No. 749,272. PATENTED JAN. 12, 1904.

S. T. DODD.

MOTOR CONTROL.

APPLICATION FILED JUNE 13, 1903.

NO MODEL. 2 SHEETS—SHEET 1.

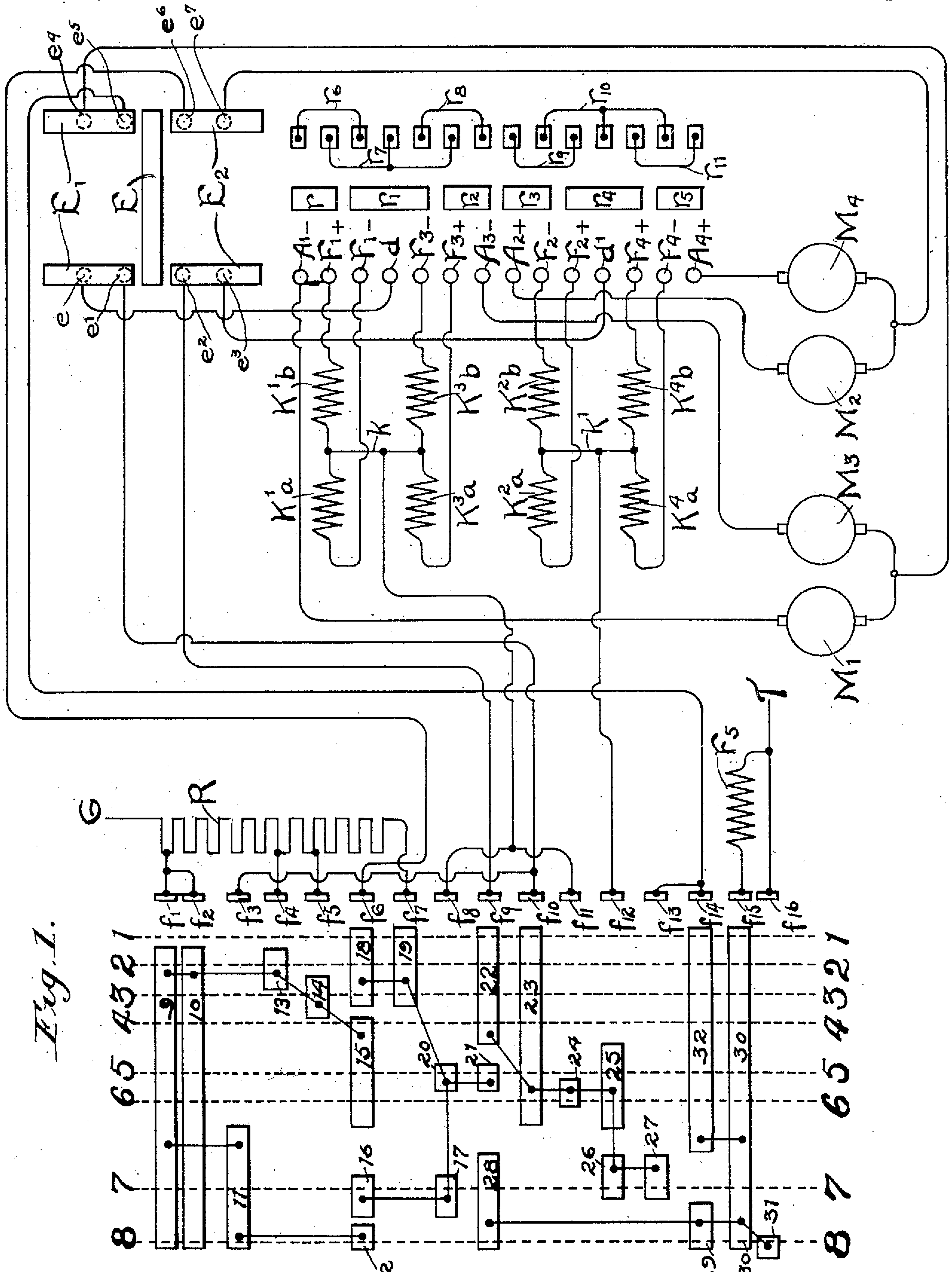


Fig. 1.

