W. F. HENDRY.

AUTOMATIC MOTOR STARTER.

APPLICATION FILED DEC. 21, 1905.

921,989.

Patented May 18, 1909.

2 SHEETS—SHEET 1.

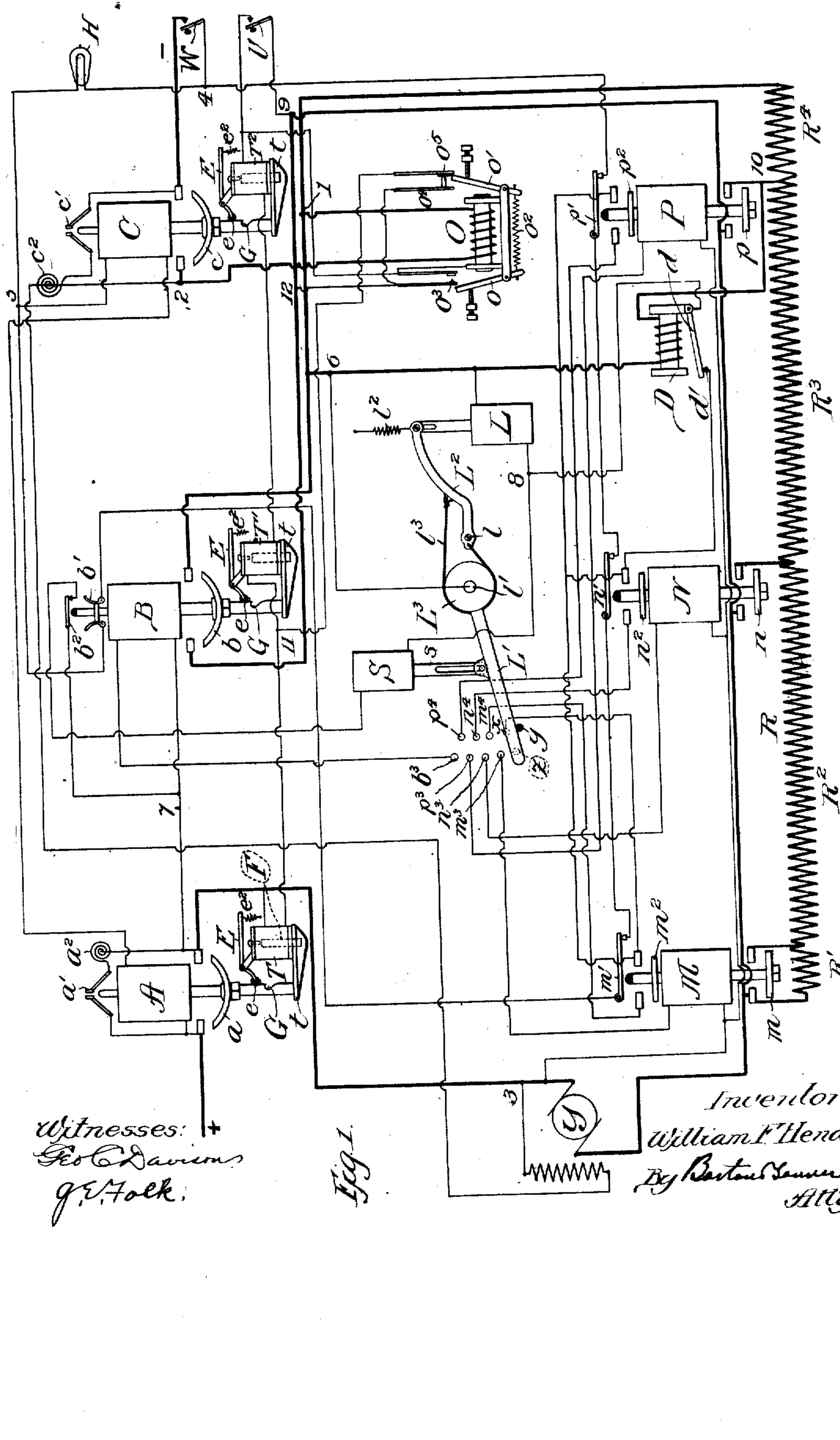

Fig. 1.

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2 SHEETS—SHEET 2.

Fig 2.

