

May 2, 1967

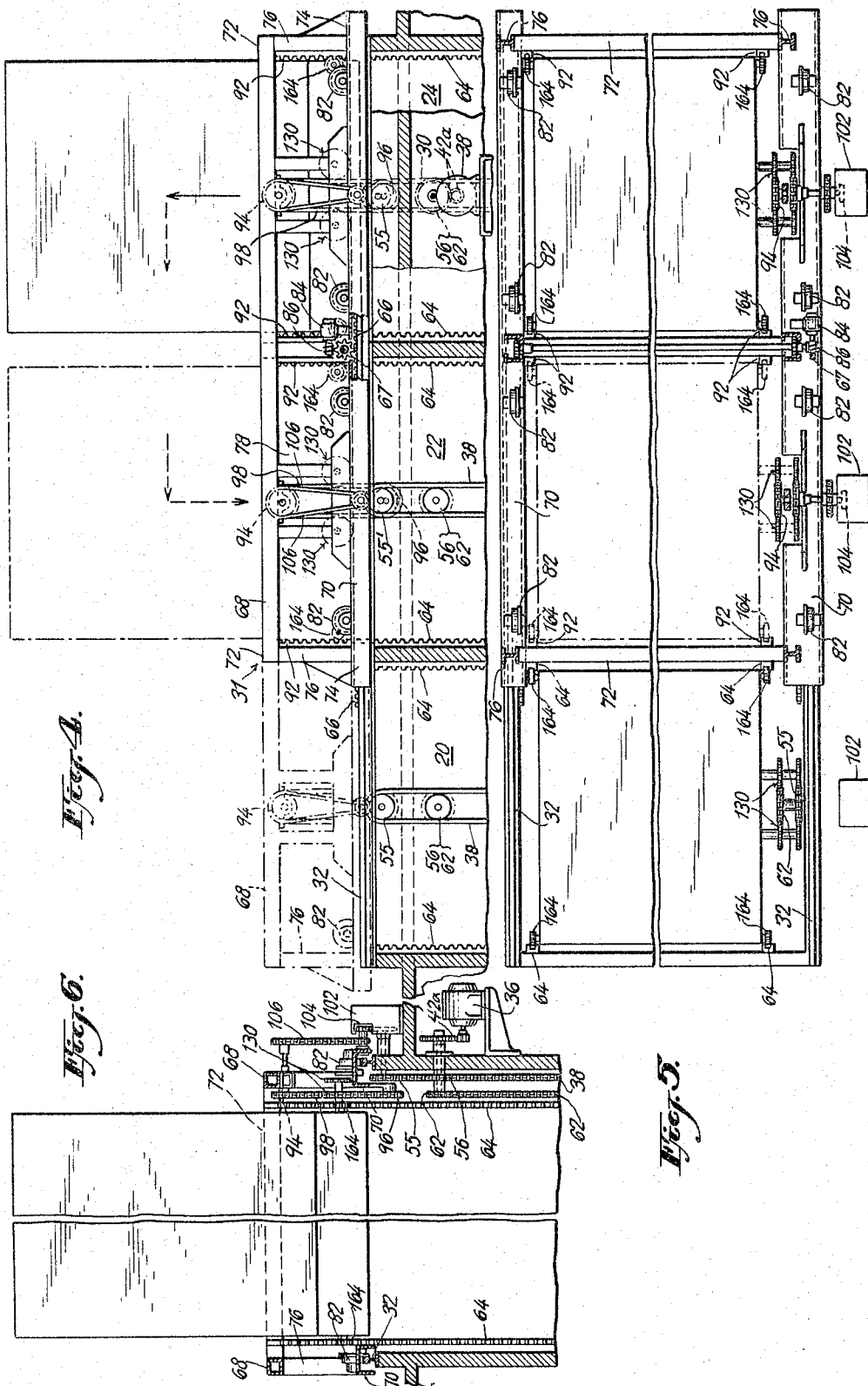
A. H. KEHOE

3,317,005

ELEVATOR SYSTEM

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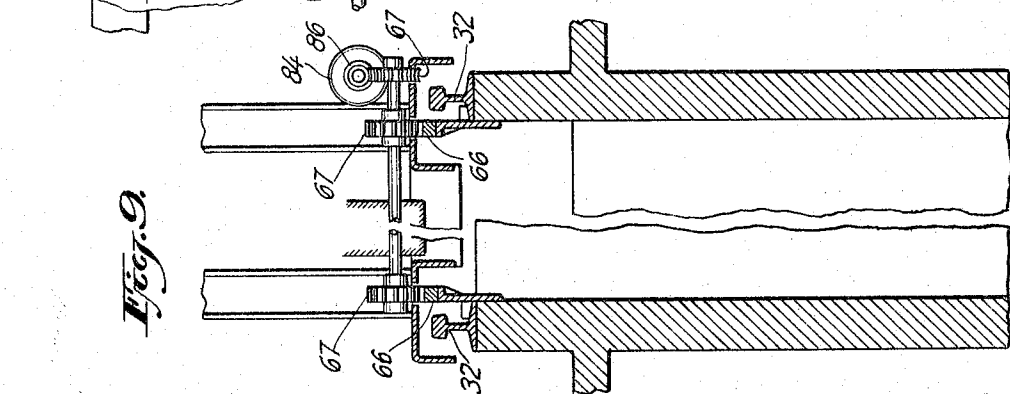
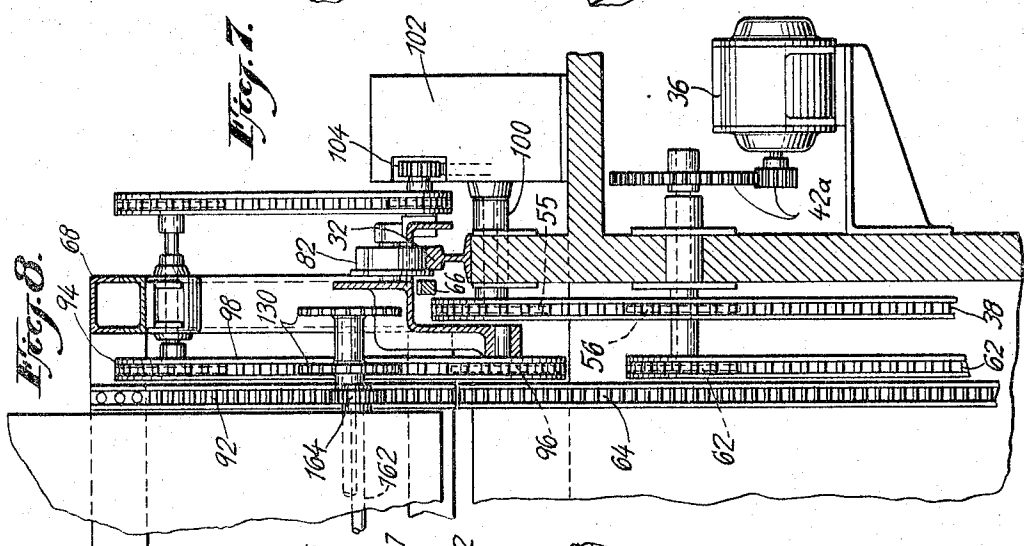
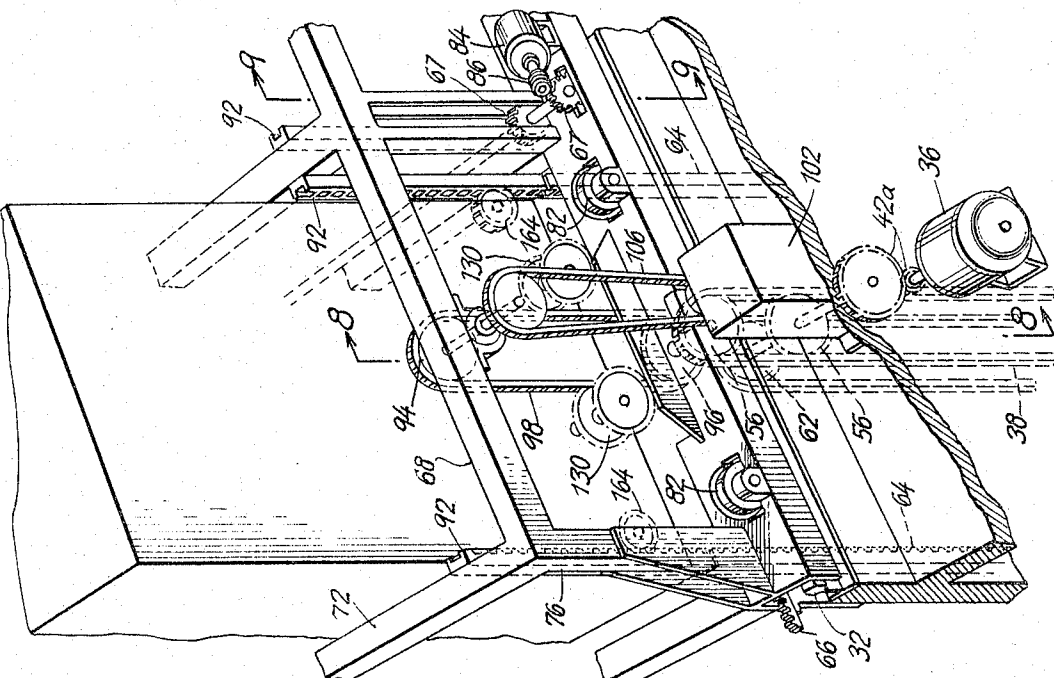
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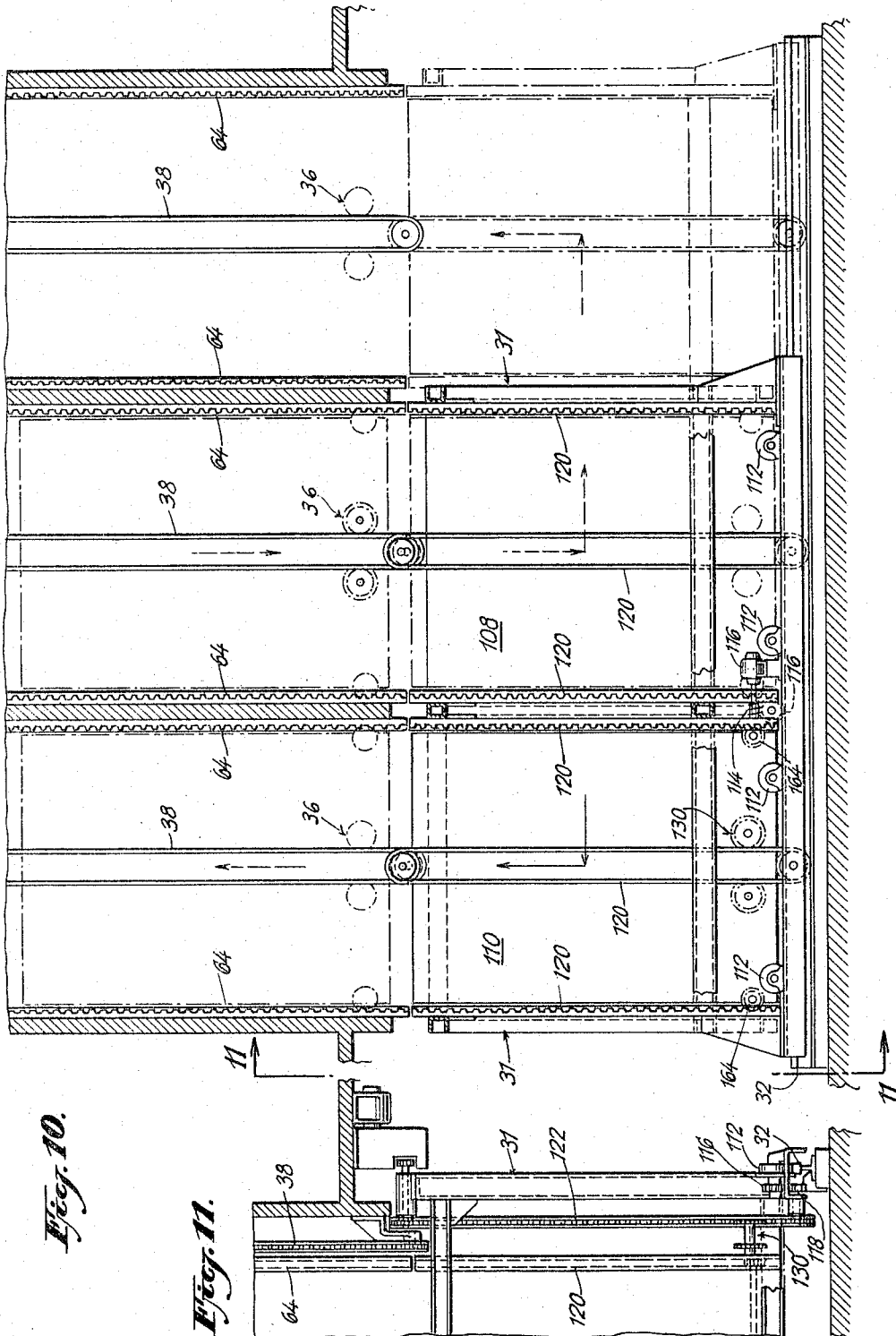
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Fig. 12.

