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The Institution of Post Office Electrical Engineers.

Modern Electric Passenger Lifts

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R. S. PHILLIPS, A.M.I.E.E.

A Paper read before the South Lancashire Centre of the Institution on the
9th December, 1935.

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Introduction.

This subject has become one of increasing importance during recent years and it is therefore rather surprising to find that comparatively little information is available. So far as I am aware a paper on lifts has not yet been read before this Institution, whilst the few that have been read before other Institutions were written so long ago that much of the information given therein does not represent up-to-date practice. This paper is an attempt to describe some of the various modern types of equipment in use and the methods which have been adopted during the past few years to improve the lift service in this country. A brief indication is also given of the lines along which development is proceeding in America.

The geared winding engine consisting of motor, brake and gearing, is still being produced in large numbers by British manufacturers for car speeds below about 400 feet per minute and up to the present time has been employed on all lifts installed in Post Office buildings. Owing to the withdrawal of certain building restrictions and the consequent erection of many large and high buildings, however, the demand for car speeds of 400 feet per minute and over has increased. With the introduction of higher speeds the gearless winding engine became a practical proposition and a number of these machines have been installed during recent years. The variable voltage method of controlling the lift motor speed has many advantages over the older methods and is now rapidly becoming part of the standard equipment of our high grade installations employing either geared or gearless machines. New methods of car control have been introduced and the collective and signal systems deal with calls in the order in which the landings are reached even though the car is in motion when the call is made. This obviates the drawback of the ordinary push button automatic control with which it is possible for persons waiting at a landing to see the car pass without being able to gain admittance. Considerable attention has also been given to car levelling and with several of the schemes now in use it is possible to obtain automatic levelling to within about ¼ inch and, further, to maintain the level regardless of rope stretch or varying load. Power operated doors are becoming very popular and many of these are now arranged to open automatically after the car has correctly levelled. It may be said, therefore, that a typical modern high speed British lift incorporates a gearless winding machine, the motor being controlled by the variable voltage method, full wrap roping with U grooved sheave, collective or signal control, automatic levelling and automatic power operated doors. I am of the opinion that, despite the increased cost, lifts with many if not all of these features will be installed in the near future in all the large and more important Post Office buildings.

In America, where the conditions are entirely different from those existing in this country, greater advance has been made and double decked cars are employed whilst in at least one building two independent cars are operating one above the other in the same well. Moreover, whilst the maximum car speed in this country is about 500 feet per min. the height of some of the American " skyscrapers " has allowed speeds of 1400 ft. per min. to be reached for express service to the top portions of the buildings. It is believed that this is the limit of speed for passenger lift service because of the discomfort caused to passengers resulting from rapid change of air pressure due to altitude, and the effect of high rates of acceleration and retardation even if smoothly attained. Some idea of the magnitude of lift traffic in America will be gained from the fact that after a census taken in New York a few years ago it was revealed that the number of passengers carried by the city's 15,000 lifts was greater than the total number carried by all the subway, surface and elevated railways.

Types of Drives.

Two main types of drive are employed, namely, the drum and the traction or sheave drive. In the former, one end of the car cables and one end of the counterweight cables are securely anchored to a cast iron drum which has U section grooves on its periphery. The other ends of the car and counterweight cables are fastened to the car and counterweight respectively. A traction drive installation employs one set of ropes, these passing from the car over a U or V grooved traction sheave and thence to the counterweight. The driving force is, therefore, supplied by the friction between the ropes and the sheave grooves.

The main advantage of the drum drive is that the ropes have a longer life than those used on traction drive installations due to the absence of the wedging action of the ropes in the grooves. As the height of travel increases, however, the drum becomes unwieldly and this drive is, therefore, seldom used on lifts which have travels of more than 100 feet; so far as Post Office lifts are concerned the drum machine is now obsolescent. Moreover, if the car overtravels the top or bottom landings and the limit switches fail to operate, either the car or the counterweight will be wound into the overhead structure with serious results. A similar occurrence with a traction drive would result in rope slip immediately the car or counterweight reached the bottom of the well and would be attended by no serious consequences, this fact constituting the main advantage of the traction machine. Other advantages which make the traction drive the most popular are cheapness, simplicity, and the fact that standard equipment can be used irrespective of the height of travel. Either U or V grooves are used on traction sheaves although modified forms of the U groove, as shown in Fig. **2**, have been used on a number of lifts. The U groove has a radius slightly larger than that of the rope and the V groove employs an angle of between 30° and 45°, the standard angle for sheaves on Post Office lifts being 35°. The advantage of the former lies in quietness of operation, but the traction is so low as to necessitate the use of the double wrap method of roping, with consequent greater cost. Increased traction, shorter ropes and cheaper construction result from the use of V grooved sheaves, but they have the disadvantage of reducing the life of the ropes and causing noisy operation, especially at the higher car speeds. Several factors have to be considered in obtaining a satisfactory traction drive, the most important being to secure adequate traction, otherwise increased wear of ropes and sheaves will result. The problem of obtaining sufficient traction resolves itself on the ratio which can exist between the tensions in the ropes on the two sides of the driving sheave. The maximum ratio between these two tensions before slipping occurs may be calculated as shown in Appendix I.

A half drum, half traction type of drive has been employed in which a single spiral U grooved drum is used, the cables being given $2\frac{1}{2}$ wraps around the drum without being secured. The drive is by friction between the cables and the drum, the former moving from one end of the drum to the other during the travel of the car.

Ropes and Roping.

The hoisting ropes are probably the most important part of a lift installation and a brief description of the types of ropes employed will now be given.

Steels of various tensile strengths and ductilities are employed in the construction of lift ropes, the strongest and consequently hardest ropes being made from improved plough steel having an ultimate tensile strength of 120 tons per square inch, whilst ropes of high ductility are made from the best mild steel having an ultimate strength of 90 tons per square inch. The former type is usually employed with V sheave drives in order to reduce rope wear, whilst the ductile ropes are used on installations in which a number of reverse bends occur in the roping system. When the conditions are particularly severe, ropes made from ductile steel of low carbon content having an ultimate tensile strength of 40 tons per square inch are sometimes used, particularly in America, for full wrap two-to-one systems employing a number of idle pulleys. The ropes on Post Office lifts are made from steel of tensile strength between 80 and 90 tons per square inch.

A common rope construction is six strands of nineteen wires per strand known as 6 × 19 construction. Each strand has a central wire about which is placed a layer of six wires. Outside the six-wire layer is another of twelve wires, both layers being twisted in the same direction. The rope is formed by laying six of these strands about a hemp heart impregnated with oil. Another form of construction which results in a more flexible rope is the 6 × 37 construction. This is built up in a similar manner to the 6 × 19 rope, but each strand has a third layer of eighteen wires. In the most usual form of rope all the wires are of uniform size, but in the " Warrington " construction, which is sometimes employed, three different sizes of wires are used. The inner seven wires are of the same size and the outer twelve are alternatively large and small in a 6 × 19 " Warrington " rope. This construction results in a rope of cross section and strength about 10% greater than that of a uniform rope. A further type known as the " Seale " construction also employs wires of different sizes in which the crowns of the inside wires fit into the valleys of the outside wires and results in a rope of larger effective cross section and consequent greater strength and life than either the uniform or " Warrington " types of the same overall diameter. During recent years a rope having a flattened strand construction has been largely used, the object being to present a larger wearing surface to the sheave grooves.

In laying the strands two different methods are used, namely, the ordinary lay and Lang's lay. In the former the strands are twisted in the opposite direction to the wires of the strands, *e.g.*, strands clockwise and wires counter-clockwise. Both wires and strands of a Lang's lay rope, however, are twisted in the same direction and thus a greater wearing surface is produced than with an ordinary lay. Furthermore, a Lang's lay rope is slightly more flexible than the ordinary rope of similar size and construction.

