

*(Abstract of Paper No. 3614.)*¹

"The New Inclines of the São Paulo Railway, Brazil."

By JAMES FFORDE, M. Inst. C.E.

DESCRIPTIONS have already appeared in the "Proceedings" of the Institution² by Mr. D. M. Fox, M. Inst. C.E., of the rope incline of this railway, a single line of 5-foot 3-inch gauge with a gradient of 1 in 9.75, which has been worked with safety for 33 years. The Paper, of which this is an abstract, describes the doubling, on an improved basis, of this particular length of the whole doubled line, in order to meet increase of traffic. The improvements consist of the attainment of an easier gradient, 1 in 12½, by means of a new alignment which is fully described, and the adoption of the "endless rope," the advantages of which are fully detailed, instead of the "tail-end" system of the old incline. The new inclines are about 6½ miles in length, and rise 2,606 feet in that distance.

Before any rope system was decided on for the duplication, the question of a locomotive line, by the rack or other contrivance, was fully considered and rejected. The work, which was begun in 1896 and completed in 1901, at a cost of £1,453,751, including its share of rolling-stock and all charges, of which full details are given, is of a very heavy character, there being nineteen tunnels and sixteen viaducts. The description of the great difficulties with one of the former, and of the means by which they were overcome, forms an instructive part of the Paper. To avoid excessive rope-weight the incline is divided into five nearly equal lengths, each about 1¼ mile, equality being adopted because the time of passing over the whole set of inclines is regulated by the length of the longest one. Between these lengths are bank-heads 142 yards in length, each having a hauling-engine. The gradient on these is level for the rising trains and 1 in 57 for the descending ones. Here the trains pass each other, and change from one rope to another. There are also passing-places at the middle of each length.

¹ The original Paper is filed at the Institution.

² Minutes of Proceedings Inst. C.E., vol. xxx, p. 29, and vol. lxi, p. 127.

The track has three rails, of Vignoles type, weighing 93 lbs. per yard, adopted as offering greater facilities for the application of the emergency rail-clip brake, one rail being common to both lines. The sleepers for the three-rail tracks are 14 feet by 10 inches by 5 inches. This arrangement is of course departed from at the passing-places, where there are double lines. The endless rope is worked as follows: there is a horizontal return-wheel 14 feet in diameter at the bottom of the incline, round which the rope passes, fixed on a carriage travelling on rails laid on a track 105 feet in length to a gradient of 1 in 8, and placed in a chamber (details of which are given) underneath the lines of rail. To the lower end of this carriage a chain is attached by means of a flexible wire-rope and pulley-blocks, which passes under and over the pulleys, and has an adjustable weight of 5 tons at the end, suspended in a pit. By means of a special contrivance, fully described, the daily expansion and contraction, as well as the permanent extension of the cable, are provided for. After leaving this gear, the rope is deflected to the track by two pulleys, 8 feet in diameter, the upgoing part of it, after traversing the incline, passing, by means of another deflecting-pulley, to the first-motion rope-drum of the engine, and from there to the second-motion drum. Making four half-turns round each drum, it passes then to the upper fixed return-pulley, 14 feet in diameter, at the back of the engine-house, and thence to another deflecting-pulley and along the down track to the return-pulley at the foot of the incline, to which it is guided by the second deflecting-pulley.

The hauling-engine has two cylinders, driving direct on to the winding-gear. The cylinders, which are 22 feet 6 inches apart, centre to centre, are 32 inches in diameter and 60 inches stroke, fully steam-jacketed, and with valve-gear of the Corliss type. Full details and descriptions of the engines and engine-houses are given in the Paper.

