H. F. STRATTON.

ELECTRIC CONTROLLER.

APPLICATION FILED SEPT. 9, 1915.

1,225,686.

Patented May 8, 1917.

3 SHEETS—SHEET 1.

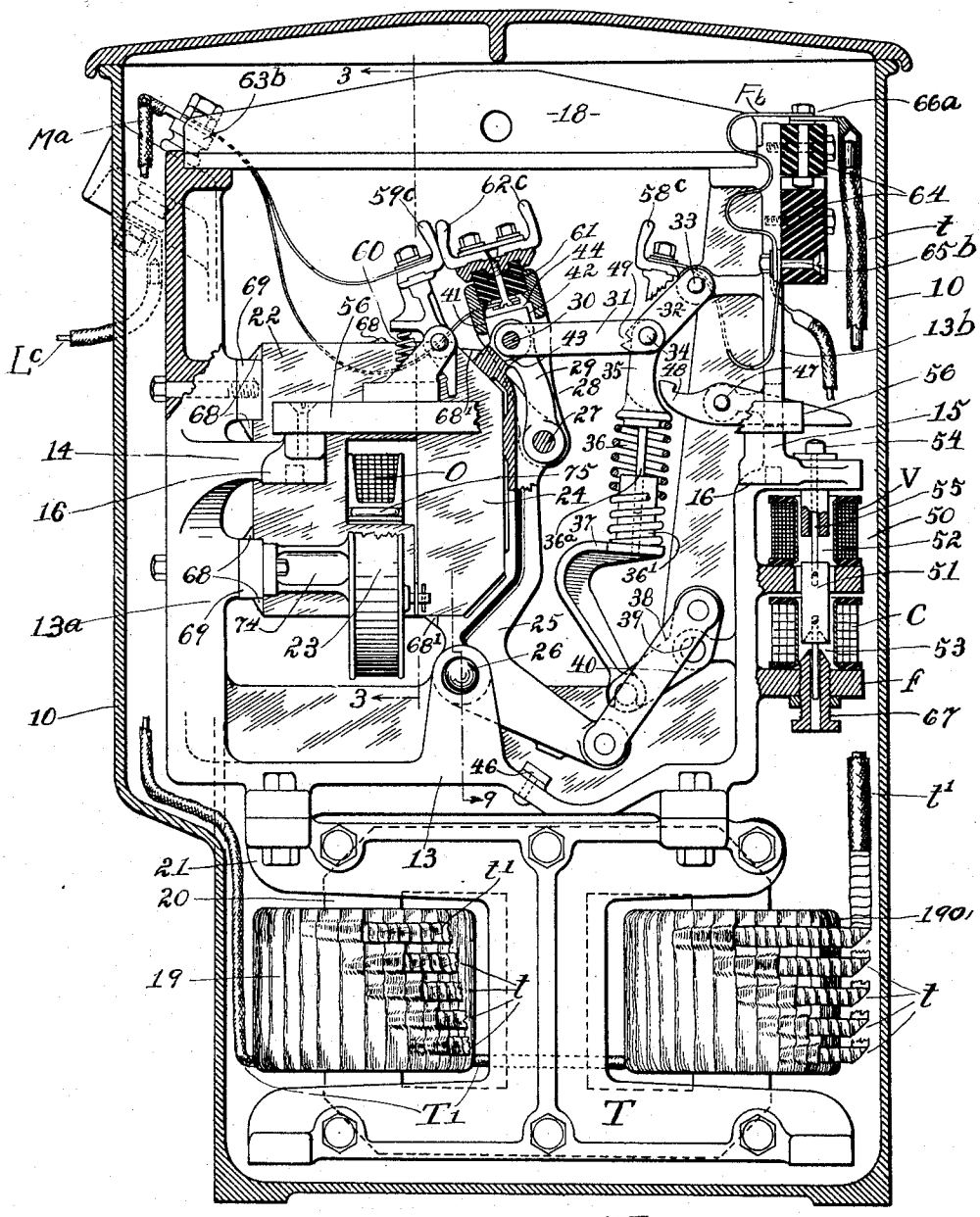


Fig. 1

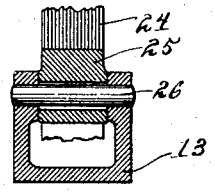


Fig. 9

INVENTOR

H. F. Stratton

by F. N. Barber

Att'y.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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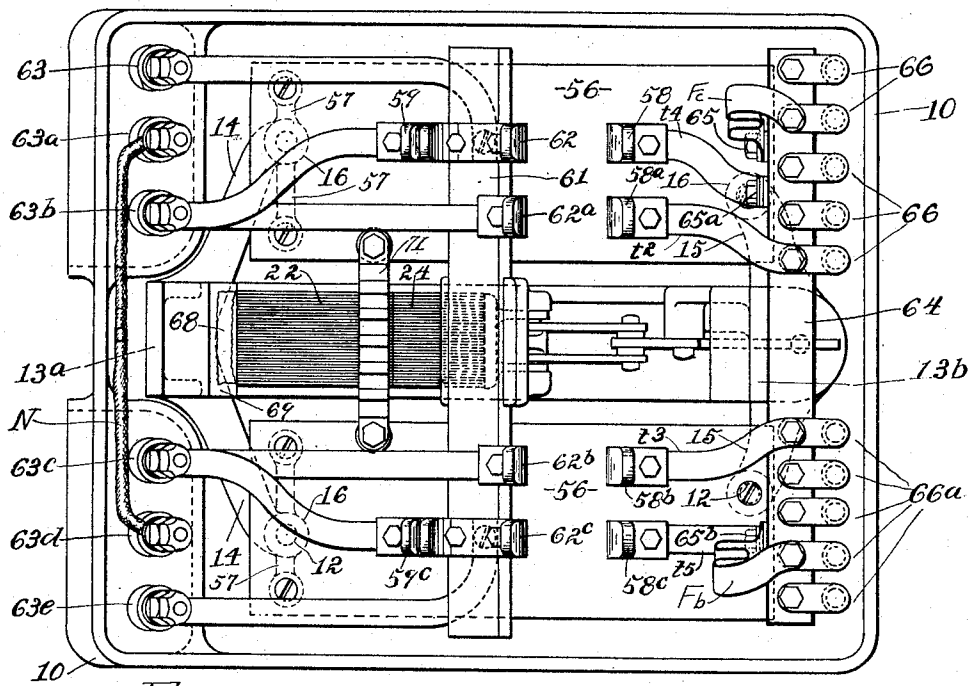


