The invention relates to safety systems and particularly to safety systems for elevators.

In elevator operation, when the elevator car, during its descent, is brought to an emergency stop by the operation of safety apparatus, such as car safety brakes or car buffer, the stop may occur under such conditions as will result in the car being retarded at a rate considerably in excess of gravity. Such a stop may cause considerable discomfort or possible injury to the occupants of the car, owing to the abruptness with which the car comes to rest. Furthermore, the counterweight will slow down at a lower rate than the car under such conditions and, therefore, will continue its upward movement after the car comes to rest. This continued upward movement of the counterweight after the car has come to rest may occur also as a result of other conditions under which the emergency stop occurs. Whenever such continued upward movement of the counterweight takes place, slack will develop in the hoisting ropes, permitting the counterweight, upon coming to rest, to fall back. The counterweight, in falling, may develop considerable kinetic energy by the time that the slack developed has been taken up. As this kinetic energy is transmitted to the hoisting ropes at the instant they become taut, excessive and dangerous stresses may result. Furthermore, this may result in the elevator car being jerked upwardly and, as a consequence, in the occupants of the car being subjected to considerable shock if not actual injury.

When the counterweight, during its descent, is brought to an emergency stop, the stop may occur under such conditions that the elevator car slows down more slowly than the counterweight. In such event, the elevator car will continue its upward movement after the counterweight comes to rest and thereafter fall back. Should the car safety brakes not act to stop the falling car before the slack developed in the hoisting ropes is taken up, the car may come to such a sudden stop as to cause serious stresses and shock or injury to its occupants.

Emergency stops also may occur under such conditions, and with the moving bodies at such positions in the hatchway, that the ascending body may crash into the overhead work. This will not only cause damage to various parts of the elevator installation but also, in the event that the elevator car is the ascending body, may result in shock or injury to the occupants of the car.

The object of the present invention is to cause emergency stops to be effected in such manner that the danger of shock or injury to the occupants of the elevator car and the possibility of damage to the elevator installation is minimized.

One feature of the invention resides in preventing excessive retardation of the descending body of an elevator system during an emergency stop.

Another feature of the invention is to prevent the continued ascent of the ascending body after the descending body has come to rest.

Other features and advantages will become apparent from the following description and appended claims.

The invention contemplates arranging the tensioning sheave for the compensating ropes in such manner that its upward movement is prevented. Thus the elevator car, counterweight and roping are caused to function as a closed system during emergency stops. When an emergency stop occurs, therefore, not only are all the elements of this closed system retarded as a unit but the forces exerted on both the car and the counterweight sides act together on the total mass of the system to effect the retarding action.

In carrying out the invention, according to the preferred arrangement, the tensioning sheave for the compensating ropes is permitted freedom of movement in the down direction and a limited movement in the up direction for the purpose of taking care of changes in the length of the elevator roping such as might be caused by temperature
or humidity variations or stretch of the ropes.

In the drawings:

Figure 1 is a schematic representation of an elevator system embodying a suitable arrangement for preventing more than a limited upward movement of the tensioning sheave for the compensating ropes;

Figure 2 is a view of a releasing carrier, this view being in partial section, taken along line 2—2 of Figure 1;

Figure 3 is a view of a car safety brake, this view being taken along line 3—3 of Figure 1;

Figure 4 is another view of the car safety brake shown in Figure 3, this view being in partial section, taken along line 4—4 of Figure 1;

Figure 5 is a view in partial section taken along line 5—5 of Figure 4;

Figure 6 is a view in front elevation of the compensating rope tensioning sheave arrangement shown in Figure 1, parts being shown in section;

Figure 7 is a view of the arrangement shown in Figure 6, taken along line 7—7 of Figure 1, parts being broken away;

Figure 8 is an enlarged fragmental detail of one of the paws shown in Figure 6;

Figure 9 is a view similar to Figure 7 of another arrangement for preventing more than a limited upward movement of the tensioning sheave for the compensating ropes;

Figure 10 is a top view of the arrangement shown in Figure 9, with parts shown in section;

Figure 11 is a view in section taken along line 11—11 of Figure 10;

Figure 12 is a view in section, taken along line 12—12 of Figure 11; and

Figure 13 is a diagrammatic representation of an elevator system employed in explaining the invention.

Referring to Figure 1, the elevator car 20 and counterweight 21 are raised and lowered by means of the hoisting motor 22. An electromagnetic brake 23 is provided for bringing the hoisting motor, and therefore the car and counterweight, to a stop. The hoisting ropes 24 for the car and counterweight extend from the top of the elevator car over the hoisting sheave 25 on the motor shaft to the top of the counterweight. Compensating ropes 26 extend downward from the bottom of the counterweight, around the tensioning sheave 27 in the elevator pit, and upwardly from this sheave to the bottom of the elevator car. Suitable arrangements for preventing more than a limited upward movement of the tensioning sheave will be described later. Guide shoes 28 are provided for the elevator car and co-operate with the guide rails 30 to guide the car in its movement up and down the hatchway. Similarly, guide shoes 31 are provided for the counterweight and cooperate with the guide rails 32 to guide the counterweight in its movement up and down the hatchway.

The buffer for the elevator car is positioned in the elevator pit but is not shown in Figure 1 as it would appear in front of the tensioning sheave 27 and would thus tend to obscure the arrangement of this portion of the elevator system. This buffer, however, is shown in Figure 7, being illustrated as an oil buffer and designated as a whole by the numeral 33. The buffer 34 for the counterweight is shown in Figure 1 and is illustrated as an oil buffer and as suspended from the counterweight. The bumper 29 for the counterweight buffer is indicated in Figure 7.

