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PAPER

NOTES ON THE MELBOURNE CABLE TRAMWAY SYSTEM.

By W. R. Pollock.

This paper, originally intended to be some notes on tramway cables, has at the last minute been amplified to include notes on the power and machinery, and as the time has been short the author asks members to excuse any errors of arrangement that they may notice.

The motive power is steam, supplied by marine type multi-tubular boilers of grate area 18 square feet, and in some cases 24 square feet, grate area, with working pressure of 100 lbs. per square inch. Each boiler is approximately seven feet in diameter by fifteen feet long, and all were made in Melbourne and fitted with Fox corrugated furnace. At two power-houses the boilers are Babcock and Wilcox water tube, and all the original boilers are still at work and in good order. At Richmond power-house the Babcock and Wilcox boilers have been at work for nearly 42 years, the only renewals being a few tubes in the fire row. This is rather a wonderful performance for a water tube boiler.

The steam is delivered to horizontal engines either 24 by 48 in. by 60 r.p.m., or 20 by 40 in. by 72 to 80 r.p.m., equal to 560 or 800 I.H.P. The former are by Shanks and Co., Scotland, in three power-houses; the remainder were built locally. It is interesting to note that the locally made engines have caused us much less trouble and expense than the imported ones. At two of the power-houses the 24 inch cylinders have each been replaced by one 25 inch cylinder.

The 20 x 40 engines are fitted with Myer expansion valves. The 24 x 48 engines have cylindrical expansion valves working in cylinders formed on the back of the main slide valves, the ports being diagonal and the expansion being altered either by hand or governor by turning the expansion valves. In the new cylinders this type of valve has been dispensed with. The engine exhausts into a heater, and thence to the atmosphere. The top half of the heater is filled with quartz or agricultural pipes, and the feed water enters at the top through a rose, meeting the exhaust steam which enters under the quartz or piping, and by this means the feed water is heated to boiling point. This, no doubt, accounts in a

large measure for the excellent condition of our boilers to-day. We also recover about 16 per cent. of the steam.

As before stated, the engines run at 60 r.p.m. for the larger sizes, and 72 to 80 for the smaller. The engines are in duplicate, so that continuity of operation is assured. They are each coupled by means of a crank pin and loose bush to a shaft, on which is mounted the rope wheel about 8 feet diameter for transmitting the power to the main driving shaft, on which is another rope wheel 24 feet diameter, and on the other end of this shaft the cable drivers are keyed.

The drive is transmitted by seven inch circumference manilla driving ropes. It is interesting to note that the first set of manilla ropes ran for about thirty years. This well illustrates the economy of this type of power transmission when the pulleys are large and the design is on generous lines.

The horse power required to run the ropes and machinery varies with the different lines. A straight line, such as Sydney-road, takes less than a line with a number of curves; it will run from 100 to 190 h.p., the average being about 175 h.p.; and the average h.p. for peak traffic hours is about 300 h.p. At St. Kilda-road power-house—the heaviest line—average power came out at about 411 h.p. in 1918, with a maximum of 683 h.p. At this time there were 75 trams on the rope of this particular power-house at peak load.

The horse power per tram is approximately 9.5, including ropes and machinery, and excluding power for ropes, etc., approximately 6 to 7 h.p. The greater the average load the less the horse power per tram on lines. Where there are few trams out during the greater part of the day the horse power per tram average may go up to 14.

There is a considerable starting effort needed to start in the morning. This is illustrated by the following case: At a certain power house traffic had been run with 60 lbs. to the square inch on the boilers at certain periods. But one Sunday morning it was required to move the engines, and it was found impossible with 60 lbs. on the boilers to move them, even though there were no trams out.

One of the greatest advantages of the cable system is the lightness of the rolling stock, a car and dummy empty weighing only 5 tons 3 cwt. This gives a ratio of load to weight of vehicle probably higher than any other mode of locomotion. The lightness of the rolling stock coupled with the fact that the wheels are not drivers, is reflected in the life of the permanent way, a large percentage of the original rails being still in the road.