Fig. 2

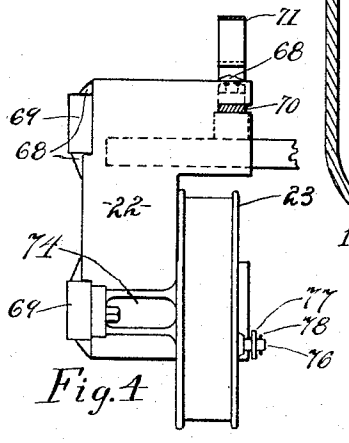


Fig. 4

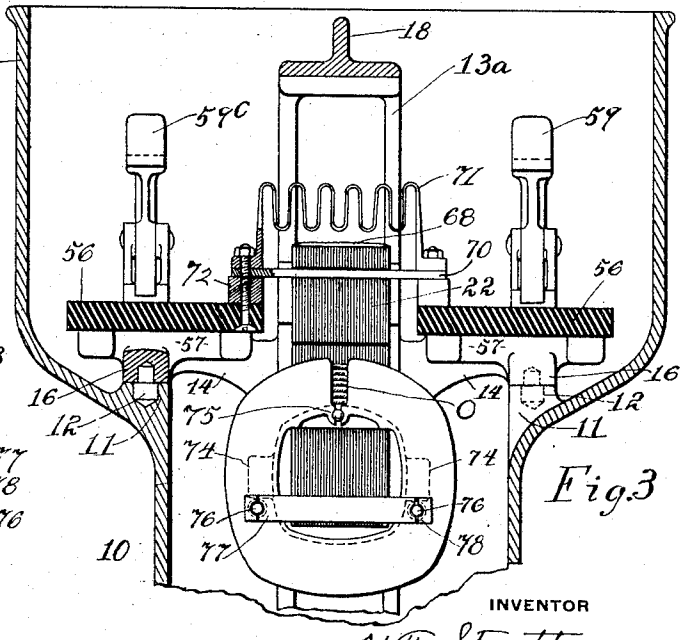


Fig. 3

INVENTOR

H. F. Stratton

by F. N. Barber

Att'y.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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3 SHEETS—SHEET 3.

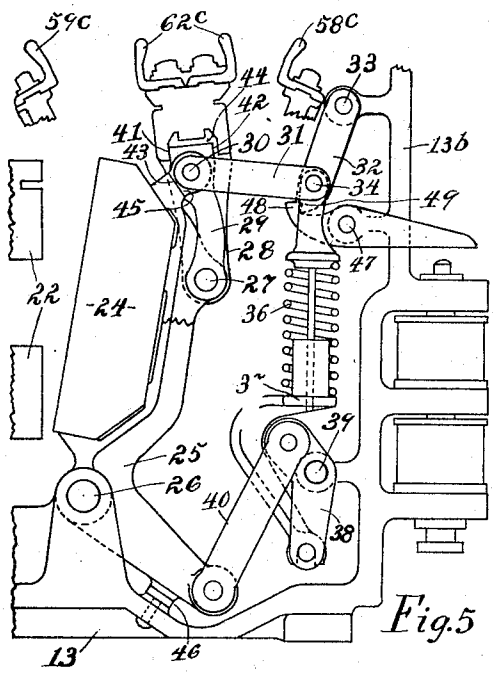


Fig.5

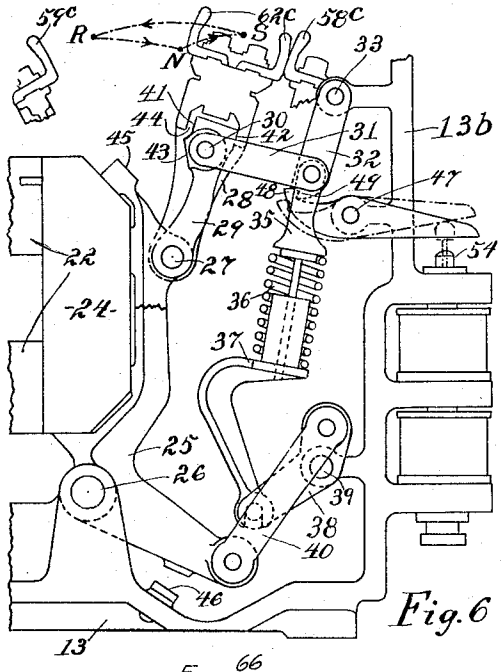


Fig.6

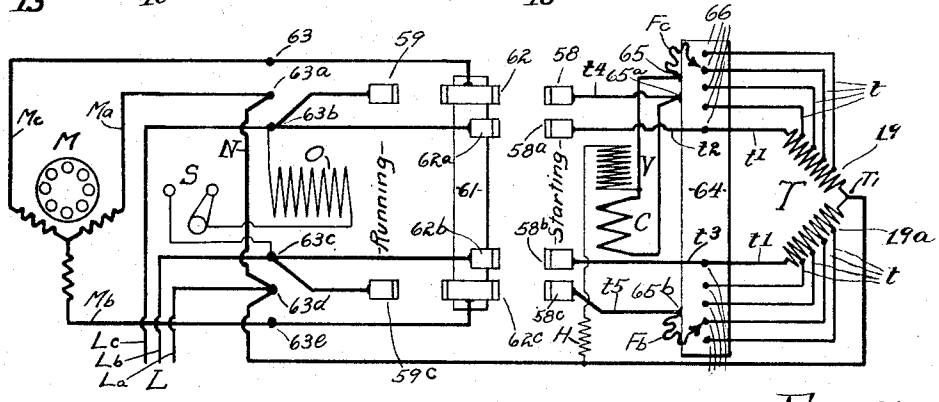


Fig.7

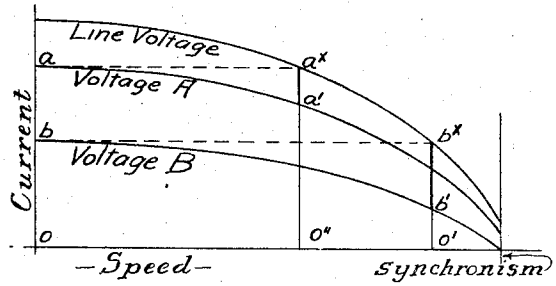


Fig.8

INVENTOR

H. F. Stratton

by F. N. Barber

Att'y.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

HARRY FROST STRATTON, OF CLEVELAND, OHIO, ASSIGNOR TO THE ELECTRIC CONTROLLER & MANUFACTURING COMPANY, OF CLEVELAND, OHIO, A CORPORATION OF OHIO.

