(No Model.)

H. W. LEONARD.

APPARATUS FOR CONTROLLING ELECTRIC MOTORS.

No. 568,088. Patented Sept. 22, 1896.

Fig-1-

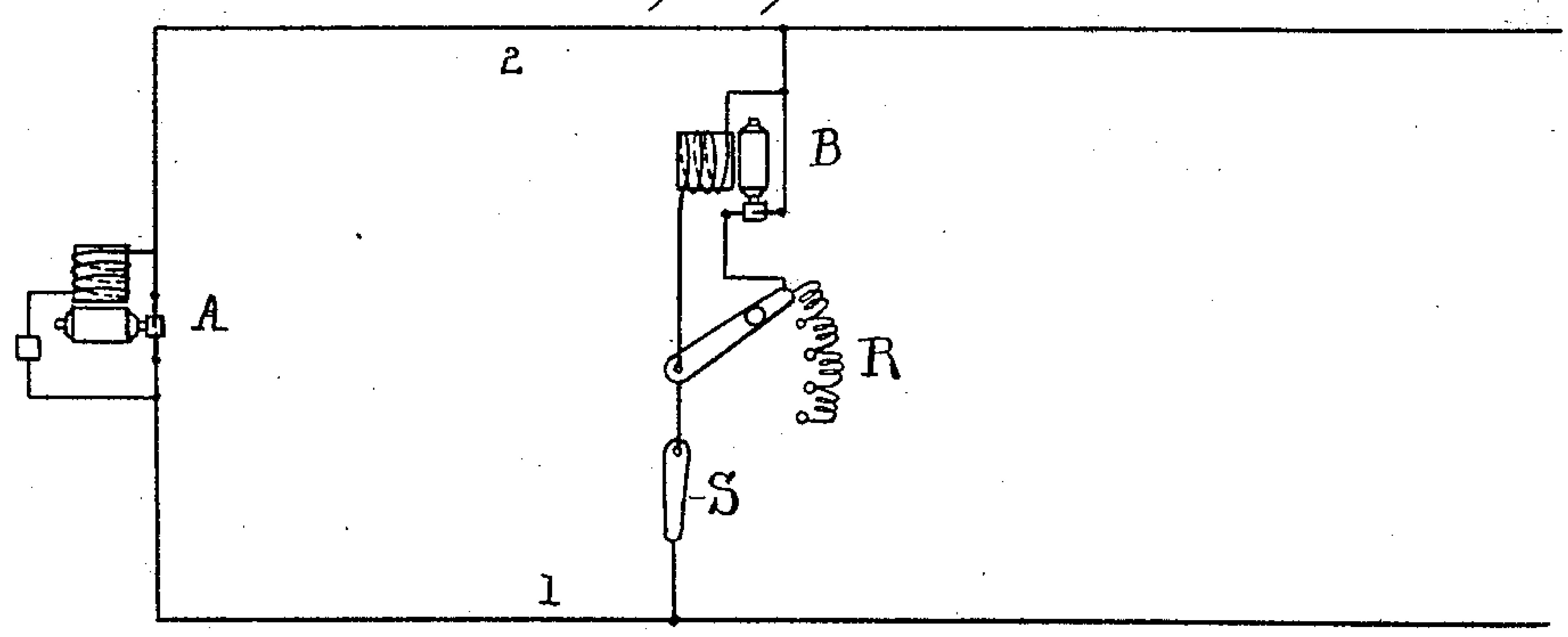
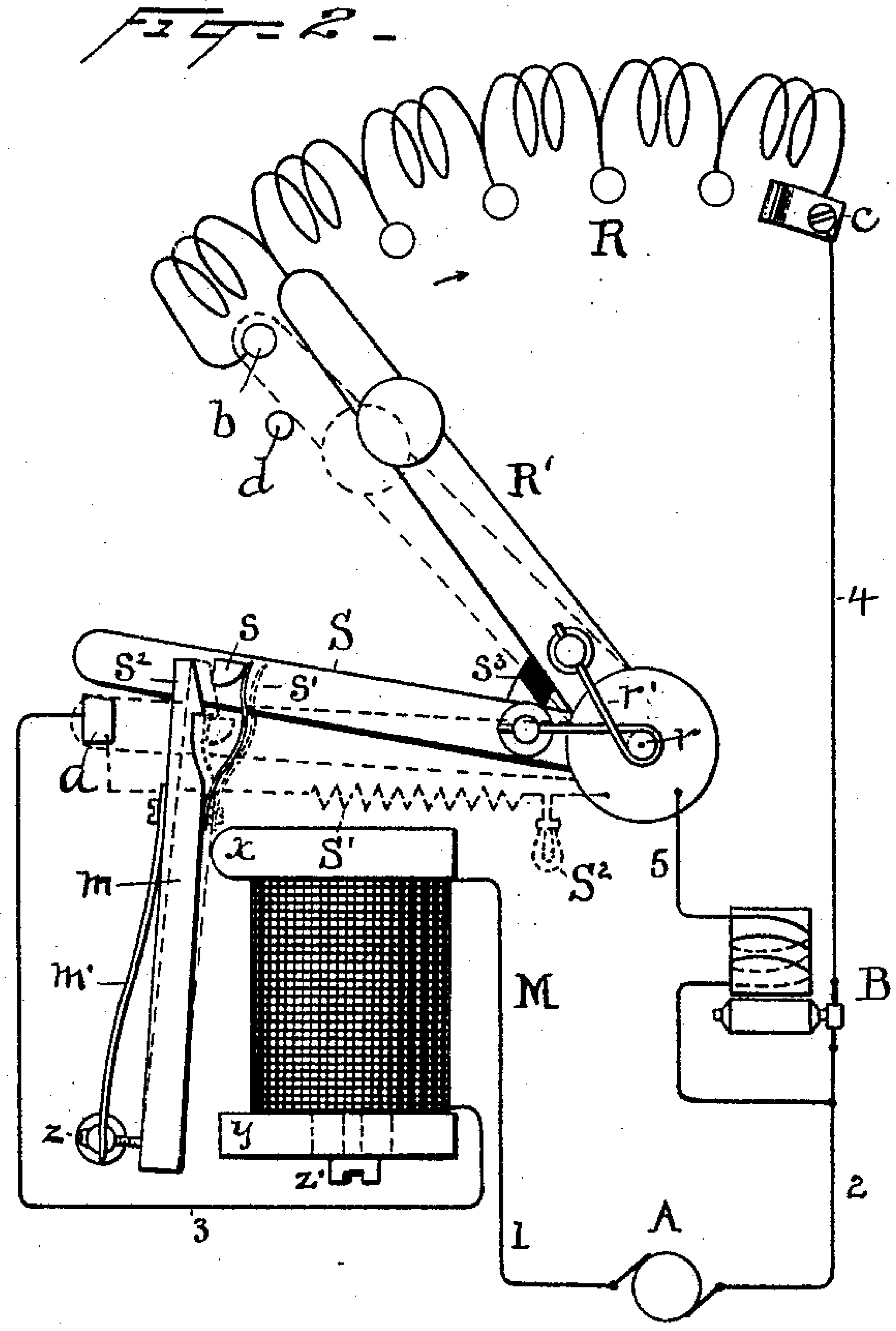