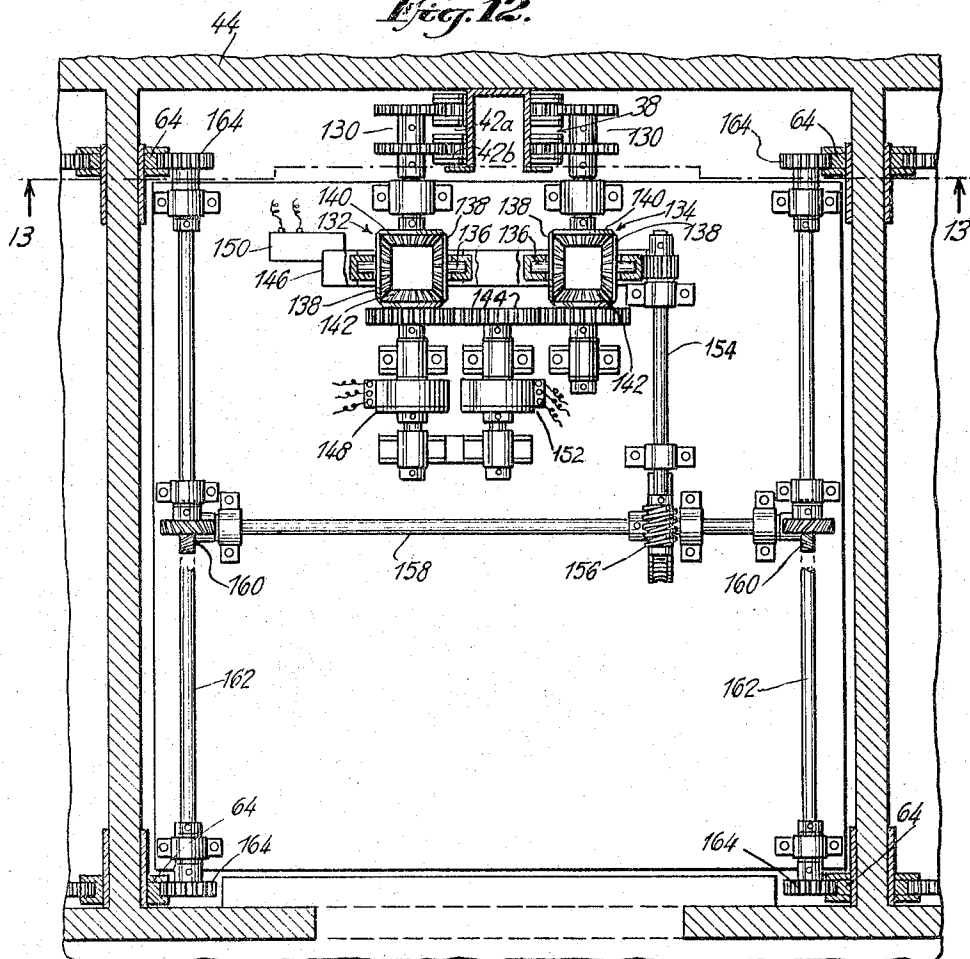
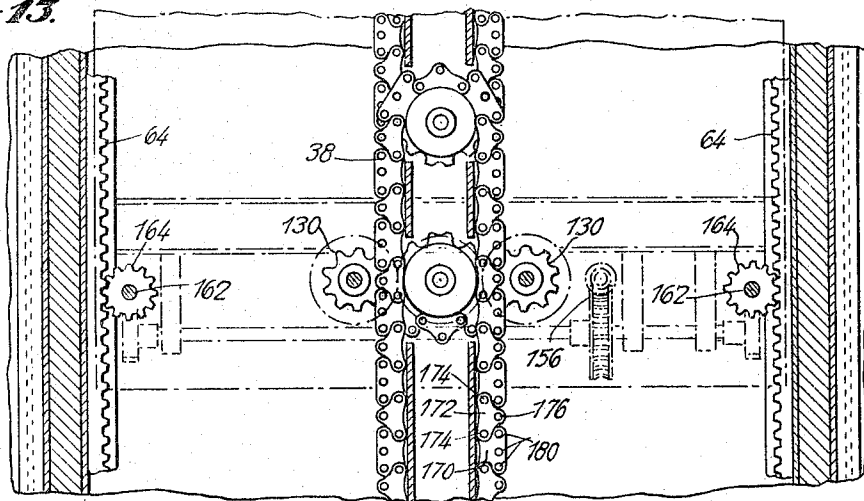


Fig. 13.



