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Smith

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[54] **ELEVATOR CONTROL SYSTEM FOR INDICATING DAMAGE TO AN ELEVATOR STRUCTURE**

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[52] **U.S. Cl.** .... **187/29 R**
[51] **Int. Cl.** **B66b 5/02**
[58] **Field of Search** 187/29

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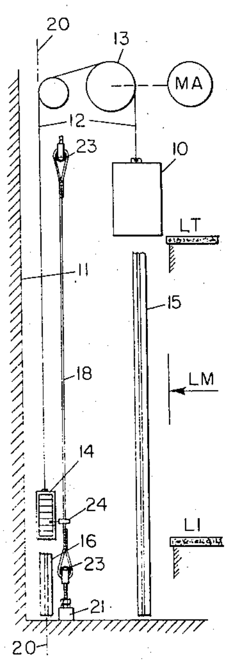
[57] **ABSTRACT**

An elevator control arrangement for detecting the physical displacement of one of the system's movable components from its normal operating position and thereafter restraining further movement of the car to a direction in which such movement increases the physical separation of the car from its counterweight.

10 Claims, 5 Drawing Figures



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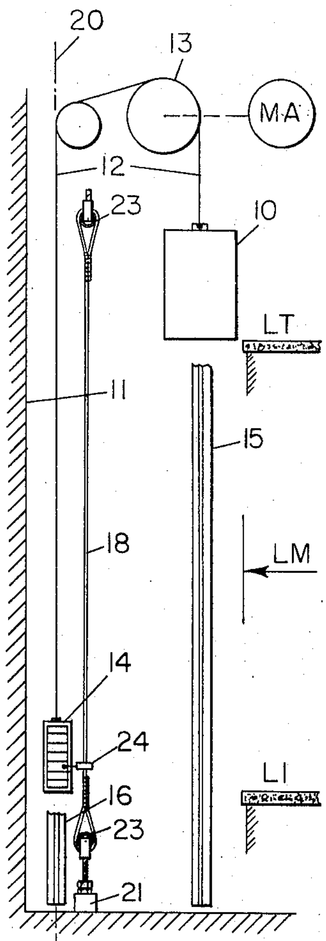