Fig-2-



Witnesses
Norris A. Clark.
W. Pelzer

Harry Ward Leonard Inventor
By his Attorneys
Dyer & Driscoll.

UNITED STATES PATENT OFFICE.

HARRY WARD LEONARD, OF EAST ORANGE, NEW JERSEY.

APPARATUS FOR CONTROLLING ELECTRIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 568,088, dated September 22, 1896.

Application filed April 30, 1896. Serial No. 589,671. (No model.)

To all whom it may concern:

Be it known that I, HARRY WARD LEONARD, a citizen of the United States, residing at East Orange, in the county of Essex and State of New Jersey, have invented a certain new and useful Improvement in Apparatus for Controlling Electric Motors, of which the following is a specification.

My invention relates especially to apparatus for automatically protecting electric motors and their controlling rheostats; but it is also applicable to any circuit in which certain actions are desired to automatically occur when the current falls below a certain predetermined amount or when the current exceeds a certain predetermined amount. In the ordinary way of controlling a shunt-wound motor, that is, with a switch and rheostat, the contact-arm of the rheostat is adjusted so that all the resistance of the rheostat will be in series with the motor-armature. The switch is then closed and a current passes through the rheostat and armature, which in a fully-excited field is usually sufficient to start the armature into motion. If, however, this initial current does not produce sufficient torque to start the armature, the contact-lever of the rheostat is moved so as to gradually cut out resistance, increasing the current through the armature until the necessary starting torque is produced. When the armature begins to revolve in the full field, an electromotive force is produced which is opposed to the line electromotive force, and this counter electromotive force will always be equal to the line electromotive force, less the volts represented by the product of the current flowing times the ohms in circuit. With a constant load on the armature the current through the armature in the constant field will be constant, except for the temporary increase of current required to accelerate the armature to a higher speed when some of the resistance is cut out of the rheostat. It will be noted that the current will be due to the difference between the line electromotive force and the counter electromotive force divided by the ohms in circuit. If the resistance be cut out quickly, the counter electromotive force, which depends upon the acceleration of the motor-armature and its load, will not develop as quickly as the resistance is cut out, and the result will be an excessive current through the armature and that portion of the rheostat in circuit.

One of the objects of my invention is to make it necessary for the operator to move the contact-lever with sufficient slowness to permit of the development of enough counter electromotive force to prevent a detrimentally large current from passing through the motor-armature and rheostat. I accomplish this object by placing in circuit with the armature a device which automatically opens the circuit when the current exceeds a certain predetermined amount.

A further difficulty met with in rheostats is that a rheostat amply large enough to start the motor and which is kept in circuit only a few seconds is ordinarily too small to be kept in circuit for any length of time. Hence it is desirable to provide means which automatically prevent the contact-lever of the rheostat being kept in circuit upon a contact-plate intermediate between the two extreme positions. This I accomplish by providing the contact-lever of the rheostat with a spring, which always tends to return the lever to the starting position, *i. e.*, with all the resistance in circuit, and I also provide a friction-clip or other means for holding the contact-lever at the position where all the resistance will be cut out of circuit.

Another difficulty experienced with rheostats and motors is that occasionally the supply of current will fail when the motor is running at full speed and with the resistance all cut out of circuit. Under these circumstances the motor-armature comes to rest with the armature connected directly across the line with no rheostat-resistance in circuit, so that if the full electromotive force of the source be again suddenly thrown on the motor-armature will receive an enormous current, which would be damaging to the armature and even to the generator-armature. My invention provides two safeguards against such an emergency: first, if the current falls below a certain predetermined amount the circuit is automatically opened, so that when the electromotive force is again thrown on the circuit to the motor-armature will be open;

second, the automatic device is so constructed that if from any cause the automatic device fails in the first instance to open the circuit when the line electromotive force fails, then the large current developed when the full line electromotive force is again thrown on instantly causes a further operation of the automatic device, which will open the motor-circuit without fail.

Another desirable safeguard for motors is to provide means for automatically opening the circuit if for any reason the motor becomes overloaded while running at full speed. This may occur by the heating of the bearings from overload or by the failure of the motor field-circuit or from an excessive increase in the current from any other cause. As above stated, my automatic device causes the circuit to be opened whenever the current exceeds the predetermined maximum due to any cause, and hence protects the motor against any such emergency. It is frequently desirable that the circuit of a generator should be automatically opened not only when the current becomes excessive, but also when it falls below a certain point—for example, when a storage battery is in multiple with a generator and the electromotive force of the generator falls below that of the battery from any cause, such as the failure of its motive power. In such a case my automatic device will open the circuit when the current falls approximately to zero, and hence protects the generator and battery from excessive current. In electric lighting it is often desirable to have all the conductors in a building automatically disconnected from the main circuit when the lights are turned off, so as to reduce to a minimum the danger from fire. This may also be accomplished by my automatic device. Instead of opening the circuit by means of the automatic switch, as above indicated, I may provide a high resistance shunted around the switch, so that upon the opening of the switch the motor-circuit is maintained closed, but through a resistance which will bring the motor to rest. Such an arrangement avoids sparking at the switch-contacts and may be employed as an indicator for the operator by inserting an incandescent electric lamp or other signaling device in series with the resistance.