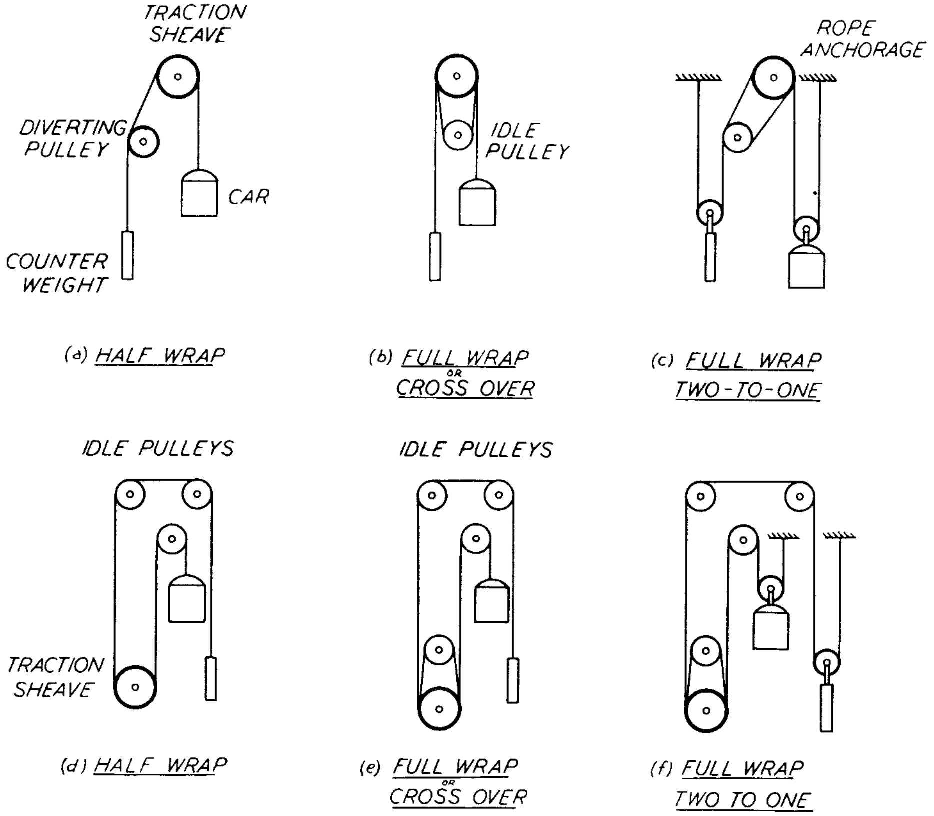
One disadvantage of the Lang's lay is the possibility of the rope unlaying, but as lift cars and counterweights run in guides and positive rope fastenings are used this objection is not serious so far as lifts are concerned. The Post Office and the majority of British lift makers specify Lang's lay right hand ropes, whilst in America the ordinary lay rope is very popular. A further type of rope known as a preformed rope has become very popular with lift makers during the past few years and at the present time is being tried by the Post Office. In this rope the wire in the strands and the strands are formed to their exact final shape during manufacture and the rope therefore has no tendency to unlay when cut, which is a decided advantage from the maintenance point of view.

Many different roping schemes are employed on modern lifts, and the system adopted depends to a large extent upon local conditions. The selection of a satisfactory scheme, however, is important in so far as it largely governs the future maintenance costs, of which rope renewals are by far the largest items.

The various roping systems for traction and drum machines will now be described.

Traction Type Machines.

The half wrap one-to-one method of roping, shown in Fig. **1**(*a*), is the simplest of all and is employed wherever possible. The system is so called because the ropes wrap the traction sheave for approximately 180° and the speed of the car is equal to that of the periphery of the traction sheave. A diverting pulley is unnecessary when the diameter of the traction sheave can be made equal to the distance between the car and counterweight centres. Fig. **1**(*b*) shows a full wrap one-to-one drive in which the ropes are in contact with the driving sheave for approximately 360°. The ropes pass from the car around the traction sheave, idle pulley, traction sheave again, and thence to the counterweight. The full wrap is employed on high speed lifts in which the traction sheave has U grooves. By using the roping scheme, shown in Fig. **1**(*c*), part of the load may be removed from the winding engine and a ratio of two-to-one between the peripheral speed of the traction sheave and the car obtained. This two-to-one drive is employed in order to obtain slow car speeds, for accurate levelling and for direct drive installations where no gearing is used. The speed of the motor in a gearless lift is, therefore, equal to the speed of the traction sheave and the two-to-one speed ratio afforded by the roping permits the use of a higher speed and consequently cheaper motor. The disadvantage of the two-to-one method of roping, and in fact all methods in which reverse bends are employed, is that the ropes have a comparatively short life. Figs. **1**(*d*), **1**(*e*), **1**(*f*), show half wrap, full wrap one-to-one, and full wrap two-to-one roping schemes with the winding engine located in the basement. In each of the figures only one rope is shown for clearness, but it must be remembered that the number of ropes employed in practice is often as many as six and is sometimes eight.



(a) HALF WRAP

(b) FULL WRAP OR CROSS OVER

(c) FULL WRAP TWO-TO-ONE

(d) HALF WRAP

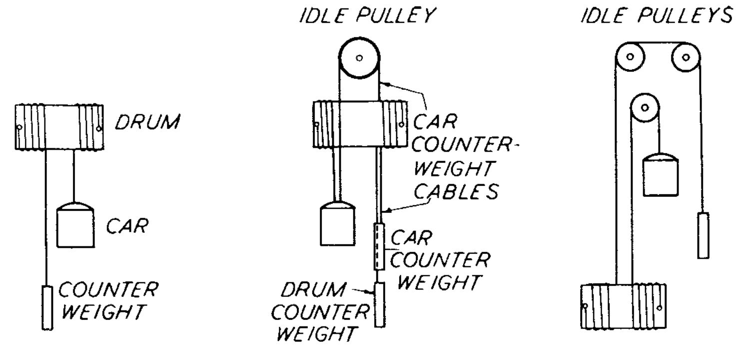
(e) FULL WRAP OR CROSS OVER

(f) FULL WRAP TWO TO ONE

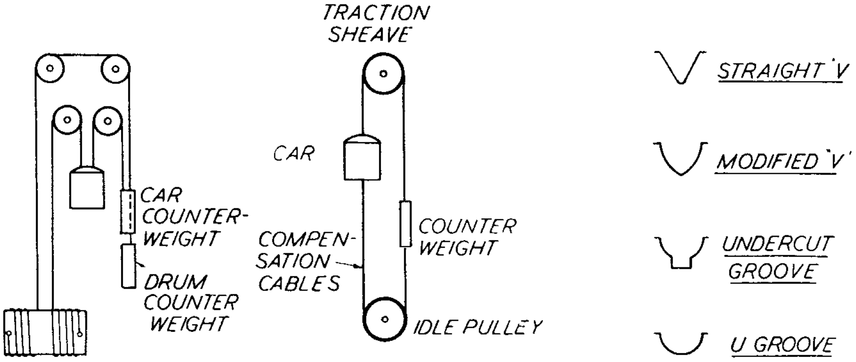
Fig. **1**.

Drum Machines.

In Fig. **2**(*a*) the drum is located overhead and only one counterweight, known as the drum counterweight, is used. Both car and counterweight ropes are securely anchored to the drum and pass to the car and counterweight respectively *via* one or more idle pulleys. By using a second counterweight as in Fig. **2**(*b*), known as a car counterweight, part of the weight of the car can be removed from the drum and car cables and the drum counterweight thereby



(a) DRUM OVERHEAD DRUM COUNTERWEIGHT ONLY (b) DRUM OVERHEAD DRUM & CAR COUNTERWEIGHT (c) DRUM BELOW DRUM COUNTERWEIGHT ONLY



(d) DRUM BELOW CAR & DRUM COUNTERWEIGHTS (e) COMPENSATION CABLES (f) TYPES OF GROOVES

Fig. 2.

reduced. This removes part of the load from the drum shaft bearings. The car counterweight, which is usually about 400 lbs. less than the weight of the car, is often fitted on large capacity lifts for the reasons stated above. Both counterweights run in the same guides with the car counterweight above in order that a failure of the drum counterweight cables will not cause this counterweight to fall on the car counterweight which would result in a wreck. The drum counterweight cables pass through the car counterweight as shown in Fig. **2**(*b*). Figs. **2**(*c*) and **2**(*d*) show the drum in the basement, the former employing a single counterweight and the latter both car and drum counterweights.

The overhead traction type of drive is simpler and less expensive than the basement location and is consequently much favoured by lift engineers. For installations such as hospitals where the slightest noise is objectionable, however, it is advisable to locate the machine in the basement. An objection which is sometimes raised to the overhead position of the winding engine is that it increases the load on the overhead structure, but this is only true in the unlikely event of the winding engine weighing more than the combined weight of the car, load and counterweight.

Compensating Cables.

These are employed in high installations in order to make the load constant during a run from the top to the bottom of the well. When the car is at the top of the well the load on the motor is reduced by an amount equal to the weight of the car cables which is appreciable with long travels. Several different methods of cable compensation are employed, probably the best of which is shown in Fig. **2**(*e*). Ropes, similar in weight and number to those employed for hoisting, pass from the car around an idle pulley in the bottom of the well and thence to the counterweight. The hoisting ropes are therefore balanced irrespective of the position of the car. In some methods compensating chains are used instead of ropes, but these are prone to noisiness especially at the higher car speeds.

