No. 782,732. PATENTED FEB. 14 1905.

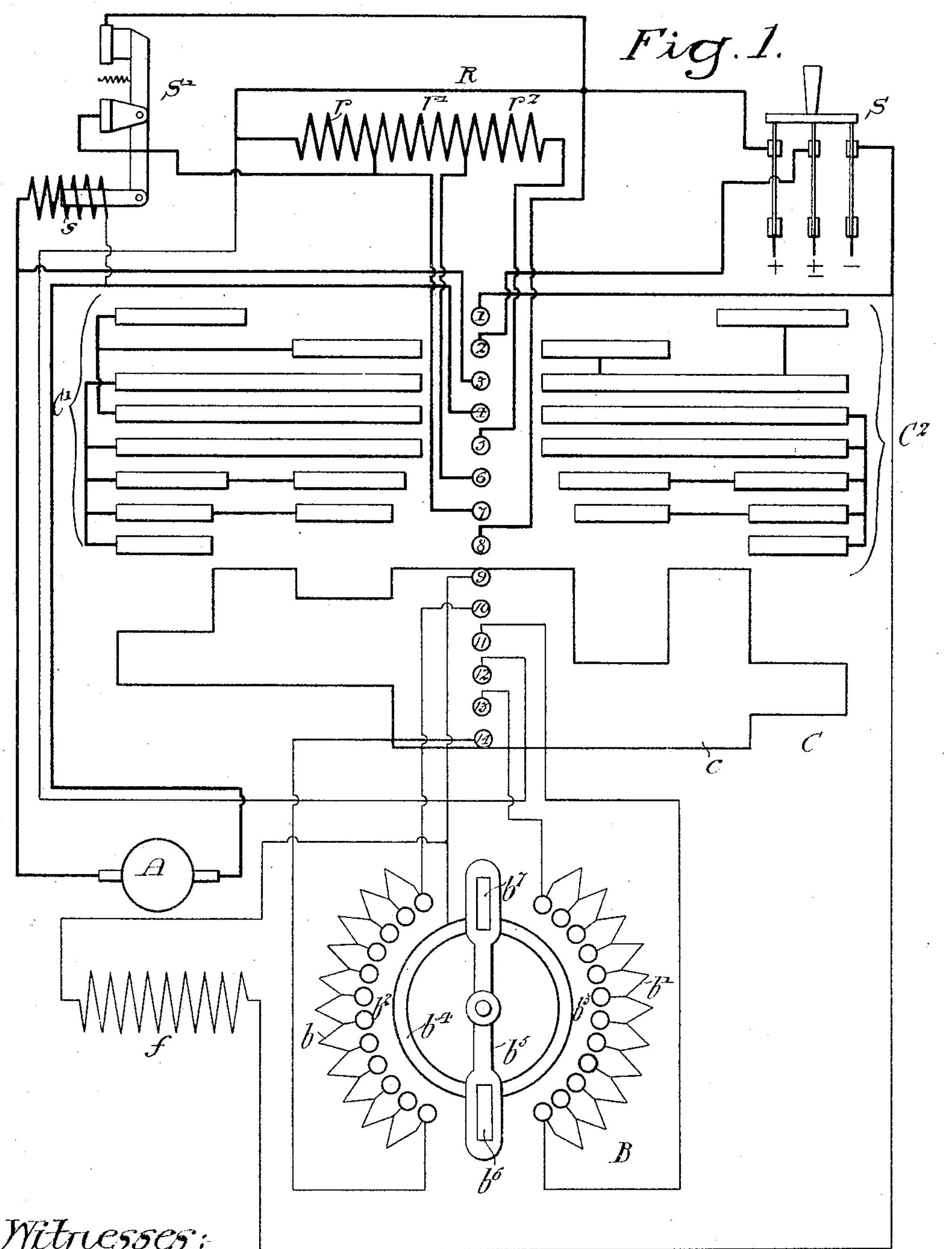
A. C. EASTWOOD.