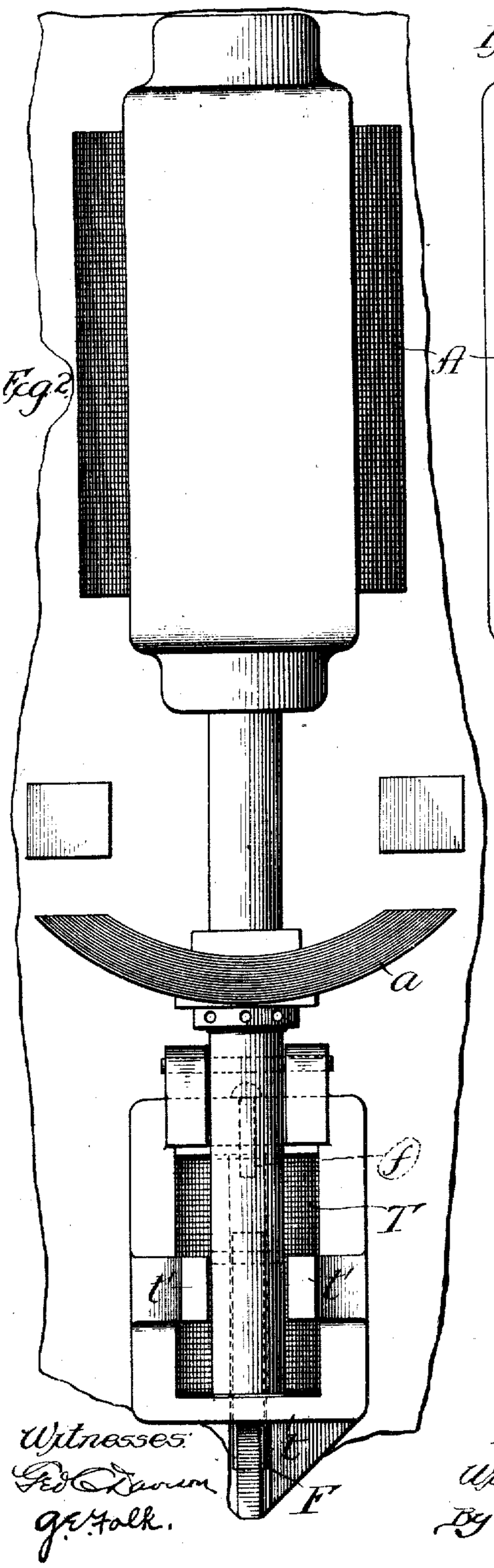
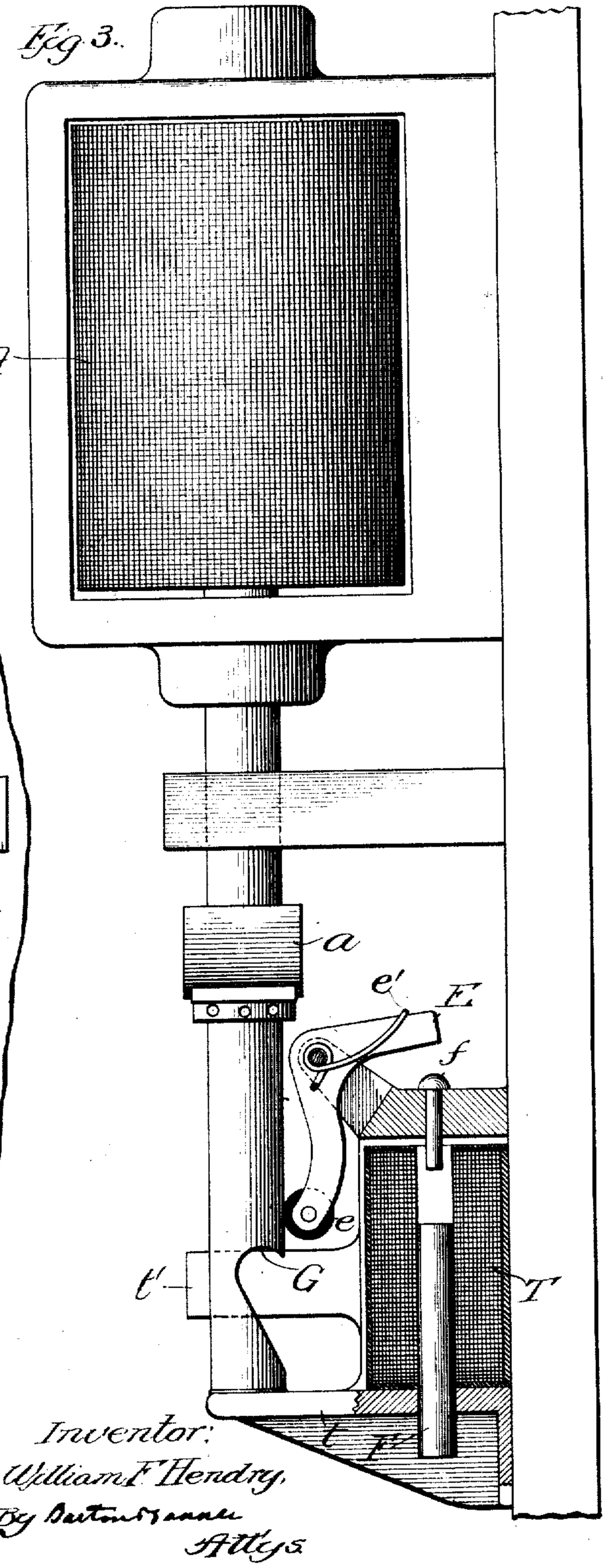