Car safety brakes are indicated by numerals 35 and 36 and are illustrated as supported by the safety plank 37 of the car framework. These safety brakes are arranged to be operated in the event that the elevator car overspeeds by a certain amount during its descent, this operation being effected by means of the governor 38. A plunk switch 39 is also supported by the safety plank 37 and is arranged to be operated when the safety brakes are applied. The governor is driven by the elevator car acting through the governor rope 40. The governor rope is attached to the arm 41 of a bell crank lever 42 pivoted on the car framework, with the other arm 43 of the lever attached to a releasing carrier 44, such arrangement being suitable for the type of safety brake chosen for purposes of description. The governor rope extends from its point of attachment around the governor sheave 45 and thence around a tensioning sheave 46 in the elevator pit. This tensioning sheave is provided with a tensioning weight 47 mounted in guides 19.

In causing the operation of the safety brakes, the governor acts through a pair of jaws 48 and 50. Jaw 48 is arranged on one side of the governor rope, being pivotally mounted in a bracket 49. Jaw 50 is arranged on the opposite side of the governor rope and is geared to jaw 48. Jaw 50 is pivotally mounted on a pin extending through the yoked end of rod 51. Rod 51 is slidable mounted in a guide support 52 and is provided with a spring 53. Jaw 48 is formed with an extension 54 to which a link 55 of the governor is operatively attached. A spring pressed latch 56 engages the extension 54 to maintain the jaws in the position illustrated during normal operation of the elevator car. Should a predetermined overspeed occur during descent of the elevator car, however, the governor acts through link 55 to overcome the latch 56, thus effecting the release of the jaws 48 and 50. These jaws fall under the influence of gravity to grip the governor rope with a pressure determined by the force of spring 53. The motion of the
governor rope is thus retarded, causing movement of lever 42 about its pivot to effect the operation of the safety brakes, as will be explained later.

As shown in Figure 2, the lever 42 is pivoted on a rod 57 supported by channel members 58 of the car framework. Arm 43 of lever 42 is secured to the lock bar 60 of the releasing carrier 44 as by a screw 59. This bar is carried by the releasing carrier bracket 61 secured to one of the channel members. A boss 62 is formed on one side of the lock bar 60. A jaw 63 is yieldingly maintained in a recess 64, formed in boss 62, by means of the spring 65. This spring is arranged on a bolt 66 extending through an aperture in the jaw 63, a slot in the lock bar 60 and through the bracket and the channel to which the bracket is secured. During normal operation of the car, the jaw 63 is maintained in the recess 64 of the lock bar to maintain lever 42 in the position shown in Figure 1, in which position the safety brakes are not operated. Upon the gripping of the governor rope with the car descending, however, the lever 42 is swung clockwise about its pivot to cause the operation of the safety brakes, the lever being released by the lock bar 60 moving to the right in Figure 2, forcing the jaw 63 out of recess 64 against the force of spring 65.

The operation of the safety brakes by the above described movement of the lever 42 is effected through a lift rod 67. This rod is connected at its upper end to arm 41 of lever 42 and is pivotally connected at its lower end to the operating lever 68 of safety brake 35. The operating lever is keyed to a rock shaft 69, this shaft extending across the car to safety brake 36 and being supported in bearings 70 formed in the safety brake housings 71. An operating lever 72 for safety brake 36 is keyed to shaft 69 at the end opposite to that in which the operating lever for safety brake 35 is secured.

In order that one of the advantages of the invention may be readily understood, the safety brakes have been illustrated as of the type which may be released by upward movement of the car. These safety brakes are of similar construction and, therefore, only one of them, namely, safety brake 35, will be described. The construction of this safety brake is illustrated in Figures 3, 4 and 5.

Within the housing 71 of safety brake 35 are provided a pair of jaw members 73 and 74. These jaw members are pivotally mounted on a vertical shaft 75 secured to the housing and, by a nut 76, the jaw members being retained on the shaft as by a nut 77. A wedge 78 is carried by the portion of jaw member 73 opposite the guide rail 30, being supported at the bottom by a bracket 80 secured to the jaw member and being retained against the jaw member at the top by a stop plate 81 secured to the housing 71 and extending into a recess 82 formed in the wedge. The wedge is free to swivel with respect to the jaw member, the bearing surfaces of the wedge and jaw member being semi-cylindrical, as indicated at 83, to permit this movement. The inclined surface of the wedge faces the guide rail and is formed at its lower end with a depression 84 to conform to the surface of the safety brake operating roller 85. This roller is carried by a frame 86 pivotally mounted on a boss 87 formed on the end of lever 68 as by screws 88. One of these screws also serves to connect the lift rod 67 to lever 68. The upper surface of boss 87 is abutted by roller 85, this surface being curved and concentric with the axis of pivot screws 88 so as to permit the roller to roll on this surface as the frame 86 swings on its pivot. When the safety brake is not operated, the lever 68 is supported by the bracket 80, this bracket being formed with a hooked portion 90 upon which the boss 87 rests. A bracket 91 is secured to the under surface of jaw member 74 and extends to the other side of the guide rail where it is formed with a beveled portion 92 extending parallel to the side of the guide rail. This beveled portion engages the roller 85 when the safety brake is not operated, thus retaining the roller away from the guide rail and against the depressed surface 84 of wedge 78.

A releasing wedge 93 is carried by the portion of jaw member 74 opposite the guide rail 30. This portion of jaw member 74 is inclined upwardly toward the guide rail, the inclined surface having a dovetail guideway 94. The releasing wedge has a dovetail tongue 95 which fits into the guideway, thus permitting a sliding movement of the releasing wedge with respect to the jaw member. The sides of the guideway 94 and the tongue 95 are of bearing metal and are secured to their respective parts as by screws. The releasing wedge is urged upwardly with respect to jaw member 74 by the compression spring 96. This spring extends from a bracket 97 secured to jaw member 74 into a recess 98 formed in the releasing member, being arranged on a pin 100 secured to the bracket. A projecting web 99 is formed on jaw member 74 and is adapted to engage an abutment 101 formed on jaw member 73 when the safety brake is in released position.

