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CABLE MACHINERY FOR STREET RAILWAYS.

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To all citizens of Sydney, particularly to the engineering section, this subject should be of peculiar interest, by the fact that, in the near future, the system of cable railways will be running through the centre of our city, and some explanation of the details for this mechanism may prove interesting to the members of our Association.

The author makes no claim to demonstrate that cable railways are superior to electric, steam, or other traction power used for street passenger traffic, but will endeavour to explain some of its principal parts, and while doing so, will in some measure respond to the wish our President expressed, when discussing the relative merits of the pumping machinery for the Crown-street pumping station last year, that papers upon our locally made machinery should prove an interesting subject, from the fact that we would know the engineer who designs, the firm that manufactures, and have the opportunity to judge by personal inspection of the machinery in service of the standard of excellence we had attained, and we might by friendly criticism, aided by the experience of our members, assist in raising the colonial mechanical engineering profession equal to the best.

Great ingenuity had to be exercised by the pioneer engineers of this system in overcoming the difficulties of guiding the cable without interference to vehicular traffic, while making the connection from the passenger-car to the running cable a certainty at will of the car driver, and maintaining the roadway of sufficient strength to resist the heaviest traffic. Perfection is not reached yet, and Australia has the opportunity to give the world more perfect mechanism than we are yet acquainted with. To our American cousins we are largely indebted for cable haulage being so popular a system for street passenger traffic; over 1,000 patents have been issued in the United States alone, relating to this subject. They have, and are, devoting a great amount of energy and capital in extending or improving the system.

The first successful cable tram was Clay-street, San Francisco, started August, 1873, and it proved its superiority for steep grade street railways, as gradients 1 in 6 were negotiated without difficulty. 'Frisco still holds the lead in cable roads; over 100 miles are in operation in this city, the passengers carried in 1890 being 70,630,000, an average distance of six miles for five cents. There are five other cable roads in this city, California-street, Geary-street, Union Presido, Market-street, and Los Angelos. Chicago inaugurated cable roads in 1883, although, unlike San Francisco, it has comparatively level roads, but it is subject to extreme variations of temperature, from a tropical summer to snow falls with the thermometer 25° below zero.

In 1886 New York had 11½ miles working, and after five years' operating, its success is such that the most important road in New York, Broadway, has been closed for a time to permit the laying of a cable railway, which is to have cars starting every forty seconds through the busy parts of the day. The clear breadth of streets traversed by cable trams in this city varies from 60 to 25 feet. Cincinnatti, Kansas City, St. Louis, Denver (Colorado), Baltimore, Cleveland, Columbia, Seattle, Oakland, Michigan, St. Paul, St. Josephs, Butte, Omaha, Lincoln, Hoboken, Texas, Portland, Providence, and San Diego, have in all some 700 miles in operation.

The first country outside of America to adopt the cable was New Zealand, then London, Edinburgh Birmingham, Glasgow, Paris, while Portugal and Turkey have since followed the lead. Birmingham has horse, steam, cable, and electric cars running at nett profits for 1890 as follows :—Horse, $1\frac{1}{4}$ per cent.; steam, $9\frac{3}{4}$ per cent, ; electric $10\frac{1}{4}$ per cent. : cable, $12\frac{7}{8}$ per cent.

The latest power plant laid down is the Broadway Cable Railway, which started in May of this year in New York, where engines of the Corliss type, each of 800 h.p. are working, to supersede horse traction on five miles of road running over eleven miles of cable, and erecting a magnificent central power house on the site occupied for stabling the 2,000 horses previously employed on the roads.

Every new cable railway differs materially in the details of construction, as no uniform or standard type is accepted for the conduit, power houses, or street mechanism, which we might think should be a simple matter, as all rqeuirements are for the same purpose, to guide or guard a running endless rope. Conduits, or cable tubes, are of various designs, for making a tube with a narrow slot on the top side of sufficient strength to sustain vehicular traffic, and of sufficient internal diameter to accommodate the guide pulleys necessary to keep the cable in position. Conduits have been made wholly of cast iron, but have proved faulty. The Broadway conduit has wrought iron plating between the frames.