ELECTRIC CONTROLLER.

1,225,686. Specification of Letters Patent. Patented May 8, 1917.

Application filed September 9, 1915. Serial No. 49,687.

To all whom it may concern:

Be it known that I, HARRY F. STRATTON, a citizen of the United States, residing at Cleveland, in the county of Cuyahoga and State of Ohio, have invented new and useful Improvements in Electric Controllers, of which the following is a specification.

My invention relates broadly to controlling apparatus for electric motors, but more particularly to controllers for accelerating alternating current motors from standstill to normal running speeds.

One object of this invention is to provide a starting apparatus for alternating current motors which provides a single operating magnet for first connecting the motor to the supply mains through a voltage reducing means and subsequently connecting the motor directly to the said mains. Another object is to accomplish the object aforesaid by mechanism which permits the armature of the starting magnet to move to its full closed position immediately upon energization of the magnet, whereby the magnet is not left with its magnetic circuit open while the starting switch is in the starting position. Another object is to provide a controlling device whereby the starting switch when released will be automatically moved from the starting to the running position by power stored up by the closing movement of the armature. A still further object of this invention is to provide a means for releasing the starting switch when in starting position, whenever the motor current drops to such a value that it will not, on the movement of the switch to the running position, rise to a value substantially equal to the initial value of the current, irrespective of the voltage of the starting current. Other objects are to provide a starting switch with improved details and combinations. Further objects will appear hereinafter.

Referring to the accompanying drawings, Figure 1 is a side elevation of an apparatus containing the principle of my invention, parts being in section; Fig. 2, a top plan view of the said apparatus with the cover of the casing and the bar 18 removed; Fig. 3, a vertical section on the line 3—3, Fig. 1; Fig. 4, a side elevation of the switch-operating magnet and adjacent parts, portions being in section and broken away; Fig. 5, a partially diagrammatic view of the switch mechanism in neutral position; Fig. 6, a view like Fig. 5, except that the switch mechanism is shown in the starting position; Fig. 7, a typical diagram of one of several electric circuits which I may employ in connection with a squirrel-cage motor; Fig. 8, a diagram of curves illustrating the use of my invention with currents of different values; and Fig. 9, a section through the pivot 26 and the parts connected thereby.

On the drawings, 10 designates an oil-containing casing, or tank having the laterally contracted lower portion 10′; bosses 11 being provided on the shoulder which connects the said contracted portion to the upper portion of the casing.

13 is a U-shaped casting constituting the main frame for supporting the various parts of my invention. The member 13^a of the frame has the arms 14, and the other member 13^b, the arms 15, the said arms having their ends 16 resting on the bosses 11 and provided with the centering pins 12 fitting in holes in the said bosses. The T-bar 18 is secured to the upper ends of the members 13^a and 13^b, and constitutes a support by which the frame 13 and the parts carried thereby may be lowered into the casing and removed therefrom.

The transformer T, which in the present instance is a three-phase auto-transformer with the open delta coils 19 and 19^a and the core 20, is supported by the frame 21 secured to the under side of the frame 13. The coils are each shown with the taps t and the open or upper end connections t'. The lower ends of the coils are connected to the common conductor T′.

I employ a magnet having the U-shaped laminated core 22 provided with the magnetizing winding O wound on the cast-metal spool 23 which surrounds the lower leg of the core. The laminations of the core are secured together by the transverse strips 68 of welding material, the rear strips being welded also to the plates 69 which are bolted to the inner face of the member 13^a. The spool has preferably integral therewith the legs 74 bolted to the lower plate 69. Its upper side is shown with a slit extending entirely across the same to prevent the induction of currents in the spool. 75 is a spacing rod of fiber or other

insulating material seated in grooves in opposite walls of the said slit to maintain the slit at the desired width.

To prevent the chattering of the armature 24 on the upper pole of the magnet, I embed a portion of a closed conductor or loop in the face of the said pole. This conductor comprises two members, one a strip of metal 70 having its intermediate portion embedded as described and its end portions bolted to the second member 71, preferably a corrugated casting which introduces a resistance into the closed loop and radiates heat produced in the loop by currents induced therein by the alternating flux in the upper pole piece by the winding O which is connected by the switch S across two of the line conductors L. The flux induced in the upper pole by the loop alternates with the flux produced by the winding O, whereby the said pole continuously holds the armature 24 against it.

The armature 24 is welded by the transverse strips 68′ to the upstanding member of the lever 25 pivoted between its ends on the pin 26, which fits loosely in the lever whereby the pin will not interfere with any movements of the lever required to make the armature fit squarely on the upper pole of the magnet and squarely on the plate 77 held loosely between the armature and the lower pole of the magnet. This plate has at its ends holes to receive the two studs 76 projecting from the face of the spool 23, the holes being slightly larger than the studs in order that the plate may adjust itself so as to rest squarely against the lower pole. The studs 76 have the cotter pins 78 to keep the plates from sliding off therefrom. The plate 77 is made of wear-resisting, non-magnetic material having high resistance, such as nickel steel. It serves to maintain a non-magnetic gap to prevent the armature from sticking to the lower pole when the winding O is deënergized. The high resistance of the plate prevents excessive heating by eddy currents.

The pin 26 is supported by the base of the frame 13 below the armature 24, and is preferably composed of nonmagnetizable material to reduce the flux flowing through the pivotal connection between the frame 13 and the lever 25.

The lever 25 carries above the pivot 26 the horizontal pivot pin 27 on which the upwardly-extending movable switch member 28 and the upwardly-extending stop-arm 29 are mounted to swing. The stop-arm 29 carries the pivot 30 to which one end of the link 31 is connected, the other end thereof being connected to one end of the link 32 by the pivot pin 34. The other end of the link 32 is connected to the pivot pin 33 supported by the member 13^b of the frame 13. The links 31 and 32 constitute toggle members, their connecting pivot 34 being beneath a line connecting their end pivots 30 and 33.

The pivot 34 supports the depending upper compression member 35. A spring 36 has its upper end seated on the lower end of the compression member 35, and its lower end on the upper face of the lower compression member 37, which is provided with a centering core 36′ for the spring, the two compression members 35 and 37 being kept in alinement with the axial center of the spring 36 by the stem 36^a, carried by the member 35 and slidable in a central opening in the core 36′.