Fig 3.



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UNITED STATES PATENT OFFICE.

WILLIAM F. HENDRY, OF NEW YORK, N. Y., ASSIGNOR TO WESTERN ELECTRIC COMPANY, OF CHICAGO, ILLINOIS, A CORPORATION OF ILLINOIS.

AUTOMATIC MOTOR-STARTER.

No. 921,989. Specification of Letters Patent. Patented May 18, 1909.

Application filed December 21, 1905. Serial No. 292,817.

To all whom it may concern:

Be it known that I, WILLIAM F. HENDRY, a citizen of the United States, residing at New York, in the county of New York and State of New York, have invented a certain new and useful Improvement in Automatic Motor-Starters, of which the following is a full, clear, concise, and exact description.

My invention relates to motor starting devices, and its object is to provide automatic means for gradually cutting out the starting resistance of electric motors.

Prior to my invention all motor starters of the automatic type, commonly called "self starters," were operated by one or more solenoids, which may close the line circuit and which short circuit the starting resistance. These solenoids require a certain amount of current to hold their switches tightly closed, and herein lies one of the great objections to automatic starters.

My invention broadly comprises an automatic starter which uses no current after it has performed its function of starting the motor. In my invention the devices for cutting out the starting resistance, and preferably also the device or devices for closing the circuit, lock themselves in their running position, but open automatically in case of failure of the current supply or an excess of current. Said devices preferably consist of solenoid switches provided with mechanical self-locking means for retaining said switches in closed position, and additional means, under the control of the operator, for opening said switches, said means being also automatically operated in case of overload or underload.

An additional feature of my invention is the provision of means whereby an external source of energy resets the entire apparatus in case of failure of the current supply. While any external source of energy may be used, I preferably employ the energy developed by the inertia of the revolving motor armature and the machinery which it may be driving to accomplish this purpose.

These and other novel features of my invention will be more readily understood by reference to the accompanying drawings, in which,

Figure 1 is a diagram showing the apparatus and circuits employed in my invention; Figs. 2 and 3 are front and side elevations, respectively, of the self-locking solenoid switch employed in my invention.

Similar letters of reference refer to similar parts wherever they are used.

The apparatus comprises two solenoids A and C for operating switches *a* and *c*, respectively, which close the circuit of the main line; solenoids M, N, P and B controlling switches *m*, *n*, *p* and *b*, respectively, for gradually cutting out the starting resistance R of the motor armature; three tripping magnets T, T′, T², adapted when energized to actuate means for unlocking switches *a*, *b*, *c*, respectively; a master rheostat solenoid S actuating a lever L′ for controlling the admission of current to the coils of the solenoids M, N, P and B; a solenoid or brake coil L, controlling brake mechanism of the lever L′; a relay D controlling a short circuit about the brake coil L; and an overload and underload relay O.