Beyond the crank-shaft, the frames supporting the cylinders are extended to carry a second shaft, parallel to the crank-shaft, which is required to carry the second hauling-wheel and a pulley, which receives motion from the fly-wheel, to drive the second hauling-wheel and its shaft. On each of these shafts are two rope-wheels, 25 feet in diameter and 4 feet 11½ inches in width, having sixteen grooves for transmission-ropes and a flat space for a brake-strap. By means of these wheels, fitted with cotton driving-ropes 2 inches in diameter, 50 per cent. of the power is transmitted to the second shaft, which is rotated at the same speed as the crank-shaft, so that the hauling-wheels fixed on the two shafts above referred to move at

the same speed. These hauling-wheels or drums are 14 feet in diameter, and are furnished with sufficient grooves to enable the hauling-rope to take five or less laps round them, passing half round the wheel on the crank-shaft and then the same amount round the second wheel. These drums are of the "Walker" pattern, particulars of which are given, and the object of which is to remove the bad effects arising from the unequal wear of the grooves, and the consequent strain on all parts resulting from the differential motion.

The engine and gear are controlled by an engine-driver stationed, with his levers, etc., within reach, on a raised platform between the cylinders, and at a height of 10 feet above them; from this position, through a sight-hole, he can see an approaching train, and he has also an indicator before him showing how the trains are moving, as well as pressure- and vacuum-gauges.

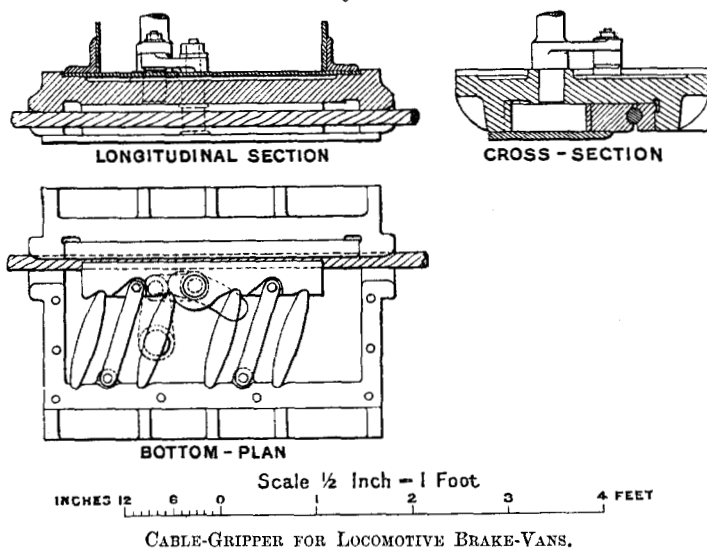
There are four boilers of the Lancashire type at each bank-head, three for regular working and one in reserve, each 7 feet 6 inches in diameter and 27 feet in length, with two flues. The shell is $\frac{3}{8}$ inch in thickness, and the flues are 3 feet in diameter tapering to 2 feet 4 inches, and of $\frac{1}{2}$ -inch plates. The steam-pressure is 150 lbs. per square inch, reduced by a "Royle" reducing-valve, to 100 lbs. per square inch in the cylinders, the object being to enable the steam generated during the interval between the trips to be accumulated, and to avoid having to blow off much steam to waste. An automatic damper is provided to check the production of steam when the pressure rises above normal, and "Vicars" mechanical stokers are used.

The ropes, $1\frac{1}{8}$ inch in diameter, are of six strands, each of nine wires $\frac{1}{8}$ inch in diameter covering seven smaller wires $\frac{3}{32}$ inch in diameter, and a manilla core of three strands $\frac{1}{8}$ inch in diameter, which had been soaked in composition, each wire-strand being about $\frac{9}{16}$ inch in diameter. They were guaranteed to have a breaking-strength of 96 tons and to take a working-load of 12 tons. The rope weighs $13\frac{1}{4}$ lbs. to the yard, and was supplied in two lengths for each incline, the splices, 72 feet in length, having been made on the works. It is supported on sheaves fixed at intervals of 29 feet 6 inches on the straight and 19 feet 6 inches on the curves, the minimum radius of which is 600 metres, or about 30 chains. The sheaves are 16 inches in diameter, of cast steel, with thin flanges and a thickened tread. The bearings are lined with white metal and are provided with "Stauffer" lubricators, and each end of the axles is turned to a form approximating to Scholes' curve as used by him for footsteps of turbines, etc. On curves, special features are required as to inclina-

tion, distance, etc., which are fully described. To prevent slip, a Bullivant rope-nipper, hitherto only used for marine purposes, is employed.

