(No Model.)

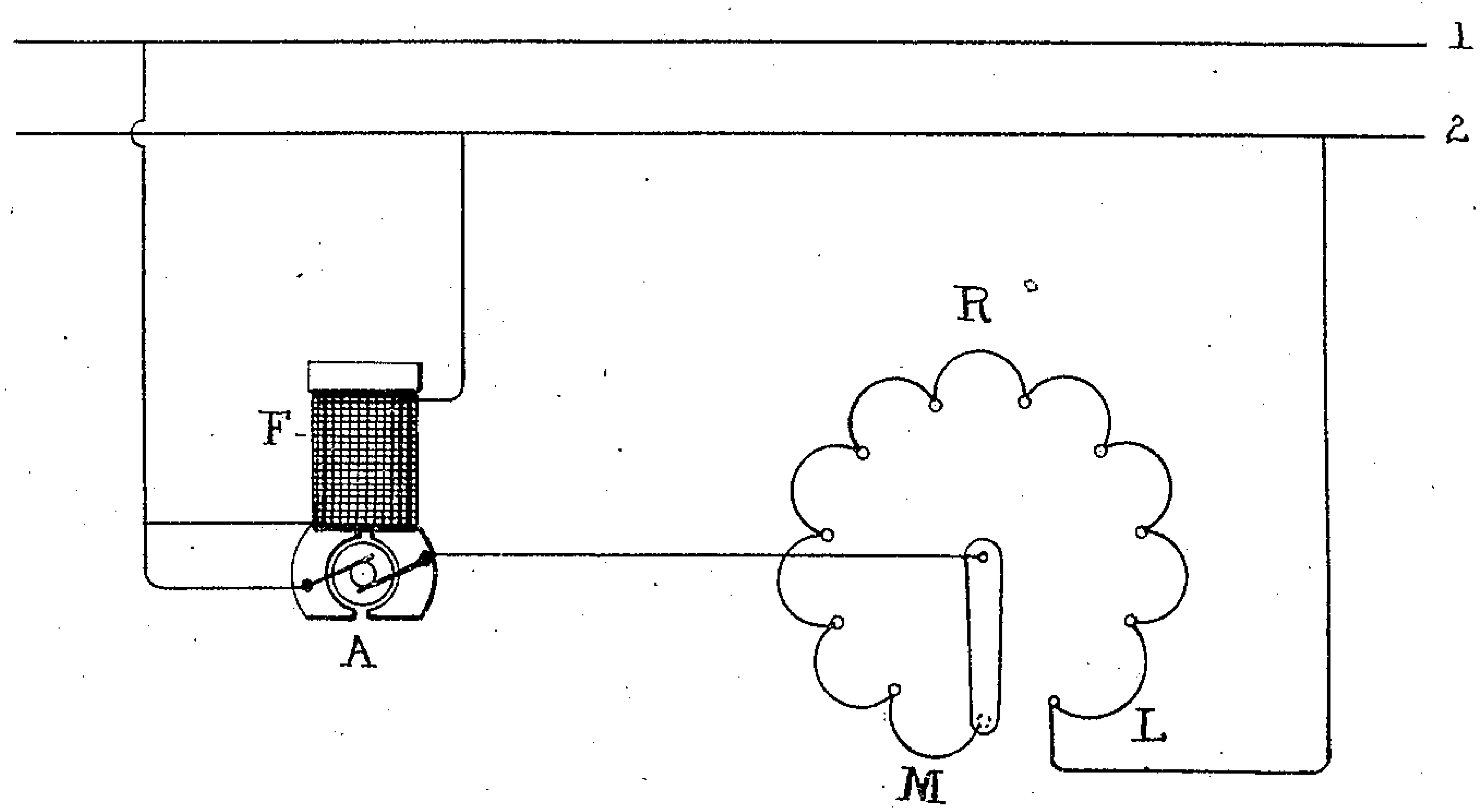
2 Sheets—Sheet 1.

H. W. LEONARD.

RHEOSTAT FOR ELECTRIC MOTORS.

No. 563,600. Patented July 7, 1896.

Fig. 1.



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(No Model.) 2 Sheets—Sheet 2.

