FACTS AND DATA ON OVERHEAD HEAD TROLLEY WIRE CONSTRUCTION

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Few people who travel daily on the tramway network stop to consider the work necessary to provide and maintain an efficient and continuous transport system.

Considering one phase only, that of supplying power to drive the trams: This requires an intricate system of overhead wiring with its inherent electrical and mechanical problems.

To transmit power from the 25 automatic substations strategically placed over the system to the trolley wire and thence to the actual tramcar it has been necessary to erect approx. 13,168 poles, 534 wall attachments (in lieu of poles) to support 274 miles of trolley wire weighing 341 tons, and 116 miles of feeder cable weighing 538 tons.

In addition, in order to provide facilities for track telephones, supervisory control and testing approximately 544 miles of overhead pilot wire are attached to these poles.

Erection of Poles

Unless the nature of the ground is rocky and requires the use of a crow bar or blasting, all poles are dug by special boring tools which gives a hole of uniform diameter for the full depth of the pole which is 5 ft for a 30 ft centre pole, 6 ft for a 32 ft pole and 7 ft for a 35 ft pole. All poles must be given exact rake (for which a special plumb is used). In cases where poles are under strain in more than one direction, rake must divide the angle between them. Rake is necessary on poles so that, when the load is applied, the pole will not pull up quite perpendicular. Poles erected exactly perpendicular appear to the eye to be converging at the top. Poles are set in concrete and neatly finished off slightly above ground level sloping up all round from outside edge to pole.

In the case of anchor poles which will be subjected to heavy loading, it is necessary to put in additional concrete at the heel and breast.

Steel Poles

The most satisfactory means of preserving steel poles has been found to be a heavy coating of (red lead) and then two coats of aluminium paint. This should last approximately 5 years before poles require further painting.

Wood Poles

The danger line of wood poles is approximately 1 ft above and below ground lines where air and dampness are able to attack the wood. The most satisfactory method of staying this decay is to "char" the pole over this section with oxyacetylene flame and then, when the pole is hot, treat with "Creosote".

Suspension of Trolley Wire

The trolley wire is clipped into an ear which is bolted to a hanger. This hanger slips on to the span wire which is supported between poles on either side of roadway.

Pole bands anchoring the span wires are attached to the pole in such a position varying with the width of the road to provide a sag of 1 in 10 for 0.126 trolley wire and a sag of 1 in 7 for 0.2 trolley wire.

The trolley wire is maintained at a height of 18 ft 6 ins above rail level in the span support. Efforts are made to keep the maximum distance between spans to 110 ft giving a trolley wire sag of 6.5 ins at a temperature of 60^{o}F midway between poles.

With span spacings in excess of 110 ft, keeping the normal tension to 1800 lbs. would incur too much sag and excessive freedom of movement causing abnormal side wear of the trolley wire. Excessive sag in trolley is also not pleasing to the eye and the only alternative is to excessively strain the wire. As the section of the wire decreases with wear, it will not stand this strain but will only stretch and excessive sag is the result.

The span wire is a 7 strand 12 gauge galvanised steel wire. A 5 ins reel insulator is attached to pole band by means of a shackle. At a distance of 5 ft from the pole an egg insulator is cut into the span likewise an egg insulator is cut in midway between trolley wires, and at a distance of 30 ins outside each trolley wire. Thus there is treble insulation between trolley wire and pole and single insulation between trolley wires. Trolley wires are jumpered by 0.25 or 0.3 VIR cable every 10 poles for 0.126 wire and every 5 poles for 0.2 wire.

Over a number of years, trouble was experienced in the corrosion of span wires, particularly on routes adjacent to the sea front. The cause of this trouble was the accumulation of road dust and dampness on the insulator which built up and finally allowed passage for a low current across the insulator. This was most pronounced near the sea front where the salt spray deposited on the insulators.

Various types of insulation were tried, but it was found that the 5 ins reel insulator gave the best protection due to a better drip surface, a larger protection surface, a better appearance and was easier to erect and maintain.

Curve Construction

The distance between pull-offs on curve work will vary according to the radius of the curve. As shown in the table hereunder, it will be seen that the smaller the radius of the curve the shorter the distance will be between pull-offs. The reduction of angle at each pull-off is approx. 5^{o} to 7^{o}. Thus in a 60 ft radius 90^{o} curve, it will be necessary to have approximately 18 pull-offs. If the change of angle at each pull-off is greater, excessive wear on the trolley wire will result.

