No. 654,410. Patented July 24, 1900.

F. A. MERRICK & E. W. STULL.

APPARATUS FOR CONTROLLING ELECTRIC MOTORS.

(Application filed Nov. 22, 1899.)

(No Model.) 3 Sheets—Sheet 1.

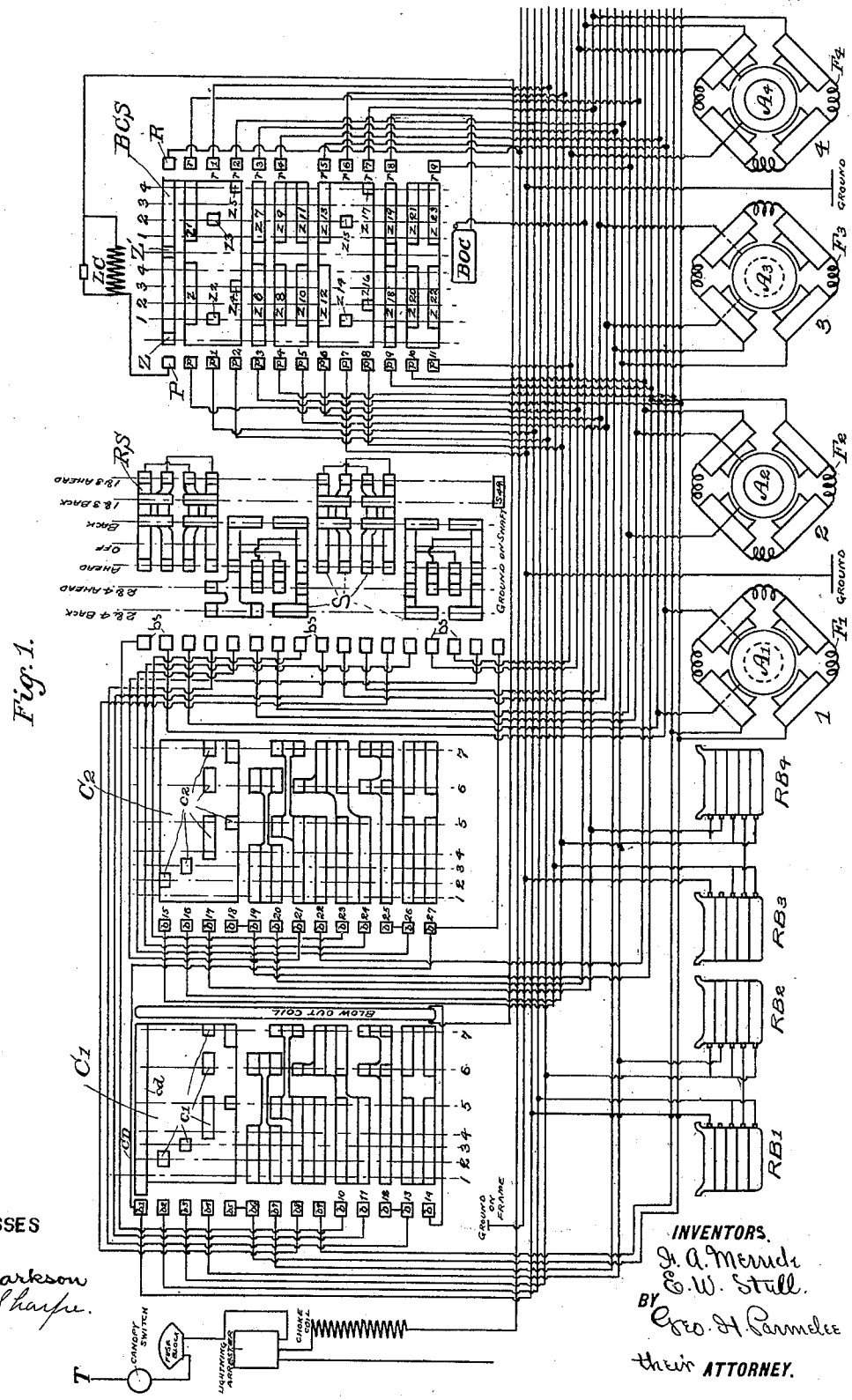

Fig. 1.

