sheaves of small diameter, and chains instead of wire cables, working like the proverbial string over the nail. The author has letters in reply to representations, in which one of these firms say it is not their practice to use wire ropes, and they do not believe in them for lifts. That same firm made a set of lifts in England to the author's plans for a Pitt-street warehouse, and although the specification distinctly said the sheaves were not to be less than 2 ft. 6 in. diameter, they were actually made and sent out only 21 in., and those lifts on trial showed 55 per cent. lost in friction. Contrast that with the horizontal hydraulic jiggers having sheaves four feet diameter, fitted with anti-friction bearings, and carrying wire ropes in turned grooves, made a few years afterwards by the same firm to the author's drawings for Messrs. Hordern's ironmongery store, where the friction is nearer 15 per cent. than 55 per cent.

It is needless to say that all lift-makers use wire cables now, but they are all inclined, owing to competition, to use sheaves of too small diameter, unless there is a consulting engineer to look after them. Before leaving these horizontal hydraulic engines attention may be called to a feature patented by the author, which consists of partly rotating the carrier containing the moving sheaves. The drawing (Plate XI.) shows how, by so doing, one of the moving sheaves takes the cable off one of the fixed sheaves and leads it on to the next fixed one, so that all the lines of cable work are parallel at all times and there is no side play on the sheaves, as is the case with English machines having the cable angled backwards and forwards from one end to the other.

By the year 1884 there were a number of very good lifts in Sydney, and the public had become accustomed to their use, but the rate of travelling was slow, and in some cases (particularly with screw lifts) the noise and vibration was very bad, and the smooth, even working with high speed of the present day was then unknown. In 1884 and 1885 the author examined scores of lifts in America and on the continent of

Europe, and the result was to show him that the average speed in the United States of America was much higher than in Europe, although there were no power companies in that great country. They worked their lifts almost universally from wooden tanks on the roofs of the buildings. The Western States had a few direct lifts, but in the Eastern States suspended lifts were nearly universal. In London and Paris, at that time, however, the best lifts were of the direct-acting hydraulic type, although an American Company was making great efforts to introduce the cheaper Baldwin lift into those cities. The result of widespread observations was to impress him with the great superiority of the direct-acting hydraulic lift, both for safety and smoothness of working, in all cases where capital was available for the increased first cost necessary for sinking shaft, &c.

Since his resumption of business in 1886 the author has devoted a great deal of attention to the designs of improvements in passenger lifts to secure the following points:—A high speed with perfect smoothness of starting and stopping reducing the concussion in the pipes when closing the pressure valves, varying the speed of travel while under way, reducing the work of the attendant in handling the valve, and providing a controlling gear which can be held in the hand during the whole travel instead of the ordinary handline running through the car. Other devices are intended to balance the rams as they protrude from the casing, to arrest the descent of the ram and cage should the cylinder be broken, and to land the cage softly on the bottom floor if descending at a high speed. Some of these refinements are only intended for the very highest class of passenger elevators.

Hydraulic balanced lifts on the author's patents have been erected at the Central Wharf, the Sydney Hospital, Royal Hotel and Messrs. Bull's warehouse with the annular balance, but without special compensation for protrusion of the ram, which is not important with short lifts. In lofty buildings the protrusion of the ram must be compensated for, and the following buildings have the tumbling balances shown on plan similar to Plate XII.:—At the Mutual Life Association, George and Wynyard-streets, two lifts of 97 feet travel; the Hotel Australia, two, each 104 feet travel. There are also three at the Government Works and Lands Office, and two at Messrs. A. Hordern's new warehouse, 97 feet travel, the hydraulic pressure being in each case 700 lb. to the inch. As the passenger lift at Messrs. Hordern's is the latest, and embodies all the detail improvements referred to, a description of that will suffice, and as it is allowed by experts to be in many respects the most advanced passenger lift in the world at present, it will conclude this paper. In saying it is the most advanced it does not mean it takes up the heaviest load. There are several plates on the table showing the great lifts on the Hudson River at New York, the Mersey tunnel lifts and others, a description of which would be interesting, but would be outside the title of this paper. Messrs. Hordern's goods lift is 97 feet travel, with a $6\frac{1}{2}$ inch steel ram, and the passenger lift is 85 feet travel, with a $6\frac{3}{4}$ inch ram, and as the displacement of the two is very similar, the hydraulic balances are identical in design. The hydraulic pressure is 700 lb. to the inch. The power ram suspended from the upper cross-head of the balance is $7\frac{1}{2}$ inches diameter. The cylinder of this power ram forms externally the displacement ram which forces up the lift ram. The displacement ram is $16\frac{1}{2}$ inches diameter by 14 feet 10 inches net stroke; the area of power ram ($7\frac{1}{2}$) is 44·17 square inches, and of the displacement ram ($16\frac{1}{2}$ dia.) 213·8 square inches. Then 700 lb. multiplied by 44·17 and divided by 213·8 gives 144·1 lb. to the square inch as the pressure in the displacement and lift cylinders, and this, multiplied by the area of the lift rams ($6\frac{3}{4}$ diameter), 35·78 area, gives 5,155 lb. as the average static force under the lift rams, apart from friction, and it will thus be seen that there is a very large margin to lift 20 or 25 passengers at 15 to the ton. A column of water 85 feet high has a pressure of about 38 lb. to the inch, and as this lift ram has an area of 35·75 square inches it is evident that when it is run right out its lifting power would be 1,359 lbs. less than when it was commencing to lift, unless there was compensation provided. In order to secure this compensation great numbers of devices have been adopted; the simplest and most obvious one is to attach a balance weight to the car by means of a chain which weighs one-half the column of water of corresponding length. In the Works Office lift two ¾″ chains, and in the Lands Office four wire ropes, were used for this purpose. In these cases, when the lift is down the chains or cables hang on the inner or cage side, and thus reduce the effect of the balance weight as they travel over the pulleys at the top; when the lift rises they pass to the outer or balance weight side and thus increase the effect of the balance weights. The result of this action in very high lifts, however, is to cause the ram to hang from the car at the top of the stroke and place it alternately in tension and compression—a bad feature.

