Nov. 12, 1957 A. E. R. ARNOT 2,813,240

ELECTRIC MOTOR REGULATING APPARATUS

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Fig.2.

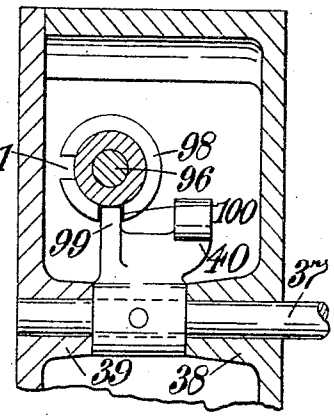
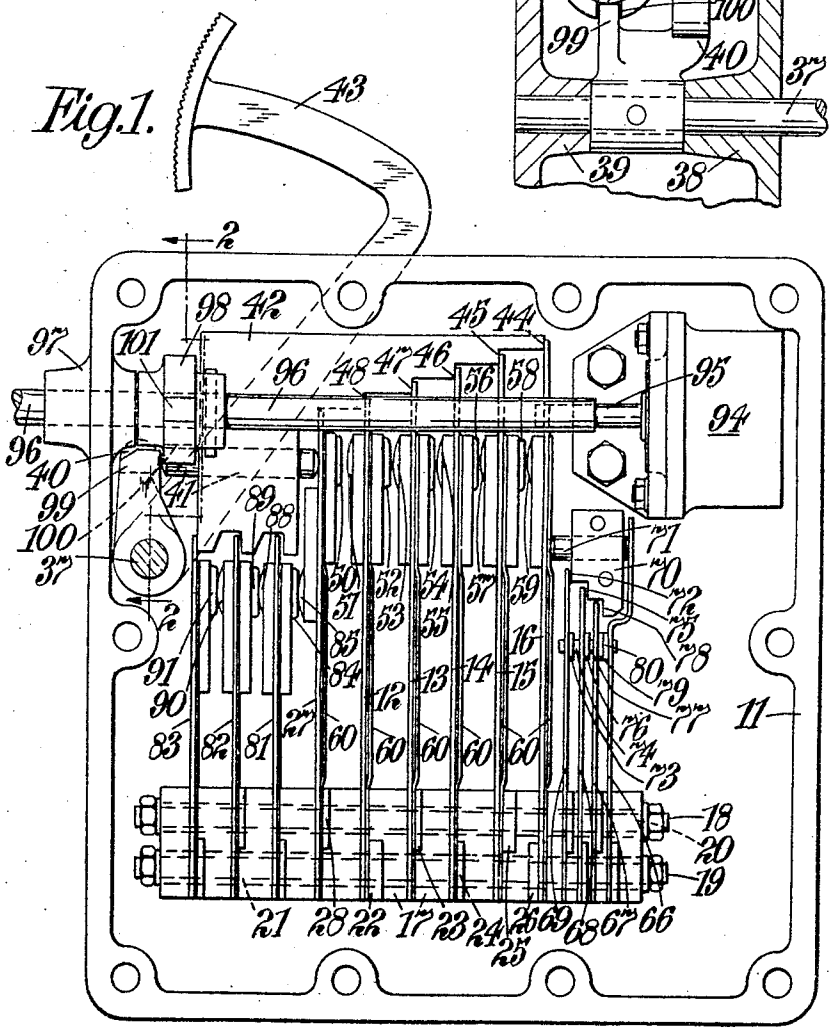


Fig.1.



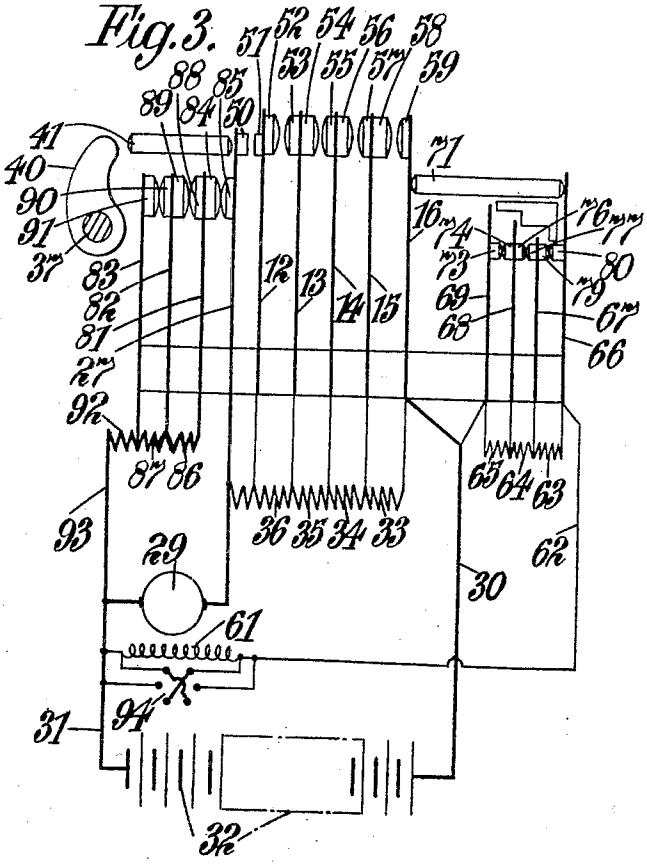
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Fig. 3.



