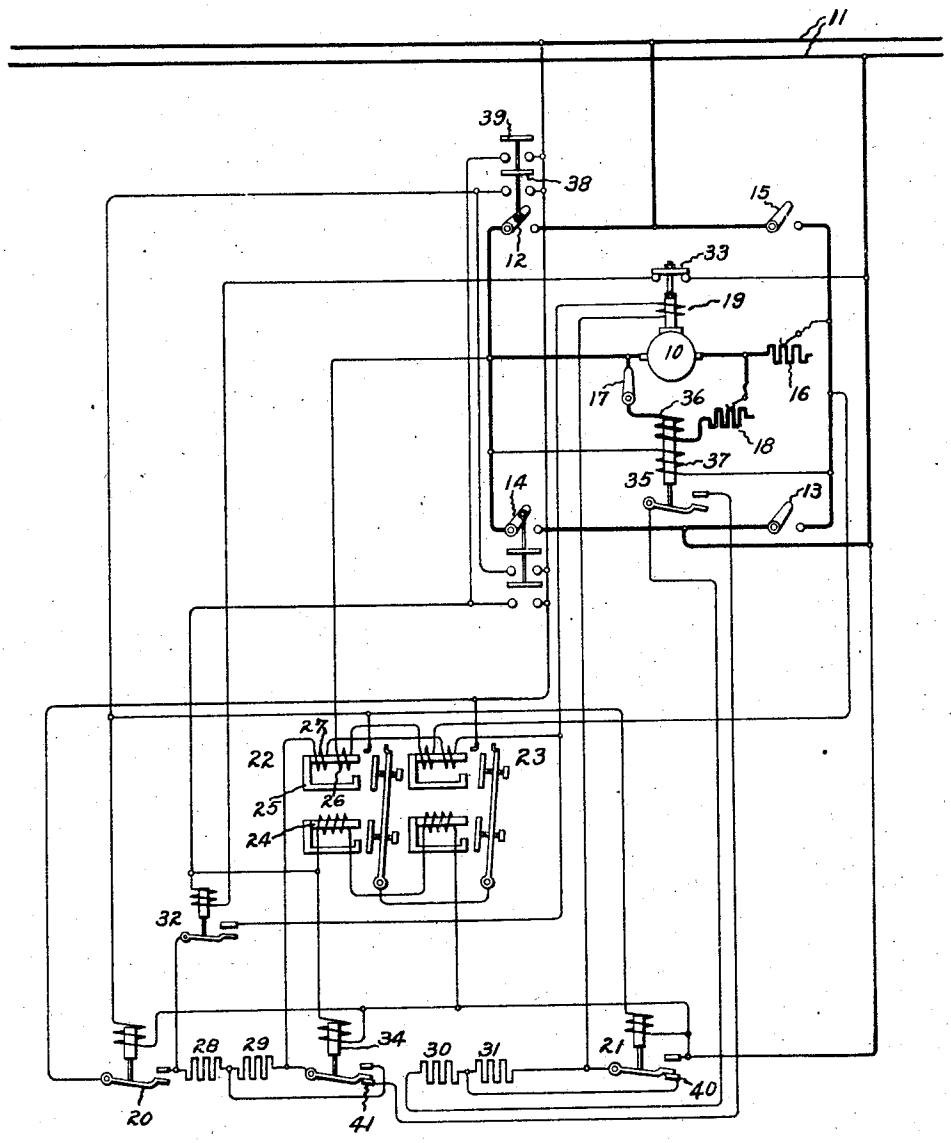
Aug. 25, 1925. 1,551,401

B. W. JONES

BRAKING SYSTEM

Filed Feb. 14, 1925



Inventor:
Benjamin W. Jones,
by Alexander F. Lunt
His Attorney

Patented Aug. 25, 1925. 1,551,401

UNITED STATES PATENT OFFICE.

BENJAMIN W. JONES, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

BRAKING SYSTEM.

Application filed February 14, 1925. Serial No. 9,328.

To all whom it may concern:

Be it known that I, BENJAMIN W. JONES, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Braking Systems, of which the following is a specification.

My invention relates to braking systems and in particular to an arrangement for accurately controlling the braking effect applied to reversing drives of various sorts, although in certain of its aspects the invention is not necessarily limited to reversing drives, but is equally applicable to non-reversing drives.

