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Tintoré

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[54] **METHOD AND APPARATUS FOR GRAVITY-ACTUATION OF ELEVATORS**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **187/15,** 187/94, 60/55

[51] **Int. Cl.** **B66b 17/12**

[58] **Field of Search** 187/17, 94, 15; 254/178; 271/88; 60/22, 55, 25

[56] **References Cited**

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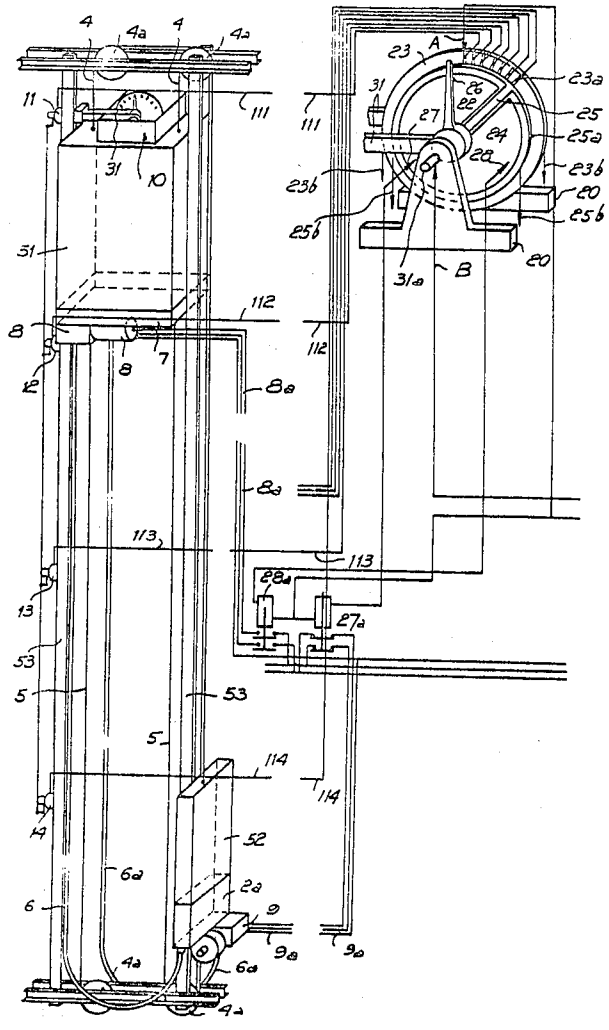
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[57] **ABSTRACT**

A method and apparatus for operating elevators. The elevator is operated exclusively with gravitational forces. Accelerating and decelerating movements of the elevator are brought about by conversion of potential into kinetic energy and kinetic into potential energy in a controlled manner. The elevator and a counterweight are suspended from a cable and pulley assembly. At locations primarily beneath the elevator and counterweight, there are masses carried by the elevator and counterweight and transferred between the elevator and counterweight to bring about the application of the gravitational forces which will accelerate and decelerate the elevator as required.

10 Claims, 13 Drawing Figures



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SHEET 1 OF 6

FIG. 1a

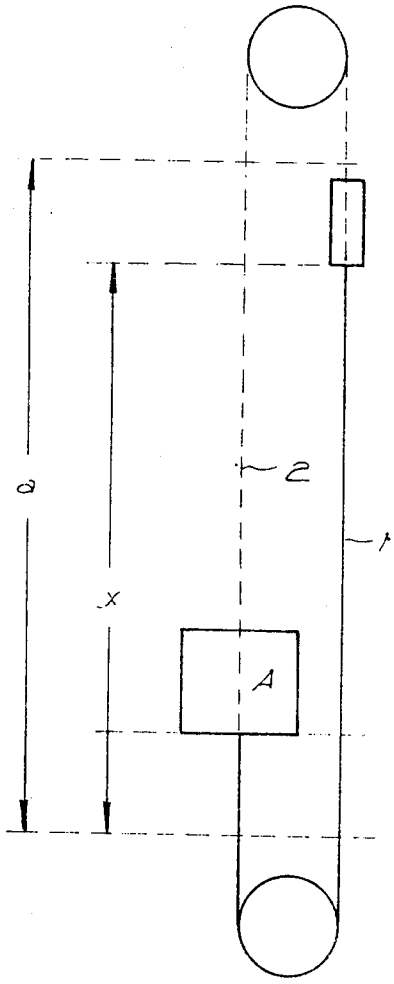
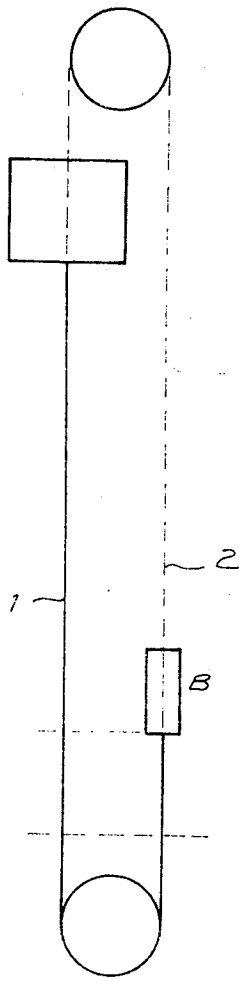


