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G. R. PURIFOY

2,669,679

DYNAMIC-BRAKING MOTOR-PROTECTION

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2 Sheets-Sheet 1

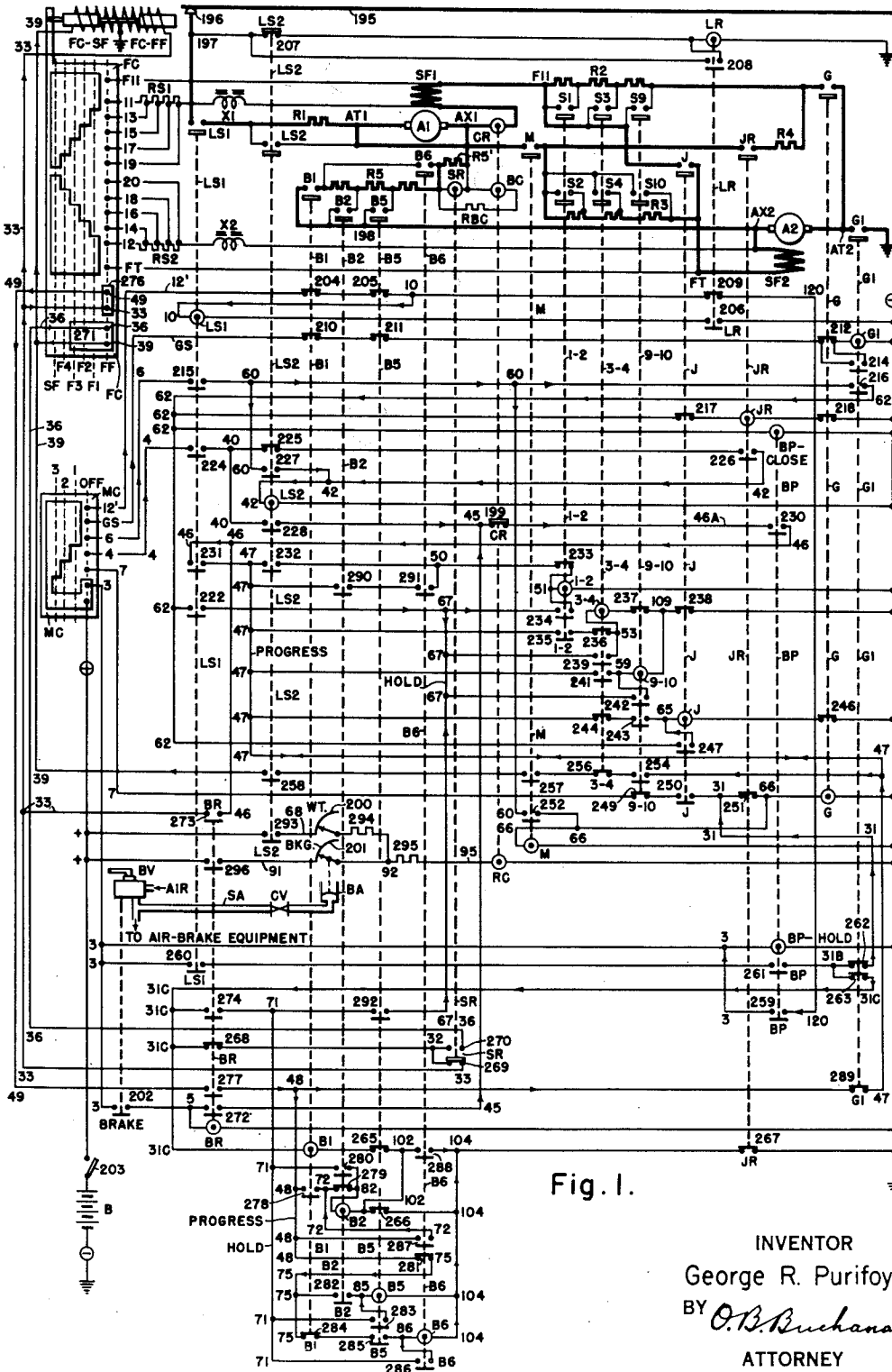


Fig. 1.

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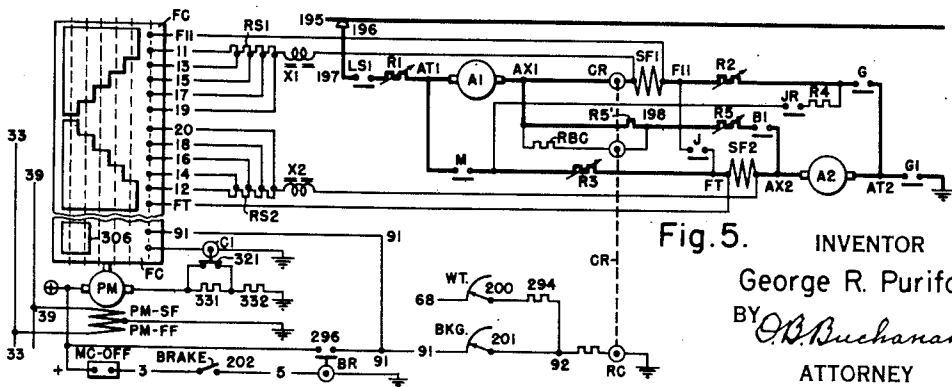
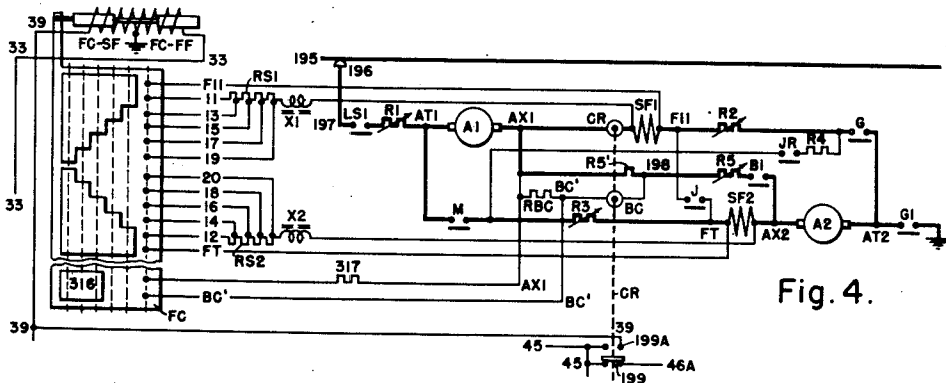
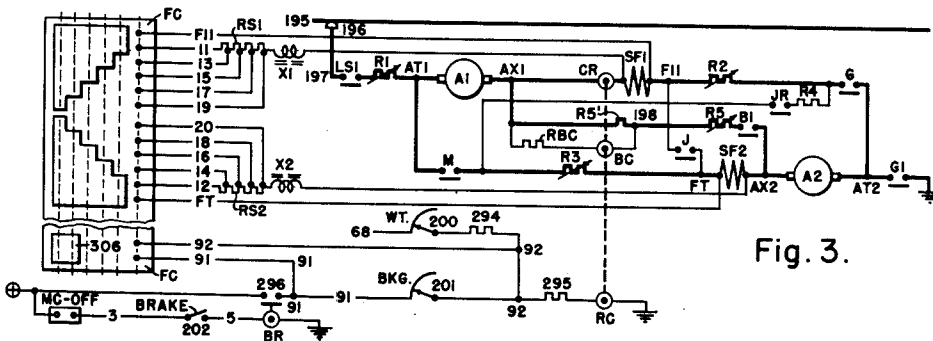
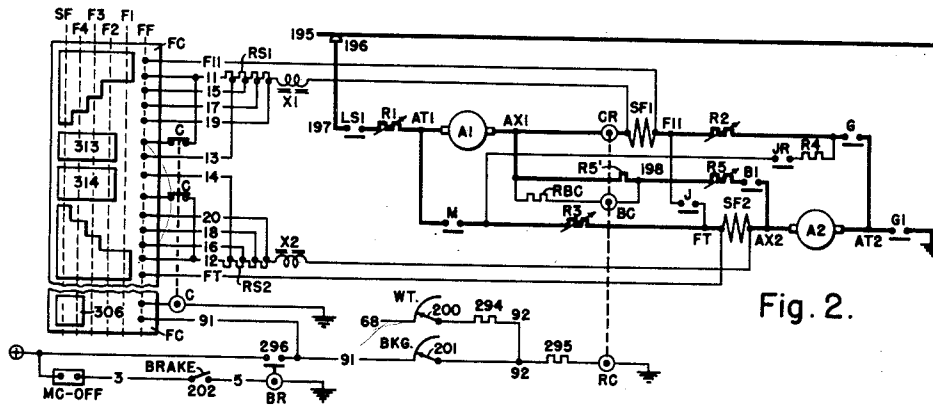
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2 Sheets-Sheet 2



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DYNAMIC-BRAKING MOTOR-PROTECTION

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Application November 28, 1952, Serial No. 323,046

23 Claims. (Cl. 318—56)

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My invention relates to direct-current electrically propelled railway-vehicles, and it has particular relation to electrical control-systems therefor, in which provision is made for dynamic braking. The principal object of my invention is to provide a new means or instrumentality for reducing the high buildup-rate and overshooting of the motor-current and the motor-voltage when the dynamic-braking circuits are established while the motors are being operated at high speeds. Excessive motor-current and excessive motor-voltage result not only in a rough brake-application, but also in motor-flashing. My invention is an improvement over the control-equipment which is shown in an application of William L. Barclay, Jr. and myself, Serial No. 295,794, filed June 26, 1952, in which other means were provided in order to mitigate overshooting when dynamic braking is applied.