A compression spring 102 is provided for causing the releasing wedge 93 to engage the guide rail upon jaw member 73 being swung about shaft 75 as a result of the engagement of roller 85 with the guide rail, as will be explained later. This spring is arranged on a bolt 103 between the ends of the jaw members 73 and 74 away from the guide rail. Spring 102 may be placed under no initial compression or under any initial compression that may be desired by varying the thickness
of washer 112. The head of this bolt extends into a square recess 105 arranged in jaw member 73, thus preventing the bolt from turning. A semi-annular web 106 formed on jaw member 73 and a plate 107 secured to the jaw member serve to retain the spring seat 108 and the spring in position with respect to jaw member 73. Likewise, a semi-annular web 110 formed on jaw member 74 and a plate 111 secured to the jaw member serve to retain the washer 112 and the spring in position with respect to jaw member 74.

A small compression spring 113 is arranged on a bolt 114 between an angle bar 115 and a washer 116 abutting against the head of the bolt. The angle bar 115 is supported by another angle bar 117 secured to the lower side of the safety plank 87. The bolt 114 extends through an aperture in angle bar 115 and through a similar aperture in a lug formed on jaw member 74. Nuts 118 are provided on the threaded end of bolt 114. By adjusting these nuts, the force exerted by spring 113 may be varied. This construction serves to maintain the jaw structure as a unit against stop plate 81. Thus stop plate 81 not only serves as means for maintaining the wedge 78 against the jaw member 73 but also as a stop for the jaw structure.

A cam 16 is secured to the rock shaft 69 (see Figure 1). The operating lever 17 for the plan switch 39 is disposed in the path of rotative movement of the cam 16 so as to be engaged thereby during the rotative movement of rock shaft 69 to effect the operation of the safety brakes. The plan switch is arranged in the control circuits for the hoisting motor.

In operation, upon the occurrence of a predetermined overspeed during the descent of the car, the governor 88 operates, as previously described, to cause the jaws 48 and 50 to grip the governor rope, thus causing the lever 42 to be released by the releasing lever 52 and swing clockwise about its pivot. The lever 42 acts through lift rod 67 to cause operating lever 68 of safety brake 36 to swing upwardly. Operating lever 72 of safety brake 36 is also swung upwardly as a result of the movement of lever 42, being connected to operating lever 68 through rock shaft 69, as previously described. As these safety brakes operate in a similar manner, the operation of only one of them, namely, safety brake 36, will be described.

As operating lever 68 swings upwardly it carries the roller 85 upwardly along the inclined surface of wedge 78 into engagement with the guide rail 80. The roller thereupon rolls on the guide rail and forces wedge 78 away from the guide rail, thus causing jaw member 73 to swing about shaft 75. Jaw member 73 acts through spring 102 to cause jaw member 74 to swing about shaft 75, moving releasing wedge 93 into engagement with the guide rail. Continued upward movement of roller 85 causes an increasing compression of spring 102 and a corresponding increase in the braking force exerted by roller 85 and releasing wedge 93 upon the guide rail. The engagement of the roller with the stop plate, as the roller nears the upper end of the wedge 78, prevents further upward movement of the roller and, therefore, further compression of the spring 102. The braking action thus exerted by safety brake 36, along with the braking action similarly exerted by safety brake 36, causes the car to be brought to a stop.

As the levers 68 and 72 swing upwardly during the operation of the safety brakes, cam 16, on rock shaft 69, engages operating lever 17 (see Figure 1), effecting the operation of plan switch 39. The plan switch is arranged in the control circuits to act through electromagnetic switches to effect the discontinuance of the supply of power to the hoisting motor and the application of the electromagnetic brake to bring the hoisting motor, and therefore the hoisting sheave, to a stop.

The safety brakes may be released by by-passing the plan switch and energizing the elevator motor 22 so as to move the car in the up direction. Considering only the action of safety brake 36, as brake 36 is released in the same manner, during the initial movement of the car in the up direction, the releasing wedge 93 remains stationary on the guide rail, owing to the frictional force between this wedge and the guide rail. The inclined surface of jaw member 74 slides upwardly along the inclined surface of the releasing wedge and toward the guide rail, the jaw member thus swinging counter-clockwise about the shaft 75, as viewed in Figure 4. As a result, the spring 102 expands, decreasing the force exerted by roller 85 against the guide rail. The frictional forces exerted upon the roller by wedge 78 and the guide rail being reduced, the roller rolls upon the guide rail and slides along wedge 78 as the car moves upwardly. As the roller moves away from the stop plate 81, the spring 102 further expands causing jaw member 73 to swing about shaft 75. The roller is brought to rest between bracket 91 and the depressed portion 84 of wedge 78 as the boss 87 engages the hooked portion 90 of bracket 80. As the roller moves onto the inclined surface 92 of bracket 91, spring 113, being compressed, acts through bolt 114 to cause the jaw member 73 to swing about shaft 75 in a direction to effect the separation of the releasing wedge 93 from the guide rail. As this movement of jaw member 74 occurs, spring 96, having been compressed as a result of the upward movement of jaw member 74 with respect to the releasing wedge, expands to cause the releasing wedge.
to slide upwardly along the inclined surface of the jaw member until the upper end of the wedge abuts against the housing 71. Thus the safety brake is restored to released position. During the releasing of the safety brakes, the cam 16 disengages the operating lever 17 of plank switch 39, restoring this switch to its normal position. With both safety brakes released, the resetting of jaws 48 and 50 of the governor 38 and the replacing of the jaw 63 of the releasing carrier 44 within the recess 64 of lock bar 60, places the system in its original condition.