Electric elevators, hoists and the like present various problems in accurately controlling the braking effect and the present invention is particularly applicable to service of that nature.

In an electric elevator, for example, the accurate control of the braking effect is especially important because of the present day requirements of high speed of operation, safety, and comfort for the passengers. There are numerous variable conditions to be taken care of, among which may be mentioned, the variations in the load on the elevator car, the variations in the speed of the car, the change in the movement of the overbalanced weight—the difference between the weight of the car and the counterweight—since this overbalanced weight is sometimes moving in the up direction, whereas at other times it is moving in the down direction, and the variations in the value of the overbalanced weight as passengers are taken on and let off. Thus, with a lightly loaded car proceeding in the up direction, the overbalanced weight will be moving in the down direction because of the fact that the counterweight is heavier than the car and the weight therein, whereas with a heavily loaded car proceeding in the up direction, the overbalanced weight will be moving in the up direction since the car with the weight therein is heavier than the counterweight.

It can readily be seen that unless provision is made for automatically taking into account these variable conditions, the operator will be unable to effect smooth and accurate landings at all times since he will be unable to make manually the necessary allowances for the variables, even though he were able to estimate exactly the allowances necessary which, of course, he could not do at all times. However, if the variables are all automatically compensated for, the ordinary operator will soon discover the distance from the landing at which the controller should be thrown to the off position in order to effect a smooth and accurate landing and he will thereafter unconsciously operate his elevator properly.

One of the objects of the invention is to provide improved means whereby all of the ordinarily encountered conditions are automatically taken care of so that the braking effect is accurately applied as necessitated by the conditions encountered during the time in which the braking effect is applied.

A further object of the invention is to provide improved means for regulating the action of a mechanical brake in accordance with the dynamic braking effect applied to the driving motor.

Another object is to provide an arrangement whereby the application of the mechanical brake will be in accordance with a function of the difference between the decreasing value of the energization of the brake magnet and the decreasing value of the generated voltage of the motor during the stopping interval.

Another object of the invention is to regulate the braking effect of a mechanical brake in accordance with some or all of the following controlling conditions:—the generated voltage of the driving motor, the current in a circuit in which the brake coil is included to cushion the action of the brake, the current in the dynamic braking circuit in which the motor is included, and the extent of the application of the brake, the various controlling effects being so regulated, proportioned and coordinated that the variable conditions encountered will all be automatically compensated for so as to obtain a smooth and accurate stop for the controlled device.

For a better understanding of the invention, reference is had to the accompanying drawing.

Referring to the drawing, the electric motor having the armature 10 is provided for driving apparatus not shown in the draw-

ing. It will be assumed that the motor is suitable connected to drive an elevator, hoist, or the like, and that the motor is provided with a suitable shunt field (not shown in the drawing). This motor is indicated as of the direct current type and it is arranged to be connected to the source of supply 11 by means of the pairs of reversing switches shown. The switches 12 and 13 are provided for connecting the motor for the hoisting direction and the switches 14 and 15 are provided for connecting the motor for the lowering direction. These switches serve to connect the motor to the source of supply for the desired direction of motor operation, and while the switches are shown as of the manually operated type, it will be understood that I contemplate that these switches may be operated in any suitable manner as, for instance, the switches may be of the electromagnetically operated or contactor type, and these switches may be operated under the control of a suitable master switch.

The accelerating resistor 16 in the motor armature circuit is provided for the usual purpose. The motor armature is arranged to be included in a dynamic brake circuit by means of the switch 17, and the variable resistor 18 is provided in the dynamic brake circuit for regulating this braking action. It will be understood that I contemplate that the variation of the effective portions of the resistors 16 and 18 and the operation of the switch 17 may also be under the control of the master controller (not shown). The motor control arrangement above described is well known to those skilled in the art who will supply the desired master controller for operating the various switches and for varying the above named resistors in order to effect the desired control of the motor. I have not shown the details of such a remote control arrangement, for the reason that it would not help those skilled in the art to an understanding of the invention since the invention is directed primarily to the regulation of the braking effect on the motor.