H. W. LEONARD.

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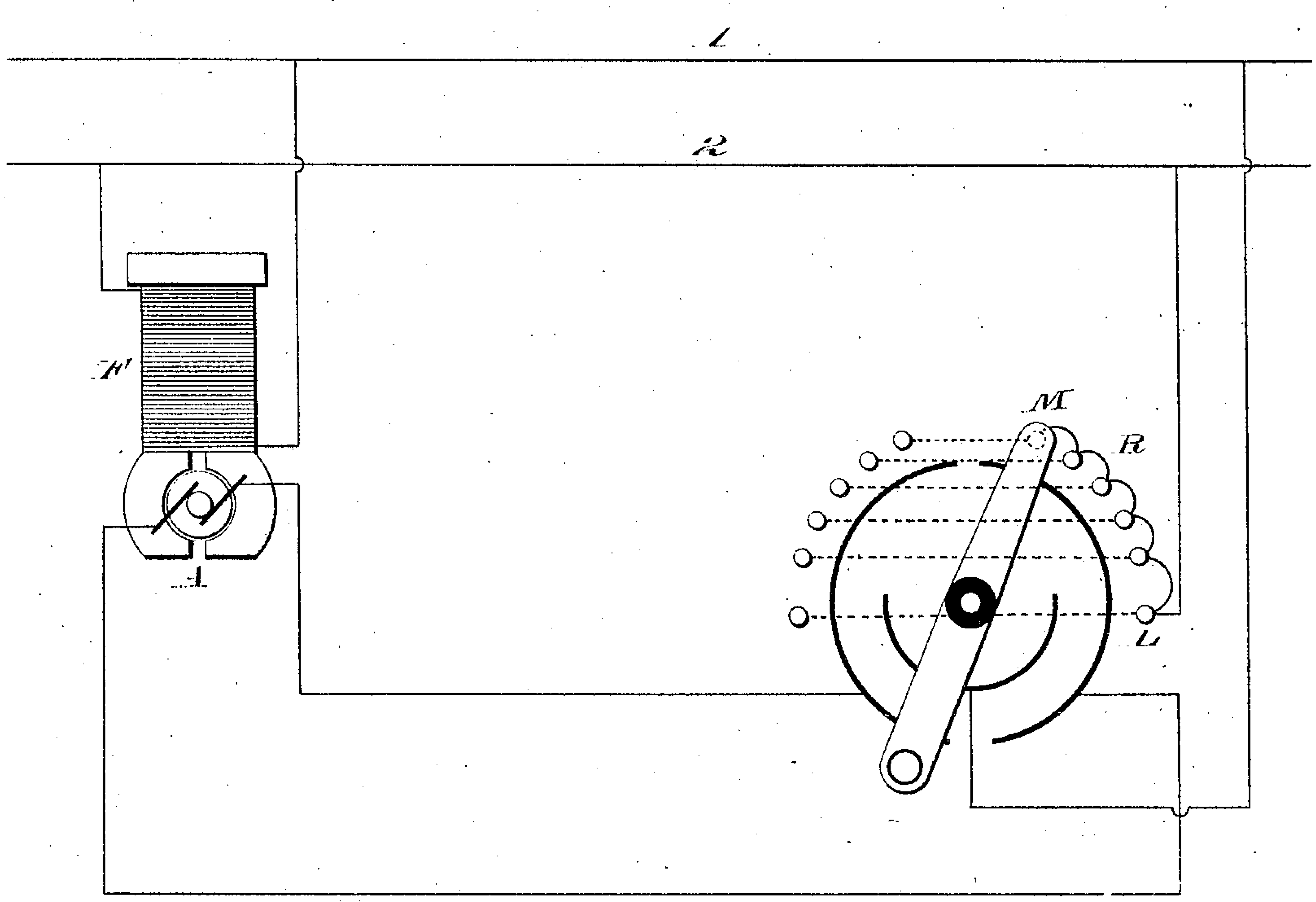
Fig. 2



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UNITED STATES PATENT OFFICE.

HARRY WARD LEONARD, OF NEW YORK, N. Y.

RHEOSTAT FOR ELECTRIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 563,600, dated July 7, 1896.

Application filed June 21, 1895. Serial No. 553,538. (No model.)