CONTROLLER FOR ELECTRIC MOTORS.

APPLICATION FILED SEPT. 14, 1904.

2 SHEETS—SHEET 1.

Fig. 1.



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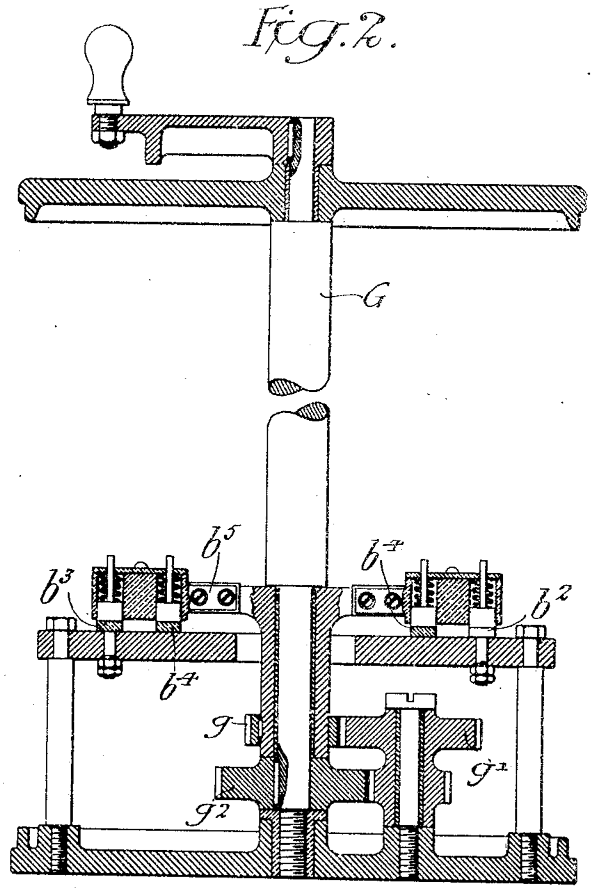
2 SHEETS—SHEET 2.

Fig. 2.



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No. 782,732. Patented February 14, 1905.

UNITED STATES PATENT OFFICE.

ARTHUR C. EASTWOOD, OF CLEVELAND, OHIO.

CONTROLLER FOR ELECTRIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 782,732, dated February 14, 1905.

Application filed September 14, 1904. Serial No. 224,432.

To all whom it may concern:

Be it known that I, ARTHUR C. EASTWOOD, a citizen of the United States, residing in Cleveland, Ohio, have invented certain Improvements in Controllers for Electric Motors, (Case B,) of which the following is a specification.

This controller is applied to the control of variable-speed motors operated on a two-voltage (ordinarily three-wire) circuit in which variation in the motor speed is obtained by the use of two voltages applied to the armature of the motor and by varying the motor-field strength by means of resistance inserted in the shunt field-winding.

One object of my invention is to provide means whereby the motor may be operated at any of a large number of speeds, as described in my pending application for patent on an improved controller filed of even date herewith, it being also desired to provide a construction by means of which at least a portion of the field resistance, with its corresponding contacts, may be used for speed variation in connection with both of the voltages which may be applied to the armature, at the same time providing means whereby the controller may be readily adapted to various ranges of speed control.

Another object of the invention is to provide means for protecting the motor from injury at the time of transition from the higher to the lower voltage lines and also contemplates the provision of such a combination of apparatus as will prevent a heavy rush of current, no matter how rapidly the controller may be operated, to effect the transition from the higher to the lower voltage or to reverse the direction of rotation of the motor.

I further desire to accomplish the above-noted objects by means of a relatively simple and inexpensive combination of apparatus and connections.