The plungers of the solenoids A, B and C are extended below the switches *a b c*, respectively, and are supported when said solenoids are deënergized, upon the base of the brackets *t*, the lugs *t′* of which as shown in Fig. 2, act as guides for said plungers. The lower end of each of these plungers has a groove G cut in it. A trigger or latch E is supported above the magnet T and carries on one end a roller *e*. When the solenoid plunger is raised to close the switch, a spring *e′*, as shown in Fig. 3, or *e²* as shown in Fig. 1, causes the roller *e* of the latch E to engage the groove G and thus hold the switch in closed position, regardless of whether or not the solenoid is energized.

For the purpose of unlocking the latches E and releasing the plungers of the solenoids A, B, C, the tripping magnets T, T′, T², respectively, are provided. The energization of these magnets, as will be hereafter described, is under the control of a stop button V, as well as the overload and underload coil O. When magnets T, T′, T² are energized, their core pieces or plungers F are drawn up and the pin *f* is actuated to deliver a blow upon the lever E sufficiently to overcome the tension of the spring *e′* or *e²*. The roller *e* is thus withdrawn from the groove G, permitting the corresponding switch to be opened. While I have shown the latch E adapted to be locked by the spring *e′* or *e²* and to be unlocked by the solenoids T, T′,

T², I do not wish to limit myself to this particular arrangement, as obviously changes might be made to meet special cases.

By operating the starting switch W, a circuit is closed from the mains through the solenoids A and C. The windings of these solenoids are connected across the line in series with each other and in series with a parallel circuit, one branch of which passes from the point 5 through the lamp resistance H to the point 4. The other branch extends from the point 5 through a switch b', closed when the solenoid B is deënergized, and from thence through switches m', n', p', closed when solenoids M, N and P, respectively, are deënergized, to the point 4. When the last described branch is open, the current flowing through the other branch, owing to the high resistance of the lamp H, is insufficient to energize the solenoids A and C sufficiently to close the corresponding switches a and c. The solenoids A and C are further provided with switches a', c', respectively. Said switches break the main circuit and are located in the strong magnetic field of powerful blowout coils a^2 c^2, which disrupt the arcs. When the parts are in normal condition, however, the closing of the switch W, causes the solenoids A and C to close the main line switches a and c respectively. When the switches a and c are closed the latches E serve to retain them in the closed position, as above described, and hence the necessity for a continued flow of current through the solenoids A and C is eliminated. Therefore when the operator removes his finger from the push button W, the current through said solenoids is cut off, but the switches a and c remain closed.

When the switches a and c are closed a circuit is completed from positive terminal of the mains, through switch a, the motor armature Y, the resistance R to the point 1, and from thence through the relay O to the point 2, and from thence through the switch c to the negative terminal of the mains. The shunt field of the motor armature extends from the point 3 through the shunt field resistance to the point 2, and is energized as soon as switches A and C are closed.

The resistance R is arranged in a plurality of steps or blocks R', R², R³, R⁴. The plungers of the solenoids M, N, P and B operate switches m, n, p and b, respectively, for successively cutting out these steps of blocks of resistance R. While for the purpose of description I have shown the armature resistance arranged in four blocks and adapted to be cut out by four switches, it is obvious that any desired number of blocks and switches may be used.

As shown in Fig. 1, the circuits through the windings of solenoids M, N, P and B are normally open at the contact buttons m^3, n^3, p^3 and b^3, respectively. Said contacts are adapted to be closed by a lever L', which is pivoted at l', and is adapted to be drawn successively over the buttons m^3, n^3, p^3, b^3, by the upward movement of the plunger s of the solenoid S, said plunger having a slot in its lower end through which it is pivotally connected by a pin to the lever L'.

When the switches a and c are closed in the act of starting the motor, a circuit is also completed through the switch a, the point 7, the switch b^2 at the top of solenoid B, the solenoid S, the point 8, the solenoid or brake coil L, point 6, point 1, and from thence through the relay O and switch c to the negative terminal of the mains. A short circuit of the windings of the solenoid L extends from the point 8 to the point 6, through the contact point d' and lever L', said short circuit being closed at one of the buttons x, m^4, n^4 or p^4, and being controlled by the armature d of the relay D at the contact d'.

The relay D is in series with the armature circuit, its windings being included in a parallel branch circuit extending from the point 10 to the point 1.

