

United States Patent

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Continuation-in-part of application Ser. No. 582,871, Sept. 29, 1966.		

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[54] PROGRAMMED BRAKING FOR ELEVATORS AND THE LIKE

20 Claims, 11 Drawing Figs.

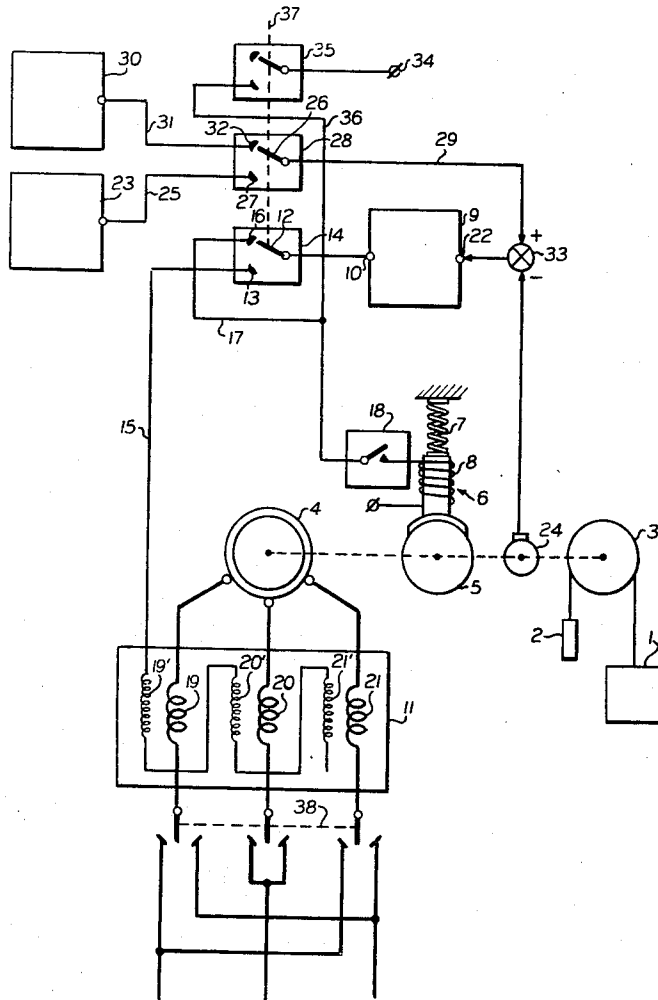
[52] U.S. Cl. 187/29 R
[51] Int. Cl. B66b 1/32
[50] Field of Search 187/29;
318/229, 363, 369, 372, 143

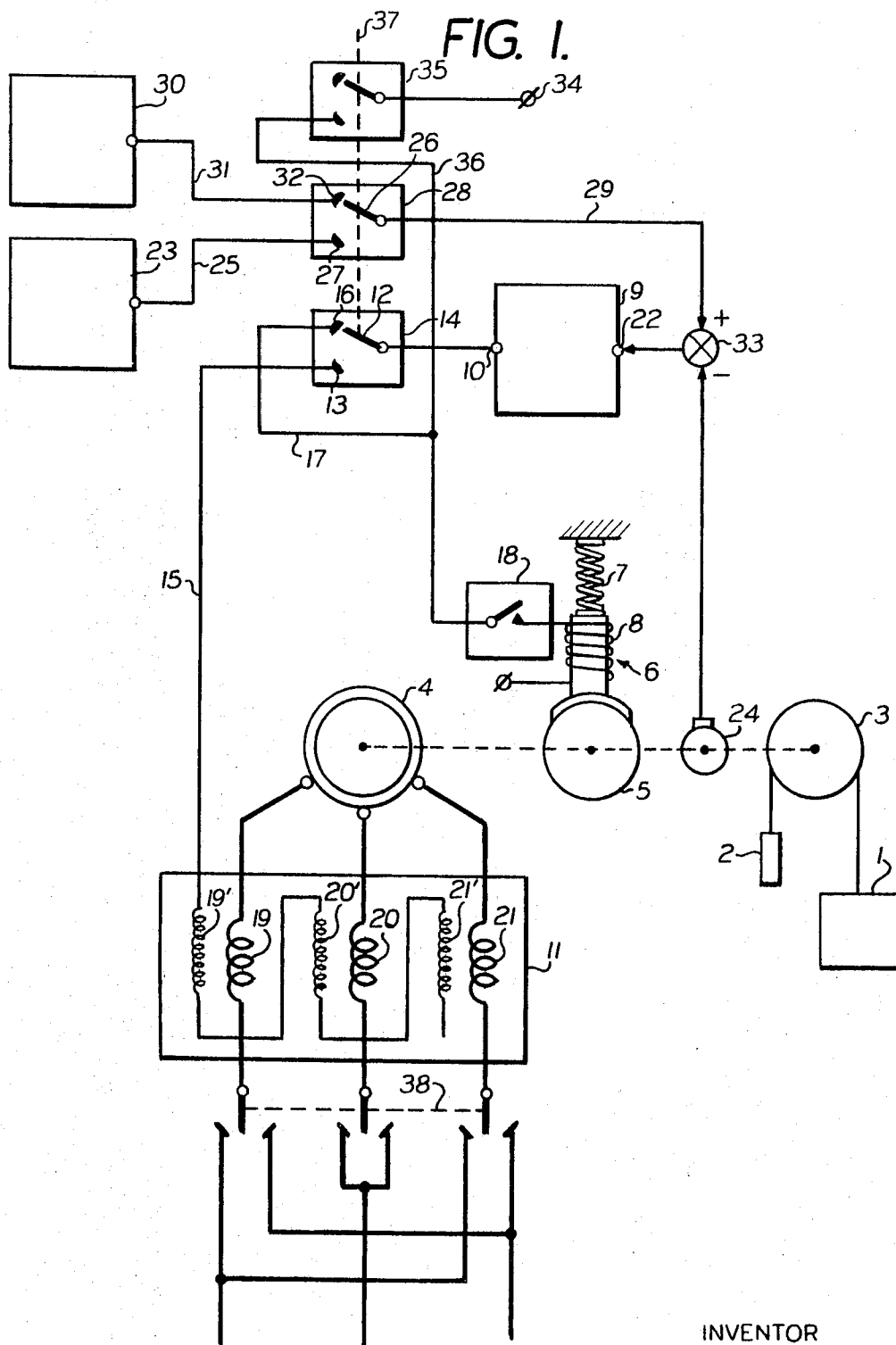
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ABSTRACT: An elevator includes a motor for accelerating a cab and a brake for decelerating it, the two being operated during mutually exclusive time intervals. The brake mechanism is biased to brake the cab and has an electrical winding to defeat the biasing spring. An amplifier is connected by means of a selector switch to control energization of the motor during acceleration and of the brake winding during deceleration. The input to the amplifier comes from a summing network which develops the difference between two control signals. One of the control signals comes from a tachometer generator and is proportional to the speed of the elevator car, while the other control signal comes from a brake program device or an acceleration program device. The program devices are designed to provide braking and acceleration programs respectively which are functions of the distance of the elevator car from a particular floor. During deceleration the braking effort is smooth and continuous right up to the moment of dead stop.