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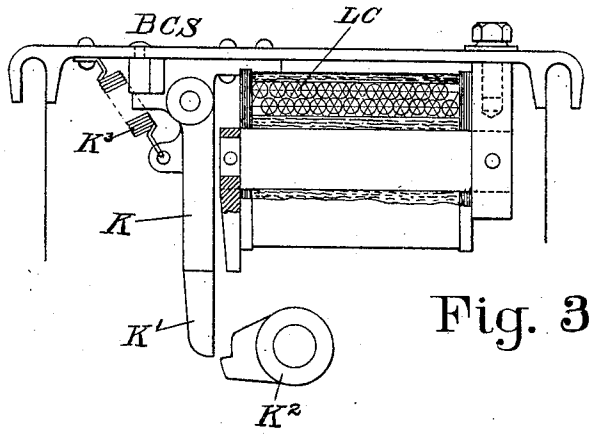

Fig. 3

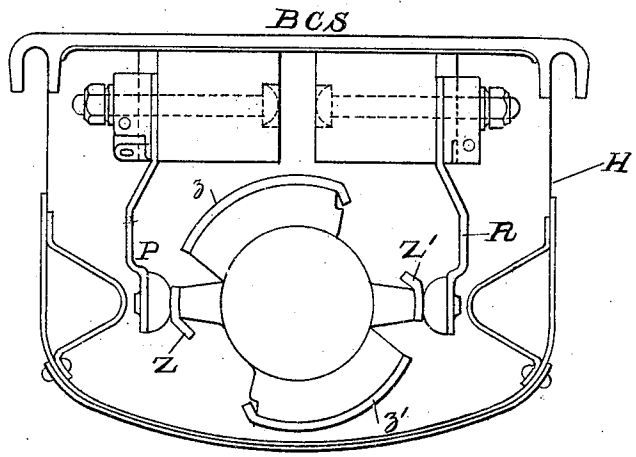

Fig. 4

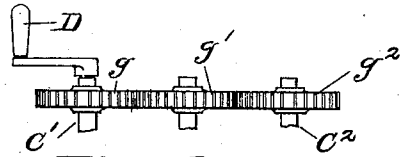

Fig. 2

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APPARATUS FOR CONTROLLING ELECTRIC MOTORS.

(No Model.) (Application filed Nov. 22, 1899.) 3 Sheets—Sheet 3.

