

June 23, 1964

P. C. KEIPER ET AL
ELEVATOR CONTROL SYSTEM

3,138,223

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3 Sheets-Sheet 1

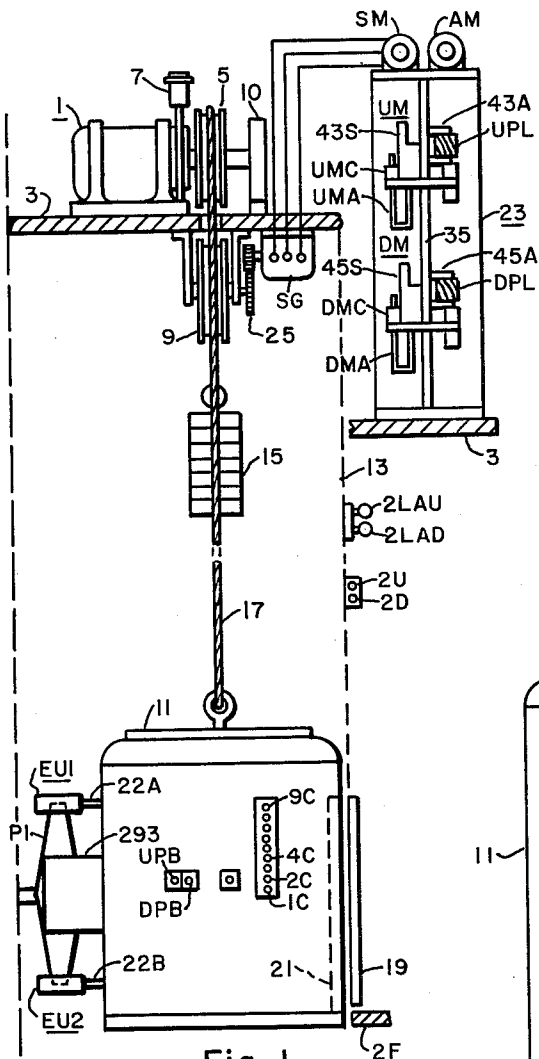


Fig. 1

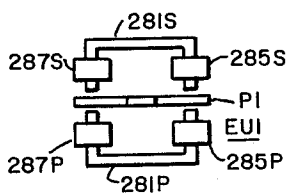


Fig. 2

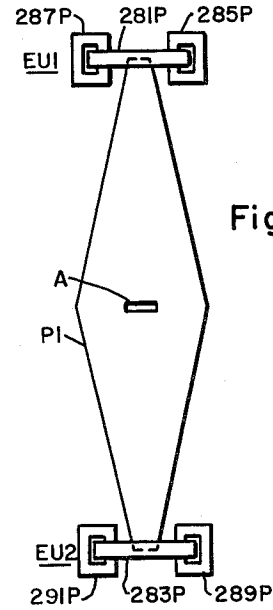


Fig. 3

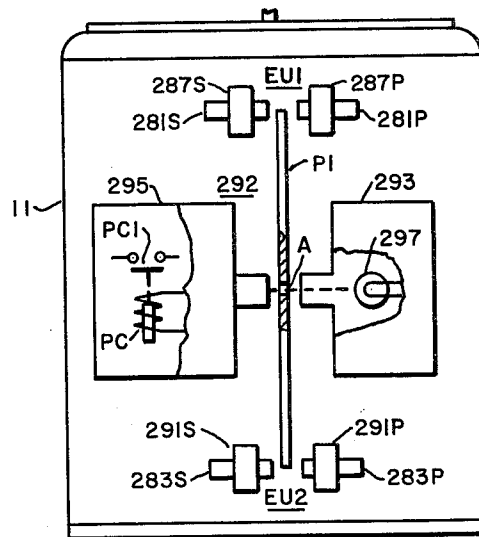


Fig. 1A

WITNESSES

Leon J. Laga
S. Friedman

INVENTORS
Phillip C. Keiper, William M. Ostrander
and Alvin O. Lund

BY *P. L. Friedman*
ATTORNEY

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3 Sheets-Sheet 2

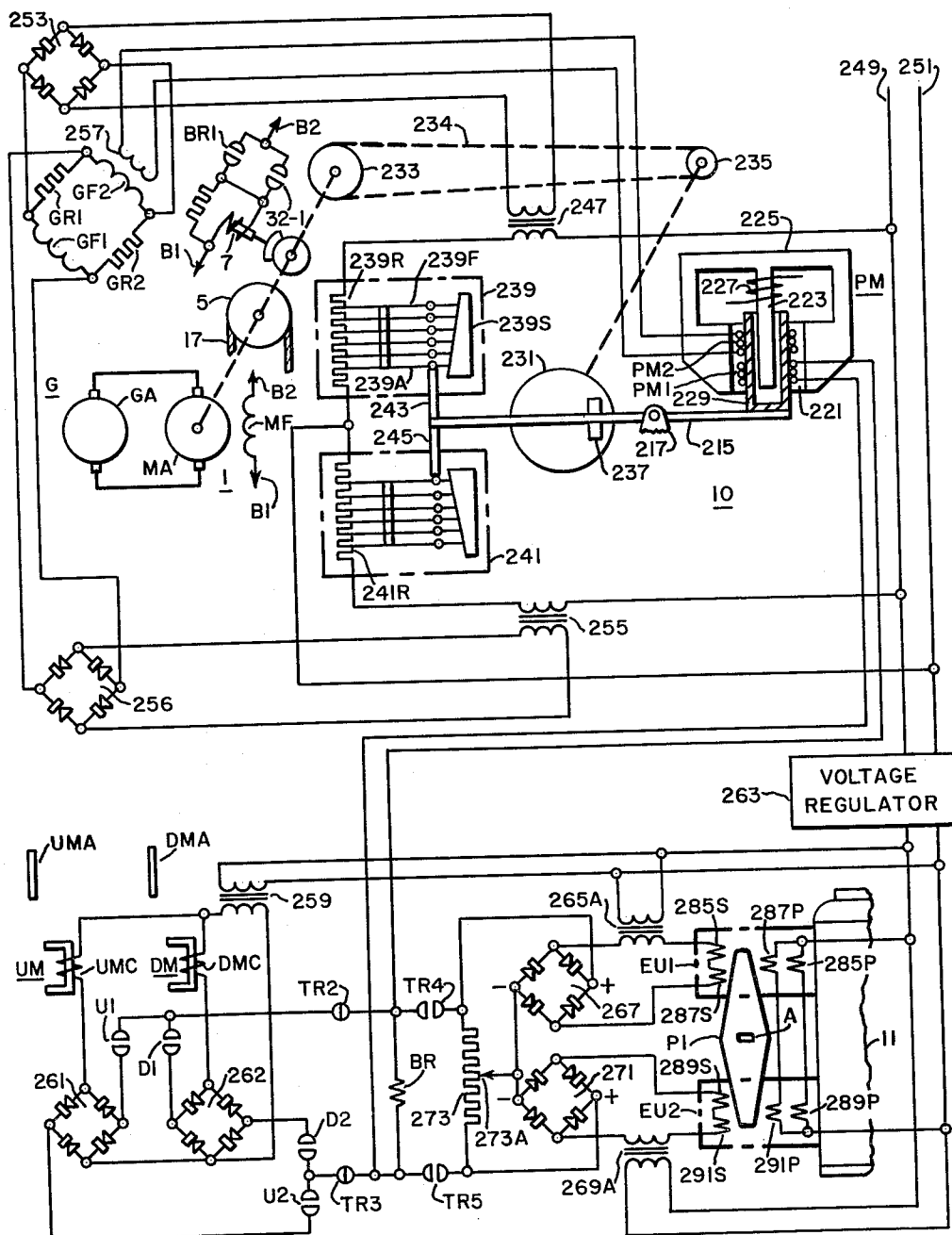


Fig. 4

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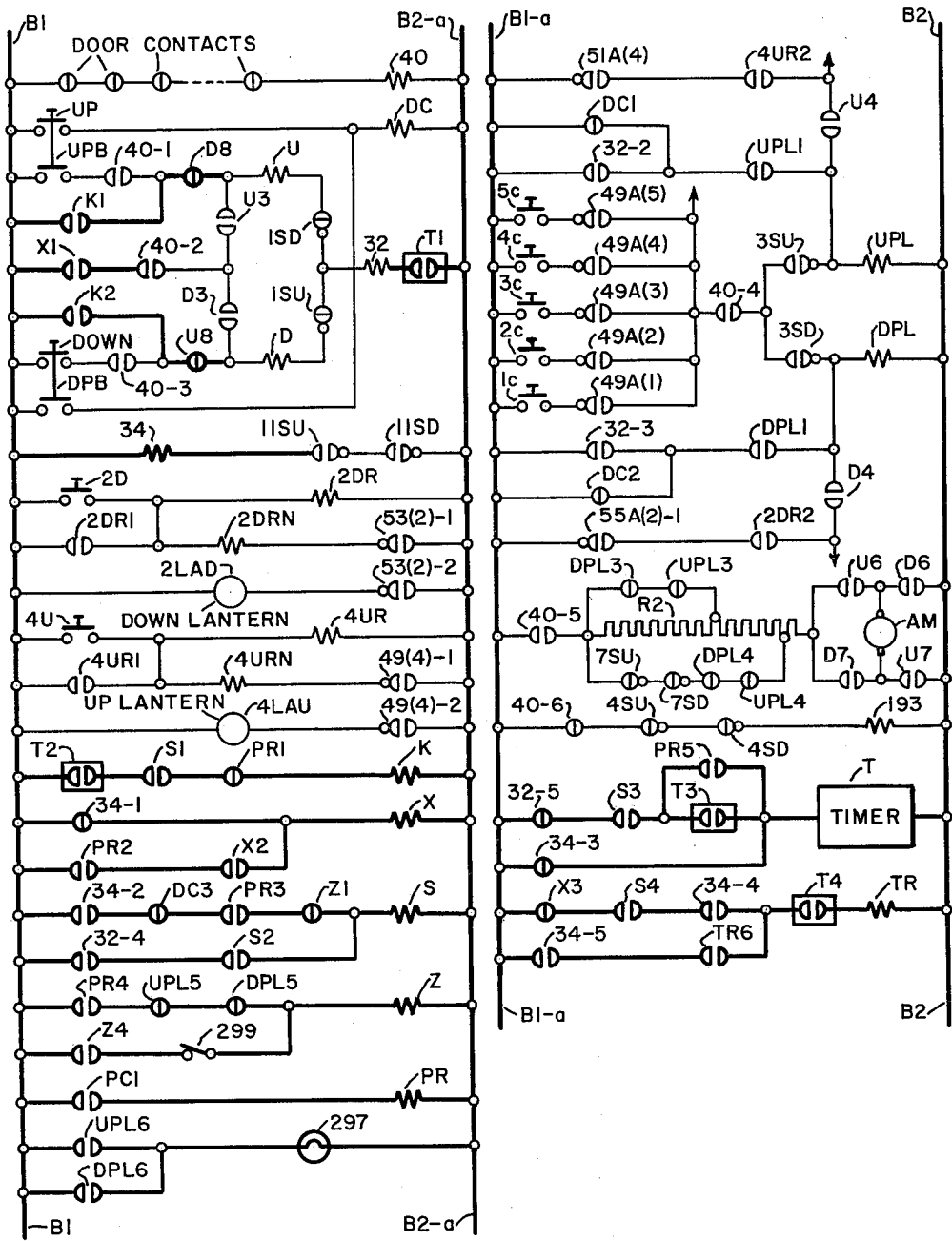


Fig. 4A

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ELEVATOR CONTROL SYSTEM

Phillip C. Keiper, Shrewsbury, William M. Ostrander, Hackensack, and Alvin O. Lund, Great Notch, N.J., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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This invention relates to motor-control systems, and it has particular relation to mechanisms and systems for controlling the starting and stopping of elevator cars.

Although the invention may be employed in whole or in part with various types of motor-control systems, it is particularly suitable for elevator systems wherein an elevator car stops automatically in response to calls for service. The calls for service may be registered by means of car-call buttons positioned within the elevator car or by means of floor buttons operated by waiting passengers at the various floors served by the elevator car. The elevator system may be of the automatic type wherein an elevator car starts automatically in response to registration of a call for service. However, the invention also is suitable for an attendant-operated elevator system wherein an attendant in the elevator car must perform some function in order to permit the elevator car to start for the purposes of answering a call for service.

In an elevator system embodying the invention, means are provided for the purpose of controlling the acceleration, slow-down and position of an elevator car. In a preferred embodiment of the invention, certain slowdown points adjacent each of the floors served by the elevator car, the stopping point for each of the floors, and car-leveling operations are controlled by highly accurate equipment located on the elevator car and in the hoistway within which the elevator car operates. Such equipment includes radiant energy sensitive apparatus controllable to provide a plurality of accurate control points for effecting a stopping operation of the elevator car at a floor or landing at which it is desired the car shall stop. Thus, as the elevator car approaches such a floor, the radiant energy sensitive apparatus may effect a predetermined slow-down operation of the car when the car is at a distance which may be, for example, of the order of 10 inches from the desired floor. When the car arrives at a predetermined position of registration with the floor, the radiant energy sensitive apparatus may effect the completion of the stopping operation by causing a brake to be applied to the motive means which moves the car. Preferably, leveling means are provided for maintaining the elevator car in the desired position of registration with the floor at which it has stopped.

According to the invention, the radiant energy sensitive apparatus comprises a radiant energy receiving and detecting device mounted on the elevator car for movement therewith. In addition, a radiant energy transmitting device, which is operable to direct radiant energy to the detecting device, also is mounted on the elevator car for movement therewith. As the car approaches a landing at which it is desired the car shall stop, means are provided for controlling the reception of such radiant energy by the detecting device. Conveniently, this may be accomplished by the use of a vane or plate mounted in the hoistway adjacent the landing and positioned to intercept the radiant energy transmitted by the transmitting device when the car is displaced from the landing by a distance of the order of the aforementioned 10 inches. Thereupon, means responsive to the detection and non-detection of radiant energy by the detecting device operate to effect slow-down and leveling of the elevator car.