FIG. 1

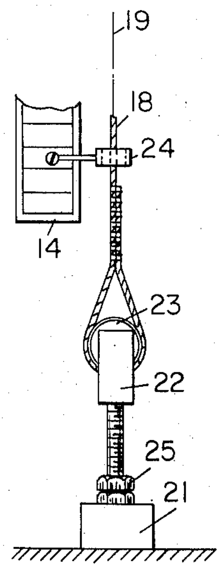

FIG. 2

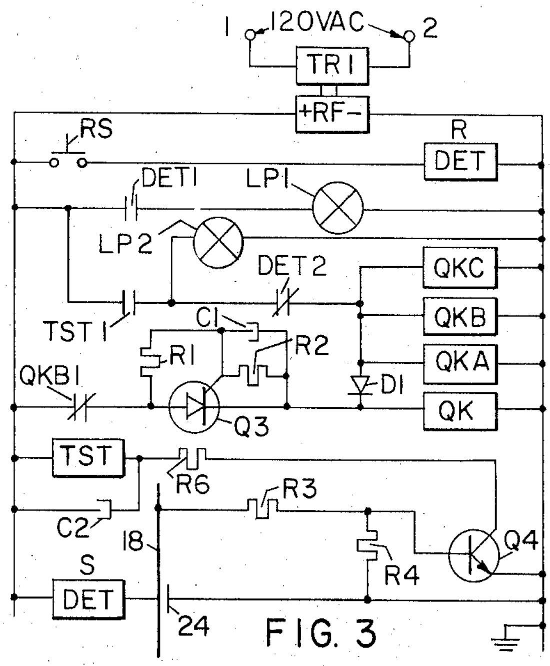

FIG. 3

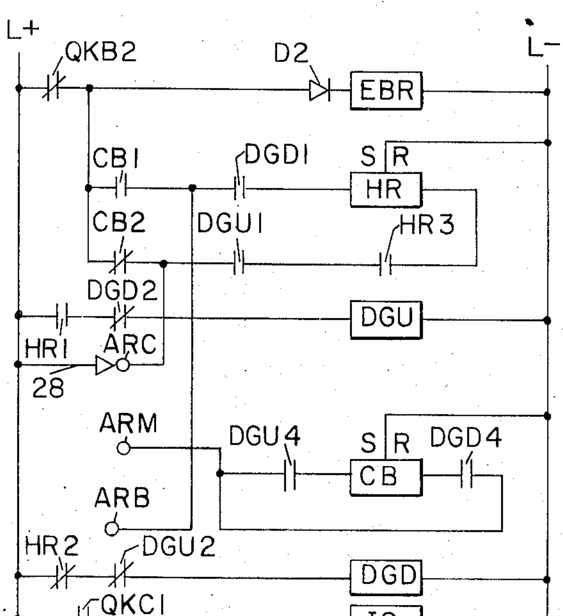

FIG. 4

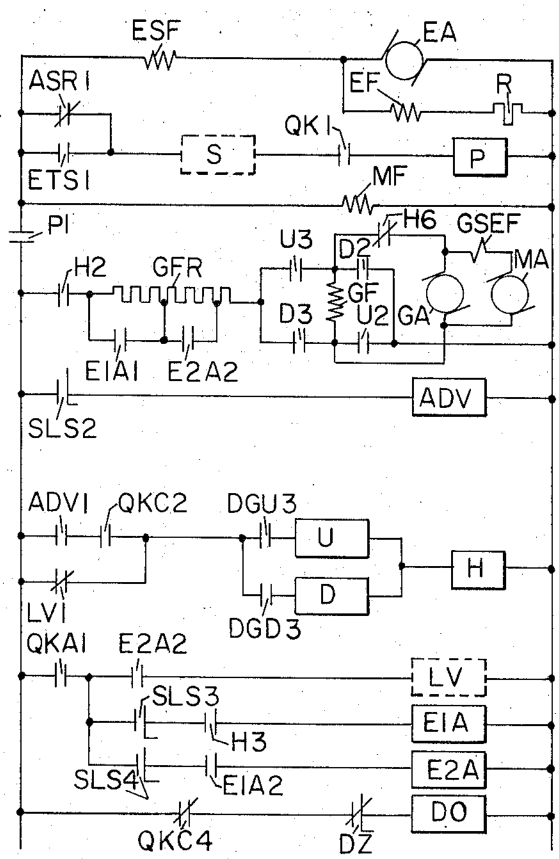

FIG. 5

ELEVATOR CONTROL SYSTEM FOR INDICATING DAMAGE TO AN ELEVATOR STRUCTURE

This invention relates to improvement of safety of elevators, and more particularly relates to an arrangement for detecting and responding to the damage caused to elevators by high-shock forces that commonly accompany earthquakes, explosions, and the like.

When an elevator system is subjected to high-shock forces, such as may be associated with an earthquake, damage to the system in the form of displacement of components may occur. When this happens, the continued operation of the elevator may be undesirable as the passenger's safety may be impaired and as further damage to the apparatus may occur. It is possible, of course, to stop the operation of all elevators in a building after an earthquake until a physical inspection of the equipment of each indicates its suitability for renewed operation. However, because the demands for elevator service may, for a short time, rise significantly after such an occurrence, it is desirable to maintain in operation those elevators that have not suffered safety-impairing displacements.

It has been suggested that a seismic disturbance sensor be used to deactivate the elevator system or systems if a disturbance in excess of a predetermined value is experienced. It is understood that its effectiveness is thought to be variable, depending in some instances, upon the position of its installation and the threshold level at which the sensor unit operates its associated switch. If used it may control the power supply for all electromechanical apparatus within a building; and when so used the sensor may be located in a place other than the elevator shaftway. It is possible that the effect of shock forces acting in the elevator shaftways may differ considerably from those experienced in other parts of the building; and a distantly located sensor may produce indications that are not especially applicable to the elevators.