The type of safety brake above described applies a practically constant pressure against the guide rails throughout its application. The retarding force exerted, however, depends not only upon the pressure exerted against the rails but also upon the smoothness of the rails, the amount of their lubrication and the kind of lubricant employed. The safety brakes are set in actual practice, therefore, so as to have sufficient margin to stop the elevator car under the worst conditions, namely, with fully loaded car at the top of the hatchway, parted hoisting ropes, polished guide rails and excessive lubrication. With such a setting, the safety brakes may, under certain conditions, cause the car to be retarded at a rate considerably in excess of gravity. This may result in discomfort and possible injury to the occupants of the car. The counterweight, owing to its kinetic energy, is retarded more slowly than the car under the above conditions and will continue its upward movement after the car comes to rest. Inasmuch as the tractive effort of the hoisting sheave, acting through the hoisting ropes assists this kinetic energy of the counterweight, as will be seen from later description, the extent of the continued upward movement of the counterweight may be considerable. Slack will develop as a result of the continued upward movement of the counterweight, permitting it, upon coming to rest, to fall back. Although friction between the ropes and the hoisting sheave may prevent a free fall, nevertheless, unless the amount of slack is small, the falling counterweight will have attained considerable speed at the instant the ropes become taut and the resulting shock will cause excessive stresses. Furthermore, the shock will be transmitted through the hoisting ropes to the car, causing the release of the safety brakes and considerable discomfort if not injury to the occupants of the car. As the length of the compensating ropes is fixed, the counterweight, in order to continue its upward movement after the car has come to rest, must lift the compensating rope tensioning sheave. If the lifting of this sheave is prevented, the slowing down of the counterweight at a lower rate than the car and, therefore, the continued upward movement of the counterweight after the car has come to rest is prevented. It is preferred, however, not to rigidly secure the tensioning sheave against upward movement but to permit a limited upward movement to allow for any contraction of the roping due to temperature and humidity changes.

A suitable arrangement for preventing more than a limited upward movement of the tensioning sheave for the compensating ropes is shown in Figure 1 and is illustrated in detail in Figures 6 and 7. Referring particularly to Figures 6 and 7, the tensioning sheave is mounted on ball bearings 120 positioned between sleeves 121 arranged on shaft 122. Grooves 123 are provided around the periphery of the sheave for the compensating ropes 26. As only two compensating ropes and two hoisting ropes are shown in Figure 1 for convenience of illustration, the tensioning sheave is shown with only two grooves in Figure 6 to correspond with the illustration in Figure 1. The shaft 128 is supported by the sides of the tensioning sheave frame 124. This frame consists of two similar portions 125 and 126, bolted together as by bolts 127 extending through aligned apertures provided in bosses formed on each part. Guides 128 are formed on the outside of each of the frame portions 125 and 126. These guides cooperate with the inner legs 129 of the vertical angle bars 130 and 131 to guide the frame 124, and therefore the sheave 27, during any movement thereof that may occur. The angle bars 130 and 131 are secured at the bottom to an angle bar 132 bolted to the floor of the elevator pit. Angle bar 130 is secured at its top to an angle bar 133 while angle bar 131 is secured at its top to an angle bar 134. From their respective vertical angle bars, the angle bars 133 and 134 extend across the elevator pit to the car buffer 33 where they are secured to channel members 135 and 136. These channel members are secured to the buffer. At their ends these members are secured to the car guide rails 30, this arrangement not being shown.

A portion of the inner leg 129 of vertical angle bar 130 adjacent the top of tensioning sheave frame 124 is serrated to form a rack 137. The portion of the inner leg 129 of vertical angle bar 131 opposite the rack 137 is also serrated to form a rack 138. A pawl 140 for rack 137 is pivotally mounted on a shaft 141 supported by two lugs 142 formed on the top of frame portion 125. Similarly, a pawl 143 for rack 138 is pivotally mounted on a shaft 144 supported by two lugs 145 formed on the top of frame portion 126. These paws are formed so that their weights tend to cause them to turn outwardly about their pivot shafts and, as a result, the operating ends of the paws are maintained in cooperative relation with their respective racks.
Also, each pawl is constructed so as to be flat on the bottom (see Figure 8), this flattened portion cooperating with the tensioning sheave frame to limit the outward movement of the pawl about its pivot shaft.

The above described arrangement permits the tensioning sheave and frame to move downwardly, thus preventing any slack in the compensating ropes. In order that this may be clearly understood, assume that the frame 124 is in such position that the pawls 140 and 143 extend into tooth recesses 146 and 147 respectively with the compensating ropes taut. Assume further that, as a result of stretching of ropes, slack tends to develop in the compensating ropes. As this stretching takes place the tensioning frame and sheave, owing to their weight, move downwardly, guided by angle bars 139 and 131, keeping the compensating ropes taut. As this downward movement occurs, the pawls 140 and 143 will be moved inwardly about their pivots by the rack teeth 148 and 150 respectively. Upon the disengagement of the ends of the pawls and the teeth 148 and 150, the pawls will swing outwardly under the influence of gravity until their flattened portions engage the top of the tensioning sheave frame, this being the position of parts illustrated in Figure 6. In the event of further downward movement of the tensioning sheave and frame, the pawls will act in the same manner with respect to the next lower teeth of their respective racks.

This rack and pawl arrangement permits limited upward movement of the tensioning sheave and frame, even under the conditions where the pawls have just moved into a new tooth slot, owing to the fact that there is clearance between the top of these pawls and the bottom of the rack teeth next above, as illustrated by the position of parts in Figure 6. Thus, the tensioning sheave and frame may adjust themselves to any changes in the length of the elevator roping due to temperature and humidity variations.

Should the operation of the safety brakes occur under such conditions that the counterweight tends to retard more slowly than the elevator car, a force is exerted tending to lift the compensating rope tensioning sheave, causing the engagement of the pawls with the bottom of the rack teeth next above them. Upon the engagement of the pawls and rack teeth, any further upward movement of the tensioning sheave is prevented. The car and counterweight, therefore, are retarded as a unit and come to a stop simultaneously. Thus, as the continued upward movement of the counterweight after the car has come to rest is prevented, the counterweight can fall back at the most only an amount corresponding to the slack developed in the hoisting ropes during the stop. This slack, however, is necessarily small owing to the limited upward movement of the tensioning sheave allowed for contraction of roping. Thus, no shock results when this small amount of slack is taken up and, therefore, the danger of serious stresses, release of the safety brakes and shock or injury to the occupants of the car is eliminated.