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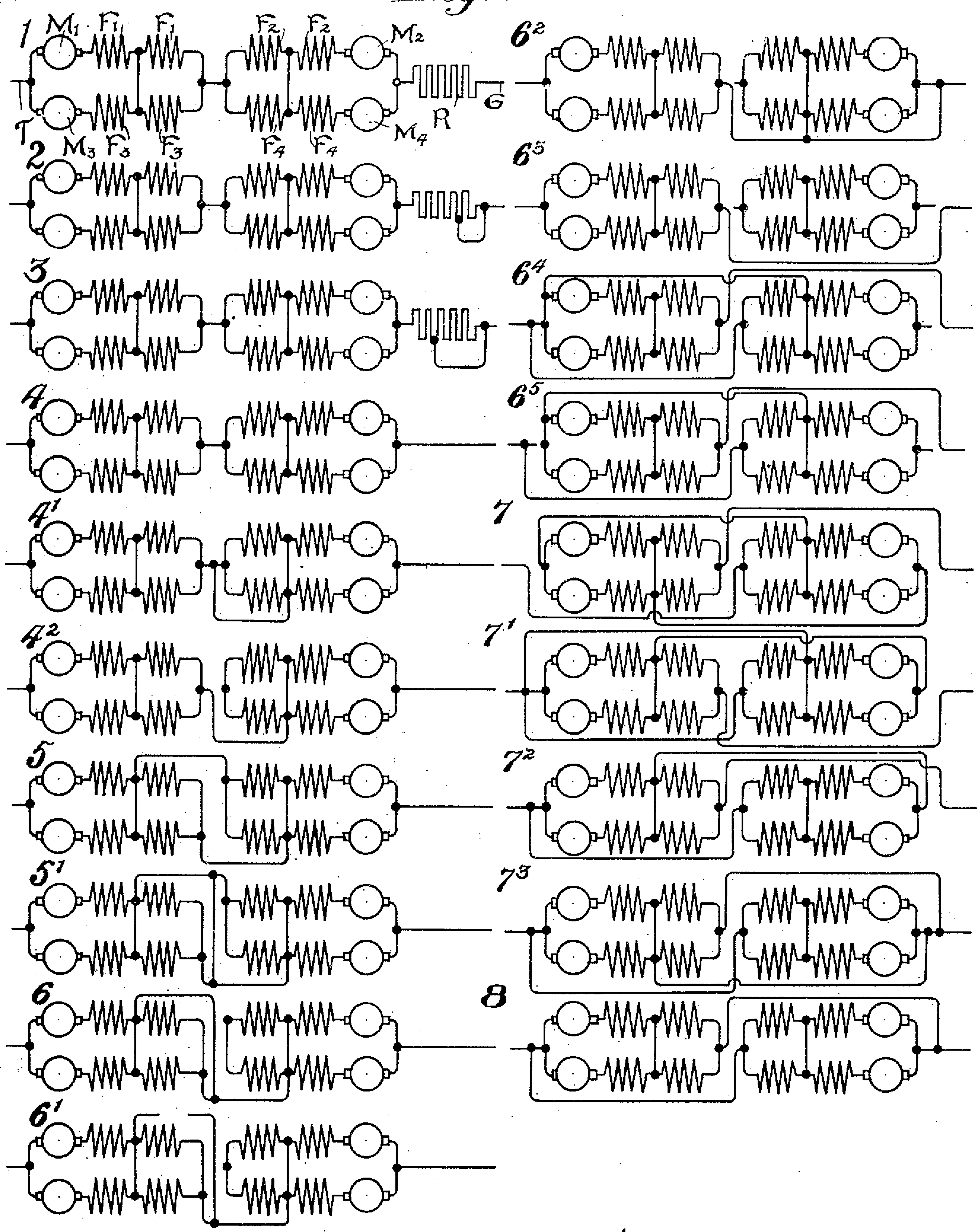
NO MODEL. 2 SHEETS—SHEET 2.