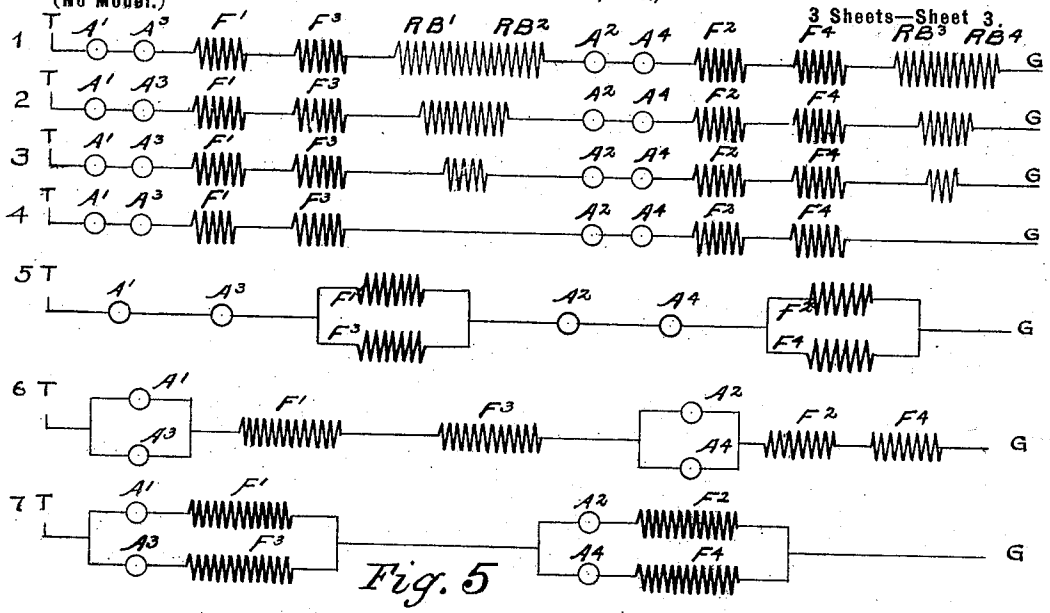

Fig. 5

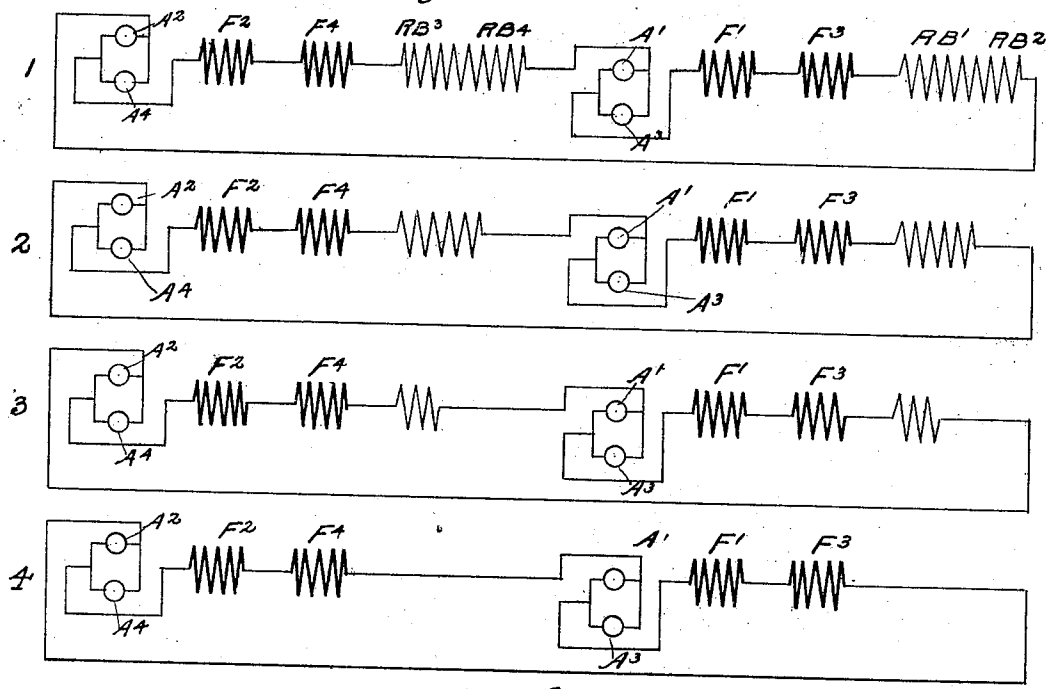

Fig. 6

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UNITED STATES PATENT OFFICE.

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APPARATUS FOR CONTROLLING ELECTRIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 654,410, dated July 24, 1900.

Application filed November 22, 1899. Serial No. 737,879. (No model.)

To all whom it may concern:

Be it known that we, FRANK A. MERRICK and EMMETT W. STULL, of Johnstown, in the county of Cambria and State of Pennsylvania, have invented a new and useful Improvement in Apparatus for the Control of Electric Motors, of which the following is a full, clear, and exact description, reference being had to the accompanying drawings, which form a part of this specification.

Our invention has relation to apparatus for the control of electric motors, and is more particularly designed for use on electric-railway cars which are propelled by four motors, although in part it is equally applicable in connection with two motors.

One object of our invention is to provide apparatus by which a plurality of electric motors may be started from a position of rest in which all their elements are connected in series and changed over to a multiple position in which pairs of the motors are connected in multiple and the multiple pairs in series with each other through a series of intermediate circuit changes of suitable character to accelerate the motors without injury to their coils or brushes. By handling the motors in this manner we are able to get a maximum effect of torque, particularly in starting from a position of rest. We also make it possible to use a higher potential on the line with less drop in potential along the line.

A further object of our invention is to provide a brake-controlling switch of novel character for connecting the motors in a closed circuit independent of the line and in a manner whereby their braking action when running as generators driven by the momentum of the car may be effectively utilized; also, to provide means whereby said switch cannot be operated until the motors have been disconnected from the line-circuit, thereby preventing injury to the motors by reason of any movement of the brake-switch tending to cause them to act as generators while they are still receiving current from the line; also, to provide means whereby the motors cannot be connected with the line except when the brake-switch is at the "off" position, so that as long as the motors are connected to run as generators no current can be made to pass to them from the line.

Other minor objects of the invention will hereinafter appear.