The tube frame section is of first importance, as it must fulfil the duties of an arch, minus a key. Plate IX., Fig. 1, gives a view of the yokes or frames used with a timber conduit, as first adopted in the early days of cable railways. The other frame is the class used in our Ocean-street Roadway for concrete tubes, and fulfils the conditions of design for greater strength with least metal, combined with simplicity of adjusting braces, with the least disturbance of roadway. The slot beams attached between the frames should be nearly as heavy as the track rails, to absolutely maintain the slot an exact width for the gripper to pass through easily. Special sheaves and frames are necessary for curved roadways; some engineers adopt the vertical pulley with a lower flange, only having a recess turned out for the rope, while others use leading horizontal rollers as guide pulleys. In Ocean-street the vertical pulley without a leading pulley will be used, as shown on Plate IX., Fig. 2. At tangent and terminal roadway, sheaves are of diameter equal to the centres of the double roadway (about 8ft.), and revolve upon a fixed pin in a heavy cast iron sole plate. The pits in which they are fixed are of a size that admits of easy inspection at any time. Automatic alarm bells are placed at various positions in the road to warn the driver, should his attention be diverted at that moment, that he must loose his gripper at this point. Another piece of machinery under ground is the depression gear, which is necessary to keep the cable from rising out of the slot in depressed parts of the roadway; it is like the alarm gong acted upon by the gripper, which strikes a lever causing the depression pulleys to move clear of the gripper at approaching, and moving it back to position after passing. These were made from Mr. Fischer's designs, and he will doubtless give us the results from actual service at some future time. Some roads use the electric alarms in preference to the mechanical gong for signalling attention. The bearings of pulley spindles are now generally made of Lignum Vitæ, the street sweepings cutting up and destroying metal bearings very quickly. A material called "Carboid," that requires no lubrication, is now being used in the Edinburgh Tramway Co's. Road with good results. In the roadway bearings, the absence of the necessity for daily lubrication makes it especially economical, while the life of the bearing, it is claimed, exceeds Lignum Vitæ. In the North Sydney Roadway, a trial bearing is fitted with this compressed carbon block, but sufficient time has not elapsed to prove its worth here.

The *gripper* is an important factor in cable traction, and although of various forms can be described as a powerful vice to hold the cable from the floor of the dummy car at the will of the gripman ; this is the connecting rod from the cable to the car, some are worked by foot levers, others by hand wheels and screws, but the majority with hand levers. There is room for improvement here, and no doubt some of our members, with the more intimate acquaintance we shall shortly have of these grippers, will scheme some better mechanical contrivance than the gripper of to-day. The plan, Plate X., is the gripper, made by Hudson Bros., Ltd., last year for the North Sydney Tramway, and acts well in deep conduits. This machine is worthy of a paper to itself, as it is a constant subject for patents.

In the driving drums for the cable no uniformity of design is followed, as some engineers warp round the two drums, some twice, three times, others prefer the cable to cross between the drums, forming the letter S or figure 8. The average diameter of these drums is 12ft. when warped round the drums, but with the S drive they are reduced to 8ft.—but drums are in use from 8ft. to 16ft. diameters. When two roads are driven from the one drum shaft at different speeds, the variations of each pair of drum's diameters is a necessity; in some plants only one drum shaft is geared to the engine, the second drum being driven by the cable's friction. In other plants both cable drum shafts receive power direct from the engines. In the North Sydney power plant the first method is in use, but the Ocean Street plant will have power given direct to each drum shaft, and the best results are obtained by this method, provided sufficient accuracy is obtained with the gear to drive each shaft at absolutely the same speed. Cable drums usually overhang the bearings to facilitate putting on the cable, and strong wrought-iron compression rods, with adjustable brasses attached to the outer end of the shafts to resist the strain of the winding cable. In some plants these compression rods are not used, the shaft being made of greater strength in preference.

In the early cable drums the grooves for cables were turned out of the solid, but this method proved faulty by the grooves, which the cable entered on, wearing down faster than the others causing excessive strain on the cable, until it slipped to compensate for the different speeds it was driven on the same drum, increasing the fault, and rapidly destroying the cable. Plate XI., Fig. 1, shows a section of solid pulleys taken out after three years service, with a table showing the relative depths of the grooves in eight different drums. This table is taken from "The Street Railway Journal of January, 1891." Segmental lining pieces were introduced so that unequal wear could be adjusted; but, later, a number of loose rings fitting on a cylinder, as shown in Plate XI., Fig. 2. This latter class is in use in our new North Sydney plant, and has six loose rings —four is the usual number. The six are not in service at the one time, but more changes can be made on the running grooves before returning or renewing the rings. The rings are made of wrought iron, and are as accurately turned as piston packing rings, and bored to fit the turned cast-iron rim. These rings are held from slipping round the rim by an outer ring-plate and screw bolts exactly as the junk ring of a steam piston is held down to its packing ring. This drum dispenses with any wear of the grooves, or any wear of the cable while on the grooves. Should there be any inequality in diameter of rings in first construction, or by wear in use, the rings will adjust themselves while the drum is in motion, so there can be no undue strain on any of the warps on the drum, as the rings move slightly backwards or forwards to compensate irregularities. These rings have the friction of the cable on the grooves transferred to the flat of the drum on the underside of the rings; the friction sufficient to move one is adjusted to about one-fortieth the strength of the cable, thus compensation is accomplished without excessive wear upon the cable. Two sets of these drums are in the North Sydney plant, the 10ft. diameters work the cable from the termimus to the ferry wharf, and haul 15,000 ft. of cable upon rising grades the whole distance, the greatest being 1 in 14, at the rate of 8 miles per hour, and the drums driving Falcon-street extension are 11ft. 3in. diameter, driving 8,400ft. of cable on a comparatively level road with one curve. Eight trains are driven at the one time, five having one dummy and two cars, and three with one dummy and one car. The dummy and two cars loaded weigh eleven tons, unloaded six tons. The drums were supplied to our firm by the patentees, The Walker Manufacturing Coy., Cleveland, Ohio, and are the first of this type in Australia, and are the only parts of the plant not manufactured in the colony by Hudson Bros.