As the setting of the threshold response of the sensor is a matter for choice, it is possible that the one chosen may result in either shutting down undamaged elevators or not detecting sublevel forces that actually cause safety-impairing displacements. It is thought an accelerating force that is one-half the force of gravity that may well result in damage to an elevator system. Even at this level, however, that is not a matter for certainty; as it seems that some elevators may remain operational while other seemingly identical installations sustain service-disrupting damage when exposed to forces of this approximate magnitude.

It is known that the likelihood of safety impairing displacements increases as the severity of the shock force increases. Likewise it is believed that for a given severity all elevators of a group may not be similarly affected; some being affected, others not.

It is therefore believed desirable to provide a simple and relatively inexpensive detector that may be individual to each elevator or to a group of elevators and which may equally well be installed either at the time of original installation or at a later date. Such a detector may be arranged to coact with the elevator's control system so as to remove from service only those elevators of a group of elevators that experience safety-impairing displacement. In this way, under the emergency conditions presented in a building sustaining a

high-shock, only those elevators that have actually suffered service-impairing displacements need be removed from service, thus preserving for service those elevators that have not been adversely affected. Furthermore, as regards such elevators, a determination can be made of how best to move the elevator to facilitate the removal of its passengers.

It is an object of this invention to improve the safe operation of an elevator by detecting immediately the damage caused to it by high-shock forces.

It is another object to detect immediately a displaced component, such as a counterweight, of the system, and thereafter to restrain the operation of the elevator to a safe manner.

It is a feature of this invention that the vertical position and direction of travel of the elevator car relative to its displaced component is determined practically instantaneously and controls movement of the elevator car subsequent to the displacement.

In carrying out the invention in a preferred embodiment, there is provided an electrical conductor, or sensing wire, suspended vertically in the hoistway and disposed so as to lie within a plane parallel to the path of travel of the counterweight. It has impressed upon it a low voltage that is effective to actuate associated control circuitry upon the displacement of the counterweight from its guide rails.

The invention is adaptable to substantially any type of elevator control system. It will be described herein as being applied to an elevator utilizing a Ward-Leonard type of motor speed control, and a selector for monitoring the car position relative to the various landings of the building and the direction of car travel. As explained, the car normally proceeds from a bottom terminal landing to a top terminal and vice versa, such as would occur with a terminal type dispatching and supervisory control of a group of such cars.

When a displaced component is detected the car is stopped as in the case of loss of operating potential. Following this stop an evaluation is made of the car's last direction of travel and its position with respect to its counterweight. If these were such that the separation between car and counterweight was increasing, movement of the car to the next adjacent landing is effected at a controlled low, or leveling speed.

Conversely, if the last direction of travel was not such as to increase the separation from the counterweight, the car's direction of movement is reversed before its movement is resumed.

Features and advantages of the invention will be apparent to those skilled in the elevator art from the following description and appended claims when considered in conjunction with the drawing in which:

FIGS. **1** and **2** are simplified representations of a single elevator employing the invention; and

FIGS. **3, 4** and **5** are simplified schematic wiring diagrams in straight-line form of the essential control circuitry of the invention and of typical elevator control circuitry used in cooperation therewith.

The electromagnetic relays or switches disclosed herein and the reference characters used therewith are designated as follows:

ADV—Advancer Relay
ASR—Automatic Start Relay
CB—Counterweight-Below Relay
D—Down Direction Switch
DET—Displacement Sensor Relay

DGD—Auxiliary Down Direction Switch
DGU—Auxiliary Up Direction Switch
DO—Door Open Relay
E1A—First Speed Switch
E2A—Second Speed Switch
EBR—Car Call Button Reset Relay
ETS—Excitation Time Switch
H—Field and Brake Switch
HR—Reversal Switch
IS—Independent Service Switch
LV—Leveling Switch
P—Potential Switch
QK–First Sensor Control Relay
QKA—Second Sensor Control Relay
QKB–Third Sensor Control Relay
QKC—Fourth Sensor Control Relay
S—Safety Switch
TST—Sensor Test Relay
U—Up Direction Switch