Geared Winding Engines.

The most usual form of winding engine consists of a motor—either A.C. or D.C.—brake, and worm and worm wheel reduction gear mounted on a common bedplate to form a self-contained unit. For car speeds up to about 400 ft. per min. this geared drive is almost invariably adopted, the engine being located either in the basement or at the top of the well.

D.C. Motors.

If the supply is D.C. a shunt motor with series starting coils with or without interpoles, may be used, the series field giving the maximum torque per ampere during starting. When the load is an overhauling one, however, *e.g.,* full load down, the motor operates as a generator, the back e.m.f. being greater than the applied volts. Under these conditions the motor acts as a brake to prevent overspeeding. The shunt and series windings will now oppose each other and the results are reduced braking power, weakened field and increased speed. Arrangements are therefore made in the controller so that the series winding is only in circuit during the initial accelerating period, thus preventing the possibility of a dangerous condition arising. For slow speeds up to about 120 ft. per min. a single speed motor with automatic acceleration by means of starting resistances on a definite time basis may be used. The motor is slowed down by introducing the series field and the starting resistances.

For speeds up to about 400 ft. per min. adjustable speed motors having speed ranges of two-to-one or three-to-one are used, the higher speed being obtained by shunt field weakening and no series field is required. During the acceleration period the field is fully excited in order to give a high torque. Slowing down is accomplished by strengthening the field, introducing the starting resistances and shunting the armature.

A.C. Motors.

When the supply is A.C. one of several different types of motors may be employed depending upon the car speed required and whether the installation is to be a single or multi-speed one. The single speed squirrel cage motor, if properly designed, is suitable for speeds up to 120 ft. per min. and is usually connected directly across the line. It is sometimes necessary, however, to reduce the starting torque in order to give a smooth start by connecting a resistance in the primary circuit. The motor has a small diameter high resistance rotor which gives rapid changes in speed and maximum torque at starting. With a motor of this type the controller is very simple, but the disadvantage, possessed by all squirrel cage motors, is the tendency to overheat if the duty is severe. Mainly on account of its high starting current this type of motor is not used on Post Office lifts. Closer speed regulation and higher efficiency may be obtained by using a wound rotor motor which is started with sufficient secondary resistance to restrict the starting torque and current to less than the maximum values. Acceleration is obtained by cutting out the rotor resistance.

Multi speed motors must be used for speeds up to 400 ft. per min. in order to obtain a slow speed for accurate levelling and these are of the pole changing induction, tandem or A.C. commutator types. In the two-speed squirrel cage motor the stator is so arranged that the same winding has two polar combinations which may be connected by a switch to give the two synchronous speeds. The speed ratio is such that the low speed is less than 100 ft. per min. for landing purposes. In another form of two-speed squirrel cage motor two separate stator windings are employed giving two polar combinations for the two speeds. This type is being used with speed ratios up to 6 to 1, the control equipment operating the motor on either stator winding depending on the speed required. The motor is started by resistance in series with the high speed winding, the resistance being short circuited in steps as the motor speed rises. The slow speed winding is used for landing and when connected at the high speed the motor acts as an induction generator, and the car is slowed down by regenerative braking. Arrangements are usually made in the control equipment so that the mechanical brake is not brought into operation until the regenerative braking effect has almost finished. The disadvantage of the double winding is its complexity, and the difficulty of repair in the event of damage to one of the windings.

In order to obtain the two speeds with a slip ring motor the general arrangement of the rotor windings must be similar to the stator windings and the connections changed whenever the connections to the stator are changed. On account of the additional slip rings and extra complication associated with the wound rotor, the squirrel cage type of rotor is usually employed.

The " Tandem " two-speed A.C. motor is more efficient than either of the types mentioned and has been fitted in a large number of recent lift installations. A wound rotor and a squirrel cage rotor, forming the high and low speed sections respectively, are assembled on the same shaft and the two frames are bolted together to form a single two-bearing unit. Fig. **3** shows a tandem lift motor in part section, the low speed portion being on the right hand side. In a typical tandem lift motor the high speed section provides a speed of 960 r.p.m. and the low speed section one of 160 r.p.m., both sections being magnetically and electrically independent internally. It is usual to start up on the high speed section with resistance in the rotor circuit, this resistance being gradually cut out until the final running speed is reached. In order to slow down from full speed, a change over switch disconnects the high speed section and energises the slow speed section. On change over to slow speed, regenerative braking occurs, and a reverse torque of approximately four times full load torque is obtained. To prevent the deceleration from being excessive, a buffer resistance is inserted in the star point of the squirrel cage winding, the resistance being short circuited by a contactor after a short interval.

A large number of A.C. poly-phase variable speed commutator motors are in use on multi-speed lifts operating at speeds up to about 400 ft. per min. The arrangement of the windings differs from that of an ordinary induction motor in that the primary winding is located on the rotor and the secondary winding on

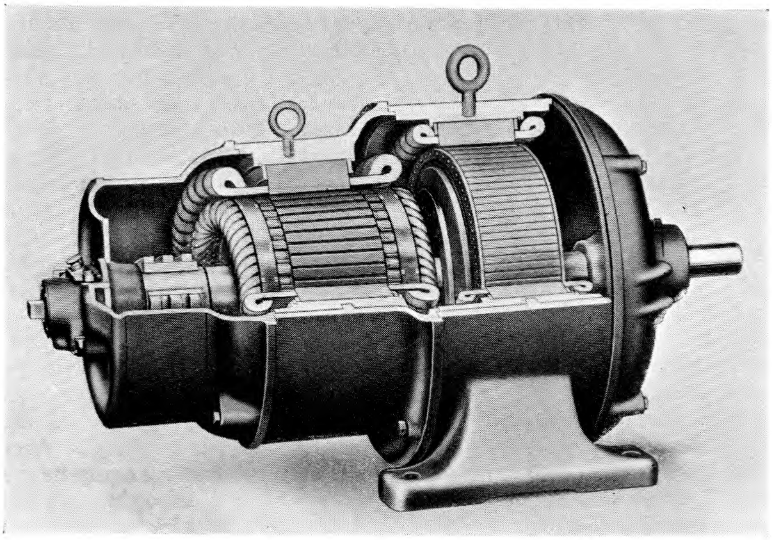


FIG. 3.—PART SECTIONAL ELEVATION OF TANDEM MOTOR.

the stator. In addition to the three phase primary winding a regulating winding is placed in the rotor slots and is connected to a commutator in a similar manner to that of a D.C. motor. The commutator is provided with two brush rockers which can be moved relatively to each other by means of a small pilot motor. One end of each phase of the stator winding is connected to a brush of one rocker and the other ends of the phases to the corresponding brush of the opposite rocker. Hence the greater the distance the two sets of brushes are moved apart, the greater will be the amount of regulating winding connected in series with the secondary winding. By moving the brushes in this manner the e.m.f. injected into the secondary winding, and therefore the speed of the rotor, can be varied. Resistances may be introduced in the secondary winding in order to obtain creeping speeds. Speeds above and below synchronism are obtained and in the small sizes speed changes up to seven to one are possible, whilst the larger sizes are being built with speed changes as high as fifteen to one. It is necessary to ensure that the brushes are driven back to the slow speed position in the case of stoppage from any cause. The operating characteristics of this motor are better than those obtainable with any other type of self contained A.C. motor. A very smooth speed transition is given and the currents both for starting and acceleration are lower than with multi-speed induction motors. On the other hand the motor is rather noisy and the large and heavy rotor causes slow acceleration, whilst the commutator and brush gear are rather undesirable features.

When the supply is single phase, repulsion induction motors operating at one speed are usually used. This type starts as a repulsion motor in order to give the necessary high starting torque. When a predetermined speed has been reached the commutator is short circuited and the brushes lifted by a centrifugal governor, after which the motor runs as an induction motor. With the decrease in the cost of condensers during recent years capacitor motors are now sometimes used for single phase working, the condenser being either a part of the motor assembly or a separate unit. Two-speed lifts, operating from single phase supply, have been built using single phase shunt commutator motors with power factor compensation. The speed is raised above synchronism to provide the running speed of, say, 200 feet per min. by injecting into one set of brushes a small pressure provided by a speed controlling transformer. A landing speed of half the maximum speed is provided by reversing the connections to the primary of the transformer. Another method of dealing with the rather difficult problem of two speeds from a single phase supply is to install a rectifier and use a D.C. machine. With rectifiers, however, regeneration is impossible, except with the latest grid controlled type, and the Post Office therefore prohibits their use when the travel exceeds 30 feet.