In the accompanying drawings, Figure 1 is a diagram illustrating a shunt-wound motor connected across a circuit in the ordinary manner, and Fig. 2 is a diagrammatic view illustrating my invention and the circuit connections.

Referring to Fig. 1, A is the source of supply, and 1 2 the circuit extending therefrom. B is a shunt-wound motor connected across the circuit 1 2. S is the switch, and R the rheostat. In this figure the motor-circuit is closed and all sections of the rheostat are cut out of circuit.

Referring to Fig. 2, A is the source of supply, and 1 2 the circuit extending therefrom. B is the shunt-wound motor; S, the switch; R, the rheostat; R′, the contact-arm of the rheostat; M, an electromagnet for automatically controlling the switch S, and S′ the high resistance shunted around the switch S, which may be employed, if desired, and having a signaling device S^2, of any suitable character, in series therewith. The switch-arm S and rheostat-arm R′ are pivoted upon a spindle *r*, and a spring *r′*, rigidly connected to each arm, is coiled around the spindle and always tends to move the arms toward each other, but they are so constructed that this movement is limited to a certain angle, the object of which will be hereinafter explained. The armature *m* of the electomagnet M is carried by a spring *m′*, and the armature is so carried that it will be nearer to the pole-piece *x* than to the other pole-piece, *y*, of the magnet. An adjusting-screw *z* is provided for adjusting the position of the armature *m* relative to the pole-piece *y* of the magnet, and the pole-piece *y* may also be made adjustable by means of a slot, through which a screw *z′* passes into the core of the magnet and by which the pole-piece is secured in position.

The circuit connections are as follows: From generator A by wire 1 through electromagnet M, wire 3 to contact *a* through switch-arm S (when closed) and rheostat-arm R′ to the coils of the rheostat, from the last section of the rheostat by wire 4 to the armature of motor B, and by wire 2 back to generator A. The shunt connection for the field of the motor is by wire 5 from the arms S and R′ to wire 2.

In the position indicated in Fig. 2 (and disregarding the high-resistance shunt S′) the motor-circuit is open at *a* and the motor is at rest. To start the motor, the arm R′ is moved onto the contact *b* of the rheostat. This movement moves arm S onto contact *a*, completing the motor-circuit through the magnet M and all the sections of the rheostat. The movement of arm S causes the insulated stud *s* to engage with the spring-finger *s′* and moves the armature *m* into contact with the pole-piece *x* of the magnet M. This action causes the hooked end s^2 of the armature to engage the stud *s*, whereby the switch-arm is locked in contact with *a*, and since the magnet is now energized the armature *m* will be held in contact with the pole-piece *x* against the pull of spring *m′*. The function of the spring-finger *s′* is to move the armature mechanically into contact with the pole-piece *x* by its engagement with the stud *s*, and the magnetism serves only to hold the armature against the pole-piece. It will be understood, however, that the spring-finger *s′* may be dispensed with and the armature *m* drawn against the pole *x* by magnetism to lock the switch S, but I prefer to do this mechanically, since the action is more positive and certain.