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FIG. 2.

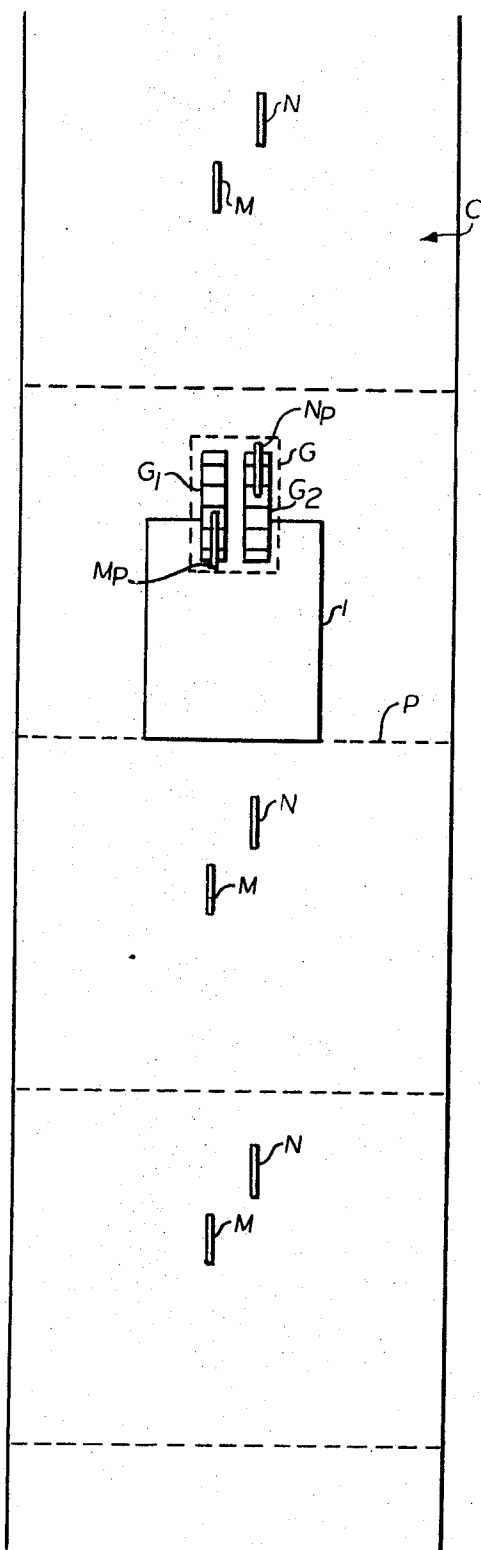
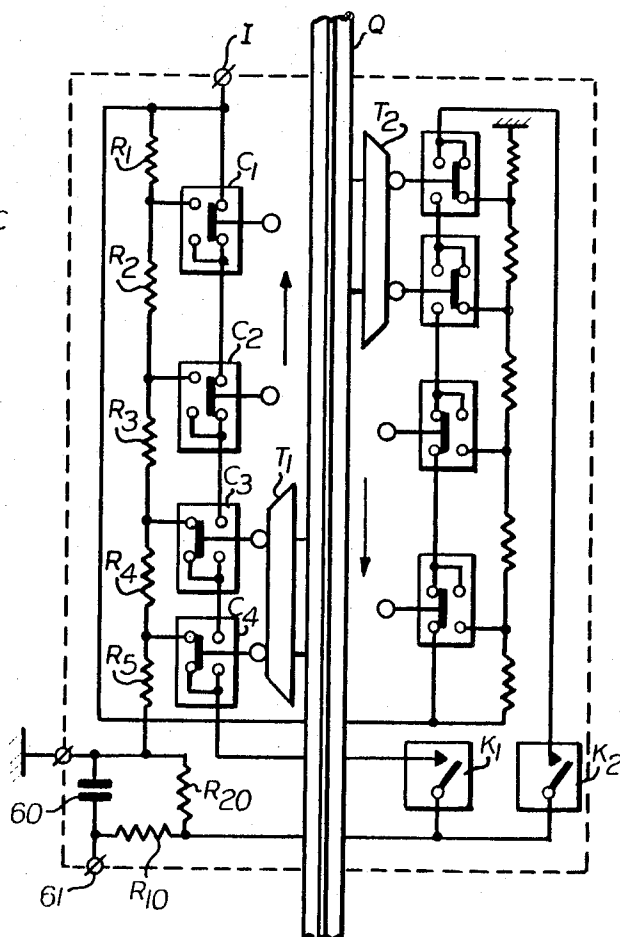


FIG. 3.



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FIG. 4.

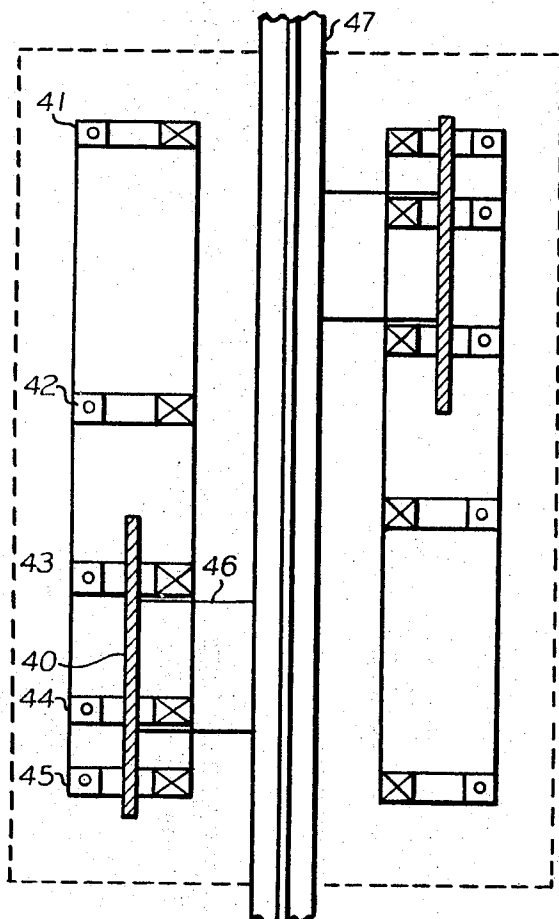


FIG. 5.