Gearing.

In order to obtain a satisfactory rope life the Post Office specifies that the diameter of the driving sheave or any idle pulleys should not be less than fifty-five times the diameter of the rope. Hence, if the rope diameter is $\frac{5}{8}''$ the minimum sheave or pulley diameter should be 34″. With a car speed of 400 ft. per min. it will be seen that the speed of the motor for a direct drive installation should be 45 r.p.m. In order to use a motor of the general purpose type, running at say 1000 r.p.m., it is therefore necessary to use gearing and the type invariably adopted is the worm and worm wheel. The gearing is totally enclosed, the worm being either above or below the wheel and there are probably as many of one type in use as the other. The former is termed the over type worm gear and the latter the under type. The worm over appears to be the better arrangement with moderate rubbing speeds and tooth pressures, and has the advantages that the low speed load carrying shaft and the centre of gravity of the winding engine are lower down. Furthermore, with this type, the worm, which suffers the most wear, is capable of easy inspection and it is not so difficult to maintain oil tight joints in the gear casing. On the other hand, when the under type gear is employed, the winding engine is cheaper and lubrication probably more complete. The driving sheave or drum and the worm wheel are fixed to the worm wheel shaft by two keys in each case at right angles, or by a spider coupling, and the brake drum and motor armature spindle to the worm shaft by one key. The worm wheel consists of a renewable phosphor bronze rim shrunk on and bolted to a cast iron centre, whilst the worm is usually of nickel steel forged solid with the shaft and case hardened. In order to obtain an extra degree of safety, the gearing is sometimes cut with a dynamically self sustaining angle so that the efficiency is not more than 50%. The tendency, however, is towards more efficient gearing and the provision of a handle in the car or a speed governor in the motor room, either of which opens the main limit switch and applies the brake in cases of emergency or overspeed respectively. Double-thrust ball bearings, to take up the thrust in both directions of the worm, are provided. Where the duty is severe, tandem gearing is employed in which the two worms are respectively left and right hand cut, the worm wheel being meshed together as well as the worm and wheels. This results in two equal and opposite thrusts and no thrust bearings are required.

Brakes.

A lift brake should be of good design and well constructed, as the safety of the passengers may be entirely dependent upon it. The design should be such that it will operate in about 1/100 second in order that good floor levelling may be obtained. The brake employed is of the electro-mechanical type and is situated between the motor and the gearbox with the brake drum on the worm shaft side of the coupling so that the brake will hold the car in the event of the armature being taken out for repairs. The shoes, usually in two halves, are lined with Ferodo, or similar material, and are operated by spiral springs. Release is effected by an electro magnet acting on the shoes either directly or through link mechanism, and it is so arranged that the solenoid is de-energised and the brake operated when the controller is in the off position or the power fails. The design of a satisfactory brake for operation on A.C. is more difficult than that for D.C. working, and a number of lift manufacturers install D.C. brakes irrespective of the character of the supply, a rectifier being fitted when the supply is A.C. Furthermore, since the rotor of an A.C. machine is larger than that of a D.C. motor, the brake must be correspondingly larger. The main differences between the two types which have to be considered in the design are, whereas the D.C. brake takes the same current regardless of position, the A.C. brake takes a much larger current when the air gap is large than it does when closed. Also, in the A.C. magnet the pull is nearly constant throughout the travel, whilst in the D.C. case the pull is approximately inversely proportional to the square of the air gap. The operation of a D.C. brake is smoother than that of the A.C. type and dashpots are often fitted to the latter in order to make the operation less fierce. Solid magnetic circuits are employed in a D.C. brake and laminated circuits in an A.C. brake so that the eddy current losses are kept to a minimum. The braking system is sometimes built in two independent halves, the object being that in the event of failure of one half the other is available for braking. A.C. brakes for larger lifts are now operated by torque motors. The shoes are released by cams on the rotor shaft and gradually applied by a dashpot, the piston of which is driven by the rotor shaft.

Gearless Winding Engines.

The use of gears for speeds above 500 ft. per min. is impracticable because of their low efficiency and low rates of acceleration possible. With speeds of 400 ft. per min. and above, however, the use of a gearless machine with a consequent higher mechanical efficiency became practicable and many of these machines are now in use in this country. The gearless machine consists of a low speed D.C. motor having the driving sheave and brake drum mounted on the motor shaft, the whole being fixed to a cast iron bedplate to form a single unit. The motor bearings, therefore, carry not only the weight of the armature sheave and brake drum, but the load of the car, counterweight and cables. In order to prevent vibration being transmitted to other parts of the building the tendency during recent years is to fix the baseplate to a heavy slab of concrete which rests on pads of compressed cork laid on the supporting beam. A source of trouble with early gearless machines was a slight loosening of the spider on the armature shaft, causing a creaking noise during operation. The best practice now is to use a one-piece shaft and spider of hollow construction with the brake drum and sheave directly coupled to the spider. Oiling is performed by a positive method as there is a tendency for rings to slip at the low motor speeds. The motor is a shunt wound machine and admits of a certain amount of speed variation by alteration of the field strength. Fig. **4** shows a typical installation employing variable voltage control in which normal speed of the motor is 80 r.p.m., the driving sheave 24″ diameter, and the car speed 500 ft. per min. The motor speed is capable of being reduced to 3 r.p.m., resulting in a landing speed of 20 ft. per min. Higher motor speeds are permissible when a two-to-one roping system is employed. The major portion of the braking is accomplished electrically by regenerative means and the brake is only brought into operation when the car comes nearly to rest. Rheostatic control consisting of resistance in series with, and in parallel with, the armature was employed to vary the speed in the earlier gearless

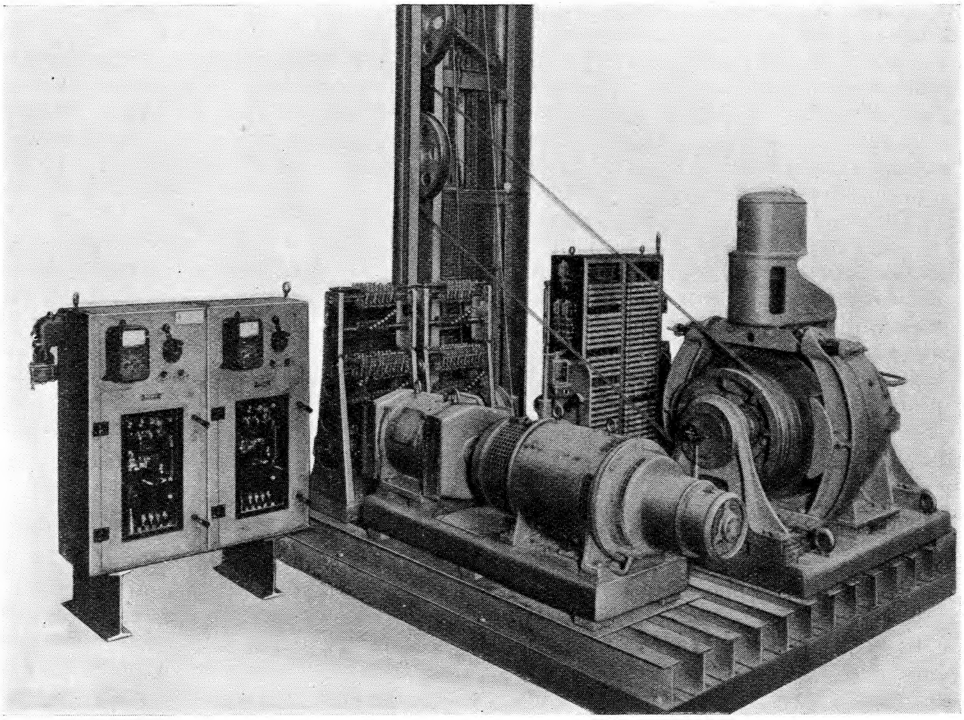


FIG. 4.—GEARLESS WINDING MACHINE ON TEST AT WORKS. VARIABLE VOLTAGE MOTOR GENERATOR SET, CONTROLLER, AND FLOOR LEVELLING GEAR ARE SHOWN.

lifts. The most successful method, however, of varying the speed is by employing variable voltage control in which the major portion of the speed variation is effected by varying the voltage supplied to the motor. The remaining small change is accomplished by motor field control.

Variable Voltage Control.