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ELECTRIC MOTOR REGULATING APPARATUS

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8 Claims. (Cl. 318—262)

This invention relates to improvements in or relating to electric motor regulating apparatus.

The invention relates to motor-starters or speed regulators of the type in which when the motor is to be started (or speed increased in the case of a speed regulator), sections of resistance in series with the motor armature are cut out by closing armature-resistance control contacts in parallel with them one at a time until full voltage is applied and in which when the motor is to be reduced in speed or stopped the resistance is replaced in circuit by opening the contacts one after another before the circuit is broken.

In such an apparatus, as the resistance is replaced in circuit there is ordinarily a tendency to arc at the contacts, particularly if the motor is taking heavy current, and one feature of the present invention relates to the prevention of such arcing.

Further features of the invention relate to control of the shunt field of a shunt wound motor and to rheostatic braking.

Arcing depends partly upon the material of which the contacts, which control the resistance, are made and partly upon the voltage and current in operation. With contacts of a particular material, there will be a particular voltage across the contacts above which an arc can occur and below which there will be no arc. This is called the "minimum arcing voltage," and for copper contacts is approximately 12.5 volts.

According to the present invention, in a motor starter or regulating resistance of the type described, each section of the resistance in series with the armature has such a value that, in combination with the resistance of the motor armature and any other resistance between itself and the motor armature, the voltage at the break of the regulating-resistance control-contacts which short-circuit it, when the motor is carrying maximum or stall current, will be less than the minimum arcing voltage of the material of which the contacts are made.

Further features of the invention relate to a construction of regulating resistance or starter which is convenient for use when the resistance is graduated as above described, to means for further varying motor speed by regulating field resistance and to rheostatic braking.

The following is a description by way of example of one construction of motor starter and regulator in accordance with the invention.

In the accompanying drawing:

Figure 1 is an elevation of a motor starter and regulator in accordance with the invention having a cover of its case removed to show the construction of the working parts,

Figure 2 is a detail in section upon the line 2—2 of Figure 1, looking in the direction of the arrows, and

Figure 3 is a connection diagram.

The actual resistance elements of the apparatus about to be described may be located in any desired position where they are well ventilated but the controlling contacts and means for moving them are all located in a flat

compact box 11 which for a motor of two or three horse-power need not be more than 7 or 8 inches square and 2 or 3 inches in depth.

The bottom of the box is covered with an insulating sheet and carries an assembly of spring-contact arms including a series of arms 12, 13, 14, 15 and 16 for the regulating resistance control contacts. The arms are supported by insulating blocks 17 and are drawn together by two screw-threaded stems 18, 19 which are surrounded by insulating bushes 20, 21 and which pass through holes punched in pairs near the roots of each of the contact arms. Each of the arms 12–16 has a connection tag 22, 23, 24, 25 or 26 for connection to the various sections of regulating resistance. A further contact arm 27, having a tag 28 is provided for connection to an electric motor armature 29 and the tag 26 of the arm 16 is connected to the supply wire 30 as shown in Figure 3. The other terminal of the armature 29 is connected to the other supply wire 31, and the supply wires 30, 31 lead to the terminals of a storage battery 32. The various sections of the regulating resistance are shown in Figure 3 at 33, 34, 35 and 36, but the leads to these resistances are omitted from Figure 1.

A rock-shaft 37 extends through bearings 38, 39 in the sides of the case 11 and carries an operating lever 40 which bears on a push rod 41 adapted to bear on the back of contact 27. The push rod 41 is made of a hard insulating material and it slides through a fixed insulating block 42 which is secured to the insulating back-plate and extends down behind the contact 27. Outside the box 11 the rockshaft 37 carries an accelerator pedal 43. If the control box is installed on an electric motor-driven truck in a suitable position, the operator can work the rockshaft 37 by pressure of his foot on the accelerator pedal.