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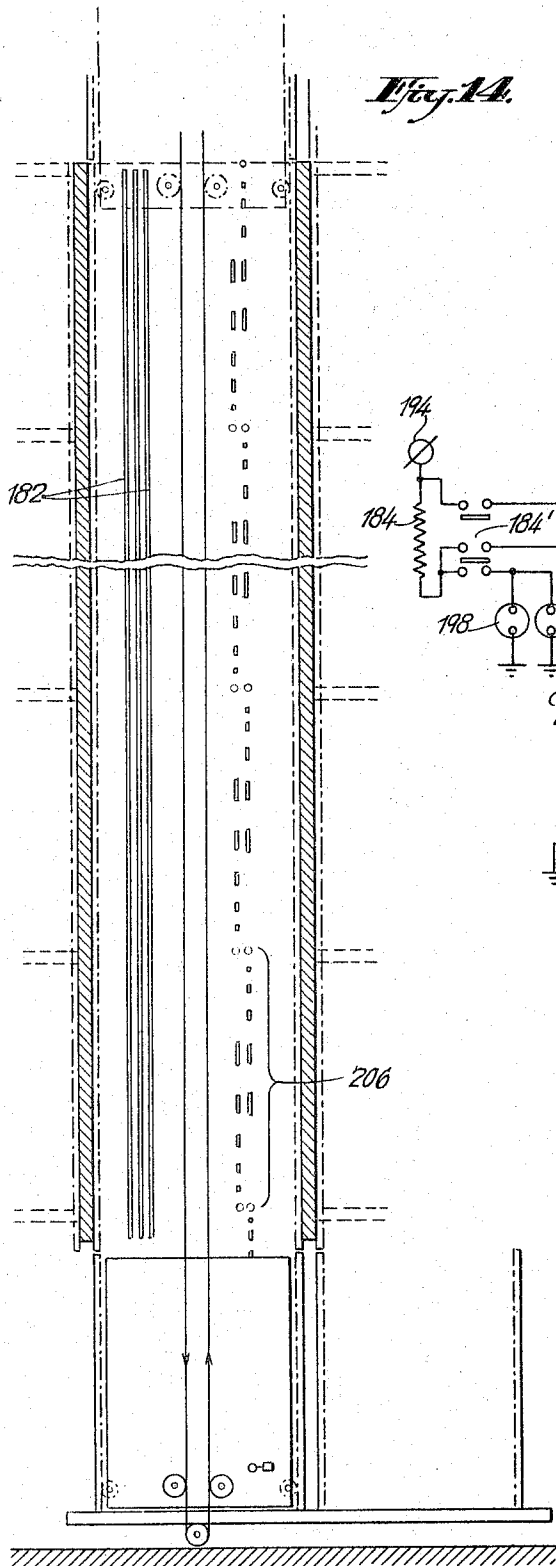


Fig. 15.

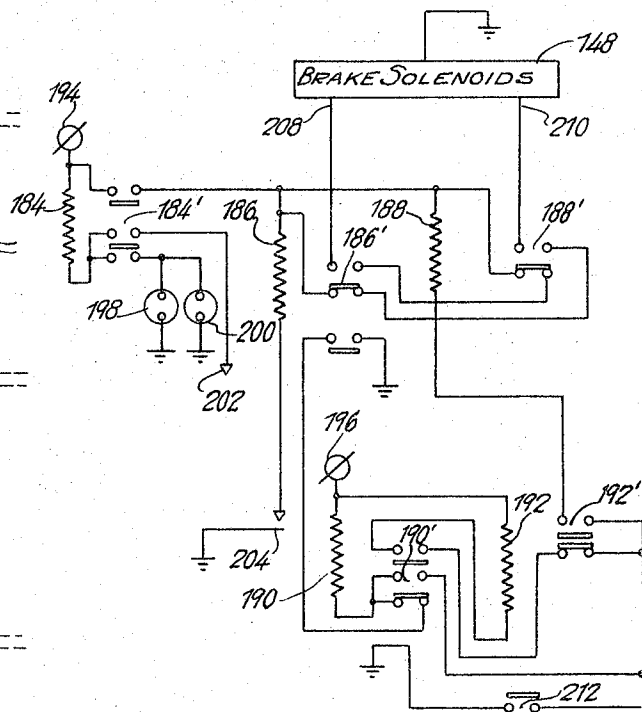
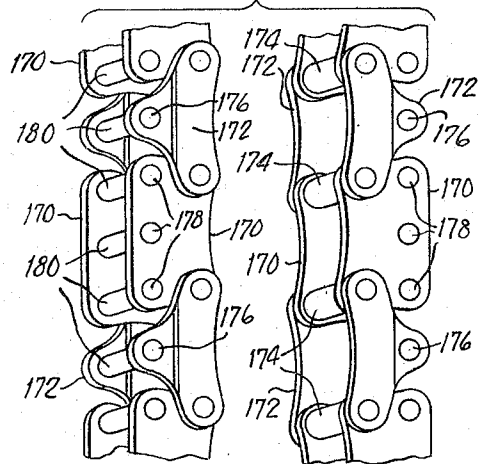


Fig. 13A.



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Fig. 17.

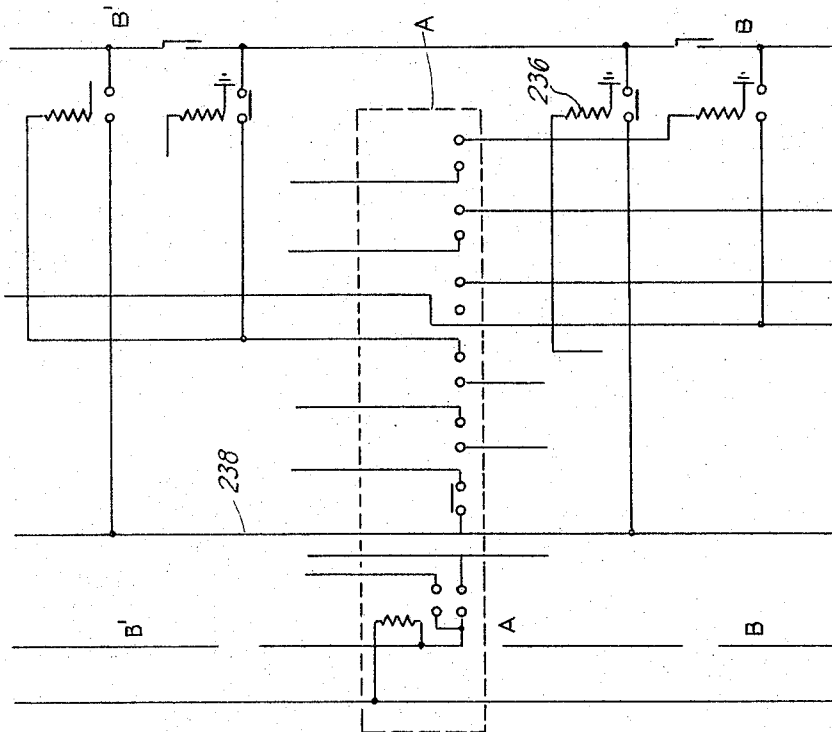
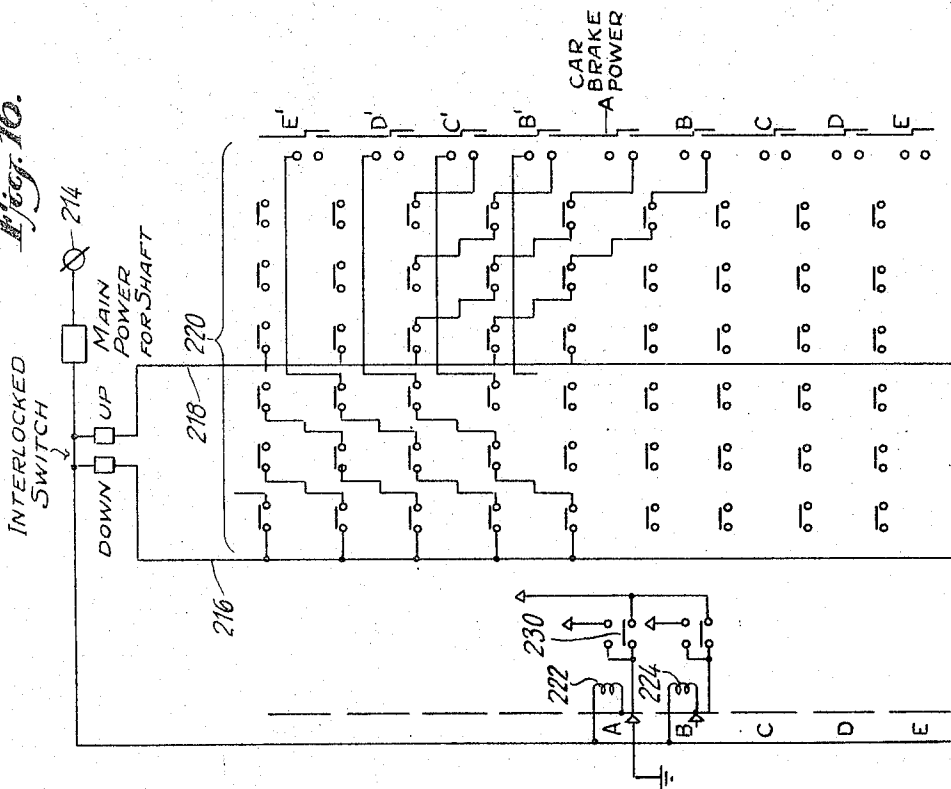


Fig. 16.