This is employed in the highest grade installations both with geared machines running at speeds up to 400 ft. per min. and gearless machines operating at speeds from 400 to 1400 ft. per min. Several lifts employing this method of control are at present being installed by the Post Office in different parts of the country. The equipment consists of a D.C. shunt lift motor connected to the driving sheave either directly or through gearing and a separately excited D.C. generator driven by a constant speed motor which obtains its supply from the mains. When main motor micro levelling is employed the generator is provided with two separate fields, one for normal running, and the other to supply the small voltage to the gearless machine for the slow levelling speed. A small exciter is installed to provide the D.C. for the lift motor and generator fields and magnets of the brake and control gear when the supply is A.C. The exciter, generator and its driving motor are mounted on a cast iron bedplate which is insulated from the main beams by pads of cork, rubber or other similar material. A variable voltage set, incorporating motor, generator and exciter is shown in the foreground of Fig. **4**.

The armature of the winding motor is permanently connected to the armature of the driving generator. The field of the generator may be varied or reversed by the control apparatus and it is seen, therefore, that the speed and direction of rotation of the lift motor are controlled entirely by the strength and polarity of the generator field. This type of control may be used either on A.C. or D.C. mains; in the former case a general purpose squirrel cage motor is employed for the driving motor, and in the latter, a D.C. compound motor is used. The advantages possessed by the variable voltage method of control are as follows :—

(*a*) The controller is comparatively simple and its contactors handle small currents of the order of a few amperes instead of the full power as in the case of rheostatic control.

(*b*) The acceleration and retardation are smoother than that obtained with any other form of control.

(*c*) By using a suitable driving motor the set may be employed on A.C. or D.C.

(*d*) The energy consumption is low, due to the elimination of rheostatic losses when accelerating and retarding, or running at reduced speeds.

The speed/load characteristic of the set is a falling one and some method is invariably adopted in order to raise this, *i.e.,* make the speed independent of car load variations. In order to provide accurate floor levelling it is desirable in practice to arrange that the machine speed is slightly higher when lifting full load than when it is being lowered and this involves a rising characteristic. There are several methods of effecting this, one of which is the over-compounding of the generator field to give an increase in generator voltage when operating against full load. With large capacity high speed lifts it has been found that the presence of this heavy current inductive winding affects the performance of the machine which becomes unstable under certain conditions. In some cases the regulation has been improved by incorporating auxiliary generator field control points, these being operated by a speed governor. Another method, and one which has proved satisfactory in practice, involves the use of a small booster whose armature is connected in series with the generator shunt field and its field in series with the armature of the generator. Hence, as the generator load increases, the speed of the lift motor tends to decrease, but the booster generates a correspondingly increased e.m.f., thus boosting the generator shunt field and holding up the lift motor speed. With an overhauling load the generator armature current and booster field current are reversed and thus the voltage generated by the booster is also reversed. The resultant generator field and output volts are therefore reduced in value and this counteracts the tendency of the overhauling load to produce an increase of speed. The diagram, Fig. 5, shows a complete variable voltage set with exciter and booster.

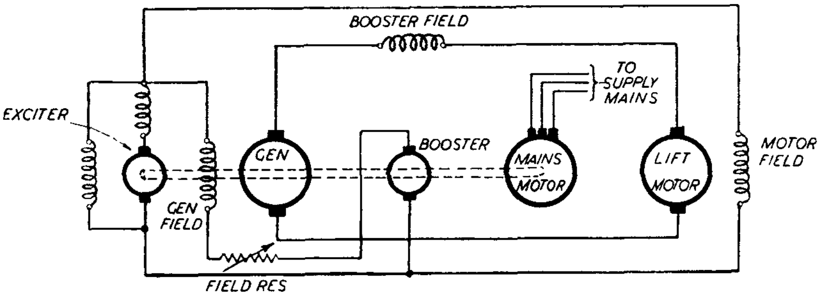


FIG. 5.—VARIABLE VOLTAGE SET WITH BOOSTER.

In another method of improving the regulation a motor generator set is employed, the generator of which incorporates in itself a series connected booster, the complete booster—armature and field—being joined in series in the loop circuit. The advantages of this scheme are the absence of time lag in building up the lift motor voltage and that there is no possibility of the generator field being overpowered under any conditions of loading with consequent danger to the lift when in motion.

Car Control.

Many different methods of control are in use and the type adopted for any particular installation depends upon the service for which the lift is intended. The various methods will be described and some indication given of the conditions under which each type is employed.

(*a*) *Car Switch.*

In the simplest form, three positions are provided for the car switch; up, down and off. The switch should be arranged so that when released, it automatically returns to the off position either by spring pressure or weights. A call button is fitted on each landing. This control is employed when the traffic is heavy and the service will justify the regular employment of a lift attendant.

When a multi-speed motor is used, the car switch is provided with additional positions which permit of running at slow speed and also enables the operator to effect more accurate landings than would be possible if levelling from the high speed was performed. Accurate car levelling, independent of the operator's judgment in centering the car switch, can be obtained by installing automatic levelling gear. In one form of control the centering of the car switch will cause the car to automatically slow down and level at the next landing.

(*b*) *Automatic Push Button.*

In this form a button for each floor and an emergency stop button are provided in the car in addition to a call button on each landing. This is employed where the traffic does not justify an attendant and the car is under the control of the passenger.

(*c*) *Dual Control:*

Is a combination of methods (*a*) and (*b*). A car switch is fitted in addition to the buttons required for automatic service and change-over from (*a*) to (*b*) or *vice-versa* is affected by a two-way switch in the car. This is very useful in buildings where there is a rush period of traffic when the service can be improved by employing an attendant and using car switch control.

(*d*) *Semi-Automatic.*

This system is normally employed on lifts serving two floors only. Up, down, and stop buttons are fitted in the car and on each landing. Momentary pressure of an up or down button causes the car to move in the direction indicated. Stopping is performed automatically on reaching the landing, the stop button being used only in cases of emergency. This control is useful for passenger lifts where the traffic is intermittent and for goods lifts.

(*e*) *Collective Control.*

"Up" and "Down" buttons are fitted on each intermediate landing, single buttons on each terminal landing and a button for each floor in the car. Every button pressed, whether the car is stationary or in motion, registers a call, and up calls are answered on the up journey in the order in which the floors are reached. The direction of travel is reversed after all the up calls have been answered and the down calls are dealt with on the downward journey. Arrangements can also be made for the return of the car to any selected floor if no other calls are waiting. This is very useful in certain cases, such as, when the traffic is usually in the up direction the car can be made to return automatically to the ground floor after all calls have been answered. If, on the other hand, the traffic is usually in the down direction the car will park at, say, the sixth floor to give prompt service from the upper floors. The first Post Office lift employing collective control is the one recently installed in the Director General's Office in London.

(*f*) *Pre-Register Control.*

Is used with busy high speed lifts where the traffic warrants a permanent attendant and the button system is similar to that for collective control. The pressure of a button either in the car or on a landing registers a call in advance, and when the car nears that floor the attendant is advised by a visual automatic signal. After receiving the signal the operator centres the car switch and the car slows down and stops level with the floor. The car and landing door controls are on the car switch, so that when the switch is moved to the start position the doors close and the car starts. When stops are required at adjacent floors on a high speed lift the full speed is not reached, but automatic slow down and signal are given just as if performed from full speed. This control makes the accurate stopping of car switch lifts possible by the simple operation of centering the switch, and the operator is free to attend to the passenger.

(*g*) *Signal Control.*

This is employed in groups of high speed lifts using variable voltage self-levelling equipment and power operated landing doors and car gates. The button system is similar to that used for collective control. As the passengers enter the car they call the number of the floor at which they wish to stop and the attendant presses the corresponding button. Stops are made in the order in which the floors are reached. The pressure of a landing button registers a call on a control panel and the first car travelling in the desired direction will automatically answer the call. The stopping of the car is thus normally independent of the attendant. The car or landing buttons may be pressed in any order and the stopping of one car re-sets the control so that unnecessary stops are not made by other cars.

In large buildings where a number of lifts are installed adjacent to each other, in order to get the best possible service it is necessary to ensure that several lifts do not serve the same landing simultaneously. This is effected by automatic dispatching or scheduling of the cars. For example, with seven cars in which the round trip time is 210 seconds, the cars will be signalled to start at intervals of 30 seconds. Red, green and white lights are fitted in each car, the red being the signal for departure from the top floor, the green the bottom floor signal and the white indicates to the attendant whether the schedule has been maintained up to the half-way position in the well. He, therefore, knows whether he is ahead or behind schedule at the terminal landings and at mid travel. The signalling is performed automatically by an electric motor and gearing operating a system of contacts which control the lights. The contacts can be adjusted to cater for out of balance traffic during rush periods, *e.g.*, the red and white lights can be adjusted to allow of longer running times in the up direction during heavy up morning traffic, say, 120 seconds up and 90 seconds down.