The resistance of the first step is so high as to cut the current down to such an extent that the rheostat can safely carry it continuously without overheating. The rheostat-arm R′ is now moved in the direction of the arrow, thus cutting out the successive sections of the rheostat, and hence the speed of the motor gradually increases until the arm R′ reaches spring-clip *c*, when all sections of the rheostat will be cut out of circuit, and the motor will run at full speed. The spring-clip *c* is provided to hold the arm R′ in this position against the tension of its spring *r*′. In stopping the motor, arm R′ is moved by hand to disengage it from clip *c*, and when released spring *r*′ will move arm R′ rapidly toward contact-plate *b*, where it will stop, by reason of the arm striking the stud *d* and stop s^3. The entire resistance will then be in circuit, and the motor will come to rest. It will be noticed that the armature-circuit is never opened entirely, since it always has a closed circuit through its shunt-field and the rheostat. Furthermore, if the high-resistance shunt S′ around the automatic switch be employed the circuit connections would never be disturbed. This not only reduces the tendency to sparking in stopping the motor, by keeping the field and armature circuit always closed on each other, but also makes the action of the magnet M more positive in holding the armature while its hooked end is in engagement with the stud *s*. If the movement of the lever R′ is too rapid in starting up the motor, the strength of the magnetic pull at the pole *y* of the magnet M increases because of the largely-increased current, and the armature *m* will be drawn toward the pole *y*, the pole-piece *x* of the magnet being the fulcrum about which the armature *m* is moved. This movement of the armature causes the hooked end s^2 to become disengaged from the stud *s*, and the switch-arm S now being released the spring *r*′ will throw that arm toward the rheostat-arm R′, the movement of the arm S toward R′ being limited by the stop s^3. This movement of the switch-arm S opens the circuit at the contact *a*, interrupting the current to the motor, and the magnet M becomes demagnetized and the spring *m*′ returns the armature *m* to its normal position, as illustrated in Fig. 2. To close the circuit again, the rheostat-arm R′ must be brought back and placed in contact with the contact *b*, at which position the switch-arm S will again be in contact with the plate *a* and again locked by the hook s^2, as above explained. If while the motor is running at full speed it for any reason receives an excessive current through its armature, the armature *m* of the magnet will be drawn toward the pole *y*, whereupon the circuit will be automatically opened, as above explained. If for any reason the line electromotive force fails, the magnet M will become deënergized and the spring *m*′ will withdraw the hooked end of the armature from engagement with the stud *s*, thus permitting the opening of the circuit at *a* and preventing the sudden loading up of the motor when the electromotive force of the line is restored. In practice I prefer to wind the magnet M with four wires, and arrange them four in parallel for one-hundred-and-twenty-five-volt motors, two in parallel and two in series for two-hundred-and-fifty-volt motors, and all four in series for five-hundred-volt motors.

The spring-actuated contact-arm R′ is desirable in motor-starting rheostats; but for regulating-rheostats the contact-arm should not be spring-actuated, because in such apparatus the arm must be capable of remaining at any intermediate point, but in all cases the switch-arm S must be actuated by a spring or otherwise to open the switch or to place the high resistance S′ in circuit when the hook s^2 is withdrawn from engagement with stud *s*.

What I claim is—

1. The combination with an electric motor, of a rheostat, a line-switch closed through the movement of the rheostat contact-lever, and means for automatically opening said switch independently of the working positions or movement of said rheostat contact-lever when the energy in the circuit exceeds a certain amount, substantially as set forth.

2. The combination with an electric motor, of a rheostat, means operating independently of the working of the rheostat, for preventing or reducing the flow of current when the energy in the circuit falls below or exceeds certain amounts, said means being controlled by a single electromagnet having one winding, and a single armature, substantially as set forth.

3. The combination with a rheostat, of a contact-lever for varying the resistance in circuit, a separate switch-lever in series with the rheostat for controlling the flow of current through the rheostat, and a locking device for said switch, said locking device consisting of a magnet having a single armature which under normal conditions when the switch is closed locks the same, and which armature is affected when the energy in the circuit exceeds certain amounts to release the switch and prevent or reduce the flow of current, substantially as set forth.

4. The combination with a rheostat, of a contact-lever for varying the resistance in circuit, a separate switch-lever for controlling the flow of current through the rheostat, and a locking device for said switch, said locking device consisting of a magnet having a single armature which under normal conditions when the switch is closed locks the same, and which armature is affected when the energy in the circuit falls below or exceeds certain amounts to release the switch and prevent or reduce the flow of current, substantially as set forth.

5. The combination with a rheostat, of a contact-lever for varying the resistance in circuit, a separate switch-lever for closing a circuit through the rheostat, an electromagnet, a single armature for said magnet having a device for locking said switch when closed, said armature being held in locking position by said magnet under normal conditions, and being affected when the energy in the circuit falls below or exceeds certain amounts to release the switch, and means for opening the switch when so released, substantially as set forth.