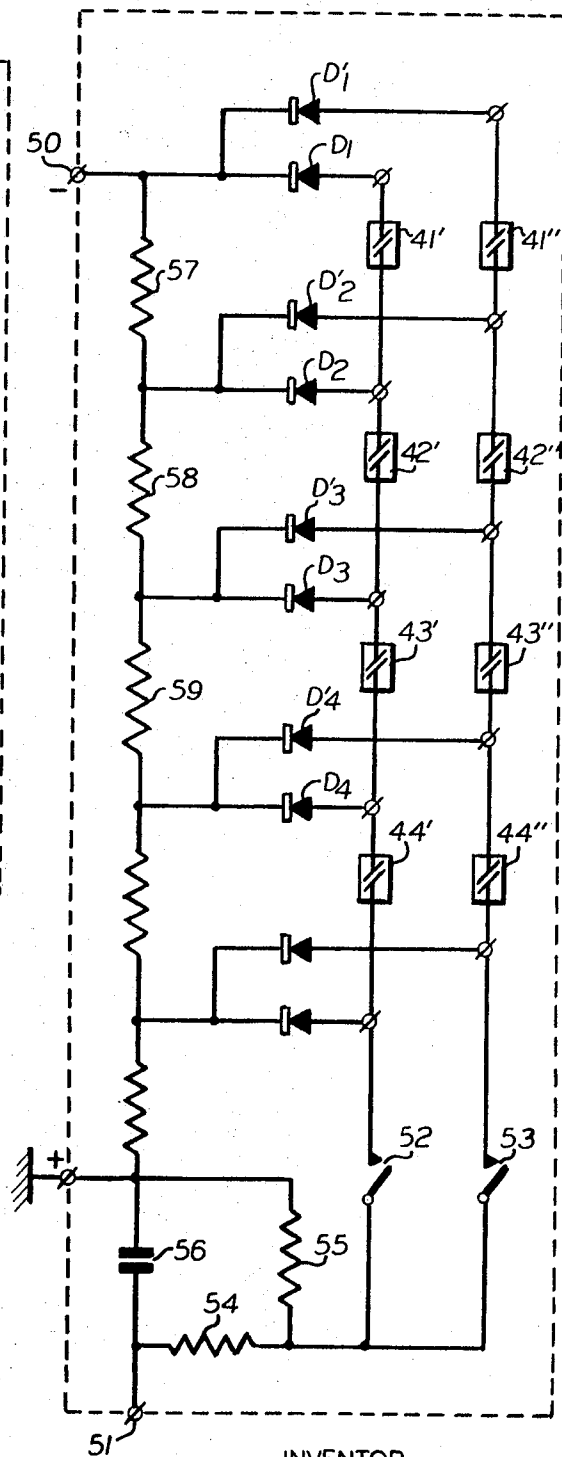


FIG. 6.

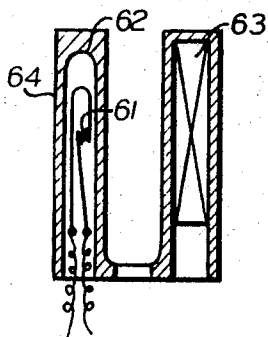
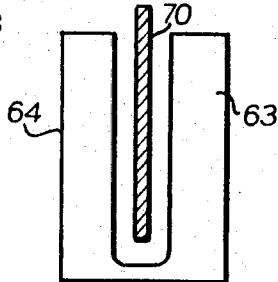
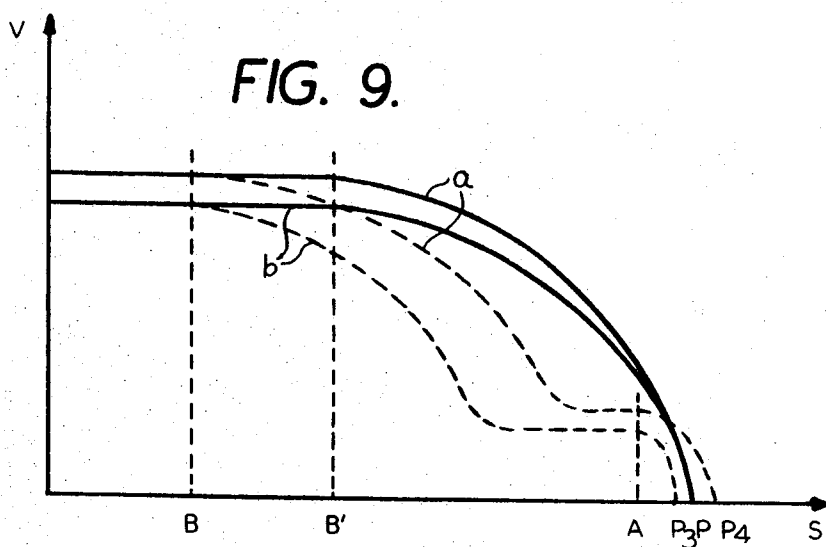
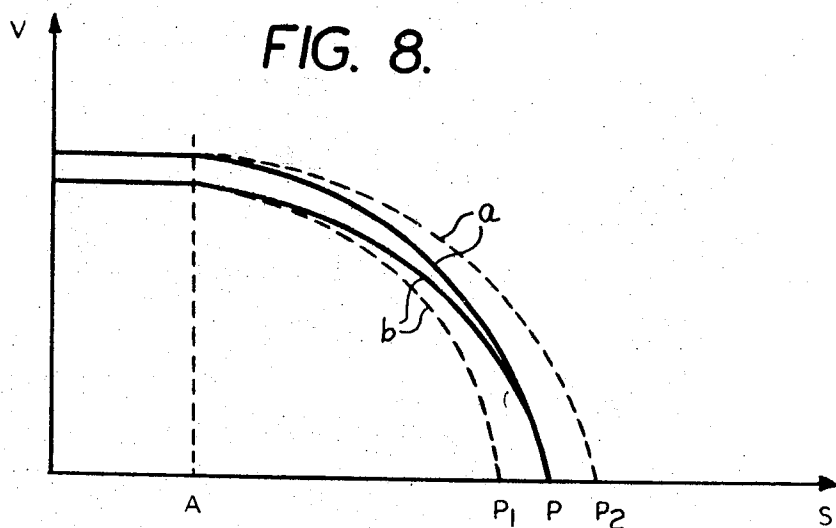


FIG. 7.



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FIG. 10.