Owing to the fact that the outward swinging movement of the pawls about their pivots is limited by the engagement of their flattened bottom portions with the top of the tensioning sheave frame, the pawls are prevented from applying lateral thrusts to the angle bars upon their engagement with rack teeth as a result of a lifting force being applied to the tensioning sheave. Thus, the spreading of the angle bars is prevented. As soon as the lifting force decreases sufficiently, the tensioning sheave again becomes free to take up slack in the elevator roping.

Another arrangement suitable for preventing more than a limited upward movement of the tensioning sheave is illustrated in Figures 9 to 12 inclusive. The arrangement of the tensioning sheave 149 and frame 179 is the same as previously described, the frame being provided with guides 128 for cooperation with the inner legs 151 of the vertical angle bars 132 and 133. A cross-head 154 is arranged above the frame 179, being supported by means of compression springs 155 and 156 extending from the top of the frame into recesses 175 and 176 respectively formed in the cross-head. Lugs are formed in the recesses for positioning springs 155 and 156 at their upper ends. These springs are positioned at their lower ends as by the heads of screws threaded into the top of the tensioning sheave frame. A projection 159 is formed on the cross-head, this projection extending downwardly toward the frame 124.

The ends of the cross-head are provided with openings 160 and 161 into which the inner legs 151 of angle bars 132 and 133 extend. A pair of wedge blocks 162 and 163 are formed within opening 161, one on each side of the leg of angle bar 133. The wedge block 162 is positioned in a slot 164 provided in the cross-head at the side of opening 161 and is proof against a projection 155. This projection extends into a recess 166, the wedge block being secured to the cross-head as by a screw 167 extending through the cross-head into the projection. The wedge block 163 is secured to the cross-head in a similar manner, being positioned in a slot 168. The inclined surfaces of these wedge blocks face the sides of the leg 151. Between the wedge blocks and the side of leg 151 are arranged a pair of wedges 170 and 171. The sides of slot 164 and the projection 172 formed on wedge block 162 serve as retainers for wedge 170 while the sides of slot 168 and a similar projection 173 formed on wedge block 163 serve as retainers for wedge 171. Wedge 170...
blocks and wedges are arranged within the opening 160. As the arrangement of these wedges and blocks is the same as described for wedges 170 and 171 and blocks 162 and 163, no detailed description of this portion of the mechanism will be given.

A portion 174 of the cross-head is formed to extend around the leg 175 of angle bar 153. This portion 174 and the portion 176 of the cross-head on the other side of the angle bar are connected by a plate 169, secured thereto as by screws 177. The portions 174 and 176 extend slightly beyond the back side of leg 173, thus providing clearance between the plate and the angle bar. The portion 176 of the cross-head projects downwardly along the back side of leg 151 while portion 174 projects downwardly along leg 153. These projections are connected at the bottom by a plate 178, secured thereto as by screws 180. This arrangement is such that there is a slight clearance between the plate and the back side of leg 175. Webs 181 are provided for strengthening these projections. As the other end of the cross-head is arranged in the same manner, the arrangement will not be described.

The above described arrangement permits the tensioning sheave and frame to move downwardly to take up any slack in the compensating ropes. The cross-head 154 moves downwardly along with the tensioning sheave and frame, the wedges being released sufficiently to permit this movement. The wedges follow along with their wedge blocks during this downward movement, thus being constantly in engagement with the sides of the legs 151 of the angle bars. Any appreciable upward movement of the cross-head, however, is prevented. Upon an upward force being applied to the cross-head, the resulting slight upward movement of the wedge blocks forces the wedges into clamping engagement with legs 151 of angle bars 152 and 153, preventing any further upward movement. There is clearance, however, between the top of the tensioning sheave frame and the projection 159. Thus, although upward movement of the cross-head is prevented, the tensioning sheave and frame may move upwardly a short distance against the force of springs 155 and 156. This limited upward movement permits the sheave and frame to adjust themselves to any changes in length of elevator roping due to temperature and humidity variations.

Should the operation of the safety brakes occur under such conditions that the counterweight tends to retard more slowly than the elevator car, a force is exerted tending to lift the tensioning sheave and frame. Upon this lifting force being applied, the tensioning sheave and frame move upwardly, compressing springs 155 and 156, into engagement with projection 159. The wedge blocks act, upon this upward force being transmitted to the cross-head, to force their wedges into clamping engagement with the angle bar legs 151, thus preventing any further upward movement of the cross-head, and, therefore, of the tensioning sheave and frame. The car and counterweight, therefore, are slowed down as a unit and come to a stop simultaneously. Thus, as continued upward movement of the counterweight after the car has come to rest is prevented, the counterweight can fall back only an amount corresponding to the slack developed in the hoisting ropes, which slack is necessarily small owing to the limited upward movement of the tensioning sheave allowed for contraction of roping. Thus, no shock results when this small amount of slack is taken up and, therefore, the danger of serious stresses, release of the safety brakes and shock or injury to the occupants of the car is eliminated.

The plates 169 and 178, and their corresponding plates on the other end of the cross-head, act to prevent any skewing of the cross-head, upon upward forces being applied, as might otherwise take place as a result of unequal clamping actions on the two legs 151.

As soon as the lifting force decreases sufficiently, the tensioning sheave and frame move downwardly until the roping becomes taut. Springs 155 and 156, therefore, expand and, as the upward pressure against the cross-head is relieved, the cross-head becomes free to move downwardly of its own weight. The inclined surfaces of the wedges and their cooperating wedge blocks are such as to insure not only the clamping of the wedges against the angle bar legs 151 upon an upward force being applied to the cross-head but also the releasing of the wedges upon this pressure being relieved. Thus, as the upward pressure against the cross-head is relieved, the wedge blocks slide downwardly on the inclined surfaces of their respective wedges, thus relieving the pressure of the wedges against the legs 151, the cross-head being brought to rest by the springs 155 and 156.