The instantaneous variations of load on a tramway system are very considerable. With the steam engine and rope drive these variations were not noticed to any extent, the engine merely slowing up momentarily. This variation was brought home to us when a self-synchronising electric motor was coupled to the driving shaft, when the loading became too great for the engines to manage alone. This type of motor is of absolutely constant speed, and during peak hours, with the engine giving out say 580 h.p., we frequently got instantaneous readings on the h.p. meter of 700 h.p., or a total of 1280 h.p.. Such was the price of constant speed. Needless to say the gear box would not stand up to this; so then the motor was worked as an ordinary induction motor, and the slip obtained by this means gave a much smoother operation.

It might interest members to know that with high tide and strong westerly winds the Yarra fills our tunnels in parts of South and Port Melbourne with water to within 12 or 15 inches of the roadway. This means that all our line pulleys are under water, which increases our power necessary to pull the ropes. Also, as soon as the water recedes, we have to regrease all these pulleys.

We are also troubled in certain parts by sudden tropical rain such as we get at certain seasons. About 20 minutes of such rain sufficed to fill the tunnels and pits, and the water has risen to within 12 inches of the power-house floor. Under these conditions the drivers are about one-third submerged. All the 12 ft. angle sheaves and other road gear are totally submerged. At such times it is impossible for the engines to pull the load, and they run slow until the water is pumped out, which, of course, is not until the municipal drains have cleared the roadway. Members may remember some few years ago in South Melbourne the water being up to the seats of the dummies for a whole day. On this occasion tram traffic was in no way interfered with, although passengers on the dummy had to perch on the backs of the seats.

When the cables were first started in November, 1885, they were of $3\frac{3}{8}$ in. circumference and 11 in. lay, consisting of six strands of 7, 15, or 19 wires each; the latter being made by Roebling, of U.S.A., and being of ordinary construction—e.g., the wires in the strand being laid the opposite way to that of the strand in the rope. All the other makes were and are still of Lang's lay—that is, with the wires of the strand laid the same way as the strand in the rope.

The Lang's lay is used for two reasons, first because when ropes of this lay bend round pulleys the wires in the strand

tend to slacken, whereas with ordinary construction they tighten, and therefore break on the crowns. Also, there is more surface exposed to wear with Lang's lay.

The rope circumferences increased with the traffic from $3\frac{3}{8}$ to $3\frac{3}{4}$, $3\frac{7}{8}$ to 4 in. full and developed into a standard of seven wires per strand, and 4 in. full circumference with 10 in. lay.

It has recently been found advisable for particular roads to get ropes of $4\frac{1}{4}$ circumference and 15 wire construction. This, while sacrificing some life due to wear of grips, gives added life for bending round curves owing to greater flexibility, with the result that we get a greater average life in these roads.

Ropes are made from what is known as "Special Acid Steel" of the highest quality procurable, having a large admixture of best Swedish material. The construction, as before stated, is 6-7—that is, 6 strands of 7 wires over a medium hard laid up manilla coil.

The rope is of 4 in. full circumference and 10 in. lay, strands $1\frac{3}{8}$ diameter, and $4\frac{1}{2}$ in. lay of 6 wires of .142 diameter with one core wire of soft iron of .144 diameter. Core of manilla usually about 2 in. diameter and 2 in. lay. Weight approximately 2-6 lbs. per ft.

The 6-15 ropes are 6 strands of 15 wires over a medium hard laid up manilla coil. The rope is of $4\frac{1}{4}$ in. circumference and 10 in. long. Strands $1\frac{3}{8}$ diameter x $4\frac{3}{8}$ lay, consisting of 8 outer wires of .117 diameter over a core strand $\frac{3}{8}$ circumference by $2\frac{1}{2}$ in. lay, consisting of 6 inner wires of .066 diameter over a core wire of iron of .069 diameter. Core manilla $2\frac{1}{8}$, lay $2\frac{1}{4}$ in. Weight approximately 2.65 lbs. per foot.