To all whom it may concern:

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

My invention relates to the construction of rheostats, particularly starting and reversing rheostats for electric motors. Heretofore in the construction of such rheostats it has been customary to arrange the sections of the resistance so that the number of ohms in the successive sections gradually decreased from the starting-point. For example, in a rheostat having ten steps or sections and a total resistance of fifty ohms the sections would probably be graduated as follows: seventeen ohms at the starting-point, then twelve, eight, five, three, two, 1.5, one, 0.5, and the last 0.25, the size of the wire gradually increasing from the first step to the last, so that the carrying capacity was much greater at the last step than at the first step, and with coils having the same length of wire for each step the resistance would naturally decrease per step as the cross-section of the wire increased. That arrangement I found was the cause of rheostats continually burning out and that the weakest point of the rheostat was the last step. To illustrate this, I will explain the condition under which a rheostat constructed as above stated operates when used as a starting-rheostat for a five-horse power shunt-wound motor supplied from a constant-potential circuit of five hundred volts. Such a motor when developing five-horse power would take about ten amperes.

It is customary to have the field directly across the line and to have a rheostat in circuit with the armature across the line, as illustrated in Fig. 1 of the accompanying drawings.

In that diagram, 1 2 indicate the circuit-wires extending from the source of supply, A the armature of the motor, and F the field-magnet. The rheostat R is connected in series with the armature and across the line.

L is the last contact of the rheostat or contact nearest the line, and M the first contact or contact nearest the motor.

In practice it is usual to put in the rheostat a total resistance of such a number of ohms that the line-pressure would send through the rheostat and motor-armature at rest a current of about the full-rated current of the motor; that is to say, for the five-horse-power five-hundred-volt motor a resistance of about forty-nine ohms in the rheostat would be employed, which would allow about ten amperes to pass when the contact-lever was on M and the armature at rest, the resistance of A being considered as one ohm.

If the torque of the work to be done is such that the torque of the motor due to the ten amperes is sufficiently large, the armature will start to revolve, and in so doing will develop a counter electromotive force which will tend to reduce the current, and the motor-armature will revolve only slowly. If it is then desired to accelerate the speed of the armature, the contact-lever of the rheostat is moved slowly from M toward L, gradually cutting out the successive sections of the resistance and allowing an increased current to pass until the armature can accelerate to a new speed and develop a counter electromotive force sufficient to reduce the current to that necessary to maintain the speed without material variation. It will be noticed that the counter electromotive force of the armature A, plus the volts represented by the current through the resistance of the rheostat and armature, must equal the line-volts. If the armature A be free and not attached to any load, it will accelerate in speed very quickly as the contact-lever is moved from M to L, because the balancing counter electromotive force will be very quickly developed, but if the armature A has a very heavy load to move it will take some time for it to accelerate to a new speed as each successive section of the resistance is cut out. Therefore the length of time required for the armature to reach full speed from rest will be dependent upon the load to be moved. If the contact-lever of the rheostat be moved too rapidly, that is, from one contact to another before the armature has had time to accelerate, the rheostat will receive a larger current than desirable. The current at any time will be the line-volts less the counter-volts divided by the ohms in the rheostat and armature. Hence it is evident that the armature will receive an excessive current if the contact-lever of the rheostat is moved too quickly over the successive contacts.

Now suppose the motor is working with a heavy load and the operator moves the contact-lever from M toward L quickly to bring the motor up to full speed. On account of the great inertia of the load the motor-armature cannot respond quickly. Hence its counter electromotive force remains practically constant while the sections of the resistance are rapidly cut out, permitting a constantly-increasing current to pass, with the result that when the last section of the resistance is reached there is left in circuit only 0.25 of an ohm in series with the armature. The total resistance then in circuit is 1.25 ohms, and supposing the counter electromotive force is three hundred volts, there would be a net voltage of two hundred volts and a current of one hundred and sixty amperes would flow through the resistance. This current passing through the final section of the resistance (0.25 of an ohm) would burn it out unless this last step be made impracticably large as to current capacity. My invention overcomes this difficulty, and consists in making the final section of the resistance as high as practicable instead of very low, as heretofore. This may be accomplished, for example, by making the last section of the rheostat longer than the other sections, as I have illustrated diagrammatically in the drawings. For instance, I might make the last section of the resistance nine ohms instead of 0.25 of an ohm, the other sections of the resistance being preferably all smaller in amount than nine ohms. Now suppose a five-horse-power motor to be working on a circuit of five hundred volts and under the same conditions above stated, and that the contact-lever of the rheostat be moved quickly up to the last section of the resistance, there would be in circuit the resistance of nine ohms plus the resistance of the armature, which was assumed to be one ohm, making a total of ten ohms, and supposing the counter electromotive force to be three hundred volts and the net voltage two hundred volts, we would have a current of twenty amperes passing through the last section of the resistance. This is extremely important, because the heat developed in a certain size of wire of definite material per unit of length varies as the square of the current. As above stated, in rheostats as heretofore constructed the last section of the resistance would have to carry a current of one hundred and sixty amperes as compared to twenty amperes in my construction. Thus by my improvement the final section of the resistance is not subjected to excessive currents, no matter how rapidly the contact-lever be moved over the successive contacts.