The vane is provided with an aperture which permits reception by the detecting device of radiant energy trans-

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mitted by the transmitting device when the elevator car is in the desired position of registration with the floor. In response thereto, the brake is applied to the car motive means. If the car should move away from the position of registration for any reason such as a change in car load, reception of radiant energy by the detecting device again is interrupted by the vane, and the leveling means become operative to return the car to its position of registration. In a preferred embodiment of the invention, the vane is constructed of electro-conductive material and the leveling means comprises electromagnetic apparatus carried by the elevator car and cooperable with the vane, which is shaped to control the output of the electromagnetic apparatus.

Although it has been proposed in the prior art to employ radiant energy sensitive means for controlling the operation of an elevator car, such means as disclosed herein is fail-safe under all conditions of operation. For example, if the transmitting device or the detecting device fails to operate properly when it is desired to slow down the elevator car, a circuit is provided to effect deenergization of the car motive means and application of the brake thereto in order to terminate movement of the car. Additionally, if the transmitting or the detecting device fails when the car is in its position of registration with a floor at which it is stopped, such failure results in the prevention of car movement by its motive means until the failure is remedied.

It is, therefore, an object of the invention to provide improved radiant energy sensitive means for controlling the operation of an elevator car.

It is a further object of the invention to provide radiant energy sensitive means for controlling the operation of an elevator car to effect slow-down of the car at a floor at which it is desired the car shall stop and to stop the car at a predetermined position of registration with such floor.

It is another object of the invention to provide a common control element for radiant energy sensitive means and electromagnetic apparatus which control the operation of an elevator car.

It is still another object of the invention to provide radiant energy sensitive means for controlling the operation of an elevator car and which is fail-safe under all conditions of operation.

It is also an object of the invention to provide an elevator system having radiant energy sensitive means for effecting slow-down of an elevator car as the car approaches a predetermined floor with means for stopping the car and for applying a brake to the car motive means in the event of malfunction of the radiant energy sensitive means during such approach.

It is an additional object of the invention to provide an elevator system having radiant energy sensitive means for controlling operation of an elevator car and means responsive to malfunction of the radiant energy sensitive means when the car is stopped at a floor for preventing subsequent movement of the car by the car motive means.

Other objects of the invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a schematic view with parts shown in elevation, parts broken away and parts shown in cross section of an elevator system embodying the invention;

FIG. 1A is a view in side elevation with parts broken away and parts not shown of the elevator car illustrated in FIG. 1;

FIG. 2 is a view in top plan of leveling apparatus suitable for the system of FIG. 1;

FIG. 3 is a view in side elevation of the leveling apparatus shown in FIG. 2; and

FIGS. 4 and 4A are schematic views showing control

circuits in straight line form suitable for the elevator system of FIG. 1.

General System

Although the invention may be employed in various types of elevator control systems, the system herein described is similar to that disclosed in the Oplinger Patent 2,874,806. Thus, FIGS. 1, 4 and 4A of the present application are based on the corresponding figures of the aforesaid Oplinger patent, changes in and additions thereto being indicated in the present FIGS. 1, 4 and 4A by extra-heavy lines.

As in the case in said Oplinger patent, it will be assumed that the system of FIG. 1 is designed for what is known as "signal operation." Referring to FIG. 1, an elevator motor 1 is secured to the upper surface of a floor 3, which may be located in the penthouse of a building being served by the elevator system. The elevator motor 1 has a traction sheave 5 secured to its shaft, and an elevator brake 7 is associated with the elevator motor and the traction sheave in a conventional manner. As will be pointed out below, the elevator brake is spring applied to hold the traction sheave 5 stationary and is released in response to energization of a solenoid. A secondary or idler sheave 9 is secured to the lower surface of the penthouse floor 3. A control unit 10 is operated by the shaft of the motor 1. This control unit is employed in controlling the speed of the motor 1 and will be discussed below.

An elevator car 11 is mounted for movement in a hoistway 13 to serve the various floors or landings of the building associated therewith. The elevator car is connected to a counterweight 15 by means of one or more ropes or cables 17, which pass around the traction sheave 5 and the secondary sheave 9 in a conventional manner.

At each floor served by the elevator car, a hoistway or floor door 19 is provided. In addition, the elevator car has a gate 21, which registers with the hoistway door at any floor at which the elevator car is stopped. The doors and the gate may be of conventional construction and may be operated automatically in any conventional way. However, for present purposes, it will be assumed that the gate and doors are opened and closed by an elevator car attendant.

In order to register calls for floors desired by passengers traveling in the elevator car, a plurality of car call buttons 1c through 9c are provided. It is assumed that the building served by the elevator car has nine floors requiring service. The elevator car also contains an up push button UPB and a down push button DPB, which are operated by the car attendant in order to condition the elevator car for up travel or down travel.

As is illustrated in FIG. 1, an up push button 2U is provided at the second floor 2F for operation by a person desiring transportation in an up direction. A similar push button would be provided at each of the floors from which a person may desire to travel in an up direction. Hereinafter, each such push button will be identified by the reference character U preceded by a number corresponding to the floor at which the button is located. In a similar manner, FIG. 1 shows a down push button 2D which may be operated by a person desiring to travel in a down direction. A similar push button would be located at each floor from which a person may desire transportation in a down direction.

In order to signal the approach and direction of travel of the elevator car to an intending passenger, suitable floor signals such as lanterns may be provided. Thus, in FIG. 1, an up floor lantern 2LAU and a down floor lantern 2LAD are illustrated. Similar lanterns may be provided at each floor requiring such signals.

As the elevator car approaches a floor at which it is to stop, it is desired that the elevator car stop automatically and accurately in registration with the desired floor. To this end, position-responsive mechanism is provided in the hoistway and on the elevator car. Thus, FIG. 1 shows

a pair of electromagnetic units EU1 and EU2 respectively mounted on brackets 22A and 22B, which are secured to the elevator car. A separate inductor plate or vane P1 constructed of electroconductive material such as steel is located in the hoistway adjacent each of the floors served by the elevator car. Preferably, the length of the plate P1 is substantially less than the distance between successive floors. Such distance generally will be a minimum of approximately eight feet, and consequently the plate P1 preferably is substantially less than eight feet in length. In the present instance, it will be assumed that the plate has an overall length of approximately twenty inches. When the car is stopped accurately at a floor, the units EU1 and EU2 are associated with the plate P1 for such floor in the manner illustrated in FIG. 1. It will be appreciated that the length of the plate and the distance between the units EU1 and EU2 are exaggerated in FIG. 1 for the purpose of clarity.

To facilitate leveling of the elevator car, each of the units EU1 and EU2 has an electrical output, the magnitude of which is dependent upon the displacement of the car from registry with a landing or floor at which the car is to be stopped.

The construction of the units EU1 and EU2 and of the plate P1 is shown more clearly in FIGS. 1A, 2 and 3. The unit EU1 includes a pair of soft magnetic cores 281P and 281S, which are C-shaped and which have pole faces adjacent each other to define a rectangular magnetic path. Similarly, the unit EU2 includes a pair of soft magnetic cores 283P and 283S, which also are C-shaped and which have pole faces adjacent each other to define a rectangular magnetic path. It will be noted that the pole faces of the cores of each of the units are spaced to provide air gaps through which the plate P1 may pass.

The core 281P is provided with primary windings 285P and 287P, which are connected to direct magnetic flux in the same direction around the associated magnetic path. The magnetic core 281S has secondary windings 285S and 287S, which have voltages induced therein by fluxes passing through the associated magnetic path. Likewise, the core 283P is provided with primary windings 289P and 291P, which are connected to direct magnetic flux in the same direction around the associated magnetic path, while the magnetic core 283S has secondary windings 289S (not shown) and 291S, which have voltages induced therein by fluxes passing through the associated magnetic path.

It will be observed that the plate P1 is generally diamond-shaped, that is, it has a double tapered configuration, and that it is so mounted that the pole faces of the magnetic cores pass closely adjacent that plate as the elevator car approaches the associated floor. The magnitude of voltage induced in each of the secondary windings 284S, 287S, 289S and 291S depends upon the position of the plate P1 with respect to their associated magnetic cores. When the units EU1 and EU2 are displaced vertically from the plate P1, maximum voltage is induced in each of the secondary windings, as a result of the relatively low reluctance path for flux in each of the cores and its associated air gaps. When the plate P1 is located between the magnetic cores, it tends to shield the secondary windings from the magnetic flux produced by the primary windings. The extent of the shielding depends upon the position of the plate with respect to the magnetic cores. Maximum shielding is obtained when the magnetic cores of a unit are adjacent the middle or widest portion of the plate P1; the shielding decreases as the magnetic cores approach either end of the plate going away from the mid portion.

Assume that the elevator car is approaching the second floor while traveling in the up direction and that the primary windings of the units EU1 and EU2 are energized. When the units EU1 and EU2 both are displaced downwardly from the plate P1, maximum voltage is induced in each of the respective secondary windings, as afore-

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said. When the unit EU1 is located adjacent the lower end of the plate P1, the plate slightly shields the secondary windings 285S and 287S from magnetic flux produced by the primary windings 285P and 287P. Due to the tapered configuration of the plate P1, the shielding between the pole faces of the cores 281P and 281S continues to increase as the car proceeds upwardly, and correspondingly decreasing voltage is induced in each of the secondary windings 285S and 287S. Such voltage reaches a minimum when the pole faces are adjacent the widest part of the plate P1, since at that point the shielding therebetween is maximum.

Further upward travel of the car results in gradually decreasing shielding between the pole faces of the cores 281P and 281S as a result of the tapered configuration of the upper portion of the plate P1, and the voltages induced in the secondary windings 285S and 287S consequently continuously increase. When the elevator car reaches the position illustrated in FIG. 1 adjacent the second floor, close to maximum voltage is induced in each of the secondary windings 285S, 287S, 289S and 291S, since the units EU1 and EU2 are adjacent the upper and lower ends, respectively, of the plate P1. As the car continues to move upwardly, voltages induced in the secondary windings 285S and 287S become and remain at maximum, while voltages induced in the secondary windings 289S and 291S first decrease and then increase in a manner which will be apparent from the preceding discussion of the changing voltages induced in the secondary windings 285S and 287S.

The induced voltage-distance relationships for downward travel of the elevator car will be apparent from the foregoing discussion of upward travel thereof. Thus, it will be appreciated that the voltage induced in each of the secondary windings 285S, 287S, 289S and 291S is dependent upon the vertical positions of the units EU1 and EU2 with respect to the plate P1.

It is desirable to provide a relatively steep output voltage-versus-floor distance relationship of the secondary windings around floor level to insure precise leveling of the elevator car. The distance over which this steep characteristic is obtained and its steepness are controlled by the length of the plate P1 and the width of its blunted ends, respectively. The application of the units EU1 and EU2 will be discussed further in connection with FIGS. 4 and 4A below.

Operation of the elevator car also is controlled by photoelectric control apparatus 292 comprising a transmitting device 293 and a detecting device 295, which is spaced from the transmitting device. The transmitting device projects a beam of radiant energy to the detecting device across the space therebetween. The radiant energy projected by the transmitting device 293 may have a frequency selected from a wide range. For example, the transmitting device may be designed to project visible light or infrared radiant energy. Conveniently, the transmitting device may include an incandescent lamp 297 which is effective when energized to emit visible light.

The detecting device 295 may be of any type responsive to the radiant energy received from the transmitting device 293. Thus, the detecting device may be of the photoemissive type, the photoconductive type, or the photovoltaic type as desired. The detecting device 295 also includes a photocell relay PC. When radiant energy is not being received by the detecting device 295, the relay PC is deenergized and dropped out to open its make contacts PC1. When radiant energy is received and detected by the detecting device 295, however, the relay PC is energized and picked up to close the contacts PC1. Transmitting and detecting devices of the type hereinabove referred to are well known in the art.

As is clearly shown in FIG. 1A, the transmitting and detecting devices are so mounted that the plate P1 is disposed to pass therebetween. If the lamp 297 is energized to emit light, the relay PC will be energized and

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picked up to close its contacts PC1 when the transmitting and detecting devices 293 and 295, respectively, are displaced vertically from the plate P1. As the elevator car approaches the associated floor, the plate P1 interrupts the reception of radiant energy by the detecting device 295 to deenergize and drop out the relay PC (when the car is ten inches from the floor, in the present example). It will be noted that the plate P1 has a relatively small aperture A midway between the ends of the plate. In a preferred embodiment of the invention, the aperture A is of a substantially rectangular configuration. Thus, when the elevator car is in a position of registry with the floor, the detecting device 295 receives through the aperture A radiant energy transmitted by the transmitting device 293 to energize and pick up the relay PC. As the car moves away from the floor (up to a distance of ten inches therefrom), the plate P1 once again is effective to interrupt the reception of radiant energy by the detecting device 295 to drop out the relay PC. Consequently, energization of the relay PC is controlled accurately as the elevator car moves in its hoistway and is dependent upon precise positions of the car with respect to each of the floors served thereby. The application of the transmitting device 293 and the detecting device 295 also will be discussed further in connection with FIGS. 4 and 4A.

Control of the operation of the elevator car also is provided by a floor selector 23 (FIG. 1) which conveniently may be mounted on the penthouse floor 3. This floor selector has two drive inputs supplied thereto. One is a drive input by an advance motor AM located on the top of the floor selector. The second drive input is supplied for the purpose of driving the floor selector in accordance with movement of the elevator car. Such a drive input may be provided in any desired manner. For example, a drive tape may be provided in a known manner for mechanically driving the selector unit in accordance with movement of the elevator car. However, in FIG. 1, a preferred drive is provided of the self-synchronous type. Such a drive includes a transmitter or generator SG, which is electrically connected to a receiver or motor SM. The transmitter or generator SG is coupled to the secondary sheave 9 through suitable gearing 25.