A bell-crank lever 38 is pivoted on the pin 39 supported by the member 13^b near the lower end thereof. One arm of the lever 38 is connected to the lower arm of the lever 25 by the link 40, while the other arm of the lever 38 is pivoted to the lower end of the compression member 37, the latter having an open pivot-bearing to facilitate its removal and replacement. The member 37 is curved so that when the parts are as in Fig. 5 the upper arm of the lever 38 will not interfere with the said member.

The upper end of the stop-arm 29 has three stop surfaces 41, 42, 43, the surfaces 41 and 42 being on opposite sides of the arm 29. The switch member 28 has a recess 44 between the opposite side-walls of which the upper end of the stop-arm 29 moves, the recess being slightly longer than the distance between the stop surfaces 41 and 42, whereby there exists some lost motion between the members 28 and 29, the switch member 28 having a small angular movement on the pivot 27 independently of the stop-arm 29. The stop surface 43 is adapted to rest on the stop 45 on the armature lever 25.

46 is a preferably non-magnetic stop on the frame 13 to support the armature lever 25 when in its neutral position, as shown on Fig. 5.

48 is a latch pivoted between its ends on the pin 47 supported by the member 13^b. The lower end of the link 32 has a notch 49 adapted to be caught by a hook on the upper side of one end of the latch so as to prevent the straightening of the toggle members 31 and 32 by the spring 36 until they are released by the latch. The other end of the latch lies over the upper end of a two-coil tripping device 50, having the movable core 51, separated from a fixed core in the upper coil V by the air-gap 52, and from the adjustable core 67 in the lower coil C by the air-gap 53. These coils exert opposite pulls on the core 51. Under certain conditions, to be explained presently, the pull at the gap 52 preponderates, whereupon the core moves upwardly, and the head 54, connected to the core 51 by the rod 55, strikes the latch 48 and causes the latter to release the link 32 in an evident manner.

The arms 14 and 15 support two slates or other insulating bases 56, the arms 14 being provided for this purpose with additional arms 57. These slates carry a group of spring cushioned stationary starting contacts 58, 58^a, 58^b, and 58^c, and a group of similar running contacts 59 and 59^c. The switch member 28 carries a wooden or other insulating cross-arm 61, on which groups of contacts 62, 62^a, 62^b, and 62^c are mounted.

With the parts in the neutral position shown on Fig. 5, it will be noted that the latch is in locking engagement with the link 32, the spring 36 is in its expanded condition, the armature 24 is in its unattracted or neutral position, and the armature lever 25 rests on the stop 46. These parts assume these positions under the action of gravity and the compression spring 36 when the winding O is deënergized. When the winding O is energized, the armature 24 is drawn to the core 22 and carries the lever 25 with it. The latch 48 prevents any movement of the toggle member 32, so that, as the pivot 27 moves forward with the lever 25, the arm 29 swings on the pivot 30, causing the end of the arm 28 above the pivot 30 to move toward the starting contacts, and finally to move the contacts 62, 62^a, 62^b, and 62^c into engagement with the said starting contacts, as shown on Fig. 6. While the operation just described is taking place, the lever 25 has, through the link 40, turned the bell-crank lever 38 from the position shown on Fig. 5 to that shown on Fig. 6, the lower arm of the lever 38 moving upwardly from its neutral or idle position below its pivot 39 so as to cause the spring 36 to be compressed between the compression members 35 and 37. The parts will remain as in Fig. 6 until the tripping device 50 operates to release the latch 48, whereupon the spring 36 will cause the toggle members 31 and 32 to be extended and the switch member 28 to be moved into the position shown on Fig. 1, in which the movable contacts 62^a and 62^c are shown in engagement with the running contacts 59 and 59^c, respectively, and the said movable contacts are shown disconnected from the starting contacts. The parts will remain in this position until the winding O is deënergized, when they will return to the neutral position shown on Fig. 5.

The blow of the movable contacts 62 upon the starting or the running contacts, causes the latter to overtravel a slight distance. If the movable contacts came inflexibly into engagement with the starting or running contacts, this overtravel of the latter would cause a momentary opening of the electrical circuits established by the engagement of the movable and the starting or running contacts. To prevent this momentary interruption of the circuits, I provide sufficient lost motion between the stop arm 29 and the movable switch member 28 to which the movable contacts are rigidly connected, so that the latter may follow the starting or running contacts in their overtravel and may thereby maintain continuous contact with the starting or running contacts as long as the movable contacts are in the starting or running position respectively. It will be understood that the overtravel of the starting or running contacts and the coördinating follow-up of the movable contacts are but momentary and that both contacts rapidly assume their normal positions under the influence of the cushioning springs which coöperate with the starting or running contacts.

On the casing 10 is a row of terminals 63, 63^a, 63^b, 63^c, 63^d, and 63^e. The motor lead M^c and the contact 62 are connected to the terminal 63. The motor leads M^a and M^b are connected to the terminals 63^a and 63^e, respectively. The terminals 63^a and 63^d are connected together by the wire N. The contacts 59 and 62^a are connected to the terminal 63^b, and the contacts 62^b and 59^c to the terminal 63^c. The three-phase supply mains L^a, L^b, and L^c are connected to the terminals 63^d, 63^c, and 63^b, respectively. The winding O has one end connected to the terminal 63^b and the other end to the terminal 63^c through the master switch S. The motor is indicated by the letter M and is of the squirrel-cage type with star-connected stator windings, but I do not limit myself to any definite type of motor or any definite arrangement of windings therefor.

On the member 13^b of the frame 13 I mount the insulating block 64 which supports a row of horizontal terminals 65, 65^a, and 65^b, and a row of terminals 66 and 66^a, having sockets to receive the ends of the wires t and t'. The current coil C has its end connected to the terminals 65 and 65^a in series with the motor current, and the voltage coil V has its ends connected across the conductor T′ and the conductor containing the coil C. It will be noted that the coil V is energized by the secondary voltage of the transformer and not by the line voltage, and that the voltage on the coil V will automatically be changed when the transformer taps are adjusted to change the motor starting voltage. The voltage coil V has, preferably in series therewith, the high resistance H or other equivalent impedance device, which is designed to prevent a high current transient, which might occur in the said coil when first excited, from exerting a sufficiently large pull across the gap 52 to lift the core 51 and trip the latch 48 prematurely.