The braking effect on the motor and the apparatus controlled thereby is supplied by the provision of the dynamic braking circuit heretofore referred to and by means of the mechanical brake 19 which is of the type arranged so as to normally apply a braking effect to the motor and the apparatus controlled thereby. This brake is provided with a winding as indicated in order to release the brake and to regulate the braking effect thereof by controlling the current through the brake winding. The brake winding is arranged to be connected to the source of supply under the control of the directional line switches 12 and 14, and after the brake is connected to the source of supply, the current through the brake winding is regulated by electroresponsive means under the joint control of the generated voltage of the motor, the current in the brake winding and the current in the motor-dynamic brake circuit.

This electroresponsive means comprises the contactors 20 and 21 which are provided for connecting the brake winding to the source of supply, the relays 22 and 23 which are provided with windings energized in accordance with the generated voltage of the motor and the current in the brake winding circuit so as to control the time at which the contactors 20 and 21 open after the opening of the particular set of directional switches so as to thereby maintain the brake winding connected to the source of supply at a reduced value of energization and thus effect for a certain time interval a partial application of the mechanical brake. The relays 22 and 23 are substantially identical and are each provided with two electromagnets and corresponding armatures. The electromagnet 24 of the relay 22 is arranged to be connected to the source of supply upon the closing of either of the line switches 12 or 14 so as to magnetically close the relay. The electromagnet 25 of this relay is provided with two coils, one coil 26 being connected so as to respond to the potential applied to the motor when either line switch 12 or 14 is closed and to respond to the generated potential of the motor when the line switch which had previously been closed is opened. The coil 27 of relay 22 is connected in the circuit of the winding of the mechanical brake 19 under certain conditions, and these two windings 26 and 27 of the relay cooperate to effect a joint control of the energization of the brake winding, as will be hereinafter fully explained. The two windings 26 and 27 are arranged to act cumulatively under certain conditions and to act differentially when this particular relay is governing the contactors 20 and 21. The coils of relay 23 are connected in series with the similar coils of relay 22 and these two relays are provided for accomplishing similar results at the time they are intended to function.

The relay 22 is arranged so as to function to effect a control of the brake magnet winding when the directional switches 12 and 13 are closed and subsequently opened and the relay 23 is provided for effecting a similar result when the directional switches 14 and 15 are closed and subsequently opened.

The resistance, having the sections 28, 29, 30 and 31, is provided for effecting a reduction of the energization of the brake magnet winding to limit the heating of the winding and to regulate the energization thereof so as to effect a partial application of the brake. The contactor 32 is under the joint control of the directional switches 12 and 14 so as

to connect the brake winding directly to the source of supply when the selected set of directional switches is closed, and this contactor is also under the control of the auxiliary switch 33 which is mechanically operated by the brake 19 so as to open the contactor 32 and insert the section 28 of the resistance to limit the heating of the brake winding after the brake has released to the desired degree. The contactor 34 is entirely under the control of the directional switches 12 and 14 and this contactor is provided for short-circuiting the resistor section 29 in its attracted position, and in its biased or unattracted position (that shown in the drawing) for including the brake winding in a local circuit so as to regulate the application of the brake.

The contactor 35 is provided for controlling the local circuit in which the brake winding is included at a certain interval in the application of the mechanical brake 19, and this contactor is provided with a winding 36 in the motor dynamic brake circuit and a winding 37 which is connected similarly to the windings 26 of the relays 22 and 23.

As thus constructed and arranged and with the parts in their respective positions shown in the drawing, the operation of my invention is as follows:

Assume that it is desired to operate the motor in the hoisting direction. The directional line switches 12 and 13 will be closed, thereby connecting the motor armature to the source of supply. The contactors 20 and 21 will be energized to close through the auxiliary switch 38 associated with the line switch 12, and the contactors 32 and 34 will be energized through the auxiliary switch 39 associated with the line switch 12. The winding of the electromagnet brake 19 will be energized and the brake will be fully released, the auxiliary switch 33 being thereupon opened so as to deenergize the contactor 32 and connect the section 28 of resistance in series with the brake winding. When the directional switches 12 and 13 are closed the windings 24 of the relays 22 and 23 and the windings 26 of these relays are energized from the source of supply so as to magnetically close the relay contacts. The closing of these relays at this time produces no effect on the energization of the brake winding. It will be observed that upon the opening of the contactors 32, the winding 27 of the relays 22 and 23 will be included in the brake winding circuit.