The floor selector 23 may be of any suitable type. Conveniently, it may be similar to the floor selector described in the aforesaid Oplinger patent, and such a floor selector is here illustrated generally in FIG. 1.

To facilitate consideration of the selector, the following components thereof in FIG. 1 are listed which are identical with components bearing the same reference characters in the aforesaid Oplinger patent:

AM-----	Advance motor.
SM-----	Motor of self-synchronous drive.
35-----	Guide rail.
43S, 45S-----	Synchronous carriages.
43A, 45A-----	Advance carriages.
UPL-----	Up pawl relay.
DPL-----	Down pawl relay.
UM-----	Up solenoid control unit.
UMC-----	Coil for unit UM.
UMA-----	Magnetic armature for unit UM.
DM-----	Down solenoid control unit.
DMC-----	Coil for unit DM.
DMA-----	Magnetic armature for unit DM.

For a complete understanding of the floor selector, reference may be made to the aforesaid Oplinger patent and to the Savage Patent 2,657,765, which is referred to in the Oplinger patent.

Elevator Control System

As previously pointed out, the invention may be employed with various types of elevator control systems. In order to illustrate the application of the invention to a suitable elevator control system, reference will be made to the circuits shown in FIGS. 4 and 4A, which, as has

been noted, are based on FIGS. 4 and 4A of the aforesaid Oplinger patent. In these circuits, a number of electromagnetic relays and switches are illustrated. These relays and switches may have contacts of the make type, which are closed when the relay or switch is energized or picked up, and which are opened when the relay is de-energized or dropped out. Alternatively, the relays or switches may have break contacts which open when the relay or switch is energized or picked up and which are closed when the relay or switch is deenergized or dropped out. Each of the relays and switches will be designated by a suitable reference character, and each set of contacts will be designated by an appropriate suffix in the form of a numeral. For example, the expression U1 designates the first set of contacts for the up switch U, whereas the expression U3 designates the third set of contacts for the up switch U.

In order to facilitate consideration of the control system, the following components of FIG. 4A are listed which are identical with components bearing the same reference characters in the aforesaid Oplinger patent:

B1, B2, B1-a, B2-a	Direct-current buses.
40	Door relay.
UPB	Up push button.
DPB	Down push button.
DC	Door closing relay.
U	Up switch.
D	Down switch.
32	Car running relay.
2D, etc.	Down floor call push buttons.
2DR, etc.	Down floor call registering relays.
2DRN, etc.	Down floor call cancelling coils.
2LAD, etc.	Down lanterns.
1U, etc.	Up floor call push buttons.
1UR, etc.	Up floor call registering relays.
1URN, etc.	Up floor call cancelling coils.
1LAU, etc.	Up lanterns.
1C, etc.	Call call push buttons.
UPL	Up pawl relay.
DPL	Down pawl relay.
AM	Advance motor.
R2	Advance motor speed control resistor.
193	Sprocket wheel release coil.
1SU, 1SD, 3SU, 3SD, 4SU, 4SD, 7SU, 7SD, 11SU, 11SD	Pile-up switches.
49, 49A, 51A 53, 55A	Pile-up switches of floor-stop units.

For a complete understanding of the above listed components, reference may be made to the aforesaid Oplinger patent. In addition to these components, the present FIG. 4A includes the following new components:

34	Landing relay.
K	Leveling control relay.
X	Transfer control relay.
S	Check relay.
Z	Safety relay.
PR	Auxiliary photocell relay.
297	Lamp.
T	Timer.

As in the aforesaid Oplinger patent, the direction of travel of the elevator car is determined by the operation of the up push button UPB or the down push button DPB by the attendant in the elevator car. Operation of one of these buttons energizes the door closing relay D.C. and under suitable conditions completes an energizing circuit for the car running relay 32 and either the up switch U or the down switch D. The switches U and D determine the direction of travel of the elevator car. Operation of those portions of the energizing circuits for the switches U and D and the car running relay 32 indicated in FIG. 4A by extra-heavy lines, which serve to

designate modifications in the circuits of the Oplinger patent, will be discussed below.

In the present FIG. 4A, the coil of the landing relay 34 replaces the coil of the transfer relay TR of the aforesaid Oplinger patent. (Operation of the transfer relay TR, whose coil presently is located at the bottom of the right-hand column of FIG. 4A, will be discussed below.) Thus, the relay 34 is connected across the direct-current buses B1 and B2-a through the switches 11SU and 11SD of the floor selector. As in the Oplinger patent, these switches are operated by relative movement between the advance and synchronous carriages of the floor selector, and both of the switches are closed only if the elevator car is within a predetermined distance from a floor at which it is to stop, such as twenty inches.

When the elevator car is within a predetermined distance, such as ten inches, from a floor at which it is desired the car shall stop as the car is moving toward such floor, the break contacts PR1 of the auxiliary photocell relay PR will be closed, as will the make contacts T2 of the timer T. In addition, if certain conditions, to be discussed hereinafter, previously have been satisfied, the make contact S1 of the check relay S also will be closed, and the leveling control relay K thus will be energized and picked up.

When the landing relay 34 is deenergized, its break contacts 34-1 are closed to energize and pick-up the transfer control relay X. Such pickup results in the closure of the make contacts X2 partially to complete a holding circuit for the relay X. Closure of the make contacts PR2 results in the completion of this holding circuit to maintain the relay X picked up despite the subsequent opening of the break contacts 34-1. The relay X is provided with a slight time delay in dropout by any conventional means for reasons which hereinafter will be apparent.

As the elevator car approaches a floor at which it is to stop, the check relay S initially is energized through the make contacts 34-2 and PR3 and the break contacts DC3 and Z1. Pickup of the relay S is accompanied by closure of its make contacts S2 to maintain energization of the relay through the make contacts 32-4 as long as the car running relay 32 is picked up, regardless of the subsequent opening of the aforesaid initial energizing circuit of the relay S. The check relay S also is provided with a slight time delay in dropout by any conventional means for reasons which will be discussed below.

If the auxiliary photocell relay PR is energized and the pawl relays UPL and DPL are deenergized, the make contacts PR4 and the break contacts UPL5 and DPL5, respectively, are closed to energize the safety relay Z. Pickup of the relay Z is accompanied by closure of its make contacts Z2 to complete a holding circuit for the relay through a normally-closed manually-operable switch 299.

Energization of the auxiliary photocell relay PR is controlled solely by the make contacts PC1 of the photocell relay PC. Thus, as long as the photocell relay is picked up to close the contacts PC1, the auxiliary photocell relay PR also will be energized and picked up.

Energization of the lamp 297 is controlled by the pawl relays UPL and DPL. If the elevator car is approaching a floor at which it is to stop and is within a predetermined distance therefrom while traveling in the up direction, the make contacts UPL6 will be closed to energize the lamp. Similarly, if the car is approaching a floor at which it is to stop and is within a predetermined distance therefrom while traveling in the down direction, the make contacts DPL6 will be closed to energize the lamp. Thus, the lamp is energized only when the elevator car approaches a floor at which it is to stop.

The timer T initially is energized through the break contacts 34-3. It will be recalled that when the elevator car is twenty inches from a floor at which it is to stop, the landing relay 34 is picked up, thus opening the contacts 34-3. Inasmuch as the car running relay 32 also

is energized at this time, its break contacts 32-5 are open. Thus, the timer T starts to time out. Under normal operating conditions, however, the elevator car will reach the aforementioned floor and the contacts 32-5 will close to reenergize the timer through its make contacts T3 and the closed make contacts S3 before the timer times out. In addition, as long as the elevator car is in a position of registry with the floor, the make contacts PR5 in parallel with the contacts T3 remain closed. Conveniently, the timer T may have a ten-second delay in dropout. This will allow sufficient time for the elevator car to reach floor level during all normal approaches and leveling operations. Since such a timer is well known in the art, it appears unnecessary to describe it further.

The transfer relay TR controls leveling and leveling operations of the elevator car. This relay initially is energized through the break contacts X3 and the make contacts S4, 34-4 and T4 when the elevator car is displaced by a distance of the aforementioned ten inches from a floor at which it is to stop. Pickup of the relay TR is accompanied by closure of its make contacts TR6 to establish a holding circuit for the relay through the make contacts 34-5 and T4. Consequently, the relay TR is maintained energized and picked up until the elevator car is to move to another floor. The remaining contacts, TR2 through TR5 (FIG. 4), of the relay TR serve the same functions in the present control system as in that of the Oplinger patent, as will be apparent hereinafter.

Referring now to FIG. 4, which, as has been indicated is based on FIG. 4 of the aforesaid Oplinger patent, the only material variations from the latter are in the lower right-hand corner thereof, as indicated by the extra-heavy lines in the present FIG. 4. Consequently, with the exception of these modifications, reference may be made to the Oplinger patent for a complete understanding of the components of FIG. 4. To facilitate consideration of FIG. 4, the following components thereof are listed which are identical with components bearing the same reference characters in the aforesaid Oplinger patent:

1	Elevator car motor.
MA	Motor armature.
MF	Motor field.
G	Generator.
GA	Generator armature.
GF1, GF2	Generator field windings.
GR1, GR2	Generator field resistors.
10	Control unit.
PM	Pattern motor.
PM1, PM2, 227	Pattern motor windings.
215	Pattern motor lever.
231	Electroconductive disc.
237	Permanent magnet.
239, 241	Rheostats.
247, 255	Generator field transformers.
257	Generator anti-hunt winding.
UM	Up solenoid control unit.
DM	Down solenoid control unit.
259	Solenoid control unit transformer.
263	Voltage regulator.
BR	Auxiliary brake relay.

In the interest of accuracy, the electromagnetic units EU1 and EU2, which replace the electromagnetic unit EU of the Oplinger patent, are brought into operation during the last stage of the approach of the elevator car to a floor at which it is to stop, in order to terminate movement of the car accurately at the floor and to maintain it level with the desired floor. Thus, as the elevator car reaches the desired zone, the transfer relay TR opens its break contacts TR2 and TR3 and closes its make contacts TR4 and TR5 to render the electromagnetic units EU1 and EU2 effective for controlling the elevator car.

It will be noted that the primary winding 285P of the unit EU1 and the primary winding 289P of the unit EU2 are connected in series across the output terminals of the

voltage regulator 263, while the primary winding 287P of the unit EU1 and the primary winding 291P of the unit EU2 are connected across the output terminals of the voltage regulator. The secondary windings 285S and 287S of the electromagnetic unit EU1 are connected in series aiding with the secondary winding of a transformer 265A across the input terminals of a full-wave rectifier 267. Similarly, the secondary windings 289S and 291S of the electromagnetic unit EU2 are connected in series aiding with the secondary winding of a transformer 269A across the input terminals of a full-wave rectifier 271. The primary windings of the transformer 265A and 269A are connected to the output terminals of the voltage regulator 263. The output of the rectifier 267 is applied across the upper half of a resistor 273, whereas the output of the rectifier 271 is applied across the lower half of the resistor 273. The specific portion of the resistor utilized as a load for each of the rectifiers may be adjusted by means of a tap 273A on the resistor.

To illustrate the operation of the electromagnetic units EU1 and EU2, it will be assumed that each of the transformers 265A and 269A has a secondary voltage of the order of twelve volts. Furthermore, it will be assumed that movement of the magnetic plate P1 through the electromagnetic unit EU1 results in a total output voltage from the secondary windings 285S and 287S which varies continuously between zero and seven volts. Likewise, it will be assumed that movement of the plate P1 through the electromagnetic unit EU2 results in a total output voltage from the secondary windings 289S and 291S which varies continuously between zero and seven volts. The polarities of the windings are such that the voltages across the windings 285S and 287S and the secondary winding of the transformer 265A are in phase with each other and the voltages across the windings 289S and 291S and the secondary winding of the transformer 269A also are in phase with each other.

When the electromagnetic units EU1 and EU2 respectively are located adjacent opposite ends of the plate P1, as is illustrated in FIG. 4, the voltages induced in the secondary windings of the units are substantially maximum. Thus, the outputs of the rectifiers 267 and 271 as applied to the resistor 273 are equal in magnitude (approximately sixteen volts, taking into account winding resistance drop and rectifier forward drop) and opposite in polarity. Consequently, the resultant voltage across the resistor 273 is zero. If the electromagnetic units EU1 and EU2 are displaced upwardly from such position to a point wherein the unit EU2 is midway between the ends of the plate P1, the output of the rectifier 271 gradually decreases to approximately ten volts, whereas the output of the rectifier 267 is maintained at approximately sixteen volts with the polarities illustrated in FIG. 4. This means that the upper terminal of the resistor 273 gradually becomes more positive with respect to the lower terminal thereof to a maximum of approximately six volts, as the electromagnetic unit EU2 moves from a position adjacent the lower end of the plate P1 to a position adjacent the middle thereof. As the unit EU2 continues to move upwardly from a position midway between the ends of the plate P1, the upper terminal of the resistor 273 gradually becomes less positive with respect to the lower terminal thereof until the unit EU2 passes the upper end of the plate P1, at which time there is once again zero net voltage across the terminals of the resistor 273.

Conversely, displacement of the elevator car in the opposite direction from a position of registry with the floor results in the application of voltage to the terminals of the resistor 273 such that the lower terminal of the resistor is positive with respect to the upper terminal thereof. It will be apparent that the magnitude of this latter voltage varies in a manner similar to that of the voltage when the units EU1 and EU2 are displaced upwardly, as explained heretofore. It follows that when

the resistor 273 is connected across the winding PM1 of the pattern motor, the excitation of the generator G is always in a proper direction to move the elevator car into registry with the floor at which it is to stop. Inasmuch as the electromagnetic units EU1 and EU2 are mounted directly on the elevator car, whereas the plate P1 is mounted directly in the hoistway of the car, accurate leveling of the elevator car is assured.