The plunger of the solenoid L is normally held upward by a spring l^2. A lever L² is pivoted at one end to said plunger, and its other end is pivoted to the framework at l. A band l^3 passes around the enlarged circular end or drum L³ of the lever L', the ends of the bands being secured at different points on the lever L². As a result of this construction, when the solenoid or brake coil L is energized and draws in its plunger, the lever L² is rocked on its fulcrum l, and the band l^3 is tightly drawn over the drum L³, acting as a brake upon the movement of the lever L'.

The starting resistance R may be of such value as will allow a current to pass of any predetermined amount, say about fifty per cent. above the normal running current of the motor. The relay D is adjusted to operate at this current and opens contact d', thus opening the short circuit around the brake coil L, allowing said coil to be energized and thereby preventing the master solenoid S from moving the lever L' over the contacts m^3, n^3, p^3, b^3, as before described. As the motor armature speeds up the flow of current in the circuit, including relay D, is reduced thereby, and the relay D releases its armature d, thus closing contact d'. The short circuit about the windings of solenoid L being closed at contacts d' and x, said solenoid is deënergized and its plunger is retracted by the spring l^2, carrying with it the end of the lever L², and thus loosening the band l^3, thereby removing the brake from the lever L'. The solenoid S is then free to move the lever L' over the double row of contacts, and when said lever rests upon the contact button m^3, a branch circuit is completed through the windings of the solenoid M, contact m^3, lever L' to point 6. The energiza-

tion of solenoid M closes the switch m and cuts out the first step or block R′ of starting resistance R. The switch m^2 is also closed by the energization of the solenoid M.

When the block R′ of resistance is cut out the current through the armature circuit immediately increases to, say, fifty per cent. above normal, and the relay D attracts its armature and opens the short circuit about the brake coil L, which thereupon becoming energized prevents further movement of the lever L′. As the motor speeds up, the current decreases, the relay D releases its armature and the brake coil L is short circuited through contact d', switch m^2, contact button m^4 and lever L′. This allows the master solenoid S to further raise its plunger and to further draw the lever L′ over the row of contacts to the contact button n^3, whereupon the solenoid N is energized and cuts out an additional block R^2 of resistance. This operation of gradually cutting out steps of resistance continues as the motor speeds up.

It will be observed that unless the solenoid M has previously operated to cut out a block of resistance and at the same time to close the switch m^2, the short circuit about the brake coil L, even though closed at contacts d' and m^4 will still be open at said switch m^2, and hence the brake upon lever L′ will be maintained. It is apparent therefore that the lever L′ cannot advance beyond contacts m^4, n^4, or p^4 until the corresponding magnet M, N, or P has operated and thereby closed the corresponding switch m^2, n^2, or p^2.

When the lever L′ reaches the last contact button b^3, the solenoid B is energized and closes the switch b, which switch is held in closed position by the latch E. The closing of switch b cuts out the last step R^4 of the resistance and at the same time short-circuits the relay D, which is in shunt with the said block R^4 of resistance.

As the solenoid B raises its plunger, the switch b^2 is operated to open the circuit through the solenoids S and L. Thereupon the lever L′ is returned by the force of gravity to its initial position against the stop y and rests upon the button x and the dead button z. In case the lever should stick at any of the intermediate contacts m^3, n^3, p^3 or b^3, thereby energizing the corresponding resistance solenoid and cutting out armature resistance, the corresponding switch m', n', p' or b' at the top of said resistance solenoid would be opened and it would be impossible to start the motor until said resistance solenoid had been deënergized by moving the lever to the initial position. This is due to the fact that with their circuits open at any of the switches m', n', p' or b' the solenoids A and C would not receive enough current through the branch including the lamp H to close the switches a and c. In the initial position of the lever the resistance solenoids can receive no current, as the lever then rests on the dead button z.

From the foregoing description of the operation of my automatic motor starter it is apparent that with the parts in normal position, as shown in Fig. 1, a momentary closing of the starting button W is sufficient to close switches a and c, which are mechanically locked in closed position. The release of the starting button opens the circuit of solenoids A and C which receive current only as long as is necessary to close their switches. It is also apparent that as soon as the solenoid B is energized to close switch b, which is also mechanically locked in closed position, thereby cutting out all of the starting resistance R, or in other words, as soon as the motor has gotten up to full speed, the flow of current through the main switch operating solenoids A and C, as well as through the resistance controlling solenoids M, N, P and B, the master rheostat solenoid S, the brake coil L and the relay D is entirely eliminated. This not only protects said magnets and prolongs their utility but results in a saving of the current.