PRIOR ART

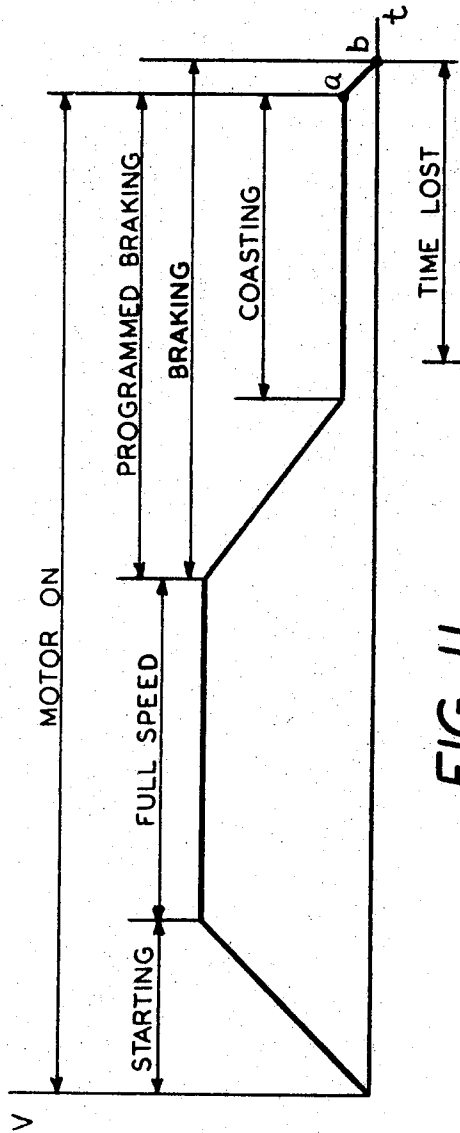
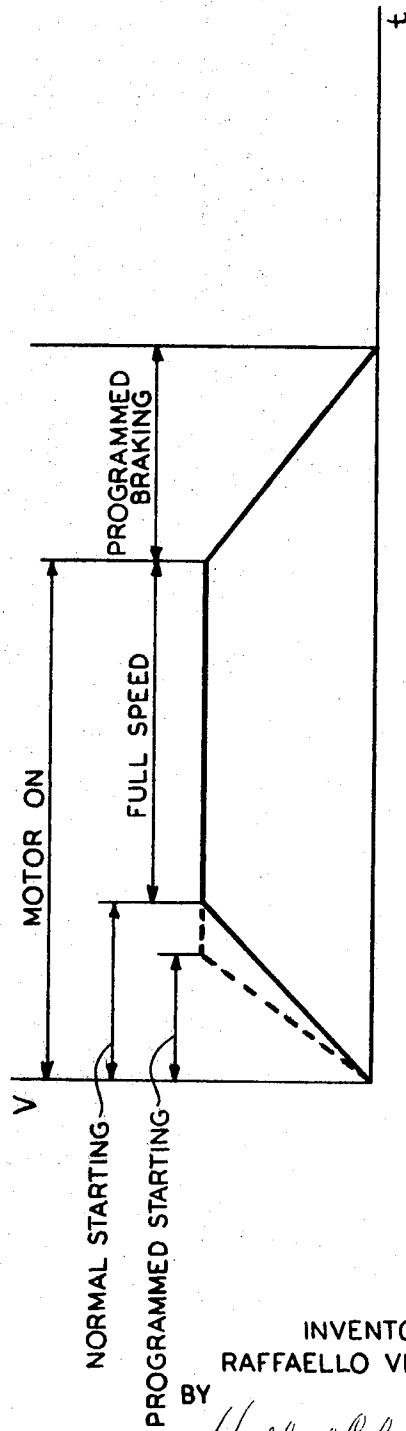


FIG. 11.



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PROGRAMMED BRAKING FOR ELEVATORS AND THE LIKE

CROSS-REFERENCES

This application is a continuation-in-part of my earlier application Ser. No. 582,871 filed Sept. 29, 1966, entitled "Apparatus for Controlling Lifts and the Like."

FIELD OF THE INVENTION

The present invention relates to apparatus for the control of lifting equipment such as elevators, cable cars, funicular railways, conveyors and the like. It is primarily concerned with programmed braking of such equipment.

THE PRIOR ART

Elevators and other types of lifting equipment are commonly driven by an electric motor. Means are provided in the elevator shaft for sensing the position of the elevator cab relative to a floor of the building, and the energization applied to the electric motor is increased as a function of cab displacement so as to obtain gradual acceleration when leaving that floor. Braking apparatus is also provided which acts on the mechanical transmission between the motor and cab to decelerate the cab when it reaches its destination. The brake mechanism is electrically controlled according to a predetermined program as a function of the approach of the elevator cab to its destination floor.

The principal object of such programmed braking is to provide a gradual and therefore pleasant stop for the occupants of the elevator cab, free of jolts. Another important object of programmed braking is to stop the elevator cab on a level with the destination floor. Prior art programmed braking systems, however, are inadequate in these and other respects.

One type of system which has been used for the gradual stopping of elevator equipment employs a large flywheel on the shaft of a single speed elevator drive motor. In such a system the flywheel helps to smooth the acceleration and deceleration of the cab, but it is not a satisfactory solution. Current consumption consequent heating of the motor windings are excessive when accelerating the large flywheel mass, and conversely the brake linings suffer extensive wear and heating upon deceleration.

Some improvement is obtained by using a two-speed motor in conjunction with a heavy flywheel, particularly a motor of the type which can be switched from a relatively small number of poles to a relatively large number. In that type of system the higher speed of the motor serves for acceleration and constant speed operation, while the lower speed is used for braking. But even with a two-speed motor, the flywheel must still be relatively large in order to provide gradual speed transitions and an adequate degree of precision in stopping the cab at floor level. Thus, the problems associated with the use of a massive flywheel are not entirely avoided by the use of a two-speed motor. Specifically, the problem of brake lining wear is reduced because of the braking contributed by the motor; but the problem of motor heating remains because of the need to accelerate the massive flywheel, and is even increased because motor braking heats the motor windings during the deceleration phase. Moreover, such systems have sharp speed transitions which are detectable by the passengers; and the slow coasting intervals which follow the transitions consume an inordinate amount of time for each stop, inconveniencing the passengers and lowering the service efficiency. Under conditions of high demand, this is a serious drawback.

Further improvement has been obtained by employing a prior art system of the type seen in U.S. Pat. No. 2,746,567 of Guttinger, which determines the difference in voltage between a signal representing the actual instantaneous speed of the elevator, and another signal that varies in a manner representing the desired elevator speed as a function of its instantaneous displacement from the destination level. This difference voltage is then used to control the instantaneous braking force

during an initial phase of deceleration; but during the latter stages of deceleration the Guttinger system abandons any attempt at proportional control as a function of actual speed, and instead allows the elevator to coast at a predetermined and constant speed regardless of variable conditions. Thus, like the two-speed motor approach, the Guttinger system also has two distinct deceleration phases, with a discernible speed transition between them; and suffers from the time-consuming inefficiency of a slow coasting interval. Moreover, in order to vary the brake program signal as a function of displacement, Guttinger employs a slide wire potentiometer. Such a device can not easily be adapted to a system requiring a nonlinear relationship between voltage and displacement. Yet such a relationship is needed for a sophisticated brake program which maximizes passenger comfort.

