H. E. WHITE.

CONTROL OF ELECTRICALLY OPERATED SWITCHES.

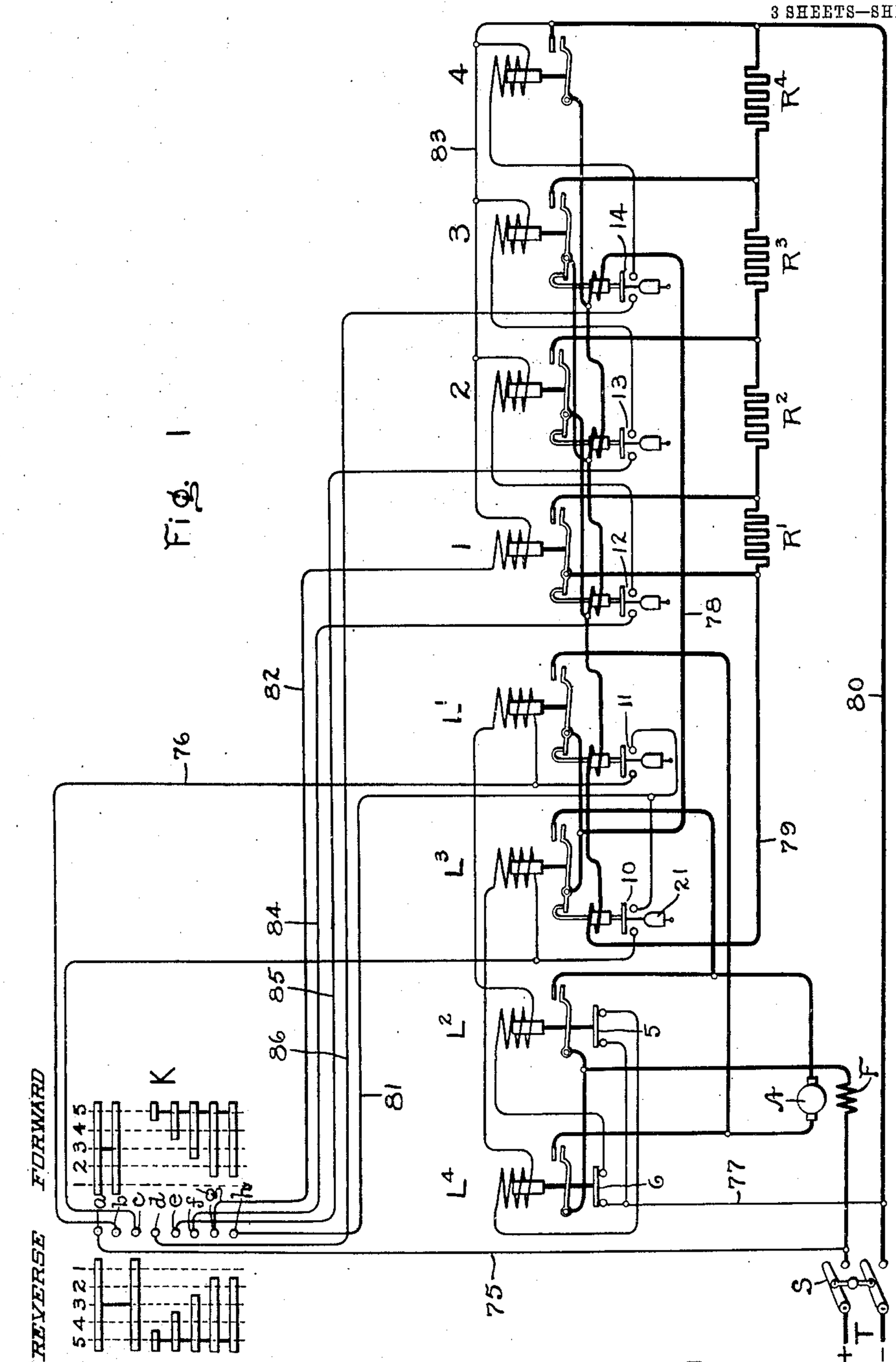
APPLICATION FILED FEB. 27, 1909.

969,584.

Patented Sept. 6, 1910.