The lengths of cables vary from 17,000 feet to 25,200 feet. One line (now electrified) took a rope of 30,000 feet, weighing approximately 35 tons.

Breaking strain is 66 to 68 tons per square inch. We find from experience that if we can get a rope of from 66 to 67 tons we get a better rope for our work than one of 69 to 70 tons. It is apparently difficult for the makers to keep down the tensile strength and still maintain the quality of the wire.

All the wires are either brazed or welded, the joints being the same diameter as the wire, so that the wire is in one continuous piece for the length of the rope.

The ropes come out coiled in troughs in the ship's hold, and are unloaded hand over hand and coiled on to pairs of lorries, and thus carted to the power house, where they are

either coiled down in a trough or are reeled up on a reel ready for being put into the road when required.

When it is desired to put a new rope in a section clamps which we have for the purpose are put on the rope to hold it tight in the road, and the tension in power house slacked. The rope is then cut, and the outgoing end is spliced to the end of the new rope (which is already on a reel); the free end of the incoming rope is taken and made fast to another reel to which a small engine is attached. When all is ready the clamps are taken off and the engine run slow, drawing the new rope into the road against a brake, the engine on the other reel winding up the slack as it comes into the power house. The present drivers consist of a C.I. wheel, generally 14 ft. diameter, although we have some 12 ft. and 13 ft. diameter, fitted with segments of cast steel V shaped with wood bottoms. Before traffic got so heavy the rope ran in H.W. blocks, and the form of drive was different, there being two drivers geared together. For obvious reasons this was unsatisfactory, as well as very noisy, so this drive has been replaced in every case by one driving wheel and an idler, where it is seen that the rope comes in from the road round the driver, round the idler, thence round a tension wheel, and out into the road again. The weight in the tension bucket may be anything from 2 to 5 tons, according to the conditions of the particular road. The cables have run at various speeds in different sections at different times; at present they are all $13\frac{1}{2}$ or $12\frac{1}{2}$ miles per hour, with two sections still at 11 miles per hour. Some small auxiliary cables are slower, but as these are not more than a few hundred feet long they are not of much account as regards speed.

The rope is carried in the tunnels on pulleys set every half chain, and around curves either by means of a 12 ft. sheave or by a series of curve pulleys or drums of about 2 feet diameter.

(The author exhibited an ordinary carrying pulley such as is placed every half chain along the road. This had been badly corrugated. These corrugations occur usually in curve pulleys or crown wheels which have extra weight on them. It is an extraordinary example of synchronisation, as the marks tally with the lay of the rope. One would say that such a thing was impossible until one sees the evidence.)

While running the ropes are under constant supervision, weak spots being observed and broken wires looked out for. Any particular place on the rope may be run into the power house, and the engine stopped to examine it. This is made possible in the following manner.

Every calculation is based upon what is termed the 1 splice—that is, the splice that the rope goes in the road with (it may have half a dozen in before it comes out). A counter is attached to the driving shaft, and an oblong figure on a blackboard marked off into the number of revolutions it takes for the splice to go from the power house round the road and back again. Any damage done to the rope, or any broken wires which develop, are noted as being so many revolutions in front of or behind the splice and marked on the board, which really becomes a drawing of the rope. By this means the condition of the rope is readily seen at any time, and any desired spot on the rope may be picked up and examined.

When the new rope is run in the road we proceed to fill the interstices between the wires and strands with a composition known as "Rope Filling." This keeps the water out of the rope. When the rope is filled (after about three weeks) it is regularly lubricated with rope oil once or twice a day, sometimes oftener. The rope filling must be liquid enough to run into the innermost spaces between the strands. It must set, and when set remain plastic so that it will not crack and fall out when rope is being bent round curves, etc., and it must be waterproof and of a lubricating nature. Keeping the water out of a rope is an important factor in its life.

The practice is to put new ropes in city and important sections, and then take them out before they are worn out and put them in suburban and less important sections, by this means getting a longer average life and running less risk of holding up the traffic through rope trouble.