Throughout the description that follows, these letter designations will be applied to the coils of the above-identified switches. Also, with reference numerals appended thereto, they will be applied to the contacts of these switches. The circuits are shown in across-the-line form in which the coils and contacts of the various switches are separated in such a manner as to render the circuits as simple and direct as possible. The electromagnetic switches are illustrated in deenergized condition. Switches DET, HR and CB, which are of the latching type, are shown in the reset condition. Each of these latching type switches has two coils, one an operating or set coil and the other a reset coil. In the following description identification of the set and reset coils is accomplished by appending "–S" and "–R", respectively, to the letter designation of the switch.

As indicated in FIG. **1**, elevator car **10** is suspended in a vertical hoistway **11** by hoist ropes **12** from sheave **13**, which is mounted on the shaft of motor armature MA of the direct current elevator hoisting motor. Suspended by the same ropes is counterweight **14**. The movable car **10** and counterweight **14** are guided by their respective guide rails **15**, **16**. The car serves a plurality of landings represented herein as the lowermost landing L**1**, the uppermost landing LT, and a midpoint of travel in the hoistway, which is also referred to herein as middle landing LM.

The sensor includes an electrical conductor or wire **18**, the axis **19** (FIG. **2**) of which is parallel to the plane containing the longitudinal axis **20** of counterweight rails **16**. The sensing wire **18** is shown as being in the space between the paths of travel of the car **10** and its counterweight **14**. It is mounted in the hoistway extending from a point above the upper terminus to a point below the lower terminus of travel of the counterweight **14**. It is mounted in a taut condition and is insulated from ground. Tensioning block **21** (FIG. **2**) supports adjustable sheave mount **22** which in turn tensions the wire **18** around insulating sheaves **23**. A contactor **24**, here ring-shaped, is attached to and supported by counterweight **14** and during normal operation encircles the sensing wire **18** throughout its length without contacting it. Upon displacement of the counterweight by a predetermined amount from its normal position, contactor **24** touches sensing wire **18** and thereby connects it to ground potential.

As indicated in FIG. **3**, line **1** and **2** supply alternating potential to transformer TR1 and rectifier RF. The set coil DET–S and reset coil DET–R of the detector relay, and coil TST of the test relay are connected across rectifier RF. Lamp LP1 is connected through contacts DET1 of the detector relay across the lines. The sensor relay coils QK, QKA, QKB and QKC are energized through making contacts TST1 of test relay TST and breaking contacts DET2 of the detector relay. Resistors R1, R2 and capacitor C1 form a timed voltage divider connected to the gate electrode of silicon controlled switch Q3. This arrangement supplies power to coil QK through the back contacts QKB1 a predetermined interval after sensor relay coil QKB is deenergized.

Coil TST of the test relay is connected through resistor R6 to the collector of transistor Q4, whose emitter is at ground potential and base is connected to sensing wire **18** through the voltage divider comprising resistors R3 and R4. Lamp LP2 is shunted between ground potential and the connection between contacts TST1 and DET2. Coil DET–S of the detector relay is provided with energizing potential when contactor **24** contacts sensing wire **18**.

Referring now to FIG. **4**, lines L+ and L– provide suitable potential to coils HR, DGU and DGD of the reversal switch and auxiliary direction switches; to coil EBR of the car call button reset relay; to coil IS of the independent service switch and coil CB of the counterweight-below relay. The switches DGD, DGU, HR and IS and relay EBR form part of a typical control system for terminal-to-terminal travel of the car. Both the direction reversal relay HR and the counterweight-below relay CB have three-lead, mid-point tapped coils and are "set" when the portions HR–S or CB–S of the coils are energized, and "reset" when the portions HR–R or CB–R of the coils are energized. The "set" and "reset" portions of coil CB are connected to selector contact ARM through the making contacts DGU4 and DGD4, respectively.