3 SHEETS—SHEET 1.

Fig. 1



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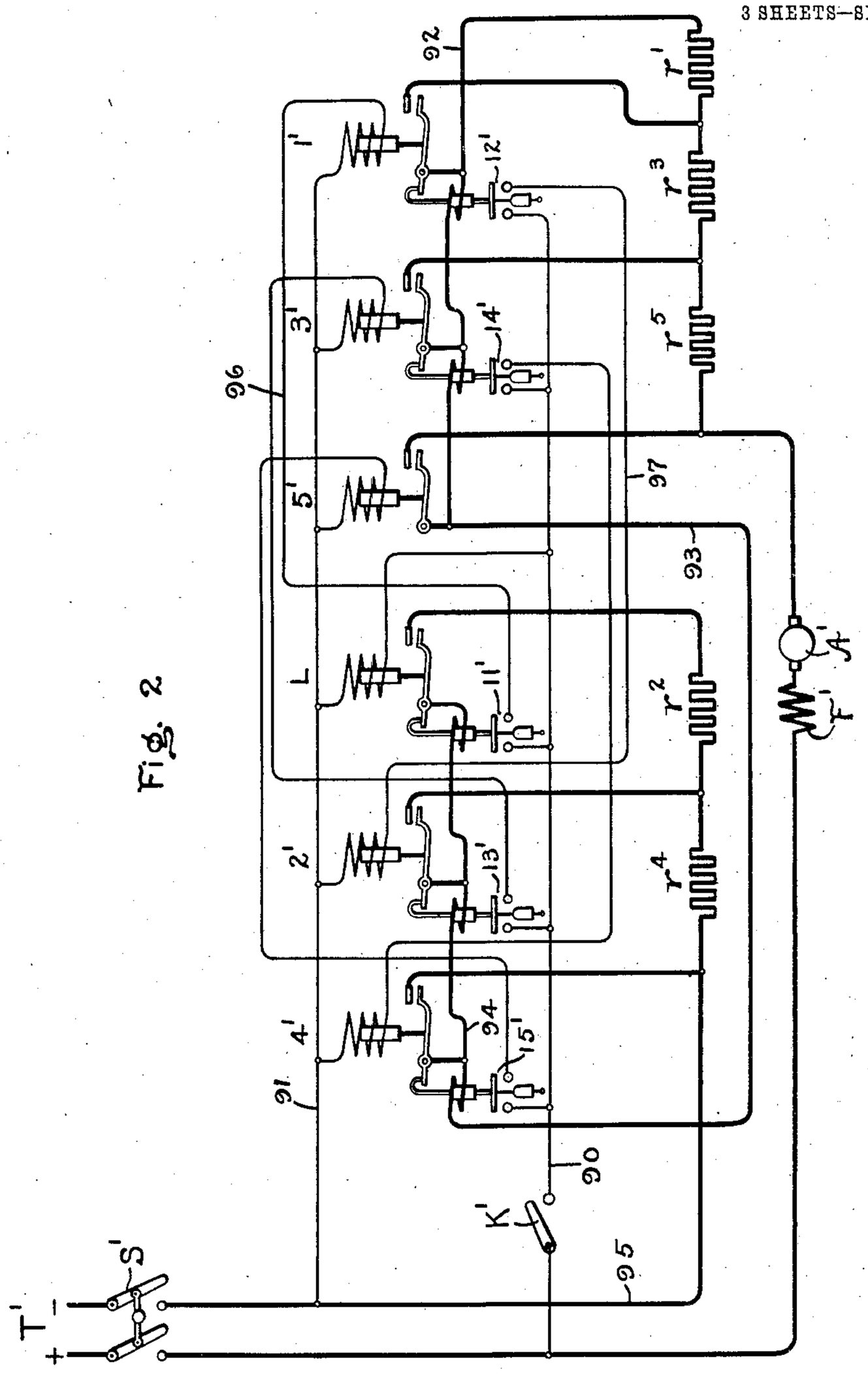

Fig. 2

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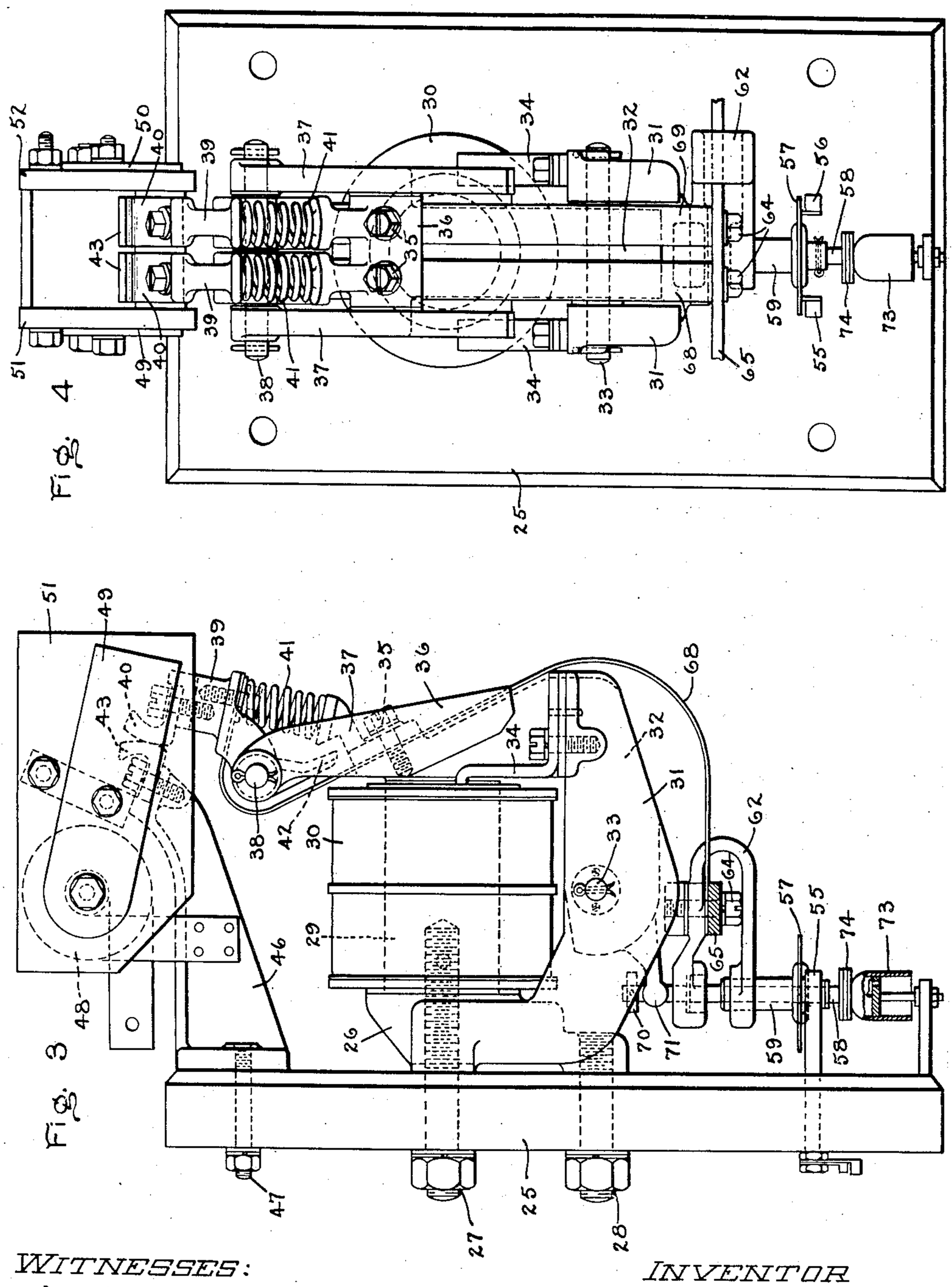

Fig. 4

Fig. 3

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UNITED STATES PATENT OFFICE.

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CONTROL OF ELECTRICALLY-OPERATED SWITCHES.

969,584. Specification of Letters Patent. Patented Sept. 6, 1910.