The winding 37 of the contactor 35 is also energized across the supply circuit by the closing of the directional switches 12 and 13 so that the contacts of this contactor will automatically close upon the closing of the said line switches. Assume now that the motor has operated the driven device to the desired limit of operation, the directional switches 12 and 13 will be opened, thereby disconnecting the motor from the source of supply and connecting the motor armature in the dynamic brake circuit previously referred to.

Although the contactors 20 and 21 were previously closed in response to the closing of the directional switch 12, these contactors will not immediately open after the opening of the contactor 12, by reason of the fact that the relays 22 and 23 are energized to magnetically hold their respective contacts closed and thus establish a maintaining circuit for these contactors 20 and 21.

The opening of the line switch 12 deenergizes the electromagnets 24 of the relays 22 and 23 so that the opening of these relays will be under the control of their respective coils 26 and 27. For this direction of motor operation the fluxes set up by the coils 26 and 27 of relay 22 will oppose each other, whereas the corresponding coils of relay 23 will set up fluxes which assist each other. The relay 23 will thus be maintained closed, but the relay 22 will automatically open when the difference between the flux set up by the coil 26 and the flux set up by the coil 27 is less than a predetermined value. It will be observed that the deenergization of the contactor 34, due to the opening of the directional switch 12, effects the inclusion of the resistor section 29 in series relation with the brake winding and the resistor section 28 and simultaneously therewith the connection of resistor sections 30 and 31 in multiple with the brake winding through the lower contact of the contactor 34 and the contacts of contactor 35. The contactor 35 will be maintained energized and closed by reason of the fact that the coil 36 of this contactor is energized by the current in the motor dynamic brake circuit and the coil 37 is energized by the generated voltage of the motor.

The inclusion of the resistor 29 in series with the brake winding and the resistor sections 30 and 31 in multiple with the brake winding effects a gradual reduction in the energization of the brake winding, thereby in turn effecting a partial application of the brake.

The generated voltage of the motor will gradually reduce due to the lowering of the motor speed, and the current in the brake winding also gradually decreases so that until the difference between the flux set up by the coil 26 and the flux set up by the coil 27 of relay 22 has reduced to a predetermined value, the relay 22 will remain closed for an interval but will automatically open when this difference is the predetermined value, thereby deenergizing the contactors 20 and 21 and effecting the disconnection of the brake winding from the source of sup-

ply. The deenergization of the contactor 21 effects the closing of a circuit through its lower contact 40, thereby shunting the resistor section 31 and leaving the brake winding in a local circuit including the lower contact 41 of the contactor 34, the coils 27 of relays 22 and 23, the brake winding, the lower contact 40 of contactor 21, resistor section 30 and the contacts of the contactor 35. A further gradual reduction of the current in the brake winding circuit is thus effected by reason of the fact that the brake winding is disconnected from the source of supply and included in a comparatively low resistance local discharge circuit. By reason of the inductive action of the brake magnet, it will take an appreciable time interval for the brake to fully apply, the local discharge circuit serving to provide a cushioning action of the brake in setting.

When the current in the dynamic brake circuit and the generated voltage of the motor have reduced to such a value that the coils 36 and 37 of the contactor 35 will not maintain this contactor in its closed position, this contactor will open and thereby open the local discharge circuit to effect a complete application of the brake.

The operation of the invention is the same when the set of directional motor switches 14 and 15 are closed for operation in the opposite direction instead of the directional switches 12 and 13 as previously described for the hoisting direction. However, in this case the coils 26 and 27 of the relay 22 will set up fluxes which are cumulative and the similar coils of relay 23 will set up fluxes which are differential with respect to each other, so that the relay 23 will automatically open in a manner similar to the previously described operation of relay 22 to disconnect the brake winding from the source of supply and include the same in the previously described local discharge circuit. This is because of the fact that the direction of the current through the brake winding is the same as before but the generated potential of the motor will be in the opposite direction to that which was the case when the motor was operating in the hoisting direction.