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ELEVATOR SYSTEM

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8 Claims. (Cl. 187-16)

This invention relates to elevator systems and more particularly it concerns an improved high speed elevator arrangement suitable for use in high buildings.

As building heights increase, their various service facilities, including, and especially, the elevator systems, become more and more burdensome. The elevator systems in high buildings present a particularly formidable problem, for during periods of high density traffic (e.g., morning and evening rush hours), a great number of people must be moved between the main floor and each of the various upper floors of the building within a very short period of time.

Conventional elevator arrangements handle these high density loads by providing a plurality of elevator shafts, each extending from the main floor to its own particular group of upper floors and each provided with its own single elevator car. This permits each group of floors to be serviced independently and simultaneously so that persons may be transported down from say the 60th floor in one shaft at the same time that others are being transported down from the 17th floor.

This multiple shaft arrangement, however, reaches a point of diminishing returns as building height increases.

This is because for each additional group of floors there must be provided an additional shaft extending down through all of the lower floors. As a result, the available occupancy space in each of the lower floors is diminished, so that eventually the increase in upper story space is more than offset by the corresponding decrease in lower story space.

One of the methods heretofore proposed for eliminating the above-described difficulty has been to provide a plurality of elevator cars in each shaft so that several floors could be serviced simultaneously from one shaft. However, in order for each car in a given shaft to reach the main floor, it is necessary to provide transfer arrangements at the tops and bottoms of the shafts so that one car upon completing its descent may be removed from a shaft so as to permit a subsequent car to complete its descent in the shaft.

The transferring of cars between shafts presents a further problem in that it requires each elevator car to be provided with its own self-contained power source or driving means so that it can be disconnected readily from one shaft and thereafter reconnected into another shaft. While elevator cars have been built with their own electrical drive motors, the weight of these motors and the space which they occupy severely reduces the efficiency of the elevator system.

All of the above difficulties have been eliminated by the arrangement of the present invention. According to the invention, multiple elevator shafts are provided, each containing a number of individually controllable cars. Stationary power sources are provided at various floors and these operate to drive mechanical power transmission means which extend up through each of the shafts. These stationary power sources may be constant speed induction or synchronous motors as opposed to the variable speed motors usually required for first class passenger service. By means of a novel coupling arrangement, each of the elevator cars in a common shaft is independently controllable and is readily disconnectable from the mechanical power transmission means for easy transfer from one shaft to another. The power sources therefore may be of the constant speed variety as opposed to the variable

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speed motors usually required for first class elevator service.

In one embodiment of the invention, there are provided a plurality of adjacent elevator shafts each having a chain loop extending longitudinally therethrough and driven continuously by means of motors mounted at various floors. The chain loops are specially shaped and constructed to form in each shaft, a pair of gear racks, one of which moves upwardly in the shaft, and the other of which moves downwardly. Each elevator car is provided with input pinion gears which mesh with these racks and which drive through associated epicyclic trains or differential gearing systems mounted within the cars. These differential systems operate drive pinion gears which in turn are meshed with stationary gear racks fixedly mounted on the sides of the shaft. By use of braking arrangements to control the rotation of selected portions of the differential gear systems, it is possible to obtain effective control of the movements of the cars within each shaft.

Transfer carriages are provided at the upper and lower ends of the elevator shafts and are mounted to move horizontally over the shafts. These transfer carriages are constructed to receive a car, to disconnect it from its elevator shaft and to transport the car to an adjacent shaft for movement therein. The transfer carriages are provided with wells in which are located stationary racks and a short chain loop. These racks and chain loops form extensions of the racks and chain loops in the shafts so that for each position of the transfer carriage, its wells, in effect form continuations of the shafts. Thus, an elevator at one end of its shaft can readily move into the transfer carriage. The carriage is then moved horizontally until the car is positioned over a different shaft whereupon it is released into the shaft to begin its journey toward the transfer carriage at the opposite end of the shaft.

According to a further feature of the present invention, each shaft chain loop is actually formed of a multiplicity of segment loops, each of which extends over a distance of a few floors. In order to provide a continuous chain loop effect, the various segment loops are driven in synchronism and are actually provided with inner and outer chain sections which overlap to a certain extent. This overlap, as well as the interconnection between successive segment loops, takes place at transfer stations located at selected floors. There are also provided, as will be described more specifically hereinafter, certain electrical control arrangements whereby the individual cars in each elevator shaft may be automatically braked with sufficient precision to come to an accurate stop at any designated floor. These arrangements, of course, permit the stopping of the car either by control within the car or by control at a given floor. Additional means are also provided for insuring that no car may approach an adjacent car closer than a certain distance.

There has thus been outlined rather broadly the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto. Those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized in a variety of ways for carrying out the several purposes of the invention. It is important, therefore, that the claims be regarded as including such equivalent ways as do not depart from the spirit and scope of the invention.

A specific application of the invention is shown in the

accompanying drawings and is described in the following portions of the specification. In the drawings:

FIG. 1 is a front elevational section view schematically illustrating an elevator system comprising a multiplicity of shafts and cars arranged according to the present invention;

FIG. 2 is a side elevational section view, partially broken away, and illustrating certain chain loops and their interconnected transfer stations along the elevator shafts of FIG. 1;

FIGS. 3a and 3b are front and rear elevational views, respectively, of the chain loop arrangement partially illustrated in FIG. 2;

FIG. 4 is an enlarged front elevational view of the tops of the elevator shafts shown in FIG. 1, and further showing an upper transfer carriage movable above the tops of these shafts;

FIG. 5 is a top plan view of FIG. 4;

FIG. 6 is a side elevational view of FIG. 4;

FIG. 7 is a perspective view of the portion of the elevator system which is shown in FIG. 4; and illustrates in greater detail the interconnection of various working elements in the elevator shafts and the transfer carriage;

FIG. 8 is a section view taken along lines 8—8 of FIG. 7;

FIG. 9 is a further section view taken along lines 9—9 of FIG. 7;

FIG. 10 is an enlarged front elevational view of the bottoms of the elevator shafts of FIG. 1 and further showing a lower transfer carriage movable under the bottoms of these shafts;

FIG. 11 is a fragmentary side elevational view of FIG. 10;

FIG. 12 is an enlarged bottom plan view looking up under one of the elevator cars of FIG. 1 and illustrating a drive mechanism for such car;

FIG. 13 is a front elevational view taken along lines 13—13 of FIG. 12;

FIG. 13a is a fragmentary perspective view illustrating the chain link construction used in the illustrative embodiment;

FIG. 14 is a further front elevational view of a typical elevator shaft, shown in schematic and illustrating the electrical control elements used in furnishing electrical control signals to the various cars moving in each elevator shaft;

FIG. 15 is an electrical circuit diagram schematically showing the electrical relays and connections carried by the individual elevator cars for controlling their movements;

FIG. 16 is an electrical schematic illustrating the connections along an elevator shaft used in preventing adjacent elevator cars from approaching one another too closely; and

FIG. 17 is an enlarged view showing a portion of the arrangement of FIG. 16.

In the elevator system illustrated in FIG. 1, there are provided three elevator shafts 20, 22 and 24 which extend vertically and in side by side relationship up through the several floors 26 of a building 28. Above the uppermost floor 26a and below the lowermost floor 26b are provided upper and lower transfer carriages 30 and 31 which ride horizontally along on carriage rails 32 positioned such that the transfer carriages may be aligned with any of the several shafts.