I have provided a novel means, responsive to the establishment of dynamic braking during a short-field condition of the traction motor, for reducing overshooting during the initial second of the dynamic-braking operation. I am showing several forms of embodiment of my invention, all of them having the general effect of preventing a too-rapid restoration of full-field operating-conditions in the traction motors, during the initial period of the dynamic-braking operation.

In what is perhaps the least expensive, and therefore preferred, form of embodiment of my invention, a choke-valve is interposed in the connection between the pneumatically operated dynamic-brake actuator and the so-called "straight"-air pipe of the air-brake system, so that, when the brake-handle of the brake-valve is moved to any adjusted braking-position, the resulting air-pressure adjustment in the straight-air pipe will not be communicated too rapidly to the dynamic-brake actuator, so that the dynamic-brake actuator will not instantly adjust itself to its full-brake position, even though a full-brake application is called for, by the brake valve, while the train is running fast with a shunted condition of the field-windings of the traction motors. As is common in railway control systems to which my present invention is applicable, the brake-actuator controls a braking rheostat which is included in series with the rate-coil of the overcurrent limit-relay when dynamic-braking conditions are established, so that, according to the amount of braking which is called for by the brake-valve, more and more resistance will be inserted by this rheostat, thereby decreasing the energization of the rate-coil, and thus increasing the current-setting of the limit relay. In accordance with my present invention, this current-setting of the limit-relay is momentarily held at its minimum value, when a full-brake application is called for during a short-field op-

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erating-condition, and this causes the limit relay to open its back-contact and thus prevent a rapid or uninterrupted adjustment of the field-controlling means from its short-field condition to its full-field condition. In this way, I prevent the too-rapid building-up, and overshooting, of the dynamic-braking current of the traction motors.

In an alternative form of embodiment of my invention, an auxiliary contactor is energized whenever the dynamic-braking circuits are established during a short-field operating-condition, and this contactor is used to immediately reinsert some of the previously cutout resistance of the field-shunting circuit, thus quickly strengthening the motor-fields, thereby producing an immediate surge of braking-current sufficient to pick up the limit relay and thus interrupt the movement or adjustment of the field-controlling means from its short-field condition to its full-field condition. This is enough to prevent the immediate full-scale adjustment of the field-shunting circuit. Hence, the field-shunting circuit is not completely cut out during the first second, more or less, of the dynamic-braking operation, even though a full-brake application is called for, while the train is running fast with a short-field condition of its motors.

A second alternative form of embodiment of my invention uses a short-field condition of the field-controlling apparatus to by-pass the previously mentioned braking rheostat which is in series with the rate-coil of the limit-relay, so that, even though this braking-rheostat should be too quickly adjusted to its maximum-resistance condition, as a result of high air-pressure in the dynamic-brake actuator, the resistance cannot be inserted in the rate-coil circuit because of the presence of the shunting or by-passing circuit which I thus provide.

A third alternative form of embodiment of my invention utilizes a short-field condition of the field-controlling apparatus to by-pass a resistance which is in series with the commonly employed brake-coil of the limit relay, thus increasing the energization of this brake-coil, which results in reducing the current-setting of the limit relay, with the results which I have already described. Since this brake-coil, as it has been known, for some time, is energized across a resistance which is included in the dynamic-braking circuit, this shunting or by-passing of the resistance, which is included in the brake-coil circuit in response to a short-field condition of the field-controller, becomes effective, in controlling the setting of the limit relay, only when the dynamic-braking motor-circuit is established.

A fourth alternative form of embodiment of my invention uses the previously described auxiliary contactor, or one like it, to delay the ad-

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justment or movement of the field-controlling means from its short-field condition toward its full-field condition, as by reducing the speed of the field-controller motive-means, or by slightly delaying the actuation of the means which moves the field-controller in the direction toward its full-field position or otherwise delaying this movement.

With the foregoing and other objects in view, my invention consists in the circuits, systems, apparatus, combinations, parts, and methods of design and operation, hereinafter described and illustrated in the accompanying drawing, wherein:

Figure 1 is a simplified circuit-diagram of the parts of one car, which are necessary to illustrate my present invention, omitting many parts which are known to be needed in a successful railway-control equipment of the type to which my invention is applied, but which are not necessary to be discussed in setting forth the nature and operation of my present improvement, and

Figs. 2 to 5 are simplified diagrammatic views of parts of the equipment which is shown in Fig. 1, illustrating the previously described four alternative forms of embodiment of my invention, respectively.

Fig. 1 represents some of the equipment which is carried by a single electrically propelled railway-car embodying my invention. Direct-current power is supplied to the car from a third rail 195, or a trolley wire, which is engaged by a third-rail shoe 196, or a trolley pole, pantograph, or other current-collecting equipment, carried by the car. The third-rail shoe 196 energizes a line 197 which constitutes a supply-circuit for the car.

The traction-motors for the car are series motors, which are indicated, by way of showing a simple example in Fig. 1, as comprising two motor-armatures A1 and A2, each being associated with its own series field winding SF1 and SF2, respectively, the ordinary reversing-switches being omitted for the sake of simplicity. Two series-motor means, or circuits, are shown. The first series-motor means comprises, in series, an armature-terminal AT1, a motor-armature or armatures A1, an intermediate connection-point AX1, a series field winding or windings SF1, for supplying the field-excitation for said armature or armatures, and a field-terminal F11. The corresponding parts for the second series-motor means are indicated at AT2, A2, AX2, SF2, and FT.

A series-parallel motor-control arrangement is shown in the drawing, in which a line-switch or relay LS1 and a ground-switch G1 are used as power-switch means for establishing a power-circuit for energizing the motors, by connecting the first armature-terminal AT1 to the supply-circuit 197, and connecting the second armature-terminal AT2 to ground. For completing the series-circuit connections, a switch JR is closed in addition to the power-switches LS1 and G1. For parallel-motor operation, two switches M and G are closed in addition to the power-switches LS1 and G1. The parallel-motor switch M provides a circuit-connection between the armature-terminal AT1 of one series-motor means and the field-terminal FT of the other series-motor means; while the other parallel-motor switch G provides a circuit-connection between the other armature-terminal AT2 and the other field-terminal F11. During an intermediate transition-period, a switch J is closed.

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These motor-controlling connections are all in accordance with a well-known switching-system.

Dynamic-braking circuits are established by opening the two power-switches LS1 and G1 and closing a braking-switch B1 in addition to the two parallel-connection switches M and G, also in accordance with a well-known system or arrangement. The braking-switch B1 provides a common dynamic-braking circuit-connection 198 between the respective intermediate connection-points AX1 and AX2 of the two series-motor means, thus providing two dynamic-braking circuits wherein the motor-armature or armatures of each of said series-motor means are loaded by the field winding or windings of the other one of said series-motor means, respectively.

A suitable number of series-connected accelerating resistances are used, as indicated at R1, R2, R3 and R4. The resistance R1 is disposed between the supply-line 197 and the first armature-terminal AT1, and is shorted out by means of a second line-switch LS2. The resistance R2 is in series with the first field-terminal F11, and is progressively shorted out by means of switch-contacts S1, S3 and S9. The resistance R3 is in series with the second field-terminal FT, and is progressively shorted out by switch-contacts S2, S4 and S10. The resistance R4 is in the series-motor connection which is made by the switch JR, and this resistance is finally shorted out by the transition-switch J, for obtaining the full-series power-circuit connection of the motors.

During parallel motor operation, the switch-contacts S3, S4 and S9, S10 are successively or progressively closed, during the acceleration of the motor, and after all of the accelerating-resistances R2 and R3 have been cut out, the field-strengths of the motors are progressively reduced, to provide short-field operating-conditions.