It will thus be seen that the control of the application of the mechanical brake is governed jointly by the opening of either the directional switches 12 and 14, the generated voltage of the motor, the current in the brake winding circuit and the current in the motor dynamic brake circuit. The coils 27 of the relays 22 and 23 will function to give a time controlled regulation of the operation of these relays, because of the fact that with the resistor sections 28 and 29 in series relation with the brake winding and with the resistor sections 30 and 31 in shunt to the brake winding, the value of the current through the brake winding will gradually decrease to the value determined by these resistances. The windings 27 of the relays are designed to set up fluxes which normally predominate over the fluxes set up by the respective coils 26. This will give a pure time function and the time function will be the predominating function. The energization of the coils 26 of the relays 22 and 23 will be governed directly in accordance with the generated voltage of the motor after the disconnection of the motor from the source of supply. This generated voltage will decrease as a measure of the decrease of the motor speed. Thus, if the motor 10 is employed for operating an elevator and if the elevator car is heavily loaded and proceeding in the "up" direction, the overbalanced weight will also be proceeding in the "up" direction. The action of gravity will be assisting the friction of the various parts to reduce the speed of the elevator car and this action of gravity will be cumulative with respect to the action of the mechanical brake 19 and the motor dynamic braking effect. Until the brake winding is disconnected by the source, the brake will effect a partial braking torque. When the difference between the fluxes set up by the relay coils 26 and 27 of the particular relay intended to function for this direction of operation (in the present case the relay 22) has decreased to the predetermined value, the relay will automatically open its contacts, thereby disconnecting the brake winding from the source of supply and including the same in a local discharge circuit of relatively low resistance so as to effect a further application of the mechanical brake. By reason of the fact that the flux of the coil 27 is the predominating flux of relay 22 and this flux reduces at a definite rate, since the reduction of the generated voltage of the motor will decrease at a somewhat corresponding rate, the difference between the fluxes will decrease at a low rate and the operation of the relay will be relatively slow. This is desirable since the action of gravity is assisting to bring the car to a stop and it is undesirable to apply too great a braking effect. The reduction of the current in the brake winding circuit when the brake winding is thus connected in the local discharge circuit, is again a true time function. The mechanical brake will be fully applied in all events after the expiration of the time interval of the reduction of the current in the brake winding discharge circuit. However, this time interval may in certain cases be too long and the motor may come to rest before this time interval has elapsed. It is desirable that the mechanical brake shall be fully applied when the motor and the elevator car have substantially stopped so as to thereby avoid the well known settling ac-

tion or dropping back of the elevator before the brake is fully applied to hold the elevator. The contactor 35 prevents this settling action of the elevator because of the fact that there will be an appreciable current in the motor dynamic brake circuit until the motor has practically stopped rotating and the coil 36 of this contactor will be sufficiently energized to maintain the contactor closed. However, when the motor has substantially stopped rotating, the generated voltage of the motor will be very small and the coil 37 of the contactor will be practically deenergized and the coil 36 of this contactor will also be practically deenergized so that the contactor will automatically open its contacts, thereby opening the local discharge circuit in which the brake winding is included and effect an immediate and full application of the brake.

In case the car were proceeding in the "up" direction, lightly loaded, so that the overbalanced weight was proceeding in the "down" direction, the action of gravity on the counterweight will in this case attempt to keep the car in motion. The coil 27 of the relay 22 will again function to give a time interval control of relay 22 and the coil 26 will function as before to give a control of the relay, dependent upon the speed of the motor. Since the generated voltage of the motor will reduce at a relatively low rate, the difference between the flux of coil 27 and coil 26 will reduce comparatively quickly so that the disconnection of the brake winding from the source of supply will be effected in a shorter interval of time than was the case when the overbalanced weight was proceeding in the "up" direction. This is desirable since the action of gravity is in this case tending to keep the car in motion and the braking effect must be comparatively great. The contactor 35 will function as before to give a control of the mechanical brake so that the brake will be fully applied as soon as the motor has practically come to rest.

With the elevator car proceeding in the "down" direction, the relay 23 will function instead of the relay 22 and the functioning of this relay will produce similar results to those produced by the functioning of the relay 22 for the "up" direction. If the car is heavily loaded and proceeding in the "down" direction, the overbalanced weight will also be moving in the "down" direction and conditions will be present similar to those encountered when the car was proceeding lightly loaded in the "up" direction. The relay 23 will function to automatically take care of these conditions in the same manner as the relay 22 functioned previously to take care of similar conditions when the car was proceeding in the "up" direction. If the car is proceeding in the "down" direction lightly loaded, the overbalanced weight will be moving in the "up" direction and conditions will be similar to those encountered when the car was heavily loaded and proceeding in the "up" direction. The relay 23 will function to automatically compensate for the variations in the overbalanced weight, the speed of the car and the degree of application of the brake. The contactor 35 will also function as before to effect a full application of the mechanical brake to hold the elevator car when the motor has practically come to rest.