6. The combination with a rheostat, of a switch, a high-resistance shunt around said switch, means for opening said switch, and a protective device for controlling said switch designed to lock the same in its closed position under normal conditions and operating to release the same when the energy in circuit falls below or exceeds certain amounts, to prevent or reduce the flow of current, substantially as set forth.

7. The combination with a rheostat, of a contact-lever for varying the resistance in circuit, a separate switch-lever for controlling the flow of current through the rheostat, a high-resistance shunt around said switch, an electromagnet, an armature for said magnet actuating a locking device for said switch, to hold the same closed under normal conditions, and said armature being affected when the energy in the circuit falls below or exceeds certain amounts to release the switch, substantially as set forth.

8. The combination with a rheostat, in the circuit of an electrical translating device, of a switch mechanically connected with the contact-arm of the rheostat, so that by the movement of said arm in one direction said switch is closed, means controlled by an electromagnet energized upon the closing of said switch for maintaining said switch in its closed position under normal conditions, said switch being released by said means when the energy in the circuit exceeds certain amounts, and means operating independently of the working positions or movement of the contact-arm of the rheostat for opening said switch when so released, substantially as set forth.

9. The combination with a rheostat in the circuit of an electrical translating device, of a switch mechanically connected with the contact-arm of the rheostat, so that by the movement of said arm in one direction said switch is closed, means controlled by an electromagnet energized upon the closing of said switch for maintaining said switch in its closed position under normal conditions, said switch being released by said means when the energy in the circuit falls below or exceeds certain amounts, and means operating independently of the contact-arm of the rheostat for opening said switch when so released, substantially as set forth.

10. The combination with a rheostat in the circuit of an electrical translating device, of a switch for closing a circuit through the rheostat, an electromagnet, an armature for said magnet, said armature being moved mechanically into contact with one pole of said magnet and held in contact therewith by the magnetism of said magnet, means controlled by said armature for holding the switch in its closed position when the armature is held by said pole of the magnet, and means for opening said switch when said armature moves toward the other pole of the magnet, substantially as set forth.

11. The combination with a rheostat, of a contact-lever for varying the resistance in circuit, a separate switch-lever for closing a circuit through the rheostat, an electromagnet, an armature therefor moved mechanically toward one pole thereof by the switch, means on said armature for locking said switch in its closed position, said armature being held in locking position by magnetism and said armature being so located relative to the poles of the magnet that it will be attracted by the second pole thereof when the energy in the circuit exceeds a certain amount to disengage said locking means, and means for retracting said armature to disengage said locking means when the energy in the circuit falls below a certain amount, and means for opening said switch when so released, substantially as set forth.

12. The combination with a rheostat, of a protective device having a controlling-magnet, and one armature therefor which in practice assumes three positions, one position due to a normal working current, a second position due to an abnormally large current, and a third position due to an abnormally small current, substantially as set forth.

13. The combination with a rheostat, of a switch for closing a circuit through the rheostat, an electromagnet, a locking device for said switch controlled by a single armature for said magnet, which armature in practice assumes three positions, one position being the locking position due to a normal working current, and two positions in which the switch is released, which positions are due respectively to an abnormally large current and an abnormally small current, and means for opening the switch when so released, substantially as set forth.

14. The combination with a rheostat, of a pivoted contact-lever for varying the resistance in circuit, a pivoted line-switch, said switch and lever being pivoted upon the same center and arranged so that the movement of the contact-lever in one direction moves the line-switch to close the circuit, and means for automatically opening the line-switch independently of the movement or working positions of the contact-lever, substantially as set forth.

15. The combination with a switch for electrical circuits, of a locking device therefor moved mechanically into engagement there-

with, an electromagnet and an armature for controlling said locking device, said armature being operated upon an abnormal increase or decrease in the magnetism of said magnet to release said locking device, and means for opening said switch when so released, substantially as set forth.

This specification signed and witnessed this 27th day of April, 1896.

H. WARD LEONARD.

Witnesses:
EUGENE CONRAN,
W. PELZER.