In accordance with a usual arrangement, the motor-fields are reduced by equipping each of the series field windings SF1 and SF2 with a field-shunt, comprising an inductive reactor X1 or X2, as the case may be, and a variable resistor RS1 or RS2, respectively. The field-shunts X1—RS1 and X2—RS2 are first connected in parallel relation to their respective field-windings SF1 and SF2, by means of contact-terminals 11 and 12, respectively, of a progressively or sequentially operating field-controlling means, which is herein illustrated as an electrically operated drum-type field-controller FC. After the respective field-shunts have been connected into operation, the field-shunt resistances RS1 and RS2 are then progressively shorted out by successive controller-points 13, 15, 17 and 19, for RS1, and 14, 16, 18 and 20, for RS2, as the field-controller FC is moved from its initial full-field position FF, through its intermediate positions F1, F2, F3 and F4 to its short-field position SF, at which point the field-winding currents are reduced to about fifty per cent of their unshunted values.

During dynamic braking, the two motors are connected by the common dynamic-braking circuit-connection 198, which contains the braking-switch B1 and a braking-resistance R5. This resistance R5 is used, in addition to the previously mentioned accelerating-resistances R2 and R3, in establishing the complete dynamic-braking circuit. The braking-resistance R5 is progressively shorted out by means of braking-switches B2, B5 and B6, during dynamic-braking opera-

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tions, after which the acceleration resistances R2 and R3, or portions thereof, are progressively shorted out, as by the switch-contacts S3, S4, and S9, S10. (The switch contacts S1 and S2 are permanently closed during the dynamic-braking operations, in the illustrated system.)

The progressive operation of the various resistance-shortening switches, during both motorizing operation and dynamic braking, is under the automatic control of a suitable limit-relay or relays, which are energized to be responsive to conditions which accompany excessive torque in the motors. Such a limit-relay is illustrated in the form of a current-relay CR, having an actuating-coil CR which is connected in series-circuit relation between the terminal AX1 and the series field winding SF1. This current-relay CR also has a back-contact 199 (also marked CR), which is normally closed, that is, which is closed in the non-actuated or low-current position of the relay.

The current-relay CR is also provided with certain recalibrating-means. In accordance with previous practice, this relay is provided with a cumulatively operating rate-coil RC, which is energized through a weight-responsive rheostat 200, during accelerating operations, and which is energized through a braking-responsive rheostat 201 during dynamic-braking conditions. The weight-responsive rheostat 200 is automatically adjusted according to the variable weight or live load carried by the car, so that the rate-coil RC is the most strongly excited during light-load conditions, thus reducing the minimum-current setting at which the limit-relay CR picks up and opens its back-contact 199. The braking-responsive rheostat 201 is automatically changed in response to the position of a brake-valve BV, which will be subsequently described, so that the rate-coil RC has its maximum excitation when a low braking-rate is called for, thus providing a low minimum-current setting at which the limit-relay CR picks up and opens its back contact 199, and also providing limit-relay calibration which is different for braking and power-operating conditions. The brake-valve BV carries a contact 202 which will be subsequently referred to.

All of the electrically controlled relays and switches which are shown in the drawing are diagrammatically indicated as having vertical switch-stems (indicated by dotted lines), which are biased by gravity toward their lowermost positions, and all of these switches and relays are shown in their deenergized or non-actuated positions. All of the relays and switches are electrically controlled, and they are illustrated as being electrically or magnetically operated, by means of an appropriately numbered or lettered coil or solenoid, represented by a circle, acting magnetically to lift an armature which is represented diagrammatically by a small circle inside of the coil-circle. In general, the same switch-designation is applied to any particular switch, its coil, and its contacts, by way of identification of the parts belonging to a given switch or relay.

The various electrical control-circuits for a train are under the control of a number of train-line wires, which extend from car to car, throughout the entire length of the train (not shown). In the simplified circuit-diagram of the drawing, eight of these train-line wires are used, being given their usual designations, namely (+), 3, 4, 5, 6, 7, 12' and GS.

Energy for the various relay-circuits or

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switch-circuits is provided by means of a battery B on each car. The negative terminal (—) of each battery is permanently grounded, while the positive terminal of each battery is connected, through a switch 203, to the positive train-line wire (+).

Each end of each car is provided with a motor-man's master controller MC, only one of which is indicated in the drawing. The illustrated master controller MC is indicated as being an accelerating-controller having an off-position and three on-positions 1, 2 and 3. In each of the three on-positions of the master-controller, MC, the positive control-wire (+) is connected to the train-line wires 12', GS and 6. The train-line wire 12' is the energizing-wire for the operating-coil LS1 of the line-switch LS1; while the train-line wire GS is the energizing-wire for the operating-coil G1 of the ground-switch G1, as will be subsequently described.

In the second and third on-positions of the accelerating-drum of the master controller MC, the train-line wire 4 is energized from the positive bus (+); while in the third on-position of this controller, the train-line wire 7 is energized from the positive bus (+).

In the off-position of the accelerating drum or master controller MC, a connection is made from the positive control-wire (+) to the train-line wire 3. In the master controller MC, in accordance with a known practice, there is an overlap between the off-position contact which energizes this conductor 3, and the on-position contacts which energize the conductors 12' and GS, so that, during the notching-off of the master-controller MC, the contact at 3 is made before the contacts at 12' and GS are broken. This overlapping construction is particularly necessary in properly controlling a braking-operation protective-relay BP which will be subsequently described, and which also constitutes the subject matter of a Riley Patent 2,597,183, May 20, 1952.

The first on-position of the accelerating-controller MC, in Fig. 1, is a switching position, in which the control-wires 12', GS, and 6 are all energized. The control-wire 12' energizes a control-circuit wire 10, through interlocks which are provided, by the braking-switches B1 and B5, in the form of back-contacts 204 and 205, respectively; and the control-circuit wire 10 is used to energize the operating-coil LS1 of the line-switch LS1.

In accordance with a usual practice, the exciting-circuit for the line-switch operating-coil LS1 also contains a make-contact 206 of a line-relay LR, which is a voltage-responsive relay which drops out upon a voltage-failure of the supply-line 197. This line-relay LR is shown as an undervoltage relay which has an operating-coil LR which is connected between the supply-line 197 and ground, through a back-contact 207 of the line-switch LS2, said back-contact 207 being paralleled by a make-contact 208 of the line-relay LR.

As set forth in an application of R. E. Burkhart and myself, Serial No. 269,752, filed February 4, 1952, the control-wire 10 energizes a control-wire 120 through a back-contact 209 of the line-relay LR. This line-relay back-contact 209 thus closes in the event of a power-line voltage-failure, which might result from either a third-rail gap or from any other cause; and if the master-controller MC is, at the time, on any on-position, the conductors 12' and 10 will be energized, and hence the line-

relay back-contact 209 will energize the control-wire 120, which I use as an auxiliary holding-circuit for the protective-relay or brake-power relay BP, which I will subsequently describe in more detail.

The train-line wire GS energizes the operating-coil G1 of the ground-switch G1, through interlocks which are provided by back-contacts 210, 211 and 212, which are carried by the braking-switches B1 and B5, and by the parallel-operation switch G, respectively. The back-contact 212 is paralleled by a make-contact 214 of the ground-switch G1.

The train-line wire 6 is connected, through an LS1 make-contact 215, to a relay-circuit 60, 15 which is connected, through a G1 make-contact 216, to a circuit 62 which constitutes a hold-circuit for the switch-progression for the accelerating-resistance short-circuiting switches S1 to S10 and J. This hold-circuit 62 is used to energize 20 the operating coil JR of the series-motor-circuit switch JR, through interlocks on the switches J and G, in the form of back-contacts 217 and 218, respectively. The said hold-circuit 62 is also used 25 to directly energize the close-coil or actuating-coil BP-Close of the braking-operation protective-relay BP.

The result of the mast-control energization in the No. 1 on-position of the master-controller MC, is thus to close the main-circuit or power-circuit contacts of the traction-motor switches LS1, G1 and JR, thereby completing a series-connection motor-circuit for causing a slow movement of the train, for so-called "switching" purposes, with all of the accelerating-resistances in series with the motors. This circuit can be traced from the supply-circuit 197, through the main LS1 contact, the resistor R1, the armature A1, the current-relay coil CR, the series field SF1, the resistance R2, the resistance R4, the main JR contact, the resistance R3, the series field SF2, the motor armature A2 and the main G1 contact, to ground.

At the same time, the energization of the braking-operation protective-relay BP paves the way 45 for the subsequent energization of the dynamic-braking circuits of the motors, and also for the automatic progression-control, under the control of the limit-relay or current-relay CR, both for the motoring progression during acceleration, and 50 for the dynamic-braking progression during an application of the brake-valve BV, as will be subsequently described.

The hold-circuit 62, which is energized in the No. 1 on-position of the master-controller, is also 55 connected, through an LS1 make-contact 222, to a hold-circuit 67, which is used in the subsequent progression-control.

