

movable element for varying the resistance, a switch in series therewith, mechanical restraining means for holding said switch in closed position, and electroresponsive means for releasing said restraining means to automatically control the opening of said switch by the movement of said element when substantially all of the resistance is in circuit.

2. The combination of a rheostat having a movable element for varying the resistance, a switch in series therewith, mechanical restraining means for holding said switch in closed position, and electroresponsive means for releasing said restraining means to automatically control the opening of said electroresponsive switch, said means being operated by the movement of said element at the initial position of said element.

3. The combination of a rheostat having a movable element for varying the resistance, a switch in series therewith, mechanical restraining means for holding said switch in closed position, electroresponsive means for controlling the release of said restraining means to automatically control the opening of said switch, and means for closing the circuit of said electroresponsive means by the movement of said element and thereby control the opening of said switch.

4. The combination of a rheostat having a movable element for varying the resistance, a switch in series therewith, mechanical restraining means for holding said switch in closed position, electromagnetic means for controlling the release of said restraining means to automatically control the opening of said switch, and means for closing the circuit of said electromagnetic means carried by said element.

5. The combination of a rheostat having a movable element for varying the resistance, a switch in series therewith, mechanical restraining means for holding said switch in closed position, electromagnetic means for controlling the release of said restraining means to automatically control the opening of said switch, and means operated by said element at its initial position for closing the circuit of said electromagnetic means and thereby control the opening of said switch.

6. The combination of a rheostat having a movable element for varying the resistance, a switch in series therewith, mechanical restraining means for holding said switch in closed position, and means comprising an electromagnetic device for controlling the release of said restraining means for effecting the opening of said switch, said second-named means being operated when said element is at the initial position to cause the current-flow to be interrupted at said switch.

7. The combination of a rheostat having a movable element for varying the resistance, a switch in series therewith, mechanical restraining means for holding said switch in closed position, and means comprising an electromagnetic device for controlling the release of said restraining means for effecting the opening of said switch to interrupt the current-flow, said device being actuated by the movement of said element when substantially all of said resistance is in circuit.

8. The combination of a rheostat having a movable element for varying the resistance, said element having means whereby the element may be moved manually, a switch in series therewith, a no-voltage device for retaining said element at its final position after being manually moved to said position, and electromagnetic means for controlling the opening of said switch, said means being controlled by the movement of said element.

9. The combination of a resistance having a movable element for varying the resistance, said element having means whereby the element may be moved manually, a no-voltage device for retaining said element in its final position after being manually moved to said position, a switch in series with said resistance, electromagnetic means for controlling the opening of said switch, and means engaged by the movement of said element to the initial position for closing the circuit of said electromagnetic means.

10. The combination of a resistance having a movable element for varying the resistance, two independently-closable switches in series with each other and with said resistance, means for controlling the opening of both of said switches automatically when excessive current flows, and means operated by the movement of said element for controlling the opening of at least one of said switches.

11. The combination of a resistance having a movable element for varying the resistance, two independently-movable switches in series with each other and with said resistance, means for opening said switches automatically upon the occurrence of overload, and means affected by the movement of said element for controlling the movement of at least one of said switches.

12. The combination of a circuit-breaker comprising two switches in series with each other, an electric motor, a controlling variable resistance, said resistance being in series with the armature of said motor and with said switches, means for opening at least one of said switches upon the occurrence of overload-current, and electroresponsive means for protectively relating at least one of said switches and the movable element of said resistance.

13. The combination of an electric motor, a starting-rheostat, means associated with the movable element of said rheostat for protecting the circuit from abnormally low voltage, two independently-movable switches in

series in the circuit of said motor, and means for automatically opening said switches upon the occurrence of abnormally large current.

14. The combination of an electric motor having a field-winding energized by a current independent of its armature-current, a switch in series with the armature and which switch also controls the current in said field-winding, means comprising an electroresponsive winding energized by a current independent of said armature-current and of said field-current for controlling said switch, and a motor-rheostat having a movable element for varying the resistance, the said element being arranged to affect the current in said electroresponsive winding after the resistance of said rheostat has been placed in circuit and thereby control the opening of said switch.

15. The combination of a constant electromotive-force-supply circuit, a branch circuit connected across said supply-circuit, said branch circuit containing in series a motor-armature, a variable armature-controlling resistance having a movable element and an automatic circuit-breaker, said circuit-breaker comprising two independently-movable switch elements in series with each other in said branch circuit, and means for affecting said circuit-breaker by the operation of said element.

16. The combination of a constant electromotive-force-supply circuit, a branch circuit connected across said supply-circuit, said branch circuit containing in series a motor-armature, a variable armature-controlling resistance and an automatic circuit-breaker, said circuit-breaker comprising two independently-movable switch elements in series with each other in said branch circuit, and means for protectively relating said variable resistance and at least one of said switch elements of the circuit-breaker.

17. The combination of a rheostat having a movable element for varying the resistance, a quick-acting switch, means for electrically controlling the opening of said switch by the movement of said element, a no-voltage magnet for holding said element in its restrained position, and automatic means for controlling the opening of said switch upon a predetermined current-flow.

18. The combination with a resistance having a movable element for controlling said resistance, of an automatic circuit-breaker in the motor-circuit, a control-coil for the circuit-breaker, and a contact at or near the initial position of said element for energizing said coil.

19. The combination with a motor-rheostat, of a circuit-breaker, a circuit-closer on the movable element of said rheostat, and means whereby said circuit-closer controls the operation of the circuit-breaker only when said element is in its initial position.