It will thus be seen that the relays 22 and 23 effect an automatic regulation of the application of the mechanical brake in accordance with the conditions encountered at the time the motor directional switches are opened to stop the motor. The timing function of these relays supplied by the relay coils 27 is the predominating function, but the time interval introduced in the regulation of the brake winding is governed by the rate at which the generated voltage of the motor decreases. The generated voltage of the motor will decrease as a function of the speed of the car at the time the directional switches are opened, the value of the overbalanced weight and the direction in which this overbalanced weight is moving. It can thus be seen that these relays automatically take into account the variations in the overbalanced weight, discriminate as between the overbalanced weight moving in the "down" direction with the car proceeding in the "up" direction, the condition in which the overbalanced weight is moving in the "up" direction with the car proceeding in the "up" direction, the condition in which the overbalanced weight is moving in the "up" direction with the car proceeding in the "down" direction, and the condition in which the overbalanced weight is moving in the "down" direction with the car proceeding in the "down" direction. The operator of the car need, therefore, pay no attention to these various conditions encountered, since compensation is made therefor by the action of the relays.

The contactor 35 is particularly useful during inching operations of the elevator. When the motor directional switch mechanism is operated so as to effect a slight movement of the elevator car, the dynamic braking effect of the motor will be comparatively small so that this contactor will function to automatically very quickly open the local discharge circuit for the brake winding so as to thereby effect a comparatively quick application of the brake. It will also be understood that under these conditions the relays 22 and 23 will function to likewise effect a comparatively quick application of the brake, as is desirable.

In accordance with the provisions of the

patent statutes, I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means.

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

1. In combination, a driving motor, means for applying a braking effect to the apparatus driven by the motor, electroresponsive switch mechanism for controlling the value of the braking effect applied by said means, a timing device for controlling the said braking means, and means for regulating the time interval of operation of said device in accordance with the speed of said motor.

2. In combination, a driving motor, a normally applied mechanical brake having a winding arranged to be connected to a source for releasing the brake, means for controlling the energization of the driving motor to start the motor and effect the connection of the brake winding to the source, the said means being arranged to initiate a reduction of the current taken by the brake winding from the source when the energization of the motor is reduced to stop the motor, and means responsive to an operating condition of said motor after the operation of said first mentioned means to stop the motor for automatically disconnecting the said winding from the said source and connecting the same in a local circuit to effect a greater degree of application of the brake.

3. In combination, a driving motor, a normally applied mechanical brake having a winding for releasing the brake, a resistance, electroresponsive switch mechanism for controlling the said resistance and for controlling the connection of the said winding to a source of supply, and connections whereby the said resistance effects a reduction of the current taken by the said winding from the source to effect a partial application of the brake when the energization of said motor is reduced to stop the motor, and the brake winding is subsequently disconnected from the source of supply and included in a local circuit with a portion of said resistance to increase the braking effect.

4. In combination, a driving motor, a normally applied mechanical brake having a winding for releasing the brake, a resistance, electroresponsive switch mechanism for controlling the said resistance and for controlling the connection of the said winding to a source of supply, and connections whereby the said switch mechanism is governed to include the said resistance in multiple with the said winding while maintaining the connection of the winding to the source for an interval after the energization of said motor is reduced to stop the motor and the said winding is subsequently disconnected from the source and included in a local circuit with a portion of said resistance.

5. In combination a driving motor, a normally applied mechanical brake having a winding for releasing the brake and for regulating the application thereof, switch mechanism for controlling the said winding, and means jointly controlled by the disconnection of the motor from the source of supply, the generated voltage of the motor and the current in the said brake winding circuit for controlling the said switch mechanism to gradually reduce the energization of the said winding while maintaining the connection of the winding to the source for an interval of time after the disconnection of the motor from the source and to then disconnect the winding from the source to include the same in a local circuit to further gradually reduce the energization thereof.