The No. 2 position of the accelerating-controller MC is the first of two running-positions 2 and 3. It initiates the accelerating progression of the series-motor connections, by energizing the train-line wire 4, which is connected, through an LS1 make-contact 224, to a conductor 40. The conductor 40 is connected, through an LS2 back-contact 225, and a JR make-contact 226, to a conductor 42, which energizes the operating-coil LS2 60 of the second line-switch LS2, which acts as the first acceleration-progression switch, by short-circuiting the first accelerating-resistor R1. This LS2 switch has a make-contact 227 which picks up and serves as a holding-circuit contact between the circuits 60 and 42.

This second line-switch LS2 also has a make-contact 228 which connects the circuit 40 to a 75

circuit 45. The circuit 45 is connected, through the CR limit-relay back-contact 199, to a circuit 46A, and thence, through a BP make-contact 230, to a circuit 46, which constitutes the main limit-relay progression-circuit of the control-equipment. This limit-relay progression-circuit 46 is thus not only under the control of the limit-relay or current-relay CR, which is responsive to excessive motor-currents, but it is also under the control of the braking-operation protective-relay BP, which must be closed (with the protective relay in its actuated position), before there can be any progression during either the motoring operation or the braking operation.

This limit-relay progression-circuit 45 is connected, through an LS1 make-contact 231, to a progression-wire 47, which is connected through an LS2 make-contact 232 to a control-wire 50. The control-wire 50 energizes the operating-coil 1-2 of a second resistor-shortening progression-switch 1-2, which carries the two main contacts S1 and S2, this energization being effected through a back-contact 233 of this same switch 1-2. Thus, this energizing-circuit from the conductor 50 includes the switch-out interlock 233, a conductor 51, and the coil 1-2. This second progression-switch 1-2 picks up and closes a holding-circuit make-contact 234, which energizes the circuit 51 from the hold-circuit 67.

The actuation of the second resistance-shortening switch 1-2 also closes a make-contact 235, which energizes a circuit 53 from the progression-circuit 47, through a back-contact 236 of a third resistance-shortening switch 3-4, which is the switch which carries the main switching-contacts S3 and S4. The energizing-circuit for this switch extends from the conductor 53, through the operating-coil 3-4 and a back-contact 237 of a fourth resistance-shortening switch 9-10, thence through a control-circuit conductor 109, and a J-switch back-contact 238, to the grounded negative battery-terminal (-). The actuation of the third resistance-shortening switch 3-4 closes a make-contact 239 which establishes a holding-circuit for the conductor 53 from the hold-wire 67.

The actuation of the third progression-switch 3-4 also closes a make-contact 241, which completes a circuit from the progression-wire 47 to a conductor 59, which energizes the actuating coil 9-10 of the fourth resistance-shortening switch 9-10, which carries the main switching-contacts S9 and S10, the negative terminal of said coil 9-10 being connected to the previously described wire 199. The actuation of this fourth switch 9-10 also closes a make-contact 242 which establishes a holding-circuit for the conductor 59 from the hold-wire 67.

The actuation of the fourth resistance-shortening switch 9-10 also closes a make-contact 243, which is connected between the progression-wire 47 and a circuit 65, through a back-contact 244 of the third resistance-shortening switch 3-4. This circuit 65 energizes the operating-coil J of the transition-switch J, through a G-switch back-contact 246. The transition-switch J then closes its main or power-circuit contact J, which constitutes the last step in series motor-connection for the traction-motors, cutting out the last accelerating-resistance R4. This transition-switch J has a make-contact 247 which establishes a holding-circuit from the conductor 65 back to the hold-line 62. The previously described J-switch back-contacts 217 and 233 are 75 opened, upon the energization of the transition-

switch J, thus dropping out the initial series-connection switch JR, and the third and fourth accelerating-switches 3-4 and 9-10.

The next step in the acceleration of the traction-motors is accomplished by a movement of the master-controller MC to its No. 3 position, which is a parallel-motor running-position. This position 3 of the master-controller energizes the train-line wire 7, which is connected, through a back-contact 249 of the fourth accelerating or resistance-shorting switch 9-10, and a make-contact 250 of the transition-switch J, so as to energize a control-circuit 31, which is in turn connected, through a JR back-contact 251, to a control-circuit 66 which energizes the operating-coils M and G of the parallel-motor-connection switches M and G. These switches M and G thereupon connect the traction-motors in parallel, between the supply-circuit 197 and ground, with only the first two of the resistance-shorting switches energized, in the illustrated form of embodiment of my invention, namely the second line-switch (or first progression-switch) LS2, and the second progression-switch 1-2 which carries the main switching-contacts S1 and S2. The energization of the parallel-connection switch G opens the previously described back-contact 246, which drops out the transition-switch J. The energization of the parallel-connection switch M closes a make-contact 252, which establishes a holding-circuit for the conductor 66 from the line 60.

Responsive to the dropping-out of the transition-switch J, the back-contact 233 of this switch recloses, and re-initiates the switch-progression of the resistance-shorting contacts S3 to S10, under the control of the switches 3-4 and 9-10, through the circuits which have been previously described. This establishes the maximum armature-voltage conditions on the motors, and it completes the connections for the full-field parallel-connection operation of the traction-motors.

As soon as the resistance-shorting switch 9-10 closes, it closes an additional contact 254, which energizes a field-controller actuating-circuit from the progress-wire 47, said circuit extending from the wire 47 through the previously mentioned make-contact 254 of the resistance-shorting switch 9-10, a back-contact 256 of the third progression-switch 3-4, a make-contact 257 of the parallel-connection switch M, and a make-contact 258 of the line-switch LS2, and thence to the short-field wire 39 of the field-controller FC.

The short-field wire 39 of the field-controller FC energizes the short-field coil FC-SF, or other means which may be used to move the field-controller from its full-field position FF to its short-field position SF. This starts the progressive operation of the field-controller, and it may be brought about in any one of several ways. In the illustrated form of embodiment, since the power for the short-field wire 39 is obtained from the progress-wire 47, which is under the control of the limit-relay CR, the field weakening progression of the field-controller FC progresses under the control of the limit-relay CR, until the short-field position SF is reached. This completes the connections for the short-field parallel-connection operation of the traction-motors, thus completing the acceleration-progression.

If, now, the master-controller MC is returned to its off-position, the car or train being now

running at some considerable speed, the master-controller will energize the train-line wire 3, which may be described as the brake-wire 3, because it is used to set up the dynamic-braking circuits for the motors during the coasting operation. When the braking-protective relay BP is used, as shown, the brake-wire 3 is also used to directly energize a hold-coil BP-Hold of the braking-protective relay BP, and this hold-coil may be regarded as representative of any holding-means which is effective only after the protective relay BP has previously been moved to its actuated position. When a separate holding-coil, BP-Hold, is used as such a holding-means for the BP relay, said coil will be made so as to be too weak to pick up the BP relay if the relay is in its non-actuated position when the hold-coil is energized, but the hold-coil BP-Hold has enough energy to hold the relay actuated or closed, once it has been actuated.

As set forth in the previously mentioned application of Burkhart and myself, the BP-Hold coil is also provided with a second energizing-circuit, which is independent of the brake-wire 3, and thus operative in any of the three on-positions of the master-controller MC. This second hold-coil energizing-circuit includes a make-contact 259 of this brake-protective relay BP, and this make-contact 259 is used to energize the brake-wire 3 from the previously described control-circuit 120, which is under the control of the line-relay LR, so that the control-circuit 120 is energized whenever there is a failure of the line-voltage, at a time when the train-line wire 12' is energized, that is, at a time when the master-controller is on any one of its three on-positions, as previously described. In this way, I not only maintain the energization of the BP-Hold coil under the no-voltage conditions just described, thus making sure that the brake-protective relay BP remains in its actuated condition, but I also immediately energize the brake-line 3, without waiting for the master-controller MC to be returned to its off-position, which establishes the coasting braking-circuit connections, as will now be described.

The brake-wire 3 is connected, through an LS1 back-contact 260 and a BP make-contact 261, to a control-circuit 31B. This control-circuit 31B is connected, through a G1 back-contact 262, to the previously described control-circuit wire 31, which energizes the previously described parallel-motoring switches M and G through the JR back-contact 251 and the control-wire 66. The control-conductor 31B is also connected, through a G1 back-contact 263, to a control-wire 31C, and thence to the positive terminal of the braking-switch coil B1, the negative terminal of which is connected in a circuit which includes a B5 back-contact 265, a conductor 102, another B5 back-contact 266, a conductor 104, and a JR back-contact 267, and thence to the grounded negative battery-terminal (-). The closure of the switches M, G and B1 completes the establishment of a weak coasting-operation dynamic-braking circuit-connection for the traction-motors, with all of the available dynamic-braking resistances R5, R2 and R3 in circuit, this dynamic-braking resistance being large enough so that the braking tractive-effort is usually quite weak, at moderate motor-speeds, thus permitting the train to coast, with little or no sensible or perceptible braking-effect, as long as the field-controller FC remains in its short-field position.