These objects I attain as hereinafter set forth, reference being had to the accompanying drawings, in which—

Figure 1 is a diagram of the connections of my improved controller, showing it as employed with a shunt-wound motor supplied with current from a three-wire circuit; and Fig. 2 is a sectional elevation showing the preferred construction of certain features of the controller proper preferably used in carrying out my invention.

In operating a shunt-motor from a balanced three-wire circuit it is obvious that the speed of the motor with full field strength and with two hundred and twenty volts, for example, applied to its armature will be practically double its speed under similar field conditions but with one hundred and ten volts applied to the armature. If further speed variation be desired, this may be secured by inserting resistance in the field-circuit both when the armature is supplied with two hundred and twenty and when it is supplied with one hundred and ten volts, it being noted, however, that inasmuch as it is desirable to obtain as much speed variation as possible on the higher voltage a higher field resistance must be available on said higher voltage than is required on the lower voltage. To provide for this, I employ two sections of resistance which in general will be operated in parallel when the lower voltage is applied to the armature and one of which will be cut out and the other used for field control when the motor has the higher voltage applied to it. If the two sections be of equal resistance, the resistance in circuit at the lower voltage would be one-half that employed at the higher voltage. By varying the relative resistances of the sections any proportion of the desired speed may be obtained on one or other of the applied voltages.

I have frequently noticed in the case of motors operated as above described that when the controller is brought rather rapidly from the full speed position to the "off" position an objectionable flash or arcing takes place at the commutator of the motor at the instant of the transition from the higher to the lower voltage. This flashing is particularly severe and injurious in cases where the motor drives a machine which involves a considerable amount of inertia and acts as a fly-wheel in storing up energy—for instance, a horizontal boring-mill having a revoluble table of large diameter. If a given motor be operating at maximum speed with the higher voltage—say two hundred and twenty volts—applied to its armature and with a weak field, the armature will be generating a counter electromotive force of, say, two hundred volts. If now the controller-lever is moved toward the off position, the field of the motor will be strengthened, and if the inertia of the armature and moving parts of the driven machine is sufficent to maintain the speed during this interval the voltage generated by the armature may increase beyond two hundred volts, due to the increase in field strength. Should the armature now be suddenly connected to the one-hundred-and-ten-volt mains while it is still generating two hundred volts, it will tend to force current back into said mains at a very rapid rate, so that we may momentarily have the condition of a five-horse-power motor acting as a generator at two hundred volts attempting to operate in multiple with perhaps a five-hundred-horse-power one-hundred-and-ten-volt generator in the power plant. The result is a very sudden discharge of the energy stored up in kinetic form in the armature of the motor and driven machine, with a consequent heavy rush of current, which causes flashing at the brushes and pitting of the commutator, as well as serious mechanical strains in the armature, gearing, &c.

Referring to Fig. 1, A is the armature of a motor, having a shunt field-winding f and supplied with current from a three-wire system through a main switch S of the three-pole type. A field-rheostat B is provided in which are two banks of resistance b and b', connected, respectively, at a number of points to two series of contact-buttons b^2 and b^3, arranged in the arc of a circle and supported in any desired manner known to the art. Placed concentrically with these contact-buttons is a contact-segment b^4 in the shape of a ring, and the rheostat is provided with a contact-arm b^5, carrying at its ends brushes b^6 and b^7, whereby any of the contact-buttons may be connected to the ring b^4. A bank of armature resistance R is provided, and this in the present instance is divided into three sections r, r', and r^2, one end of the bank being connected directly to the positive pole of the switch S, while the ends of the three sections are respectively connected to contact-fingers 7, 6, and 5 of a reversing-controller C, whereby the operation of the motor is governed. In Fig. 1 the drum of this controller is shown as developed, and there are on it two groups of contact-segments C' and C², placed, respectively, on the two sides of the line of off position and also one large contact-segment c, extending through and on both sides of said line. The various interconnections of the segments are plainly illustrated, it being seen that the fingers 1 to 8, inclusive, are so placed as to engage either of the two groups of segments C' and C², while the fingers 9 to 14, inclusive, operate solely on the segment c, being all in contact therewith when the controller is in its off position. The finger 9 is connected to the ring b^4 of the rheostat B and also to one end of the motor field-winding f, the other end of said winding being connected directly to the negative pole of the main switch S.