The frictional contact between the cable and driving drums is maintained by a large sheave fitted on a truck with about 18 feet of travel, held back by balance weights which works upon another truck, held in position by some adjustable mechanism, having sufficient travel to compensate for several months' stretch of cable, consequently reducing the number of times necessary to re-splice the cable. There are several forms of these tension carriages in use. The one in North Sydney is of a different class to the Ocean-street carriage. Spur and rope gear is usually adopted for transmission of power to cable drum shafts, rope gear having the balance of favor. Our tramway engineers have adopted rope driving for both our local plants. The large wheel for the Ocean-street plant is 19ft. 6in. in diameter, with 15 grooves, is built in eight segments, and weighs nearly 20 tons. It was intended to turn this in position, but the foundation not being completed in time we arranged to turn it at Clyde, which entailed taking it asunder and rebuilding on the site. When the members visit the plant, they can judge with what accuracy it went together. The smaller wheel is 6ft. 9in. in diameter, and is keyed with two keys on intermediate shaft and cast in one piece, it weighs, finished, 6 tons. The shafts are all forged from scrap iron at Clyde, as the terms of specification demanded. One shaft had a piece cut out of the heart, which was tested at the University by Professor Warren, standing the specified test very satisfactorily in every respect.

The engines for cable driving may be any class; that in most favor is the horizontal type with an automatic cut-off. The engines are invariably in duplicate, to permit of adjustment without delaying traffic. They vary in power from 180 to 1,500 H.P. The average H.P. per car provided in Melbourne is 15, but it requires 25 for the North Sydney trams, due to the heavy gradients. The average engine power required to move the cable alone is 55 per cent, and some roads absorb as much as 75 per cent. of the total horse power developed. The Americans have adopted the Corliss type of engine for their standard, and New South Wales is doing the same. The engines for North Sydney are High Pressure Compound, of the Horizontal Girder Type with Corliss valve gear. Diameters of cylinders are 19in. and 30in., with 36in. stroke, the H.P. cylinder is fitted up with Spencer Inglis trip gear, regulated by Porter Governor to a speed of 64 revolutions per minute. The steam in the L.P. cylinder is not automatically cut off. The steam and exhaust valves of each cylinder are driven by independent eccentrics and discs, which admits of the advantage of regulating the valves independently, and is a common practice with English builders, but finds no favor in America, where the single eccentric works the four valves. These engines are designed to indicate 270 H.P., with 120lbs. to the square inch boiler pressure. The short stroke was a necessity by want of space. Both cylinders are steam-jacketted, and are built up of four pieces, and are, the author believes, the first made on this method in Sydney. It gives a great advantage for moulding, but the extra machining and joints increase the cost. The fly-wheel is 10ft. 10in. diameter, and weighs 10 tons, this small diameter was a necessity caused by the confined space in the basement which forms the engine room, and the pistons have no tail rods through the same cause.

The first engines used for this cable road were 18in. diameter x 36in. stroke, with boiler pressure at 90lb. per square inch. These engines are to be coupled and made the reserve engines. This gives the best possible opportunity of testing the value of high pressure compounds, as they will perform the same work, and are supplied with steam from the same boilers, under exactly alike conditions in every respect. On some future occasion, no doubt, Mr. Fischer, the Engineer for Construction, will be in a position to give us some data to satisfy us all on the value of high pressure compounds.