A connection is also provided, for controlling the field-controller FC during the coasting-operation. In accordance with a known practice, I provide a circuit extending from the control-wire 31C, through a back-contact 268 of a brake-relay BR, to a control-circuit 32, and thence through the back-contact 269 of a spotting-relay SR, to the full-field wire 33 of the field-controller FC. The brake-relay BR was shown and described in a Riley-Purifoy Patent 2,523,143, granted September 19, 1950. The spotting relay SR is a previously used relay, having an operating-coil SR which is included in the common brake-circuit connection 198, as by being connected in shunt across a portion R5' of the braking-resistance R5, in the dynamic-braking circuit-connection 199. Thus, the spotting relay SR is responsive to the braking-circuit current. This spotting-relay SR is adjusted to have a low-current pickup-value, so that it can hold the braking-circuit current to a small value suitable for spotting purposes, during the coasting operation of the traction-motors, as is well understood in the art.

The full-field wire 33 of the field-controller FC energizes a full-field coil FC—FF, or other means for causing the field controller FC to move or progress from its short-field position SF to its full-field position FF. This energization of the full-field coil FC—FF under the control of the spotting relay SR thus progressively adjusts the field-controlling means FC toward its full-field position, as spotting-conditions may require.

In accordance with a known control-method, the spotting-relay SR has a make-contact 270 which connects the circuit 32 to a circuit 36, which goes to a field-controller contact-segment 271, which is closed only during certain early points in the progressive movement of the field-controller FC from its full-field position FF toward its short-field position SF. This field-controller segment 271 is preferably opened at a certain point near the short-field position SF, preferably before the field-controller reaches this short-field position SF. As shown, I prefer to have this field-controller segment 271 closed at the positions FF through F3 of the field-controller FC. This field-controller segment 271 is used to connect the wire 36 to the short-field wire 39 of the field-controller FC. In this way, when the spotting current is too large, that is, large enough to pick up the spotting-relay SR, the spotting current is reduced by adjusting the motor-fields toward a weaker condition, by making the field-controller FC progress in the direction towards its short-field position, but this progression is usually arrested before the field-controller returns all of the way back to its original short-field position SF, which it occupied before the spotting-control commenced to operate.

A service braking-application is made by the closure of the brake-valve contact 202, which energizes the full-brake wire 5 from the brake-wire 3. This full-brake wire 5 is connected directly to the coil BR of the brake-relay BR. The brake-relay BR has a make-contact 272, which connects the full-brake line 5 to the conductor 45 which leads up to the limit-relay progression-circuit 46, thus putting the braking progression under the control of the back-contact 199 of the limit-relay or current-relay CR, as well as under the control of the BR make-contact 230, both of which are in circuit between the conductor 45 and the limit-relay progression-circuit 46. At the

same time, the opening of the back-contact 268 of the now-actuated brake-relay BR takes the braking progression out of the control of the spotting relay SR.

Whenever a braking-application is called for, the energization of the brake-relay BR closes a BR make-contact 273, which is used in the initiation of the dynamic-braking progression. Thus, the BR make-contact 273 is used to make a connection from the limit-relay progression-circuit 46 to the full-field wire 33 of the field-controller FC. This causes a progression of the field-controller FC until it reaches its full-field position FF, under the control of the limit-relay CR.

The closure of the brake-relay BR also closes a make-contact 274 which makes a connection from the control-wire 31C to a braking-operation hold-wire 71, in readiness for use in the subsequent brake-progression operations.

When the braking-controlling progression has proceeded to the point at which full-field conditions are restored in the traction-motors, the field-controller FC closes a full-field contact-member 275, which closes a circuit from the full-field wire 33 to a conductor 48, and thence through a BR make-contact 277 to a braking-progression circuit 49.

The energization of the braking-circuit progression-wire 48 immediately serves, through a B1 make-contact 278, which is already closed, to energize a circuit 72, which is connected, through a B2 back-contact 279, to a circuit 82 which is connected to the positive terminal of the B2 actuating-coil, the negative terminal of which is connected to the previously described conductor 102. The B2 switch thus picks up and closes its main contact B2 which shorts out a part of the braking-resistance R5 in the common dynamic-braking circuit 199 of the traction-motors. The actuation of the B2 switch also closes a make-contact 280 which establishes a holding-circuit for the wire 82 from the hold-wire 71.

A circuit is next established from the lower end of the progression-wire 48, through a B6 back-contact 281, to a conductor 75, and thence through a B2 make-contact 282, which has just been closed, to a conductor 85 which is connected to the positive terminal of the B5 actuating-coil, the negative terminal of which is connected to the previously mentioned wire 104. The B5 switch closes its main-circuit contact B5, which shorts out more of the braking-resistance R5 in the common dynamic-braking circuit 198 of the traction-motors. At the same time, the B5 switch closes a make-contact 283 which establishes a holding-circuit from the conductor 85 back to the hold-wire 71.

The energization of the braking-progression switch B5 opens its previously mentioned back-contacts 265 and 286, thus dropping out the switches B1 and B2, the main contacts of which are both short-circuited, now, by the main contact B5. The dropping-out of the B1 switch closes its lowermost back-contact 284, which completes a circuit from the conductor 75 to a B5 make-contact 285, and thence to a wire 86, which is connected to the positive terminal of the B5 coil, the negative terminal of which is connected to the wire 104. The B6 switch thus closes, and closes its main contact B6 which further shorts out some of the braking-resistor R5, thus still further reducing the effective braking-resistance in the dynamic-braking circuits. At the same time, the actuation of the B6 switch closes its make-contact 286, which establishes a

holding-circuit for the wire 86 from the wire 71.

The actuation of the B6 switch also closes a make-contact 287, which connects the progression-wire 48 to the previously described conductor 72, thereby reenergizing the B2 switch, the negative circuit of which is now completed from the wire 102, through a B6 make-contact 288, to the wire 104.

It will be understood that all of these braking-progression operations are under the control of the limit-relay progression-circuit 46, which interrupts the progression whenever an excessive motor-current causes an opening of the current-relay back-contact 199, which is connected in the energizing circuit for said wire 46, thus interrupting the progression until the motor-current subsides to a desirable value.

The braking-circuit progression-wire 48 is also connected, through a G1 out-contact or back-contact 289, to the accelerating-resistance progression wire 47.

After the second closure or actuation of the B2 switch, so that the B2 and B6 switches are now both closed, a circuit is made, from the accelerating - resistance progression-wire 47, through a B2 make-contact 290 and a B6 make-contact 291, to the previously described conductor 50, thus re-initiating the progression of the switches 1—2, 3—4, and 9—10, which progressively close the accelerating-resistor switches S1 to S10, thereby cutting out the accelerating resistors R2 and R3 which are in the individual portions of the respective dynamic-braking circuits of the traction-motors, this progression being also under the same limit-relay control.

Ever since the actuation of the B5 switch, a B5 make-contact 292 has been energizing the accelerating-resistance hold-circuit 67 from the braking-operation hold-wire 71, in readiness for this progression of the accelerating-resistor switches S1 to S10. The braking-progression thus continues until substantially all of the braking-resistance is removed from the dynamic-braking circuit, thus resulting in the completion of the dynamic-braking operation, during which the speed of the car or train has been reduced from the initial speed at which the dynamic brake was applied, down to a low speed at which the dynamic brake fades out.

If a braking-operation is to be discontinued, after once having been started, the braking-circuit switches are released by an opening of the brake-contact 202, without requiring the establishment of a (perhaps momentary) power-circuit (or MC on-position), in order to deenergize the braking hold-wire 71. This is accomplished by the BR-contact 274, which is in series with the hold-wire 71. The opening of the brake-contact 202 deenergizes the brake-relay BR and opens its contact 274, without requiring an on-position of the master controller MC to release the brake-wire 3, in order to deenergize the conductor 31C and hence the hold-wire 71.

It has long been customary to automatically adjust the calibration or setting of the limit-relay CR, in order to cause this relay to drop out in response to various accurately controlled desirable minimum motor-current values, during both the acceleration-progression and the dynamic-braking progression. This is conveniently done by various controls for the energization of a brake-coil BC and a rate-coil RC, both of which act cumulatively with respect to the main over-current-coil CR of the limit-relay CR.

In Fig. 1, I have shown that the brake-coil BC

is energized in shunt across the previously mentioned resistance-portion R5' which is a part of the dynamic-braking circuit 198. This is the same resistance-portion R5' across which the spotting-relay coil SR is energized. In the case of the brake-coil, it is customary to include a brake-coil resistance RBC in series with said brake-coil BC.

In Fig. 1, I have shown two previously known circuits for the rate-coil control or calibration. One such rate-coil circuit involves the weight-responsive rheostat 200, and is traceable from the positive control-power line (+) through an LS2 make-contact 293, a conductor 68, the aforesaid weight-responsive rheostat 200, a resistance 294, a conductor 92, a resistance 295, and the rate-coil wire 95. A second old or known rate-coil energizing-circuit involves the braking-responsive resistance 201, and is traceable from the positive bus (+) through a BR make-contact 296, a conductor 91, and the aforesaid braking-responsive rheostat 201 to the conductor 92. In accordance with a known form of construction, the rate-coil rheostats 200 and 201 are both pneumatically actuated.