FIG. 1b



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FIG. 2a

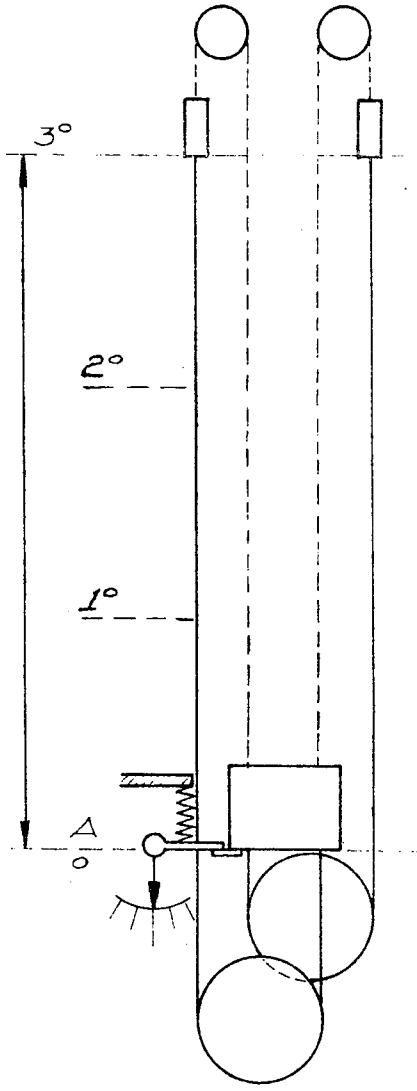
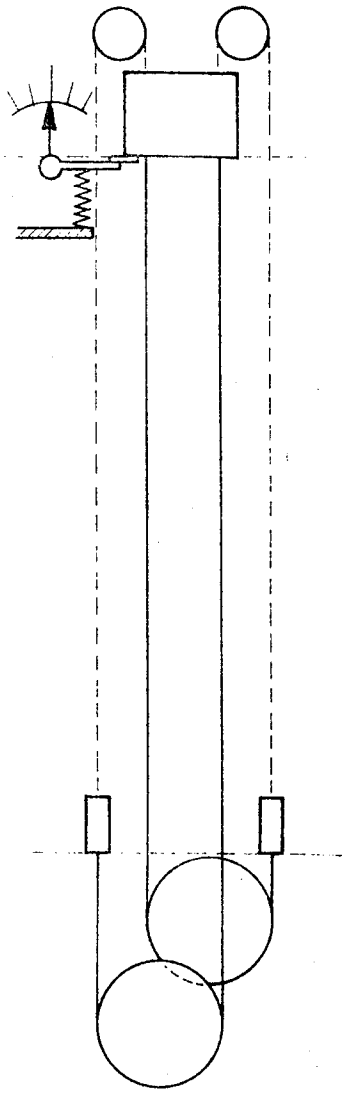


FIG. 2b



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FIG. 3a

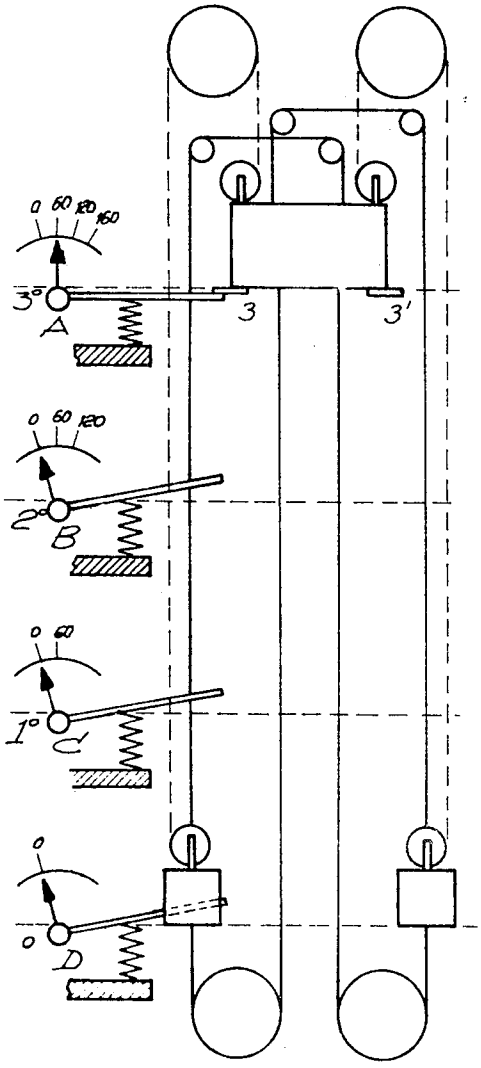
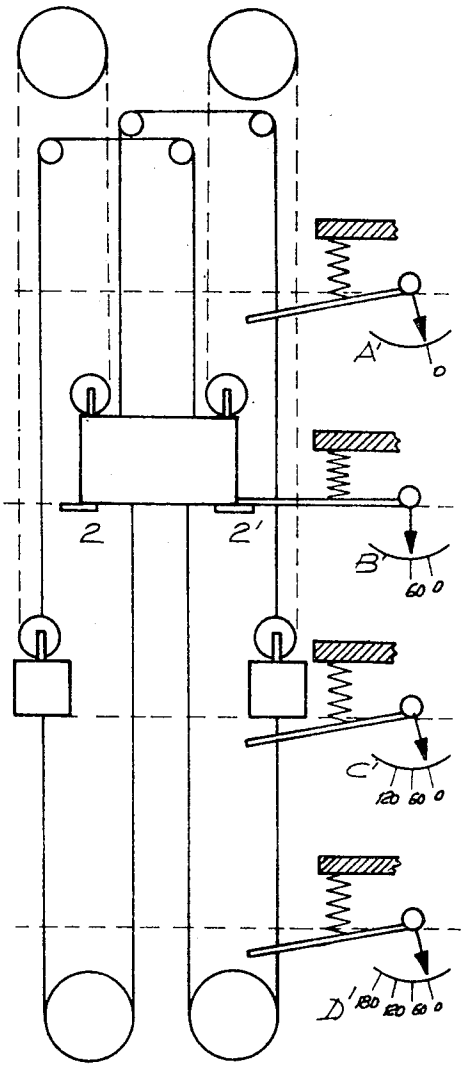


FIG. 3b



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FIG. 4a

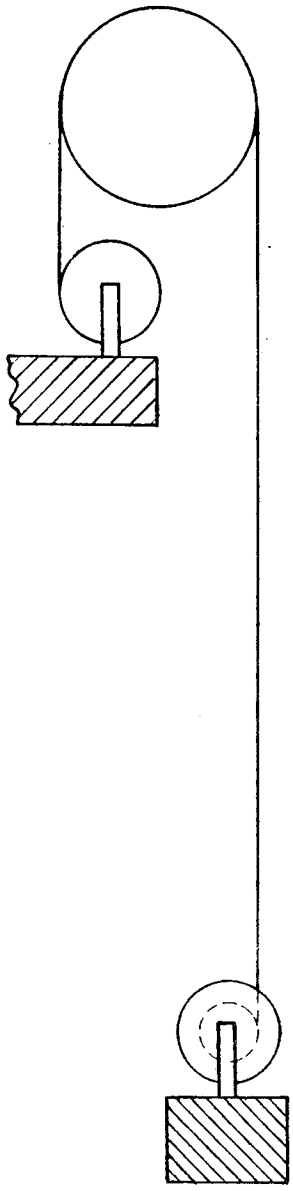
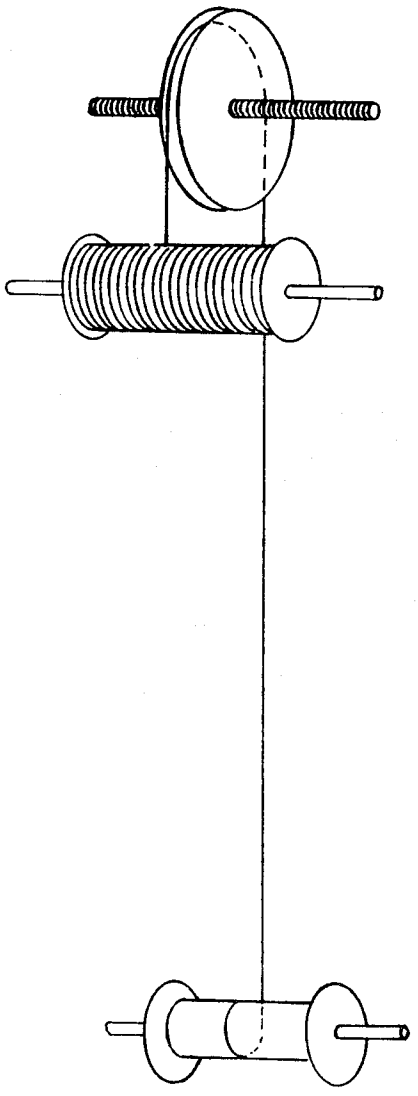