With these objects in view the invention consists first in the combination, with four electric motors, of a pair of controller-drums intergeared one with the other, so that they may be simultaneously operated by the movement of a simple handle-lever, each drum having contacts and connections for changing from series to parallel one pair of the motors through a series of intermediate steps in which the strength of the fields and the ohmic resistance of the circuits are gradually changed to gradually accelerate the motors, the two drums being electrically connected in series.

Our invention further consists in a brake-controlling switch having contacts, brushes, and proper electrical connections whereby the motors may be connected to operate as generators and the ohmic resistance of the motor-generator circuit may be reduced as the speed of the armatures decreases; also, in the provision of contacts carried by the brake-controlling switch and controlling the passage of current from line to the motors; also, in the provision of an electromagnetic locking device for the brake-switch, whereby it cannot be operated until the current is cut off from the motors.

In connection with the apparatus we employ artificial resistance for the rheostatic control of the motors in starting from a position of rest and for using in the braking-circuit. We also employ a combined reversing and cut-out switch having certain novel features hereinafter pointed out.

Referring to the accompanying drawings, Figure 1 is a diagram which shows the various apparatus and connections for a four-motor equipment. Fig. 2 is a detail view showing the mechanical connection between the two controller-drums. Fig. 3 is a detail view showing the lock for the brake-controller. Fig. 4 is a horizontal section through the brake-controller. Fig. 5 is a diagram showing conventionally the several positions of the motors for the respective indicated or notch positions of the controller-drums. Fig.

6 is a similar view showing the several positions or circuit positions effected by the operation of the brake-controlling switch.

In the diagrams Figs. 1, 4, and 5, A' A^2 A^3 A^4 designate the respective armatures of four electric motors, (designated as 1, 2, 3, and 4,) and F' F^2 F^3 F^4 the respective field-coils of the same.

C' C^2 designate two controller-drums shown in development and each of which is provided with a plurality of contacts c' or c^2, arranged upon rotation of the drum to be engaged by contact brushes or fingers b' b^2, &c. Drum C' controls motors 1 and 3, while the drum C^2 controls the motors 2 and 4. These drums are mechanically of the well-known cylinder type and need not be further described. The arrangement of contacts on each drum is in accordance with the system and apparatus for controlling motors described and claimed in the applications of F. A. Merrick, Serial Nos. 713,690 and 726,928, filed April 4, 1899, and August 11, 1899, respectively—that is to say, each drum has contacts so arranged as to change two motors from series to parallel relation through a series of intermediate relations in which artificial resistance in series with the motors is first gradually removed from circuit as their counter electromotive force increases, then the fields are connected in multiple with the armatures in series, then the armatures are connected in multiple and the fields in series, and finally the two motors as a whole are connected in multiple. The two drums are duplicates of each other, except that the upper group on the drum C^2 are grounded on shaft, while the drum C' is provided with a continuous contact c d for the upper brush b', to which is connected the conductor C D, which connects the two drums electrically in series.

g g' g^2 are intermeshing gear-wheels which connect the shaft of the two drums, and D is the operating handle or lever.

R S represent the reversing and cut-out switch, which is also in general of a well-known type, with a plurality of contacts S and brushes b s for engagement therewith. This switch has seven different positions, indicated by the dotted vertical lines and marked, respectively, "2 & 4 back," "2 & 4 ahead," "A ahead," "off," "back," "1 and 3 back," "1 and 3 ahead."

The conductor C D is connected to the brush b^{27} of the controller C^2, and this brush is connected to a contact s^{49}, which is grounded on the shaft of the reversing and cut-out switch. This connection provides an immediate ground connection for motors 1 and 3 when the reversing and cut-out switch is set in position to run these two motors either forward or backward.

RB', RB^2, RB^3, and RB^4 designate, respectively, four resistance-boxes or rheostats arranged in two pairs, whose individuals are electrically connected in each pair and having their elements or resistance units arranged and connected so that portions of the resistance of each box may be successively cut into and out of circuit by the action of the controller-drums C' C^2 and also by the action of the brake-controlling switch presently described, each of said drums controlling the relation to circuit of one pair of the boxes.