The weight-responsive rheostat 200 is actuated to adjustable positions in accordance with the weight or passenger-load on the car, by well-known means (not shown), which are not necessary to an understanding of my present invention.

The braking-responsive rheostat 201 is commonly actuated by means of a dynamic-brake actuator BA which is energized from the so-called "straight-air" pipe SA of the air-brake equipment. This straight-air pipe contains air at a variable pressure, which is under the control of the brake-valve BV, according to the degree of brake-application which is called for by the on-position adjustment of the brake-handle of this brake-valve. When a heavy braking-operation is called for, the brake-handle is moved to its full-on service-position, thus applying a maximum air-pressure in the straight-air pipe SA. At intermediate on-positions or braking-positions of the brake-handle of the brake-valve BV, the air-pressure is less. During all on-positions, or brake-application positions of the brake-valve BV, the previously mentioned brake-valve contact 202 is closed, which connects the train-line wire 5 to the train-line wire 3.

In accordance with the form of embodiment of my invention which is shown in Fig. 1, I interpose, in the straight-air connection to the brake-actuator BA, a choke-valve CV, which admits air only slowly from the straight-air pipe SA. If a mild brake-application is called for by the brake-valve BV, the air-pressure in the straight-air pipe SA is small enough so that the braking-rheostat 201 is operated at a reasonably slow rate, by the brake-actuator BA, thus only gradually increasing the recalibrating resistance of the rheostat 201 in the energizing-circuit of the rate-coil RC.

When, however, a full-brake or a heavy-brake application is called for by the brake-valve BV, the air-pressure in the straight-air pipe SA is high enough so that, previous to my incorporation of the choke-valve CV, the brake-actuator BA would be moved very rapidly to its full limit of operation, thus inserting all of the resistance of the braking-rheostat 201 in the energizing-circuit of the rate-coil RC, and doing this in a matter of a second, or less. Thus, before the limit-relay CR had a chance to pick up its back-con-

tact 199 in the circuit 46A, the decreased excitation of the rate-coil RC would so far increase the current-setting of the limit-relay CR, that this relay would not pick up at all, until the field-controller FC was adjusted to its full-field position FF, as a result of the continued energization of the circuit 46A—230—46—273—23, and thence to the full-field operating-coil FC—FF of the field-controller FC. This resulted in setting up a full-field condition in the motors very rapidly, at the very beginning of the dynamic-braking operation.

This condition would occur during the high-speed operation of the train, and hence during a high-speed operation of the motors, which are now operating as generators for supplying the dynamic-braking current. The speed is high, because the field-controller FC is never adjusted, in the first place, to its short-field position, until the last stages of the acceleration-notching of the motor-control during the motor-operation. If the motorman had coasted for a considerable time, in the "off" position of his master-controller MC, after having reached the full-parallel shunted-field power-circuit motoring-condition, on a level or an uphill track, the train would coast down to a sufficiently low speed, so that the spotting-relay SR would gradually notch back the field-controller from its short-field position SF until it finally reached its full-field position FF. But if the field-controller FC is in or near its short-field position SF, the train will be operating at a fast speed.

With the traction-motors operating as generators at a fast speed, under spotting-conditions, if a full-brake application is called for by the brake-valve BV, and if the brake-actuator BA is permitted to practically instantly operate the braking-rheostat 201 to its full-resistance position, then the calibration of the limit-relay CR will be so high that this limit-relay cannot pick up and deenergize the full-field coil FC—FF of the field-controller, with the result that the field-controller moves very quickly to its full-field position, thus causing overshooting of the dynamic-braking control.

In accordance with my invention, as shown in Fig. 1, the added choke-valve CV, in the air-inlet of the brake-actuator BA, prevents this brake-actuator from moving too fast, in response to a high-pressure condition in the straight-air pipe SA, as a result of a full-brake application of the brake-valve BV. In this way, the limit-relay CR is left at its minimum setting long enough to enable this relay to pick up, in response to the dynamic-braking current, thereby opening the limit-relay back-contact 199 which deenergizes the circuit 46A—23, which immediately deenergizes the full-field coil FC—FF of the field-controller FC. This arrests the movement of the field-controller in the direction toward its full-field position FF. After that, this field-controller movement is resumed, in a step-by-step fashion, under the control of the limit-relay CR, thus making the field-controller FC reach its full-field position FF only after a time which is long enough to avoid the overshooting troubles which have previously been mentioned.

In the event of only a small braking-application of the brake-valve BV, the air-pressure of the straight-air pipe SA is applied only gradually to the brake-actuator BA, even without the choke-valve CV, so that the addition of this choke-valve does not produce any sensible alteration in the mild-brake operation of the appara-

tus, in which there has never been any trouble due to over-shooting. Any added delay, due to the presence of the choke-valve CV, during a mild-brake application, would not be noticed at all in the operation of the train.

In the alternative form of embodiment of my invention which is shown in Fig. 2, instead of working on the braking-rheostat 201, to prevent it from upwardly calibrating the current-setting of the limit-relay CR too rapidly, I have provided an auxiliary contactor C, which I use to give the motor-fields a "kick," or a sudden increment in excitation, enough to cause the motor-current to practically instantly rise to a value which corresponds to the current-setting of the limit-relay CR, even though this current-setting is recalibrated to its maximum value by the speedy operation of the brake-rheostat 201. This auxiliary contactor C, in Fig. 2, is provided with an operating-coil C, and two back-contacts C, which are normally closed, as by gravity, being opened when the operating-coil C is energized.

The operating-coil C is energized from the relay-circuit 91, in series with a field-controller contact-segment 306, which energizes the coil C whenever the circuit 91 is energized, and whenever, at the same time, the field-controller FC is on or near its short-field position SF, as, for example, when the field-controller is on either one of its positions F4 or SF. It will be recalled that the control-circuit 91 is energized from the positive bus (+) in series with the make-contact 296 of the brake relay BR. It will also be recalled that this brake-relay BR is energized in response to the train-line wire 5, which is energized through the brake-valve contact 232, the train-line wire 3, and the "off" position of the master controller MC, as indicated at MC—OFF in Fig. 2.

The two back-contacts C of the auxiliary contactor C in Fig. 2, are connected in series with two field-controller segments 313 and 314, respectively, which are respectively connected between the circuits 11 and 13, and between the circuits 12 and 14. These contact-segments 313 and 314 of the field-controller FC effect a circuit-closure in the field-controller positions between F2 and SF. Thus, even though the field-controller FC is in one of these positions, from F2 to SF, during which the field-shunting resistances RS1 and RS2 would normally be partially short-circuited, between the circuits 11 and 13, and between the circuits 12 and 14, respectively, if the auxiliary contactor C is energized, these portions of the field-shunting resistors RS1 and RS2 will be cut back again into circuit, thus increasing the resistance of the field-shunts, and increasing the current through the motor-fields SF1 and SF2.

The operation of this apparatus, as shown in Fig. 2, will therefore be obvious. Whenever a dynamic-braking operation is called for during a short-field operating-condition, the brake-relay contact 296 will be closed, and a contact will be completed at the contact-segment 306 of the field-controller FC, thus energizing the auxiliary contactor C, and increasing the current-strength in the motor-fields SF1 and SF2. This increases the braking-current enough to pick up the limit-relay SR, thus instantly interrupting the adjustment of the field-controller FC toward its full-field position, in the manner which was described in connection with Fig. 1. In Fig. 2, as the field-controller is moving from its short-field position SF toward its full-field position FF, in a step-by-step fashion as controlled by the lim-

it-relay CR, when the field-controller FC leaves its F4 position and moves to its F3 position, the auxiliary contactor C will become deenergized at 306, thereby increasing the shunting current and decreasing the field-current, causing the field-controller to pause, at this position, long enough to prevent the previously described overshooting difficulties.

In the form of my invention which is shown in Fig. 3, the field-controller contact-segment 306 is retained, but the contact-segments 313 and 314 of Fig. 2 are not used. In Fig. 3, the contact-segment 306 of the field-controller FC is used to connect the control-wires 91 and 92. This has the effect of using field-controller segment 306 to by-pass the braking-rheostat 201 whenever the field-controller FC is in either its position F4 or SF, or otherwise in a position at or close to its shunt-field position SF. In this manner, the field-controller segment 306, during short-field operation, shorts out, or nullifies, the braking-rheostat 201, so that it does not matter if a full-brake application of the brake-valve BV causes a too-rapid actuation of this braking-rheostat 201. In this manner, the limit-relay CR is left at its minimum-current adjustment, during the first second (more or less) of a dynamic-braking operation which is instituted while the field-controller FC is at or near its short-field position SF. This prevents overshooting in the manner which has already been described.