To arrange for these different methods of control it will be appreciated that there is a large number of types of controllers on the market. This number is further increased by the different types of motors in use and to give descriptions of the various types of controller made is outside the scope of this paper. The main line and reversing contactors, floor relays, accelerating and decelerating relays are of the electromagnetic type. The controller should be as simple as possible and employ the minimum number of magnets which should be interchangeable as far as possible. All controller contacts should preferably be carbon to carbon or carbon to copper, and where copper to copper contacts are used these should be designed to give a rolling contact and be fitted with efficient blow-outs where necessary. D.C. contactors are free from hum, give a more even pressure and are generally more reliable than those of the A.C. type, and it is the Post Office standard practice now to fit a rectifier which gives a D.C. voltage of about 200 volts for the controller when the supply is A.C. The various items of the control equipment, including any accelerating rheostats, are usually mounted on a panel of slate or "Sindanyo" which is fixed to a light angle iron frame in the motor room.

A recent type of controller, which merits a brief description, employs a separate low voltage D.C. supply for the control circuit, the line voltage being carried only by the contacts of the main motor contactor. The brake coil is fed from a separate rectified D.C. circuit at a voltage of about 160. All other circuits, including the coils of the main and reversing contactors, work from 50 v D.C. obtained from line voltage *via* a transformer and rectifier. An earthed shield transformer isolates the low voltage circuits from the mains voltage.

The units comprising the controller are housed in one main cabinet consisting of a steel frame containing a number of shelves on which the apparatus is mounted. The controller is enclosed in steel covers which are removable for access to working parts. The top shelf—Terminal Shelf—contains all the terminals required to make the external connections. The second shelf—Power Shelf—incorporates the circuit breaker, overload devices, brake rectifier, control fuses, together with the rectifier and transformer for the 50 v D.C. supply. The third shelf—Reverser Shelf—contains the reversing switches and a gate relay. The fourth shelf—Speed Shelf—contains the apparatus for control of slip ring and two-speed motors, when required, and the fifth, or Auto Shelf, contains a " jack " mounting for the floor selector relay units for automatic push button control. These relays are built into units and fitted with dust covers, the units being similar to those employed in Post Office telephone exchanges.

The controller may be used on any A.C. supply whether single, two or three phase, and can be adapted for any form of control, *e.g.,* car switch, automatic, automatic levelling, parking, collective, etc. The advantages claimed for this type of control are silence, reliability, safety, compactness, and lower maintenance charges.

Automatic Levelling.

" Inching," caused by inaccurate floor levelling, results in poor service and can be responsible for a large increase in wear on the contacts and in the energy consumption. It is therefore important that good levelling should be maintained and many different methods have been adopted during recent years to secure accurate and automatic car levelling.

In the " Micro Drive " a small motor takes control and performs the final levelling at slow speed during the last few inches travel of the car. The micro gear consists of a small motor, brake and worm reduction gear, the worm wheel of which is fastened to and drives the housing of the main brake. During the normal travel of the lift the main brake operates in the usual manner, but when the micro gear is brought into action the brake acts as a friction clutch and drives the main motor armature and traction sheave. The micro motor is operated by a levelling switch on the car frame, the switch making contact with stationary cams fitted in the well. Two cams are fitted at each landing, one for up direction and the other for down.

If the main machine levels inaccurately, the levelling switch engages with the cam in the well and operates the micro gear which drives the car up or down at slow speed. This levelling switch interrupts the micro motor circuit and stops the car when properly levelled. A magnet mounted on the levelling switch and energized when the main motor is in circuit prevents the operation of the gear as the car passes a landing.

The " Levelectric " system of levelling also employs a small motor which effects the final levelling. This motor is mounted on the main motor frame and is connected to it by a chain drive and a speed operated friction clutch. The change over from one motor to the other is effected by a levelling switch mounted on the car, the switch engaging with an aluminium ramp at each landing. The ramp has a depression in the centre corresponding to the proper level and the levelling switch on falling into this depression cuts off the auxilliary motor. The switch is magnetically withdrawn when the main motor is in circuit so that it does not come into contact with the ramp when the car passes a landing.

A modification of the ramp in the well method consists of reproducing the movement of the car on a selector switch in the motor room, thus removing the contacts from the well. The selector is driven from a drum which is connected to the car by means of a flat steel tape or fly rope.

A novel and accurate form of levelling which is fitted on a number of lifts employs thermionic valves. The levelling unit, including the valves, is mounted on the car and consists of a simple oscillating circuit with the conventional grid and plate coils, the oscillation being maintained through the inductive relation between the coils. The constants are such that during oscillation the plate current taken from the supply is nearly zero. When the inductance between the coils is reduced, the plate current rises sufficiently to operate a relay in series with the plate. This brings the control into operation to slow down and level the car. The relay is shunted by a condenser which passes the A.C. during oscillation, but will not pass the plate current which therefore operates the relay. The oscillation is destroyed by a metallic plate passing between the grid and plate coils. One plate is fitted at each landing in a position corresponding to the proper car level. The number of valves required depends upon the speed and other factors. The coils are mounted about an inch apart and the device is so sensitive that it is claimed the maximum error is only ⅛″. A diagram of the levelling unit is shown in Fig. **6**.

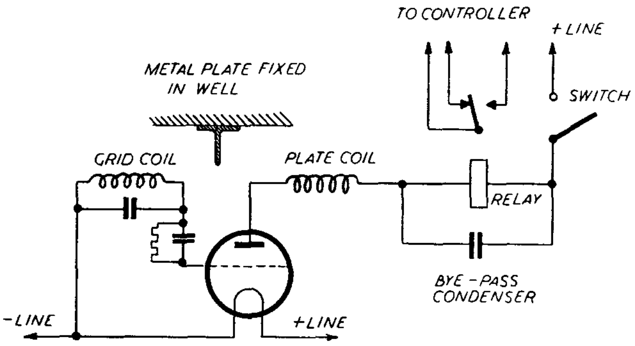


FIG. **6**.—ELEMENTARY DIAGRAM OF THERMIONIC VALVE LEVELLING UNIT.

The inductor system of levelling also makes use of metallic plates fixed in the well at positions corresponding to the proper floor levels. The inductor, which is fixed to the top of the car, consists of a contact normally operated due to its proximity to a permanent magnet. When an inductor plate passes between the magnet and contact, the latter is opened and this results in the power being cut off from both motor and controller. The inductor levelling scheme is being provided on the lifts now in course of construction at Telephone House, Birmingham.

With slow speed gearless motors employing variable voltage control, automatic levelling is performed by running the main motor at a slow speed and an auxiliary machine is not required. This is known as main motor micro operation, the change over to the slow levelling speed being effected by one of the methods described above.

Gates and Gate Locks.

The collapsible iron gate of the overhung type is still very popular and is used on the majority of installations both on the landings and the car. The car gate is usually of the mid bar type in order to eliminate the possibility of a passenger's foot being passed between the bars whilst the lift is in motion. The Post Office specifies that the distance between any mid bar and an adjacent picket should not exceed 2½" when the gate is closed. In another recent type a hollow steel or bronze tube construction is adopted, the tubes being linked together by aluminium links near the ends and in the centre. This gate when opened is arranged to run around the side of the car and has the advantage of giving an exit equal to the full car width. Many landing doors are now constructed either of light steel or wood, and are finished to harmonize with the surroundings. The advantages of solid doors are the elimination of draughts from the lift well and a reduction in fire risks. Another recent innovation is the operation of the car and landing doors by power. The doors are opened automatically when the car reaches the landing, the operation being effected either by pneumatic means or by an electric motor. In one form of operation the doors are both opened and closed by power, whilst in another they are opened by power and closed by springs. The doors on some push button lifts are arranged to open automatically when the landing is reached and to close automatically after a passenger has entered and pressed the button to despatch the car. If a passenger does not enter, the doors close automatically after a definite time interval, thus leaving the lift so that it can be used by any person at another landing. The closing pull of the doors is usually not sufficient to injure any person who may be trapped. In some American installations, however, the possibility of power operated doors closing on a passenger is guarded against by focussing one or more light beams across the lift entrance on photo-electric cells connected in the door control circuits. Should a passenger step into the path of the doors after they commence to close they will immediately re-open. With car switch control the opening is done automatically, but the closing is always under the control of the operator. The movement of the car switch to the up or down position is sometimes arranged to complete the circuit of the door closing motors and even after the doors have commenced to close the return of the car switch to the off position will cause them to open.