SUMMARY AND OBJECTS OF THE INVENTION

The principal objective of this invention is to achieve smooth elevator braking and precise stopping. Another object is to provide a comfortable, jolt-free and transition-free ride for elevator passengers, particularly during the deceleration phase. Still another object is to stop the elevator precisely on a level with the destination floor each time, without regard to variations of elevator load. It is also an object to avoid service slowdowns and achieve a level of efficiency which is adequate for peak demand periods. A subsidiary object of the invention is to take further advantage of the apparatus which achieves this improvement in braking performance to aid also in the gradual acceleration of the elevator cab.

In order to achieve these objectives, apparatus in accordance with this invention includes means for producing an electric signal proportional to the speed of the elevator, preprogrammed signal producing means, variable force braking means, and a control circuit for the brake means. Throughout the entire deceleration of the elevator, the control circuit produces a signal which is a function of the difference between the signal from the preprogrammed means and the speed-proportional signal, and supplies this difference signal to the brake means for varying the brake force in accordance therewith.

The apparatus thus briefly summarized has the advantage that the braking force is applied continuously (although diminishing proportionately) right up to dead stop. This eliminates the sense of discontinuity which the passengers experience when multiphase braking apparatus shifts from one phase to the succeeding phase. Moreover, a special nonlinear brake program can be employed to maximize passenger comfort. In addition, this type of system adjusts the braking force as a function of the difference between the instantaneous speed of the elevator cab and the programmed speed called for at that moment, rather than as a function of the distance from the destination floor. The result is precise and repeatable stopping of the elevator cab on a level with the destination floor regardless of variable elevator load conditions. The system is also faster, more efficient, and more economical in several respects.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic circuit diagram of an elevator braking and starting program control circuit in accordance with this invention;

FIG. 2 is a schematic illustration of an elevator car and a vertical shaft in which the car moves, with position sensing means mounted on the walls of the shaft for use with the program control circuit of FIG. 1;

FIG. 3 is a schematic circuit diagram of position sensing switches used with the means of FIG. 2;

FIG. 4 is a schematic illustration of an alternative set of position sensing switches for use with this invention;

FIG. 5 is a schematic diagram of a circuit employing position sensing switches of the kind illustrated in FIG. 4;

FIG. 6 is a sectional view, partly schematic in nature, showing details of a typical position sensing switch of the kind in FIGS. 4 and 5;

FIG. 7 is a schematic illustration of the sensing switch of FIG. 6 in conjunction with an activating element which is mounted on the elevator cab;

FIG. 8 is a graph of elevator cab velocity versus displacement comparing the performance of a prior art system, using a single speed motor, with that of the present invention under varying elevator load conditions;

FIG. 9 is a similar graph of elevator cab velocity versus displacement comparing the performance of another prior art system, using a two-speed motor, with that of the present invention under varying conditions of elevator load;

FIG. 10 is a diagram of elevator cab velocity versus time for a prior art system of the two-speed motor type; and

FIG. 11 is a diagram comparable to FIG. 10 but showing the performance of the system of this invention.

The same reference characters refer to the same elements throughout the several views of the drawing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 provides an overall view of the elevator control system of this invention, in which a conventional single speed three-phase electric motor 4 is mechanically connected to drive a brake drum 5 and an elevator drive pulley 3. Suspended from the drive pulley are an elevator cab 1 and its counterweight 2.

The motor 4 has reaction windings 19, 20 and 21 which are in series respectively with three phases of the motor drive windings, and are energized under control of a switch 38. When the switch 38 is closed in one direction the motor 4 lifts the elevator cab 1, and when the switch is closed in the other direction the motor lowers the elevator cab. The reaction windings are wound on saturable cores (not shown) controlled by respective magnetizing windings 19', 20' and 21' of a motor speed control magnetic amplifier circuit 11. A lead 15 is connected in series with the magnetizing windings 19', 20' and 21' to apply a speed control signal to the circuit 11. This series connection imposes a voltage drop upon the three-phase system, but this is not excessive under the power consumption conditions likely to occur in an elevator system of this kind.

The brake drum 5 is acted upon by a brake 6 in response to the urging of a biasing spring 7. The arrangement is a fail-safe one, in that the spring 7 normally causes the brake to act upon the drum, and thus prevent a precipitous drop of the elevator cab 1. Operation of the brake 6 is defeated only when the spring 7 is positively overcome by energizing a brake defeat winding 8 which raises the brake 6 against the urging of the spring 7. Thus it is apparent that the brake 6 will operate when the system is totally disabled and the brake defeat winding 8 cannot be energized.

The elevator system further includes an acceleration program circuit 23 and a brake program circuit 30 which are designed to provide gradual starting and stopping respectively, so as to minimize passenger discomfort. An additional purpose of the brake program circuit 30 is to reduce the elevator cab speed prior to dead stop, so that the cab can then be halted accurately on a level with the destination floor.

The program circuits 23 and 30 are combinations of switches mounted upon the elevator and actuated at proportionate distances from the various floors during the passage of the elevator cab 1 in order to sense the position of the cab relative to a floor. These circuits also comprise various additional components connected to the position detecting switches to provide programmed control signals on leads 25 and 31 which control the speed of the motor 4 and the decelerating force of the brake mechanism 6 respectively. In order to accomplish this, the voltage on the lead 25 controls the speed control signal applied over lead 15 to circuit 11, and

the voltage on lead 31 controls the energization of the brake defeat winding 8.

In accordance with this invention, a tachometer generator 24 rotates with the mechanical transmission of the elevator and produces a voltage output which is proportional to the speed thereof. This voltage is then applied to one input of a difference network 33. The other input to the difference network arrives over a lead 29 which can be connected either to lead 31 to receive the output of the brake program circuit 30, or to lead 25 to receive the output of the start program circuit 23. The selection between these two leads is made by means of a switch 37 including three ganged sections 35, 28 and 14. Switch section 28 has an arm 26 which can be moved between contacts 32 and 27 to connect lead 29 to leads 31 or 25 as required.

The plus and minus signals at the two inputs to the difference network 33 do not necessarily indicate the absolute polarity of these inputs, but rather indicate that these inputs are subtracted within the network so that the resulting output applied to terminal 22 of an amplifier 9 is a signal representing the difference between the actual speed of the elevator cab 1 as the desired speeds of the elevator cab, rather than of mere distance from the destination floor without regard to speed. The desired speed called for by the brake program circuit 30 is, of course, a function of the distance of the elevator cab from the destination floor, as in the past. But the desired speed is related to the actual speed of the cab by the difference network 33 to develop the signal which actually controls braking. Moreover, the brake winding 8 remains under control of the variable signal provided by program circuit 30 during the entire deceleration.