Fingers 10 and 14 are respectively connected to the ends of the section b of the field resistance, while fingers 11 and 13 are similarly connected to the ends of the section b'. Finger 12 is directly connected to the positive pole of switch S, and it will be noted that the shape of the segment c is such that this finger is always in contact with it. Finger 1 is connected to the negative pole of the switch S, finger 2 to the neutral pole of said switch, and finger 8 to the positive pole thereof, while fingers 3 and 4 are respectively connected to the terminals of the motor-armature A.

In addition to the above apparatus I also provide an automatic switch S', having its actuating-solenoid s connected across the armature-terminals of the motor, said switch being so constructed that it is normally maintained closed—as, for example, by means of a spring. The terminals of the switch are connected in shunt to the section r of the bank of resistance R, so that as long as said switch is closed this section is short-circuited. This switch S' is so adjusted that when the lower voltage of the supply-mains is applied to the armature of the motor its coil s is not sufficiently excited to cause it to open, though the adjustment is such that when once the switch has been opened—as, for example, by the application of the higher voltage to the armature—it will not close until the electromotive force generated in the armature has dropped to substantially the value of the lower voltage of the circuit.

The rheostat B under ordinary conditions forms part of and its arm b^5 is operated from the same source of power as is the controller C, as shown in Fig. 2, the various parts being preferably arranged as described and claimed by me in an application for patent filed of even date herewith.

The contact-segments C' and C² are mounted upon the shaft G of the controller proper, although they are omitted for the sake of clearness from Fig. 2, as are also the coils or grids comprising the resistance b and b'. The arm b^5 is driven from the shaft G through gearing which includes pinions g, g', and g^2, so that its angular velocity under operating conditions is substantially equal to twice that of the drum carrying the contact-segments.

Under operating conditions as the drum of the controller is moved in either direction from its off position the armature of the motor is supplied with current which flows from the positive pole of the switch S through switch S', sections of resistance r' and r^2, and to the neutral pole of switch S. Further motion of the drum causes fingers 6 and 7 to successively engage their segments and so short-circuit said resistance, it being noted that the two groups of segments C and C^2 constitute a reversing-switch, being so arranged that the motor is operated in one direction when one of them is engaged by the fingers and in the opposite direction when the other group is engaged.

Leaving out of consideration for the time being the effect of the rheostat B and its contacts on the motor, the continued motion of the drum of the controller C causes a transition from the lower to the higher voltage, fingers 2, 6, and 7 passing off of their segments, and thereby open-circuiting the motor. Immediately thereafter, however, said segments, hitherto connected to the segments engaged by the finger 2, are electrically connected to the negative pole of switch S through finger 1, thus supplying full voltage to the motor, after which the two sections of resistance r' and r^2 are again placed in circuit and shortly thereafter cut out when the controller finally reaches its full "on" position. In the meantime the switch S′ has been opened by the application of the higher voltage to its coil, and while this temporarily places resistance-section r in circuit the latter is immediately thereafter cut out by the engagement of finger 8 with its segment. If now the drum of the controller be turned toward its off position, the finger 8 is open-circuited, and since the coil of switch S′ is excited by the higher voltage the resistance-section r will be placed in circuit with the armature and will, moreover, be maintained in such circuit until the speed of the motor has so far fallen that its armature generates a voltage substantially equal to the lower voltage of the circuit. The resistance of section r is so proportioned as to limit the current-flow to a safe value, and since it is not cut out until the electromotive force generated by the motor-armature has fallen as above noted there can be no shock or excessive rush of current when switch S′ is finally permitted to close.