The cause of this transient may be explained as follows: At the moment of interrupting the alternating current in the coil

V during the preceding operation of the device, the current may be at such a value that it will leave residual magnetism in the magnetic circuit of the coil. At the moment of reënergizing the coil V for another operation, the instantaneous value of the first wave of the alternating current may be of such sign and of such amount as to add to the residual magnetism in the circuit. During this first wave, since the magnetism does not begin to increase from zero, or since it does not have to be reduced to zero from an opposite sign and then increased from zero, the rate of change of the magnetism during this first portion of the first alternating cycle will be comparatively small, and therefore a smaller counter electromotive force will be generated in the coil to limit the current than will be generated by subsequent, successive, more stable waves, and hence an abnormally large current will be permitted to flow in the winding; this abnormally large current in turn generates an abnormally large flux, and it is this flux of the first wave which may cause a premature operation, as above described. This abnormally large current which tends to flow in the first wave under the circumstances described, is substantially prevented from flowing by the non-inductive resistance H. According to principles well understood, this resistance H is so designed as not to materially affect the value of the subsequent, stable, normal current of the coil V, the normal current being almost entirely determined by the inductance of the coil V after the first alternating wave has passed, the effect of the resistance of the coil circuit being negligible.

The four taps t to the winding 19 of the transformer T are connected to the four outer terminals 66 at one end of the block 64, and the four taps t to the winding 19^a of the transformer are connected to the four outer terminals 66^a at the other end of the said block. The open ends of the windings 19 and 19^a are connected by the wires t' to the two inner terminals 66 and 66^a, the latter being connected respectively to the contacts 58^a and 58^b by the flexible conductors t^2 and t^3. The flexible tap-connector F^c has one end connected to the terminal 65, its other end being removably connected to any selected one of the four outer terminals 66, and the flexible tap-connector F^b has one end connected to the terminal 65^b and its other end detachably connected to any selected one of the four outer terminals 66^a. The terminal 65^a is connected to the contact 58 by the flexible conductor t^4, and the terminal 65^b is connected to the contact 58^c by the flexible conductor t^5.

Suppose the parts to be in their neutral positions, as shown on Figs. 5 and 7. To start the motor M the switch S is closed, causing the winding O to be energized and the parts to be moved, as already described, to the starting position shown on Fig. 6, in which the contacts 62, 62^a, 62^b, and 62^c are in engagement with the starting contacts 58, 58^a, 58^b, and 58^c, respectively. In this position the supply main L^b is connected through the contacts 62^b and 58^b to the open terminal of the transformer winding 19^a, and the supply main L^c is connected through the contacts 62^a and 58^a to the open end of the winding 19, the supply main L^a being always connected to the remaining ends of the transformer windings irrespective of the starting switch contacts. The motor lead M^c is connected to the second terminal 66 through the contacts 62 and 58, the current coil C and the tap-connector F^c. The motor lead M^b is connected to the second terminal 66^a through the contacts 62^c and 58^c and the tap-connector F^b, the motor lead M^a being always connected to the common point T' through the conductor N. Thus, only a portion of the transformer is connected to the motor leads M^b and M^c, causing the motor to start under a voltage less than the line voltage. For any given connection of the tap connectors F^b and F^c with the tap terminals 66^a and 66, the upward pull of the coil V on the core 51 remains practically unchanged for the same line voltage, but the downward pull on the core varies with the current through the motor. When the switch member 28 is first moved into starting position, the rush of current in the coil C causes the downward pull on the core 51 to overpower the upward pull thereon caused by the current in the coil V. When the motor current decreases to such a value that the pull produced by the coil C is overpowered by the pull produced by the coil V, the latch 48 is tripped in the manner hereinbefore explained, and the parts move to the running position (Fig. 1), in which the supply main L^b is connected directly to the motor lead M^b through the contacts 59^c and 62^c, and the supply main L^c is connected directly to the motor lead M^c through the contacts 59 and 62, the supply main L^a being connected to the motor lead M^a through the conductor N. The transformer and the coils C and V are disconnected from the supply mains, and the full voltage of the source of current supply is impressed on the motor, whereby the motor is quickly accelerated to running speed. When the winding O is deënergized the switch member 28 quickly assumes its neutral position shown on Fig. 5, with the latch 48 in locking engagement with the toggle member 32.

The length of the gap 53 may be adjusted by screwing the plug up or down in the bottom member f of the E-shaped magnetizable frame which supports the windings C and V and constitutes portions of the mag-

netic circuits. I adjust the gap 53 so that the pull produced by the coil V will overcome the pull produced by the coil C when the motor current is reduced to such a value that the closing of the running contacts will cause the current to rise to the initial value, that is, to the value of the current impressed on the motor at the instant the starting contacts are closed. The ampere turns of coils C and V are relatively so proportioned that the magnetic circuit of the coil C is energized at higher degrees of magnetization than that of the coil V, and the adjustment just described is made when the tap connectors F^b and F^c are on that pair of tap terminals 66 and 66^a which give the lowest motor starting voltage. When the tap connections are changed to give higher starting voltages, the magnetic flux of the coil V will increase approximately in proportion to the voltage, but the flux of the coil C will not be increased in proportion to the motor current at the higher voltage because the magnetic circuit of the coil C is more nearly saturated than that of the coil V. It will thus be seen that as the starting voltage is adjusted the ratio between the voltage and the current at which the tripping device 50 operates, will decrease as the starting voltage is increased. When the gap 53 of the trip device 50 has been adjusted, as just described, with the tap connectors F^b and F^c on one pair of tap terminals 66 and 66^a, no adjustment is required to adapt it to changes of voltage and current values caused by connecting the tap-connectors to any other pair of tap terminals. This important characteristic of my invention is graphically illustrated on Fig. 8, in which the three curves in solid lines indicate the current flowing through the motor during its acceleration with three different voltages impressed on the motor. If the motor is started on voltage B and initial current ob, the trip device 50 operates to trip the latch 48, so that, when the transition to full line voltage occurs, the current through the motor will rise to its initial value ob. The line $b\ b^\times$ is drawn parallel to the line $c\ o'$, its end $b^\times$ meeting the line voltage curve. The line $o'\ b^\times$ is drawn parallel to the line $o\ b$. The line drawn from o' to the intersection b' of the line $o'\ b^\times$ with the curve for voltage B, obviously represents the current value at which the transition to full line voltage should occur.