A large percentage of lift accidents is attributable to gates and gate locks and it is, therefore, very important that particular attention should be given to the design of car and landing gate locks. In a satisfactory design it should be impossible for any gate to be opened whilst the car is in motion and, furthermore, for the car to be moved away from a landing when any gate is open. The mechanical lock and the electrical interlock are now usually separate portions of the lock with the former operating slightly in advance of the latter. Hence the door is in the locking position before the electrical circuit of the control gear is made and is mechanically locked when the car leaves the floor. The lock is released by a ramp on the car when the landing is reached or passed. It is therefore seen that even with a lock of this type the desired conditions mentioned above are not fully met as it is possible to snatch open the landing gate when the car passes. This bad practice, apart from the possibility of temporarily putting the lift out of service, is liable to cause damage since the gate contacts are not designed to break current. The fitting of what is known as a retiring ramp ensures that the striker on the gate lock is not operated when the car passes a landing, thus not only preventing the gate from being snatched open, but also eliminating the noise caused by the ramp hitting the striker when passing. The retiring ramp consists of an electro-magnet fitted on the car, and the magnet, being energized when the main motor is in circuit, withdraws the ramp beyond reach of the gate lock striker when the car passes a landing. This type of ramp could be fitted with advantage on many of our lifts especially those operating at the higher speeds where the snatching of a gate and the consequent over-running of the car might leave the well exposed to waiting passengers.[1]

Safety Devices.

It is obvious that some means must be provided to prevent the car falling to the bottom of the well in the event of the ropes breaking. The types of car safety gear in use to-day are much the same as those used twenty years ago. In one form serrated cams, fitted on the underside of the car, clamp the car to its guides if the ropes break or stretch unduly. The cams, one on each side of the car, are connected together by links which operate both cams simultaneously. The operation of the cams, however, is practically instantaneous and they are therefore not suitable for speeds above 200 ft. min. Further, there is danger of the guides being damaged when

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[1] Since the preparation of this paper, the Post Office has decided to fit retiring ramps on all new lifts in which the travel exceeds two floors.

the cams are brought into operation. The wedge clamp type safety gear, which is gradual in action, is the better type and is composed of two heavy steel jaws which are gradually closed by the rotation of a drum fixed under the car. The drum operates the jaws through screws and link gear. It is necessary to ensure that the jaws on each side exercise an equal pressure on the guides at the same moment.

Safety gear is often fitted on the counterweight in addition to the car and invariably when there are floors under the lift well. On some recent installations switches have been fitted on the safety gear which, by breaking the control circuit when the proper clearance does not exist between the gear and the guides, stop the car. One method of operating either type of gear is by means of a fly rope connecting the gear to the counterweight so that if the hoisting ropes break or stretch a tension is put on the fly rope which operates the safety gear. A better method, and one which guards against failure of the lifting mechanism, is to use an over-speed governor which operates the safety gear when the speed of the car in descent exceeds a predetermined value.

Limit switches are fitted which by opening the control circuit and applying the brake prevent the car over-travelling the top or bottom landings by more than a few inches. The usual form of operation consists of an endless fly rope passing round a sheave in the bottom of the lift well and connected to the limit switch in the motor room. A striker on the car engages stops on the fly rope, the stops being fitted from 3″ to 12″ above and below the top and bottom landings respectively, the distance depending on the available overtravel.

Buffers are fitted in the bottom of the lift well and constitute the final emergency device. Their object is to lessen the shock in the event of the car over-travelling and the limit switches failing to function. The most common form of buffer consists of spiral or volute springs; two under the car and two under the counterweight. The strength of the springs and their travel should be such that they will bring the car to a gradual standstill from full speed without risk of breaking. The tendency is towards the use of piston type oil buffers, one for the car and one for the counterweight and these are now almost invariably fitted when the speed exceeds about 350 ft. per min. With this type it is usual for the counterweight buffer to be fitted to the underside of the counterweight and to operate on a bumper in the bottom of the well. By this means the buffer is made to form part of the counterweight itself. The piston travel allowed of course varies with the speed and is about 30″ for a speed of 500 ft. per min. If the well is totally enclosed and solid type landing doors are fitted it is possible to use the column of air below the car as a buffer. Although I believe this has been made use of in America, I am not aware to what extent.

Sufficient clearance must be given at the top of the well to ensure that the car does not foul the overhead structure when the counterweight is compressing its buffers. Similarly, clearance must be allowed for the counterweight when the car is on its buffers.

The minimum overhead clearances allowable for the car and counterweight vary with car speeds and are about 2 ft. and 1 ft. respectively for a speed of 300 ft. per min.

To allow of sufficient over-run a space must be provided between the bottom of the car and its buffers when the car is at the bottom landing. The specified over-run depends upon the speed of the car and should be not less than 3 ft. and 5 ft. for car speeds of 300 ft. per min. and 500 ft. per min. respectively.

Guides and Shoes.

Two balance weight guides and two or more car guides are necessary; the number and positions of these guides depending upon the landing openings required. Landing openings on one side of the car permit of the simplest guide arrangement, the balance weight guides being fixed to the wall opposite the landings and the car guides, one on each of the remaining two walls. In some lifts it is necessary to cater for landing openings on two opposite sides of the well, in which cases, a car guide is supported on each of the two remaining walls and the balance weight guides on one of these walls. Openings on adjacent sides are sometimes required and this involves guiding the car, diagonally, at two of its corners or alternatively at each of the four corners.

Car guides are frequently made of round steel with screwed socket joints. The best method of fixing these guides, particularly for long floor spans, consists in mounting them on cast iron seatings, fixed to " H " section steel backings, the latter being secured to the lift well at points not more than four feet apart, either by Lewis bolts or by bolts passing through the walls and fastened on the outer sides by steel plates. In either case a sound fixing is necessary and when Lewis bolts are employed, they should be sunk into the wall at least six inches, and firmly bedded. The use of backings avoids the necessity of employing large section guides in order to secure rigidity, and further, enables the safety gear to operate on the backings instead of on the polished guides.

During the past few years, car guides made of " T " section polished steel have become very popular and these are now being used on most modern high speed lifts. One advantage of these guides is that there is no tendency for the shoes to get out of place as is possible with round guides. " T " section guides are jointed by means of a machined spigot and socket joint along the webs, whilst the flanges are machined and jointed by a steel fishplate. The actual method of fixing the guides depends upon the construction of the well. The guides are secured to suitable steel brackets, by means of clamps, the brackets in turn being fixed to the well either by Lewis bolts or to the steel well structure by nuts and bolts. The guide fixings are spaced at distances of about six feet throughout the length of the guides.

Balance weight guides are either " H " section steel, round steel or " T " section steel, the latter being the best practice.

Guide shoes are fitted on both balance weight and car. Four shoes are provided for the balance weight; two at the top—one on each side—and two similarly placed at the bottom. The number of car shoes employed depends upon the number and positions of the landing openings required. With openings all on one side,—the best and most usual arrangement—four car shoes are provided, similarly placed to those for the balance weight. For round or " T " section guides, both car and balance weight shoes are of phosphor bronze and they should have ample bearing surfaces and be readily adjustable and renewable. Compression springs are fitted to the shoes in order to ensure an even pressure on the guides.

Maintenance.

The importance of efficient lift maintenance will be realized by everyone as not only is the quality of service largely governed by the efficiency of the maintenance engineer, but the safety of a number of people may be entirely dependent upon adequate attention having been paid to the safety gear during the periodical inspection. The time which elapses between successive inspections depends upon the importance, amount of traffic, and size of the particular installation. In large and important buildings where perhaps ten modern lifts may be working, a qualified lift mechanic is often employed in the building continuously. The Post Office practice is to ensure that each lift gets a thorough inspection at least once every month.