It is to be understood that other arrangements may be employed to prevent upward movement of the tensioning sheave. Owing to the fact that such arrangements act in effect to tie down the tensioning sheave, for convenience of further description, the tensioning sheave will hereinafter be referred to as tied down.

Should the emergency stop occur under such conditions that the counterweight tends to slow down at a higher rate than the car, such unequal retardation also is prevented, owing to the fact that the hoisting sheave cannot move downwardly and the length of the hoisting ropes is fixed. Thus, so long as the roping is intact, the car, counterweight and roping are caused to slow down as a unit.
during any stopping operation, regardless of the conditions under which the stop occurs. The car, counterweight and roping, therefore, function as a closed system. Owing to the fact that in a closed system all the forces must act on the total masses to effect the retarding action, the rate at which the car, counterweight and roping are retarded as a result of the operation of the safety brakes, is not excessive. This may be demonstrated by computation. In this connection, reference should be had to Figure 13 wherein the closed system is diagrammatically shown.

Let

\[ C = \text{the weight in lbs. of the empty car,} \]

\[ L = \text{the weight in lbs. of the load in the car,} \]

\[ W = \text{the weight in lbs. of the counterweight,} \]

\[ R = \text{the weight in lbs. of one-half of the elevator roping, the weight of the roping on each side of the hoisting sheave being equal regardless of the position of the car and counterweight in case of complete compensation, here assumed,} \]

\[ R_p = \text{the weight in lbs. of that portion of the hoisting ropes between the top of the car, point a, and the point b at the hoisting sheave,} \]

\[ S = \text{the retarding force in lbs. of the safety brakes,} \]

\[ T_1 = \text{the rope tension in lbs. at the point b,} \]

\[ T_2 = \text{the rope tension in lbs. at the point d,} \]

\[ a = \text{the acceleration in feet per sec. per sec.} \]

Although the equation which will be developed for the closed system is applicable to all emergency stops during which the counterweight tends to slow down more slowly than the car, actual calculations for acceleration will be made only for conditions wherein the car in a system in which the compensating tensioning sheave is not tied down, would tend to slow down at a rate in excess of gravity.

Certain factors, such as the weight of the tensioning sheave and frame, the weight of the control cables and the mechanical friction of the car and counterweight on the guides will be neglected, as this may be done with only small error. The car will be assumed to be descending, indicated by the direction of the arrow on the hoisting sheave. The direction of motion of the system being clockwise, this direction will be considered as positive. The acceleration of the system as a result of the application of the safety brakes may be found from Newton's basic formula

\[ F = Ma \]  

where “F” is the summation of the forces, M is the summation of the masses and “a” is the acceleration.

When the safety brakes are applied, as by operation of the governor, the plank switch 39, acting through electromagnetic switches as previously explained, causes the discon-

\[ T_2 = KT_1 \]  

in which “K” is the traction relation and is a quantity greater than unity. This quantity varies between certain limits but is generally assumed in elevator calculations as 2. Thus

\[ T_2 = 2T_1 \]  

Under stopping conditions where the counterweight tends to lift the tensioning sheave for the compensating ropes, owing to the fact that a limited upward movement of the tensioning sheave is permitted, there will be a tendency for slack to develop in the hoisting ropes at the point a, slack being indicated in Figure 13. The tension in the ropes at point a, therefore, will be zero.

Applying Newton's law to determine the value of \( T_1 \)

\[ R_a - T_1 = \frac{R_a}{g} a \]

whence

\[ T_1 = \frac{R_a - R_a}{g} \]

Substituting the value of \( T_1 \) in Equation (3)

\[ T_2 = 2R_a - \frac{2R_a}{g} a \]

As the acceleration of all the elements of the closed system is the same, the acceleration may be found by considering any portion of the system. The force existing at point d now being known, the acceleration will be calculated by considering that portion of the system extending from the top of the car, point a, down around the tensioning sheave and up to the point d. The summation of the forces for this portion of the system is

\[ F = -S + C + L + (R - R_a - W - R - T_2) \]
Substituting the value of \( T_2 \) as found in Equation (4) and simplifying

\[
F = -S + C + L - R_a - W + 2R_a \frac{2R_a a}{g}
\]

or

\[
F = (-S + C + L + R_a - W)g - 2R_a a
\]  

The summation of the masses for this portion of the system is

\[
M = \frac{C + L + (R - R_a) + W + R}{g}
\]

Simplifying

\[
M = \frac{C + L + 2R - R_a + W}{g}
\]  

Applying Newton's law

\[
(-S + C + L + R_a - \frac{W}{g})g - 2R_a a = \frac{C + L + 2R - R_a + W}{g}
\]

Transposing and simplifying

\[
(2R_a + C + L + 2R - R_a + W)a = (-S + C + L + R_a - W)
\]

or

\[
a = \frac{-S + C + L + R_a - W}{R_a + C + L + 2R + W}g
\]  

Before assuming actual values and calculating the acceleration for the closed system, an equation will be derived for acceleration in a system wherein the tensioning sheave is not tied down, under conditions where the car is retarded as a result of the application of the safety brakes at a rate in excess of gravity. Owing to the fact that the tensioning sheave is free to move upwardly in such system, the weight and mass of the counterweight, the weight and mass of the roping on the counterweight side of the hoisting sheave and the weight and mass of the roping above the car on the car side of the hoisting sheave are not factors to be considered in deriving this equation. Thus, considering the direction of motion as positive as before, the summation of the forces is

\[
F = -S + C + L + (R - R_a)
\]  

The summation of the masses is

\[
M = \frac{C + L + (R - R_a)}{g}
\]  