As before stated, the latches E, which hold the switches a b c closed are under the control of tripping magnets T, T′, T^2, respectively. Said magnets are in turn under the control of a stop button V and an overload and underload coil O.

When it is desired to cut off the current from the motor to stop the same, this is accomplished by pressing the stop button V. A circuit across the line through the relays T, T′, T^2 is thus closed, which circuit may be traced as follows: from the plus terminal through the windings of relays T, T′, T^2, contact closed by stop button V, switch b, point 1, relay O, point 2, switch c to minus terminal of the mains. As before described, the energization of relays T, T′, T^2 causes their plungers to operate to release the rollers e of the latches E from the grooves G in the plungers of solenoids A, B, C, permitting said plungers to fall by gravity and open switches a, b, c thereby cutting off the current from the motor and restoring the parts to their initial position shown in Fig. 1.

The starter is also provided with a specially designed overload and underload device which consists of the ordinary overload coil O with two armatures o and o', one at each end of the relay. The armature o is calibrated to be drawn up in case of overload. The armature o' is arranged to be drawn up at, say, about five per cent. of full load current in opposition to a spring o^2 which tends to pull the armatures o and o' away.

The overload armature o provides for automatically operating the tripping magnets T, T′, T^2 in case of an excessive flow of current through the armature circuit, thus protecting the motor from possible injury

therefrom. In case of such excessive flow of current, the armature *o* is drawn up closing contact o^3. A circuit is thus closed through the tripping magnets, which circuit may be traced as follows: from the positive terminal through switch *a*, windings of magnets T, T′, T^2, contact o^3, switch *b*, point 1, and from thence through the coils of relay O to the negative terminal. The energization of said tripping magnets operates in the manner previously described to open the switches *a b* and *c* and cut off the flow of current from the motor.

The underload armature *o′* is arranged to be drawn up at say, about five per cent. of full load current. When the current dies down below this point or entirely fails the spring o^2 retracts the armature *o′*, thereby permitting the spring o^4 to close contact o^5. In case the current does not entirely fail, the line itself, upon the closing of contact o^5, furnishes current for energizing the coil of tripping magnet T. The circuit through relay T, in this event, may be traced from the positive terminal through switch *a*, relay T, point 11, contact o^5, point 12, switch *b*, point 1, and from thence through the coil of relay O to the negative terminal. In case the supply of current entirely fails, an arrangement of circuits is provided for utilizing electromotive force generated by the revolving armature of the motor, which will run long enough to furnish the slight amount of current required to energize the magnet T to trip the latch E. This circuit may be traced as follows: from one side of the armature Y, through point 3, coil of magnet T, point 11, contact o^5, points 12 and 9, to the opposite side of armature Y. The counter-electromotive force furnishes a current of sufficient strength to energize the tripping magnet E and cause it to accomplish its function, thereby opening the main switch *a*. Switches *b* and *c* are still closed, and hence the switch *b′* at the top of solenoid B is open, thereby preventing the coils of solenoids A and C from receiving the allotted current required to close the main switches. It will be necessary, therefore, to push the stop button V, as soon as the source of supply is again restored, and energize the tripping magnets T′, T^2, before the motor can again be started. By this provision of an underload armature *o′*, if the current supply should fail, or die down below a predetermined amount, the motor is fully protected from any subsequent sudden rush of current.

Having thus described my invention, I claim:

1. In a motor starting device, the combination with a motor having a resistance included in the circuit of its armature, of an electromagnet, a switch operated thereby for cutting out said resistance, means independent of the energization of said electromagnet for locking said switch in its closed position, means for opening the circuit of said solenoid and thereby eliminating the consumption of current by said starting device, when said resistance is entirely cut out, a restoring electromagnet having a circuit normally open during the closure of said switch, and means for closing the circuit of said restoring electromagnet, said electromagnet being adapted upon its energization to release said switch from its locked condition.

2. A motor starting device comprising an electromagnet, a switch operated thereby, mechanical means for holding said switch in closed position, means for opening the circuit of said magnet upon the closure of said switch, a tripping electromagnet for controlling said mechanical means to open said switch, and a circuit for said tripping magnet having a manually controlled switch and also a switching mechanism automatically closed upon an abnormal increase or decrease, or upon a complete failure of the supply of current to the motor.