Referring to FIG. **5**, hoist motor armature MA is in series connection with the Ward-Leonard controlled armature GA and its series field winding GSEF. Exciter EA has both series field ESF and shunt field EF and supplies current to shunt fields MF and GF of the motor and direct current generator, respectively. Coil P of the potential switch is connected across operating potential through conventional safety switch S (represented by broken-line rectangle) and making contacts QK1. Coil H of the field and brake switch and coils U and D of the directional control switches are connected to power through making contacts QKC2 of the sensor relay and ADV1 of the advancer relay. Coils E1A and E2A of the first and second speed switches and those of the leveling switches LV (shown in broken-line rectangle) are connected to operating potential through making contacts QKA1 of the sensor relay QKA. And, coil DO of the door open relay is so connected through back contacts QKC4 of the sensor relay QKC.

Assume now that power is applied to the elevator system, it being set for "down" travel of car **10** (FIG. **1**) from the top landing LT; that counterweight **14** is in its normal position between rails **16** and that the displacement detector system is operational in its non-actuated state. Coil DET-S (FIG. **3**) of the displacement sensor relay is de-energized with its making contacts DET1 separated and breaking contacts DET2 engaged. Coil TST of the sensor test relay is energized with making contacts TST1 engaged, and lamp LP2 illuminated, indicating operating potential on sensing wire **18.** Coils QK, QKA, QKB and QKC of the sensor relays are energized. Also, the counterweight **14** (FIG. **1**) is at its lower terminus of travel and the counterweight-below relay CB (FIG. **4**) is in the set condition.

Down direction coil DGD (FIG. **4**) is energized and direction reversal coil HR is reset. Upon initiating travel, selector brush **28** disengages from contact ARC, and, upon reaching middle landing LM, it engages contact ARM. This impresses a voltage through contacts DGD4 to reset coil CB–R of the counterweight-below relay, separating contacts CB1 and engaging contacts CB2 (without effect at this time). This, in conjunction with the reset condition of reversal switch HR indicates that the counterweight is moving upward from the midpoint of the hoistway **11.**

As the car proceeds downward the selector brush **28** moves from contact member ARM, the coil CB–R remaining reset. Upon the elevator car reaching the lower landing L1 (brush reaching ARB), coil HR–S of the reversal switch HR is energized through closed contacts DGD1. Contacts HR–2 separate de-energizing the down direction relay coil DGD and up direction relay coil DGU is energized as contacts HR1 and back contacts DGD2 engage, preparing for upward movement of the car.

As the car **10** travels upwards brush **28** once again engages contact member ARM; a voltage is now impressed, through contacts DGU4 to the "set" coil CB-S of the counterweight-below relay CB, engaging contacts CB1 and separating contacts CB2 (again without immediate effect). The counterweight **14** (FIG. **1**) is now at or below the mid-point of the hoistway **11** and is proceeding downward.

Now assume that, while the elevator car **10** (FIG. **1**) is again proceeding downward from the top landing LT toward the middle landing LM (reversal switch HR now being "reset") the counterweight **14** is displaced and the contactor **24** contacts sensing wire **18.** Coil DET–S of the displacement sensor relay DET is energized causing contacts DET1 to engage and contacts DET2 to separate. Lamp LP1 is illuminated, indicating the occurrence of a detected counterweight displacement. Coil QK of the first sensor control relay QK and coils QKA, QKB and QKC of the other sensor control relays QKA, QKB and QKC are de-energized. Transistor Q4 ceases conduction and coil TST is de-energized. Lamp LP2 extinguishes with the opening of TST1 contact. Upon de-energization of coil QKB, back contacts QKB1 engage preparing for later re-energization of coil QK when capacitor C1 receives sufficient charge to cause conduction in silicon controlled switch Q3.

Referring now to FIGS. **3** and **5,** upon de-energization of coil QK making contacts QK1 in the circuit of potential coil P (FIG. **5**) disengage thereby de-energizing coil P of the potential switch and its contacts P1 disengage. This removes power from the generator armature GA, motor armature MA, field and brake coil H and a major portion of the conventional controls. As a result, the brake sets and rapid stopping of the elevator occurs.