It will be seen that the switch S′ and the resistance r also come into action to limit the current flowing to the motor when the controller is suddenly reversed, for under these conditions the counter electromotive force generated by the armature and the newly-applied electromotive force of the lower voltage will be added together, and hence the voltage applied to the coil s will be high enough to cause the switch S′ to open. Such opening will place the section of resistance r in circuit with the motor and will so maintain it until the voltage has dropped to approximately the value of the lower voltage, or, in other words, until the forward rotation of the armature has been checked.

Referring now to the remainder of the apparatus for controlling the speed of the motor, it will be seen that the field-winding of the motor is constantly excited by the higher line voltage, the current flowing from the positive pole of switch S to finger 12, through segment c to finger 9, and thence through the field-winding to the negative pole of switch S. It will be noted, however, that I do not confine myself to this specific connection for the field-winding.

The segment c is of such shape that when the controller is in its off position or in the position of transition between the lower and higher voltages the finger 9 is in direct connection with the positive supply-main, so that the field of the motor is at its maximum strength, while the field resistance is short-circuited. As the drum of the controller is moved from its off position and just at the time when the last section r^2 of the armature resistance is short-circuited by the finger 7 the brush b^6 on arm b^5 of rheostat B will connect with the lowermost of the contact-buttons b^3 and the ring b^4, while the brush b^7 will similarly connect said ring and the uppermost of the buttons b^2. Immediately thereafter finger 9 is open-circuited.

With the continued motion of the controller-drum current will flow from finger 12 to finger 10, hence to a portion of resistance b, to the brush b^7, to the ring b^4, and from thence to the field-winding f and the negative pole of switch S. Current will also flow from finger 12 to the finger 11, through a portion of resistance b', through the lower brush b^6 of arm b^5, through ring b^4, and to the field-winding of the motor, it being noted that the two banks of resistance b and b' are thus connected in multiple to each other and in series with the field-winding. As the drum is moved farther from its off position increasing amounts of resistance are cut into the field-circuit, thus increasing the speed of the motor.

The mechanical connections between the various parts of my device, as described in my application above referred to, are so arranged that at the instant of transition from the lower to the higher voltage the brush b^6 on the arm b^5 is in engagement with the uppermost of the contact-buttons b^3, while the brush b^7 is similarly in contact with the lowermost of the buttons b^2. During the transition period the field of the motor is again supplied with current at full voltage, and when the armature resistance is again cut out the brush b^6 is in such position that it connects between the uppermost of the contacts b^3 and the ring b^4, while the brush b^7 connects between said ring and the lowermost of the contacts b^3. It will be noted, however, that just as the last of the armature resistance is cut out the finger 10 is open-circuited, so that current can no longer flow from the field-winding of the motor through the resistance b. Said field is, however, connected to the positive supply-main through finger 11, a portion of resistance b', the brush b^6, and ring b^4. By the time that the controller finally reaches its full on position all of the resistance b' is in circuit with the field-winding of the motor and the motor will be running at its maximum speed.

In tracing the flow of current when the drum is moved in a reverse direction from its off position it will be seen that said current enters the rheostat B from fingers 13 and 14, thus accommodating the connections to the reversed motion of the arm b^5.

I claim as my invention—

1. A controlling system for electric motors operated on a multivoltage-circuit, the same including a motor, a bank of field resistance, a bank of armature resistance and a controller including means for cutting out said armature resistance as the motor is started on the lower voltage, means for connecting the field resistance in circuit with the field after the armature resistance is cut out, means for cutting in the armature resistance when the higher voltage is applied to the armature, means for again cutting out the armature resistance and an electromagnetic switch having connected to it a device for limiting the current in the motor-circuit to a predetermined amount, substantially as described.