The insulating block 42 is formed with a number of steps which form stop-elements 44, 45, 46, 47 and 48 behind the contact arms 12—16 respectively and 27. These elements prevent the contact arms from moving back more than a certain distance when pressure is relieved from the push rod 41 and they serve to ensure that when pressure is relieved the contacts on the arms are all opened with a suitable spacing from one another. The contacts are shown in the drawings secured to the arms at 50, 51; 52, 53; 54, 55; 56, 57; and 58, 59. The contacts are made of copper and of suitable size to carry the motor current except the first contact 50, 51 which is made of arc-resistant material which will not arc on full battery voltage at the comparatively low starting current. In order to assist the electrical conductivity of the assembly, the contacts are connected to the terminal tags 22–26 and 28 by means of copper strips 60, which extend alongside the spring contact arms 12–16 and 27 respectively. It will be seen that pressure on the accelerator pedal 43 first moves the contact arm 27 and after some movement this brings the contacts 50, 51 together. Further movement will cause the contacts 50, 51 to move over and press the contacts 52, 53 together, and so on throughout series. When the contacts 58, 59 meet, the motor starting and regulating resistance is entirely cut-out and the motor is running directly on the full battery voltage.

Further increase of speed can be obtained by inserting resistance in the circuit of the motor field-winding 61 (Figure 3). This is connected by a line 62 to field-regulating resistance sections 63, 64, 65 and thence to the supply wire 30. In order to control the field-regulating resistance four spring contact arms 66, 67, 68 and 69 are included in the assembly held together by the screws 18, 19, beyond the contact arm 16 of the armature resistance control contacts. The contacts 67, 68, 69 are so set that they tend to move to the right, as viewed in Figure 1, but the contact 66 is given a strong bias to the left, so that it overcomes the force of the other contacts

and in the absence of any other control holds them firmly together, as shown in the drawing. In this position the field-regulating resistance is short-circuited so that the motor starts on full field current. A fixed insulating block 70 is provided behind the contact 16 through which slides a push rod of a hard insulating material 71. The end of the contact 66 is extended up so as to come in line with the end of the push rod. If the accelerator pedal is further depressed beyond the position in which the contacts 58, 59 close, the contact 16 moves the push rod 71 to the right, as viewed in the drawing, and presses the contact 66 away. The contacts 67—69 follow it up, but after a short distance the contact 69 engages a stop-surface formed on the block 70, and is unable to move further. The contact elements 73, 74, between the contact arms 68, 69 therefore separate and insert the section 65 of the field-regulating resistance. A little further movement makes the contact arm 68 engage a stop 75 on the block 70 and this results in the contact elements 76, 77 between the contact arms 68 and 67 becoming separated so that the second section 64 of field-regulating resistance is put in circuit. Finally the contact arm 67 engages a stop 78 and the contacts 79, 80 between the contact arms 67, 66 separate and insert the third section 63 of the field-regulating resistance in series with the field-winding 61. If the accelerator pedal 43 is allowed to rise, the operations are reversed.

To the left of the contact arm 27, as viewed in Figure 1, there are placed three rheostatic braking contact arms 81, 82, 83. The arm 81 carries a contact 84 to engage with the contact 85 on the back of the contact arm 27. If the operator allows the accelerator pedal 43 to rise beyond the position at which the contacts 50, 51 open, the contacts 84, 85 close and a circuit is connected from the motor armature 29 through the contact arm 27 and contact arm 81 to a rheostatic braking resistance arranged in two sections 86, 87 (Figure 3). If the pedal is allowed to rise further contacts 88, 89 between arms 81, 82 close and the first section of rheostatic braking resistance is cut out, thus increasing the effect of the braking exerted by the motor 29 as a generator. If the accelerator pedal is allowed to rise further, the contacts 90, 91 between the arms 82, 83 close and the section 87 of the rheostatic braking resistance is cut out. In order to limit fierceness of the braking there is a further section of resistance 92, between the contact arm 83 and the lead 93 which returns to the motor armature.

In the box 11 there is disposed a reversing switch 94 which is operable by a rotatable spindle 96. The spindle 96, is carried on across the box in front of the contact arms already described and passes through a bearing 97 to the exterior of the box where it carries a reversing lever (not shown). The reversing switch is such that one-quarter of a turn of the spindle 96 is sufficient to operate it. On the spindle 96 inside the box is an interlock collar 98 which is located in the path of a projection 99 on the lever 40. The interlock collar 98 has a slot 100 cut in it to allow the projection 99 to move forward when the reversing switch is in one of its positions and a slot 101 to allow similar movement when the reversing switch is in its other position. Unless the reversing switch is fully operated therefore, it is not possible to operate the accelerator pedal 43. Similarly any depression of the accelerator pedal carries the projection 99 into one of the notches on the collar 98 and prevents operation of the reversing switch, so that reversal cannot be effected when the motor is running.