A plurality of elevator cars 34 are guided and driven within each of the elevator shafts by means of rack and pinion arrangements to be described more fully hereinafter. Power for driving the cars in each shaft is supplied from various stationary motors 36 mounted at selected floors immediately adjacent each shaft. These stationary motors together drive an overall continuous chain loop 38 which extends up through each shaft. As will be described in greater detail hereinafter, the chain loop is driven at constant speed and is in continuous mesh with

certain input pinion gears on the cars. The movements of the chain loop supplies mechanical power via the input pinion gears to the cars. By controlling the flow of this power within each car, it can be individually controlled to move or to remain stationary within its shaft.

The continuous chain loop 38 is actually of composite construction, being formed by individual segment loops 40 which extend between various transfer stations 42. As shown, the stationary motors are connected to the chain loops at these transfer stations.

FIGS. 2, 3a and 3b show in greater detail the construction of the segment loops 40 and the construction of the various transfer stations between the adjacent loops which provide a continuous overall chain loop effect. As shown in FIG. 2, the chain loops of each shaft are arranged to be mounted on a back wall 44 of the shaft. It will, of course, be apparent to those skilled in the art, that suitable arrangements may also be made for mounting the overall chain loop in operative arrangement along any of the other walls of the elevator shaft. Each transfer station 42 includes a plurality (preferably four) parallel drive axles 46 which extend through and are rotatably mounted on the back wall 44. Outside the wall there are provided a number of sprocket drive gears 48, each of equal size and each mounted on an associated one of the drive axles 46. One of the several synchronous drive motors 36 is also mounted behind the wall 44 at each transfer station 42 and is driveably connected via a worm and gear arrangement 50 to the sprocket drive gears 48, so that each of the gears is caused to turn under the influence of the drive motor 36. The opposite ends of each of the drive axles are fitted with an inner and an outer chain drive sprocket 52 and 54. The interconnections between the worm and gear arrangement 50 and the sprocket drive gears 48 is such that these gears are all driven in the same direction. By means of this arrangement all sprockets turn in the same direction.

As shown in the drawings, each segment loop 40 of the overall chain loop 38 is made up of an inner section 40a and an outer section 40b which engage, respectively, the inner and outer chain drive sprockets 52 and 54.

The inner and outer chain loop sections are mounted in staggered or overlapped arrangement. That is, the inner section 40a extends around the upper three drive sprockets 52 of a lower transfer station and around only the lower one drive sprocket 52 of the next higher transfer station. At the same time, outer section 40b extends around only the upper one drive sprocket 54 of a lower transfer station and around the lower three drive sprockets of the next higher transfer station. This gives an overlapping effect so that there will always be presented a flat exterior of at least one section of the chain segment loops at every point along each elevator shaft. This is important, for as will be described more fully hereinafter, the exterior of the chain loop 38 forms moving gear racks one side going up and the other coming down. The movement of these racks supplies the driving power for the elevator cars.

The pattern of chain arrangement described above is repeated for all transfer stations intermediate the uppermost and lowermost floors 26a and 26b. At these points, the chain arrangement is somewhat altered so that the movable transfer carriages may more easily be brought into operative relationship with the chain system. Thus, at the uppermost floor 26a there is provided an uppermost transfer station 42a having two inner chain sprockets 55 and 56 on corresponding upper and lower axles 58 and 60 and only one outer chain sprocket 62 on the lower axle 60. The inner chain section 40a extends up about the two inner chain sprockets 55 and 56 while the outer chain section 40b extends about the outer chain sprocket 62. Similarly, at the lowermost floor 26b there is provided a lowermost transfer station 42b of like construction.

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The construction of the upper transfer carriage 30 is shown more fully in FIGS. 4 and 5. In these figures, each of the elevator shafts 20, 22 and 24 is shown with the upper end of its respective chain loop 30 extending about the sprockets 55, 56 and 62 of its upper transfer station 42a. FIG. 4 additionally shows fixed shaft racks 64 fixed to and extending along the walls of each shaft. These shaft racks are engaged by the various elevator cars 34 and serve to provide guidance and traction so that the cars may be driven up and down within the shafts.

The upper carriage rails 32 extend horizontally above and on either side of each of the elevator shafts and provide tracks upon which the upper transfer carriage 31 rides. Immediately adjacent these rails there are provided carriage drive racks 66 which are engaged by drive pinions 67 on the upper transfer carriage for driving it from one position to another above the different shafts.

As shown in FIGS. 4 and 5, the upper transfer carriage is of open framework construction. It includes upper and lower longitudinal bars 68 and 70 on either side thereof and upper and lower transverse bars 72 and 74 at its ends and midpoint. Vertical bars 76 serve to space the upper and lower transverse and longitudinal bars. The longitudinal bars 68 and 70 are of sufficient length to extend over the width of two adjacent shafts while the transverse bars 72 and 74 are of sufficient length to extend across each shaft. This construction provides left and right car accommodating wells 78 and 80 into or out from which the elevator cars 34 may pass. Thus, when the upper transfer carriage 31 is in its rightward position, as shown, one elevator car (shown in phantom outline) may be discharged from the left well 78 into the middle elevator shaft 22 while a second car (also shown in phantom outline) is loaded into the right well 80 of the carriage from the right elevator shaft 24.

The upper transfer carriage 31 is provided with wheels 82 which ride the horizontal rails and guide the carriage in its movements over the elevator shafts. An electric carriage drive motor 84 is mounted on the carriage and operates through a worm drive 86 and a shaft 88 to turn the drive pinions 67 engaged in the carriage racks. By controlling the speed and direction of the carriage drive motor 84, the transfer carriage may be moved so that its wells 78 and 80 are accurately positioned over the different elevator shafts.

Each of the wells in the upper transfer carriage has fixedly mounted therein a plurality of well gear racks 92. These well gear racks are located to form extensions of the shaft racks 64 of the particular shaft over which the well of the transfer carriage happens to be positioned.

There are also mounted in each well of the upper transfer carriage upper and lower chain sprockets 94 and 96 about which a single section chain loop 98 extends. As shown in FIGS. 6-9, the lower chain sprocket 96 extends down below the level of the carriage rails 32 so as to be positioned at a short distance below the uppermost inner chain sprocket 56 of the uppermost transfer station 42a. The upper and lower chain sprockets 94 and 96 on the upper transfer carriage 30, as can be seen, are positioned in vertical alignment with the outer chain sprockets 54 and 62 of the various transfer stations 42 and 42a so that when a transfer carriage well is in position above a shaft its chain loop 98 forms a partial overlap with and a short extension of the chain loop 38 of the shaft.

It will be appreciated from the above that the wells 78 and 80 of the upper transfer carriage 30, together with their gear racks 92 and chain loops 98, in effect form extensions of the elevator shafts over which the wells are positioned. Thus by operating the chain loops in the transfer carriage in synchronism with the continuous chain loops in the associated shafts, elevator cars may be transferred between the shafts and the carriage simply by causing them to operate in their normal manner.

Various means may be provided for driving the carriage chain loops in synchronism with the chain loops of

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the shafts over which the carriage is positioned. One such means is shown in FIG. 7. Here the uppermost transfer station 42a of a shaft is shown with its drive motor 36 connected to drive the lower chain sprockets 56 and 61 of the station. Because of its connection to the inner section 40a of the associated segment loop 40, the upper sprocket 55 of the uppermost transfer station is driven along with the lower sprockets 56 and 62. The upper sprocket in turn is connected via an axle 100 to the input of a synchromesh mechanism 102. The output of this mechanism is adapted to be engaged by an input gear 104 on the transfer carriage when the particular well of the carriage comes into position over the elevator shaft. When this occurs, the input gear 104 is gradually brought up to speed and into synchronous rotation with the shaft chain loop 38.

The carriage input gear 104 is connected via a drive chain 106 to the upper chain sprocket 94 on the carriage. In this manner, the chain loop 98 on the transfer carriage is driven in synchronism with the shaft chain loop 38.

In certain situations, it may be desirable to provide means for raising and lowering the transfer carriage slightly with respect to its wheels so as to provide vertical disengagement of its gear racks and chain loop drive from the shaft racks and chain prior to any horizontal movement of the carriage. This, of course, may be done whether or not a car is in the carriage since no relative movements occur between the gear racks and chain loop.

FIGS. 10 and 11 illustrate the construction of the lower transfer carriage 30. This carriage is basically similar in construction and operation to the upper transfer carriage 31, the only differences being those which are peculiar to the nature of the location of the lower carriage. Thus, the lower carriage 31 is of frame construction with right and left adjacent car receiving wells 108 and 110 which fit under adjacent elevator shafts. The horizontal rails 32 for the lower carriage 31 are the same as for the upper carriage 30; and the lower carriage rides these rails on wheels 112 and is driven by a motor 114 which turns pinion gears 116 meshed with stationary gear racks 118 mounted alongside the rails 32. Fixed vertical gear racks 120 are provided in each well and located to come into alignment with the shaft racks and a synchromesh driven single section chain loop 122 is provided as in the upper carriage to form a partial overlap with and an extension of the chain loop 38 in the particular elevator shaft with which the well is aligned.