It should be noted that the transformers 265A and 269A are provided in order that the rectifiers 267 and 271, respectively, are continuously maintained in conducting condition, regardless of what signals are fed in from the secondary windings of the electromagnetic units EU1 and EU2. This results in greater circuit efficiency, since, if the transformers 265A and 269A were eliminated, approximately one-half of the power output of the electromagnetic units would be lost in that half of the resistor 273 associated with the rectifier which is non-conducting at the time, and larger electromagnetic units would be required.

Operation

(A) CAR MOVES FROM FIRST FLOOR TO FOURTH FLOOR

It is believed that an understanding of the invention will be facilitated by a discussion of certain typical operating sequences for the elevator system. For the first sequence, it will be assumed that the elevator car is parked at the lower terminal floor in a position of registry therewith, that the car gate 21 and the hoistway door 19 are open and that a passenger desiring to proceed to the fourth floor enters the elevator car. It further will be assumed that the switch 299 (FIG. 4A) is in its closed condition.

While the elevator car is parked at the lower terminal floor with its doors open, the landing relay 34 is energized. Also, the coil 193 is energized. As is explained in the aforesaid Oplinger and Savage patents, this coil, when energized, effects resetting of the synchronous carriages 43S and 45S relative to the advance carriages 43A and 45A (FIG. 1). In addition, the down pawl relay DPL is energized, and its make contacts DPL6, therefore, are closed to energize the lamp 297. Since the car is in a position of registry with the first floor, the detecting device 295 (FIG. 1A) receives radiant energy from the lamp 297 through the aperture A in the plate P1. Detection of such energy by the detecting device results in energization of the photocell relay PC to close the break contacts PC1. Consequently, the auxiliary photocell relay PR (FIG. 4A) is energized and picked up. Furthermore, the check relay S, the timer T and the transfer relay TR also are energized. All other electromagnetic relays and switches in FIGS. 4 and 4A are deenergized at this time.

When the passenger enters the elevator car, the elevator attendant operates the car call push button 4C to register a car call for the fourth floor. As is explained in the aforesaid Oplinger patent, this push button remains in its operated condition until the car has completed an up trip.

Next, the elevator car attendant operates the up push button UPB to energize the door closing relay DC. This relay, when energized, initiates closure of the hoistway door for the lower terminal floor and the car gate in a conventional manner. As a result of such closures, the door relay 40 is energized. This relay closes its make contacts 40-2, 40-3, 40-4, and 40-5 to prepare certain circuits for subsequent energization. In addition, the break contacts 40-6 open to deenergize the coil 193. As the result of such deenergization, free movement of the synchronous carriages 43S and 45S (FIG. 1) is prevented.

When the door closing relay DC was energized, it opened its break contacts DC1, DC2 and DC3. Opening of the contacts DC1 has no immediate effect on operation. Opening of the contacts DC2 results in deenergization of the down pawl relay DPL, while opening of the

contacts DC3 effects deenergization and dropout of the check relay S. Opening of the make contacts DPL6 upon dropout of the down pawl relay results in deenergization of the lamp 297. This, in turn, effects deenergization and dropout of the photocell relay PC (FIG. 1A) to open the make contacts PC1. Consequently, the auxiliary photocell relay PR drops out to close its break contacts PR1 and to open its make contacts PR2, PR3, PR4 and PR5 without immediately affecting system operation. (It is assumed that the contacts PR4 open before the safety relay Z can pick up as a result of the closure of the break contacts DPL5 upon dropout of the down pawl relay.) Upon dropout, the check relay S opened its make contacts S1, S2 and S4 without immediate effect on operation and opened its make contacts S3 to deenergize the timer T. Since the timer has a ten-second delay in dropout, however, its deenergization also has no immediate effect on operation.

The operation of the up push button UPB also completes the following circuit following closure of the make contacts 40-1:

B1, UPB, 40-1, D8, U, 1SD, 32, T1, B2-a

The switch 1SD is positioned to have its contacts closed from a position wherein the elevator car is approximately 1 foot below a stop to a position wherein the selector advance carriages are fully advanced for travel in an upward direction.

The energization of the up switch U closes the make contacts U1 and U2 to connect the coil PM1 of the pattern motor PM to the rectifier 261, when the contacts TR2 and TR3 close, for energization in the proper direction for up travel of the elevator car. The make contacts U3 close to prepare a holding circuit for the switch U and the car running relay 32 for subsequent completion. The make contacts U4 close to prepare to up pawl relay UPL for energization as it approaches a floor for which an up floor call is registered. The make contacts U6 and U7 close to complete an energizing circuit for the advance motor AM. The direction of energization of the advance motor, as determined by the contacts U6 and U7, is correct for up travel of the elevator car. Finally, the break contacts U8 open to prevent energization of the down switch D.

At this stage, a substantial part of the resistor R2 is shunted, and the armature of the advance motor is energized through the circuit:

B1-a, 40-5, 7SU, 7SD, DPL4, UPL4, U6, AM, U7, B2

As is explained in the aforesaid Oplinger patent, the advance motor AM rapidly moves the advance carriage 43A (FIG. 1) in an upward direction through the distance permitted by the lost-motion coupling between the advance and synchronous carriages. The relative motion of the advance and synchronous carriages results in movement of the armature UMA away from the coil UMC of the up solenoid control unit UM.

As the advance carriages are moved by the advance motor relative to this synchronous carriages, the switch 1SU opens. By reference to FIG. 4, it will be noted that such opening prevents energization of the down switch D. Additionally, the switch 4SU opens to prevent energization of the coil 193.

As the advance carriages continue to move, the switch 3SU closes to permit energization of the up pawl relay UPL by a registered car call. However, for reasons which will be set forth below, such energization cannot take place until the advance carriage nears a floor for which a car call is registered.

Continued movement of the advance carriage results in movement of the armature UMA (FIG. 1) out of the associated solenoid coil UMC to provide minimum impedance of the solenoid coil. For present purposes, it will be assumed that the characteristics of the control sys-

tem are such that suitable acceleration of the elevator car is obtained if the solenoid coil UMC has minimum impedance.

During movement of the advance carriages, the switch 11SU (FIG. 4a) opens to deenergize the landing relay 34. This occurs when the movement of the advance carriages is equivalent to 20 inches of car travel. In addition, the switch 7SU opens as the advance carriages near their fully advanced positions to introduce a substantial portion of the resistor R2 in circuit with the armature of the advance motor AM. This reduces heating of the advance motor, but sufficient torque is produced by the advance motor under these conditions to force the advance carriages to follow the synchronous carriage movements.

Upon dropout, the landing relay 34 closed its break contacts 34-1 to energize the transfer control relay X. Closure of the make contacts X1 completes a holding circuit for the relay 32 and the up switch U which may be traced as follows:

B1, X1, 40-2, U3, U, 1SD, 32, T1, B2-a

Closure of the make contacts X2 partially completes a holding circuit for the relay X, while closure of the break contacts X3 have no immediate effect on operation.

Opening of the make contacts 34-2 and 34-4, when the landing relay 34 dropped out, also had no immediate effect on operation. Closure of the break contacts 34-3 results in reenergization of the timer T, but such reenergization has no immediate effect on operation for the reason that it is assumed that the ten-second time delay in dropout of the timer had not expired before the break contact 34-3 closed.

Opening of the make contacts 34-5 in the holding circuit of the transfer relay TR results in dropout of the transfer relay to close the break contacts TR2 and TR3 (FIG. 4) and to open the make contacts TR4 and TR5 to place the coil PM1 and the relay BR through the contacts U1 and U2 under control of the up solenoid control unit UM. Opening of the make contacts TR6 (FIG. 4A) prevents energization of the transfer relay through its holding circuit.

Since the up switch U and the car running relay 32 now are energized through a holding circuit, the car attendant may release his up push button UPB. Such release deenergizes the door closing relay DC, which closes its break contacts DC1, DC2, and DC3. The closure of these contacts has no immediate effect on system operations.

It will be assumed that the advance carriages now are fully advanced. From this point on, the advance carriages can advance only with the associated synchronous carriages.

If desired, the elevator system may be so designed that the elevator car starts to move before the advance carriages reach their fully advanced positions. However, in a preferred embodiment of the invention, the advance carriages are moved rapidly and reach their fully advanced positions before the elevator car starts to move.

It will be recalled that the car running relay 32 was energized at the same time at which the up switch U was energized. As a result of its energization, the car running relay 32 closed its make contacts 32-1 to release the elevator car brake. Such release permits upward travel of the elevator car. The car running relay when energized also closed its make contacts 32-2 and 32-3 to prepare holding circuits for the pawl relays UPL and DPL for subsequent operation. Closure of the make contacts 32-4 prepared the check relay S for subsequent energization through its holding circuit, while opening of the break contacts 32-5 had no immediate effect on operation.

Inasmuch as the break contacts TR2 and TR3 and the make contacts U1 and U2 are closed, the winding PM1 of the pattern motor PM and the auxiliary brake relay BR are connected across the secondary winding of the transformer 259 through the rectifier 261 and the coil UMC of

the up solenoid control unit UM. Since the coil UMC now has minimum impedance, maximum energization is applied to the winding PM1 of the pattern motor, and the resultant torque applied to the lever 215 decreases materially the effective resistance of the rheostat 241. The decreased resistance of the rheostat 241 results in the flow of substantial current through the primary winding of the transformer 255, and the generator G consequently is excited for full speed operation in the up direction. The energization of the field windings GF1 and GF2 is accompanied by the inducing of voltage in the winding 257 to energize the winding PM2 of the pattern motor PM. This develops a force acting in opposition to the force produced by energization of the winding PM1. However, the energization of the winding PM2 exists only while the energization of the field windings is changing. The purpose of the winding PM2 is to decrease hunting of the motor 1.

The motor 1 now accelerates to move the elevator car in the up direction. Such acceleration is accompanied by acceleration of the disc 231 which is electromagnetically coupled to the lever 215 through the magnet 237. As the speed of the motor increases, the torque applied to the lever 215 by the disc 231 increases until a condition of equilibrium is reached, at which time the speed of the motor corresponds to the desired running speed of the elevator car 11. Any deviation of the elevator car from the desired speed results in a change in the torque applied to the lever 215 by the disc 231. This change is in the proper direction to restore the motor 1 to the desired speed.

As the elevator car moves, car motion is transmitted through the transmitter or generator SG (FIG. 1) to the motor SM. This motor thereupon drives the synchronous carriages 43S and 45S in accordance with car movement. Since the advance carriages 43A and 45A now are biased by the advance motor AM in the direction of travel of the synchronous carriages, it follows that all of the carriages move as a unit.

As is stated in the aforesaid Oplinger patent, one of the switches in the set of pile-up switches 49A (FIG. 4A) is employed for picking up car calls in either direction of travel of the elevator car. Thus, the switch 49A(1) is in the floor stop unit for the first floor, the switch 49A(2) is in the floor stop unit for the second floor, etc. However, the closure of one of these switches is effective for a control operation only if the associated car call push button is in operated condition.

As the advance carriage nears the fourth floor, it closes the switch 49A(4) for the fourth floor. This closure may take place when the advance carriage is short of the position which it occupies when the elevator car is at the fourth floor by a distance of the order of four feet measured in terms of car travel. Assuming, as in the Oplinger patent, that the advance carriage leads the elevator car by a distance equivalent to twenty feet of car travel, it follows that the switch 49A(4) is closed when the elevator car is approximately twenty-four feet from the fourth floor.

Upon closure of the switch 49A(4) the following circuit is completed:

B1-a, 4c, 49A(4), 40-4, 3SU, UPL, B2

Upon energization, the up pawl relay UPL closes its make contacts UPL1 to complete a holding circuit for the up pawl relay through the make contacts 32-2. Opening of the break contacts UPL3 and UPL4 introduces substantial resistance in series with the advance motor AM shortly before the advance carriage is brought to a stop.

Opening of the break contacts UPL5 prevents subsequent energization therethrough of the safety relay Z. Closure of the make contacts UPL6 results in energization of the lamp 297. Since at this point of car travel the plate P1 (FIG. 1A) is not interposed between the transmitting device 293 and the detecting device 295, re-

ception and detection of radiant energy from the lamp 297 by the detecting device results in energization and pickup of the photocell relay PC to close the make contacts PC1. Such closure results in energization and pickup of the auxiliary photocell relay PR (FIG. 4A). Opening of the break contacts PR1 and closure of the make contacts PR4 and PR5 have no immediate effect on system operation. Closure of the make contacts PR2 completes the holding circuit for the transfer control relay X through its make contacts X2, while closure of the make contacts PR3 prepares the check relay S for subsequent energization therethrough.

The energization of the up pawl relay UPL also projects a cam into position for operating the set of switches 49 for the fourth floor (see the discussion of the cam 105 in the aforesaid Oplinger patent). The expression "49(4)" designates the set for the fourth floor. One of these switches, 49(4)-1, is closed by the cam to energize the cancelling coil 4URN for the fourth floor in the event that a floor call is registered for the fourth floor. However, under the assumed conditions, no floor call has been registered. The cam also closes a switch 49(4)-2 for the purpose of energizing the up lantern 4LAU for the fourth floor.

In addition, the energization of the up pawl relay UPL projects a stop pawl into position to engage a lug associated with a clamp of the floor stop unit associated with the fourth floor (see the discussion of the stop pawl 95, the lug 97 and the clamp 113 in the aforesaid Oplinger and Savage patents). Consequently, as the advance carriages continue their upward travel, the pawl engages the lug for the floor stop unit of the fourth floor to bring the advance carriages to a stop.