At the time the displacement occurs contacts HR2 and DGU2 (FIG. **4**) are engaged in the circuit of auxiliary down direction switch DGD. Also contacts CB1 are engaged and CB2 are disengaged in the circuit of coil HR of the reversal switch HR. The counterweight **14** is in the lower half of the hoistway and further movement of the car in its downward direction would move it and its counterweight into closer proximity, which would be undesirable. This is avoided by the action of the third sensor control relay QKB which engaged its contacts QKB2 in the circuit of coil HRS of the reversal switch HR when its coil QKB was de-energized.

Upon reapplication of operating power to the system as will be next explained the set coil HR–S of reversal switch HR will be energized through closed contacts QKB2, CB1 and DGD1 to cause the opening of contacts HR2 in the circuit of coil DGD and the closing of contacts HR1 in the circuit of coil DGU of the auxiliary up direction switch for energization of auxiliary up direction switch DGU when its back contacts DGD2 re-engage as their coil DGD is de-energized. The next movement of the car will now be in the up direction and that of the counterweight in the opposite direction. At this time the car call button reset relay coil EBR will have been energized to cancel all car calls that are then in registration; and the engaged contacts QKC1 in the circuit of the coil IS of the independent service relay will have separated to remove the elevator from the group supervisory control (if any is involved).

The time period of operational de-energization which started when the first sensor control relay QK separated its contacts QK1 (FIG. **5**) is determined by component values of the timed voltage divider, **R1, R2, C1** (FIG. **3**) in the circuit of silicon controlled switch **Q3.** Upon completion of the time delay, power for re-energizing coil QK of the sensor relay is supplied through semiconductor device **Q3.** Contacts **QK1** (FIG. **5**) re-engage energizing coil P of the potential switch and contacts P1 are re-engaged. Prior to this time contacts QKC2 in the circuit of coils U and D of the direction switches are disengaged and the back contacts LV1 of the leveling switch LV are engaged. Contacts DGU3 and DGD3 in that circuit are disengaged. Contacts QKA1 of the second sensor control relay QKA (FIG. **3**) are disengaged in the circuit of the leveling switch coil LV, and the speed control coils E1A and E2A. Contacts QKC4 are engaged in the circuit of door-open switch coil DO.

When operational power is reapplied by the re-energization of first sensor control relay QK and up direction control is re-established by the release of relay DGD and the actuation of relay DGU the car moves upwardly as contacts DGU3 (FIG. **5**) are closed. The circuit therefor is through closed contacts LV1, contacts DGU3, coil U and field and brake coil H. At this time door zone contacts DZ are separated. As the car enters the door zone of the next-above landing coil DO of the door open relay is energized thus opening the doors to stop the car at that landing. Inasmuch as there is no provision for restarting the car from that landing until the DET–R coil of the detection relay (FIG. **3**) is energized by the manual operation of reset control RS, the car remains at that landing awaiting further inspection and services.

Consider now the operation that would have occurred had the displacement of the counterweight occurred as the car was moving upwardly before arriving at the top terminal landing LT (FIG. **1**). At this time contacts CB1 would have been engaged and CB2 would have been separated (Coil CBS of the counterweight-below relay having been energized) and contacts HR1 would have been closed in the circuit of coil DGU of the auxiliary up direction switch DGU, with the complementary contacts HR2 separated in the circuit of coil DGD of the auxiliary down direction switch DGD. Coil HRS of the direction reversal switch would have been energized and contacts HR3 would have been engaged. The car would have been moving upwardly and its counterweight downwardly.

Further movement of the car upwardly would serve to increase the separation of the car and its counterweight. Accordingly, when contacts QKB2 of the third sensor relay QKB closed the reversal switch HR was maintained in its set condition; the circuit through coil being open at contacts DGD1 and contacts CB2. Thus, when contacts P1 (FIG. 5) reengage at the end of the time-controlled period for conduction of silicon controlled rectifier Q3 and operational power is re-applied to the system the car resumes movement in its upward direction at a controlled low or leveling speed, to the next above landing where it stops with its doors opened and remains until the necessary inspection and servicing is effected.