2. In a current-controlling system for electric motors operated on a multivoltage-circuit, the combination of a motor, a bank of armature resistance, two banks of field resistance and a controller including means for cutting out said armature resistance as the motor is started on the lower voltage, means for bringing the banks of field resistance into circuit in parallel as the armature resistance is cut out, means for cutting in the armature resistance at the time of the application of the higher voltage to said armature, means for again cutting out said armature resistance, means for short-circuiting the field resistance during the cutting in and out of the armature resistance, and means for cutting out one bank of the field resistance when the higher voltage is applied to the armature, substantially as described.

3. A controlling system for electric motors operated on a multivoltage-circuit, the same including a motor, two banks of field resistance and a controller including means for first starting the motor on a low voltage and afterward applying to it the higher voltage, means for connecting said two banks of resistance to the field in multiple with each other when the motor is operating on the lower voltage, and means for short-circuiting said resistance at the time when the motor is supplied with the higher voltage, substantially as described.

4. A controlling system for electric motors operated on a multivoltage-circuit, the same including a motor, two banks of field resistance and a controller including means for first starting the motor on a low voltage and afterward applying to it the higher voltage, means for connecting said two banks of resistance to the field in multiple with each other when the motor is operating on the lower voltage and means for cutting out one of said banks of resistance and supplying current to the field through the other bank when the motor is supplied with the higher voltage, substantially as described.

5. A controlling system for motors operated on a multivoltage-circuit, the same including a motor, and a controller having means for first connecting said motor to low-voltage mains and afterward connecting it to mains supplying current at a higher voltage, with automatic, electrically-actuated means for limiting the current-flow from the motor when it is connected to low-voltage mains, after being in connection with the high-voltage mains, substantially as described.

6. A controlling system for a motor operated on a multivoltage-circuit, the same including a motor, a controller having means for first connecting said motor to low-voltage mains and afterward connecting it to mains supplying current at a higher voltage, a bank of resistance and a switch connected to automatically cut said resistance into circuit with the motor before the latter is connected to low-voltage mains after having been connected to high-voltage mains, substantially as described.

7. In a controlling system for electric motors operated on a multivoltage-circuit, the combination of a bank of armature resistance, a switch, and means for maintaining said switch in a position to short-circuit said resistance when the voltage generated by the armature of the motor is equal to or lower than one of the voltages of said multivoltage-circuit, substantially as described.

8. In a controlling system for electric motors operated on a two-voltage circuit, the combination of a bank of armature resistance, a switch connected thereto, means for maintaining said switch in position to short-circuit said resistance when the voltage generated by the armature of the motor is equal to or lower than the lower voltage of said two-voltage circuit, and means for causing said switch to open when the voltage generated by the armature of said motor is higher than the lower voltage of said two-voltage circuit, substantially as described.

9. In a controlling system for electric motors operated on a multivoltage-circuit, the combination of a motor, means actuated by the electromotive force of said armature for cutting resistance into circuit therewith when the voltage across the terminals of said armature is higher than the voltage of the supply-circuit, and means for short-circuting the resistance when the voltage across the terminals of said armature is substantially equal to or lower than the voltage of the supply-circuit, substantially as described.

10. In a controlling system for electric mo-

tors operated on a multivoltage-circuit, the combination of a motor, armature resistance and means for cutting the same in and out of circuit as the motor is speeded up, two banks of field resistance, means for controlling the insertion of the same in circuit, means for cutting out one bank of field resistance when the higher voltage is applied to the motor, and a switch for inserting additional resistance in the armature-circuit of said motor when the controller is operated to change the voltage from the high to the low, substantially as described.

11. In a controlling system for electric motors operated on a multivoltage-circuit, the combination of a source of current-supply, a motor, two banks of field resistance, means for connecting said banks in parallel with each other and in series with the field when the low voltage is applied to the armature, and means for cutting out one bank of said resistance as the voltage is raised, substantially as described.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

ARTHUR C. EASTWOOD.

Witnesses:
WILLIAM F. BEATON,
MURRAY C. BOYER.