As the elevator car continues in the upward direction, the synchronous carriage 43S (FIG. 1) moves with respect to the advance carriage 43A to operate the switch 1SU and similar switches mounted on the advance carriage. These switches are operated in accordance with the developemnt illustrated in FIG. 7 of the aforesaid Oplinger patent.

The movement of the synchronous carriage 43S relative to the advance carriage 43A also operates to move the armature UMA toward the coil UMC of the up solenoid control unit UM. The movement of the armature is accompanied by a gradual increase in the impedance of the coil UMC and a gradual decrease in the energization of the winding PM1 (FIG. 4) of the pattern motor PM. The resultant reduction in the torque applied to the lever 215 by the pattern motor results in movement of the lever in a clockwise direction about its pivot 217 to increase the effective resistance of the rheostat 241. This decreases the current supplied to the primary winding of the transformer 255 and thereby the excitation of the generator G. Since the excitation changes, a voltage is induced in the winding 257 which is in a proper direction for minimizing hunting of the motor 1.

When the elevator car reaches a distance of the order of twenty inches from the fourth floor, the switches 11SU and 11SD close to complete an energizing circuit for the landing relay 34. This relay opens its break contacts 34-1 without affecting operation, since the transfer control relay X remains energized and picked up through its holding circuit. The make contacts 34-2 close to complete the following energizing circuit for the check relay S:

B1, 34-2, DC3, PR3, Z1, S, B2-a

Closure of the make contacts S1 prepares the leveling control relay K for subsequent energization therethrough (it will be recalled that the break contacts PR1 are open at this time). Closure of the make contacts S2 completes the holding circuit for the relay S through the now closed make contacts 32-4, while closure of the make contacts S3 and S4 have no immediate effect on system operation.

When the landing relay 34 picked up, its break con-

tacts 34-3 opened to deenergize the timer T, and the timer started to time out. In addition, the make contacts 34-4 closed to prepare the transfer relay TR for subsequent energization therethrough, and the make contacts 34-5 closed partially to complete a holding circuit for the transfer relay.

It will be recalled that when the elevator car is at a distance of twenty inches from the fourth floor, the electromagnetic unit EU1 is adjacent the lower end of the plate P1 and that as the car continues its upward movement the voltages induced in the secondary windings 285S and 287S of the unit EU1 gradually decrease. Such decrease, however, has no effect on system operation for the reason that the transfer relay TR is deenergized at this time, and the make contacts TR4 and TR5 consequently are open, as aforesaid.

When the elevator car reaches a distance of ten inches from the fourth floor, the lower end of the plate P1 (FIG. 1A) interrupts reception by the detecting device 295 of radiant energy from the transmitting device 293. Such interruption results in deenergization and dropout of the photocell relay PC to open the make contacts PC1. As a result thereof, the auxiliary photocell relay PR (FIG. 4A) is deenergized and drops out. Closure of the break contacts PR1 completes the energizing circuit for the leveling control relay K, while opening of the make contacts PR2 interrupts the holding circuit for the transfer control relay X. Since, as noted heretofore, the relay X has a slight time delay in dropout, the make contacts K1 close to maintain the up switch U and the car running relay 32 energized before the make contacts X1 open to interrupt the other holding circuit for these relays. Closure of the make contacts K2 has no immediate effect on operation.

Dropout of the auxiliary photocell relay PR also is accompanied by the opening of its make contacts PR3. The check relay S, however, remains energized and picked up through its holding circuit. Opening of the make contacts PR4 and PR5 has no immediate effect on operation.

When the transfer control relay X drops out, its make contacts X2 open to prevent subsequent energization therethrough of this relay. Closure of the break contacts X3 completes the following energizing circuit for the transfer relay TR:

B1-a, X3 S4, 34-4, T4, TR, B2

Pickup of the transfer relay TR results in closure of its make contacts TR6 to complete the holding circuit for the transfer relay. In addition, this relay also opens its break contacts TR2 and TR3 (FIG. 4) to disconnect the coil UMC of the up solenoid control unit UM from the winding PM1 and the auxiliary brake relay BR. The make contacts TR4 and TR5 close to connect the winding PM1 and the relay BR for energization under the control of the electromagnetic units EU1 and EU2.

At the time the transfer is made, the unit EU1 is adjacent the middle or widest portion of the plate P1, which consequently has substantial shielding effect on the unit EU1, whereas the unit EU2 is spaced downwardly from the plate P1. Thus, maximum voltages are induced in the windings 289S and 291S, while minimum or negligible voltages are induced in the windings 285S and 287S. Consequently, a larger current is provided by the rectifier 271 than by the rectifier 267, and the winding PM1 of the pattern motor is energized with proper polarity to continue the upward motion of the elevator car at a slow rate of speed.

As the elevator car continues its upward motion, the current supplied by the rectifier 267 continuously increases, while the current supplied by the rectifier 271 remains at a maximum, and thus the difference between the currents supplied by these rectifiers decreases. This gradually reduces the energization of the winding PM1 and consequently reduces the speed of the elevator car.

When the car reaches a position of registry with the fourth floor, the electromagnetic unit EU1 is adjacent the upper end of the plate P1 and the unit EU2 is adjacent the lower end thereof. As a result, both of the units have substantially maximum output, and the voltage applied to the winding PM1, therefore, is reduced to zero to reduce the elevator car speed to zero. Consequently, the car comes to rest accurately at the fourth floor. At this stage, the voltage applied to the auxiliary brake relay BR also reduces to zero, and this relay opens its make contacts BR1. Furthermore, the aperture A (FIG. 1A) of the plate P1 now is adjacent the transmitting device 293 and the detecting device 295. Consequently, radiant energy once again is received through the aperture by the detecting device 295 to energize and pick up the photocell relay PC. Closure of the make contacts PC1 results in energization of the auxiliary photocell relay PR (FIG. 4A), and this relay closes its make contacts PR2, PR4 and PR5 without immediately affecting operation and opens its break contacts PR1 to deenergize the leveling control relay K. Upon dropout, the relay K opens its make contacts K1 to interrupt the holding circuit for the up switch U and the car running relay 32. Opening of the make contacts K2 has no immediate effect on operation.

The deenergization of the up switch U is accompanied by opening of its make contacts U1, U2, U3, U4, U6 and U7 without immediate effect on the operation of the system. The dropout of the car running relay 32 is accompanied by the opening of its make contacts 32-1 (FIG. 4), to permit application of the brake 7, since the make contacts BR1 now are open. Opening of the make contacts 32-2 and 32-3 has no immediate effect on system operation.

It will be recalled that the check relay S is provided with a slight time delay in dropout. Consequently, opening of the make contacts 32-4 to interrupt the holding circuit for the check relay has no immediate effect on operation, inasmuch as the make contacts PR3 closed when the auxiliary photocell relay PR picked up. Thus, energization of check relay is maintained through the contacts 34-2, DC3, PR3 and Z1. Closure of the break contacts 32-5 results in reenergization of the timer T before the timer times out.

Should the elevator car be displaced from the fourth floor for any reason, such as cable contraction or stretch, after the car is stopped in a position of registry with the floor, the car will be returned into registry with the floor as a result of the following sequence of operations. Such displacement of the car results in interruption by the plate P1 (FIG. 1A) of the radiant energy transmitted by the transmitting device 293. Since the detecting device 295 does not receive and detect radiant energy, the photocell relay PC is deenergized and drops out to open its contacts PC1. Such opening results in the deenergization and dropout of the auxiliary photocell relay PR (FIG. 4A), and the make contacts PR3 open to deenergize the check relay S. It will be recalled that the check relay has a slight delay in dropout. Consequently, when the auxiliary photocell relay PR dropped out, its break contacts PR1 closed to energize the leveling control relay K momentarily. Upon dropout of the check relay S, however, its make contacts S1 open to deenergize the leveling control relay K. The make contacts S2 also open without immediate effect on operation. (It is assumed that the time during which the leveling control relay K was energized momentarily to close its make contacts K1 and K2, was insufficient to result in pickup of the car running relay 32 and either the up switch U or the down switch D. Thus, the make contacts 32-4 remained open to prevent reenergization of the check relay S through its holding circuit.) Opening of the make contacts S3 results in deenergization of the timer T, and the timer consequently starts to time out. Opening of the make contacts S4 has no effect on operation

of the transfer relay TR for the reason that the transfer relay remains energized and picked up through its holding circuit.

Inasmuch as the elevator car is displaced from its position of registry with the fourth floor, the outputs of the electromagnetic units EU1 and EU2 (FIG. 4) are unbalanced. Consequently, the auxiliary brake relay BR is energized and picked up, and its make contacts BR1 are closed to effect release of the brake 7. In addition, the pattern motor winding PM1 is energized with proper polarity to return the elevator car slowly into accurate registration with the fourth floor, as will be understood from the foregoing discussion.

When the car arrives at such position of registry, the detecting device 295 (FIG. 1A) receives radiant energy through the aperture A in the plate P1. Consequently, the photocell relay PC is energized to close its make contacts PC1, and the auxiliary photocell relay PR (FIG. 4A) thus is energized. This results in closure of the make contacts PR3 to reenergize the check relay S; and the check relay in turn closes its make contacts S3 to reenergize the timer T before the timer times out. Furthermore, when the car reaches its position of registry with the fourth floor, the auxiliary brake relay BR (FIG. 4) drops out to open its make contacts BR1, thus resetting the brake 7.

As is pointed out heretofore, the timer T has approximately a ten second time delay in dropout. Such time delay is sufficient to allow the elevator car to reach floor level during all normal releveing operations before the timer times out. Assume in the immediately preceding example, however, that becomes a fault in the control system the elevator car fails to releve to its position of registry with the fourth floor before the timer T times out, that is, before the make contacts S3 reclose to reenergize the timer, as aforesaid. As a result thereof, the make contacts T1 open to prevent subsequent energization of the up switch U or the down switch D and the car running relay 32; the make contacts T2 open to prevent subsequent energization of the leveling control relay K; the make contacts T3 open to prevent subsequent energization therethrough of the timer; and the make contacts T4 open to deenergize and drop out the transfer relay TR. Consequently, power is removed from the elevator car motor and cannot be reapplied thereto until the control system fault is corrected. In addition, the auxiliary brake relay BR is deenergized, and its make contacts BR1 open to set the brake 7 until such correction is made.

It also will be recalled that the ten-second time delay in dropout of the timer T is sufficient for the elevator car to arrive at a position of registry with a desired floor during all normal approaches thereto. If, however, the car should stop short of the floor as a result of a control system fault, the timer T once again will drop out to open its make contacts T1 through T4. The effects of such openings will be apparent from the preceding discussion, i.e., power is removed from the car motor and the brake is applied to prevent subsequent movement of the car until the fault is corrected.

(B) CAR MOVES FROM FOURTH FLOOR TO SECOND FLOOR

Next, it will be assumed that the elevator car is positioned at the fourth floor during a down trip. The down pawl relay DPL is assumed to have been energized to bring the car to a stop at the fourth floor, and the down lantern for the fourth floor is illuminated. At this time, a prospective passenger on the second floor operates the push button 2D for the second floor in order to register a down floor call. By reference to FIG. 4A, it will be noted that operation of the push button 2D energizes the down floor call registering relay 2DR. This relay closes its contacts 2DR1 to establish a holding circuit for itself. In addition, the relay closes its make contacts 2DR2 to prepare for subsequent energization therethrough of the down pawl relay DPL.

The car attendant now operates the down push button DPB to energize the door closing relay DC. This initiates closure of the hoistway door for the fourth floor and the car gate. The door closing relay also opens its break contacts DC1, DC2 and DC3. In opening, the contacts DC1 have no immediate effect on operation, while the contacts DC2 deenergize the down pawl relay DPL, and this relay thereupon opens contacts 53(4)-2 (corresponding to contacts 53(2)-2 for the second floor) to interrupt the illumination of the down lantern for the fourth floor. The opening of the contacts 53(4)-1 (corresponding to 53(2)-1 for the second floor) and DPL1 has no immediate effect. The break contacts DPL3 and DPL4 close to permit shunting of substantial parts of the resistor R2, while the make contacts DPL6 open to deenergize the lamp 297. Opening of the break contacts DC3 deenergizes the check relay S. The check relay in dropping out opens its make contacts S1, S2 and S4 without affecting operation and opens its make contacts S3 to deenergize the timer T. Consequently, the timer starts to time out.

Termination of the transmission of radiant energy by the transmitting device 293 (FIG. 1A) upon deenergization of the lamp 297 results in deenergization and dropout of the photocell relay PC. Opening of the make contact PC1 (FIG. 4A) effects deenergization and drop out of the auxiliary photocell relay PR, but such dropout has no immediate effect on system operation. (When the down pawl relay DPL dropped out its break contacts DPL5 closed, but it is assumed that the make contacts PR4 open before the safety relay Z can pick up.)

Closure of the car gate and the hoistway door energizes the door relay 40. This relay closes its make contacts 40-1, 40-2, 40-4 and 40-5, but such closures have no immediate effect on the operation of the system. In addition, the relay opens its break contacts 40-6 to deenergize the coil 193 in order to permit the motor SM (FIG. 1) to drive the synchronous carriages 43S and 45S.

The operation of the down push button DPB (FIG. 4A) by the elevator car attendant also completes the following circuit after closure of the make contacts 40-3:

B1, DPB, 40-3, U8, D, 1SU, 32, T1, B2-a

The resulting energization of the down switch D closes the make contacts D1 and D2 to prepare the coil PM1 of the pattern motor PM for energization in the proper direction for down travel of the elevator car. Closure of the make contacts D3 and D4 has no immediate effect on the operation of the system, while opening of the break contacts D8 prevents subsequent energization therethrough of the up switch U. The closure of the make contacts D6 and D7 completes an energizing circuit for the advance motor AM, the direction of energization being correct for down travel of the car. Since the resistor R2 is shunted, the advance motor rapidly advances the associated advance carriages.