Application filed February 27, 1909. Serial No. 480,482.

To all whom it may concern:

Be it known that I, HAROLD E. WHITE, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Control of Electrically-Operated Switches, of which the following is a specification.

My invention relates to the operation and control of electrically controlled switches, and particularly to the operation successively in a certain order of a plurality of such switches. It is especially useful in connection with systems of motor control in which a plurality of electrically controlled switches or contactors are arranged to operate in succession to increase step-by-step the voltage applied to the motor. Arrangements of this kind are employed in starters for electric motors and have been so arranged that, by closing a single master-switch, contactors are caused to operate automatically in succession to cut out section by section the resistance interposed in the motor circuit on starting, or in some other way to increase step-by-step the voltage applied to the motor. Similar arrangements have also been used in systems of motor control in which the master-switch has a plurality of "on" positions and serves to regulate the operation of the series of contactors, the arrangement being such that the master-switch may either directly control the operation of the contactors one at a time, or may cause a number, or all of them, to operate automatically in succession. In such systems of control it is desirable that a certain time interval, the length of which depends upon the condition of service, should elapse between the operation of successive contactors. It is also often desirable that the rate of successive operation of these contactors depend, to a certain extent, upon the current in the motor circuit; that is, that the operation of a succeeding contactor be prevented if the closing of the preceding one has resulted in producing a current in the motor circuit in excess of a certain safe value. Various arrangements have been used for giving this so called "time and current limit" to the action of a series of switches used for the above described purposes.

It is a general object of my invention to provide a new and improved system of control for a plurality of contactors such that said contactors will not only close but will also open in succession under the control of the conditions in the power circuit.

In one aspect, my invention comprises an arrangement in which a plurality of contactors, intended for operation in succession, are each controlled by an auxiliary switch which is controlled in its closing and opening by an electromagnet energized from the power circuit to be regulated, the connections being such that each of said contactors in closing deënergizes the magnet of the auxiliary switch which controls the preceding contactor.

More specifically considered, my present invention comprises certain modifications in a type of control for a plurality of contactors covered by a joint application for Letters Patent by Eugene R. Carichoff and myself, Serial No. 480,483, filed February 27, 1909. In the system of control shown in that application closing of the contactors in succession under the control of the current in the power circuit is obtained, but opening of the contactors in response to excessive current in the power circuit was not contemplated or provided for. In the particular embodiment of my invention, hereinafter described, I arrange a system of control of this general type so that not only will closing of the contactors take place in succession under the control of the current in the power circuit, but also opening of said contactors in reverse order will take place if, at any time either during closing of said contactors or after they have all closed, the current in the power circuit exceeds a certain value.

Another application for Letters Patent filed by me concurrently with this application, namely,—February 27, 1909, Serial No. 480,481, covers certain improvements in the system covered by the joint application above referred to. Specifically considered, one of the objects of the invention covered in said application, Serial No. 480,481, is to provide means for insuring that, at all times and under all conditions, the closing of the auxiliary switches shall be under the control of their coöperating electromagnets.

In one of its aspects, the present invention comprises other means for insuring that the auxiliary switches shall always be controlled by their coöperating electromagnets. In the arrangement hereinafter de-

scribed, this means comprises a retarding device, such as a dash-pot applied to each auxiliary switch, for delaying the closing of said switch after it is released by its corresponding contactor.

In still another aspect, my invention comprises a new and improved form of auxiliary switch attachment for use with contactors in systems of control of the types covered in the applications above referred to.

Other aspects in which my invention may be viewed will be hereinafter pointed out in the following description and in the appended claims.

In carrying out the first of the above named objects of my invention, I so arrange the magnetizing coils of the auxiliary switch attachments with reference to the contactors and power circuit that said coils are initially energized and each contactor in closing completes a circuit which results in the deënergization of the magnetizing coil of the auxiliary switch attachment which controls the control circuit for the preceding contactor. The electromagnet of each auxiliary switch is so designed that although it will allow the switch to close, when its corresponding contactor has closed, if the current in the power circuit is below a certain value, said magnet will cause the auxiliary switch to open if at any time the current in the power circuit rises above a certain value which is higher than that at which said switch closed. With auxiliary switch attachments so designed and arranged with relation to the contactors, at any instant during the operation, the magnets of those auxiliary switches are deenergized which control the control circuits of the closed contactors previous to the last closed contactor. If, therefore, after some or all of the contactors have closed the current in the power circuit reaches the value at which said auxiliary switches are electromagnetically opened, the auxiliary switch controlling the last closed contactor opens, thereby causing opening of said contactor which in opening causes the energization of the magnet of the auxiliary switch controlling the previous contactor; and, if the excess current continues to exist, opening of the contactors in succession will continue until the current in the power circuit falls below that value at which the auxiliary switches are caused to open. In the particular embodiment hereinafter described, I have so arranged the magnet coils of the auxiliary switch attachments that they will all be connected in the motor circuit upon the initial completion thereof through all of the starting or control resistance and each resistance controlling contactor will in closing short circuit its section of resistance, and so that each resistance controlling contactor, except the first, will at the same time complete a shunt circuit around certain of the magnetizing coils of those auxiliary switches which control the control circuits of the previous contactors. With such an arrangement it is clear that the resistance controlling contactors may be made to close automatically in succession and to open automatically in reverse succession, the closing taking place when the current in the motor circuit is below a certain value and the opening taking place when the current in the motor circuit exceeds a certain higher value.

In carrying out the second object of my invention, as above stated, I provide each auxiliary switch attachment with a dash pot, or similar device, which retards the closing of the auxiliary switch when the same is released by the closing of its corresponding contactor. The time interval thus given to the closing of an auxiliary switch is sufficient to allow the current in the motor circuit to increase in response to the closing of the contactor and become effective in the magnetizing coil of the auxiliary switch attachment.

In carrying out the third object of my invention, as above mentioned, I provide the construction of auxiliary switch attachment shown in Figures 3 and 4 and hereinafter described.