*Fig. 2*

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# UNITED STATES PATENT OFFICE.

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## MOTOR CONTROL.

**SPECIFICATION** forming part of Letters Patent No. 749,272, dated January 12, 1904.

Application filed June 13, 1903. Serial No. 161,271. (No model.)

*To all whom it may concern:*

Be it known that I, SAMUEL T. DODD, a citizen of the United States, and a resident of Pittsfield, Massachusetts, have invented certain new and useful Improvements in Motor Control, of which the following is a specification.

My invention relates to electric-motor control, and more especially to the control of electric-railway motors.

The object of my invention is to provide a novel method of controlling the speed and acceleration of the motors with a minimum use of external resistance and yet with maximum safety to the motors and with as little as possible complication of circuits, and also to provide a method adapted either for the control of two motors or four motors, and also to provide a method necessitating the smallest possible number of contacts on the different switches employed.

I believe that by the use of my invention a much smaller controller may be used than with any method of four-motor control heretofore devised.

Referring to the drawings, Figure 1 is a diagram showing the contacts of the various switches adapted to the employment of my method of control, and Fig. 2 is a diagram representing the various changes made in the circuit.

Turning first to Fig. 1, I will explain the method of control which I employ and show how the various switches perform their allotted functions. The controlling-switch shown at the left of the figure comprises the sixteen contact-fingers $f'$ to $f^{16}$ and four groups of contacts 9 to 15, 16 to 21, 22 to 27, and 28 to 32. The said four groups of contacts are thus carried by the controller-drum and are movable to make contact with the fingers $f'$ to $f^{16}$. $F^5$ represents the winding of the blow-out magnet. R represents an external resistance. $M'$ to $M^4$ represent the armatures of the four motors, and $k'^a$ $K'^b$ $K^{2a}$ $K^{2b}$ $K^{3a}$ $K^{3b}$ $K^{4a}$ $K^{4b}$ represent the field-windings of the motors, the winding of each motor being divided, as shown, into two parts, as $K'^a$ $K'^b$, each of said parts comprising half of the field-winding.

$r$ to $r^{11}$ indicate contacts of the reversing-switch carried on the drum B and $A'^-$.

$F'^+$ $F'^-$, &c., represent the fourteen contact-fingers of the reversing-switch.

E $E'$ and E $E^2$ are the movable contacts of the cut-out switch G, and $e$ to $e^7$ are the fixed contacts thereof.

For the purpose of explaining the method of control employed by the movement of the controlling-switch the cut-out and reversing switches may be considered as closed, the former at the position shown with contact E out of engagement with any of the fixed contacts, and contacts $E'$ and $E^2$ engaging the fixed contacts to connect them in pairs, as shown, while the reversing-switch may be considered as closed, with contacts $r$ to $r^5$ in engagement with the fixed contacts of the switch.

The general scheme of control is to maintain the motors in two sets, there being two motors in each set in parallel with each other, and the two sets being started in series with each other, preferably with an ordinary rheostat, and the two sets being afterward changed to parallel relation without at any time opening the main circuit, by successive changes in which the connections to mid-points in the fields of the different motors are shifted to different parts of the circuit, so as to make different combinations of such half-fields and the remaining parts of the motors. Thus continuing the general description as of two motors, the motors are started in series, then a higher speed is obtained by placing half of one field in parallel with half of the other field without disturbing the series connection of the remaining coils of the motors. Then a still further speed is obtained by short-circuiting half the field-coil of each motor, and then a still further speed connection is obtained by placing the armatures and half of the fields of each of the motors in parallel while maintaining half of the field of each motor in series. Finally the motors are placed in full parallel.