A special feature of the new inclines is the locomotive brake-van, which contains the picking-up gear and the rope-nipper, as well as the hand-brake, the automatic vacuum-brake, and the two emergency clip-rail brakes, one for each rail. These machines, with their appliances, which weigh in working order 30 tons, contain many novel features. They are placed at the lower end of the train, and are also used at the bank-heads to move the train for the distance

Figs. 8.



necessary to enable it to grip one rope after leaving hold of the other, as well as to do any shunting that may be required.

Their principal dimensions are:—

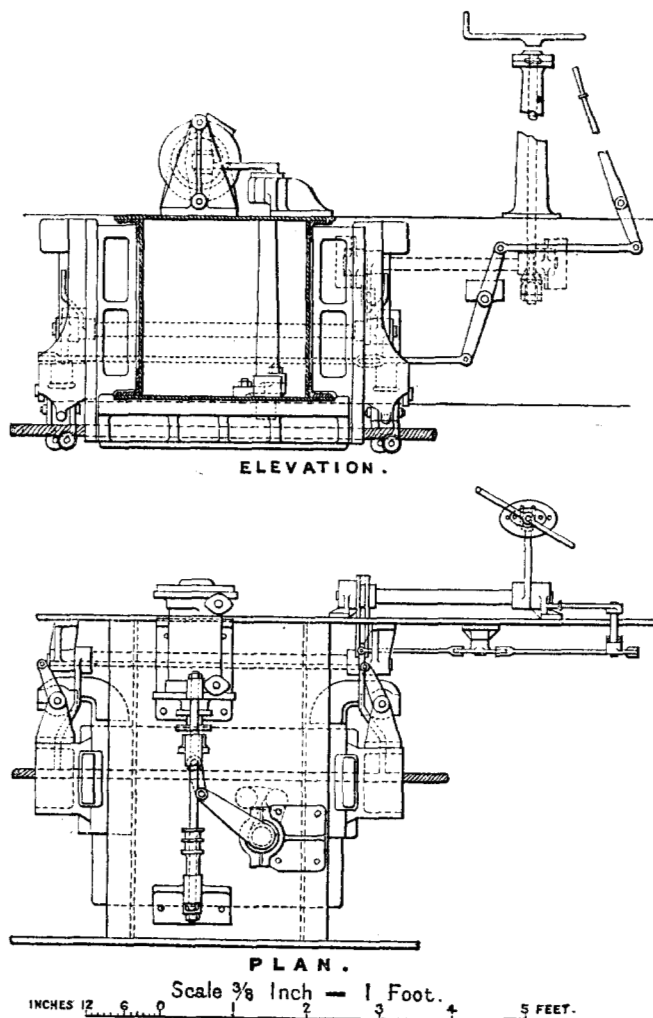
Length over all	19 feet 9 inches.
Cylinders (two)	{ 12 inches in diameter, 16 inches stroke.
Steam-pressure in boiler	150 lbs. per square inch.
" " " cylinder	125 " " " "
Four-wheels-coupled	3 feet in diameter.
Tractive force, about.	8,000 lbs.

The engine carries a coal-bunker and tanks.

The boiler is of the locomotive type, placed so that the bottom of

the fire-box is level with the top of the frame-plates, thus allowing sufficient space under the bottom of the boiler. Between the frame-

Figs. 9.