Referring to the drawings, Fig. 1 illustrates diagrammatically a system of motor control having my invention incorporated therein; Fig. 2 is another embodiment of my invention arranged as an automatic starter for a direct current motor; Fig. 3 is a side elevation of a contactor having my improved auxiliary switch attachment applied thereto; and Fig. 4 is a front elevation of the device shown in Fig. 3.

Although I have shown in Figs. 1 and 2 my invention as applied to a simple system of motor control and to a simple automatic starter for a direct current motor, these applications of it are, of course, merely illustrative, and, as will be obvious to those skilled in this art, the invention may equally well be applied to other forms of dynamo-electric machinery and to other types of control; or, in fact, employed in any connection where it is desired to regulate the conditions in a power circuit by means of a plurality of switches operating in succession.

In the diagrammatic representation used and in the figures which illustrate the mechanical and electrical construction of the switches or contactors which effect connections in the motor circuits, I have shown contactors which are electromagnetically operated, but it will, of course, be understood that my invention is equally applicable to those systems of control, now well known, in which the switches are operated pneu-

matically. It is, therefore, my intention to cover such systems in this application and wherever I have used the expression "electrically controlled switch" or "contactor," I mean to include both those which are operated electromagnetically and those which are operated electropneumatically or otherwise.

Referring to the drawings, particularly Fig. 1, a source of current is indicated at T, to which the power and control circuits of the system are connected through a switch S. The armature of the motor to be controlled is indicated at A and its field at F, the motor in this case being a series motor, although other types of motor might equally well have been shown. Electrically controlled switches or contactors of any suitable construction, as for example, that illustrated in Figs. 3 and 4 and hereinafter described, are indicated at L^1, L^2, L^3 and L^4 as arranged to connect the motor to the source for either direction of rotation. A starting or control resistance is shown as made up of sections R^1, R^2, R^3 and R^4 which may be short circuited by suitable contactors 1, 2, 3 and 4, respectively, the construction of these contactors and of their auxiliary switch attachments being shown in Figs. 3 and 4 and hereinafter described. A master-switch K is shown developed in the usual conventional manner and as of the type in which a drum, provided with suitable segments, coöperates in both directions from "off" position with a set of fingers *a*, *b*, *c*, *d*, *e*, *f*, *g* and *h*. This master-switch serves to regulate the operation of the contactors for both directions of rotation of the motor, one direction of movement serving for forward and the other for reverse operation. Contactors L^2 and L^4 are provided, respectively, with auxiliary switches 5 and 6 interposed respectively in the control circuits of the contactors L^3, L^4 and L^1, L^2. These auxiliary switches are shown in a well known conventional manner and may consist of a contact disk which is mechanically connected to the movable element of the contactor and is arranged to bridge two fixed contacts when the contactor is in its open position. With this arrangement it will be clear that the contactors L^1, L^2, L^3 and L^4 are so interlocked that one pair can close only when the other pair is open. Contactors L^1, L^3, 1, 2 and 3 are provided with auxiliary switch attachments, the construction of which will be more fully explained in connection with Figs 3 and 4, in which they are illustrated. These auxiliary switches are denoted in Fig. 1 by the characters 10, 11, 12, 13 and 14. Briefly stated, these auxiliary switch attachments comprise fixed contacts which are bridged by a contact disk of usual form, to which is secured a core of magnetic material having extending upwardly from it a rod, which at its upper end is engaged by a part of the movable member of the contactor being thereby held in its raised position when the contactor is open and permitted to fall when the contactor is closed. Said core is arranged to move in the field of an electromagnet, the energization of which depends upon the current in the motor circuit, the magnet coil in the arrangement shown being connected in the motor circuit, as hereinafter explained. The movable member of each auxiliary switch attachment is retarded in its movement in the direction to close the auxiliary switch by a dash pot 21 which, however, does not impede the auxiliary switch in opening. The electromagnet of the auxiliary switch attachment is so designed that it will hold the auxiliary switch open after the movable member of the same is released by the closing of the corresponding contactor, while the current in the motor circuit exceeds a certain value; and so that said electromagnet will cause said auxiliary switch to open after it has closed, if the current in the motor circuit exceeds a certain higher value. The arrangement of motor and control circuits in the system shown will be clear from the drawing and from the description hereinafter given of the mode of operation of the system, but in general it may be stated that the control circuit of each of the resistance controlling contactors 1, 2, 3 and 4 is connected to the source through the auxiliary switch 11, for one direction of rotation, and through the auxiliary switch 10, for the other direction of rotation; and the control circuit for each of contactors 2, 3 and 4 passes also through the auxiliary switch 12, 13 or 14 coöperating with the previous contactor 1, 2 or 3. It may be noted also that each resistance contactor 2, 3 and 4 in closing causes the deenergization of the electromagnet of the auxiliary switch which controls the control circuit for the preceding contactor, by shunting both its particular section of resistance R^2, R^3 or R^4 and the electromagnet coöperating with the auxiliary switch which controls the control circuit for the preceding contactor.

Referring now to Figs. 3 and 4, I will proceed to describe the particular arrangement of contactor and auxiliary switch attachment which I have found well suited to the carrying out of my invention. As far as the construction of the contactor itself is concerned, that shown in Figs. 3 and 4 is substantially the same as that illustrated in my application, Serial No. 480,481, filed February 27, 1909, above referred to. This particular construction of contactor I do not regard as my invention, and I wish it to be understood that many other forms may be employed equally well. A backboard 25