FIG. 4b



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FIG. 5

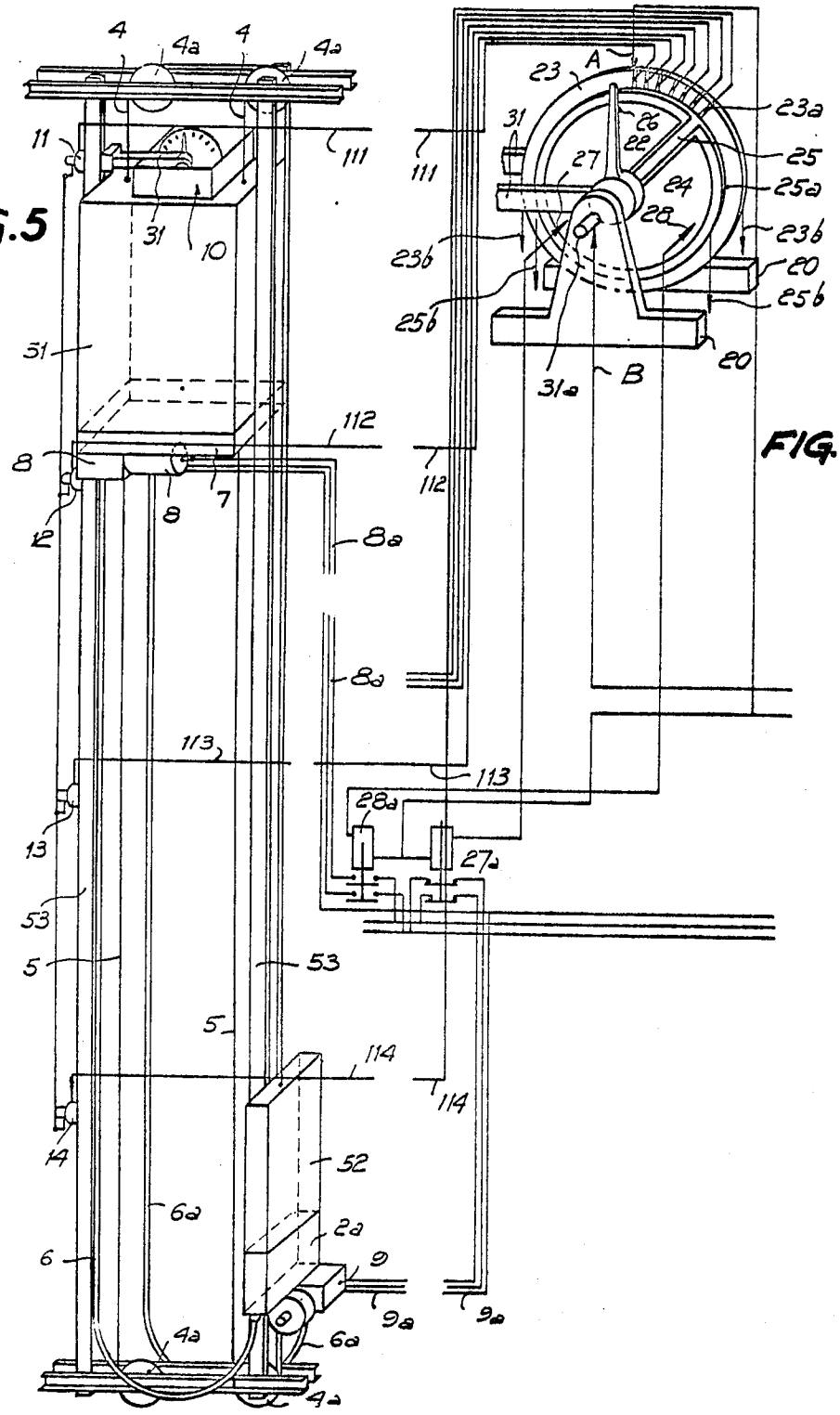


FIG. 5A

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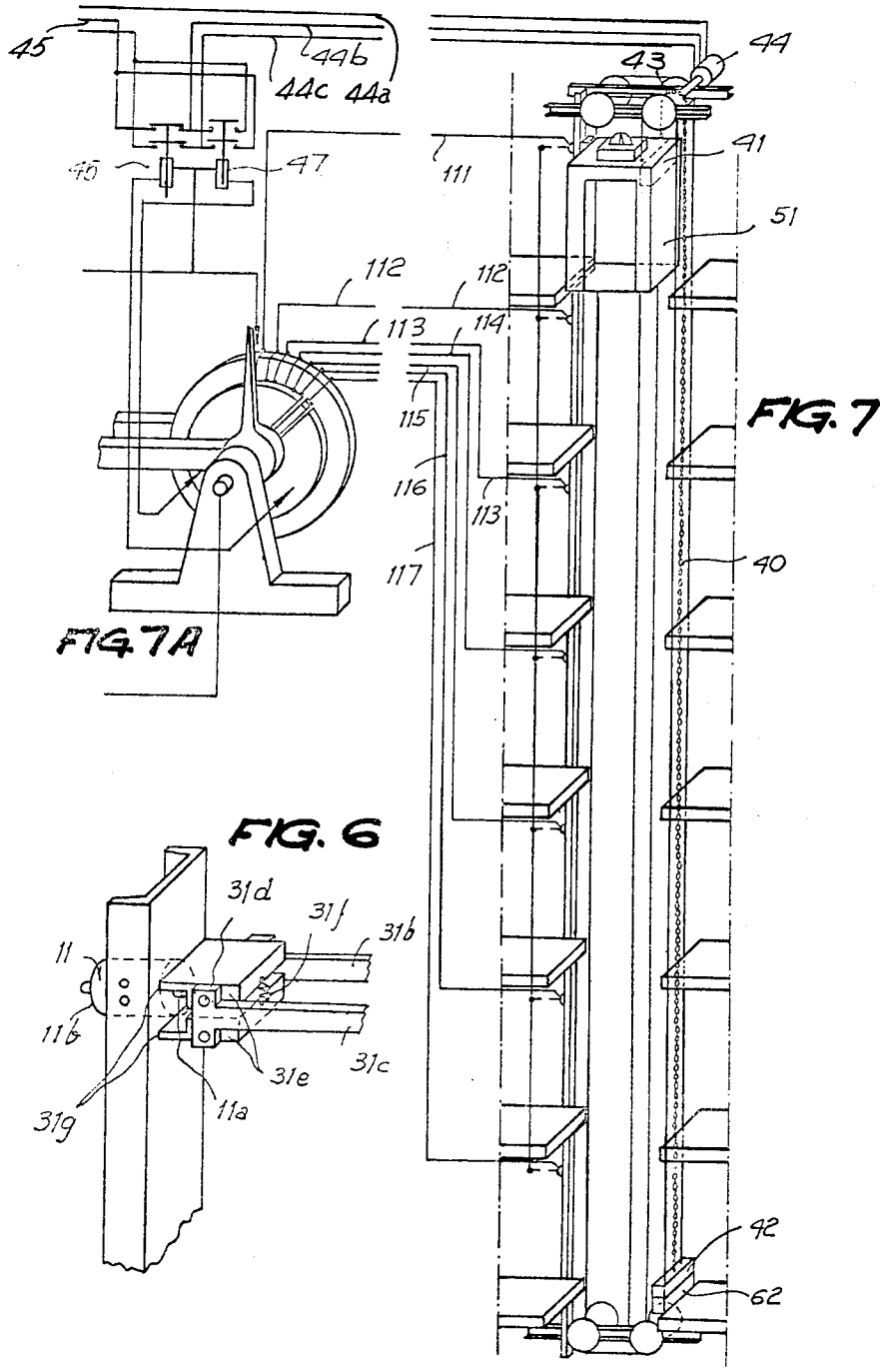


FIG. 7A

FIG. 7

FIG. 6

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METHOD AND APPARATUS FOR GRAVITY-ACTUATION OF ELEVATORS

BACKGROUND OF THE INVENTION

The present invention relates to elevators.

In particular, the present invention relates to a method and apparatus for operating elevators.

As is well-known, the operation of an elevator to move it up and down to various levels such as the stores of a suitable edifice involves complex, power-consuming components which often become faulty and which are expensive to install, purchase, and maintain.

SUMMARY OF THE INVENTION

It is a primary object of the invention to provide an elevator-operating method and apparatus which are relatively simple and inexpensive and which do not involve complex assemblies which consume large amounts of power.

In particular, it is an object of the invention to provide an elevator-operating method utilizing exclusively gravitational forces applied to the elevator to bring about the up-and-down movement thereof.

In particular, the invention involves a method and apparatus for transferring masses between an elevator and a counterweight in such a way that potential and kinetic energy amounts are converted one into the other and vice versa so as to bring about the required acceleration and deceleration of the elevator.

Thus, the invention relates to improvements applicable to systems of gravity-actuated elevators which include a cage or cabin for receiving the load and counterweights. The counterweights and the elevator are interconnected with each other by way of pulley-and-cable transmissions and suspensions.

One of the important features of the invention resides in the regulation of the amount of potential energy which is converted into kinetic energy during a period when the masses are accelerated as well as of regulating the quantity of kinetic energy which is converted back into potential energy during the period of deceleration or braking. While in most cases the elevator will carry out vertical movements, the invention also is applicable to inclined movements with a given vertical component.

The regulation of the quantities of potential and kinetic energy is achieved preferably along the path followed by the cabin or cage of the elevator by utilizing at least two cables or other flexible transmissions, or a fluid transmission having an analogeous function may be used. The components of greater unit weight hang below the cabin and the counterweight, and continuously during the entire movement of the cabin there is a transfer of masses. The cable suspensions of lesser unit weight are located over the cabin and counterweight and extend over suitable pulleys to form suspension cables remaining above the cabin and counterweight during the entire operation. In order to transfer the elevator between two given levels, both the load variation which can be achieved in the cabin at one of the levels as well as the weight of the corresponding length of cable to achieve movement of the loaded cabin to another level is achieved by transferring masses from the cabin to the counterweight or vice versa until the required transfer has been accomplished. At the same time, the action can be recorded on suitable control devices.