As the advance carriages are moved relative to their associated synchronous carriages, the switch 1SD opens to prevent energization of the up switch U. The switch 3SD closes to permit energization of the down pawl relay DPL when the elevator car is to answer a registered car call. The switch 4SD opens to prevent energization of the coil 193 during down travel of the elevator car. The switch 7SD opens to introduce resistance in series with the armature of the advance motor shortly before the advance carriages reach their maximum advance for the down direction. Finally, the switch 11SD opens to deenergize the landing relay 34, and this relay closes its break contacts 34-1 to energize the transfer control relay X. Opening of the make contacts 34-2 and 34-4 has no immediate effect on operation. Closure of the break contacts 34-3 reenergizes the timer T before the timer drops out. The make contacts 34-5 open to deenergize the transfer relay TR, which closes its break contacts TR2 and TR3 and opens its make contacts TR4, TR5 and TR6.

The car running relay 32, upon being energized, closes its make contacts 32-1 to permit release of the elevator brake. The make contacts 32-2 and 32-3 close, the latter contacts preparing a holding circuit for the down pawl relay DPL for subsequent operation. Closure of the make contacts 32-4 partially completes the holding circuit for the check relay S. Opening of the break contacts 32-5 has no immediate effect on operation.

It will be recalled that the advance carriages reach their maximum advances in the downward direction prior to movement of the elevator car. The advance of the carriage 45A is accompanied by movement of the armature DMA away from the coil DMC of the down solenoid control unit DM to reduce the impedance of the coil. Consequently, a substantial current is supplied to the winding PM1 of the pattern motor PM from the secondary winding of the transformer 259 through the low impedance of the coil DMC, the rectifier 262, the make contacts D1 and D2 and the break contacts TR2 and TR3. The auxiliary brake relay BR also is energized and picked up. The current to the pattern motor is in the proper polarity to produce downward motion of the elevator car. Thus, the pattern motor applies a torque to the lever 215 acting in a clockwise direction about the pivot 217. The resulting movement of the lever 215 operates the springs 239A through 239F to reduce the effective resistance of the rheostat 239. This permits substantial current to flow through the primary winding of the transformer 247, and the transformer supplies through the rectifier 253 direct current to the field windings GF1 and GF2 of the generator G with proper polarity for down movement of the elevator car.

As the motor 1 accelerates, it rotates the disc 231 to apply through the magnet 237 a torque to the lever 215 which acts in opposition to the torque applied by the winding PM1. An equilibrium finally is reached when the elevator car operates at the desired speed. As previously noted, the winding 257 operates to minimize hunting of the system.

As the elevator car moves in the down direction, the position generator or transmitter SG (FIG. 1) energizes the motor SM to drive the synchronous carriages 43S and 45S in synchronism with movement of the elevator car. Since the advance carriages are maintained in their advanced positions, they move in unison with the synchronous carriages during full speed travel of the elevator car in the down direction.

Registered down floor calls are picked up by one of the switches in each of the sets 55A (FIG. 4A). As the advance carriage 45A approaches each of the associated floor-stop units in succession, it operates successively the sets of switches 55A. When the advance carriage reaches a predetermined point, such as a position which may be four feet (measured in terms of car travel) before the second floor, it closes the switch 55A(2)-1. This is one of the switches of the set 55A associated with the floor-stop unit for the second floor. Since the advance carriage may lead the elevator car by a distance such as twenty feet (measured in terms of car travel), it follows that the switch 55A(2)-1 is closed when the elevator car is about twenty-four feet from the second floor.

Upon closure of the switch 55A(2)-1, the down pawl relay DPL is energized through the following circuit:

B1-a, 55A(2)-1, 2DR2, D4, DPL, B2

The down pawl relay closes its make contacts DPL1 to establish through the now closed make contacts 32-3 a holding circuit for the down pawl relay. In addition, the break contacts DPL3 and DPL4 open to insert additional resistance in series with the advance motor AM shortly before the advance carriages are brought to a stop. Furthermore, the break contacts DPL5 open to prevent subsequent energization therethrough of the safety relay Z, while the make contacts DPL6 close to energize the lamp 297. This results in energization and pickup of the aux-

iliary photocell relay PR to close the make contacts PC1 in a manner which will be apparent from the preceding discussion of the approach to the elevator car to the fourth floor.

Opening of the break contacts PR1 and closure of the make contacts PR4 and PR5 have no immediate effect on system operation. Closure of the make contacts PR2 completes the holding circuit for the transfer control relay X while closure of the make contacts PR3 prepares the check relay S for subsequent energization there-through.

The down pawl relay DPL upon energization operates the set of switches 53 for the second floor. This set includes a switch 53(2)-1, which is closed to energize the cancelling coil 2DRN. Such energization cancels the call registered for the second floor. In addition, a second switch of the set, 53(2)-2, closes to energize the down floor lantern 2LAD for the second floor.

The energization of the down pawl relay DPL also operates to bring the advance carriages to a stop when the elevator car is approximately twenty feet from the second floor. Continued movement of the elevator car results in movement of the synchronous carriages relative to the advance carriages. It will be recalled that such relative motion operates a plurality of switches mounted on the advance carriage 45A (FIG. 1).

The relative motion of the carriages also moves the armature DMA (FIG. 4) toward the coil DMC to increase the impedance of the coil in a gradual manner. The increase in impedance of the coil results in a gradual decrease in current supplied to the winding PM1 of the pattern motor PM. The resultant movement of the lever 215 increases the effective resistance of the rheostat 239 and consequently reduces the excitation of the generator G. As a result, the elevator car is gradually slowed as it approaches the second floor.

When the car reaches a distance of the order of twenty inches from the second floor, the switches 11SD and 11SU close to energize the landing relay 34. This relay opens its break contacts 34-1, but such opening has no effect on operation for the reason that the transfer control relay X is maintained energized through its holding circuit. The make contacts 34-2 close to energize and pick up the check relay S. The break contacts 34-3 open to deenergize the timer T, and the timer starts to time out. The make contacts 34-4 close to prepare the transfer relay TR for subsequent energization there-through, while the make contacts 34-5 close to prepare the holding circuit for the transfer relay for subsequent operation.

In picking up, the check relay S closes its make contacts S1 without immediate effect on operation, since the break contacts PR1 of the auxiliary photocell relay in series therewith are open at this time. Closure of the make contacts S2 completes the holding circuit for the check relay. Closure of the make contacts S3 prepares the timer T for subsequent reenergization there-through. Finally, closure of the make contacts S4 prepares the transfer relay TR for subsequent energization there-through.

When the elevator car reaches a distance of ten inches from the second floor as it continues its downward travel, the upper end of the plate P1 (FIG. 1A) interrupts reception of radiant energy from the lamp 297 by the detecting device 295. Such interruption effects dropout of the photocell relay PC, and the make contacts PC1 (FIG. 4A) open to deenergize and drop out the auxiliary photocell relay PR. Closure of the break contacts PR1 completes the energizing circuit for the leveling control relay K. Opening of the make contacts PR2 interrupts the holding circuit for the transfer control relay X. Opening of the make contacts PR3 does not effect operation of the check relay S for the reason that this relay remains energized through its holding circuit. Opening of the make contacts PR4 has no effect on operation, since the break contacts DPL5 in series therewith are open at this time.

Lastly, opening of the make contacts PR5 has no effect on operation of the timer T. (It will be recalled that the timer is timing out at this stage.)

When the leveling control relay K picks up, its make contacts K1 close without affecting operation, and its make contacts K2 close to establish a second holding circuit for the down switch D and the car running relay 32. Thus, since the transfer control relay X has a slight time delay in dropout, the opening of its make contacts X1 upon such dropout has no immediate effect on operation, that is, the down switch D and the car running relay 32 are maintained energized through the now closed make contacts K2 as aforesaid. Opening of the make contacts X2 prevents subsequent energization of the transfer control relay through its holding circuit.

Closure of the make contacts X3 of the transfer control relay, however, results in energization of the transfer relay TR. This relay closes its make contacts TR6 to complete the holding circuit therefor. In addition, the break contacts TR2 and TR3 open to interrupt the energization of the winding PM1 through the coil DMC. Closure of the make contacts TR4 and TR5 connects the winding PM1 and the auxiliary brake relay BR for energization under the control of the electromagnetic units EU1 and EU2.

When the transfer occurs, the electromagnetic unit EU2 is adjacent the middle or widest portion of the plate P1 for the second floor, while the electromagnetic unit EU1 is spaced upwardly from the plate. In this position of the elevator car, negligible voltages are induced in the secondary windings 289S and 291S of the unit EU2 because of the shielding effect of the plate P1, whereas maximum voltages are induced in the secondary windings 285S and 287S of the unit EU1. Consequently, the rectifier 267 supplies substantially more current to the resistor 273 than does the rectifier 271. The resultant voltage across the resistor energizes the winding PM1 of the pattern motor PM with proper polarity for continued down travel of the elevator car.

As the car continues its approach to the second floor, the width of the plate P1 between the cores 283P and 283S of the unit EU2 continuously decreases to decrease the shielding action between the primary and secondary windings of this unit, and the voltage applied to the winding PM1 consequently decreases gradually. This means that the speed of the elevator car also is gradually decreased until the car reaches registry with the second floor. At this point, the electromagnetic unit EU2 is adjacent the lower end of the plate P1, and the unit EU1 is adjacent the upper end thereof. Consequently, the voltage across the resistor 273 is reduced to zero, and the speed of the elevator car also is reduced to zero. The auxiliary brake relay BR drops out to open its make contacts BR1, thus permitting application of the brake 7. In addition, radiant energy from the lamp 297 (FIG. 1A) now is received by the detecting device 295 through the aperture A in the plate P1 to reenergize the photocell relay PC. Closure of the contacts PC1 (FIG. 4A) effects pickup of the auxiliary photocell relay PR, which opens its break contacts PR1 to deenergize and drop out the leveling control relay K. Opening of the make contacts K2 deenergizes the down switch D and the car running relay 32, and the make contacts 32-1 open to permit application of the brake 7. Should the elevator car be displaced from the second floor for any reason, such as cable contraction or stretch, the electromagnetic units EU1 and EU2 would effect a return of the car into registry with the second floor, as will be understood from the foregoing discussion.

During the final movement of the elevator car, the switch 4SD closed (such closure may occur when the car is two feet from the second floor). Such closure prepares the coils 193 for subsequent energization. In addition, the switch 1SD closed when the car was within one foot of the second floor to prepare the up switch U for subsequent energization.

The elevator car attendant now opens his car gate and the hoistway door for the second floor to receive the waiting passenger. Such openings result in deenergization of the door relay 40. Opening of the make contacts 40-1, 40-2, 40-3, 40-4 and 40-5 has no immediate effect on the operation of the system. However, the closure of the break contacts 40-6 completes an energizing circuit for the coil 193. This coil, upon being energized, permits registration of the advance and synchronous carriages.

When the passenger has entered the elevator car, the car attendant operates the down push button DPB to effect movement of the car to the lower terminal floor by a sequence of operations which will be clear from the preceding discussion.

It should be noted that when the elevator car makes a short run, such as a run from the second to the first floor, the advance carriages may be brought to a stop before they reach their full advance. For example, let it be assumed that the elevator car attendant operates the car call push button 1c for the first floor. Following operation of the down push button DPB, the advance carriages start to advance in the manner previously described. However, if the first and second floors are separated by less than twenty feet, the advance carriages do not reach their full advance before the switch 49A(1) associated with the floor-stop unit for the first floor is closed. The closure of the switch 49A(1) completes an energizing circuit for the down pawl relay DPL, and this relay operates in the manner previously described to bring the advance carriages to a stop.

If the first and second floors are spaced by say fifteen feet, the armature DMA is not completely withdrawn from the coil DMC, and the coil will not have its minimum impedance. Consequently, the elevator car will not accelerate as rapidly for the short run as it does for a long run. With this exception, it will be appreciated that the system operates for a short run in a manner analogous to the operation of the system for a longer run. Since the photoelectric control apparatus 292 and the electromagnetic units EU1 and EU2 operate for a very limited travel of the elevator car, it is clear that they are always employed for controlling the car whether the car is operated on a run from one floor to the next floor or on a longer run. Consequently, they are always available for establishing an accurate slow-down pattern for the elevator car as it nears the floor at which the car is to stop.

Fail Safe Operation of Photoelectric Control Apparatus

In order to illustrate the fail safe features of the invention, let it first be assumed that the elevator car is located in a position of registry with a landing. As has been explained heretofore, when the car is in such position the lamp 297 (FIG. 1A) of the transmitting device 293 is energized to direct radiant energy through the aperture A in the plate P1 to the detecting device 295; and the detecting device receives and detects such radiant energy to energize the photocell relay PC.

Suppose, however, that either the radiant energy source 297 or the photocell of the detecting device 295 fails when the car is in such position of registry, as a consequence of which the photocell relay PC is deenergized and drops out. Opening of the make contacts PC1 (FIG. 4A) results in deenergization and dropout of the auxiliary photocell relay PR. Such dropout in turn opens the make contacts PR3 to deenergize the check relay S. (It will be recalled that the closure of the break contacts PR1 to energize the leveling control relay K momentarily is insufficient to effect pickup of the car running relay 32 through the make contacts K1 or K2, i.e., insufficient to effect closure of the make contacts 32-4 in the holding circuit of the check relay S before the check relay drops out, although, the latter relay has a slight time delay in dropout.) Opening of the make contacts S3 deenergizes the timer T, and the timer starts to time out.