If the tap connectors F^b and F^c be changed so as to start the motor on a higher voltage, as voltage A, the initial current through the motor will be oa, and the transition to full line voltage will take place when the current drops to the value $o''\ a'$, the point a' being at the intersection of the curve for voltage A with the line $o''\ a^\times$, parallel with the line oa, the point $a^\times$ being in the curve for line voltage. The trip device 50 will operate to cause the successive accelerating current peaks to be substantially equal while constant voltage is being impressed on the motor. The peaks for voltage A will be higher than for voltage B, but if the windings of the coils C and V are proportioned properly the peaks for voltage A will be approximately equal to each other and those for voltage B will also be approximately equal to each other. I do not limit myself to the ideal theoretical operation just given, as in practice it may sometimes be preferable not to have equality of current peaks as described, but merely to cause the transition to occur in such a manner that progressively higher currents will occur at transition with the use of progressively higher starting voltages. Although I have, for simplicity described only the ideal theoretical operation having equality of current peaks, my invention broadly comprises all means for increasing automatically and self-adjustably the current peaks at the transition to line voltage when higher starting voltages are employed.

The described coördinated mechanism permits the armature 24 to close the magnetic circuit of the operating magnet immediately upon energization, thereby preventing the waste of the large wattage and the probable destruction of the winding O by overheating, which would occur if the closure of the said magnetic circuit should be delayed until the running contacts are closed. The said mechanism also causes the hardest work of the operating magnet to come at the time when the gaps between the armature and the poles of the magnet have become short and, therefore, when the magnetic pull on the armature has approximated its maximum. From Fig. 5 it is seen that, during the earlier part of the movement of the armature 24 toward the poles of the magnet, the armature has to swing the switch member 28 and the arm 29 on their pivot 27 to the positions shown on Fig. 6, which requires but little power. At the same time the lever 25 moves the lower arm of the lever 38 on nearly a horizontal line, whereby the spring 36 is only slightly compressed. After the contacts 58 and 62 have engaged each other and the lower arm of the lever 38 begins to move upwardly rapidly, the armature 24 has moved so close to the poles of the operating magnet that it is drawn to the same with great power, causing the spring 36 to be placed under high compression, capable of quickly extending the toggle members and moving the parts to the running position shown on Fig. 1, as soon as the trip device 50 releases the latch 48 from the toggle member 32. The arrangement of the moving parts is such that, at the beginning of the movement of the mov-

able contacts from their starting to their running position, the rotative effort about the pin 27, due to the spring 36, is relatively small, but toward the end of said movement and practically during engagement with the running contacts, the rotative effort of the spring 36 acting on the switch member 28, through the toggle levers 31 and 32, is a maximum. Such a design permits the employment of a spring on which minimum compressive effort is required, and leads directly to the use of a smaller and cheaper operating magnet.

The movement of the parts from their starting position to their running position causes the running contacts 59 and 59c to be moved back from their idle positions, thereby placing their springs 60 under compression. The springs 60, reacting through the various parts of the mechanism, tend to move the lower end of the armature about the upper pole of the magnet as a center, toward the lower pole thereof to prevent chattering, the loose fit of the lever 25 on its pivot 26, and of the spacer 77 on its supporting studs 76 permitting the armature to move freely so that it may fit squarely against the upper pole and the plate 77.

The movable contacts have a plurality of centers of rotation, which permit the armature to move at once to its closed position and at the same time permit the contacts 62 to 62c to be moved first to the starting position and subsequently to the running position. The contacts 62 to 62c do not, owing to the said centers of rotation, travel on a single line from their neutral position to their starting and running positions, and back to their neutral position, but describe a triangular path as shown by the dotted lines near the top of Fig. 6, where the neutral, starting, and running positions are indicated, respectively, by the letters N, S, and R, the arrow heads showing the direction of travel.

While I have shown my invention in connection with apparatus for starting squirrel-cage motors, it is obvious that some of the principles thereof may be applied to direct current apparatus and to alternating current motors controlled by different voltage-controlling means from those shown. I do not limit myself to the use of three-phase source of supply or to the squirrel-cage type of motor.

While I have shown a traction magnet consisting of a two-pole stationary electromagnet and a pivoted armature arranged to be attracted thereto as the source of mechanical power for operating my invention, it will be apparent that manual means or other types of electromagnetic means capable of developing mechanical power and coöperating with the mechanism which I have shown, or with other forms of mechanism, may be employed without departing from the spirit of my invention.

I claim—

1. In a motor control system, a source of supply, an induction motor, a transformer for supplying a reduced starting voltage for the motor, means for connecting the motor to the transformer and directly to the source, and means controlling the change of the motor connection from the transformer to the source, said means including two opposing windings, one of which is connected in series with the motor and the other of which is energized by the starting voltage.

2. In a motor control system, a source of supply, an induction motor, an adjustable transformer for supplying starting voltage for the motor, means for connecting the motor to the transformer and directly to the source, and means controlling the change of the motor connection from the transformer to the source, said means including two opposing windings, one of which is connected in series with the motor and the other of which is so connected with relation to the transformer that when the transformer is adjusted to increase or decrease the starting voltage, the energizing current of the winding will be respectively increased or decreased.

3. In a motor control system, a source of supply, an induction motor, an adjustable transformer for supplying starting voltage for the motor, means for connecting the motor to the transformer and directly to the source, and means controlling the change of the motor connection from the transformer to the source, said means including two opposing windings, one of which is energized by the motor current and the other by the motor starting voltage, and means whereby when the transformer is adjusted to increase the starting voltage, the energizing voltage of the other winding will be increased.

4. In a motor controller, movable contacts, starting and running contacts arranged to be engaged thereby, a single electromagnet for operating said contacts and for holding them in their operated positions, and means coöperating with said magnet for causing the movable contacts to engage the starting contacts before engaging the running contacts, but permitting the return of said movable contacts from the running contacts to neutral position without engaging the starting contacts.

5. In a motor controller, movable contacts, starting and running contacts arranged to be engaged thereby, a single electromagnet for operating the contacts, and means coöperating with the magnet for causing the movable contacts to engage the starting contacts by movement in one di-

rection and to engage the running contacts by movement in the opposite direction.

6. In a motor controller, a motor, a motor circuit to be controlled, starting and running contacts in the motor circuit, movable contacts adapted to engage the starting and running contacts, a single electromagnet for operating said movable contacts, and means coöperating with said magnet for causing the movable contacts to engage the starting contacts to close the motor circuit, and start the motor before engaging the running contacts, but permitting the return of said movable contacts from the running contacts to neutral position without engaging the starting contacts.