BRIEF DESCRIPTION OF DRAWINGS

The invention is illustrated by way of example in the accompanying drawings which form part of this application and in which:

FIGS. 1*a* and 1*b* schematically illustrate a simple system of a cabin and counterweight and the parts interconnecting the same;

FIGS. 2*a* and 2*b* show a system having double counterweights and a double compensating transmission;

FIGS. 3*a* and 3*b* respectively show a system similar to that of FIG. 2 with recording and indicating devices;

FIGS. 4*a* and 4*b* are respectively sectional and perspective views schematically representing the manner in which masses may be transferred in the case where masses are constituted by cables wound on spools;

FIG. 5 is a schematic representation of a specific embodiment where liquid forms the mass which is transferred;

FIG. 5A shows at an enlarged scale as compared to FIG. 5 the weighing device on top of the elevator and the electrical circuitry;

FIG. 6 is a fragmentary enlarged perspective illustration of the outer end of lever assembly of the weighing device and the manner in which it coacts with a lock means;

FIG. 7 is a schematic fragmentary perspective illustration of another embodiment according to which a chain forms the transferred mass; and

FIG. 7A shows at an enlarged scale the weighing device of FIG. 7 and the electrical circuitry.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIGS. 1*a* and 1*b*, there is schematically illustrated therein the total mass A of the cabin which forms the elevator with the load carried thereby. The entire counterweight mass B is also indicated. A suspension cable 2 is indicated schematically in a dotted line to distinguish it from a load-transferring or mass transferring cable 1 which has a unit weight quite different from that of the suspension cable 2. The suspension cable 2 is guided over an upper pulley and is located at all times above the elevator A and counterweight B. The cable 1 is designated in a solid line and is guided around a lower pulley as shown in FIGS. 1*a* and 1*b*. Through suitable mechanisms it is possible to wind the cable 1 onto spools carried by the elevator A as well as to unwind it from such spools and rewind it onto spools carried by the counterweight B. Thus, masses of cable 1 can be transferred from a location directly beneath the elevator to a location directly beneath the counterweight and from the latter to a location directly beneath the elevator, to bring about the required mass transfer which will regulate the conversion of potential into kinetic energy and the conversion of kinetic into potential energy to bring about the movement of the elevator and load A. As may be seen from FIGS. 1*a* and 1*b*, it is possible in the illustrated example to move the elevator through the vertical distance *a*, representing the maximum change in elevation possible for the elevator, and at the same time the counterweight B can have its elevation changed through the distance *x*.