The result is that the braking force is not divided up into distinct phases. Nor is it required to be fully on or fully off. Instead, the force exerted at all times is proportional to the instantaneous difference between the actual and desired elevator cab speeds. Consequently it varies smoothly, and continues over the entire deceleration interval without sudden transitions as in a multiphase braking program. Indeed the braking effort continues right through to the moment of dead stop.

In FIG. 8 the solid line graphs depict the velocity V of the elevator cab as a function of its displacement S when the cab is traveling upward toward a destination floor, and is decelerated according to this invention. Curve b represents a condition of positive load (cab plus load heavier than counterweight), while curve 2 represents a condition of negative load (cab plus load lighter than counterweight). A represents the point at which deceleration begins. P represents the destination floor. It is seen that the solid line curves representing deceleration in accordance with this invention converge exactly to point P ; i.e. they both stop precisely level with the destination floor P despite the difference in load conditions.

For the purpose of comparison, the dashed line curves of FIG. 8 represent deceleration by means of a single speed motor and flywheel system according to the prior art. Once again curve b is for positive and curve a for negative load conditions.

The difference between these load conditions causes the prior art curves to diverge to points $P1$ and $P2$ below and above the destination floor respectively. Thus it is apparent that the system of this invention is a great improvement in terms of precise and repeatable stopping.

FIG. 9 is a similar diagram comparing the present results with those achieved using a two-speed motor system. Once again the solid line curves represent the system of this invention for conditions of positive load (curve b) and negative load (curve a), and an upward direction of cab. The deceleration program according to this invention starts at location B' , and once again the curves converge smoothly to a dead stop at the destination floor P . In contrast, the dashed line curves, b representing positive load conditions and a representing negative load conditions, show the inferior results achieved by the prior art.

The prior art braking program must begin at a more distant location B. Then the dashed line curves undergo a fairly sharp transition to a constant speed coasting interval terminating at location A. This is followed by another fairly sharp transition to a final braking interval. The latter is not effective in most cases to stop the elevator cab precisely at the destination floor P. Instead, the negative load curve terminates at a location P4, i.e. the elevator coasts upwardly to a stop somewhat above the level of the destination floor; while the positive load curve terminates at a location P3, stopping short in its upward travel at a point somewhat below the level of the destination floor.

Since the prior art braking program begins at a more remote location B, and since a low speed coast is required, time is consumed in bringing the elevator cab to a stop. This is clearly illustrated by the comparison between FIGS. 10 and 11. FIG. 10 is a graph of cab velocity V versus time t for a prior art braking program of the multiphase type. The total time interval depicted in the graph covers a complete elevator trip, and is divided into three segments. These include a starting interval during which the velocity increases, followed by an interval of travel at a constant maximum velocity. Then there is an interval of braking which itself is divided into three phases. The first two phases, which together make up the programmed braking sequence, include an interval of maximum braking force during which the cab velocity declines, followed by an abrupt transition to an extended coasting interval of travel at a nearly constant low speed until the cab reaches point a . Then there is another sharp transition to a second interval of maximum braking which finally brings the cab to a dead stop at point b .

For comparison purposes, FIG. 11 shows the corresponding curve for an elevator in accordance with the present invention. Once again the trip starts with an acceleration interval (which can be programmed or not), followed by a travel interval of constant, maximum speed and an interval of programmed braking. Here again we see that the brake continues without sharp transitions right down to dead stop. But note also that the trip ends in a much shorter time than the one illustrated in FIG. 10, as shown clearly by the "time lost" interval.

The graph of FIG. 11 also reveals that with the system of this invention the motor is off during the programmed braking interval. This is in contrast to the prior art elevator trip of FIG. 10 in which the motor is on, either for acceleration or for braking, throughout the trip, generating heat all that time. In the present system braking can be left entirely to the braking mechanism 6.

Brake mechanism 6 is adequate because a massive flywheel is no longer necessary to smooth the phase transition of the prior art. With a large flywheel, electrodynamic braking by the motor would be necessary to arrest the rotating mass.

In the present system a small flywheel can be used, the sole function of which is to provide enough inertia in the system to make certain that the cab will arrive at the destination floor even under the worst load conditions. Such a flywheel is much less massive than the type required by prior art elevator control systems.

For a more detailed understanding of the brake program circuit 30, we refer to FIG. 2 showing an elevator shaft C in which the cab 1 rides. The shaft is divided into distinct floor segments by the horizontal dashed lines. Within each floor area are switch activating means M and N secured to the wall of the shaft. These are designed to actuate switches G, which are secured to the elevator cab 1 and are divided into a first group of switches G1 actuated by devices M, and a second group G2 which are actuated by devices N, at each of the floors. At the instant depicted in FIG. 2, the elevator cab 1 is at floor P and the devices M_p and N_p are positioned adjacent switch groups G1 and G2 respectively. The devices M and N at each floor are vertically offset from each other in such manner that one of them activates its associated group of switches during upward movement of the elevator cab 1, while the other activates its associated group of switches during downward movement of the elevator cab.

For a close look at one particular embodiment of a switch and actuator mechanism of the type generally illustrated in FIG. 2, we turn to FIG. 3 which shows a group of switches C1 through C4 mounted upon the elevator cab and cooperating with a switch actuator device T1 during upward cab motion. A similar series of switches is mounted upon the cab at the right-hand side of FIG. 3, and cooperates with an actuating device T2 during downward motion. The switch actuator devices T1 and T2 are both mounted on a central vertical rail Q which runs through the elevator shaft. Since the switches C1 through C4 and their counterparts at the right-hand side of FIG. 3 are mounted upon the elevator cab, they move relative to their respective fixed actuating devices T1 and T2.

Resistors R1 through R5 are connected to a power source terminal I and to the switches C1 through C4 as shown in the circuit of FIG. 3, while a similar network of resistors is similarly connected to the switches at the right-hand side of FIG. 3. As each switch plunger contacts the actuator device T1 or T2 thereof, it is driven from a position illustrated by switches C1 and C2 to the position illustrated by switches C3 and C4.

When none of the switches C1 through C4 are activated by the slide T1, the power source terminal I is directly connected over a low impedance path to a switch K1. This switch, which is closed during upward elevator cab travel, is connected to ground through an RC network comprising resistors R10 and R20 and capacitor Co. An output voltage is picked off across the capacitor and connected to a terminal U which represents the output terminal of the brake program circuit 30 of FIG. 1.