of suitable insulating material is shown, to which is secured a casting 26 by means of bolts 27 and 28 passing through the backboard 25. The form of the casting 26 will be apparent from the drawing, it being understood that the cylindrical portion 29 thereof extends outwardly to form the core upon which the actuating coil 30 of the contactor is mounted, while ears 31 extend outwardly below the coil 30 and receive between them the movable armature 32 which is pivoted upon a pin 33 extending through the ears 31 and through said armature 32. Angle irons 34, bolted to the top of the ends of the ears 31, serve to hold the coil 30 on the core 29 while at the same time providing for its easy removal. Bolted to the armature 32 by bolts 35 is a casting 36 having ears 37, between which on the pin 38 are pivoted contact fingers 39 carrying the removable lips 40 of well known form. The pivoted contact fingers 39 are forced in a counter clockwise direction by the springs 41, as shown, heels 42 which engage with a shoulder upon the casting 36 serving to limit the movement of the fingers 39 by the springs 41. The lips 40 coöperate with the lips 43 removably secured to a bracket 46 bolted to the backboard 25 by a bolt 47, as clearly shown. This bracket 46 carries a magnetic blow out coil 48 having the pole pieces 49 and 50 embedded in the walls 51 and 52 of an arc chute formed of suitable resisting material. Below the contactor and secured to the backboard 25 are fixed contact members 55 and 56 which are bridged by a contact disk 57, of well known form, carried by a rod 58. The rod 58 carries a core 59 of magnetic material, said core being arranged for movement in the field of an electromagnet having a frame 62 of magnetic material of the form shown in the drawings. This frame 62 is bolted to the bottom of the contactor frame 26 by means of bolts 64 which also serve to support the bus-bar 65 which passes through the loop of the frame 62 and serves as a magnetizing coil for the electromagnet. In the particular arrangement shown, which is adapted particularly for use in connection with the system of control shown in Fig. 2 and hereinafter described, the bus-bar 65 need not be insulated from the frame 62, and between said bus-bar and said frame are clamped the ends of flexible conductors 68 and 69 which serve to make good electrical connection between the bus-bar 65 and the movable contact fingers 39, the other ends of these conductors 68 and 69 being connected to these contact fingers, as clearly shown in the drawing and as will be understood by those familiar with contactor construction. Under certain conditions, however, it may be desirable to insulate the bus-bar 65 from the contactor frame and to connect the flexible conductors 68 and 69 with auxiliary bus-bars connecting with the bus-bars 65 at other points as, for example, as shown in the system of Fig. 1. The core 59 passes freely through a hole in the lower part of the frame 62 and the upper end of the rod 58 passes freely through a hole in the upper part of said frame as clearly seen from Fig. 3. The holes in the frame 62 may be lined with brass tubing in a well known manner to prevent sticking. The upper end of the rod 58 carries pinned thereto a disk or washer 70, beneath which on each side of the rod 58 extend heels 71 projecting from and preferably formed integral with the armature 32. The upper end of the core 59 may when in its upper position fit into a counter-sunk portion of the frame 62, as shown in Fig. 3, and a brass washer, interposed between the top of the core 59 and the bottom of the counter-sunk portion, may be used to prevent sticking between the core and the upper part of the frame 62 when the core is in its raised position. As shown in Figs. 3 and 4, the contactor and the auxiliary switch are both closed. In this position the heels 71 are in their lower position and the rod 58, carrying the contact disk 57 is free to drop unless it is held in its raised position by the magnetizing effect of the bus-bar 65, as before referred to and as hereinafter explained. The lower end of the rod 58 carries one of the parts of the dashpot 73 (denoted as 21 in Fig. 1) which, as clearly indicated, retards the falling of the core 59 and the closing of the auxiliary switch, without impeding upward movement of the core and opening of said switch. Removable disks 74 mounted on the rod 58 of the auxiliary switch may be used to vary the weight of the movable member of the auxiliary switch and thereby provide for adjustment of the current in the bus-bar 65 at which the auxiliary switch will close and open. This current limit value may, of course, be adjusted in any other way, as will be understood by those skilled in this art.

The arrangement of motor and control circuits in the system shown in Fig. 1 will be clear from the following description of the mode of operation of that system: The switch S being closed and the master-switch K being moved to its first forward position, a circuit is completed from the + side of the source, through the wire 75, through the controller fingers *a* and *b* and their coöperating segments to the wire 76, thence through the actuating coil of contactor L^1, actuating coil of contactor L^2, auxiliary switch 6, through the wire 77 to the — side of the source. The contactors L^1 and L^2 will, therefore, close and a motor circuit will be completed as follows: from the + side of the source, through the field F, main contacts of contactor L^2, armature A, main

contacts of contactor L^1, through the conductor or bus-bar 78, through the bus-bar serving as magnetizing coils for all of the auxiliary switch attachments, through conductor 79, resistance sections R^1, R^2, R^3 and R^4 and conductor 80 to the — side of the source. As long as the main switch K remains in its first forward position no further operation of the contactors will take place and the motor will remain connected to the source through all of the resistance. If the master-switch K is moved to its second forward position, the fingers *g* and *h* are brought into engagement with their coöperating segments and are connected to one another by them. It will be seen from the drawing that the finger *h* is connected by the wire 81 and through the switch 11 to the wire 76, and, therefore, if the auxiliary switch 11 is closed current will flow from the wire 76, through switch 11, wire 81, fingers *h* and *g* and their coöperating segments, wire 82, actuating coil of the resistance controlling contactor 1 and back to the — side of the source through the wires 83 and 80, thereby causing the closing of the contactor 1 and the short circuiting of the section of resistance R^1. Closing of the switch 11, however, is under the control of the current in the motor circuit, and if this exceeded a certain value at the time the master-switch was thrown to its second position, the switch 11 was not closed and closing of the contactor 1 was prevented. In this connection it is to be noted that the dash-pot 21, coöperating with the auxiliary switch 11, prevented the closing of this switch until the contactors L^1 and L^2 had closed and the motor current had energized the magnet controlling the auxiliary switch 11. As long as the master-switch remains in its second position, the line contactors L^1 and L^2 and the first resistance contactor only can close. In moving the master-switch to its third forward position, finger *f* comes into engagement with its coöperating segment and is connected to the wire 81 as was the finger *g*. A wire 84 leads from the finger *f*, through the auxiliary switch 12 to the actuating coil of the contactor 2, and thence through the wires 83 and 80 to the — side of the source. If, therefore, the switch 12 has closed the contactor 2 will be closed and the section of resistance R^2 will be short circuited. Closing of the switch 12 of course takes place under the control of the motor current, as in the case of auxiliary switch 11. It is obvious that further movement of the master-switch in the "on" direction will result in successively energizing the wires 85 and 86 and closing of the contactors 3 and 4 under the control of the auxiliary switches 13 and 14, respectively, the latter being responsive to current in the motor circuit and closing only when this current is below a certain value. It will, of course, be understood that the resistance controlling contactors 1, 2, 3 and 4 may not only be closed one at a time under the control of the master-switch K, but, if desired, the master-switch may be thrown immediately to its full "on" position, whereupon the closing of the contactors will take place automatically in succession under the control of the auxiliary switches which close only when the current in the motor circuit is below a certain value and thus prevent cutting out of the resistance too rapidly.