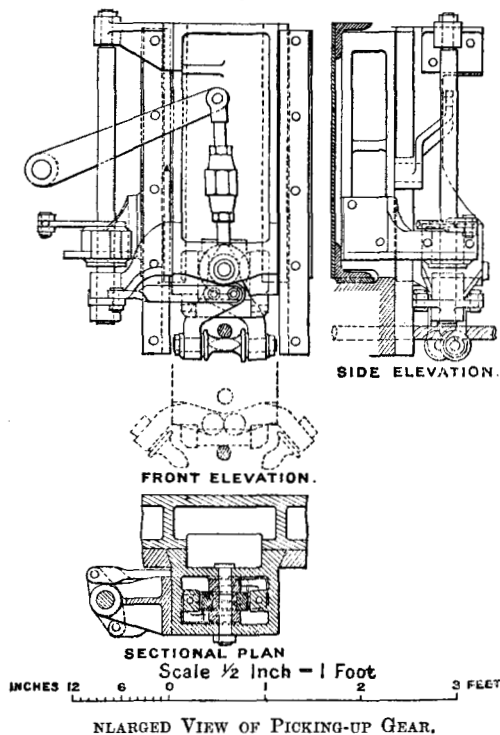


CABLE PICKING-UP AND STEAM-GEAR FOR OPERATING CABLE-GRIP FOR
BRAKE-VAN.

plates, midway between the leading and trailing wheels, a box-girder is placed connecting the frame-plates, the bottom plate of

which carries the rope-nipper; the upper plate carries the steam-gear for working it, while to the side-plates are attached the picking-up gear, one at each end of the rope-nipper, *Figs. 8, 9, and 9a.*¹

In the rear of the trailing wheels are carried, from the frame-plates, one on each side, the rail-grips, by means of which, in case of

Figs. 9a.

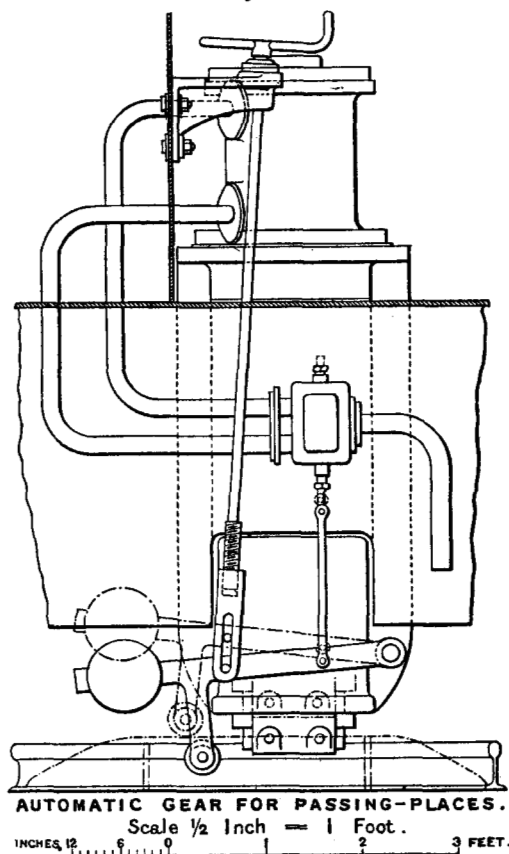
breakage of the rope-nipper, the brake and the train may be brought gradually to a standstill.

The two emergency-brakes or rail-grips are bolted to the outside of the frame-plates, and consist of a casting, in the form of a square tube, arranged to carry, at its upper extremity, a steam-cylinder 13

¹ To prevent confusion in subsequent reference, the numbers of the original drawings have been adhered to.

inches in diameter. For about 12 inches at its lower end, two sides are planed to receive a cast-steel fork, sliding freely in the casting, the range of vertical movement being controlled by two strong steel pins, one on each side, which pass through the side of the casting, rubber cushions being fixed to break the blow with which these pins

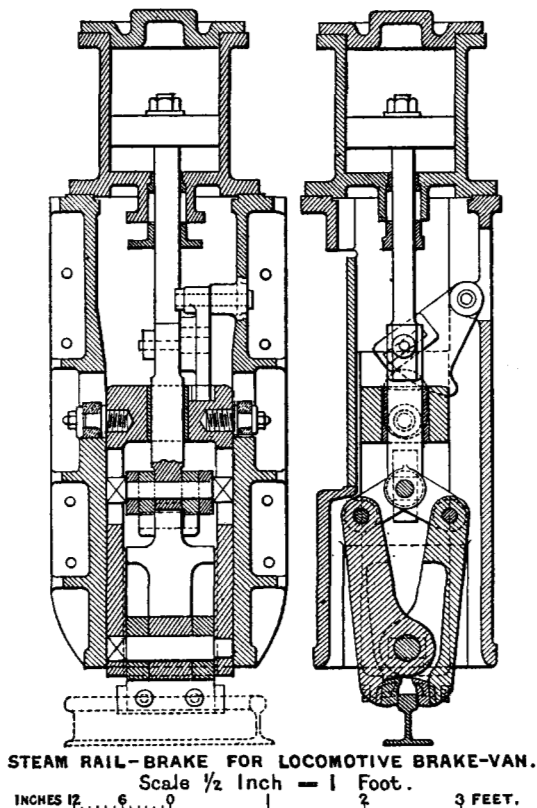
Fig. 10.