It is true that if the contact-lever of the rheostat be moved quickly over the contacts and cut out all of the sections of the resistance, instead of leaving the last section in circuit, the motor-armature having a resistance of one ohm would receive a current of large amperes, due to the net voltage of two hundred volts, and such a sudden increase of volts on the armature-terminals would tend to cause violent sparking, but the operator would avoid any such handling in practice, since the sparking would be a guide to him. Furthermore, the armature can stand a sudden large increase temporarily without serious effects, because of its greater current capacity, self-induction, &c., whereas if the rheostat were provided with a final step of 0.25 of an ohm, as heretofore, it would be almost invariably burned out. In practice I generally make the final section of the resistance such that the normal working current will cause a drop of about twenty per cent. of the total line-volts, but this will vary with the various conditions, but in all cases I make it as high as the practical conditions will permit.

This method of constructing a rheostat is of especial value for reversing-rheostats, because in cases where the current is quickly reversed the electromotive force produced by the armature of the motor is added to the line-volts, and this total voltage tends to send a current through the ohmic resistance until the armature comes to rest prior to reversing its direction of rotation. That is to say, assuming that we have a line-voltage of five hundred volts and four hundred and ninety volts net at the terminals of the armature, and assuming that the rheostat be reversed quickly, we would have the line-volts plus the counter-volts (five hundred plus four hundred and ninety equals nine hundred and ninety) acting accumulatively to send a current through the ohmic resistance of the armature plus the final section of the resistance—viz., ten ohms—and hence a current of ninety-nine amperes would flow, neglecting all opposition to the current except the ohmic resistance for the sake of simplicity. In rheostats as heretofore constructed, however, the ohmic resistance would be 1.25 ohms, and a current of seven hundred and ninety-two amperes would pass through the final section of the resistance under the same conditions.

In Fig. 2 I illustrate the application of my present invention to a reversing-rheostat of a common type, representing the parts thereof corresponding to those of Fig. 1 by the same letters of reference.

What I claim is—

1. A rheostat having a resistance divided into a number of steps or sections adapted to be cut out of circuit successively to reduce the resistance in circuit, the last or final section in circuit being of such resistance as to prevent the passage through it of a destructive current, substantially as set forth.

2. A controlling-rheostat having a final protective step of high resistance so as to prevent the net effective electromotive force in the circuit from sending a destructive cur-

rent through the rheostat, substantially as set forth.

3. The combination with a circuit in which there are both an impressed and a counter electromotive force, of a rheostat having a high-resistance final step, so that should the difference between the impressed and counter electromotive force become abnormally large, the said high-resistance step will act to prevent the flow of a destructive current through the rheostat.

4. A rheostat having a resistance divided into a number of steps or sections, the last or final step or section to be cut out as the resistance in circuit is reduced, being of greater resistance than the one immediately preceding it, substantially as set forth.

5. The combination with an electric motor, of a starting or reversing rheostat, having a resistance divided into a number of steps or sections adapted to be cut out of circuit successively to reduce the resistance in circuit, the last or final section in circuit being of such resistance as to prevent the passage through it of a destructive current, substantially as set forth.

6. The combination with an electric motor, of a starting or reversing rheostat having a resistance divided into a number of steps or sections adapted to be cut out of circuit successively to reduce the resistance in circuit, the last or final section in circuit being of such resistance as to prevent the passage through it of a destructive current if the preceding steps of the rheostat be cut out without waiting for the motor to develop its counter electromotive force, substantially as set forth.

This specification signed and witnessed this 20th day of June, 1895.

H. WARD LEONARD.

Witnesses:

EUGENE CONRAN,

W. PELZER.