Thus far I have described the operation of my system, assuming that the current in the motor circuit does not rise above the certain high value at which the auxiliary switches, although once closed, are automatically opened. It is to be noted, however, that at any instant, either during the successive closing of the contactors, or after they have all closed, the magnets of those auxiliary switches are deënergized which control the control circuits of the closed contactors previous to the last closed contactor. In other words, each contactor in closing has caused the deënergization of the electromagnet of the auxiliary switch which controls the control circuit for the preceding contactor. With this arrangement, if at any time the current in the motor circuit exceeds the high value required to electromagnetically open an auxiliary switch, that auxiliary switch which controls the control circuit for the last closed contactor opens, thereby causing said contactor to open and reinsert a section of resistance in the motor circuit, at the same time opening the shunt around the magnet of the auxiliary switch controlling the control circuit of the previous contactor. If the reinsertion of this section of resistance does not cut down the current in the motor circuit below the value at which the auxiliary switches are opened, the next previous auxiliary switch is caused to open, resulting in the opening of the next contactor and the insertion of more resistance in the motor circuit. Opening of this contactor will throw the magnet of the next previous auxiliary switch into the motor circuit, and the successive opening of the contactors will continue as before until the current in the motor circuit falls below the excessive value last mentioned. It will thus be seen that the auxiliary switch devices coöperate with the contactors to cause the same to close and open in succession under the control of the current in the motor circuit.

In Fig. 2 I have shown a system of motor control similar to that of Fig. 1, but with the contactors and sections of resistance so arranged that the connections are somewhat simplified. In the system of Fig. 2 the

master-switch has but a single "on" position, and the operation of the contactors takes place altogether automatically after the closing of the master-switch, but, of course, it is understood that the system might equally well be arranged to give forward and reverse operation of the motor under the control of a master-switch similar to that shown in the system of Fig. 1. In Fig. 2 a source is indicated at T', with which the motor and control circuits are connected through a switch S'. The motor armature is indicated at A', its field at F' and the sections of starting or control resistance are arranged in two groups, r^5, r^3, r^1, and r^2, r^4. The contactor which completes the motor circuit is indicated at L and the resistance controlling contactors at 1', 2', 3', 4' and 5'. The contactors may be of the type used in the system of Fig. 1 and shown in Figs. 3 and 4 above described, and of these contactors, L, 1', 2', 3' and 4' are each provided with an auxiliary switch attachment similar to that used in the system of Fig. 1 and illustrated in Figs. 3 and 4, hereinbefore described. A master-switch K' of simple form controls the operation of the contactors in a manner hereinafter described. The arrangement of the motor and control circuits will be clear from the following description of the mode of operation of the system of Fig. 2: The switch S' being closed and the master-switch K' being also moved to its closed position, a circuit will be completed from the + side of the source, through the master-switch K^1, wire 90, actuating coil of the contactor L and wire 91 to the — side of the source. The contactor L, therefore, closes and in closing completes the motor circuit as follows: from the + side of the source, through the field F' and armature A' of the motor, through resistance sections r^5, r^3, r^1, the bus bar 92 serving as the magnetizing coils for the auxiliary switch attachments to the contactors 1' and 3', through conductor 93, bus bar 94 serving as the magnetizing coils for the auxiliary switch attachments to the contactors 4', 2' and L, through the main contacts of contactor L, resistance sections r^2 and r^4, and through conductor 95 to the — side of the source. The auxiliary switch 11' coöperating with the contactor L closes under the retarding influence of its dash-pot, if the current in the motor circuit is not above the value at which said auxiliary switch is magnetically held open, and when said switch closes a circuit is completed from the wire 90, through said switch 11' and wire 96 and through the actuating coil of the contactor 1' to the wire 91. Contactor 1' in closing short circuits the section of resistance r^1. The auxiliary switch 12' coöperating with the contactor 1' closes under the same conditions as the auxiliary switch 11' coöperating with contactor L, and the actuating coil of the contactor 2' is connected in circuit between the wires 90 and 91 through the auxiliary switch 12' and a wire 97. Contactor 2' in closing short circuits not only its section of resistance r^2 but also that portion of the bus-bar 94 which serves as a magnetizing coil for the auxiliary switch attachment of the contactor L. Similarly, contactor 3' short circuits the sections of resistance r^1 and r^3 and also that portion of the bus-bar 92 which acts as a magnetizing coil for the auxiliary switch 12' of the contactor 1'; and in a similar way contactors 4' and 5' short circuit not only the sections of resistance r^2, r^4 and r^5, respectively, but also those portions of the bus-bars 94 and 92 which coöperate, respectively, with the auxiliary switches 13', 11' and 14', 12' for the contactors 2', L and 3', 1'. It will thus be apparent that the contactors will close in succession under the control of the auxiliary switch devices, as in the case of the system of Fig. 1, until all the resistance is cut out and the only magnet of an auxiliary switch attachment which is magnetized, is that of the switch which controls the actuating circuit for the last closed contactor, namely, contactor 5'. The foregoing operation is based on the assumption that the current in the motor circuit does not exceed the certain high value at which the auxiliary switches are designed to be magnetically opened. If the current in the motor circuit does at any time exceed this value, the auxiliary switch controlling the actuating circuit of the last closed contactor will open, thereby causing the opening of said contactor and the insertion of the section of resistance controlled by it in the motor circuit exactly as in the case of Fig. 1 hereinbefore described.

With the resistance sections and contactors grouped as shown in Fig. 2, it is obvious that the connections between the contactors and the bus-bars are very simple and easily arranged.