At the expiration of the ten-second time delay in dropout of the timer, the timer drops out to open its make contacts T1 through T4. Such openings prevent operation of the elevator car motor, as was explained heretofore for the dropout of the timer T when the elevator car was located at the fourth floor, until the failure in the photoelectric control apparatus is repaired. When such repair is made, the elevator control system will operate as previously described. (It will be noted that the make contacts PR5 in parallel with the make contacts T3 permit reenergization of the time after repair of the aforesaid fault when the car is located in a position of registry at the floor at which the fault occurred. In the absence of the contacts PR5, the timer would not be automatically reenergized to permit subsequent operation of the elevator car.)

Next, let it be assumed that the radiant energy source or the photocell fails as the car is approaching a floor at which it is to stop but when it is spaced a substantial distance therefrom. It will be recalled that at this time the transfer control relay X and the timer T are energized and picked up. As the car approaches the desired floor, the up pawl relay UPL or the down pawl relay DPL, depending upon the direction of car travel, picks up in the manner previously described. Assume, for example, that upon closure of the make contacts UPL5 or DPL5, as the case may be, the lamp 297 fails to emit radiant energy because of an open circuit therein. As a result thereof, the photocell relay PC and thus the auxiliary photocell relay PR fail to pick up. When the elevator car reaches a distance of the order of twenty inches from the desired floor, the switches 11SD and 11SU close to energize the landing relay 34. Inasmuch as the auxiliary photocell relay PR failed to pick up to close its make contacts PR3, closure of the make contacts 34-2 upon pickup of the landing relay cannot effect energization and pickup of the check relay S. Consequently, both the leveling control relay K and the transfer relay TR fail to pick up.

When the landing relay 34 picked up, its break contacts 34-1 opened to deenergize the transfer control relay X, inasmuch as the make contacts PR2 of the auxiliary photocell relay PR had failed to close. Thus, opening of the make contacts X1 results in deenergization and dropout of the up switch U or the down switch D, as the case may be, and the car running relay 32. Since the contacts U1, U2, D1, D2, TR4 and TR5 now all are open, the winding PM1 of the pattern motor PM is deenergized, and the generator G consequently has no field excitation. As a result, the motor 1 ceases running, thereby terminating movement of the elevator car. In addition, the auxiliary-brake relay BR is deenergized, and since the contacts BR1 and 32-1 both are open the brake 7 is applied. Furthermore, when the landing relay 34 picked up, its break contacts 34-3 opened to deenergize the timer T. Thus, after the car stops and the timer T times out to open its make contacts T1 through T4, subsequent energization of the car motor is prevented, as explained heretofore, until the fault is corrected.

Finally, let it be assumed that as the elevator car approaches a floor at which it is to stop, but before up pawl relay UPL or the down pawl relay DPL picks up, as the case may be, a fault such as a short circuit occurs in the detecting device 295 (FIG. 1) which results in energization and pickup of the photocell relay PC, although the lamp 297 is not energized. Closure of the make contacts PC1 (FIG. 4A) effects pickup of the auxiliary photocell relay PR, which, in turn, closes its make contacts PR4 to energize the safety relay Z through the break contacts UPL5 and DPL5, since the latter contacts are closed under the assumed conditions. The break contacts Z1 open to prevent subsequent energization of the check relay S, while the make contacts Z2 close to complete the holding circuit for the safety relay through the switch 299.

When the elevator car reaches a distance of the order

of 20 inches from the desired floor, the switches 11SD and 11SU once again close to energize the landing relay 34. Inasmuch as the break contacts Z1 now are open, closure of the make contacts 34-2 upon pickup of the landing relay can not effect energization and pickup of the relay S. Consequently, both the leveling control relay K and the transfer relay TR again fail to pick up. This results in the deenergization of the car motor, thereby terminating movement of the car, and in the application of the brake 7 by a sequence of operations which will be apparent from the discussion of the failure of the lamp 297 in the preceding example.

After the timer T times out to open its make contacts T1 through T4, subsequent energization of the car motor is prevented, as explained heretofore. It will be noted in this case, however, that even after the detecting device 295 is repaired, the safety relay Z remains energized and picked up through its holding circuit to prevent car movement. Thus, when the elevator car is to be restored to service after repair of the fault, the safety relay Z must be dropped out. Such dropout may be effected automatically, but it is assumed in the present example that the safety relay is dropped out by manually opening the switch 299 in its holding circuit. Dropout of the relay results in closure of its break contacts Z1 in the energizing circuit of the check relay S and in opening of its make contacts Z2 in the holding circuit of the safety relay. Thereafter, the switch 299 may be reclosed manually, and normal operation of the elevator car may be resumed.

While the plate P1 for the electromagnetic units EU1 and EU2 also has been used to control operation of the photoelectric control apparatus 292 in the illustrated embodiment of the invention, it will be appreciated that the invention may be employed in conjunction with other types of landing control systems. For example, the invention may be used with elevator control systems wherein the stopping of the elevator car at a desired floor is effected by a series of separate and distinct slow-down points rather than by the continuous decrease in energization of the car motor as effected by the units UM, DM, EU1 and EU2 in the illustrated embodiment. Such a control system is illustrated in the aforesaid Savage patent. In such a case, the plate P1 could have merely a rectangular rather than a diamond-shaped configuration, with an aperture at the appropriate location, to effect the desired interruption and reception of radiant energy in a manner which will be clear from the preceding description. Thus, it will be appreciated that the fail safe photoelectric control apparatus herein described may replace one or more of the inductor relays 1UL, 1DL, 2UL, 2DL, and 3L of the aforesaid Savage patent.

Although the invention has been described with reference to certain specific embodiments thereof, numerous modifications falling within the spirit and scope of the invention are possible.

We claim as our invention:

1. Load conveying apparatus comprising a first structure having a plurality of spaced landings, a load transporting structure for serving said landings, means mounting the load transporting structure for movement relative to the first structure in a predetermined path to serve said landings, motive means operable when energized for moving the load transporting structure, and control means operable in cooperation with said motive means for moving the load transporting structure, said control means including stopping means for stopping the load transporting structure adjacent each of desired ones of said landings, a brake for said motive means, first control means for controlling energization of said motive means to move the load transporting structure substantially from a first of said landings to a second of said landings, second control means for controlling energization of said motive means to stop the load transporting structure at said second landing, a radiant energy sensitive device, means automatically rendering said device operative to effect transfer

of energization of said motive means from control by said first control means to control by said second control means when the load transporting structure is in a first predetermined position displaced from said second landing as the load transporting structure approaches the second landing, means responsive to the arrival of the load transporting structure at a predetermined position of registration with said second landing for automatically rendering said device operative to effect termination of the control of energization of said motive means by said second control means to deenergize said motive means and to apply said brake to said motive means for terminating movement of the load transporting structure at said position of registration, means responsive to a malfunction of said device as the load transporting structure approaches the second landing for rendering said first and second control means ineffective further to control energization of said motive means to deenergize said motive means and for applying said brake to said motive means to terminate movement of the load transporting structure, and means responsive to a malfunction of said device when the load transporting structure is in said position of registration with said second landing for rendering said second control means ineffective further to control energization of said motive means.

2. Load conveying apparatus comprising a first structure having a plurality of spaced landings, a load transporting structure for serving said landings, means mounting the load transporting structure for movement relative to the first structure in a predetermined path to serve said landings, motive means operable when energized for moving the load transporting structure, and control means operable in cooperation with said motive means for moving the load transporting structure, said control means including stopping means for stopping the load transporting structure adjacent each of desired ones of said landings, a brake for said motive means, and first and second circuit means for controlling energization of said motive means, said stopping means comprising a first device operable when energized for transmitting radiant energy and a second device for receiving said radiant energy, said second device being operable from a first condition in the absence of reception of said radiant energy thereby to a second condition in response to the reception of said radiant energy thereby, means energizing said first device when the load transporting structure is in a first predetermined position displaced from a landing at which it is desired the load transporting structure shall stop as the load transporting structure approaches such landing under the control of said first circuit means, third circuit means, means responsive to operation of said second device in its second condition as a result of said first device energization when the load transporting structure is in said first position for energizing said third circuit means, means interrupting the reception of said radiant energy by said second device when the load transporting structure is in a second predetermined position displaced from the last-named landing as the load transporting structure continues its approach thereto, means responsive to said energization of said third circuit means and to the operation of said second device in its first condition as a result of said interruption for transferring energization of said motive means from control by said first circuit means to control by said second circuit means, means terminating said interruption when the load transporting structure arrives at a predetermined position or registration with said last-named landing, means responsive to operation of said second device in its second condition as a result of said termination for terminating the control of energization of said motive means by said second circuit means to deenergize said motive means and to apply said brake to said motive means for terminating movement of the load transporting structure at said position of registration, means responsive to malfunction of said second device wherein said second device operates from its first to its second

condition in the absence of transmission of radiant energy by said first device as the load transporting structure approaches said last-named landing for rendering said first circuit means ineffective further to control energization of said motive means to deenergize said motive means and for applying said brake to said motive means to terminate movement of the load transporting structure, means responsive to non-energization of said third circuit means when the load transporting structure is in said first predetermined position for rendering said first circuit means ineffective further to control energization of said motive means to deenergize said motive means and for applying said brake to said motive means to terminate movement of the load transporting structure, and means responsive to operation of said second device in its first condition when the load transporting structure is in said position of registration when said last-named landing for rendering said second circuit means ineffective further to control energization of said motive means.

3. Load conveying apparatus comprising a first structure having a plurality of spaced landings, a load transporting structure for serving said landings, means mounting the load transporting structure for movement relative to the first structure in a predetermined path to serve said landings, motive means operable when energized for moving the load transporting structure, and control means operable in cooperation with said motive means for moving the load transporting structure, said control means including stopping means for stopping the load transporting structure adjacent each of desired ones of said landings, registering means for controlling energization of said motive means to stop the load transporting structure at a position of registration with the last-named landing and for thereafter maintaining the load transporting structure in such position, and a brake for said motive means, said stopping means comprising a first device operable when energized for transmitting radiant energy and a second device for receiving said radiant energy, said second device being operable from a first condition in the absence of reception of said radiant energy thereby to a second condition in response to the reception of said radiant energy thereby, means energizing said first device when the load transporting structure is in a first predetermined position displaced from a landing at which it is desired the load transporting structure shall stop as the load transporting structure approaches such landing under the control of said motive means, a first circuit, means responsive to operation of said second device in its second condition as a result of said first device energization when the load transporting structure is in said first position for energizing said first circuit, means interrupting the reception of said radiant energy by said second device when the load transporting structure is in a second predetermined position displaced from the last-named landing as the load transporting structure continues its approach thereto, means responsive to said energization of said first circuit and to the operation of said second device in its first condition as a result of said interruption for placing energization of said motive means under the control of said registering means, means terminating said interruption when the load transporting structure arrives at said position of registration with said last-named landing, means responsive to operation of said second device in its second condition as a result of said termination for terminating energization of said motive means and for applying said brake to said motive means to terminate movement of the load transporting structure at said position of registration, means responsive to malfunction of said second device wherein said second device operates from its first to its second condition in the absence of transmission of radiant energy by said first device as the load transporting structure approaches said last-named landing for terminating energization of said motive means and for applying said brake to said motive means to terminate movement of the load transporting structure, means responsive to non-energization of said first circuit

when the load transporting structure is in said first predetermined position for terminating energization of said motive means and for applying said brake to said motive means to terminate movement of the load transporting structure, and means responsive to operation of said second device in its first condition when the load transporting structure is in said position of registration with said last-named landing for preventing energization of said motive means to move the load transporting structure.

4. In an elevator system, an elevator car, a structure having a plurality of spaced landings to be served by the elevator car, means mounting the elevator car for movement relative to the structure in up and down directions through a predetermined path to serve the landings, motive means operable when energized for moving the elevator car, and control means operable in cooperation with said motive means for moving the elevator car, said control means comprising a transmitting device operable when energized for transmitting radiant energy and a detecting device for receiving and detecting said radiant energy, interrupting means for each landing disposed to intersect the path of said radiant energy between said devices for interrupting the reception and detection of said radiant energy by said detecting device, means mounting said devices for movement relative to said interrupting movement in accordance with movement of the elevator car, said interrupting means for each landing being proportioned to interrupt the reception and detection of said radiant energy by said detecting device from a point corresponding to a predetermined displacement of the elevator car from the associated landing as the elevator car approaches such landing in each of said directions to a point corresponding to a predetermined position of registration of the elevator car with said associated landing, said interrupting means further being positioned to terminate interruption of reception of said radiant energy by said detecting device when the elevator car is in said position of registration with said associated landing, leveling means for controlling energization of said motive means to stop the elevator car at said position of registration with each of said landings and for maintaining the elevator car in such position, a brake for said motive means, first and second circuit means for controlling energization of said motive means, means energizing said transmitting device when said transmitting and detecting devices are displaced from said interrupting means and energization of said motive means is under the control of said first circuit means as the elevator car approaches a landing at which it is desired the elevator car shall stop, third circuit means, means responsive to reception and detection of said radiant energy by said detecting device as a result of the last-named transmitting device energization for energizing said third circuit means, means responsive to energization of said third circuit means and to interruption by said interrupting means of reception and detection of said radiant energy by said detecting device as the elevator car continues its approach to the last-named landing for transferring energization of said motive means from control by said first circuit means to control by said second circuit means and by said leveling means, means responsive to reception and detection by said detecting device of said radiant energy when the elevator car is in said predetermined position of registration with said last-named landing for terminating energization of said motive means and for applying said brake to said motive means to terminate movement of the elevator car at the last-named position of registration, means responsive to malfunction of said detecting device wherein said detecting device falsely indicates that radiant energy is being received from said transmitting device in the absence of transmission of radiant energy by said transmitting device as the elevator car approaches said last-named landing for rendering said first circuit means ineffective further to control energization of said motive means to deenergize said motive means and for applying said brake

to said motive means, means responsive to non-energization of said third circuit means as the elevator car approaches said last-named landing for rendering said first circuit means ineffective further to control energization of said motive means to deenergize said motive means and for applying said brake to said motive means, and means responsive to non-detection of said radiant energy by said detecting device when the elevator car is in said position of registration with said last-named landing for rendering said second circuit means ineffective further to control energization of said motive means.