This gives a gradual acceleration and at the same time there are no positions at which the motors can deleteriously buck each other, because each armature is always in circuit with half, at least, of its own field, and consequently there is always an independent counter electromotive force in each armature-circuit. In order to effectively employ this method of control for four motors without increasing the controlling apparatus to too large an extent, I permanently couple the motors of each set together at points midway their field-windings. I also connect the terminals of the two motors of each set together permanently so far as regards the controlling-switch, so that I am thus enabled to lead to the controlling-switch only three leads from each pair of motors, and thus have no more contacts than if only a pair of motors were to be controlled.

Another means which I employ to reduce the contacts that are necessary for controlling consists in so arranging the motor elements in the circuit and so shifting the connections that the circuit between the field and armature of each motor is never ruptured. To this end I place one pair of elements—say the armatures—at the extreme ends of the motor-circuit, and the other elements—say the fields—at intermediate points in the motor-circuit. This groups the fields of both sets of motors together and enables me to make series-multiple and other changes of such fields without disturbing the field connections between fields and armatures, as has hitherto been necessary in every controller which was based upon changes in the relations of the individual elements of the motors with respect to each other for speed regulation additional to the series and multiple positions.

With this general statement of the means I employ to control the motors and the advantages of such means, the details of the control system, as shown by Fig. 1, and its results, as shown by Fig. 2, will be readily understood. Suppose the drum of the controller is in such a position that the controller at dotted line 1 engages the contact-fingers $f'$ to $f^{16}$. Under these circumstances the current enters at T, which represents the trolley connection, passes through blow-out coil F to finger $f^{15}$, thence through contacts 30 and 32 to finger $f^{14}$, through contacts $e^5$ and $e^4$ of the cut-out switch to armatures M′ and M³. Thence through the contacts of the reversing-switch A′ and A³ the current passes in multiple through the reversing-switch and through the two field-coils K′ and K³, leaving the reversing-switch at finger $d$ and again passing through the cut-out switch and reaching the controlling-switch at finger $f^{10}$, thence by contacts 23 and 22 and finger $f^9$ through the cut-out switch to finger $d'$ of the reversing-switch, where the current divides between field-coils $k^2$ and K⁴ and out of the reversing-switch at fingers A³ and A⁴ through armatures M² and M⁴, thence through the cut-out switch to finger $f^6$, contacts 18 and 19, finger $f^7$, and through the resistance R to the ground G, thus putting the two sets of motors in series with each other and in series with the whole of the external resistance, as shown simply in position 1 of Fig. 8. Having thus traced out one step, it will not be necessary to trace out each step in detail, as the results are clearly shown in Fig. 2, the running positions of the controller being indicated by the numerals 1, 2, 3, 4, 5, 6, 7, and 8, and the transitory positions occurring momentarily at change of connections being indicated by positions 4′ 4², &c. Positions 2, 3, and 4 only vary from position 1 by the gradual reduction of the external resistance caused by the successive engagement of contacts 13, 14, 9, and 10 with fingers $f^4$, $f^5$, and $f'$ and $f^2$. At position 5 the mid-field connections $k$ and $k'$ come into play. Connection $k$ is connected to finger $f^8$ and $f^{11}$. Connection $k'$ is connected to finger $f^{12}$. At position 5 finger $f^8$ is connected to finger $f^9$ by means of contacts 20 and 21, and this causes the mid-field connection of the first group of motors to be connected to the trolley end of the second group of motors, while finger $f^{12}$ is connected by contacts 25 and 23 with fingers $f^{10}$, which connects the mid-field of the second group of motors with the ground side of the first set of motors, thus placing the half-fields of the different motors in parallel. Positions 4′ and 4² are simply transitory positions, which first short-circuit and cut out one half-field in order to connect it in parallel with the other half-field. Position 6, which is the next running position, short-circuits half of the field of each motor, thereby still further reducing the resistance of the circuit and the counter electromotive force of the motors. This short-circuit is effected by the contacts 24 and 25, which at position 6 connect together fingers $f^{11}$ and $f^{12}$, which fingers are connected to the mid-field connections $k$ and $k'$. The transitory position 5′ just before reaching position 6 differs only in that the connection is still established between the trolley side of the half-fields of the second group of motors and the trolley side of the half-fields of the first group of motors. The position 5′ could as well be a running position as position 6; but I arrange the notches of the step-by-step device which all such controllers have so as to make the running position at 6 rather than at 5, because the break at this point is one that it is very important should be certainly made. Thus if the change were made from position 5 to position 7 as quickly as possible there might be some danger of arcs being momentarily maintained between contacts 21 and 28 and between contacts 20 and 24 and their respective fingers. Under these circumstances there would be a circuit through the arcs and contacts directly between the trolley, which is connected to contact 28, and ground, which is connected to finger $f^{10}$ through fingers $f^3$ and contacts 11 and 10. By running at position 6 rather than at position 5′ I make it certain that the arc between finger $f^8$ and contact 20 will be eliminated before the controller is moved to position 7, and therefore I remove any possibility of this dangerous short circuit occurring between trolley and ground through nothing but the resistance of the arcs. At position 7, as indicated in Fig. 2, the current first passes through the half-fields of the motors of the second group. Then it passes in parallel through the remaining coils of said motors and through the armatures and half-fields of the first group of motors and then passes through the remaining half-fields of the second group of motors, this being accomplished because the current entering the controller at $f^{15}$ passes contact 28 and thence by the cut-out switch and reversing-switch to the terminals of field-coils $K^{2a}$ and $K^{4b}$. After passing through these two coils to the mid connection $k$ it of course passes through the remaining coils of these motors in the usual manner and also passes from the mid connection $k'$ to the finger $f^{12}$, contacts 26 and 27, fingers $f^{13}$ and $f^{14}$ through the cut-out reversing-switch to the armatures M′ and $M^3$, from which it passes in the ordinary manner to the mid connections $k$ of these motors, which is connected by fingers $f^8$, contacts 17 and 16, and finger $f^6$ with the armatures of the other two motors, the field-terminals of the first set of motors being connected to ground by fingers $f^3$ and contacts 11 and 10 and finger $f^2$. It is unnecessary to consider in detail 6′ to $6^5$, inclusive, as they are merely transitory positions most convenient for changing the circuit from position 6 to position 7 without troublesome sparking or inductive effects upon the motors. At position 8 the motors are connected in full parallel.