6. In combination, a driving motor arranged to be connected to a source of supply, a normally applied mechanical brake having a winding arranged to be connected to the source for releasing the brake, a resistance, electroresponsive switch mechanism for controlling the connection of said winding to the source and for controlling the said resistance, and connections whereby the said switch mechanism is governed to include a portion of said resistance in series with said winding and another portion thereof in multiple with the winding while maintaining the connection of the winding to the source for an interval of time after the motor is disconnected from the source and to then disconnect the winding from the source leaving the winding connected in a local circuit with a portion of the resistance which was previously connected in multiple with the winding.

7. In combination, a driving motor, a motor control switch for controlling the energization of the motor, a normally applied mechanical brake having a winding for releasing the brake, resistance for controlling the energization of the brake winding, electroresponsive switch mechanism for controlling the said resistance and the connection of the said winding to a source of supply and connections whereby the said switch mechanism is governed to connect the said winding directly to the source upon the closure of said motor control switch to start the motor and then include a portion of the said resistance in series with the said winding when the brake is released, another portion of said resistance is automatically connected in multiple circuit with the brake winding with the multiple circuit in series with the remainder of the resistance upon the opening of said motor control switch to

stop the motor and an interval after the opening of the said motor switch the brake winding is automatically disconnected from the source, leaving the winding included in a local circuit with a small portion of said resistance.

8. The combination in a system for controlling an electric elevator, hoist, or the like, provided with a car and a counterweight therefor, of a driving motor, directional switch mechanism for controlling the energization of the motor to hoist or lower the car, a normally applied mechanical brake having a winding for releasing the brake, and electroresponsive switch mechanism jointly controlled by said directional switch mechanism, the generated voltage of the motor, and the value of the current in the brake winding for regulating the energization of said brake winding in accordance with direction of movement of the said car and the direction of the movement of the overbalanced weight of the car and the counterweight.

9. In combination, a driving motor, a motor control switch for controlling the energization of the motor from a source of supply, a normally applied mechanical brake having a winding for releasing the brake, resistance for controlling the energization of the brake winding, electroresponsive switch mechanism controlled by the said motor switch, the speed of the motor and the energization of the brake winding for controlling the said resistance and the connection of said winding to a source of supply, and connections whereby the said switch mechanism is governed by the opening of said motor switch to automatically connect the said resistance with said winding to reduce the energization of the winding and after an interval effect a further automatic reduction of the energization of the brake winding.

10. In combination, a driving motor arranged to be connected to a source of supply, a line switch for connecting the motor to the source, a normally applied mechanical brake having a winding arranged to be connected to the source for releasing the brake, a relay governed jointly by the generated voltage of the motor and by the current in said winding for controlling the brake, electroresponsive switch mechanism under the control of said line switch and said relay, and connections whereby the opening of said line switch effects a reduction of the current in the brake winding and the said relay effects a further reduction of the current in the brake winding an interval after the opening of said line switch.

11. In combination, a driving motor, a normally applied mechanical brake having a winding arranged to be connected to a source of supply to release the brake upon the connection of the motor to the source, switch mechanism for controlling the connection of said motor and said winding to the source, and means controlled by said motor for automatically reducing the energization of the brake winding while maintaining the connection thereof to the source to effect a partial application of the brake for an interval after the disconnection of the motor from the source by the operation of a portion of said switch mechanism and for then disconnecting the said winding from the source to effect a full application of the brake by the operation of another portion of said switch mechanism.

12. In combination, a driving motor, a motor control switch for controlling the energization of the motor from a source of supply, a normally applied mechanical brake having a winding arranged to be connected to a source for releasing the brake, means automatically connected with the brake winding upon the opening of said motor switch for reducing the energization of said winding to effect a partial application of the brake, and means automatically controlled in response to the speed of the motor for completely deenergizing the said winding to effect a full application of the brake when the motor has practically stopped rotating.

13. In combination, a driving motor arranged to be connected to a source of supply, a dynamic braking circuit for the motor, a motor control switch for controlling the energization of the motor from the said source, a normally applied mechanical brake having a winding arranged to be connected to a source of supply for releasing the brake upon the closing of said motor switch to start the motor and electroresponsive switch mechanism under the control of the said motor switch, the generated voltage of the motor, the current in the brake winding and the current in the said dynamic brake circuit for automatically controlling the said brake winding upon the opening of said motor switch to effect a gradual reduction of the current in the brake winding for an interval after the opening of the motor switch and to then completely deenergize the brake winding when the motor has substantially stopped rotating.