There are two factors operating against the life of the ropes. These are the grips and the curves. Grips wear the wires and make them thin on the crown, and curves by alternate bending and straightening break the wires. By far the more potent of these is the curves. The majority of ropes are discarded through broken wires, and not because they are worn out in the sense that the grip wears the rope down.

Stoppages are due to various causes, such as cable trouble, collisions causing derailment of dummies, broken or bent grips, processions, and fire hose across tracks, etc. Stoppages due to causes other than cable troubles cannot be controlled by power house staff. All we can do is to use our best efforts to get traffic moving again. With cable trouble the stoppage may, or may not be, a power house responsibility.

The ropes when running are under the constant supervision of a skilled and experienced man, who watches them as they run through the power house. This man detects any

broken wires, and, guided by personal experience and the condition of rope, he determines whether to stop and cut the broken wire off; in any case he would watch this place every time it came into the power house. Sometimes a broken wire that has been let go will stave back for six or seven lays, in which case it is imperative to stop and cut them off. In other cases the broken wire will break off itself, when there is no further need for worry. Stops of from one to five minutes are usually due to this cause.

If a wire breaks near a place where it is known there are broken wires adjacent to each other the ropes are always stopped in order to examine that place, and make sure there is no danger of the strand slackening and being cut by a grip. It happens sometimes, when we stop to examine such a place, that only one or two wires are holding. In this case the clamps have to be put on, the rope slacked, and the strand cut out, and ends run into the heart of the rope; an operation taking from "stop to start of engine" from eight to twenty minutes, according to the men available.

On rare occasions a strand breaks out somewhere along the road and "bunches." In this case the stop may be anything from half an hour to six hours, according to the length of bunch, men available, position and characteristics of bunch. When a bunched strand occurs in the road it is heard by the gripman, who should send a signal to power house. We have heard alarm signals at frequent intervals around the track, and on these signals fairly complete information can be sent to power house. It is also possible by means of a pocket 'phone to talk to power house on this signal line. Sometimes the first information to power house staff is a five-strand piece of rope coming into power house. The engines are immediately stopped, and a search made for the bunched strand.

At various places along the road the gripmen have to throw the rope and run on some distance by momentum. Should they fail to throw the rope they carry it round what is known as a stop or check bar. This is a bar about 3 in. diameter in tunnel, the rope passing on the opposite side to grip. These bars are necessary to protect some special underground work, and carrying the rope into a bar is in reality the lesser of two evils when the gripman fails to throw.

When a rope is overcarried in this manner it is kinked; sometimes cut in two. It may be only slightly kinked, when no stoppage would occur, or more or less severely, when the stoppage may be anything up to an hour. An example of a bad kink is on view. In this case nothing could be done but

cut out the kink and splice the two ends. Sometimes a kink can be hammered into shape and trimmed up and made safe enough to complete the day's traffic, permanent repair being effected when traffic is over.

When a gripman fails to throw the rope and strikes the bar he is supposed to immediately notify the power house on the alarm signals mentioned, when all are on the alert for the damaged piece to come into the power house. I am sorry to say that this is not always done. When a rope is overcarried one or two strands are sometimes cut, and then we get the bunched strand again.

The varieties of kinks and strands are endless, and it is safe to say that no two are exactly alike, nor is the method of dealing with any two exactly the same, hence the necessity for someone of experience and in authority being quickly on the spot to determine the method of dealing with the trouble.

The worst case is when a strand is bunched and the rope parts. When this occurs the facing end flies back in the tunnel, and, as the trams are moving forward, loops form round the grips. All these loops have to be freed from the grips and slack got up on the roadway before anything can be done towards pulling the ends together preparatory to splicing.

There are various methods of dealing with bunched strands, etc., amongst which are the following:—

1. The bunched strand may be got up on road and cut off.
2. The rope can be cut, bunch taken off, and rope spliced together again, or a piece put in.
3. The rope may be cut at each end of bunch and a piece put in.
4. Combinations of the above three.
5. The bunch may be carried along the road to a suitable spot such as power house, or large pit, and bunch cut off.