With a system as described above, when disregarding the friction of the components, if the mechanism is permitted under the action of its own forces to displace itself from the position of FIG. 1*a*, then it will automati-

cally assume the position indicated in FIG. 1*b*. Of course, this action is reversible.

The velocity of the system at an ordinate point x may be calculated as follows:

$$dv/dt = \pm p\,[x-(a-x)]/M = \pm\, p(2x-a)/M \quad (1)$$

$$dx = vdt, \text{ therefore} \quad (2)$$

$$vdv = \pm(p/M)\,(2x-a)dx, \text{ and integrating} \quad (3)$$

$$C_o + v^2/2 = (p/M)\,(x^2 - ax) + C_1 = (px/M)\,(x-a) + C_1$$

For $v=0$, x is equal to a, so that $C_o - C_1 = 0$ and therefore: $v = \pm\ \sqrt{(2px/M)\,(a-x)}$, which has its maximum for $x = a-x$, that is, $x = a/2$ as was to be expected.

This maximum velocity will be, therefore: $v_{max} = \pm a\ \sqrt{(p/2M)}$, M being the total mass of the system. The maximum acceleration is $\gamma = \pm pa/M$.

It is logical to assume that the reversible process set forth above can be applied to other forms of elevator actuation. However, due to the small or exaggerated compressibility of liquids and gases, the description below refers only to methods in the form of mechanical energy, based on the action of gravity.

Referring to FIGS. 2*a* and 2*b*, it will be seen:

$$\gamma_{max} = \pm_1 2pa;/M\ v_{max} = a\quad \sqrt{p/M}.$$

In the case of FIG. 2*a*; $a = 9$m; $p = 10.07 - 0.221 = 9.849$ kg and $M = 102.5$ kg.

$$\gamma_{max} = 2 \cdot 9.849.9/102.5 = 1.73 \text{ m/sec}^2$$

$$v_m = 9\quad \sqrt{9.849/102.5} = 2.7 \text{ m/sec.}$$

In the case of FIG. 2*b*: $a = 9$m; $p = 9.949$ kg and $M = 72$ kg.

$$\gamma_{max} = 2 \cdot 9.949 \cdot 9/72 = 2.46 \text{ m/sec}^2$$

$$v'_{max} = 9\ (9.849/72) = 3.02 \text{ m/sec.}$$

The diameter of the upper pulleys therefore becomes: $D = 700d = 700 \cdot 0.51 = 350$ mm.

The diameter of the lower pulleys then becomes: $D = 500d = 500 \cdot 2.40 = 1{,}200$ mm.

Although various types of connections may be established, with one or a plurality of counterweights, there is shown in FIG. 2 by way of example one possibility of two extreme positions of the cabin and counterweight interconnected by a structure which is disclosed in other applications of the same applicant and which acts to eliminate eccentric forces on the cabin. The following description relates to important features of the invention.

A pair of cables having a composition $8 \cdot (4 \cdot 7+1)$ and of the unit weight of 10,070 grams, are connected to the cabin and the counterweight. Also, two additional cables are connected to the cabin and counterweight, these cables having a composition $6 \cdot 19+1$ and a unit weight of 221 grams. The path of the cabin of the elevator is fixed at 9 meters and the tare weight thereof is estimated at 100 kg. The load is 300 kg. Each counterweight has a tare weight of 125 kg, so that the two counterweights balance the dead weight of the cabin plus half its load.

Considering now the case of FIG. 1, it has been established that the cabin being locked, its total mass becomes equal to that of the two counterweights. This is achieved by means of the two displaceable masses X which in the position of FIG. 2*a* are 75 kg in each counterweight and 0 kg at the cabin, and with the loaded state of the latter, shown in FIG. 2*b*, they are 0 kg at the counterweights and 150 kg at the cabin.

The total mass M in the position of the part shown in FIG. 2*a* is:

$$(10.07+0.221)20+2(125+75)+300 + 100\ /9.81 = 102.5 \text{ kg}$$

The total mass in the position of FIG. 2*b* is:

$$(10.07+0.221)20+2 \cdot 125 + 100 + 150/9.81 = 72 \text{ kg}$$

As a result of the indicated connections, the maximum velocities and accelerations in the cases of FIGS. 2*a* and 2*b* theoretically behave according to the formulas and calculations set forth above. The equalization of the total masses of the cabin and of the counterweights, which constitutes another important feature of the invention, is effected by transferring masses of any kind from the cabin to the counterweights or from the counterweights to the cabin. For example, it is possible to effect this transfer of masses by spools or drums carried by the cabins and the counterweights and suitably actuated by suitable motor-driven transmissions, for example, so as to wind and unwind cable between these drums or spools and thus bring about the desired transfer of masses. Thus, these mechanisms when suitably actuated will wind one cable, which in the present example has the composition $19 \cdot 7+0$ and a unit of weight 245 grams, which, stored in its entire length at the cabin, brings about a reduction in the useful load of the cabin by $150-2(-75) = 300$ kg.

The cabin is retained in the position of FIG. 2*a* by means of a type of lock which may be in the form of a rocker mechanism whose indicating pointer A enables, after equalization of the masses between the cabin and counterweight is brought about, a recording at the mechanism of the value of a stress equivalent to $2ap = 2 \cdot 9 \cdot 9.849 = 180$ kg, in the ascending direction.

Likewise, when the cabin is retained in the position illustrated in FIG. 2*b* by a similar lock, which after the masses are balanced when the cabin is empty, permits the indicating pointer B to show a stress also of $2ap = 180$ kg in the descending direction.

According to the above description, the device is suitable only for displacing an elevator or cabin between two given levels after the stresses resulting from friction have been corrected.

However, referring to FIG. 2*a*, it will be seen that if the path of travel of the cabin is divided so as to give it two intermediate levels, it is possible to make the cabin go from the 0 level to the first level or from the 0 level to the second level provided that there is a neutralizing, respectively, of the difference of the weight of the lengths of the cables 1 and 2 included between the third and first or the third and second floors or levels.