Applying Newton's law

\[
-S + C + L + R - R_a = \frac{C + L + R - R_a a}{g}
\]

"\( a \)" being employed to designate the acceleration to distinguish from "\( a \)" in the closed system. Thus

\[
a = -\frac{S + C + L + R - R_a}{C + L + R - R_a}g
\]  

Now let it be assumed that

\[
C = 4000 \text{ lbs.,}
\]

\[
L = 3000 \text{ lbs. (full load),}
\]

\[
W = 5200 \text{ lbs.,}
\]

\[
R = 1500 \text{ lbs., and}
\]

\[
S = 12000 \text{ lbs.}
\]

Consider first the condition of empty car, with the car sufficiently near the bottom of the hatchway when the safety brakes operate that \( R_a \) may be considered equal to \( R \) with only small error. In the system wherein the tensioning sheave is not tied down, the acceleration may be found by substituting the assumed values in Equation (10). Thus

\[
a = \frac{-12000 + 4000 + 0 + 1500 - 1500}{4000 + 0 + 1500 - 1500}g
\]

or

\[
a = \frac{-8000}{4000}g = -2g
\]

Under such conditions, therefore, the car is retarded at twice gravity rate which is rather excessive. The counterweight, however, slows down at a rate less than gravity, owing to the fact that the tractive effort of the hoisting sheave tends to keep the counterweight in motion. The extent of continued upward movement of the counterweight after the car comes to rest, therefore, may be considerable. As the counterweight is retarded at a lower rate than the car under the above conditions, when the tensioning sheave is not tied down, Equation (7) for the system wherein the tensioning sheave is tied down is applicable. Substituting the assumed values in Equation (7)

\[
a = \frac{-12000 + 4000 + 0 + 1500 - 5200}{1500 + 4000 + 0 + 3000 + 5200}g
\]

or

\[
a = \frac{-11700}{13700}g = -0.854g
\]

Under the same conditions as assumed for the system wherein the tensioning sheave is not tied down, therefore, the car is retarded at a rate less than gravity. Furthermore, the car and counterweight come to rest as a unit, thus eliminating any continued upward movement of the counterweight after the car has come to rest.

Next consider the condition of empty car, with the car sufficiently near the top of the hatchway when the safety brakes operate that \( R_a \) may be considered equal to 0 with only small error. In the system wherein the tensioning sheave is not tied down, the acceleration...
tion, according to Equation (10), with the assumed values substituted, becomes

\[ a_1 = \frac{-12000 + 4000 + 0 + 1500 - 0}{4000 + 0 + 1500 - 0} g. \]

or

\[ a_1 = \frac{-6500}{5500} g = -1.182 g. \]

The counterweight will slow down at gravity rate owing to the fact that, under the conditions assumed, \( T_2 \) is equal to 0.

As the counterweight is retarded more slowly than the car under the assumed conditions, when the tensioning sheave is not tied down, Equation (7) for the system wherein the tensioning sheave is tied down is applicable.

Substituting the assumed values in Equation (7)

\[ a = \frac{-12000 + 4000 + 0 + 5200}{0 + 4000 + 0 + 3000 + 5200} g \]

or

\[ a = \frac{-13200}{12200} g = -1.082 g. \]

Thus, although the rate at which the car is retarded under the assumed conditions is not excessive with or without the tensioning sheave tied down, nevertheless this rate is less when the tensioning sheave is tied down than when it is not.

It will be seen from the above examples that the rate at which the car is retarded varies according to the position of the car in the hatchway. The load in the car, as shown by Equations (7) and (10) is another factor upon which the rate of retardation depends. As an example, assume that the car is at such position in the hatchway that \( R_2 = 1200 \) lbs. and \( L = 500 \) lbs. Substituting the assumed values in Equation (10)

\[ a_1 = \frac{-12000 + 4000 + 500 + 1500 - 1200}{4000 + 500 + 1500 - 1200} g \]

or

\[ a_1 = \frac{-7200}{4800} g = -1.5 g. \]

The counterweight, however, will slow down at less than gravity rate, owing to the tractive effort of the hoisting sheave.

As the counterweight is retarded more slowly than the car under the assumed conditions, when the tensioning sheave is not tied down, Equation (7) for the system wherein the tensioning sheave is tied down is applicable. Substituting the values assumed

\[ a = \frac{-12000 + 4000 + 500 + 1200 - 5200}{1200 + 4000 + 500 + 3000 + 5200} g \]

or

\[ a = \frac{-11500}{13900} g = -0.827 g. \]

Thus, under the conditions assumed, the car is retarded at a rate less than gravity when the tensioning sheave is tied down while, when the tensioning sheave is not tied down, the car is retarded at a rate one and one-half times gravity.

It is believed that the above examples are sufficient to show that, in a system wherein the tensioning sheave is tied down, excessive retardation of the car is prevented.

In the above example it was assumed that the hoisting ropes were intact. Should the hoisting ropes part, with the elevator car descending, the elevator car becomes a freely falling body, unless somewhat retarded by the dragging of the hoisting ropes over the hoisting sheave. The governor ropes, therefore, owing to their inertia and the inertia of the governor and governor rope tensioning sheave, cause the immediate operation of the safety brakes. Assume that the hoisting ropes part at the top of the car, point 2.

Considering the system with the tensioning sheave for the compensating ropes not tied down, so long as the conditions, such as the amount of load and position of the car in the hatchway, are such that the counterweight retards more slowly than the car, the car is retarded at the same rate as if the roping were intact. Similarly, in the case of the system with the tensioning sheave tied down, so long as the conditions, such as the amount of load and the position of the car in the hatchway, are such that the tension at point 2 during the stop would be zero if the ropes were not parted, the car is retarded at the same rate as if the ropes were intact.