The lower transfer carriage 30 is, of course, of greater height than the upper carriage 31 for it must admit cars to a degree such that their upper ends clear the bottoms of the shafts for horizontal movement. Also, the synchromesh interconnection with the shaft chain loop is made at the upper end of the lower carriage rather than at its lower end as in the case of the upper transfer carriage.

FIG. 12 shows an elevator car drive mechanism by which power is appropriated from the continuous chain loop and is directed to drive the car within the elevator shaft. As described above, the continuous chain loop 38, which extends up through each elevator shaft along its back wall 44, is formed of a plurality of segment loops 40, each of which comprises two loop sections 40a and 40b in slightly staggered or overlapped arrangement. Also, as will be described more fully hereinafter, the individual segment loops 40 are of a special construction which form moving racks along their outer surfaces. The overall effect is to provide moving racks which extend the length of the shaft. As the segment loops rotate together in synchronism, the rack formed on one side thereof moves upwardly while the rack formed on the opposite side moves downwardly.

There are provided on each elevator car a pair of dual input pinion gears 130 each of which meshes with the outside rack arrangement on the opposite sides of the

chain loop 38. The dual configuration of the input pinion gears 130 permits independent engagement with the inner and outer sections 40a and 40b of the segment loops 40 forming the overall chain loop 38.

The input pinion gears 130 are connected respectively to first and second epicyclic trains or differential gear assemblies 132 and 134. Each differential gear assembly includes a rotatable planet carrier 136 on which planet gears 138 are mounted for rotation about axles disposed radially to the rotational axis of the carrier. Front and rear gears 140 and 142 are provided on opposite sides of the planet carrier 136 in coaxial alignment therewith. These front and rear gears are meshed with the planet gears 138 to complete the differential assembly.

Each front gear 140 is connected to rotate with an associated one of the dual input pinion gears 130. The two rear gears 142 are rotatably interconnected via an intermediate gear 144 mounted between the two differential mechanisms 132 and 134.

The planet carrier 136 of the first differential mechanism 132 is provided with a emergency brake 146 and an operating brake 148. The emergency brake 146 is mechanically biased to a normally engaged condition and is held in disengaged condition as by electrical solenoid means 150 and when all critical portions of the elevator system are operating properly. When a malfunction occurs, or when the car approaches another car in the shaft too closely, the emergency brake automatically becomes engaged to stop the car.

The operating brake 148 on the first differential assembly 132, also operates to control rotation of its planet carrier 136. This first operating brake 148 works in conjunction with a second operating brake 152 connected to the intermediate gear 144 to control car movements within the shaft in normal operation. The operating brakes are arranged such that the first brake 148 is normally in its engaged condition and the second brake 152 is normally in its released condition. This, as will become apparent hereinafter, is the braking arrangement which maintains the car stopped in the shaft. Thus, to move the car, the brakes must each be activated. This provides a measure of safety, for if power fails, the brakes will automatically revert to a condition whereby the car is stopped in the shaft. The brakes are all activated electrically as by solenoids. The electrical power to these solenoids is controlled by a special circuit to be described. The planet carrier 136 of the second differential assembly 134 is rotatably connected by means of a first shaft 154, a worm drive 156, a second shaft 158, a pair of spiral gear arrangements 160 and a pair of output shafts 162 to drive four output pinion gears 164 which are meshed with the fixed shaft racks 64. Thus, when the planet carrier of the second differential assembly 134 turns, it causes the output pinion gears 164 to turn so as to drive the car up or down in the shaft. It will be noted that the worm drive provides a degree of irreversibility to the flow of power from the chain drive to the output pinion gears and thus acts to prevent the car from sliding down the shaft when power is cut off. However, as will be seen hereinafter, the dual differential arrangement inherently prevents any such inadvertent slippage.

Operation of the car drive mechanism will now be described. As stated above, the chain loop 38 in rotating, presents to the two input pinion gears 130 of each car, the effect of a pair of moving gear racks, one of which is moving upwardly in the shaft, and the other of which is moving downwardly. It will be assumed for purposes of the present discussion that the chain loop 38 is moving such that the side engaging the input pinion gear of the first differential assembly 132 is moving downwardly while the side engaging the input pinion gear of the second differential assembly 134 is moving upwardly. Since the input pinion gears are engaged by the chain loop on opposite sides, they are thus caused to rotate in the same direction, that is, clockwise looking at the rear wall 44 of the elevator shaft.

In order to cause the elevator car to move, the second operating brake 152 is engaged thus preventing rotation of the intermediate gear 144; and the first operating brake 148 is disengaged, thus releasing the planet carrier 136 of the first differential assembly 134. As a result, the rear gear 142 of the second differential mechanism is precluded from rotation so that the second input pinion rotates to drive the planet carrier of the second differential assembly 132 and this in turn operates to drive the car up or down depending upon the sense of the helical teeth on the worm and spiral gear drives 156 and 160.

While the car is thus being driven, the input pinion gear 130 to the first differential assembly 132 is caused to rotate by a greater or less amount than the input pinion to the second differential assembly 134, depending upon the direction in which the car is moving in the shaft. This is because the rate of rotation of the input pinions is dependent upon the relative velocities of the car and the side of the chain loop engaged by the particular pinion. Thus as a car begins to move upwardly in the shaft, the pinion engaged in the upwardly moving side of the chain loop begins to turn more slowly while the pinion engaged with the downwardly moving side of the loop begins to turn more rapidly.

It will be seen that while the car is driving, the rear gear 142 of the first differential assembly 132 is prevented from rotation by virtue of the engagement of the second operating brake 152 acting on the intermediate gear 144. However, during this time, the first operating brake 148 is released and allows its planet carrier to rotate so that the rotation of the input pinion merely causes the planet carrier of the first differential assembly to turn in accordance therewith.

When the elevator car is fully stopped, the condition of the two operating brakes is merely reversed; that is, the first operating brake 148 which is associated with the planet carrier of the first differential is fully engaged while the second operating brake 152, which is associated with the intermediate gear 144 is fully released. In this condition the rear gears of the two differential assemblies rotate in synchronism, and at the same time, the planet carrier 136 of the first differential assembly 132 is prevented from rotation. Consequently, the clockwise rotation of the input pinion to the first differential assembly 132 tends to produce counterclockwise rotation of the mechanism's rear gear. Meanwhile the moving chain loop causes the input pinion and front gear 140 of the second differential assembly 134 to turn at the same speed in a clockwise direction. The equal speed of the oppositely rotating front and rear gears 140 and 142 of the second differential assembly 134 produces a nullifying effect upon its planet carrier 136 and hence the planet carrier does not rotate and the car remains stationary in the shaft even while the chain loop continues to rotate.

It will be noted that in the stopped condition as above described, the chain loop may rotate at any speed without the car being moved, since equal and opposite effects are always produced on the opposite sides of the planet carrier of the second differential mechanism.

The dual differential and dual operating brake arrangement described above is especially advantageous in providing efficient starts and stops by means of power feedback from opposite sides of the chain loop. It will be appreciated that while one side of the chain loop travels upwardly at a constant speed in the shaft and the opposite side of the loop travels downwardly at the same speed, these speeds are different relative to a moving elevator car. Thus, for example, where a car is moving upwardly, and the gearing is chosen so that the car rises at one half the velocity of the upward moving side of the chain loop, then, with respect to the car, the downwardly moving side of the chain loop moves at three times the velocity of the upwardly moving side. Accordingly, for the above described case, the input pinion gear of the first differential assembly 132 rotates at three

times the speed of the input pinion gear of the second differential assembly 134. As the operating brakes are actuated power from the downwardly moving side of the chain loop is directed through the first differential assembly to the second differential where it acts in opposition to the upward car movement.

In order to cause the car to move in the opposite direction in the shaft, the direction of chain loop rotation can be reversed, although in most installations, the car would travel upwardly on one shaft and then be transferred to a parallel shaft whose chain loop is rotating in the opposite direction. In any event it will be noted that when the operating brakes are in their stop condition equal and opposite effects are produced on the opposite sides of the planet carrier of the first differential mechanism so that the car may remain stationary whether the chain loop continues to rotate or is stopped.