The splice usually put into a new rope is from 60 to 80 feet long, and is truly a work of art. In a new rope it is most difficult for even experienced men to find the splice before the rope is filled or any wear is showing on the wires, and would be quite an impossibility for a layman.

The operation of making a finished splice for traffic purposes takes seven men about two hours. The record for a

splice was 23 minutes. This time was from stop of engines to start of engines, and included putting on clamps, slackening up tension, tightening tension, and taking off the clamps. This was done one day when it was found necessary to shorten a rope during traffic hours, and, as before stated, the traffic was only held up 23 minutes. Of course there were plenty of men available, and they were organised by the late Mr. James Turnbull who, with the writer, supervised the work.

As the ropes get older and more worn, and more wires break, we get two or three wires broken together in one spot. When it is considered necessary the strand with these broken wires is cut out and a "repairing" strand put in, and the ends finished off similar to the tucks of a splice. This repairing of the ropes—cutting off wires and putting in strands, cutting out lengths of cable and replacing with other lengths—is done until it is considered the rope is unsafe or uneconomical to repair further, when it is taken out and sent to scrap.

The rope is then disposed of for various purposes, such as reinforcing concrete, flying foxes up in the timber country, and for fencing. I might state that this cable makes a most attractive fence, forming the top rail instead of wood or piping. Members may have noticed it at Albert Park, which is now almost completely fenced with it.

Very complete records are kept of every rope. These are known as rope histories. In these all the events in the life of a rope are chronicled, such as damage sustained, wires cut off, strands put in, etc. The form in which they are kept is most compact, and was inaugurated by the late Mr. J. W. Duncan.

It is comforting to find that for tramway purposes there are no ropes the world over to equal the British made article. We have tried among others both American and German.

The author exhibited drawings of the grip mechanism, explaining how the cable is thrown out, how the face of the grip is adjusted. He pointed out that the material in the slide and check bars of the grip was purposely of inferior quality, so that in case of error by the gripman to throw the cable, or in case of derailment, the grip might break and so be easily removed. The pressure exerted by the grip with a force of 60 lbs. on the handle is 2040 lbs. on the first notch, 4500 and 9120 in succeeding notches.

The Melbourne cable tramway system by its record, both financial and otherwise, has had a truly wonderful career. It is known throughout the world for its wonderful efficiency.

The credit for all this must in the first place be given to Mr. George S. Duncan, that eminent engineer who designed the system, and then to the late Mr. Clapp, Mr. H. A. Wilson, and Mr. J. W. Duncan who so successfully and efficiently operated it.

In closing these notes I should like to pay tribute to the men who, when the emergency arises, by their zeal and loyal devotion to duty really perform wonders in getting traffic moving again.

DISCUSSION

The PRESIDENT said Mr. Pollock had delivered a most interesting paper. He had been interested in various ways in the early days of the cable trams. It would be interesting to know what the cost of construction of the cable tramway was, and also the cost of running as compared with the cost of the electric system. The passing out of existence of the cable tramways would be regretted by a large section of the public.

Mr. A. McCOWAN said the paper was very interesting. He thought the removal of the cable trams from the city was a mistake. The electric trams might be a little faster, but there was a great deal more wear and tear; consequently the cost of running would be much greater than the cable trams. The cable trams had been very efficient, and the cost of running per mile was the lowest in the world. He had pleasure in proposing a hearty vote of thanks to Mr. Pollock for his paper.

Mr. A. E. BATTLE seconded the vote of thanks. Some years ago he had been commissioned to proceed to Paris to investigate the trams there. One system he inspected was specially interesting—the cars could not be distinguished from an electric car. They were worked with engines in direct drive under the cars; the boilers had an internal furnace, and were fed with superheated steam. There was absolutely no soot. The inspection convinced him that the days of the tram car running on rails had gone. It seemed a pity that on the eve of the passing of cable trams a system should be installed at great cost, which would have to be carried. Tram lines practically split the street into three. He was therefore in agreement with Mr. McCowan that it was a great pity from the point of view of the ratepayers of Melbourne that the cable tram cars were to be superseded.