The method of inspection will vary depending on the lift engineer, but a definite system must be adopted if the inspection is to be of real value. A satisfactory order in which to carry out the various tests is as follows. The motor room appears to be the obvious place to make a start and the point of commencement, the motor. This should be checked for lubrication, brush and commutator wear. If a geared machine is employed the level of oil in the gearbox and the condition of the teeth must be ascertained. Attention should be given to the worm thrust bearings which if badly worn are liable to transfer the thrust to the motor bearings and these not being designed for such work will overheat and possibly be fractured. The brake adjustment can now be checked and this is important in so far as a badly adjusted brake is liable to cause inaccurate floor levelling, inching, and consequent increase in energy consumption. The drums or sheaves should be examined for looseness on their shafts and hammer tested for cracks. Worn sheave grooves may be responsible for a considerable amount of rope wear and slip and the grooves may be tested by moving a screwdriver up and down the sheaves after the current has been switched off. Ensure that the idle or vibrating pulleys are free on their shafts. The adjustment of the governor and the condition of the controller may now be examined. The lift engineer should be on the look out for burned contacts, badly adjusted dashpots and loose connections on the controller. An insulation test should be taken on the main motor and control circuits. Before leaving the motor room the final and probably most important and difficult item of inspection is the hoisting ropes. It is very difficult to determine when a hoisting rope should be condemned as cases of rope breakage have occurred when no broken wires have been visible and others in which the ropes have given long service even after a comparatively large number of wires have failed. It should be mentioned that the factor of safety employed is 15 so that the presence of a few broken wires does not indicate that the rope should be immediately renewed. The decision is largely a matter of experience and is governed mainly by the number of adjacent broken wires. A satisfactory rule is to renew the cables if more than six wires are found to be broken in one lay of any one strand. One method of detecting broken wires is to lightly hold a wad of cotton waste against the rope and the fractures will pick out the threads. A careful visual inspection with the aid of a small mirror is probably the best method. The next items needing inspection are the landing pushes, doors and locks and it should be made certain that it is impossible to move the car with any landing door open. If the doors are power operated the mechanism should be inspected. The plate should be taken off the car buttons and the latter examined, after which the car gate locks may be tested. From the top of the car attention can be given to the ropes, their fastenings and the equalizing gear, limit switch, shoes and guide lubrication. The final position of inspection is the bottom of the well, where any necessary attention can be given to the safety gear, buffers and compensating ropes when fitted.

Recent American Developments.

In order to improve the lift service in some of the large American " skyscrapers " double deck cars have been installed. The first installation employing this new feature was that of the Cities Service Building, New York. Eight double deckers, starting from the ground floor and travelling at a speed of 1000 ft. per min., serve all floors from the 29th to the 63rd, seven single decked cars starting from the ground floor serve floors from the 16th to the 29th, whilst floors below the 16th are served by eight others running at slower speeds. The two cars of a double decker are built in one frame with an overall height of 25 ft. and travel as one unit. One deck serves floors having even numbers and the other serves odd numbered floors, the distance between the two cars being equal to that between the floors. Automatically operated doors open in answer to calls, *e.g.*, doors at 51st floor will open if called and those at 50th floor remain closed if not called. Automatic dispatching is employed to signal the cars when to start and also to indicate to the operator when he is ahead or behind schedule. Each double deck lift is driven by a gearless motor running at a normal speed of 95 r.p.m. which is controlled by variable voltage. The roping is double wrap traction and signal control is used on all lifts.

One objection to the use of double deck cars is that both cars operate at the same speed and serve the same zone. In the 11 storey Westinghouse Office Building, Pittsburgh, this objection does not exist and two independent elevators are operating in the same well. A further advantage of this scheme is that the lift shafts can be reduced by 50% and the rentable floor space thus increased. The top car operates from the 2nd to 10th floors and the bottom from the ground to 8th floors. The hoisting cables for the lower car lead down on either side of the top car and are attached to the ends of the lower car cross beam. One set of guides is used for both counterweights, the top counterweight being attached to the bottom car. The hoisting ropes are attached to the top car at the centre and lead to the bottom counterweight through a slot in the upper counterweight. Both cars are controlled by a fully automatic push button system, and each car has a set of three signal lights; green for full speed, amber half speed and red for stop. Oil buffers stop the cars at either limit of travel and an oil buffer between the counterweights prevents shock. Aluminium is used for the car sling, platform frame and doors and this metal is used wherever possible in order to decrease the weight and energy consumption.

Conclusion.

In conclusion, I desire to take this opportunity of expressing my thanks to Mr. W. Stretch, of the Technical Section, South Lancashire District, and to Mr. C. W. Govett, of the Engineer-in-Chief's Office, Power Branch, for assistance in the preparation of this paper, and to the following firms: Messrs. Etchells Congdon and Muir, The Express Lift Co., Marryat and Scott, Pickerings, Wm. Wadsworth & Sons, and Waygood-Otis, for kindly supplying information and illustrations.

Appendix I.

Ratio of Rope Tensions for a satisfactory Traction Drive.

(*a*) *Single Wrap.*

T_1 = tension on tight side of rope.
T_2 = ,, ,, slack ,, ,, ,,
θ = angle subtended by that portion of rope in contact with sheave.
bc = indefinitely small portion of BC.
$d\theta$ = angle subtended by bc.
T = tension in rope at c.
$T + dT$ = tension in rope at b.
S = resultant pressure of sheave on portion bc of rope.
μ = coefficient of friction between rope and sheave at the point of slipping.

$$(T + dT) - T = \mu S$$

$$\text{but} \quad S = T d\theta \ldots\ldots \Delta \text{ of forces, Fig. } 7(a).$$

$$\therefore \quad dT = \mu T d\theta$$

$$\frac{dT}{T} = \mu d\theta$$

$$\therefore \int_{T_2}^{T_1} \frac{dT}{T} = \mu \int_0^\theta d\theta$$

$$\therefore \quad \log_e \frac{T_1}{T_2} = \mu\theta$$

$$\text{or } \frac{T_1}{T_2} = e^{\mu\theta} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Since the rope lies in a V groove—Fig. 7(*b*),—the effect is to increase the resistance to slipping due to the wedging action between the two surfaces. The resistance to slipping in element bc is $2\mu R$.

But $S = 2R \operatorname{Sin} \alpha$ where 2α is the angle of the groove.

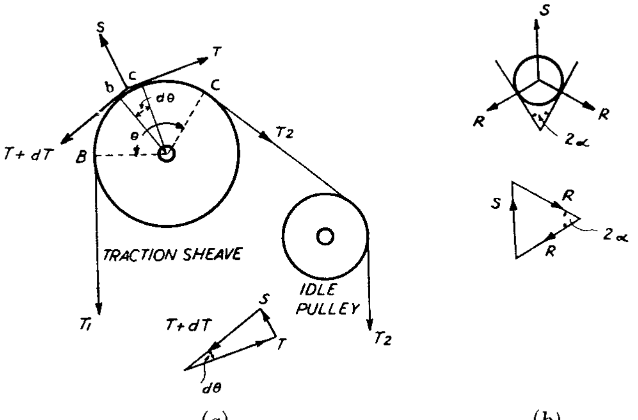
$$\therefore \quad 2R = S \operatorname{Cosec} \alpha.$$

Hence the resistance to slipping in bc is $\mu S \operatorname{Cosec} \alpha$.

In equation (1) above, which is for a flat band, the resistance to slipping in bc was taken as μS. In order that this equation shall be applicable to a rope in a V groove it is therefore necessary to substitute $\mu \operatorname{Cosec} \alpha$ for μ and the equation becomes

$$\frac{T_1}{T_2} = e^{\mu\theta \operatorname{Cosec} \alpha} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

It will be seen from equation (2) that when an idler is employed and the angle θ reduced the traction is consequently less. To be rigidly accurate the area of contact should be considered, as μ is a function of the unit pressure.



(*a*) (*b*)

Fig. 7.

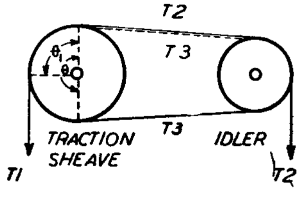


Fig. 8.

(*b*) *Double Wrap.* (Fig. 8).

$$\frac{T_1}{T_3} = e^{\mu\theta_1 \operatorname{Cosec} \alpha} \text{ and } \frac{T_3}{T_2} = e^{\mu\theta \operatorname{Cosec} \alpha}$$

$$\therefore \frac{T_1}{T_2} = \frac{T_1}{T_3} \times \frac{T_3}{T_2} = e^{\mu\theta_1 \operatorname{Cosec} \alpha} \times e^{\mu\theta \operatorname{Cosec} \alpha}$$

$$\therefore \frac{T_1}{T_2} = e^{\mu \operatorname{Cosec} \alpha (\theta + \theta_1)}$$

The traction is therefore increased by employing the double wrap method of drive.

Appendix II.

Size of Equipment.

Let the car and load be 3000 lbs. and 2000 lbs. respectively.

If counterweight = Car + 50% load

∴ ,, = 3000 + 1000 lbs.

= 4000 lbs.

Assume that speed = 400 ft./min.,

and that mechanical efficiency = 70%

$$\therefore \text{Horse Power required} = \frac{(5000 - 4000)\,400}{33000 \times 0.7}$$

$$= \underline{17.3}$$

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