At the Grand Hotel, Paris, some years ago, the ram, through this cause, became detached from the bottom of the car, and immediately the balance weight ran away with the car to the top of the building with such force that several of the passengers—members of the French nobility—were killed. As a result, numerous inventions have been introduced to do away with suspended balances in all first-class lifts. Among the many contrivances to compensate for the protrusion of the ram, one system has water tanks on the balance cross-head, to fill as the balance goes down and empty as it rises. Messrs. Waygood's system, as adopted at Messrs. Gardiner's, has a large balance weight working right down the lift shaft, and having its chain attached to the large end of a spiral fusee drum, it winds on towards the small end with gradually decreasing leverage as the balance goes up and the car descends. This spiral drum is fixed on a shaft at the bottom of the balance, which also carries two other drums, having chains led up to and drawing down the balance cross-head. Of course, this balance is correct in principle, but the friction of three chains and three drums with the bearings of the shaft is considerable, and all working down a deep hole below a basement floor—generally in water—it is far from satisfactory.

After turning over several plans the author was ultimately led to devise the plan of balance now adopted, as in Plate XII., which has the advantages of the minimum of friction with the minimum of wear and tear, and is always in sight. The friction is so small that, although rollers are provided to guide the cross-head of the balance ram, the side thrust of the tumbling balances is so small that they are not brought into play. Owing to the special form of the compensating weight it will be seen that when the balance ram is down and the lift up, all the weight is acting on the balance. At half stroke the weight is horizontal, half on its carriage and half on the balance ram, and when the lift is down the weight is entirely on its own wheels and off the balance. In Messrs. Hordern's lift just referred to, an exact compensation would require 1359 x 6 = 8154 lbs., or nearly 73 cwt. = 3 tons 3 cwt.; but as it is not desirable to have the full power right to the top of the stroke, the weights are made about 30 cwt. each. In this case the proportion of the stroke of the balance to the travel of the car is as 1 to 6, and therefore one ton of balancing requires six tons of metal, and it might be thought that this would be a disadvantage, but it is really one of the principal advantages of these hydraulic balanced lifts, for while the great weight takes comparatively no power to move when it is once started, yet in starting it absorbs all shocks and acts like a fly-wheel to store up and give out power. Hence the peculiar floating sensation one feels in travelling by these lifts.

One result of putting in so much dead weight to get into motion prevents the sudden pressure of the water acting on the nerves of the individual, but at the same time makes it much more severe on the pipes when the valves are operated suddenly. This has led the author to introduce the hydraulic cushion (Plate XIII.) on to the pipes connecting the balance and the lift rams. These cushions are simply small cylinders having pistons resting on a set of steel springs, which yield and take up the shock or concussion. The effect is to absorb nearly all the excessive pressure without any loss of power, because the springs restore the power as they come back again. Other cushions of rather smaller dimensions are interposed between the pumps and the accumulator, with the result that the working of the pumps cannot be detected in lifts.