Because of the dual differential arrangement, the mechanical power delivered by the continuous chain loop may be appropriated or not by the various cars simply by controlling their operating brakes. Further, the brakes on the cars consume only a minimal amount of energy in going into and out of engagement since they operate on intermediate portions of the differential system and hence enjoy the benefits of large mechanical advantages. They do not, of course, use any energy while the car is stopped or while it is at full speed. It will be appreciated also that the positive interconnection between the differential gearing and the chain loop permits accurate and non-oscillatory control of the car's position such that it can quickly and accurately be brought to a complete stop at a given floor. The elevator arrangement as described can be expanded to include several shafts and the traffic patterns among the shafts can be arranged according to the immediate load situation. Thus, for the morning rush hour where maximum traffic is going up, the chain loops in the right and left elevator shafts would be driven in a direction for moving the cars upward in these shafts while the chain loop in the middle shaft would be driven in the opposite direction so that its cars would be moved downwardly. Also, it is possible to drive the central shaft chain loop at a higher speed so that a greater number of empty cars may be sent down through this one shaft to provide a continuous supply of cars for the outer shafts.

When an elevator car reaches the end of a shaft, it approaches an aligned well of one of the transfer carriages which, as described above, is provided with its own fixed gear racks and chain-loop forming continuous or extensions of their counterparts in the shaft. Consequently, the elevator car may be driven completely out of the shaft and into the transfer carriage. The chain loop 98 in the carriage is stopped, thus bringing the car to a stop therein. The carriage is then driven horizontally to bring its car bearing well into alignment with another elevator shaft whose chain loop is rotating in a direction opposite from that which the loop of the first shaft was turning. Through the previously described synchronism arrangement, the transfer carriage chain loop is also driven in this direction; and the car, when put into operation, begins its journey through this other shaft.

The chain link construction of the segment loops 40, which form the overall loop 38, is shown most fully in FIGS. 13 and 13a. As illustrated therein, each loop is formed of inner and outer chain plates 170 and 172, pinned together in alternate sequence by means of sprocket pins 174. Each sprocket pin extends over a distance at least as great as the thickness of the various chain drive sprockets; and it pins together an inner and an outer chain plate 172 and 174 at each end thereof. The distance between the pin holes in the plates and the sprocket pin diameters are chosen such that the pins mesh easily in the teeth of the chain sprockets.

Each outer chain plate 172 is provided additionally with a single rack pin hole 176 while each inner plate 170 has three rack pin holes 178. Rack pins 180 extend

between corresponding holes in the inner and outer plates in a manner similar to the sprocket pins 174. The rack pins 180 and holes 176-178 are dimensioned and spaced to simulate a gear rack in the flat region of the segment loops 40 between their sprockets 54-62. It will be noted that the chain is arranged with twice as many rack pins as sprocket pins so that for each increment of chain sprocket rotation there will be produced a double amount of input pinion contact. Also, the smaller pitch which results from the increased number of rack pins serves to obviate the secant relationship problem which occurs where a sprocket chain is used as a rack.

The electrical control arrangement for regulating the movements of the various cars within the shafts will now be described. Within each shaft, and along one or more walls thereof, are provided groups of electrically conductive strips or shaft contacts 182. Certain of these contacts are maintained at ground potential while others are maintained at some finite voltage. Still others are switchable from an open circuit condition to a ground connection or to a finite voltage connection by pressing appropriate control buttons (not shown) on each floor. Since trolley type contacts for controlling elevator cars are well known to those skilled in the art and since many different arrangements of such contacts may be provided to meet the particular traffic pattern used, it will merely be stated that their extent, location, and potentials will be arranged to supply the necessary electrical signals to operate the control circuits hereinafter described when the elevator car being controlled is at certain positions with respect to the various floors.

Also, as is familiar to those skilled in the art, each elevator car is provided with trolley followers which ride upon the shaft contacts 182 and make or break circuit connections through these contacts.

Within each elevator car there is provided an electrical control circuit such as shown in FIG. 15. This circuit includes first, second, third, fourth and fifth relays, designated respectively as 184, 186, 188, 190 and 192. Each relay control is an associated one or more movable switch elements 184', 186', 188', 190' and 192', which make or break various circuit connections according to their position as controlled by the relays. When the relays are deenergized, the switch elements revert to the positions shown in the diagram.

Finite voltage sources are shown schematically at 194 and 196. Actually, these sources are located in the building itself and their potentials are brought into the cars via trolley contacts which extend the length of the shafts. Similarly, the ground connections shown in the drawing are in actuality made through the trolley contacts in the elevator shafts.

A pair of normally opened push button switches 198 and 200 are arranged in parallel between ground potential and a pair of switch contacts to one side of the first relay 184. One of the buttons is located at the particular floor at which the elevator is to be stopped; and its closing actually connects certain trolley contacts along the shaft and in the region of the floor to ground potential. The other button is on the car itself and its closing makes connection to a shaft trolley contact which is always at ground potential.

The closing of the contacts of either button causes the first relay 184 to be energized so that its switch elements 184' move to their upper position. The lowermost of these elements is of the "make-before-break" variety and is movable to close a connection from the relay to a constant source of ground potential 202, so that when the relay is energized by pushing one of the buttons 198 or 200, it becomes electrically locked in this state via this other ground connection. At the same time, the uppermost of these switch elements closes a connection from the voltage source 194 to one end of the second and third relays 186 and 188, and to one side of one of the pairs of switches contacts controlled by these relays.

The second relay 186 is connectable through a "chopper" switch 204 to ground potential. Actually this "chopper" switch is formed of a series of conductive trolley contact segments arranged in a line and leading toward the floor level at which the car is to be stopped. These segments are shown at 206 in FIG. 14. It will be noted that their spacing follows a particular pattern, generally decreasing toward the floor at which a car is to be stopped. These segments 206 are followed by a trolley element in the car, so that as the car proceeds toward the floor, the chopper switch is closed and opened so that the second relay 186 becomes energized periodically; the periodicity of energization being a function of both the car's velocity and its distance from the floor.

Each time the second relay 186 becomes energized it raises a "break-before-make" switch element 186' which in turn makes connection, as long as the third relay 188 is deenergized, between the voltage source 194 and a set brake terminal 208. The set brake terminal supplies current to a solenoid which actuates the operating brakes 148 and 152 in the car from their normal to their actuated condition for stopping the car. The duration over which the set brake terminal 208 is connected governs the degree to which the brakes are actuated and hence controls the rapidity with which the car is brought to a stop.

The third relay 188 is similarly provided with a "break-before-make" type switch element 188' and associated contacts arranged such that when the relay is energized, they make connection so long as the second relay 186 is deenergized, between the voltage source 194 and a release brake terminal 210. The release brake terminal 210 is also connected to a solenoid which is arranged to deactuate the brakes when it becomes energized.

It will be seen from the above, that the net stopping force or car deceleration is proportional to the relative durations during which the set brake and release brake terminals 208 and 210 are energized. Also, it can be seen that the set brake terminal 208 is energized only when the second relay 186 is energized and the third relay 188 is deenergized. Similarly, the release brake terminal 210 is energized only when the second relay 186 is deenergized and the third relay 188 is energized. When the second and third relays are in any other relative arrangement, the car brakes remain in their last given state.

The first time that the second relay 186 becomes energized a lower switch element 186' thereon closes a ground connection to the fourth relay 190 thus energizing it. This fourth relay in turn operates its own "make-before-break" type switch element 190' which maintains a separate connection to ground, thus locking the fourth relay in its energized state. This action also causes another switch element 190' to close a ground connection to the fifth relay 192. This last ground connection is made via a pair of contacts whose opening and closing is made by a "make-before-break" type switch element 192' controlled by the fifth relay itself. As a result of this, the fifth relay, upon becoming energized, breaks its own ground connection and thus becomes deenergized; and when deenergized, remakes its connection to again become energized. The action is similar to an electrical buzzer or vibrator, with the relay contacts in continuous back and forth motion.

The vibratory action of the fifth relay 192 causes its switch elements 192' to successively open and close a ground connection to the third relay thus causing it to become energized and deenergized at the same rate.

The action of stopping the car at a given floor is as follows: The stop button 198 or 200 is pushed and the first relay 184 is energized. The car continues until it encounters the first of the trolley segments 206. Thereupon, the second relay 186 becomes energized for a short time, causing a signal to appear at the set brake terminal 208 for stopping the car. At the same time, the fourth relay 190 becomes locked in its energized state. This

causes the fifth and consequently the third relay, 192 and 188, to undergo vibratory type action. If as a result of the initial braking action, the car decelerates too rapidly, the time until the next trolley segment is contacted is lengthened, thus allowing a greater number of vibrations or release brake signals to occur. This reduces the amount of the breaking action and consequently reduces the amount of car deceleration. If, on the other hand, the car deceleration is not fast enough, the second relay will become reenergized before a great number of release brake signals occurs.

When the car reaches the level of the floor at which it is to be stopped, a master switch 212 is opened, thus deenergizing all of the relays.