Assume next that the hoisting ropes part at some other point, for example, at the top of the counterweight, with the car descending as before. In the system wherein the tensioning sheave is not tied down, with conditions such that the counterweight retards more slowly than the car, the car is retarded at the same rate as if the roping were intact. With the tensioning sheave tied down, however, although the rate at which the car is retarded is not the same as if the ropes were intact, nevertheless, excessive retardation of the car is prevented. It is believed that this may be made clear by a single example. Assume empty car, with the car descending and near the top of the hatchway when the ropes part. The summation of the forces for this condition is

\[ F = -S + C + (R - R_a) - W \]

The summation of the masses is

\[ M = \frac{C + (R - R_a) - W}{g} \]

Therefore, the acceleration is

\[ a_2 = \frac{-S + C + R - R_a - W}{C + R - R_a + W} g \] (11)
Substituting the values assumed for these elements
\[ a_2 = \frac{-12000 + 4000 + 1500 - 0 - 5200}{4000 + 1500 - 0 + 5200} g \]
or
\[ a_2 = \frac{-11700}{10700} g = -1.09g \]

Thus the car is retarded at a rate only slightly in excess of gravity.

Should the ropes part with the car ascending, the car will come to rest and then start to fall. The falling car is retarded at the same rate under such conditions, regardless of whether the tensioning sheave is tied down or not. Assume that the car is ascending fully loaded and is near the top of the hatchway and that the hoisting ropes part at the point \( z \). The car will continue its upward movement for a short distance and then upon start to fall. With the safety brakes applied the summation of the forces exerted to stop the falling car is

\[ F = -S + C + L + (R - R_a) \]

The summation of the masses is

\[ M = C + L + (R - R_a) \]

Therefore, the acceleration is

\[ a_3 = \frac{-S + C + L + R - R_a}{C + L + R - R_a} g \] (12)

Substituting the values assumed for these elements
\[ a_3 = \frac{-12000 + 4000 + 3000 + 1500 - 0}{4000 + 3000 + 1500 - 0} g \]
or
\[ a_3 = \frac{-3500}{8500} g = -0.412g \]

The car is retarded, therefore, at less than half gravity rate. This example also illustrates the fact that the retarding force assumed for the safety brakes has ample margin to insure the stopping of the car when the hoisting ropes part under the worst conditions as regards the amount of load and position of the car in the hatchway.

In the above examples it was assumed that the operation of the safety brakes was effected either by the governor upon the occurrence of a predetermined amount of overspeed during the descent of the car or owing to the inertia of the governor apparatus in the event of the parting of the hoisting ropes.

It is to be understood, however, that the tying down of the tensioning sheave is effective to prevent excessive retardation of the car and continued upward movement of the counterweight after the car has come to rest, regardless of the mechanism effecting the operation of the safety brakes or the conditions in response to which the operation of the safety brakes is effected. Furthermore, although the emergency stops have been described as effected by safety brakes of a certain type, it is to be understood that, with the tensioning sheave tied down, excessive retardation of the car and continued upward movement of the counterweight after the car has come to rest is prevented when the emergency stop is effected by other forms of safety brakes or by the car buffer or other safety apparatus. Also, with the tensioning sheave tied down, the system will act in the same manner, when the counterweight is the descending body and is brought to an emergency stop, as has been described for emergency stops with the car the descending body. Thus, should the counterweight be brought to an emergency stop by the engagement of its buffer with the bumper block \( 29 \), by the operation of counterweight safety brakes, if provided, or by the operation of other safety apparatus, upward movement of the car after the counterweight has come to rest is prevented. In fact, the tying down of the compensating rope tensioning sheave prevents excessive retardation of the descending body during stopping and continued upward movement of the ascending body after the descending body has come to rest, regardless of the agency causing the stopping and regardless of the conditions under which the stopping occurs.

In the event that compensating ropes are not provided, it is to be understood that roping or the like may be extended downwardly from the elevator car, around a sheave and then upwardly to the counterweight, in a manner similar to the arrangement of compensating ropes, with upward movement of this sheave prevented by arrangements such as previously described.

What is claimed is:
1. An elevator system comprising: an elevator car; a counterweight; hoisting mechanism for said car and counterweight, said mechanism including hoisting roping; safety means for stopping said car, said safety means having sufficient retarding force to insure the stopping of the car under conditions where the car is fully loaded and near the top of the hatchway with the hoisting roping parted; and means for preventing said safety means causing excessive retardation of the car, regardless of the conditions under which the stopping occurs.
2. An elevator system comprising: an elevator car; a counterweight; hoisting mechanism for said car and counterweight, said mechanism including hoisting roping; roping for compensating for the unbalanced weight of said hoisting roping; a tensioning sheave for the compensating roping; safety means for stopping said car, said safety means having sufficient retarding force to
insure the stopping of the car under conditions where the car is fully loaded and near the top of the hatchway with the hoisting roping parted; and means for preventing aid safety means causing excessive retardation of the car, regardless of the conditions under which the stopping occurs, said last included means comprising means for preventing more than a limited upward movement of said tensioning sheave.

3. The combination of a car and a counterweight therefor, a compensating cable connected between the car and the counterweight and running under a sheave, a weight connected with said sheave, vertical guides in which the weight is free to move, and means interposed in the path of movement of the weight arranged to limit the upward movement thereof.

4. The combination of a car and a counterweight therefor, a compensating cable connected between the car and the counterweight and running under a sheave, a weight connected with said sheave, vertical guides in which the weight is free to move, a bar movable on the guides arranged to limit the upward movement of the weight, and means for locking the bar against upward movement.

5. In a traction elevator, a car and a counterweight arranged to run in a hoistway, a driving sheave at the upper end of the hoistway, a second sheave at the lower end of the hoistway, a cable system forming with said car and counterweight an endless connection between said sheaves, a weight connected with said sheave, vertical guides for the weight, a bar movable on the guides arranged to limit the upward movement of the weight, and means for locking the bar against upward movement.

In testimony whereof, I have signed my name to this specification.

DAVID L. LINDQUIST.