It will be noted that while I have numerous speed-stops, and therefore uniformly-graduated acceleration, and a number of changes are made in the circuit relations, yet at no step is any considerable change made and there is no complexity of circuits. It will also be noted that at no step, whether transitory or running, is found a condition in which an armature has a local closed circuit not containing at least half the field which excites that armature, so that the condition of the circuit is always a comparatively stable one, there being no tendency to what is known as "bucking" when the motor acts temporarily as a generator to produce current in a local circuit. Moreover, and what is perhaps more important, in none of the positions is any armature in the local circuit when it has not a substantial strength of field, so that if there be any tendency to generation of local current there will be no substantial sparking. It will also be noted that when the motors are in series the trolley makes connection to the first group of motors at their armature-terminals, while the connection between the ground and the second group of motors is also at the armature-terminals. In this way the fields of all the motors are together in the central portion of the circuit, so that the series-parallel changes of the half-fields are made without at any time disconnecting the field of a motor from its armature. Moreover, by coupling the half-fields as described above I also have, no matter what the circuit position, half of the field remaining in the active circuit in series with its own armature receiving the full current thereof.

I do not desire to limit myself to the particular arrangement here shown, since changes therein which do not depart from the spirit of my invention and which are within the scope of the appended claims will be obvious to those skilled in the art.

Having thus fully described my invention, what I claim, and desire to protect by Letters Patent, is—

1. The method of controlling a plurality of motors, which consists in varying the proportions of each field in the operating-circuit and in varying the connections of the half-fields to each other.

2. The method of controlling a plurality of motors, which consists in including varying proportions of each field in balanced parallel circuits, while maintaining the entire windings of both fields in circuit.

3. The method of controlling a plurality of motors, which consists in producing balanced parallel circuits of portions of the two fields and of the two armatures with portions only of their respective fields.