This latter consideration, which is the third important feature of the invention, is easily brought about in the present example by considering that the total stress resulting from decompensation of cables between the third and 0 levels is 180 kg as indicated above, so that

to the stabilizing cable which has been described, in order to compensate the load variations in the cabin, which was 75 kg at each counterweight, there should be added a compensation capacity of ½ ⅔·180 = 120/2 kg, of which 30 kg will be stored in the cabin and 30 kg in the counterweight when the former is to be sent from the ground or zero floor to the third floor or vice versa.

Referring to FIG. 3*a* it will be seen that the cabin or elevator is shown loaded and locked at the upper floor and ready to move to the second floor. For this situation, in addition to winding on each drum of the counterweight 75 kg to compensate for the difference in load, it is necessary to wind an additional 60 kg, of which 30 kg are transferred from the cabin.

On the cabin, therefore, there acts in a descending direction (400+180) = 580 kg, and in the ascending direction 2(125+75+60) = 520 kg. The difference of 60 kg is what the pointer A will indicate before releasing the locking keys **3, 3'** and first engaging the keys **2** and **2'** corresponding to the second floor.

Thus, in the case of FIGS. 3*a* and 3*b* we have: $p = 10.07 \cdot 0.221 = 9.849$ kg; $M = 114.7$ kg; $a = 3$m, 6m and 9m;

$$\gamma = \pm 2ap/M; \; v = a \sqrt{p/m}.$$

For $a = 3$m:

$$\gamma_1 = 3 \cdot 2 \cdot 9.849 / 114.7 = 0.51 \text{ m/sec}^2$$

$$v_{max1} = 3 \sqrt{9.849/114.7} = 0.87 \text{ m/sec.}$$

For $a = 6$m:

$$\gamma_2 = 2 \gamma_1 = 1.02 \text{ m/sec}^2$$

$$v_{max2} = 2v_{max1} = 1.74 \text{ m/sec.}$$

For $a = 9$m:

$$\gamma_3 = 3 \gamma_1 = 1.53 \text{ m/sec}^2$$

$$v_{max3} = 3v_{max1} = 2.61 \text{ m/sec.}$$

FIG. 3*b* shows the cabin already positioned at the second level, with the same load and ready to ascend again to the third floor.

It will be observed that to travel from the second to the first floor 30 kg of cable must be transferred from each counterweight to the cabin to register a load of 60 kg on the indicating pointer B.

If it is desired to go from the second to the ground floor, 45 kg will be transferred from each counterweight to the cabin, so that the pointer B will indicate 120 kg.

It will thus be seen that there must be four positions of the indicating pointers A and B': **0–60–120–180**; three of the pointers B and C': **0–60–120**; and two of the pointers C and D': **0–60** while the pointers D and A' one position: **0**, suffices for reasons of equilibrium and safety.

The minimum storage capacity of a stabilizing cable on each drum will, in this particular example, be 75+60 = 135 kg.

Referring to FIGS. 4*a* and 4*b*, there is schematically illustrated therein an arrangement for winding 135 kg of nonspun, crossed preformed cable, of composition 19·7+0, diameter $D = 8$ mm and $d = 0.5$ mm on a drum or spool of a diameter of 200 mm and a length of 1 m, with 100 turns per course and with a separation between grooves of 1,000 − 100.8 = 2mm, greater than $0.15D$. The diameter of the drum, 200 mm, also is greater than $380d$. The maximum number of courses is seven, and then the outside diameter will be: $D_e = 200 + 2 \cdot 7 \cdot 8 = 312$ mm. The mean diameter is estimated at 256 mm and the total weight of the cable stored is: $P = 700 \cdot 0.256 \cdot 0.245$, greater than 135 kg. The maximum load of elevation is $9 \cdot 0.245 = 2.2$ kg. The maximum velocity of elevation at 750 rpm will be: $V = 750/60 \cdot \pi 0.312 = 12.2$ m/sec. The mean velocity of elevation will be $(750/60) \cdot \pi 0.256 = 9.4$ m/sec. The nominal power of the motor will be: $N = 9.4 \cdot 2.2/75.\rho$), less than 0.5 HP. The maximum leveling time will be 700/750, less than 1 minute.

There is no doubt that any other type of structure for transferring of loads between the cabin and the counterweights can be used, such as, for example, a system for transferring water by conventional pumping methods, without modifying the essence of the invention. Thus, FIG. 5 illustrates an embodiment of the invention according to which a hydraulic system is used to transfer a mass in the form of a suitable liquid between the cabin of the elevator and the counterweight.

Referring to FIG. 5 it will be seen that the cabin **51** and a counterweight **52** are slidable along vertically extending guides **53.** The cabin and counterweight are connected with each other by a suspension cable **4** and a suitable stabilizing cable **5.** These cables **4** and **5** are of the same composition and weight. The framework supports for rotary movement suitable guide pulleys **4***a* around which the cables **4** and **5** are guided.

The lower part of the cabin **51** is provided with a tank **7** capable of containing a given load of a liquid such as water. An electrically operated pump **8** communicates with the tank **7** to pump water out of the latter. The output of the pump **8** communicates with a tank **2***a* situated at the lower part of the counterweight **52** and forming a part thereof. For this purpose an elongated flexible hose **6** is provided, this hose communicating at its opposite ends with the pump **8,** at the output end of the latter and with the tank **2***a*. A second pump **9,** also driven by an electric motor, has its inlet communicating with the tank **2***a*, and the outlet of the pump **9** communicates with a second flexible hose **6***a* whose opposite end communicates with the tank **7.** Thus, the pump **9** is capable of transferring water from the tank **2***a* to the tank **7** while the pump **8** is capable of transferring water from the tank **7** to the tank **2***a*.