While I have shown a particular arrangement of auxiliary switch attachment for use in the systems of control above described, I do not wish to be understood as in any way limiting myself thereto, since others, of course, may be used, for example, those shown and described in my application, Serial No. 480,481, filed February 27, 1909, above referred to.

What I claim as new and desire to secure by Letters Patent of the United States, is—

1. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, a plurality of auxiliary switches each arranged to control a contactor, and electromagnets energized from the power circuit each arranged to control the closing and opening of an auxiliary switch, whereby successive closing and open-

ing of said contactors takes place under the control of the conditions in the power circuit.

2. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, a plurality of auxiliary switches each arranged to control a contactor, electromagnets each controlling the closing and opening of an auxiliary switch, and connections whereby a contactor in closing deënergizes the electromagnet of the auxiliary switch which controls the preceding contactor.

3. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, auxiliary switches coöperating with certain of said contactors each arranged to control a succeeding contactor, means for holding each auxiliary switch open while its coöperating contactor is open, electromagnets each controlling the closing and opening of an auxiliary switch, and connections whereby a contactor in closing shunts the electromagnet of the auxiliary switch which controls the preceding contactor.

4. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, a plurality of auxiliary switches each arranged to control a contactor, electromagnets all energized from the power circuit upon completion thereof and each controlling the closing and opening of an auxiliary switch, and connections whereby a contactor in closing shunts the electromagnet of the auxiliary switch which controls the preceding contactor.

5. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, auxiliary switches coöperating with certain of said contactors each arranged to control a succeeding contactor, means for holding each auxiliary switch open while its coöperating contactor is open, electromagnets all energized from the power circuit upon the completion thereof and each controlling the closing and opening of an auxiliary switch, and connections whereby a contactor in closing shunts the electromagnet of the auxiliary switch which controls the preceding contactor.

6. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, a plurality of auxiliary switches each arranged to control a contactor, electromagnets energized from the power circuit each arranged to control the closing and opening of an auxiliary switch, and connections whereby at any instant during the successive operation of the contactors the magnets of those auxiliary switches are deënergized which control the closed contactors previous to the last closed contactor.

7. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, auxiliary switches coöperating with certain of said contactors each arranged to control a succeeding contactor, means for holding each auxiliary switch open while its coöperating contactor is open, electromagnets energized from the power circuit each arranged to prevent the closing of an auxiliary switch while the current in the power circuit exceeds a certain value and to open said switch if the current in the power circuit exceeds a certain higher value, and connections whereby a contactor in closing shunts the electromagnet of the auxiliary switch which controls the preceding contactor.

8. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, a plurality of auxiliary switches each arranged to control a contactor, electromagnets energized from the power circuit each controlling the closing and opening of an auxiliary switch, and connections whereby a contactor in closing both effects the desired connection in the power circuit and shunts the electromagnet of the auxiliary switch which controls the preceding contactor.

9. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, auxiliary switches coöperating with certain of said contactors each arranged to control a succeeding contactor, means for holding each auxiliary switch open while its coöperating contactor is open, electromagnets energized from the power circuit each controlling the closing and opening of an auxiliary switch, and connections whereby a contactor in closing both effects the desired connection in the power circuit and shunts the electromagnet of the auxiliary switch which controls the preceding contactor.

10. In combination with a power circuit, two groups of contactors intended for operation in succession alternately in the two groups to effect certain connections in said power circuit, auxiliary switches coöperating with certain of said contactors and arranged to control a succeeding contactor in the other group of contactors, means for holding each auxiliary switch open while its coöperating contactor is open, electromagnets energized from the power circuit each controlling the closing and opening of an auxiliary switch, and connections

whereby a contactor in closing shunts the electromagnet of that auxiliary switch cooperating with the preceding contactor in that group of contactors.

11. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, control circuits for said contactors, auxiliary switches each coöperating with a contactor and arranged to control the control circuit of a succeeding contactor, a connection between each contactor and its auxiliary switch whereby when the former is open the latter is held open and when the former is closed the latter is permitted to close, and an electromagnet, energized from the power circuit, arranged to control the closing and opening of each auxiliary switch when the corresponding contactor has closed whereby successive closing of said contactors takes place while the current in the power circuit is below a certain value and successive opening of said contactors takes place while the current in the power circuit exceeds a certain higher value.

12. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, control circuits for said contactors, auxiliary switches each coöperating with a contactor and arranged to control the control circuit of a succeeding contactor, a connection between each contactor and its auxiliary switch whereby when the former is open the latter is held open and when the former is closed the latter is permitted to close, an electromagnet energized from the power circuit arranged to control the closing and opening of each auxiliary switch when the corresponding contactor has closed, and connections whereby at any instant during the operation of the contactors the magnets of those auxiliary switches are deënergized which control the control circuits of the closed contactors previous to the last closed contactor.

13. In combination with a power circuit, a plurality of contactors intended for operation in succession to effect certain connections in said power circuit, control circuits for said contactors, auxiliary switches each coöperating with a contactor and arranged to control the control circuit of a succeeding contactor, a connection between each contactor and its auxiliary switch whereby when the former is open the latter is held open and when the former is closed the latter is permitted to close, electromagnets, the energization of which depend upon the current in the power circuit, arranged to prevent the closing of each auxiliary switch while the current in the power circuit exceeds a certain value and to open said switch if the current in the power circuit exceeds a certain higher value, and connections whereby each contactor in closing causes the deënergization of the electromagnet of the auxiliary switch which controls the control circuit for the preceding contactor.

14. In a system of motor control, a resistance, a plurality of contactors intended for operation in succession to short circuit said resistance section by section, control circuits for said contactors, auxiliary switches each coöperating with a contactor and arranged to control the control circuit of a succeeding contactor, a connection between each contactor and its auxiliary switch whereby when the former is open the latter is held open and when the former is closed the latter is permitted to close, electromagnets energized from the motor circuit arranged to prevent the closing of each auxiliary switch while the current in the motor circuit exceeds a certain value and to open said switch if the current in the motor circuit exceeds a certain higher value, and connections whereby each contactor in closing shunts both its section of resistance and the electromagnet coöperating with the auxiliary switch which controls the control circuit for the preceding contactor.