We do not deem it necessary to describe in detail the grouping and arrangement of the various contacts or to specifically point out the various electrical connections, as they are best seen and understood by reference to the drawings, and our invention is not limited thereto. Nor will it be necessary to trace out the path of the circuit in the several different positions of the drums C' C^2, as this is graphically shown in Fig. 5. By the lettering on the drawings indicating the connections of the various leads and conductors this may be readily done. Referring to Fig. 5, it will be seen that in the first position of the said drums all the elements of all four motors are connected in series, the artificial resistance being also in series with the motors, the current passing through the armatures and field-coils of motors Nos. 1 and 3, thence through one pair of the resistance-boxes RB' RB^2, and thence through the other two motors and the other pair of resistance-boxes to ground. At position No. 2 a part of the resistance is removed from circuit, and at position No. 3 still more is removed. At position No. 4 the entire resistance is removed, the motors still remaining all in series. At position No. 5 the field-coils of each pair of motors are connected in multiple. The circuit is then momentarily opened and the armatures of each pair of motors are connected in multiple with the fields in series. This is shown at position No. 6. In position No. 7, which is the final position, each pair of motors are connected in full multiple. In passing from position 4 to position 5 the field-coils of one motor of each pair are temporarily removed from circuit, and in passing from position 6 to position 7 the circuit is momentarily broken through the armature of one motor of each pair, and then through the field-coils of the same, preparatory to passing to full multiple connection of each pair. These, however, are not indicated or notch positions of the controller and are not shown in the diagram Fig. 5. Throughout all these circuit changes the two pairs of motors remain connected in series. It will be readily seen that in this way we are able to get the maximum effect of torque in starting the motors, which is important where the load is heavy. This method of control also enables a higher potential to be used on the line with a much less sudden drop in potential.

We will now proceed to describe our improved brake-controlling switch, (shown at BCS in Fig. 1.) This switch consists of a rotary drum similar mechanically to the controller-drums and carrying upon its periphery a plurality of contacts which we have marked

Z Z′ and z z', &c., to z^{23}. These contacts are arranged in seven electrically-disconnected groups. Contacts Z Z′ constitute one group, contacts z z' z^2 z^3 z^4 z^5 the second group, contacts z^6 and z^7 the third group, contacts z^8 z^9 z^{10} z^{11} the fourth group, contacts z^{12} to z^{17}, inclusive, the fifth group, contacts z^{18} and z^{19} the sixth group, and contacts z^{20} to z^{23}, inclusive, the seventh group. It will be noted that in the arrangement of contacts groups 2 and 5, 3 and 6, and 4 and 7 are respectively duplicates. It will also be noted that if a vertical central line be drawn through the said groups a similar arrangement of contacts is found, with the exception of the first group upon each side of said line with an open space between them. For engagement with these contacts two opposite sets of brushes or fingers are provided, those at one side being marked P p p' p^2, &c., to p^{11}, and those at the opposite side R r r' r^2, &c., to r^8. These two sets of brushes are designed to engage, respectively, the duplicated contacts at the two sides of the drum, there being, however, two less brushes of the r group than of the p group. The drum has four positions in which the brushes r to r^{11} and p to p^9 engage the contacts of the second, third, fourth, fifth, sixth, and seventh groups, and another or off position in which the brushes P and R engage the contacts Z Z′, the other brushes being out of contact. Boc indicates a blow-out coil for the said drum, and L C a lock-magnet-coil having an armature K, (see Fig. 3,) carrying a pawl K′, arranged to engage a tooth K^2 on the shaft of the brake-controller drum. K^3 is a spring for retracting the said armature when it is released by the magnet. The brush R is connected to the trolley or high-potential side of the line through the usual car wiring and instruments, as shown, and the brush P is connected to the bottom brush of the controller-drum C′ through the magnet-coil L C, as shown. The circuit from the trolley to the controllers C′ C^2 and the motors must therefore pass through the brush R, contacts Z Z′, and coil L C. Therefore no current can pass to the motors except the brake-controller is in its off position, and so long as the current is passing to the motors the coil L C is energized and keeps the armature-pawl K′ in engagement with the tooth K^2. The brake-controller is thereby locked and cannot be operated until the current is cut off from the motors. Brush p is connected to the negative side of the armature A^4 and brush p^{11} to the positive side of the same. Brushes p', p^2, and p^8 are connected to two of the resistance-boxes. Brush p^3 is connected to the negative side of the field-coil F′ and brush p^4 to the positive side of the same. Brush p^5 is connected to the positive side of armature A^3 and brush p^6 to the negative side of the same. Brush p^7 is connected to ground. Brush p^9 is connected to the negative side of the field-coils F^2 and brush p^{10} to the positive side of the same. Brush r is connected to the negative side of armature A^2 and brush r^9 to the positive side of the same. Brushes r' r^6 are connected to the resistance, brush r^2 to the negative side of field-coils F^3, and brush r^3 to the positive side of the same, brush r^4 to the positive side of armature A′, and brush r^5 to the negative side of the same. Brush r^7 is connected to the negative side of field-coils F^4, and brush r^8 to the positive side of the same through the blow-out coil Boc. The various connections are made by means of branches to the main leads. When the drum is moved to the first position indicated by the dotted vertical lines 1, the circuit from line to the motors is broken and the path of the current may be traced as follows: from the positive brushes of the armatures A^2 and A^4 in multiple to the brushes r^9 p^{11}, contacts z^{22} z^{32}, brush p^{10}, field-coils F^2 to brush 9, contacts z^{18} z^{19}, brush r^8, field-coils F^4, resistance-boxes RB^3 RB^4 to brush p^7, contacts z^{14} z^{12} z^{13}. The path of the current is here divided, the contact z^{12} being connected to the negative brush of the armature A′ through brush r^5, while the contact z^{13} is connected to the negative brush of the armature A^3 through the brush p^6. The current from the positive brushes of the said armatures meets in the contacts of the fourth group through the brushes r^4 p^5 and, uniting, passes to field F′ by brush p^4, returning to contact z^6, thence by contact z^7 and brush r^3 to the field-coil F^3, thence through resistance RB′ RB^2, thence to brush r', thence to contacts z z', and to the negative brushes of the respective armatures A^2 A^4.