As the elevator cab travels upward toward its destination floor, switches C1 through C4 are closed in that order. When switch C1 is closed, resistor R1 is connected in series between terminal I and the RC network. Next, when switch C2 is closed resistors R1 and R2 are both connected in series between terminal I and the RC network, and similarly for the remaining switches and resistors. In other words, as each succeeding switch C1 through C4 is closed, an additional one of the resistors R1 through R4 is cumulatively added in series between terminal I and the RC network. Even though switches C1 through C4 which were previously actuated are later allowed to reopen by the continuing motion of the elevator cab, the resistors remain in circuit. As a result, the voltage impressed upon the RC network decreases in four discrete steps. However, the integrating action of the RC network smooths these step transitions to provide a gradually decreasing brake program output voltage at terminal U. Consequently, as the elevator cab rises toward its destination floor the brake program control voltage issued by circuit 30 decreases smoothly to call for declining elevator cab speed levels. The desired speed called for is thus a function of the displacement of the cab from the destination floor; and remains so all the way to the dead stop at floor level. There is no transition to a constant coasting speed (which would not be a function of displacement).

The switches and the resistors at the right-hand side of FIG. 3 operate in the same manner for downward decelerating motion of the elevator cab, as it approaches its destination floor from above. Under those circumstances the switch K2 is closed to connect the right-hand side of the circuit to the RC network.

In order to avoid a condition in which all the switches are open for an instant during the passage from switch to switch, the vertical dimension of the actuators T1 and T2 exceeds the maximum distance between the operating plunger of any two adjacent switches actuated thereby. Thus, for example, slide T1 will close switch C2 before releasing switch C1, to avoid undesirable discontinuities in the voltage applied to the RC network.

There is no departure from the programming of brake force as a function of displacement until final stopping and holding of the elevator cab, which occurs only when the cab reaches the destination floor and opens the switch 18 of FIG. 1 to cut off the brake defeat winding 8 entirely. Thus it is seen that the braking force is continuously exerted and smoothly varied

from the beginning of the deceleration program right through to culmination in a dead stop.

The distance between adjacent switches of the series C1 through C6 and the values of the resistors R1 through R4 are selected to determine the braking program. For example, so far as upward travel is concerned, the distance between adjacent switches gradually decreases from switch C1 to switch C4. If the values of the resistors R1 through R4 are the same, and if the distance between adjacent switches decreases parabolically as a function of the distance to the destination floor so as to match the decrease in cab speed under deceleration, then the time interval between the activation of any two successive switches C1 through C4 is constant, and the decelerating force exerted by the brake mechanism is constant. This arrangement produces maximum passenger comfort as well as obtaining the best smoothing results from the RC integrating network. The same is true for the upward motion circuit depicted at the right-hand side of FIG. 3. It is evident that a nonlinear (i.e. parabolic) control function such as this would be very difficult to achieve if a slide wire potentiometer were used in place of the discrete switches C1 through C4, etc.

The switch arrangement of FIG. 4 and its associated circuit of FIG. 5 is similar in most respects to that of FIG. 3, except that there is employed a type of switch illustrated in FIG. 6. This includes a pair of magnetically actuated reed type contacts 61 enclosed within a glass envelope 62. A casing 64 of a material which is nonpermeable surrounds the envelope 62. A permanent magnet 63 is assembled with the casing 64, leaving a space therebetween which can be traversed by a soft iron plate 70 as seen in FIG. 7. Normally the magnet 63 closes the contacts 61, but when the iron plate 70 intervenes, it acts as a flux shield and allows the contacts 61 to open.

As seen in FIG. 4, a group of such switches 41 through 45 are mounted upon the elevator cab and move therewith to traverse a soft iron switch actuating shield 40 which is mounted upon a support 46 secured in place upon the vertical rail 47 within the elevator shaft. Switches 41 through 45 are actuated sequentially by the shield 40 as the elevator cab moves upwardly within the shaft, and serve a function similar to that of switches C1 through C4 of FIG. 3. A similar arrangement of switches is seen at the right-hand side of FIG. 4, and serves for downward cab movement.

FIG. 5 shows the electrical connection of switches 41 through 44 to a network of resistors 57, 58, 59, etc. which are similar in purpose to the resistors R1 through R4 of FIG. 3. There is also an RC integrating network comprising resistors 54 and 55 and a capacitor 56. The negative terminal of the network is designated 50, the output terminal at which the brake program signal voltage appears is designated 51, and a circuit point at the end of the string of resistors is grounded.

In this circuit those switches with single prime reference numerals are employed for upward motion of the elevator cab, and are connected to a switch 52 which closes in response to such motion. The switches with double prime reference numerals correspond to those at the right-hand side of FIG. 4, in that they are employed for downward elevator cab motion and are connected to a switch 53 which closes during such motion. The diodes D1 through D4 and D1' through D4' etc. are employed to prevent sneak circuits between switches 41' through 44' and switches 41'' through 44''.

When all the switches 41 through 44 in the group which is currently operative are closed, then all the resistors are out of the circuit. As switch 41' is closed first during upward cab motion or switch 41'' is closed first during downward elevator cab motion, resistor 57 is inserted into the circuit. As subsequent switches in the string are closed in numerical order as a result of continuing motion of the elevator cab, additional resistors 58, 59 etc. are inserted into the circuit in series cumulatively, i.e. in addition to those resistors previously inserted in the circuit. The result is a brake program output voltage at terminal 51 which decreases in the manner discussed above. Note that the diodes in FIG. 5 make it possible to use

only a single string of resistors instead of a double string as in FIG. 3.

With any of the brake program circuit embodiments discussed herein, the result is a continuously declining brake program voltage issuing from circuit 30 of FIG. 1 and applied over lead 31, switch section 28, and lead 20 to the input of the difference network 33. This causes the difference signal applied to the amplifier input 22 to be regulated in accordance with the brake program circuit, but with reference to the actual speed of the elevator cab 1, as measured by the tachometer generator 24. The result is a smooth and continuous application of braking force over the entire deceleration interval, right up to the opening of switch 18 when the elevator cab reaches its destination floor and makes a dead stop precisely at floor level.

Although the invention is concerned primarily with programmed braking, an additional advantage of the invention is that the difference network 33 and amplifier 9 can also be used during acceleration under control of the program circuit 23 to provide programmed starting.

Other advantages of the invention are that, with the reduction of flywheel, there is a corresponding reduction in the torque required for accelerating, and therefore power consumption during starts is reduced. This is economical not only from the standpoint of the continuing cost of electrical energy, but also permits a less expensive motor to be used, allowing a saving in initial cost. In addition the lower flywheel mass means that less kinetic energy must be dissipated upon braking, so that there is less wear on the brake linings and less heat developed. The absence of a heavy flywheel also means that under emergency conditions the brake mechanism is better able to bring the elevator to a sudden stop because there is less mass to decelerate.