Referring once again to FIG. 3, assume that there is a mere loss of voltage on sensing wire 18 without contactor 24 engaging conductor 18. Upon the occurrence of such an event, coil TST of the test relay is deenergized and contacts TST1 separate. The sequence of operations that follows is the same as that after a detected counterweight displacement, except that sensor service is restored upon voltage being restored to conductor 18 without any requirement for resetting coil DET–R of the detector relay. Thus, normal service is automatically restored by the restoration of sensing potential on conductor 18.

Various modifications in the foregoing arrangement are possible; they may be made necessary by the specifics of the control system of a particular elevator, and will be easily achieved by those skilled in the art. It is intended that the invention not be limited to the particularly described embodiment

What is claimed is:

1. A control system for an elevator having its vertically movable components operative in a hoistway to serve a plurality of building landings, said movable components comprising a car and its connected counterweight, guide rails effective to direct the vertical movement of the components in separate pathways, and motive means effective to move simultaneously said components in opposed directions along said pathways, said control system including first direction determining apparatus effective to control the direction in which said motive means moves said components, displacement detection apparatus responsive to abnormal horizontal displacement of one of said components with respect to its guide rails and productive of an indication of such displacement, and motive control apparatus responsive to said produced displacement indication and effective to stop the movement of said car by said motive means in an expedited manner.

2. A control system according to claim **1** wherein said displacement detection apparatus comprises a first sensor element carried by one of said movable components and a second sensor element in close normal proximity thereto during the usual vertical movement of said components along their separate pathways, said close normal proximity relation being disrupted when the movable component carrying said first sensor element experiences an abnormal horizontal displacement relative to its guide rails.

3. A control system according to claim **2** wherein one of said sensor elements is electrically connected to electrical ground potential and the other sensor element has impressed thereon an electrical potential differing from electrical ground potential by a preselected magnitude.

4. A control system according to claim **3** which includes electrical switching means operative a preselected time interval after an abnormal horizontal displacement of one of said components relative to its guide rail has actuated said displacement detection apparatus to initiate the stopping of car movement to effect renewed movement of the car by said motive means at a less-than-normal velocity, said control system being operative to interrupt the renewed movement and stop the car at the next encountered hoistway landing position.

5. A control system according to claim **4** wherein said system includes supplemental direction determining apparatus that is effective to cause said renewed movement of the car to be in a direction to cause the linear separation of the car from its counterweight to be increased.

6. A control system according to claim **5** wherein said supplemental direction determining apparatus is operative to control the direction of said renewed car movement only in the event the renewed car movement is controlled by said first direction determining apparatus would cause the linear separation of the car from its counterweight to be decreased.

7. A control system according to claim **4** wherein the actuation of said displacement detection apparatus in response to the abnormal displacement of one of said movable components renders said displacement detection apparatus immune to further response and in which manually actuated switching means is effective when so actuated to restore said displacement detection apparatus to its unactuated condition, provided said first sensor and said second sensor elements have been restored to their close normal proximity relation.

8. A control system according to claim **7** wherein visual indicating apparatus responsive to the presence of electrical potential on said other sensor element is effective, upon interruption of said potential supply, to cause said motive control apparatus to stop the movement of said car in an expedited manner in the same manner as occurs in the case of a produced component displacement indication, and to produce a visual indication that said potential supply has been interrupted.

9. A control system according to claim **8** wherein said visual indicating apparatus is responsive to the restoration of said potential supply to said other sensor element to restore said elevator to its normal operating condition without manual actuation of said switching means effective to restore said displacement detection apparatus to its unactuated state.

10. A control system according to claim **6** wherein said first sensor element is an electrical conductor connected at its one end to and carried by said counterweight and having an opening formed therethrough near its other end, and said second sensor element is an electrical conductor suspended vertically in said hoistway in a plane parallel to but displaced from the vertical plane of movement of said counterweight, said second sensor element passing substantially centrally through the opening formed in the second sensor element conductor.

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