15. In a system of motor control, a resistance, a plurality of contactors intended for operation in succession to short circuit said resistance section by section, control circuits for said contactors, auxiliary switches each coöperating with a contactor and arranged to control the control circuit of a succeeding contactor, a connection between each contactor and its auxiliary switch whereby when the former is open the latter is held open and when the former is closed the latter is permitted to close, electromagnets energized from the motor circuit arranged to prevent the closing of each auxiliary switch while the current in the motor circuit exceeds a certain value and to open said switch if the current in the motor circuit exceeds a certain higher value, and connections whereby each contactor in closing completes a shunt circuit around the section of resistance controlled by it and the previous sections and around the electromagnets coöperating with the auxiliary switches which control the control circuits of previous contactors.

16. In combination with a power circuit, a plurality of groups of contactors intended for operation in succession in the groups successively to effect certain connections in said power circuit, control circuits for said contactors, an auxiliary switch located adjacent each contactor and arranged to control the control circuit of a contactor in another group, electromagnets, the energization of which depends upon the current in the power circuit, arranged to control said auxiliary switches, and connections whereby

in each group of contactors and auxiliary switches, at any instant during the operation, the electromagnets of those auxiliary switches located adjacent the contactors in that group previous to the last closed contactor are deënergized.

17. In combination with a power circuit, a plurality of groups of contactors intended for operation in succession in the groups successively to effect certain connections in said power circuit, control circuits for said contactors, a plurality of auxiliary switches located adjacent each group of contactors and arranged to control the control circuits of the contactors in another group, electromagnets, the energization of which depends upon the current in the power circuit, arranged to control said auxiliary switches, and connections whereby each contactor in closing causes the deënergization of the electromagnet of that auxiliary switch which is located adjacent that group of contactors and that which controls the control circuit of the contactor in another group which has previously closed.

18. In combination with a power circuit, two groups of contactors intended for operation in succession alternately in the two groups to effect certain connections in said power circuit, control circuits for said contactors, an auxiliary switch located adjacent each contactor and arranged to control the control circuit of a succeeding contactor in the other group, electromagnets, the energization of which depends upon the current in the power circuit, arranged to control said auxiliary switches, and connections whereby each contactor in closing completes a shunt circuit around the electromagnet of that auxiliary switch located adjacent to the previous contactor in that group.

19. In a system of motor control, two groups of resistance sections, two groups of contactors intended for operation in succession alternately in the two groups to short circuit said resistance section by section, control circuits for said contactors, auxiliary switches each located adjacent a contactor and arranged to control the control circuit of a succeeding contactor in the other group, electromagnets energized from the motor circuit arranged to control each auxiliary switch, and connections whereby each contactor in closing short circuits both a section of resistance and the electromagnet of that auxiliary switch which is located adjacent the previous contactor in that group.

20. In combination with a power circuit, a plurality of groups of contactors intended for operation in succession in the groups successively to effect certain connections in said power circuit, control circuits for said contactors, auxiliary switches coöperating with the contactors of each group and arranged to control the control circuit of a contactor in another group, a connection between each contactor and its auxiliary switch whereby when the former is open the latter is held open and when the former is closed the latter is permitted to close, electromagnets, energized from the power circuit, arranged to control the closing and opening of said auxiliary switches, and connections whereby, in each group of contactors at any instant during the operation, the electromagnets coöperating with the auxiliary switches of the contactors in that group previous to the last closed contactor are deënergized.

21. In combination with a power circuit, a plurality of groups of contactors intended for operation in succession in the groups successively to effect certain connections in said power circuit, control circuits for said contactors, auxiliary switches coöperating with the contactors of each group and each arranged to control the control circuit of a contactor in another group, a connection between each contactor and its auxiliary switch whereby when the former is open the latter is held open and when the former is closed the latter is permitted to close, electromagnets, energized from the power circuit, arranged to control the closing and opening of said auxiliary switches, and connections whereby each contactor in closing causes the deënergization of the electromagnet of the auxiliary switch which cooperates with a preceding contactor in that group.

22. In combination with a power circuit, two groups of contactors intended for operation in succession alternately in the two groups to effect certain connections in said power circuit, auxiliary switches each cooperating with a contactor and arranged to control the control circuit of a succeeding contactor in the other group of contactors, a connection between each contactor and its auxiliary switch whereby when the former is open the latter is held open and when the former is closed the latter is permitted to close, electromagnets, energized from the power circuit, arranged to control the closing and opening of said auxiliary switches, and connections whereby each contactor in closing causes the deënergization of the electromagnet in the auxiliary switch coöperating with the preceding contactor in that group.

23. In a system of motor control, sections of resistance arranged in two groups, two groups of contactors intended for operation in succession in the two groups alternately arranged to short circuit said sections of resistance, control circuits for said contactors, auxiliary switches each coöperating with a contactor and arranged to control the con-

trol circuit of a succeeding contactor in the other group of contactors, a connection between each contactor and its auxiliary switch whereby when the former is open the latter is held open and when the former is closed the latter is permitted to close, electromagnets, energized from the motor circuit, arranged to control the closing and opening of each auxiliary switch after the closing of its corresponding contactor, and connections whereby each contactor in closing short circuits both a section of resistance and the electromagnet coöperating with the previous contactor in that group.

24. In combination with a contactor having a fixed contact member, a movable contact member, of an auxiliary switch attachment comprising a fixed contact member, a movable contact member, a connection between the movable contact member of said contactor and the movable contact member of said auxiliary switch attachment whereby when said contactor is open the contacts of said auxiliary switch attachment are held open and when said contactor is closed the contacts of said auxiliary switch attachment are permitted to close, a dash pot arranged to retard the closing movement of the movable contact member of the auxiliary switch attachment when the same is released by the closing of the contactor, a core of magnetic material connected to the movable contact member of said auxiliary switch attachment, a field frame of magnetic material with which said core coöperates, and a busbar passing through said frame and serving as a magnetizing coil for said field frame.

In witness whereof, I have hereunto set my hand this 26th day of February, 1909.

HAROLD E. WHITE.

Witnesses:

BENJAMIN B. HULL,

HELEN ORFORD.