7. In a motor controller, movable contacts, starting and running contacts arranged to be engaged thereby, a single electromagnet for operating said contacts, and means cooperating with said magnet upon the energization thereof for causing the movable contacts to engage the starting contacts before engaging the running contacts, but upon the deënergization of said magnet permitting the return of said movable contacts from the running contacts to neutral position without engaging the starting contacts.

8. In a motor controller, a motor, starting and running contacts, a single electro-magnet for causing first the closure of the starting contacts and then the closure of the running contacts, and means for delaying the opening of the starting contacts, the said means being controlled by two opposing windings, the current in one winding being in proportion to the current through the motor, and the current in the other being in proportion to the voltage applied to the motor.

9. In a motor controller, a motor, starting and running contacts, a single electro-magnet for operating the contacts, causing the engagement of first the starting contacts and then the running contacts, means for delaying the opening of the starting contacts, and electro-responsive means controlling said delaying means comprising opposing windings one of which is in series with the motor, the other being in shunt therewith.

10. In a motor control system, a motor, a motor circuit, starting and running contacts in the circuit, a source of supply, means for adjusting the voltage applied to start the motor, a single electromagnet for causing first the closure of the starting contacts and then the opening of the starting contacts and the closure of the running contacts, and means for delaying the opening of the starting contacts, the said means being controlled by two opposing windings, the current in one winding being in proportion to the current through the motor, and the current in the other being in proportion to the voltage applied to the motor and increasing when the voltage applied to the motor is increased.

11. In a motor controller, a motor, a transformer, a source of supply, a magnet for connecting the motor to the source through the transformer, and mechanical means acted upon by said magnet for disconnecting the motor from the transformer and connecting it directly to the source.

12. In a motor controller, a motor, a transformer, a source of supply, a magnet for connecting the motor to the source through the transformer and for supplying power for disconnecting the motor from the transformer and connecting it directly to the source.

13. In a motor controller, a motor, a transformer, a source of supply, a magnet for connecting the motor to the source through the transformer, and means acted upon by said magnet whereby energy is stored up for subsequently disconnecting the motor from the transformer and connecting it directly to the source.

14. In a motor controller, starting contacts, running contacts, a magnet for closing the starting contacts, mechanical means whereby the magnet opens the starting contacts and closes the running contacts and for causing the running contacts to open without closing the starting contacts.

15. In a motor control system, a motor, a motor circuit, starting contacts and running contacts in the motor circuit, a magnet for closing the starting contacts to give starting current to the motor, and means whereby mechanical power developed by the magnet opens the starting contacts and closes the running contacts and for causing the running contacts to open without closing the starting contacts.

16. In a motor controller, starting contacts, running contacts, a magnet for closing the starting contacts, mechanical means whereby the magnet opens the starting contacts and closes the running contacts and holds them closed, and means for temporarily preventing the magnet from opening the starting contacts.

17. In a motor controller, starting contacts, running contacts, a magnet for closing the starting contacts, means whereby the magnet opens the starting contacts and subsequently closes the running contacts, and electromagnetic delaying means for temporarily preventing the magnet from opening the starting contacts.

18. In a motor control system, a motor, a motor circuit, starting contacts and running contacts in the circuit, a magnet for closing the starting contacts to start the motor and for storing up mechanical energy for subsequently opening the starting contacts to disconnect the motor from the motor circuit and

then closing the running contacts, and means for temporarily preventing the opening of the starting contacts.

19. The combination of an induction motor, movable and stationary contacts for making the starting and running connections therefor, and means including a single operating magnet for causing said movable contacts to occupy consecutively starting, running, and neutral positions and for holding the movable contacts in the running position.

20. The combination of an induction motor, movable and stationary contacts for making the starting and running connections therefor, and means including a single operating magnet for causing said movable contacts to move in one direction to occupy the starting position, and in the opposite direction to occupy the running position.

21. The combination of an induction motor, movable and stationary contacts for making the starting and running connections therefor, and means including a single operating magnet for causing said movable contacts to move in one direction to occupy the starting position, and in the opposite direction to occupy the running position, and for causing the movable contacts to move to a neutral position upon deënergization of the magnet.

22. In a motor controller, starting and running contacts, a magnet for operating the contacts, means for closing the starting contacts when the magnet operates to close its magnetic circuit, means controlled by the current through the starting contacts for holding the starting contacts in closed position, and mechanical means acted upon by said magnet for closing the running contacts when the starting contacts are free to open.

23. In a motor controller, starting and running contacts, a magnet for operating the contacts, means for closing the starting contacts when the magnet operates to close its magnetic circuit, means controlled by the current through the starting contacts for holding the starting contacts in closed position, and means whereby the power developed by the magnet on closing its magnetic circuit closes the running contacts when the starting contacts are free to open.

24. In a motor controller, starting, running and movable contacts, a magnet for operating the movable contacts, means for causing one side of the movable contacts to engage the starting contacts when the magnet operates to close its magnetic circuit, means controlled by the current through the starting contacts for holding the movable contacts in engagement with the starting contacts, and means acted upon by said magnet for causing the other side of the movable contacts to engage the running contacts when the movable contacts are free to disengage the starting contacts.

25. In a motor controller, starting, running and movable contacts, a magnet for operating the movable contacts, means for causing one side of the movable contacts to engage the starting contacts by movement in one direction when the magnet operates to close its magnetic circuit, means controlled by the current through the starting contacts for holding the movable contacts in engagement with the starting contacts, and means acted upon by said magnet for causing the other side of the movable contacts to engage the running contacts by movement in the opposite direction when the movable contacts are free to disengage the starting contacts.

26. In a motor controller, a movable member, starting and running contacts closable thereby, a single electro-magnet which when energized immediately closes its magnetic circuit thereby moving the said member to close the starting contacts and also establishing a force for subsequently moving the said member to close the running contacts, and means responsive to the current through the starting contacts for preventing said force from closing the running contacts.

27. In a motor controller, a movable member, starting and running contacts closable thereby, a single electromagnet which when energized immediately closes its magnetic circuit, thereby moving the said member in one direction to close the starting contacts and also establishing a mechanical force for subsequently moving the said member in a different direction to close the running contacts, and means responsive to the current through the starting contacts for temporarily preventing said force from closing the running contacts.

28. In a motor controller, movable contacts normally in neutral position, two sets of contacts arranged to be engaged thereby, a single electromagnet for operating the movable contacts and for holding them in their operated positions, and means coöperating with the magnet for causing the movable contacts to move in a closed path to engage the two sets of contacts in succession and return to neutral position.