would otherwise strike the ends of the slots. The fork, near its lower extremity, has two square slot-holes in which these pins, forming the pivots of a massive pair of steel levers, are free to take a sidewise movement of the locomotive brake, the pins having square blocks at the point where they move in the slots. The steel levers, pivoting on the last-named pins at the ends of their short arms, are fitted

with removable steel dies, with which the rails are gripped. The ends of the upper and considerably longer arms are connected to the piston-rod of the steam-cylinder by two links, so that a toggle action is applied when the piston makes a downward stroke, tending to close the shorter and lower arms of these levers with considerable force, *Figs. 10 and 10a.*

Fig. 10a.



In order to clear points and crossings, the levers which grip are placed a short distance above the rails under normal conditions, descending into a gripping position when in action.

In order that the levers may be lowered to the proper level before the gripping action takes place, a cam is applied, carried by a pin on the casting, above the range of movement, and operated by another

pin on the crank-shaft which moves in a slot on the cam. This cam presses along a path cut in the top of the forked slide, and forces it down until the gripping position is reached, when the path admits of its free movement. Further, in unclipping, the opening of the jaws is ensured before the slide carrying the gripping-levers can be moved up.

To admit steam to the grips, a slide-valve is fixed to one of the frame-plates beneath the foot-plate, with a vertical screw-shaft to work it. This screw is not connected directly to the spindle of the valve, but is attached to a lever moving on a fulcrum-bolt fixed to the main casting of one of the rail-grips, and connected by a pin to the valve-spindle at a point nearer the fulcrum than that at which the vertical screw-shaft is attached. Some distance beyond the last attachment a weight is fixed to the extremity of the lever. Thus, by means of the screw-shaft, the attendant can easily admit steam to the upper side of the piston and operate the machine, and, by reversing the motion, release the grip. To render the action easier, the edges of the slide-valves are cut to a flat V-shape.

To avert the contingency of the gripping-gear, when applied to the rails, fouling the V points of bifurcation at bank-heads and crossing-places, the weight, which has been referred to in conjunction with the valves, is provided with a vertical leg placed to reach towards the rails but to the side of them, and carrying a roller in a fork at its extremity. This roller, engaging with a ramp of wood covered with iron plate fixed in the proper position, is pushed up, and the valve is put in action, ungripping the rails, the reverse action taking place when the ramp allows the leg to descend, *Fig. 10.*

A description of the buildings, water-supply, etc., is also given, with their cost.

Since their completion the new inclines have been in constant and successful operation, and the working has been so economical and the capacity so considerable that they can alone cope with the whole of the traffic, so that the use of the old inclines has been practically suspended, although they are kept ready for emergency.

The Author calls the attention of engineers to this method of dealing with steep inclines, which does not seem to have sufficiently attracted notice, it being, as it seems to him, the most economical mode of working such traffic.

The survey, plans, etc., were made under Mr. James C. Madeley, M. Inst. C.E., and the construction was carried out under the Author, who succeeded him as Engineer-in-Chief of the São Paulo Railway.

Mr. Emilio A. H. Schnoor, M. Inst. C.E., was Engineer of the division comprising the inclines. The Consulting Engineers were Messrs. D. M. Fox and A. McKerrow, MM. Inst. C.E.

The engines and hauling-gear were designed by Mr. W. T. H. Carrington, M. Inst. C.E., for Messrs. Bullivant and Company, Limited, of London, who were the contractors for the supply of the ropes and hauling-machinery. The engines were made by Messrs. Yates and Thom, Limited, of Blackburn.