To provide against any outside accident in the building, breakage of the ram castings or pipes, or other castings that may let the water out and thus allow the lift to fall, the arrangement shown on the plan (Plate XIV.) is adopted. This consists of a gripper encircling the ram and resting on the gland. The jaws are closed by a powerful cam forged on a lever, having a heavy balance weight. Under ordinary conditions this weight is kept up by a small subsidiary ram working in a cylinder secured to the walls of the lift, and acted directly upon by water from the lift cylinder. Should anything happen to let the water escape from under the main lift ram it will, of course, at once escape from the subsidiary cylinder, letting the balance weight fall when the gripper seizes the ram and compresses the packing, which assists, with the gripper, to prevent the ram from falling. This apparatus can be tested at any time by opening a cock to let the water out from under the small ram. This passenger lift also has an air cushion at the bottom, and it is probable that if it came from top to bottom at full speed it would be brought to rest without noise or hurt, as experiments have been tried in America with these air cushions by cutting the car clean away from the top of the building, with the result that a glass of water placed on the floor had none of it spilt when it stopped at the bottom (Plate XV.).

The last appliance to be described is the valve and its gearing (Plate XVI.). As is well known, it is easier to start a lift than to stop it nicely, and with a speed of 400 ft. a minute, and ordinary hand lines, it not only requires practice to arrest the rope without a jerk, but is very hard upon the attendant's hands. Schemes had already been introduced to work the main valve by means of a piston in a cylinder operated by the power of water, and leaving the attendant to work the small valve of such water engines; but it is easy to see that when once such small valve was opened the large valve would be moved to full stroke, the effect of opening the small valve, more or less, being merely to regulate the speed of the large valve's motion. The author directed his attention for a long time to find some method by which the main valve should directly respond to the motion of the small valve, so that if the small valve was moved one quarter of its travel the large one would also move the same proportional distance, and the problem was solved by placing the small valve right on the top of the large valve, as shown on the drawings. At the same time a plan was devised of working the small valve from a rod lever or handle in the car—which the attendant kept continually in his grasp—instead of by the ordinary hand line. The result is that instead of making a series of snatches at the hand line to reduce the speed of travelling, the speed of travel can be reduced or increased while under way without any shocks, and therefore a greatly increased speed of travel is possible—of great importance in this busy age. The drawing (Plate XVI.) shows that there are three ports on the back of the large valve, the centre one being drilled right through to the main exhaust, and the others lead to small cylinders at opposite ends of the valve casing. The two pistons are connected by a bridle, which embraces the main valve, and the large valve is always thus brought under the centre of the small valve, which has only about one-sixteenth inch cover. For instance, if the small valve is moved a quarter inch to the left the port to the right hand cylinder is opened and the main valve at once removed till it is brought under the centre of the small valve again and the ports closed. The drawings explain themselves, and show two methods of how the difficulty is overcome getting the water past the face on the large valve to the cylinders at ends. The regulating gear, shown on plan (Plate XVII.), is also self-explanatory. A small line, fixed at the top of the building, passes around two turned sheaves on a lever attached to the car. The attendant, by moving his hand, makes a larger or smaller "kink" in the line, which thus raises or lowers the lever of the small valve. Provision for shifting the valve at the top and bottom of the stroke automatically, should the attendant neglect his duty, is also made by an ordinary valve line and stops.

APPENDIX.

EXPLANATION OF CONTROLLING GEAR OF LIFTS (PLATE XVII^{A}).

THIS plate is intended to illustrate a number of different ways of establishing a double control to lifts, using the ordinary hand line in conjunction with a lever, handle rod, or line, which may be retained in the attendant's hand while the cage is moving, to permit a very fine and gradual control.

Figs. 1, 2, and 3 show a fixed line shortened or lengthened by kinking lever on cage. Figs. 4, 5, and 6 show a travelling line which runs with the cage. The valves B are shown of ordinary make, but are preferably fitted with a jockey valve, as Plate XVII. The stops N^1 and N^2 on line K are for automatically stopping the cage should attendant neglect to move the lever C at top or bottom. The weight Q in Figs. 1 and 2, the angling of the lines on to lever in Figs. 3 and 6, and the double sheaves on lever in Figs. 4 and 5. are all devices to bring the lever automatically to the centre to close the valve should attendant let go of controlling device. Fig. 7 shows how, by having double grooves in the sheaves G^1 and G^2, two lines may be employed to give positive motion to valve B. and dispense with balance weight L. Figs. 8 to 12 show the arrangements of the ports and slide of regulating valve to ensure the valve being closed both at top and bottom, as well as in the centre of stroke, should a line break and allow the valve lever to fall.