Mr. A. LEWIS said he had thoroughly enjoyed Mr. Pollock's paper. It appeared to have been necessary from the type of gripping gear adopted in Melbourne to evolve a type of contortionist driver. He knew of no other system that required a driver to practically kneel on the floor to operate his grip.

Mr. POLLOCK said he believed in the Edinburgh system the grip was operated by means of a wheel. The Melbourne system had the advantage of enabling the gripman to throw

the grip at the last moment if, in the stress of a difficult position, he omitted to do so at the proper time. In the case of the winding system that was impossible.

Mr. A. LEWIS said he would have liked to have heard that the Tramway Co. had given making Australian ropes a trial.

Mr. POLLOCK said it would not pay the rope makers to bring out the machinery to make the ropes. It was considered at the time of laying down the system. He should mention that some of the original rails were still in use in the road. That had been made possible by the use of the rail planer.

Mr. A. C. MITCHELL asked if the use of the rail planer had resulted in any appreciable difference at the power house.

Mr. POLLOCK said the use of the rail planer had certainly effected a great saving in the life of the rails. But it was very difficult to arrive at figures of the result at the power house. They certainly did not have the trouble with the steam that they formerly had. The load appeared to be lighter. But there were so many factors operating which could not be eliminated that it was impossible to obtain reliable figures. The last annual report showed the working expenses per tram mile to be 16.4d.

Mr. A. L. HARGREAVE wished to add his appreciation of Mr. Pollock's paper. A good deal of criticism was indulged in as between the electric and cable systems. The cable system was installed when labour and material were cheap. The cable trams ran into well-established areas, and the lines paid. If the electric trams were only run in well-established areas they would pay much better than was the case at present.

Mr. POLLOCK thought it probable that when the cable trams commenced they were run into districts that were not well established. He should have mentioned that each engine was fitted with a large flywheel, on each rim of which was fixed a steam brake.

Mr. A. L. HARGREAVE thought the cable tram was limited to a certain load—the limit of the cable.

Mr. POLLOCK said the congestion in Swanston-street between 5 and 6 p.m. was more intense to-day than during the operation of the cable trams.

Mr. R. J. BENNIE said he had much enjoyed the paper and the interesting discussion that had ensued. He had had the privilege of visiting one of the power houses, and being

shown by Mr. Pollock many of the matters described in the paper. Even though the cable tramways were about to depart, it would be of interest to the members to pay a visit to one of the power houses. It was a matter which was worthy of consideration by the Council.

Mr. A. L. Hargreave's point was that ultimately the cable would not be able to stand the extreme tension necessary to pull the traffic of the future. That was obvious from the fact that all new cables were being placed on the city lines, the old cables being transferred to the outer suburbs. Also for some years the dimensions of the cables had been increased, but the necessity for flexibility called a halt in that direction. A very interesting point was the life of the manilla rope mentioned in the paper—about 30 years. The rope was more than two inches in diameter. It showed what an efficient system of transmission of energy the rope drive was. It was interesting to note that in many of the newer textile mills other systems had been replaced by the rope drive. Ascertaining the position of a splice by counting the revolutions was an interesting point. He presumed that had to be corrected from time to time owing to the gradual creeping.

Mr. POLLOCK said the number of revolutions was recorded from time to time in chalk on the board, and it never erred to a greater extent than 3 or 4 revolutions, which were quite close enough for the man examining the rope.

Mr. R. J. BENNIE said the provision of relatively brittle steel in the body of the grip action was very necessary to save the rope.

Mr. POLLOCK said it would be readily understood that if the grip bent it was a difficult and lengthy process to get it out of the tunnel. As to the loading of the cable system, it was impossible to have more than a certain number of cars on the rope, and they were pretty near the maximum in Swanston-street. But if it was intended to extend the cable service it would not be done by lengthening the rope. They would build another power house. Therefore there would not be more than a definite load on each rope, no matter what intensity of traffic was reached.

The vote of thanks was carried with acclamation.