Radius of curve in feet	Space of pull-offs in feet (max)	Radius	Spacing of pull-offs in feet (max)
50	7	200-300	18
60	8	300-400	19
70	9	500	20
80	10	750	25
90	11	1000	33-1/3
100	12	1500-2000	50
125	13	Above 2000	100
150	14		

The pull-offs and ears will be offset inside the centre line of track. This offset will vary according to the radius of the curve, the smaller the radius of the curve the greater the offset. The main object is to endeavour to keep the trolley skid at a tangent to the curve. The amount of offset to allow for on curves was first arrived at from the following formulae:

$$S \quad = \quad \frac{EH}{G} + R - \sqrt{R^2 + P^2 - Q^2 - L^2}$$

Where

S	=	Radial offset of trolley wire towards centre of curve
E	=	Super elevation of outer rail
H	=	Height of trolley wire above rail

G	=	Track gauge
R	=	Radius of curve
P	=	Distance from centre of car to pivot of trolley base
Q	=	Distance from centre of car to centre of track
L	=	Horizontal distance from pivot of trolley base to point of contact between trolley skid and trolley wire

All values in terms of feet

This formula was found to have its limitations on account of so many different types of cars in operation. It was found that by multiplying the formula by a constant of 0.73 it gave a good theoretical figure for offsets on curves, and all curves are installed at these offsets. As there are a number of different types of cars in service and some routes have a majority of a certain type of car running on them, it is necessary in practice to adjust each curve according to wear.

The offsets vary from 7.5 ins for a 60 ft radius curve, to nil for a 500 ft radius curve. This offset does not include offset for super elevation of tracks.

As the trolley wire around a curve has a tendency to "roll", it is necessary that care be taken to put the pull-off wire through the correct slot in the double pull-off in order to counteract this tendency.

To obtain the best working conditions on a curve it is necessary to ease the tension in the trolley and make the curve "float". To do this the straight trolley wire is anchored back at the entrance of the curve. This gives a cushioning effect when the trolley wheel comes into contact with the fittings. This cushioning effect reduces the wear on both fittings and wire cuts down dewirements and the trolley wire remains in its correct position for longer periods.

Crossings on Special Work

Pull-off wires should not be attached to crossings, but crossings should be placed in between spans or between pull-offs. This gives a straight run through the crossing and minimise both the wear on the crossings and the chance of dewirements.

Locating Frog Positions

For the standard switch now being used on the system, the preliminary location of the overhead frog may be taken as 9 ft from the end of the switch casting. This will be found to be a good working figure on installation but adjustments must be made to give the best working position. Guard bars should be installed with frogs where the frog is likely to cause a trolley wheel trap.

Design of Overhead Network on Curves and Junctions

The only hard and fast rules that can be applied to the design of overhead network is the maximum spacing for the radius of curve concerned and the correct placing of crossings and frogs. Every curve and crossing must be wired on its own particular layout. Some of the points that have to be considered are:

1. The angle of intersection of the streets concerned.
2. The width of the streets.
3. The layout of footpaths.
4. Obstructions on kerb, lines of trees, poles, electric light poles, fire alarms, post office boxes and booths, underground obstructions etc.
5. "Drive-ins" and entrances to shops, factories or homes must be left clear.
6. Contour of locations. It is significant that of all the curves on the system of the MMTB there are only two curves which are identically wired. Junctions which have identical track layouts have had to be wired totally different because of some of the above features.

Maintenance and Renewal of Trolley Wire

Once the trolley wire is erected, its life can be shortened to a very marked degree unless the wire is correctly centred. If the wire is incorrectly centred, excessive side wear will shorten the life of the wire whereas correctly centred wire will give uniform wear and longer life. In adjusting wire, the ear should always be knocked away from the wear.

In the event of the trolley wire being gouged into at the entering or trailing end of an ear, it is often possible to cover up this weak point by knocking the ear either forwards or backwards, this bringing the weak point actually into the ear. This should be done before the fault becomes bad enough to warrant either a chafer plate or an anchor across the ear. In the event of the wear near the ear becoming spread over a section too long for the shifting of the ear to cover up the wear a chafer plate should be fitted. The length of the chafer plate can be increased from time to time if the wear continues to show up outside the existing plate. If the trolley wire near an ear has been worn so thin or damaged so that there is doubt about its strength an anchor ear should be placed on either side of the ear and anchored across.

When to renew trolley wire on any particular route is a problem for the Engineer. The Leading Hand Linesmen will have gauges with which to measure the wire and when this gauge will go over the trolley wire (depth) it is his duty to notify the Mains Engineer who will then inspect the route and decide whether to renew the wire or otherwise. Some of the points to be considered are as follows:

1. Location: This is a very important factor for, if the locality carries heavy pedestrian and vehicular traffic, the risk of a falling 600 volt wire cannot be taken.