In the form of my invention which is shown in Fig. 4, the field-controller segment 306 of Fig. 3 is replaced by a segment 316, which is shown as making a closed circuit whenever the field-controller FC is in any one of its positions F3, F4 or SF, although this is intended to be representative of any field-controller adjustment which is at or close to its short-field position SF. In Fig. 4, this contact-segment 316 of the field-controller FC is used to connect a parallel resistance 317 in shunt across the brake-coil resistor RBC, so as to give the brake-coil a stronger response to the braking-current which flows through the braking-circuit resistor R5'.

In Fig. 4, the brake-coil resistor RBC is shown as being connected between the intermediate connection-point AX1 of the motor circuit, and a conductor BC', from which a circuit continues through the brake-coil BC to the braking circuit 198, so that the brake-coil BC, with its serially connected resistance RBC, is connected across the braking-circuit resistance R5'. The circuits AX1 and BC' are connected to the field-controller contacts for the segment 316, preferably through the previously mentioned resistance 317, by which the degree of strengthening of the brake-coil response can be predetermined at whatever value is necessary to increase the current-setting of the limit-relay CR to the point where it is able to pick up on the first inrush of the braking current, when dynamic-braking conditions are established during a short-field operating-condition.

Since the brake-coil BC is energized in response to the current in the braking-circuit 198, and since this braking-circuit is not energized except when dynamic-braking conditions are established by the closure of the contactor B1, the field-controller contact-segment 316 of Fig. 4 has no effect upon the operation of my motor-control system except when the dynamic-braking circuit 198—B1 is established, and also ex-

cept when, at the same time, the field-controller FC is on or near its short-field position SF.

In Fig. 4, I also show a modification of the limit-relay CR so as to make the field-controller FC vibrate, as a voltage-regulator, under the control of this limit-relay CR. This same operation could be provided for in any of the other forms of embodiment of my invention, although it is shown only in Fig. 4. In accordance with this feature of my invention, the limit-relay CR, in addition to having the previously described back-contact 199, which is connected between the circuits 45 and 46A, is provided with a make-contact 199A, which is connected between the circuits 45 and 39. This circuit 39 is the circuit which energizes the short-field coil FC—SF of the field-controller FC, whereas the circuit 46A, as shown in Fig. 1, is the circuit which energizes the circuit 33 of the full-field coil FC—FF of the field-controller FC, as was explained in connection with Fig. 1.

Thus, when the limit-relay CR picks up, in Fig. 4, it energizes the short-field coil FC—SF and starts moving the field-controller FC further toward its short-field position SF. This weakens the motor-fields and thus reduces the braking-current, causing the limit-relay CR to drop out and close its back-contact 199, which energizes the circuit 46A—33, which energizes the full-field coil FC—FF, thus starting the field-controller FC moving further toward its full-field position FF. In this way, the field-controller FC oscillates back and forth, after the manner of a voltage-regulator, resulting in a gradual reduction of the shunting-current until the field-shunts are entirely cut out, which happens in the full-field position FF of the field-controller FC. It may happen, under certain adjustments of the apparatus, that the field-controller FC of Fig. 4 will not reverse its movement toward the full-field position FF, and start back toward its short-field position SF until the recalibrating circuit-contact is broken at the contact-segment 316 of the field-controller, so that the field-controller FC will oscillate between the positions F2 and F3 under this voltage-regulator operation, under the control of the make and brake-contacts 199A and 199 of the limit-relay CR.

In the form of embodiment of my invention which is shown in Fig. 5, instead of using the limit-relay CR to prevent the too-rapid movement or progression of the field-controller FC to its full-field position FF, when dynamic braking is called for during short-field conditions, I provide a means which may be broadly defined as a means for changing the rate of movement of the field-controller FC, or slightly delaying the time of that movement. Any means to that end is contemplated, within the broad purview of Fig. 5. I use an auxiliary contactor C1, which is similar to the contactor C of Fig. 2, except that it has only one back-contact 321, which is somewhat differently used. The operating-coil C1 in Fig. 5 is energized, as in Fig. 2, from the circuit 91 and the field-controller contact 306 which has already been described. The back-contact 321 of the auxiliary contactor C1 is used, in Fig. 5, to delay the starting or the rate of the field-controller movement in the direction toward its full-field position FC.

Any means, which will accomplish this purpose, may be used, in Fig. 5. The particular means which is chosen for illustration in Fig. 5 includes a field-controller FC which is actuated by an electric pilot-motor PM, as distinguished

from the magnet-coil type of control which is shown in Fig. 1. In Fig. 5, the pilot-motor armature PM is illustrated as being permanently energized from the positive train-line wire (+), through two resistances 331 and 332. The pilot-motor is provided with two oppositely connected fields PM-SF and PM-FF, which are energized from the previously described conductors 33 and 33, so that, when either one of these conductors 33 or 33 is energized, the pilot-motor PM will turn in the direction for moving the field-controller FC toward its short-field position SF, or toward its full-field position FF, as the case may be. When a dynamic-braking operation is called for during a short-field operating-condition, the auxiliary contactor C1, in Fig. 5, opens its back contact, and thus removes a short-circuit which had been placed, by this contact, across the resistance 331. This reduces the armature-current in the pilot-motor PM, and reduces its speed of operation, long enough to prevent the previously described overshooting difficulties.

While I have described my invention, and explained its manner of operation, in connection with several simplified illustrative forms of embodiment, I wish it to be understood that the efficacy of the invention would not be affected by the addition of desired additional features or safeguards, or by the omission of undesired or unnecessary features, or by the substitution of equivalent or alternative forms of various means or elements for performing the essential element-functions which have been described and explained.

I claim as my invention:

1. A motor-controlling assembly, including the combination, with a series-motor means to be controlled, said series-motor means including a motor-armature and a series field winding connected in series therewith, of: (a) a supply-circuit for the series-motor means; (b) a power-switch means, for establishing a power-circuit for energizing the series-motor means from the supply-circuit; (c) a braking-switch means, for establishing a dynamic-braking circuit for the series-motor means; (d) a variable field-controlling means, for progressively adjusting said series field winding toward a full-field condition and toward a short-field condition, respectively; (e) an acceleration-controlling means, for controlling the closure of said power-switch means, and, contingent upon such closure, progressively controlling the acceleration of said series-motor means during power-circuit operating-conditions, said acceleration-controlling means including a finally-operating means for causing said field-controlling means to progressively adjust said series field winding toward its short-field condition; (f) a braking-controlling means, for controlling the closure of said braking-switch means, and, contingent upon such closure, progressively controlling the braking-adjustment of the dynamic-braking circuit during dynamic-braking conditions, said braking-controlling means including a first-operating means for causing said field-controlling means to adjust said series field winding toward its full-field condition; and (g) an overshooting-preventive means, responsive to an application of said braking-controlling means, and responsive also to a shortened-field condition of said field-controlling means, for effecting a delay in the restoration of full-field operating-conditions during the initial period of the dynamic-braking operation.

2. The invention as defined in claim 1, char-

acterized by said overshooting-preventive means (g) being operative upon the first-operating means of the braking-controlling means (f).

3. The invention as defined in claim 1, characterized by said overshooting-preventive means (g) being operative to interpose a delay in the operation of the first-operating means of the braking-controlling means (f).

4. The invention as defined in claim 1, characterized by said overshooting-preventive means (g) being operative to control the progressive adjustment of the field-controlling means (d).

5. The invention as defined in claim 1, characterized by said overshooting-preventive means (g) being operative to change the rate of progressive adjustment of the field-controlling means (d).

6. The invention as defined in claim 1, characterized by said overshooting-preventive means (g) being operative to delay the time of adjustment of the field-controlling means (d).

7. The invention as defined in claim 1, characterized by said braking-controlling means (f) including, and being under the control of, a braking-controlling limit-relay means, having an operating-coil which is energized to be responsive to conditions which accompany a lower-than-desired braking-current in the dynamic-braking circuit; and further characterized by said overshooting-preventive means (g) being operative to produce an immediate surge of braking-current sufficient to pick up said braking-controlling limit-relay means.

8. The invention as defined in claim 1, characterized by said braking-controlling means (f) including, and being under the control of, a braking-controlling limit-relay means, having an operating-coil which is energized to be responsive to conditions which accompany a lower-than-desired braking-current in the dynamic-braking circuit; and further characterized by said overshooting-preventive means (g) being operative to immediately strengthen the motor-field of the series-motor means.

9. The invention as defined in claim 1, characterized by said braking-controlling means (f) including, and being under the control of, a braking-controlling limit-relay means, having an operating-coil which is energized to be responsive to conditions which accompany a lower-than-desired braking-current in the dynamic-braking circuit; and further characterized by said overshooting-preventive means (g) being operative upon the field-controlling means (d) to immediately effect an adjustment of the series field-winding in the direction toward its full-field condition.