29. In a motor controller, movable contacts normally in neutral position, two sets of stationary contacts arranged to be engaged thereby, a single electromagnet for developing power by a single operation thereof to operate the movable contacts and to hold them in their operated positions, and means coöperating with the magnet for causing the movable contacts to move in a closed path to engage the two sets of stationary contacts in succession and return to neutral position.

30. In a motor controller, a contacting

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member, starting and running contacts adapted to be engaged thereby, an operating element for moving the contacting member to engage the starting contacts and for also establishing a force for subsequently causing the said member to engage the running contacts, and means responsive to the current through the starting contacts for preventing said member from engaging the running contacts when the current through the starting contacts is above a selected value.

31. In a motor controller, a contacting member, starting and running contacts adapted to be engaged thereby, an operating element for moving the contacting member to engage the starting contacts and for also establishing a force for subsequently causing the said member to engage the running contacts, and an electro-responsive means for preventing the movement of the said member away from the starting contacts when the current through the starting contacts is above a selected value.

32. In a motor controller, a motor, a set of movable contacts, starting and running contacts, and means for causing the movable contacts to successively engage the starting and running contacts and then return to neutral position, the path described by the movable contacts, forming an area bounded by three sides.

33. In a motor controller, a contacting member, starting and running contacts adapted to be engaged thereby, an operating element for moving the contacting member to engage the starting contacts and for storing up mechanical energy for subsequently causing the contacting member to engage the running contacts, and means whereby a unit of force which moves the contacting member into engagement with the running contacts acts with greater moment at the end of the movement than at the beginning.

34. In a motor controller, a contacting member, starting and running contacts adapted to be engaged thereby, a storage element for mechanical energy, an operating element for exerting a force of varying amount to move the contacting member to engage the starting contacts and to store up mechanical energy in the storage element for subsequently moving the contacting member to engage the running contacts, and means whereby a unit of force exerted by the operating element to store up energy in the storage element acts with greater moment when the total force is relatively small than when it is relatively large.

35. In a motor controller, a contacting member, starting and running contacts adapted to be engaged thereby, a resilient storage member for mechanical energy, an electromagnet, a movable member therefor adapted upon the energization of the magnet to move to supply mechanical energy for moving the contacting member to engage the starting contacts and for storing up mechanical energy in the storage element for subsequently moving the contacting member to engage the running contacts, and means whereby a unit of force exerted by the movable member to store up energy in the storage element acts with greater moment at the beginning of its movement than at the end thereof.

36. In a motor controller, starting and running contacts, movable contacts adapted to engage said starting and running contacts, and a mechanism for controlling the movement of said movable contacts whereby said movable contacts are successively moved to disengage said starting contacts and engage said running contacts by movement about one center of rotation, and moved to disengage said running contacts by movement about another single center of rotation, and moved from a neutral position to engage said starting contacts by movement eccentric to both centers.

37. In a motor controller, a motor, a controlled circuit therefor, starting and running contacts, movable contacts having a neutral position and adapted to move forward from the neutral position to engage said starting contacts and backward to engage said running contacts, and a mechanism for controlling the movement of said movable contacts whereby said movable contacts move forward on one line of motion and backward on another line of motion without passing through the neutral position.

38. In a motor controller, a motor, a controlled circuit therefor, starting and running contacts, movable contacts having a neutral position and adapted to move in one direction from the neutral position to engage said starting contacts and in another direction to engage said running contacts, and a mechanism for controlling the movement of said movable contacts, whereby said movable contacts move in one direction on one line of motion and in the other direction on another line of motion without passing through the neutral position.

39. In a motor system, a source of alternating current supply, a transformer energized thereby, tap connections on the transformer, a motor, means for connecting the motor at will to selected tap connections, starting contacts for connecting the motor to the transformer through the selected tap connections, running contacts for connecting the motor to the source of supply, means for holding the starting contacts closed, means for closing the running contacts

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when the holding means is released, and means whereby the holding means is released when the current is reduced to such a value that the closing of the running contacts will cause the current to rise approximately to the initial value, irrespective of which taps are connected to the motor.

40. In an alternating current motor control system, a motor, means for supplying a starting voltage and a running voltage to the motor, means for adjusting the starting voltage to vary the current peak at starting, and means for causing the current peak at transition to running voltage to be substantially equal to the current peak at starting, regardless of the starting voltage.

41. In an alternating current motor control system, a motor, means for supplying a starting voltage and a running voltage to the motor, means for adjusting the starting voltage without changing the running voltage to vary the current peak at starting, and means for causing the current peak at transition to running voltage to be increased or decreased when the current peak at starting is respectively increased or decreased.

42. In a motor system, a source of alternating current supply, a transformer energized thereby, tap connections on the transformer, a motor, means for connecting the motor at will to selected tap connections, starting contacts for connecting the motor to the transformer through the selected tap connections, running contacts for connecting the motor to the source of supply, means for holding the starting contacts closed, means for closing the running contacts when the holding means is released, and means whereby the holding means is released at a higher value when a higher starting voltage is impressed on the motor.

43. In an alternating current motor controller, starting contacts, running contacts, a switch for successively closing the said contacts, means for holding the switch in starting position, a coil for releasing the holding means, and means for preventing abnormally large current transients in the coil from causing the coil to release the holding means prematurely.

44. In an alternating current motor controller, starting contacts, running contacts, a switch for successively closing the said contacts, means for holding the switch in starting position, a coil for releasing the holding means, and a resistance in series with the coil for preventing abnormally large current transients in the coil from causing the coil to release the holding means prematurely.

45. In a motor controller, a motor, starting and running contacts, a single electromagnet for operating the contacts, causing the engagement of first the starting contacts and then the running contacts, means for delaying the opening of the starting contacts, and electroresponsive means controlling said delaying means, comprising opposing windings, one of which is in series with the motor, the other being in shunt therewith, the circuit of both windings being made and broken on the starting contacts.

Signed at Cleveland, Ohio, this 2nd day of Sept. A. D. 1915.

HARRY FROST STRATTON.

Correction in Letters Patent No. 1,225,686

It is hereby certified that in Letters Patent No. 1,225,686, granted May 8, 1917 upon the application of Harry Frost Stratton, of Cleveland, Ohio, for an improvement in "Electric Controllers," an error appears in the printed specification requiring correction as follows: Page 3, line 109, for the word "end" read *ends;* and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 3rd day of July, A. D., 1917.

[SEAL.]

F. W. H. CLAY,

Acting Commissioner of Patents.

Cl. 172—289.