It will be seen that the motors are connected in circuit relation similar to positions 6 of the controllers C′ C^2, except that the resistance is in circuit and the armature connections are reversed. In position 2 brush p^7 loses its connection with contact z^{18} and instead brush r^6 engages the contact z^{15}. Brush p' also loses engagement with contact z^2 and brush r' engages contact z^3. The effect of these changes, it will be readily seen, is to cut out portions, respectively, of the resistances RB′ RB^3 by short-circuiting them. In position No. 3 the brushes r^6 and r' become disengaged from the respective contacts z^{15} and z^3 and instead brushes p^8 and p^2 engage, respectively, the contacts z^{16} and z^4. This short-circuits still more of the resistance. In position No. 4 brushes p^8 and p^2 lose their respective engagements and brushes r^2 and r^7 engage, respectively, the contacts z^5 and z^{17}. This, it will be seen, short-circuits the entire resistance by providing a direct return path to the brake-controller from the negative sides of fields F′ and F^4. The connection of the motors remains unchanged in positions 2, 3, and 4.

By placing the armatures in multiple and the fields in series while the motors are running as generators we are enabled to keep up the strength of the fields as the speed of the armatures decreases, so that combined with

the decrease in the ohmic resistance of the motor-generator circuit by gradually removing the artificial resistance a nearly-constant and properly-regulated braking action results, the potential of the current generated being nearly the same as that at which the motors run when connected with the line-circuit.

By the described arrangement of the contacts with duplicate brushes we provide a very compact construction of switch. The contacts of the fourth and seventh groups effect the multiple connection of the armatures and their connection with the fields, the contacts of the third and sixth groups effect the series connection of the fields, and the contacts of the second and seventh groups control the resistance.

This switch, it will be seen, may be readily adapted for use in connection with a single pair of motors by omitting one group of each of the duplicate groups and is applicable also for use in connection with various types and constructions of the motor-controllers.

It is obvious that the particular construction and arrangement which we have herein shown and described may be varied without departing from our invention as hereinafter claimed. Hence we do not wish to be limited to non-essential and unimportant details.

Having thus described our invention, what we claim, and desire to secure by Letters Patent, is—

1. The combination with four electric motors, of two controller-drums, each of which has contacts and connections for changing one pair of said motors from series to parallel, said drums being electrically connected in series with each other.

2. The combination with four electric motors, of two controller-drums, each of which has contacts and connections for changing one pair of said motors from series to parallel, said drums being electrically connected in series with each other, and gear connections between the shafts of said drums whereby they may be operated in unison.