Steam is obtained for the engines from two externally fired multitubular boilers, each 7ft. diameter x 16ft. long, each containing eighty 4in. tubes, and are slung from overhead girders without support from the brick walls. They have return flues leading to a brick stack 80ft. high. The shell is made in three rings of ⅝in. Dalzell steel plate; ends are flanged in one plate ¾in. thick, the fire bars are placed 30in. below the boiler, and have each thirty-six square feet of fire grate area. The feed water is to pass through a Llewellen feed heater. The fronts are of cast iron.

Special tests will be made to prove the evaporative power of these boilers when the feed heater connections can be completed, and the original engines are re-erected in their new position. It was expected that the two boilers would be necessary to keep steam, but one supplies all required easily. Plan XIII. shows three sets of indicator cards: No. 1, with engine driving cables only, 56 H.P.; No. 2, with light traffic, 82 H.P.; No. 3, with greatest traffic, 156 H.P. The H.P. cylinder has no excessive clearance to assist the L.P. An auxilliary steam valve, 1in. diameter, is attached to the L.P. cylinder valve chest, but it was not used when these diagrams were taken. The valve setting can be improved, but as these engines run continuously for nineteen hours out of the twenty-four, little chance is given for the purpose.

The engines for the Ocean-street Cable Tramway have been designed at Clyde, from the Tramway Engineer's specification, and are now in a forward state. They are of the same type as those made for the North Shore plant, but are condensing and of greater power. The cylinders are in one casting, the L.P. without liner weighing 9 tons. The crank shafts (steel) are of the built class, each weighing about 8 tons, and were made by Sir John Brown and Co., Sheffield. Plates XIV and XV.

The boilers are of the same dimensions and power as those for the North Shore plant, provision being made for future extensions. At some future meeting more may be said of this plant, which is intended to be the premier cable plant in Australia.

Appended is a table of the principal roads in operation (excepting the Melbourne plant). It is not as complete as could be wished, as very few works of reference are available upon existing plants.

Names.	Engines.	No. of Engines.	Piston Speed.	Working Hours.	No. of Cables.	Speed of Cables.	Total length of Cables.	Longest life of Cables.	Train Service.	Gearing.	Date of Opening.	Diameter of Fly-wheel	Weight of Fly-wheel.	Greatest Grade.
	Ins. Ins.						Ft.	Dy's.	Min's.		Aug.	Ft.	Tons.	
Clay Street	14 x 28	...	530 ft.	17	1	6 miles	11,000	450	5	Spur	1873	...	...	...
Sutter Street ...	12 x 24	...	340 ,,	19	2	do.	17,000	380	4	do.	1879	...		...
California Street ...	22 x 36	...	570 ,,	19	2	do.	9,375	660	5	do.	1878	...	...	1 in 5¼
Geary Street ...	18 x 48	...	370 ,,	19½	2	7 miles	27,600	540	3 to 6	Rope	1880	...	...	...
Union Presidio and Ferrier	18 x 36	...	350 ,,	19	2	do.	21,500	300	5	Belt	1881	...	...	1 in 4½
Market Street ...	24 & 34 x 48	...	456 ,,	20	3	8 miles	60,314	380	3	Spur	1883	...		...
Los Angelos Viaducts Bridge	26 & 48 x 42	3	600 ,,	20	7	do.	108,274	...	2½ to 5	Rope	1888	14	... 16	...
Temple Street ...	18 x 42 & 16 x 36	2	468 & 622	18	2	do.	32,622	900	...	...	1886	...	...	...
Chicago ...	24 x 48	...	520 ft.	20	5	7 & 10	106,844	...	...	Spur Helical	1882	...	...	...
Brooklyn	26 x 48	2	456 ,,	20	1	10 m'ls	11,450	...	3 to 6	...	1883	...	...	...
Tenth Avenue ...	28 x 40	...	500 ,,	20	1	8 miles	32,000	...	...	..	...	...	...	...
Broadway	800 h.p.	...	...	...	...	...		...	40 S'ds	...	...	...	...	...
New Zealand ...	13 x 27	...	...	...	...	...	7,000	...	...	...	1883	...	...	1 in 4½
High Gate Hill ...	25 h.p.	...	...	...	...	...	2,500	...	...	...	1884	...	...	...
Edinburgh	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Birmingham ..	...	...	...		...	...	...	...	...	...	...	...	...	...
Glasgow	...		...	...	...	...	...	...	...	...	...	...	...	...
Paris ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Portugal	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Constantinople ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
North Sydney ...	19 & 30 x 36	2	384 ,,	19	2	8 & 9	23,400	...	...	Rope	...	12	10	in 141
East Sydney ...	24 & 45 x 56	2	...	...	2	...	...	...	...	Rope	...	...	...	...