Of course, fail-safe braking is maintained, in that even a total failure of the electrical control system would have no greater consequences than a deenergization of the brake defeat winding, resulting in maximum braking force under spring bias, so that the elevator cab would be brought to a safe halt.

The programmed starting feature which is an additional advantage of the invention makes possible additional power economies, and a reduction in the heating of the motor drive windings, during the acceleration phase. Finally, it may be observed again that the system of this invention saves valuable time by shortening the programmed stopping time very considerably, and does so without jarring the passengers. On the contrary, there is a marked improvement in the smoothness of the deceleration surge. Furthermore, the passengers are assured of a perfectly level stop at the destination floor when the elevator comes to a halt, which is at least a convenience to the passengers and may even save them from tripping and falling when they emerge from the cab.

What is claimed is:

1. Elevator apparatus for performing a transitionless elevator braking program, said apparatus comprising:
 - an elevator,
 - an electric motor for powering said elevator,
 - a destination floor,
 - means for producing an electric signal proportional to the speed of said elevator,
 - preprogrammed means for producing a signal which is a continuous function of the displacement of said elevator from said destination floor without interruption until its arrival at said destination floor,
 - variable force brake means,
 - and control circuit means for said brake means, said control circuit means including difference means for producing a signal which is a function of the difference between the signal produced by said preprogrammed means and said speed-proportional signal, and means for supplying said difference signal to said brake means for varying the brake force in accordance with said difference signal without interruption until the arrival and stop of said elevator at said destination floor, whereby said transition-

less elevator braking program is provided until said arrival and stop.

2. Elevator apparatus according to claim 1, wherein said variable force brake means includes an electromagnetic winding for reducing braking force as excitation thereof is increased, and said means for supplying said difference signal to said brake means is continuously connected to said winding until the arrival of said elevator at said destination floor.

3. Elevator apparatus as in claim 2, further comprising means for disconnecting said brake control circuit means from said winding when said elevator arrives at said destination floor.

4. Elevator apparatus according to claim 2, further comprising switching means for deenergizing said electric motor whenever said brake control circuit means is in operation.

5. Elevator apparatus as in claim 4, further comprising means for maximally energizing said winding to reduce said brake force to a minimum whenever said electric motor is energized.

6. Elevator apparatus according to claim 2, wherein said variable brake means includes a brake drum and a member operatively engageable therewith for exerting a braking torque thereon, means for biasing said member toward said drum to exert maximum torque thereon, said electromagnetic winding being in operative relation with said member for exerting a torque reducing force on said member which varies as a function of said difference signal.

7. Elevator apparatus according to claim 6, wherein said biasing means comprises a spring.

8. Elevator apparatus according to claim 2, wherein said preprogrammed means comprises a voltage source, a plurality of impedances; and discrete switching means located at spaced locations whereby to be responsive to the distance between a preselected point on said elevator and a preselected stationary point for selectively connecting said impedances across said voltage source in discrete steps for varying the output signal produced thereby as a function of the spacing between said switch locations and of the travel of said elevator.

9. Elevator apparatus as in claim 8, further comprising integrating means for smoothing said discrete switching transitions to provide a smooth output from said preprogrammed means.

10. Elevator apparatus according to claim 8, wherein consecutive spacings between said switch locations are related nonlinearly.

11. Elevator apparatus according to claim 8, wherein said switching means comprises two groups of switches, one of said groups for upward elevator movement and the other of said groups for downward elevator movement, and said plurality of impedances comprise two groups of series connected resistors for connection across said voltage source, one of said resistor groups for connection during upward elevator movement and the other of said resistor groups for connection during downward elevator movement, said one group of switches for selectively connecting the resistors from said one group into and out of circuit across said voltage source; and said other group of switches for selectively connecting the resistors from said other group into and out of circuit across said voltage source.

12. Elevator apparatus according to claim 11, wherein said switches are borne by said elevator and include vertically spaced actuating members, and a stationary operating member means is secured adjacent said elevator in the path of travel of said actuating members for engaging said actuating members to operate said switches, said actuating members in each group being variably spaced in accordance with a parabolic relationship with the uppermost actuating members in said one group being maximally spaced and the lowermost actuating members in said other group being maximally spaced.

13. Elevator apparatus according to claim 12, wherein said

stationary operating member means comprises a pair of operating members, one for engaging the actuating members of said one group of switches and the other for engaging the actuating members of said other group of switches.

14. Elevator apparatus according to claim 13, wherein said elevator is adapted to stop at a plurality of vertically spaced preselected points when moving upwardly and downwardly, said operating member means comprising a pair of said operating members for each of said points.

15. Elevator apparatus according to claim 11, wherein each of said switches is operable between a normal and an operated position, said switches being borne by said elevator and including vertically spaced actuating members, and a stationary operating member means is secured adjacent said elevator in the path of travel of said actuating members for engaging said actuating members to operate said switches, circuit means for connecting each group of switches with its associated group of resistors, said circuit means being so arranged that when all of said switches are in their normal conditions, all of the associated resistors are short circuited, and when during upward elevator movement the uppermost switch actuating member in said one group is engaged by said operating member means, one of said resistors from said first group is connected across said voltage source, and as each successive actuator in said one group is engaged by said operating member means, an additional resistor from said one group is connected across said voltage source; said circuit means being further arranged so that when during downward elevator movement the lowermost actuator in said other group is engaged by said operating member means one of said resistors from said other group is connected across said voltage source, and as each successive actuator in said other group is engaged by said operating member means an additional resistor from said other group is connected across said voltage source, and selector switch means responsive to elevator direction for applying said voltage source to said one groups of switches and resistors and to said other groups of switches and resistors.

16. Elevator apparatus according to claim 11, wherein said switches are magnetic switches comprising contacts movable between a normal position and an operated position, a magnet for each switch spaced from said contacts for biasing said contacts to their normal position; and stationary operating member means for said switches secured adjacent said elevator for interposition between said contacts and their associated magnet, said stationary operating member means being made of ferromagnetic material for shielding said contacts from said magnets whereby to cause said contacts to move to their operated positions.

17. Elevator apparatus according to claim 1, further comprising motor control circuit means including a time dependent starting program signal producing means, means for producing a signal which is a function of the difference between the voltage produced by said starting program means and said proportional signal, and means for controlling the energization of said motor in response to said last mentioned difference signal.

18. Elevator apparatus according to claim 11, further comprising motor control circuit means including a time dependent starting program signal producing means, means for producing a signal which is a function of the difference between the voltage produced by said starting program means and said proportional signal, and means for controlling the energization of said motor in response to said last mentioned difference signal.

19. Elevator apparatus according to claim 17, wherein said energization controlling means comprises a saturable core reactor.

20. Elevator apparatus according to claim 17, wherein said motor is a multiphase motor, and said energization controlling means comprises a plurality of saturable core reactors, one in series with each phase of said motor.