14. In combination, a driving motor arranged to be connected to a source of supply, a pair of directional switches, separately operable to energize the motor from the source for each direction of operation, a normally applied mechanical brake having a winding arranged to be connected to a source of supply for releasing the brake, electroresponsive switch mechanism for controlling the connection of said winding to its source and for controlling the degree of energization of the winding, a pair of

relays energized responsively to the generated potential of the motor and to the current in the brake winding for controlling the said switch mechanism, and connections whereby upon the closing of a selected one of said directional switches the motor and the brake winding are energized, upon the opening of said directional switch a selected one of said relays operates to maintain the connection of the brake winding to its source and effect a further reduction of the current in the brake winding an interval after the opening of the directional switch.

15. In combination, a driving motor arranged to be connected to a source of supply, a dynamic braking circuit for the motor, a normally applied mechanical brake having a winding arranged to be connected to the source for releasing the brake, a line switch for connecting the motor to the source, means for reducing the current in said winding to effect a partial application of the brake, electroresponsive switch mechanism under the control of said line switch, the generated voltage of the motor, the current in the brake winding and the current in the motor dynamic brake circuit for controlling the said means and the connection of the brake winding to the source, and connections whereby upon the opening of said line switch the said electroresponsive switch mechanism maintains the said winding connected to the source and effects a reduction of the current in the brake winding circuit to effect a partial application of the brake for an interval, the brake winding is subsequently automatically disconnected from the source, leaving the brake winding in a local circuit to further increase the application of the brake, and the said local circuit is opened when the motor has practically stopped rotating to effect a complete application of the brake.

16. In combination, a driving motor arranged to be connected to a source of supply, a dynamic braking circuit for the motor, a normally applied mechanical brake having a winding arranged to be connected to the source for releasing the brake, a line switch for connecting the motor to the source, electroresponsive switch mechanism under the control of said line switch for connecting the brake winding directly to the source to release the brake upon the closing of the line switch and for establishing a shunt to the brake winding for reducing the energization of the winding upon the opening of said line switch, a relay governed jointly by the generated voltage of the motor and the current in said winding for maintaining the connection of said winding to the source after the opening of said line switch and for automatically disconnecting the winding from the source an interval after the opening of said line switch, leaving the winding connected in a local circuit to further reduce the energization of the winding, and a relay governed by the current in the motor dynamic brake circuit for opening the said local circuit to effect a full application of the brake when the motor has practically stopped rotating.

17. In combination, a driving motor arranged to be connected to a source of supply, a dynamic braking circuit supplied with current from the motor armature to reduce the motor speed when the motor is disconnected from the source, a normally applied mechanical brake having a winding arranged to be connected to the source for releasing the brake, a pair of reversing switches for connecting the motor to the source for operation in each direction, a resistance having a plurality of sections for reducing the current in the brake winding, a plurality of electromagnetic switches for controlling the connection of the brake winding to the source and for controlling the said resistance to regulate the degree of application of the brake, a pair of electromagnetic relays jointly controlled by the generated voltage of the motor and the current in the brake winding for controlling a portion of said electromagnetic switches to control the connection of the brake winding to the source of supply, a relay energized responsively to the current in the motor dynamic brake circuit for controlling the brake winding circuit, and connections whereby upon closing either of said reversing switches the motor and the brake winding are connected to the source and a section of said resistance is included in the brake winding circuit after the release of the brake to reduce the heating of the brake winding, subsequently opening the said reversing switch disconnects the motor from the source of supply and connects an additional section of said resistance in series with the brake winding and the remainder of the resistance in shunt to the brake winding, the brake winding is subsequently disconnected from the source of supply by the operation of one of said pair of relays, leaving the brake winding in a local circuit to effect a further application of the brake, and the said local circuit is opened under the control of said relay responsive to the current in the motor dynamic brake circuit to effect a full application of the brake when the motor has substantially stopped rotating.

In witness whereof I have hereunto set my hand this 13th day of February, 1925.

BENJAMIN W. JONES.