In a particular example which is illustrated in FIG. **5** there are four levels or stories between which the elevator **51** can travel. The control of the movement of the elevator is brought about by way of a weighing means **10** fixed to and carried by the upper part of the elevator **51.** This weighing means is situated on the top wall of the cabin **51** at the exterior thereof. The details of the weighing means **10** are illustrated in FIG. 5A. The weighing means includes an elongated lever or arm assembly **31.** The structure at the free end of the arm assembly **31** is illustrated in FIG. **6.** At the several levels or stories along the frame **53** which guides the elevator there are several releasable lock means **11–14,** and the elevator **51** is shown in FIG. **7** at the top level where the arm assembly **31** coacts with the releasable lock means **11.** This structure is shown in detail in FIG. **6.**

The weighing means **10** may be any conventional mechanism which responds to the weight of the elevator and the load carried thereby so as to result in turning of the arm or lever assembly **31** through an angle which is proportional to the complete weight of the

cabin. This latter complete weight is the weight of the cabin itself as well as the weight of the water in the tank 7. In the illustrated example the arm assembly 31 is fixed to a torsion bar in the form of a steel shaft 31*a* which provides the required spring force by twisting of the bar 31*a*. This torsion bar 31*a* forms a shaft on which other components of the weighing means 10 are mounted. The bar 31*a* is fixedly carried by suitable brackets 20 which are in turn fixed to the top wall of the elevator 51 at the exterior of the latter. Thus, when the arm assembly 31 of the weighing means 10 is held by the lock means 11, the entire elevator and load are supported from the arm assembly 31 with the shaft 31*a* twisting to an extent determined by the magnitude of the load so as to determine the angular position of the arm assembly 31 with respect to the axis of the shaft 31*a*. As will be apparent from the description below it is this angular position of the arm assembly 31 of the weighing means which is used to control the amount of water which is transferred so as to bring about the desired travel of the cabin 51 between any selected levels or stories.

As is apparent from FIG. 6, the arm assembly 31 includes a pair of elongated bars 31*b* and 31*c*. The bar 31*c* fixedly carries an elongated pointer or radial extension 21 which forms a brush holder and which turns together with the arm assembly 31.

As may be seen from FIG. 6, the bars 31*b* and 31*c* have T-shaped free ends supporting a pair of rods 31*d* which respectively carry a pair of dog components 31*e* capable of swinging about the rods 31*d*. These dogs have narrow ends 31*g* which coact with the lock means 11. At their opposite thicker ends the dogs are respectively interconnected by a tension spring 31*f* which tends to pull the thicker ends toward each other, and a suitable block structure is situated between the dog components to limit the extent to which they can be pulled toward each other by the spring 31*f*. The result is that during downward movement the lower dog 10 yield upwardly at its thinner end 31*g* to receive an armature of the lock means while during upward movement the upper dog can yield to receive the armature of the lock means. The lock means 11 is in the form of a solenoid having a coil assembly 11*b* surrounding the elongated armature 11*a* in the form of a rod which can project into the space between the thinner ends 31*g* of the dogs. The several lock means 12–14 are of a construction identical with that of the lock means 11 shown in FIG. 6, and described above. When the armature of the given lock means is received between the dogs the elevator will be locked at the elevation of this particular armature. FIG. 6 shows an elongated beam of C-shaped section which forms one of the guides 53, and it will be noted that the thin ends 31*g* of the dog are located quite close to this guide. The arrangement being such that the elevator will be reliably locked at the selected elevation with only a slight extent of turning of the arm assembly 31 being permitted in response to increase or decrease in weight with the consequent twisting of the torsion bar 31*a*, so that movement of the elevator will be achieved in one direction or the other only upon retraction of the armature of the particular lock means.

Referring now to FIG. 5A, the electrical structure includes a disc 23 which is on turnable on the shaft 31*a*. FIG. 5*a* schematically represents a wire cable 23*b* or the like extending to any suitable controls which automatically turn the disc 23 in a manner described below. The disc 23 is made of an electrically non-conductive material and carries electrically conductive contacts 23*a* which respectively correspond to the several stories to which the elevator can travel. It will be noted that in FIG. 5A there are more than four contacts 23*a*, so that the device can easily be adapted for any number of stories. The control means 23*b* automatically turns the disc 23 to situated in engagement with a stationary contact A a contact 23*a* which corresponds to the story at which the elevator is located. Thus, it will be noted that in FIG. 5 the elevator 51 is at the top story, and the left end contact 23*a* is shown engaging the stationary contact A. This contact A is electrically connected directly to the lines, and FIG. 5A schematically shows the negative power line connected to the stationary contact A. This contact A is stationary only in the sense that it remains stationary with respect to the elevator and the disc 23. Of course, it will move up and down with the elevator so as to be situated at all times at a given point along the circular path through which the several contacts 23*a* are turned.

The shaft 31*a* also supports for rotary movement a second disc 25*a* made of an electrically non-conductive material and connected by a wire cable 25*b*, for example, which extends along a peripheral groove of the disc 25*a* in the same way that the cable 23*b* extends along a peripheral groove of the disc 23. This cable 25*b* is operatively connected in any suitable way to controls selectively actuated by the operator for selecting a floor to which the elevator is to travel. Thus, the operator or any occupant of the elevator, will select the level to which the elevator is to travel and the result of the selection is that through the cable 25*b* the disc 25*a* is automatically turned so as to situate a brush 25 in engagement with that one of the contacts 23*a* which corresponds to the level to which the elevator is to travel. This brush 25 is in the form of an elongated radially extending electrically conductive member carried by the disc 25*a* which is non-conductive. Thus, FIG. 5A shows the brush 25 engaging the contact 23*a* which is at the other end of the row of the series of contacts from the end contact which engages the contact A, and thus in this position the disc 25*a* has been turned to select the lowermost level. This may be considered as corresponding to the level where the lock means 14 is located. The intermediate contacts of FIG. 5A may be considered as going to intermediate levels which are not illustrated in FIG. 5. As may be seen from FIGS. 5 and 5A, suitable electrical conductors extend between the contacts 23*a* and the several lock means 11–14, respectively, these conductors 111, 112, 113, and 114 being schematically represented in FIGS. 5 and 5A.

The electrically non-conductive disc 25*a* carries a pair of electrically conductive sectors 22 and 24 which are insulated from each other and from the brush 25. The arm 21 carries an electrically conductive brush 26 which engages the sector 22 in the position of the part shown in FIG. 5A, but during movement of the components this brush 26 can engage the brush 25 or the sector 24. The shaft 31*a* is itself electrically conductive and forms part of the circuit. It is permanently connected with the conductor B which extends from the positive one of the power lines indicated in FIG. 5A.

With the position of the parts shown in FIG. 5A, the operator has selected the lower level by turning the brush 25 into engagement with the right contact 23*a*.