FIGS. 16 and 17 illustrate in schematic form the circuits which operate to prevent adjacent elevator cars in each shaft from approaching one another too closely. The present arrangement maintains adjacent cars at a distance of at least three floors; although it will be readily recognized by those skilled in the art that the same arrangement can easily be extended to different limits. As shown in FIG. 16, there is provided a voltage source 214 to which is connected an electrically conductive down-riser 216 and a similar up-riser 218, each of which extends vertically throughout the elevator shaft as trolley type shaft contacts. At each floor in the shaft, there are provided a group of six relay switch elements 220 which are operated together from one of two common floor relays 222 and 224, located at each floor. The operating relays for only one of the floors are shown in FIG. 16. The first floor relay 222 is operated in response to the presence, at the floor level, of upwardly moving elevator cars, while the other floor relay is operated in response to the presence of downwardly moving cars. Each floor relay is connected between a riser 216 or 218 which extends continuously through the shaft from the voltage source 214, and one of a series of terminal plates 228, each of which runs along the shaft between adjacent floors. When an elevator car comes into position at a particular terminal plate, it bridges a connection which establishes ground potential at the plate. This produces energization of one of the floor relays 222 or 224 depending on whether the car is moving up or down in the shaft. The relay in turn moves a double throw switch element 230 and provides electrical connection to a supervision circuit (not shown). This supervision circuit indicates at a remote point which floor the elevator car happens to be located. The movement of the switch element 230 also breaks a circuit connection to a slow operating power shut off (not shown) which, in the event that the relay should fail, acts shortly thereafter to cut off brake power so as effectively to stop all of the elevator cars in the shaft.

When a floor relay becomes energized it additionally causes the group 220 of six switch elements at the particular floor to break their respective connections. As shown in the schematic circuit diagram, each of the switch contacts on each floor are connected in a separate series circuit, with similar switch contacts of two adjacent floors. Each of the switch contacts are normally closed, so that when any floor relay becomes energized, the opening of its associated group of switch contacts breaks a connection in all of the series circuits which extend to each of the adjacent three higher and the adjacent three lower floors. These series circuits each extend from the vertical risers 232 and 234 and through the switch contacts 220 to a corresponding terminal plate relay 236 (FIG. 17). This terminal plate relay, when energized, makes a connection between a third riser 238 and the terminal plate 228 which corresponds thereto. When a connection between the third riser 238 and the terminal plate is broken by the energization of a floor relay, any car in contact with the plate is deprived of a necessary ground connection. Accordingly, the car brakes revert to their deactuated condition and the car is stopped until the terminal plate is reconnected to the third riser 226.

Since the terminal plate is connectable to the third riser 226 only through a series of three switch contacts on each of three adjacent floors, it will be seen that unless there is no car present at any of these floors to energize a relay which opens one of these switch contacts, the terminal plate will not be connected to the third riser and the car cannot move in the shaft. Thus there is provided an effective arrangement for preventing adjacent cars in a given shaft from approaching each other too closely.

Having thus described my invention with particular reference to the preferred form thereof, it will be obvious to those skilled in the art to which the invention pertains, after understanding my invention, that various changes and modifications may be made therein without departing from the spirit and scope of my invention, as defined by the claims appended thereto.

What is claimed as new and desired to be secured by Letters Patent is:

1. In an elevator system, means defining a vertical elevator shaft, at least one gear rack extending up through said shaft, a source of continuous rotary power situated at a fixed position along said shaft, a chain loop extending along the length of said shaft and connected to be rotated by said power source, a plurality of elevator cars arranged to move along said shaft, each of said cars having pinion gear means rotatably mounted thereon and positioned to mesh with said gear rack, at least one input sprocket located on each car, said input sprockets being positioned to engage and become rotated by movements of said chain, and an epicyclic train mounted on each car, each epicyclic train having an input section, an output section and a control section, said input section being rotatably connected to said input sprocket, said output section being rotatably connected to said pinion gear means, and said control section being connected to controllable braking means on said car, whereby operation of said braking means effectively controls the direction of power from said chain loop to said pinion gear means for driving each car along said shaft.

2. In an elevator system, means defining a plurality of elevator shafts extending vertically in side by side relation, each elevator shaft being provided with a gear extending therealong, continuously operating power supply means situated at fixed positions along said shafts, a chain loop extending along each shaft and connected to be rotated by said power supply means, a plurality of elevator cars arranged to drive along each of said shafts, each of said cars having pinion gears rotatably mounted thereon and positioned to mesh with said shaft gear racks, at least one input sprocket located on each car, said input sprockets being positioned to engage said chain loops along their outer surfaces, control means associated with each car each said control means being interposed between the input sprocket and the pinion gear means of its respective car and further being independently operable for controlling the transmission of rotary power from said input sprocket to said pinion gear means, and horizontally movable transfer carriages arranged to move above and below said shafts, respectively, from a position of alignment with a corresponding end of another shaft, each said transfer carriage being constructed to accommodate cars emerging from the ends of said shafts for delivering same to corresponding ends of other shafts, each transfer carriage having gear racks and a chain loop forming continuations, respectively, of the gear rack and chain loop of each shaft with which it comes into alignment.

3. In an elevator system, means defining a vertical elevator shaft, at least one gear rack extending up through said shaft, a source of continuous rotary power situated at a fixed position along said shaft, a chain loop extending along the length of said shaft and connected to be rotated by said power source, a plurality of elevator cars arranged to move along said shaft, each of said cars having pinion gear means rotatably mounted thereon and positioned to mesh with said gear rack, a pair of input sprockets lo-

cated on each car, said sprockets being positioned to engage opposite sides of said chain loop respectively and to become rotated by movements of said chain, a pair of epicyclic trains mounted on each car, each said train having an input section, an output section and a control section, each input section being connected to receive rotary power from a respective one of said sprockets, said control sections being rotatably interconnected, means rotatably interconnecting the output section of one train to the pinion gear means of the car, first controllable braking means operative to control rotation of the output section of the other train and second controllable braking means operative to control rotation of said control sections, said first and second braking means being alternately operative to provide dynamic control of car movements within said shaft.

4. In an elevator system, a plurality of vertical elevator shafts positioned in side by side relationship, at least one gear rack extending up through each shaft, a source of continuous rotary power situated at a fixed position along each shaft, a chain loop extending along the length of each shaft and connected to be rotated by said power source, a plurality of elevator cars arranged to move along each shaft, each of said cars having pinion gear means rotatably mounted thereon and positioned to mesh with said gear rack, a pair of input sprockets located on each car, said sprockets being positioned to engage opposite sides of said chain loop respectively and to become rotated by movements of said chain, a pair of epicyclic trains mounted on each car, each said train having an input section, an output section and a control section, each input section being connected to receive rotary power from a respective one of said sprockets, said control sections being rotatably interconnected, means rotatably interconnecting the output section of one train to the pinion gear means of the car, first controllable braking means operative to control rotation of the output section of the other train and second controllable braking means operative to control rotation of said control sections, said first and second braking means being alternately operative to provide dynamic control of car movements within said shaft, and horizontally movable transfer carriages arranged to move above and below said shafts, respectively, from a position of alignment with one end of one shaft to a position of alignment with a corresponding end of another shaft, each said transfer carriage being constructed to accommodate cars emerging from the ends of said shafts for delivering same to corresponding ends of other shafts, each transfer carriage having gear racks and a chain loop forming continuations, respectively, of the gear rack and chain loop of each shaft with which it comes into alignment.

5. An elevator system as in claim 4 wherein each of said controllable braking means includes a mechanical brake biased to one state an electrically operated solenoid effective when energized to urge its brake toward its opposite state, electrical trolley lines along said shafts to supply electrical power to said solenoids, said electrical trolley lines including a plurality of vertically spaced constructive elements along said shafts, timing means located in each elevator car and comparison means operative to control the degree of actuation of said solenoids in response to the relationship the timing signals from said timing means and signals obtained by the passage of the car by each of said conductive elements.

6. In an elevator system, means defining an elevator shaft, a source of continuous mechanical power situated at a fixed position along said shaft, mechanical power transmission means having oppositely moving portions extending along said shaft and connected to receive mechanical power from said source, a plurality of elevator cars arranged to drive along said shaft, first and second coupling means mounted for movement on each car and engaged respectively with said oppositely moving portions of said mechanical power transmission means, means on each car for causing the car to be driven by mechanical power supplied through one of its said coupling means,

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motion reversing means mounted on each car and means on each car for interconnecting said first and second coupling means through said motion reversing means to maintain said car in a fixed position within said shaft while said mechanical power transmission means continues to operate.

7. An elevator system as in claim 6 wherein said means for causing the car to be driven includes a drive pinion on said car engaged on a rack fixed along said shaft and clutch means interconnecting said one coupling means with said drive pinion.

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8. An elevator system as in claim 6 wherein said motion reversing means comprises an epicyclic train.

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