10. The invention as defined in claim 1, characterized by said braking-controlling means (f) including, and being under the control of, a braking-controlling limit-relay means, having an operating-coil which is energized to be responsive to conditions which accompany a lower-than-desired braking-current in the dynamic-braking circuit; and further characterized by said overshooting-preventive means (g) being operative upon the aforesaid braking-controlling limit-relay means to temporarily reduce its current-setting below what it would be without said overshooting-preventive means.

11. A motor-controlling assembly, including the combination, with a series-motor means to be controlled, said series-motor means including a motor-armature and a series field winding connected in series therewith, of: (a) a sup-

ply-circuit for the series-motor means; (b) a power-switch means, for establishing a power-circuit for energizing the series-motor means from the supply-circuit; (c) a braking-switch means, for establishing a dynamic-braking circuit for the series-motor means; (d) a braking-controlling limit-relay means, having an operating-coil which is energized to be responsive to conditions which accompany a lower-than-desired braking-current in the dynamic-braking circuit; (e) a variable field-controlling means, for progressively adjusting said series field winding toward a full-field condition and toward a short-field condition, respectively; (f) an acceleration-controlling means, for controlling the closure of said power-switch means, and, contingent upon such closure, progressively controlling the acceleration of said series-motor means during power-circuit operating-conditions, said acceleration-controlling means including a finally-operating means for causing said field-controlling means to progressively adjust said series field winding toward its short-field condition; (g) a braking-controlling means, for controlling the closure of said braking-switch means, and operative progressively, only whenever a low-current condition exists in said limit-relay means, to progressively control the braking-adjustment of the dynamic-braking circuit during dynamic-braking conditions, said braking-controlling means including a first-operating means for causing said field-controlling means to adjust said series field winding toward its full-field condition; (h) a dynamic-braking recalibrating-means, responsive only in a closed condition of said braking-switch means and also responsive to the degree of brake-application of said braking-controlling means, for increasing the current-setting of the limit-relay means, as the degree of brake-application is increased; and (i) an overshooting-preventive means, for limiting the rate of response of the dynamic-braking recalibrating-means to a heavy-brake application of said braking-controlling means.

12. The invention as defined in claim 11, characterized by said braking-controlling means (g) also including a retrogressively operative means, operative only whenever a high-current condition exists in said limit-relay means (d), for causing the field-controlling means (e) to adjust said series field winding toward its short-field condition.

13. The invention as defined in claim 11, characterized by said braking-controlling means (g) being a part of an air-brake equipment and including a brake-valve which provides a supply of air at a variable pressure dependent upon the degree of brake-application; said recalibrating-means (h) including a dynamic-brake actuator and a variable-pressure air-pipe connection between said brake-valve and said actuator; and said overshooting-preventing means (i) including a choke-valve in said variable-pressure air-pipe connection.

14. A railway-motor control-assembly, including the combination; with two series-motor traction-means, each series-motor traction-means including a motor-armature or armatures, and a series field winding or windings connected in series therewith; of: (a) a supply-circuit for the two series-motor traction-means; (b) a power-switch means, for establishing a power-circuit for energizing the two series-motor traction-means from the supply-circuit; (c) a braking-switch means, for establishing two dynamic-

braking circuits wherein the armature or armatures of each of said series-motor traction-means are loaded by the field winding or windings of the other one of said series-motor traction-means, respectively, said two dynamic-braking circuits having a common dynamic-braking circuit-portion which is not a part of a power-circuit; (d) a limit-relay means having an operating-coil circuit which is energized to be responsive to current flowing in a power-circuit for a series-motor traction-means; (e) a dynamic-braking recalibrating-means, responsive only to dynamic-braking conditions, for changing the current-setting of said limit-relay means; (f) a variable field-controlling means, for progressively adjusting said series field windings toward a full-field condition and toward a short-field condition, respectively; (g) an acceleration-controlling means, for controlling the closure of said power-switch means, said acceleration-controlling means having a first-operating means, operative only whenever a low-current condition exists in said limit-relay means, for progressively controlling the acceleration of said series-motor traction-means during power-circuit operating-conditions, said acceleration-controlling means further having a finally-operating means for causing said field-controlling means to progressively adjust said series field windings toward their short-field conditions; (h) a braking-controlling means, for controlling the closure of said braking-switch means, and operative progressively, only whenever a low-current condition exists in said limit-relay means, to progressively control the braking-adjustment of the dynamic-braking circuits during dynamic-braking conditions, said braking-controlling means including a first-operating means for causing said field-controlling means to adjust said series field windings toward their full-field conditions; and (i) an overshooting-preventive means, operative only whenever said field-controlling means is in a shortened-field condition, for modifying the action of said dynamic-braking recalibrating-means in such a direction as to reduce the current-setting of the limit-relay means below what it would be without said overshooting-preventive means.

15. The invention as defined in claim 14, characterized by said braking-controlling means (h) also including a retrogressively operating means, operative only whenever a high-current condition exists in said limit-relay means (d), for causing the field-controlling means (f) to adjust said series field windings toward their short-field conditions.

16. The invention as defined in claim 14, characterized by said recalibrating-means (e) comprising an operating-coil circuit of said limit-relay means (d), which is energized to be responsive to current flowing in said common dynamic-braking circuit-portion, and said recalibrating-means (e) also comprising an operating-coil circuit of said limit-relay means (d), which is energized independently of the braking current but only whenever the braking-switch means is closed.

17. The invention as defined in claim 16, characterized by said overshooting-preventive means (i) being operative upon said operating-coil circuit which is energized to be responsive to current-flowing in said common dynamic braking circuit-portion.

18. The invention as defined in claim 16, characterized by said overshooting-preventive means

(f) being operative upon said operating-coil circuit which is energized independently of the braking current.

19. The invention as defined in claim 14, characterized by said recalibrating means (e) being an auxiliary operating-coil circuit of said limit-relay means (d), said auxiliary operating-coil circuit including a braking-controlling rheostat and an interlocking means which is closed only during a dynamic-braking operation.

20. The invention as defined in claim 19, characterized by said overshooting-preventive means (i) being operative upon said braking-controlling rheostat to provide a bypassing circuit therearound.

21. A railway-motor control-assembly, including the combination, with two series-motor traction means, each series-motor traction means including a motor-armature or armatures, and a series field winding or windings connected in series therewith; of: (a) a supply-circuit for the two series-motor traction means; (b) a power-switch means, for establishing a power-circuit for energizing the two series-motor traction means from the supply-circuit; (c) a braking-switch means, for establishing two dynamic-braking circuits wherein the armature or armatures of each of said series-motor traction means are loaded by the field winding or windings of the other one of said series-motor traction means, respectively; said two dynamic-braking circuits having a common dynamic-braking circuit-portion which is not a part of a power-circuit; (d) a limit-relay means having an operating-coil circuit which is energized to be responsive to current flowing in a power-circuit for a series-motor traction means; (e) a variable field-controlling means, for progressively adjusting said series field windings toward a full-field condition and toward a short-field condition, respectively; (f) an acceleration-controlling means, for controlling the closure of said power-switch means, said acceleration-controlling means having a first-operating means, operative only whenever a low-current condition exists in said limit-relay means, for progressively controlling the acceleration of said series-motor traction means during power-circuit operating conditions, said acceleration-controlling means further having a

finally-operating means for causing said field-controlling means to progressively adjust said series field windings toward their short-field conditions; (g) a braking-controlling means, for controlling the closure of said braking-switch means, and operative progressively only whenever a low-current condition exists in said limit-relay means, to progressively control the braking-adjustment of the dynamic-braking circuits during dynamic-braking conditions, said braking-controlling means including a first-operating means for causing said field-controlling means to adjust said series field windings toward their full-field conditions; (h) a dynamic-braking recalibrating means, responsive only in a closed condition of said braking-switch means, and also responsive to the degree of brake-application of said braking-controlling means, for increasing the current-setting of the limit-relay means, as the degree of brake-application is increased; and (i) an overshooting-preventive means, for limiting the rate of response of the dynamic-braking recalibrating means to a heavy-brake application of said braking-controlling means.

22. The invention as defined in claim 21, characterized by said braking-controlling means (g) also including a retrogressively operative means, operative only whenever a high-current condition exists in said limit-relay means (d), for causing the field-controlling means (e) to adjust said series field windings toward their short-field conditions.

23. The invention as defined in claim 21, characterized by said braking-controlling means (g) being a part of an air-brake equipment and including a brake-valve which provides a supply of air at a variable pressure dependent upon the degree of brake-application; said recalibrating means (h) including a dynamic-brake actuator and a variable-pressure air-pipe connection between said brake-valve and said actuator; and said overshooting-preventing means (i) including a choke-valve in said variable-pressure air-pipe connection.

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No references cited.