20. The combination with a motor-rheostat having a spring-pressed arm, a coil for controlling the circuit, a contact at or near the initial position of said arm for affecting the current in said coil, and restraining means for said arm at its resistance-all-out position.

21. The combination of a motor-rheostat having a movable element for varying the resistance, two switches in series with each other and with said rheostat, electroresponsive means for effecting the opening of one or both of said switches upon predetermined current-flow, a no-voltage protective device, and a contact controlled by the movement of said element for effecting the opening of one of said switches.

22. The combination of a constant electromotive-force-supply circuit, an electric motor, an armature-rheostat, two mechanically-related switches, said rheostat, switches and armature of said motor being all in series with each other in a branch circuit across said supply-circuit, means for controlling the opening of either of said switches upon overload-current passing through the armature independently of the position of the other of said switches, means for protecting the armature against conditions due to no voltage, and means for affecting at least one of said switches by said rheostat.

23. The combination of a motor having a field-winding energized independently of its armature-current, two independently-movable mechanically-related switches in series with each other and with the motor-armature, means responsive to overload-current for automatically controlling the opening of each of said switches, a starting resistance in series with the motor-armature, means for cutting out the resistance during the starting period, and means for short-circuiting said latter means after said resistance has been cut out.

24. The combination of a motor having a field-winding energized independently of its armature-current, two independently-movable mechanically-related switches in series with each other and with the motor-armature, means responsive to overload-current for automatically controlling the opening of each of said switches, a starting resistance in series with the motor-armature, means for cutting out the resistance during the starting period, means for short-circuiting said latter means after said resistance has been cut out, and means for protecting the motor-armature upon the occurrence of no voltage.

25. The combination of an electric motor having a field-winding energized by current independent of its armature-current, a re-

sistance adapted for only temporary passage of the full-load current for starting the motor, an automatic protective switch in series therewith and which switch also controls the field-circuit of said motor, electrical means dependent upon the amount of said resistance in circuit for controlling the automatic protective movement of said switch, and an electroresponsive winding for automatically protecting the motor-armature against abnormal current.

26. The combination of a resistance-controlling current-carrying movable element, said element being adapted to vary the amount of resistance in circuit but not adapted to open said circuit, electroresponsive means for retaining said element in its normal position against a constantly-acting force, an electric motor having its armature in series with said element, a switch in series with said element and motor-armature adapted to open and close the armature-circuit and which switch also controls the field-circuit, electromagnetic means for opening the circuit of the armature when said switch is closed if excessive current then passes, and electrical means for protectively relating said switch and element.

27. The combination of an electric motor, a controlling resistance having a hand-operated movable element for varying the resistance, a switch in series with the armature of said motor and which switch also controls the field-circuit of the motor, an electroresponsive winding for controlling the opening of said switch, and means for controlling the current in said winding so as to control the opening of said switch only when said element is in such position as to include said resistance in the armature-circuit, said element and said switch being mechanically independent during the closure of said switch.

28. The combination of constant electromotive-force-supply mains, an electric motor having a field-winding energized independently of the working armature-current, a controlling resistance for the motor, connections forming a permanently-closed local loop including the motor-armature, said resistance and field-winding, an automatic protective switch, said local loop and said switch being connected in series with each other across said mains, an electroresponsive winding for controlling the motor-armature circuit under certain conditions, and a branch circuit across said mains in parallel with said loop and passing through said switch, said branch containing said electroresponsive winding.

29. The combination of a resistance having a movable element for varying the resistance, a switch capable of independent movement relatively to said movable element, electrical means for controlling said switch, said means being controlled by said element, and an electromagnetic winding which independently of said means controls the opening of said switch upon the occurrence of overload.

30. The combination of a switch having a movable element, a second switch electrically connected therewith and capable of independent movement relatively to said first switch, electrical means for controlling said second switch and controlled by said movable element only when said element is in a circuit-protective position, and independent electrical means for controlling the protection of the circuit upon overload.

31. The combination of an electric motor, two switches in series with each other and with the armature of said motor, said switches being independently movable, electroresponsive means for automatically controlling the movement of said switches, a device in series with the motor-armature for controlling the electromotive force on the terminals of the motor-armature, and electrical means functionally related to said device for causing the automatic protective movement of at least one of said switches under certain conditions.

32. The combination of a translating device, an electromotive-force absorptive device in series therewith across a normally constant electromotive-force circuit, said device being adapted to vary the electromotive force upon said translating device, two protectively-related switches in series with each other and with said translating device, an electroresponsive device responsive to abnormal variations of electromotive force upon said circuit, means for automatically controlling the movement of at least one of said switches when an excessive current passes through the translating device, and electrical means for protectively controlling at least one of said switches when the electromotive-force absorptive device is in a certain condition.

33. The combination of an electric motor, a resistance-controlling switch in series with the armature of said motor, a functionally-related automatic switch in series with said armature and said first-named switch, and means for automatically controlling the circuit when no voltage occurs, when overload-current occurs and when the operator manually controls one of said switches, said means comprising three electromagnetic windings each of said windings being adapted to perform its function independently of the other two windings.

34. The combination of an electric motor, a resistance-controlling switch in series with the armature of said motor, a functionally-

related automatic switch in series with said armature and said first-named switch, and means for automatically controlling the circuit when no voltage occurs, when overload-current occurs and when the operator manually controls one of said switches, said means comprising a mechanical restraining device for one of said switches and two electromagnetic windings functionally related to said device.

In testimony whereof I affix my signature in the presence of two witnesses.

H. WARD LEONARD.

Witnesses:

L. K. SAGER,

GEO. A. HOFFMAN.