4. The method of controlling a plurality of motors, which consists in shifting said motors from series to parallel while maintaining the connection of each armature to the corresponding field and using that armature and half of its field as an element in all combinations.

5. The method of controlling a plurality of motors, which consists in first connecting a common terminal of the fields of one group to a common terminal of the fields of the other group, the mid-fields of each group being connected to common leads and the armatures of one group being connected by a common terminal to the source of current and the armatures of the other group by a common terminal to ground, then connecting in overlapped or parallel relation the groups of half-fields which lie between the mid-fields and the common field-terminal, then cutting out these groups of half-fields leaving the motors in series but each armature running in series with the half-field that lies between it and the

mid-field connection, then putting the aforesaid groups of half-fields again in series but paralleling the groups of armatures and half-fields that lie between the common armature connection and the mid-field connection, and finally connecting the two groups of motors in parallel.

6. The method of controlling a plurality of electric motors, which consists in connecting said motors in various series and parallel relations for various speeds, while maintaining throughout all combinations each armature connected to its own field and so connecting the leads from each motor as to leave on all combinations each armature connected in series with a section of its own field sufficient to force an approximately equal division of current between the armatures when connected in parallel with each other.

7. The method of controlling a plurality of electric motors, which consists in shifting said motors from series to parallel relation and, before changing from the last series position, disconnecting entirely from the circuit those terminals of said motors which on the first parallel position are to be connected to a source of current and ground respectively.

8. The method of controlling two electric motors, which consists in connecting the two motors in series with each other with one element of one motor at one side of the motor-circuit, the like element of the other motor at the other side of the motor-circuit, and the remaining elements of the motors connected together and each connected to one of the first-mentioned elements, and then shifting the motors to parallel by intermediate positions in which one motor is connected to a point intermediate of the other motor, without at any time during the shift separating the elements in an individual motor.

9. The method of controlling two series electric motors, which consists in placing the two motors in series, each with its field connected directly to its own armature but with the fields and armatures reversed relatively to each other as to their position in the circuit, and then shifting the motors by successive steps in which one motor is connected to points intermediate the terminals of the other motor until the two motors are in parallel with each other.

10. The method of controlling two series electric motors, which consists in placing the two motors in series, the connection between the two motors being from an element of one motor to a like element of the other, and in parallel, and intermediate thereto connecting the terminal of one element of one motor with the point on the unlike terminal of the other motor intermediate the terminals of said element.

11. The method of controlling two series electric motors, which consists in placing the two motors in series, the connection between the two motors being from an element of one motor to a like element of the other motor, and in parallel, and intermediate thereto making successive changes of relation of the coils of the different motors relative to each other.

12. The method of controlling two series electric motors, which consists in connecting the motors in series and in parallel with each other, and intermediate thereto producing intermediate circuit conditions by varying the connections in the circuit of one-half the field-winding of the two motors relative to each other.

13. The method of controlling two series electric motors, which consists in connecting the motors in series and in parallel with each other and intermediate thereto connecting one-half of one field-winding in parallel with one-half of the other field-winding while maintaining the remaining coils of the motors in series with each other.

14. The method of controlling two series electric motors, which consists in connecting the motors in series and in parallel with each other and intermediate thereto connecting one-half of the field-winding of one motor in series with one-half the field-winding of the other motor, the remaining coils of the different motors being in parallel with each other.

15. The method of controlling two series electric motors, which consists in connecting the motors in series and in parallel with each other and intermediate thereto producing intermediate circuit conditions by making series-parallel combinations of one-half of the field-winding of each motor and of the remaining coils of said motors.

16. The method of controlling two series electric motors, which consists in connecting the motors in series and in parallel with each other and intermediate thereto producing intermediate circuit conditions by making series-parallel combinations of one-half of the field-winding of each motor and of the remaining coils of said motors and by short-circuiting or cutting out said half field-windings.

Signed at Pittsfield, Massachusetts, this 3d day of June, 1903.

SAMUEL T. DODD.

Witnesses:
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