Turning to the question of the grading of the armature regulating resistance, the manner in which this is determined can best be explained by an illustrative example. If it be assumed that the motor armature resistance is say 0.1 ohm and that the battery which operates the motor has a voltage of 20 volts it will be seen that, assuming negligible intermediate resistance, the stalling current of the motor would be 200 amperes the voltage drop in the armature being 20 volts. If under these conditions, which are the worst possible, the operator lifts the accelerator pedal and breaks the last-closed contacts 58, 59, it is desired that the voltage drop across these contacts should not exceed 12 volts which is below the minimum arcing voltage of the copper contacts. For this purpose it is necessary to ensure that the resistance incorporated by the breaking of the contacts is 1½ times the total resistance already in circuit so that there is a voltage of 8 volts across the existing resistance and 12 volts across the amount of resistance to be inserted. Hence the section of resistance connected across the contacts 58, 59 should have a value of 1.5×0.1 ohm i. e. 0.15 ohm, and this will make the total resistance 0.25 ohm. The insertion of this resistance will reduce the current to 80 amperes. In order to obtain a voltage drop when the next pair of notches open which is not greater than 12 volts, the second section of resistance should have a value of $(0.1+0.15) \times 1.5=0.375$ ohm. In like manner the third section should have a value of

$$(0.1+0.15+0.375) \times 1.5=0.94$$

ohm. The fourth section should have a value of

$$(0.1+0.15+0.375+0.94) \times 1.5=2.36$$

ohms. The last step will be

$$(0.1+0.15+0.375+0.94+2.36) \times 1.5=5.9$$

ohms. The insertion of the last step in the resistance will make the total resistance nearly 10 ohms and reduce the current to only 2 amps., which permits the circuit to be broken with no arcing even though the voltage is 20 volts.

I claim:

1. Control apparatus comprising in combination a direct current electric motor, a number of resistances forming a circuit in series with one another and the motor armature, a series of armature control spring contacts connected to the junctions between said resistances and arranged in a series side by side and closed seriatim by pressing them together, means operating upon said contacts to insert in the circuit the said resistances in a predetermined order, means for applying voltage to the circuit and motor in excess of the arcing voltage of the metal employed for the contacts, the values of said resistances being graded so that upon breaking any pair of said contacts the voltage across them at break is less than said arcing voltage, and a series of field-regulating resistance spring-contacts located beyond said armature control contacts and mechanically connected to said armature control contacts so as to be operated to insert regulating resistances in the field-circuit upon continuance of the movement which closes the armature control contacts.

2. Control apparatus comprising in combination a direct current electric motor, a number of resistances forming a circuit in series with one another and the motor armature, a series of armature control spring contacts connected to the junctions between said resistances and arranged in a series side by side and closed seriatim by pressing them together, means operating upon said contacts to insert in the circuit the said resistances in a predetermined order, means for applying voltage to the circuit and motor in excess of the arcing voltage of the metal employed for the contacts, the values of said resistances being graded so that upon breaking any pair of said contacts the voltage across them at break is less than said arcing voltage, and rheostatic breaking contacts arranged to be closed seriatim by continuation of the armature control contact opening movement.

3. A motor-starter or regulating resistance as claimed in claim 1, wherein stops are provided for limiting the movements of the several field-resistance contacts.

4. A motor-starter or regulation resistance as claimed

in claim 2, wherein stops are provided for limiting the movements of the several field-resistance contacts.

5. A motor-starter or regulating resistance as claimed in claim 8, wherein the said operator operated mechanical means is push rod operated by a lever on a rock-shaft connected to an accelerator pedal.

6. A motor-starter or regulating resistance as claimed in claim 5, having also a reversing switch for the motor, wherein the reversing switch is interlocked with the rock-shaft so that it cannot be operated when the rock-shaft is moved to close the motor circuit.

7. A motor-starter or regulating resistance as claimed in claim 6, wherein the reversing switch is operated by a spindle extending at right angles to the rock-shaft, said spindle carries a locking disc with slots at two positions and the rock-shaft carries an interlock arm which enters one or other of the slots when it is operated to close the motor circuit.

8. An electric motor starter and regulating resistance comprising a series of armature-resistance control spring-

contacts arranged side by side, a series of field-regulating resistance spring-contacts located beside the said armature-resistance control spring-contacts, an operator operated mechanical connection to close seriatim the series of armature-resistance control spring-contacts by pressing them together, and a mechanical connection between the series of armature-resistance control spring-contacts and the series of field-regulating resistance spring-contacts, whereby the latter are operated to insert regulating resistance in the motor field circuit upon the continuance of the closing movement of the said operator operated mechanical means.

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