In the case of a city area, a broken trolley wire could easily mean a long delay to traffic on a number of routes.

A congested area would impede a tower waggon getting to the seat of the trouble as well as delaying them in carrying out repairs.

2. Position of feeders relating to trolley wire: If the trolley wire has a feeder running parallel with it or a number of feeder taps at regular intervals, the loss of section in trolley wire is not so vital, but, if the trolley wire is a stub end feed resulting in a long trolley wire feed, the loss of section would cause a voltage drop, and cause overheating of the wire which would increase the probability of a broken or burnt down wire. The time this is most likely to happen is at peak period and the dense city area where we rely on "trolley wire feed" is the most likely locality.

3. The condition of the wire at fittings: The condition of the wire at fittings must be closely examined. If the wire has been subjected to excessive wear at the ears, necessitating long chafer plates and a number of places where the trolley has to be anchored over, it means that additional danger points have been created on the route.

4. The number of bad bays of trolley wire in the section: The number of bad bays in the section must be considered as it may mean that, by replacing these bays, the section would be okay for some considerable time, but the replacement of bays must not exceed the economic limit.

It can readily be seen that the renewals of trolley wire cannot be decided by measurements at each span alone, but must be taken on general conditions of wire, locality, density of service and accessibility. Thus every route must be considered on its own economical merits, for where wire of a certain size would be quite safe to leave on one route, it would not be wise to leave it on another route.

Overhead Feeder Cables

The feeders used by the Board consist of 0.1, 0.3, 0.5, and 0.6 copper cable although there are a few sections of 0.5 and 0.8 aluminium. The majority of the feeders consist of 0.5 and 0.6 copper cable. In running feeders, the sag measured in the centre of the bay should be as follows:

	100 ft span	110 ft span	120 ft span
60^{o}F	17 ins	20.5 ins	25 ins
90^{o}F	20-1/8 ins	25 ins	29 ins

In the early days of the Board, trouble was experienced in jointing feeder cable. Owing to the high cost of the heavy feeder cable, it was not economical to terminate and anchor feeder cable at a pole and then jumper across. If this method was used it may have meant cutting off 80 ft or 90 ft or perhaps 100 ft of cable as waste. The splicing and thimbling of cable was found to be slow and expensive as well as not being mechanically sound in the event of a fire in a building close to the cable. A cone splicing sleeve was then developed. This sleeve gave a perfect mechanical as well as an electrical joint, and, in addition, was easy and quick to install. It has the added advantage of being placed anywhere in the bay of cable. When running this heavy feeder cable, a wheel is mounted on a bracket; this bracket has a shank which fits into a hole in the cross arm; the feeder cable runs on the wheel, thus doing away with any scraping or damage to the cable as well as relieving the load necessary to pull the cable into position. In anchoring feeder cable, it has been found that good practice is to reduce the length of the last two bays of cable and on the second last pole to put an anchor strain clamp on the cable as a preliminary anchor. The final anchor is made by means of a cone anchor terminal which is the same principal as the splicing cone.

With the exception of the various Porcelain Insulators, practically every fitting used on the overhead network has been designed by the Board's Staff and is manufactured in the Board's Workshops. These fittings have been designed for lightness, ease of erection and replacement, ease of adjustments and to give a better job of work. Over the years, it has been the aim of the Mains Branch to improve the type of network, and fittings, especially any that has been the cause of any trouble.

Trolley Wire Sections

Over the years, a number of various types and sizes of wire have been used. In the early days some 4/0 "Brown and Sharpe" section was used but this section did not allow for a non-fouling ear.

Then there was the British Standard non-fouling section of wire which enabled a non-fouling ear to be designed. Another good feature of this wire was that the head was small, giving a larger wearing section of wire, but this advantage was likewise a great disadvantage as the wire was not drawn from a round section and the small head and narrow throat being so much smaller in area than the base section, overheating was caused in drawing the wire. This overheating caused flaws in the wire and many broken trolley wires were the result. The British Standard grooved wire 0.125 sq ins was then tried but this did not give a non-fouling section and was not persevered with. A design was then taken out for a grooved wire which was drawn from a round section and enabled a non-fouling ear to be used with it. A wire of 0.126 sq ins section and 0.2 sq ins section was then developed and has been used with success by the Board since 1935. The new British Standard wire very closely resembles these sections.