3. The combination with four electric motors, of two controller-drums electrically connected in series, one with the other, and mechanically intergeared to rotate in unison, each of said drums having contacts and connections for connecting two motors in series, with either element of one motor in series with the corresponding element of the other motor, and the other elements in multiple, or with the two motors as a whole in parallel.

4. The combination with four electric motors, of two controller-drums mechanically connected to rotate in unison, and each having contacts, whereby two of the motors may be connected in series, or with their armatures in series and their fields in parallel, or with their fields in series and their armatures in parallel, or in parallel as a whole, and means for maintaining a series connection between the said drums in all positions thereof.

5. The combination with a plurality of electric motors, and a controller therefor, of a brake-controlling switch having contacts which control the connection of the motors and the said controller to line and which break such connection when the brake-controlling switch is moved from its off position.

6. The combination with a plurality of electric motors, of a brake-controlling switch, and an electro magnetic locking device for said switch in circuit with the motors, whereby said switch can be actuated only when the motors are disconnected from line.

7. The combination with a plurality of electric motors, of a brake-controlling switch therefor, a magnet-coil in circuit with the motors, an armature having a pawl for locking engagement with the shaft of said switch, whereby the latter is released only when the circuit through the motors is broken.

8. The combination with a plurality of electric motors, of a brake-controlling switch connected with the motor-circuit, contacts on said switch which control the connection of the motors with the line-circuit and which break such connection when the switch is moved from its off positions, a magnet-coil also in the motor-circuit, and an armature-pawl controlled by said coil engaging the shaft of said switch, whereby the latter is released only when the circuit through the motors is broken.

9. The combination with four electric motors, and a pair of controller-drums for connecting said motors and their elements in different circuit relations, of a combined reversing and cut-out switch also in circuit with said motors, said switch having a grounded contact and means for establishing a direct connection between said contact and two of the motors in certain positions of said switch.

10. The combination with a plurality of electric motors, of an electric brake-controlling switch having contacts and connections whereby the motors may be placed in a closed circuit independently of line, with their armatures in multiple and their fields in series, and their armature connections reversed.

11. The combination with four electric motors, and artificial resistance for connection in circuit therewith, of a switch for connecting said motors in a closed circuit to run as generators, and having contacts and connections whereby the motors may be series connected in two pairs with the armatures of each pair in multiple and their fields in series, and other contacts for connecting in circuit more or less of the said resistance.

12. The combination with a plurality of electric motors, controlling-switch therefor, consisting of a rotating drum having therein duplicate sets of contacts, a set of brushes or fingers for each set of contacts, and the necessary electrical connections whereby as said drum is rotated, the motors are connected in a local circuit, to run as generators, part of

the said circuit being effected through one set of contacts and fingers and another part through the other set of contacts and fingers.

13. A brake-controlling switch for four motors having fixed contact fingers or brushes, and a rotary drum having two duplicate groups of contacts, each of which groups is arranged to connect the field-coils of one pair of motors in series, two other duplicate groups, each of which is arranged to connect the armatures of one pair of said motors in multiple to run as generators, and two other duplicate groups to insert in and remove from the circuit an artificial resistance.

14. A brake-controlling switch for four motors having fixed contact fingers or brushes, and a rotary drum having two duplicate groups of contacts, each of which groups is arranged to connect the field-coils of one pair of motors in series, two other duplicate groups, each of which is arranged to connect the armatures of one pair of said motors in multiple to run as generators, and two other duplicate groups to insert in and remove from the circuit an artificial resistance, said groups being also divided into two duplicate sets, and the said brushes being arranged in two different sets, one set for each set of contacts.

15. A brake-controlling switch for four motors having fixed contact fingers or brushes, and a rotary drum having two duplicate groups of contacts, each of which groups is arranged to connect the field-coils of one pair of motors in series, two other duplicate groups each of which is arranged to connect the armatures of one pair of said motors in multiple to run as generators, and two other duplicate groups to insert in and remove from the circuit an artificial resistance, and other contacts for connecting the motors in circuit with the line when the switch is in off position.

In testimony whereof we have affixed our signatures in presence of two witnesses.

FRANK A. MERRICK.
EMMETT W. STULL.

Witnesses:
MYRTLE E. SHARPE,
ANNIE M. MOSES.