5. In an elevator system, an elevator car, a structure having a plurality of spaced landings to be served by the elevator car, means mounting the elevator car for movement relative to the structure in up and down directions through a predetermined path to serve the landings, motive means operable when energized for moving the elevator car, and control means operable in cooperation with said motive means for moving the elevator car, said control means comprising a transmitting device operable when energized for transmitting radiant energy and a detecting device for receiving and detecting said radiant energy, both said devices being mounted on the elevator car for movement therewith, interrupting means mounted on said structure for each of said landings for interrupting reception and detection of said radiant energy by said detecting device, each of said interrupting means having two portions of substantially equal length extending in the directions of movement of the elevator car, one of said portions being disposed to interrupt the reception and detection of said radiant energy by said detecting device from a first point corresponding to a predetermined displacement of the elevator car from the associated landing as the car approaches such landing in the up direction of travel to a second point corresponding to a predetermined position of registration of the elevator car with the last-named landing, the other of said portions being disposed to interrupt the reception and detection of said radiant energy by said detecting device from a third point corresponding to a predetermined displacement of the elevator car from the associated landing as the car approaches such landing in the down direction of travel to said second point, said two portions of each of said interrupting means being spaced apart to provide a gap for permitting the reception and detection of said radiant energy by said detecting device when the elevator car is in said position of registration with the associated landing, leveling means for controlling energization of said motive means to stop the elevator car at said position of registration with each of said landings and for thereafter maintaining the elevator car in such position, a brake for said motive means, means energizing said transmitting device when said transmitting and detecting devices are displaced from the interrupting means associated with a landing at which it is desired the elevator car shall stop as the elevator car approaches such landing under the control of said motive means, a first circuit, means responsive to reception and detection of radiant energy by said detecting device as a result of said transmitting device energization as the elevator car approaches the last-named landing for energizing said first circuit, means responsive to energization of said first circuit and to interruption by said interrupting means of reception and detection of said radiant energy by said detecting device as the elevator car continues its approach to said last-named landing for placing energization of said motive means under the control of said leveling means, means responsive to reception and detection by said detecting device of said radiant energy received through said gap when the elevator car is in said position of registration with said last-named landing for terminating energization of said motive means and for applying said brake to said motive means to terminate movement of the elevator car at the last-named position of registration, means responsive to malfunction of said detecting device wherein said detecting device falsely indicates that

radiant energy is being received from said transmitting device in the absence of transmission of radiant energy by said transmitting devices as the elevator car approaches said last-named landing for terminating energization of said motive means and for applying said brake to said motive means to terminate movement of the elevator car, means responsive to non-energization of said first circuit as the elevator car approaches said last-named landing for terminating energization of said motive means and for applying said brake to said motive means to terminate movement of the elevator car, and means responsive to non-detection of radiant energy by said detecting device when the elevator car is in said position of registration with said last-named landing for preventing energization of said motive means to move the elevator car.

6. In an elevator system, an elevator car, a structure having a plurality of spaced landings to be served by the elevator car, means mounting the elevator car for movement relative to the structure in up and down directions through a predetermined path to serve the landings, motive means operable when energized for moving the elevator car, and control means operable in cooperation with said motive means for moving the elevator car, said control means comprising electromagnetic means disposed on said elevator car and a control unit disposed on the structure, said electromagnetic means being responsive to the control unit for providing an electrical output having a first characteristic dependent on the direction of displacement of the elevator car from each of said landings and a second characteristic dependent on the magnitude of such displacement for moving the elevator car at a decreasing rate toward a landing at which it is to stop, said control means further including photoelectric means mounted on the car and responsive to the position of said control unit when the elevator car is adjacent each of said landings for holding the elevator car at a landing at which the car stops.

7. In an elevator system, an elevator car, a structure having a plurality of spaced landings to be served by the elevator car, means mounting the elevator car for movement relative to the structure in up and down directions through a predetermined path to serve the landings, and electromagnetic means and photoelectric means for controlling movement of the elevator car, said photoelectric means including a transmitting device operable when energized for transmitting radiant energy and a detecting device for receiving and detecting said radiant energy, means energizing said transmitting device for reception and detection of radiant energy by said detecting device as the elevator car approaches a landing at which it is desired the car shall stop, means interrupting the reception and detection of such radiant energy by said detecting device as the elevator car continues its approach to such landing, means responsive to such interruption for modifying the control of movement of the elevator car by said electromagnetic means, means responsive to the arrival of the elevator car at a predetermined position of registration with the last-named landing for restoring the reception and detection of such radiant energy by said detecting device, and means responsive to such restoration for further modifying control of movement of the elevator car by said electromagnetic means.

8. In an elevator system, an elevator car, a structure having a plurality of spaced landings to be served by the elevator car, means mounting the elevator car for movement relative to the structure in up and down directions through a predetermined path to serve the landings, motive means operable when energized for moving the elevator car, and control means operable in cooperation with said motive means for moving the elevator car, said control means comprising electromagnetic landing leveling means for controlling energization of said motive means to stop the elevator car at a predetermined position of registration with each of said landings and for thereafter maintaining the elevator car in such position, photo-

electric means and a brake for said motive means, said photoelectric means including a transmitting device operable when energized for transmitting radiant energy and a detecting device for receiving and detecting said radiant energy, means energizing said transmitting device for reception and detection of radiant energy by said detecting device as the elevator car approaches a landing at which it is desired the car shall stop, means interrupting the reception and detection of such radiant energy by said detecting device as the elevator car continues its approach to such landing, means responsive to such interruption for placing energization of said motive means under the control of said landing leveling means, means responsive to the arrival of the elevator car at said position of registration with the last-named landing for restoring reception and detection of such radiant energy by said detecting device, and means responsive to such restoration for terminating energization of said motive means and for applying said brake to said motive means to terminate movement of the elevator at the last-named position of registration.

9. In a load-transporting system, a structure having a plurality of landings between which load is to be transported, a load-receiving unit mounted for movement between said landings, motive means for moving said unit between said landings, and control means for controlling said motive means to move the unit from a first to a second one of said landings and to stop the unit at the second landing, said control means comprising radiant energy first detecting means and radiant energy second detecting means mounted for movement relative to the structure in dependence on the movement of said unit relative to the structure, radiant energy transmitting means for transmitting first radiant energy through a first air path to said first detecting means and second radiant energy through a second air path to said second detecting means, and control-modifying means secured to said structure for movement through said airpaths in response to movement of said unit relative to said structure, said control-modifying means comprising means for modifying the supply of said first radiant energy to the first detecting means as a function of movement of said unit toward said second landing, said control-modifying means including means for modifying the supply of said second radiant energy to the second detecting means in response to arrival of said unit at a predetermined position adjacent the second landing; said control means including means coupled to said first and second detecting means for controlling movement of said unit in dependence on the receipt of said first and second radiant energy by the first and second detecting means.

10. In a load-transporting system, a structure having a plurality of landings between which load is to be transported, a load-receiving unit mounted for movement between said landings, motive means for moving said unit between said landings, and control means for controlling said motive means to move the unit from a first to a second one of said landings and to stop the unit at the second landing, said control means comprising radiant energy first detecting means and radiant energy second detecting means mounted for movement relative to the structure in dependence on the movement of said unit relative to the structure, radiant energy transmitting means for transmitting first radiant energy through a first air path to said first detecting means and second radiant energy through a second air path to said second detecting means, and control-modifying means secured to said structure for movement through said airpaths in response to movement of said unit relative to said structure, said control-modifying means comprising means for modifying the supply of said first radiant energy to the first detecting means as a function of movement of said unit toward said second landing, said control-modifying means including means for modifying the supply of said second radiant energy to the second detecting means in response

to arrival of said unit at a predetermined position adjacent the second landing; said control means including means, coupled to the first detecting means and responsive to receipt of the first radiant energy by the first detecting means for slowing said unit as the unit approaches the second landing, and means coupled to the second detecting means and responsive to receipt of the second radiant energy by the second detecting means for maintaining the unit in a stopped condition.

11. In a load-transporting system, a structure having a plurality of landings between which load is to be transported, a load-receiving unit mounted for movement between said landings, motive means for moving said unit between said landings, and control means for controlling said motive means to move the unit from a first to a second one of said landings and to stop the unit at the second landing, said control means comprising radiant energy first detecting means and radiant energy second detecting means mounted for movement relative to the structure in dependence on the movement of said unit relative to the structure, radiant energy transmitting means for transmitting first radiant energy through a first air path to said first detecting means and second radiant energy through a second air path to said second detecting means, and control-modifying means secured to said structure for movement through said airpaths in response to movement of said unit relative to said structure, said control-modifying means comprising means for modifying the supply of said first radiant energy to the first detecting means as a function of movement of said unit toward said second landing, said control-modifying means including means for modifying the supply of said second radiant energy to the second detecting means in response to arrival of said unit at a predetermined position adjacent the second landing; said control means including means coupled to said first and second detecting means for controlling movement of said unit in dependence on the receipt of said first and second radiant energy by the first and second detecting means; said control-modifying means comprising shield means for decreasing the transmission of said first radiant energy to the first detecting means as the unit approaches the second landing, said shield means being shaped to provide transmission of the second radiant energy to the second detecting means when the unit is at the second landing and to block said last-named transmission when the unit is displaced from the second landing within at least a predetermined limited distance.

12. In a load-transporting system, a structure having a plurality of landings between which load is to be transported, a load-receiving unit mounted for movement between said landings, motive means for moving said unit between said landings, and control means for controlling said motive means to move the unit from a first to a second one of said landings and to stop the unit at the second landing, said control means comprising radiant energy first detecting means and radiant energy second detecting means mounted for movement relative to the structure in dependence on the movement of said unit relative to the structure, radiant energy transmitting means for transmitting first radiant energy through a first air path to said first detecting means and second radiant energy through a second air path to said second detecting means, and control-modifying means secured to said structure for movement through said airpaths in response to movement of said unit relative to said structure, said control-modifying means comprising means for modifying the supply of said first radiant energy to the first detecting means as a function of movement of said unit toward said second landing, said control-modifying means including means for modifying the supply of said second radiant energy to the second detecting means in response to arrival of said unit at a predetermined position adjacent the second landing; said control means including means coupled to said first and second detecting means

for controlling movement of said unit in dependence on the receipt of said first and second radiant energy by the first and second detecting means; said control-modifying means comprising shield means for decreasing the transmission of said first radiant energy to the first detecting means as the unit approaches the second landing, said shield means being shaped to provide transmission of the second radiant energy to the second detecting means when the unit is at the second landing and when the unit is displaced from the second landing by more than a predetermined distance, said shield means being configured to block said last-named transmission when the unit is displaced from the second landing for a substantial distance which is less than said predetermined distance.

13. In a load-transporting system, a structure having a plurality of landings between which load is to be transported, a load-receiving unit mounted for movement between said landings, motive means for moving said unit between said landings, and control means for controlling said motive means to move the unit from a first to a second one of said landings and to stop the unit at the second landing, said control means comprising radiant energy first detecting means and radiant energy second detecting means mounted for movement relative to the structure in dependence on the movement of said unit relative to the structure, radiant energy transmitting means for transmitting first radiant energy through a first air path to said first detecting means and second radiant energy through a second air path to said second detecting means, and control-modifying means secured to said structure for movement through said airpaths in response to movement of said unit relative to said structure, said control-modifying means comprising means for modifying the supply of said first radiant energy to the first detecting means as a function of movement of said unit toward said second landing, said control-modifying means including means for modifying the supply of said second radiant energy to the second detecting means in response to arrival of said unit at a predetermined position adjacent the second landing; said control means including means coupled to said first and second detecting means for controlling movement of said unit in dependence on the receipt of said first and second radiant energy by the first and second detecting means, said first detecting means having a direct output with a polarity dependent on first and second directions of displacement of the unit from the second landing and having a magnitude dependent on the magnitude of the displacement of the unit from the second landing for a substantial range of such displacement, said control means including means responsive to the polarity of said output for moving said unit from a position displaced from said second landing over

a substantial range of displacement to said second landing for each of said first and second directions of displacement.

14. In a load-transporting system, a structure having a plurality of landings between which load is to be transported, a load-receiving unit mounted for movement between said landings, motive means for moving said unit between said landings, and control means for controlling said motive means to move the unit from a first to a second one of said landings and to stop the unit at the second landing, said control means comprising a radiant energy-controlling member secured to said structure adjacent the second landing, electric, field-means carried by said load-receiving unit for producing an alternating magnetic field in a space through which the radiant-energy-controlling unit passes during movement of the load-receiving unit relative to the structure adjacent the second landing, said field means including means having an electric output dependent on the extent of the portion of said radiant-energy-controlling member positioned in said alternating magnetic field, said controlling member having a configuration for producing a predetermined continuous alteration of said electric output over a substantial range of movement of the controlling unit relative to said field means; said field means including radiant-energy detecting means and radiant-energy transmitting means for transmitting radiant energy to said detecting means across a path through which said controlling member passes as said load-receiving unit nears said second landing, said controlling member being of material capable of blocking said radiant energy and being configured to block said radiant energy for a substantial range of displacement of said load-receiving unit from the second landing, said controlling member being clear of said path when the load-receiving unit is at the second landing to permit receipt of the radiant energy by the detecting means, said control means comprising means connected to said field means and controlled by said electric output to slow said load-receiving unit in accordance with a predetermined pattern as the load-receiving unit nears the second landing, said control means comprising means responsive to the detecting means for inhibiting movement of the load-receiving unit when said detecting means receives said radiant energy as said load-receiving unit stops at the second landing.

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