3. In a motor starting device, the combination with an electromagnet, of a switch operated thereby for connecting the motor to the mains, mechanical means for locking said switch in closed position, means for opening the circuit of said magnet upon the closure of said switch, and electromagnetic means for automatically releasing said switch upon the failure of the supply of current to the motor.

4. In a motor starting device, the combination with electromagnetic switching mechanism for starting the motor, of mechanical means for holding said switching mechanism in the running position of the motor, an electromagnet adapted by its energization to release said locking means, and means for automatically closing the circuit of said electromagnet upon the failure of the supply of current to the motor.

5. In an automatic motor starter, the combination with electromagnetically operated switching mechanism for controlling the flow of current to the motor, of a restoring electromagnet adapted upon its energization to restore said switching mechanism to its initial position, and a circuit for said restoring electromagnet, automatically closed upon the failure of the supply of current to the motor.

6. In a motor starting device, the combination with electromagnetic switching mechanism for controlling the flow of current to the motor, of a restoring electromagnet, and a switch automatically operating to close a local circuit through said restoring magnet and the motor armature upon the failure of the supply of current to the motor, whereby said magnet is energized by the inertia of the revolving armature and restores the switching mechanism to its initial position.

7. In a motor starting device, the combination with an electromagnet and a switch operated thereby to control the flow of current to the motor, of mechanical means for locking said switch in the running position of the motor, a restoring electromagnet adapted upon its energization to release said switch, and a circuit for said restoring electromagnet automatically closed upon the failure of the supply of current to the motor.

8. In a motor starting device, the combination with an electromagnet and a switch operated thereby to control the flow of current to the motor armature, of mechanical means for locking said switch in the running position of the motor, and a magnet energized by the inertia of the revolving motor armature upon the failure of the supply current to the motor, whereby said locking means is released and the apparatus restored to its initial position.

9. The combination with a motor having a starting resistance included in the circuit of its armature, of a starting device comprising a manually operated starting switch, electromagnetic switching means operated by the closing of said starting switch to connect the motor to the main line, electromagnetic switching means for cutting out said starting resistance, mechanical means for locking said electromagnetic switches in the running position of the motor, and restoring electromagnets adapted upon their energization to release said switches, said restoring electromagnets having normally open circuits.

10. The combination with a motor having a starting resistance in its armature circuit, of a motor starting device comprising a plurality of solenoids, switches controlled by said solenoids for successively cutting out steps of said resistance, a relay in series with the armature circuit and controlled by the fluctuations in the motor current for controlling the admission of current to said solenoids, and a switch opened by the last acting solenoid for eliminating the consumption of current by said starting device after the operation thereof.

11. The combination with a motor having a starting resistance in its armature circuit, of a plurality of solenoids, switches controlled by said solenoids for closing the circuit of the motor armature and for successively cutting out steps of said resistance, means for opening the circuits of said solenoid upon their operation to close said switches, mechanical means for locking said solenoid switches in closed position, and electromagnetic means both automatically controlled and under the control of the operator for releasing said locking means.

12. In a motor starting device, the combination with a motor having a starting resistance in its armature circuit, of a plurality of resistance solenoids, switches controlled by said solenoids for cutting out steps of said resistance, a master rheostat solenoid, a lever actuated thereby for successively closing the circuit of said resistance solenoids, a brake coil, brake mechanism operated by said coil for controlling the response of said lever to said master solenoid, a relay in series with the armature circuit and controlled by the fluctuations in the motor current, said relay in turn controlling the energization of said brake coil, mechanical means for holding the last operating solenoid switch in closed position, whereby the entire starting resistance is cut out, and a switch adapted to be opened by the last acting solenoid and thereby prevent the consumption of current by the starting device after said starting resistance is cut out, substantially as described.

13. In a motor starting device, the combination with electromagnetic switches for controlling the flow of current to the motor, of mechanical means for locking said switches in the running position of the motor, restoring magnets adapted when energized to release said switches, a relay in the motor circuit having an underload and an overload armature operating upon an abnormally weak and abnormally strong current, respectively, to close the circuit of one or more of said restoring magnets.

In witness whereof, I hereunto subscribe my name this 23 day of September A. D., 1905.

WILLIAM F. HENDRY.

Witnesses:
N. F. ALBRIGHT,
J. W. BAUCKER.