Thus, in this position of the parts the circuit will go from the conductor B through the shaft 31*a* to the brush holder 21 and through the brush 26 to the sector 22. This sector is electrically connected by a brush 27 to a relay 27*a* which in turn is electrically connected to the negative power line which is of course connected to the contact A as pointed out above. As is apparent from FIG. 5A, the closing of this circuit by placing the brush 25 in engagement with a selected story to which the elevator is travelling will result in the illustrated example in energizing of the pump 9 connected by conductors 9*a* to the switches which are controlled by the relay 27*a* in the manner shown in the drawings. At the moment that the pump 9 starts to operate, the cabin 51 will remain at the level where it is held by the lock means 11 in coaction with the arm assembly 31 as pointed out above. However, during the continued transfer of liquid from the tank 2*a* to the tank 7 the weight of the elevator and load carried thereby will increase, thus causing the arm 31 and element 21 to turn in a clockwise direction, as viewed in FIG. 5A. The elevator will remain held by the lock means 11 until the brush 26 engages the brush 25. Thus, the brush 26 will move away from the sector 22 and into engagement with the brush 25 which is insulated from the sector 22. The result is that the circuit to the pump 9 is opened and the latter stops operating. However, simultaneously with opening of the circuit to the pump 9 the engagement of brush 26 with brush 25 completes a new circuit between contacts A and B through the brush holder 21, the brush 26, the brush 25, and the pair of lock means 14 and 11. The current flows in opposite directions respectively through the pair of lock means 14 and 11, with the result that the armature is withdrawn by the lock means 11 from the arm assembly 31 while the armature of the lock means 14 projects so that it will become situated between the pair of dog members 31*d* when the elevator reaches the level of the solenoid 14. As soon as the armature of lock means 11 is retracted the cabin moves down until the arm assembly 31 engages the projecting armature of the lock means which has been selectively energized in the above manner. When the elevator reaches the level of the lock means 14 the contact 23*a* corresponding to the level of the lock means 14 will have been automatically turned into engagement with the contact A and the brush 25 will be placed by the operator in engagement with that one of the levels to which the elevator is to travel. This will of course be an upper level higher than the level of the lower solenoid 14, and at this time the sector 24 will engage the brush 26 and a brush 28 connected to a second relay 23*a* for bringing about the reverse movement of the liquid so that by energizing the relay 28*a* the pump 8 will operate to transfer liquid from the tank 7 to the counterweight 2, the arm 31 now turning in a counterclockwise direction until it engages the brush 25 to bring about a release of the lock means 14 and the movement of the elevator up, as a result of the superior weight of the counterweight 52, until the selected level is reached.

Of course, the details of the weighing means 10 can be altered as desired. Any type of dynamometer device, may be used, for example. In the several locking means 11–14 the current always flows in opposite directions in the pair of locking means which are energized to bring about a selected operation of the elevator. Any conventional structure may be provided to regulate the current flow to bring about the corresponding opposite movement of the armatures of the pair of selected locking means. For example, a reversible electric motor may operate a plunger, corresponding tan armature, through a suitable reducing gear.

FIG. 7 shows another embodiment of an elevator of the invention according to which instead of transferring a liquid or a cable the load is transferred by displacement of the chain 40 between a pair of containers 41 and 42 respectively situated at the cabin 51 and the counterweight 62. The chain is drawn in one direction or the other in any suitable way such as by means of a rotary sprocket or other pulley 43 driven from an electric motor 44. This motor is fed from a three-phase A-C power supply 45 shown in FIG. 7A where the electrical circuitry is shown together with the weighing means which corresponds to that of FIG. 5A. The current is fed through the inverter relays 46 and 47 which correspond to the relays 27*a* and 28*a* of FIG. 5A and which are operated from the weighing means 10 through the electrical controls precisely in the same way as described above.

Thus, the operation of the embodiment of FIG. 7 through the controls of FIG. 7A is exactly the same as the above-described operation, the only difference being that the motor 44 will rotate in one direction or the other in response to the actuation of the relays 46 and 47, instead of one or the other of the pumps 8 or 9 being operated in response to actuation of relays 27*a* or 28*a*. FIGS. 7 and 7A illustrate the several conductors 44*a*, 44*b*, and 44*c* which extend between the relays and the motor 44 as well as the several conductors 111–117 which extend between the clock means at the several levels and the controls at the weighing mans shown in FIG. 7A.

What is claimed is:

1. In a method for operating an elevator by moving the elevator up and down exclusively with the application of gravitational forces, the elevator and a counterweight being connected to each other through a cable and pulley assembly by which the elevator and counterweight are suspended so that when gravitational forces acting on the elevator are greater than those acting on the counterweight the elevator will descend while when gravitational forces acting on the counterweight are greater than those acting on the elevator the elevator will ascend, said elevator accelerating when starting from a stationary position and decelerating when coming to a stop, the steps of transferring masses carried by the elevator and counterweight at predetermined locations thereof between said locations with said masses acting on the elevator and counterweight for applying said gravitational forces thereto to bring about descending and ascending of the elevator, and changing in a controlled manner the amount of a potential energy which is converted into a kinetic energy during acceleration of the elevator while also changing in a controlled manner the amount of kinetic energy which is converted to potential energy during deceleration of the elevator, said controlled changing of potential and kinetic energy being brought about by the transferring of the masses between said locations.

2. In a method as recited in claim 1 and wherein the step of transferring said masses takes place continuously during the entire movement of the elevator from one position to another.

3. A method as recited in claim 1 and wherein the transferred masses take the form of cable wound on spools with the winding and unwinding of the cable taking place between spools carried by the elevator and counterweight for transferring the masses according to the weight of the cable transferred between the spools at the elevator and counterweight.

4. In a method as recited in claim 3, the step of transferring the cable between the elevator and counterweight until forces corresponding to a load carried by the elevator are achieved for bringing about the desired regulated movement of the elevator.

5. In a method as recited in claim 4, and wherein the action of the elevator is recorded on a control device.

6. In a method as recited in claim 1 and wherein the transferred masses take the form of a liquid pumped between the elevator and the counterweight.

7. In a method as recited in claim 1 and wherein the transferred masses take the form of a chain transferred between containers at the elevator and counterweight.

8. Apparatus for gravitationally actuating an elevator, comprising an elevator cabin, means guiding the latter for vertical movement, a supporting cable assembly extending from the cabin, a counterweight connected to the supporting cable assembly, for raising said elevator cabin when the force of gravity acting on said counterweight exceeds that acting on said cabin while said cabin descends when the gravitational force acting thereon exceeds that acting on said counterweight, a pair of mass-transfer means respectively carried by the cabin and counterweight for increasing and decreasing in magnitude the mass which is carried by the cabin and counterweight by transferring mass from the cabin to the counterweight for raising the cabin and by transferring mass from the counterweight to the cabin for lowering the cabin, and control means operatively connected with said pairs of mass-transfer means for controlling the transfer of mass therebetween for controlling the movement of the elevator.

9. The combination of claim 8 and wherein said pair of mass transfer means include containers for liquid and said control means transferring liquid between said containers.

10. The combination of claim 8 and wherein said pair of transfer means include containers for chain which forms the mass and said control means transferring the chain between said containers.

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