PAPER 4

CONSTRUCTION AND MAINTENANCE OF MUSEUM OVERHEAD

L.M. Fenner

Australian Electric Transport Museum (S.A.) Inc., Adelaide, South Australia.

The techniques described in this paper are based mainly on experiences at the St. Kilda Tramway of the Australian Electric Transport Museum, though some mention of current practices of the South Australian State Transport Authority (STA, formerly MTT) and the Melbourne and Metropolitan Tramways Board (M. & M.T.B.) occurs.

Description - St. Kilda Tramway

The AETM line, of approximately 1.9 km length, is constructed largely on swampy soil and beach front. The track runs close to salt water for much of its length and both salt spray and salt laden dusts settle on the wires and fittings.

Vehicles use the tramway principally on weekends, and corrosion of fittings can occur for up to five days before they are traversed again by tramcars. Formation and breaking of corrosion crusts occurs, being significant on unprotected and painted steelwork.

The museum overhead can be divided conveniently into two sections: the depot and fanwork, which presently includes 4 wired tramroads, and the main line, which includes a passing loop near its mid-point.

The bulk of the complex curve and junction wiring occurs on the fan, which, together with the overhead inside the car depot, is strung in 7 strand 12 gauge galvanised steel wire of 26/33 tensile strength. Museums wishing to use such wire should make certain that the tensile strength is that quoted (G380 is the metric standard). High tensile strength wire is very difficult to handle and snaps easily if nicked. Our stranded wire is supported by span wires on the fan and the cross-timbers within the depot.

The main line is strung in 4/0 BSW gauge grooved cadmium-copper wire, supported mainly by bracket arms, but using span wires on two sharp curves and at the entrances to the passing loop.

Most of the specialised fittings were obtained second-hand (though unused in some cases) from the MTT/STA (Adelaide), the MTT (Perth) or the M. & M.T.B. Other tools and equipment are standard workshop items. The support poles are all ex-MTT tubular steel ones, and date from 1910.

Equipment Required

The following is a list of essential tools and fittings with their functions (where appropriate). These are the minimum necessary for a two-man construction and maintenance team. Many of the items are useful in the workshops as well, so they will not lie idle when overhead work has been completed.

Spanners (a) - ring and open ended types.
½", 9/16", 5/8", 3/4" BSW (others are useful for smaller fittings and clamps e.g. ¼", 5/16", 3/8" BSW)

(b) - adjustable types, 2 medium sized (12"), since paint layers often prevent specific sizes from fitting properly.

(c) - socket type, with extension arms. We have used these mainly while removing old fittings from poles *in situ*.

"Penetrene" -or similar rust-permeating lubricant. Mainly used for removal of old brackets, strain insulators (q.v.) and other fittings.

Mallets - Plastic faced or wooden. Very useful for tapping fittings into place. (Hammers tend to damage wires and gunmetal, and are unsuitable for work with porcelain).

Hammers (a) - Claw

(b) - Light sledge. Used in conjunction with hardwood blocks, for loosening collars, bases and finials on scrap steel poles.

Files - (a) - Mill saw type. Triangular and flat. For trimming cuts in wire, threads etc.

(b) - Round type.

Scrapers and Wire Brushes - Mainly used when salvaging old fittings. A narrow wire brush will be found very useful for cramped work.

Extension Ladders (2) - The height of these will depend on the overhead height used. 18ft wooden ladders have been adequate for our own work, due to the low overhead on most sections. They are light enough to be worked easily by one man.

We also have a 25 ft ladder for our taller (normal sized) poles. This ladder needs two men for safe and easy handling.

Aluminium ladders, though light, are very expensive and offer no insulation from earth.

Unless rectangular section poles are used, the ladders as purchased require modification to enable them to be used safely. This consists of removing the top rung of the upper section and replacing it with a clamp and chain. This system will wrap around curved poles and hold the ladder steady.

Safety Belt (2) - Our own belts are of the older leather type. More modern belts are made of synthetic webbing. These are essential for safe working, since when correctly tied, both hands are left free to work on fittings (see later).

"Come-along" clamps (2) - These grip stranded steel and copper wires strongly without causing damage. They release rapidly when not under tension, and their use speeds up straining and handling of wire enormously (Figure 1).

Shackle bolts - ½" and 5/8" for suspension work and clamp links. 3/16" for anchor ears (q.v.).

Turn buckles - Various sizes from 7/8" thread (for heavy tensioning) to ½" thread for adjusting pull-off wires. Used for permanently variable tensioning.

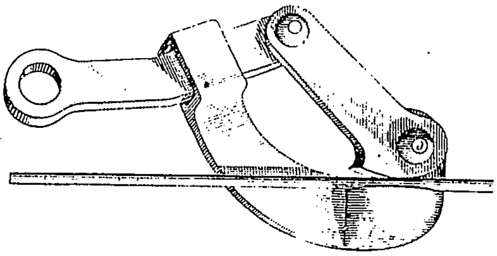
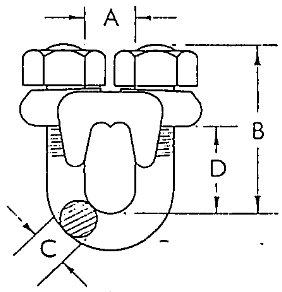


Fig. 1 "Come-along" clamp



WIRE SIZE (s.w.g.)	DIMENSIONS A inch	B inch	C inch	D inch
7/10, 7/12	½	1⅝	⅜	1
7/14	⅜	1⅜	5/16	⅞

Fig. 2 "U" clamp

U-clamps ("Crosbie" clamps) - For quick gripping of wire when setting up curves, and also for use when later adjustments are to be made (Figure 2). Can be used instead of "come-along" clamps, but are much slower for working. Several sizes will be required on layout.

Chain Hoist (1.5 tonne) - This is expensive but speeds up tensioning of trolley and spanwires since it can draw up a metre or more of slack using one clamping operation and is able to be used much more rapidly than a turn-buckle. (Such hoists are also useful for general lifting in the workshop).

Taps and Dies - Mainly used for reclamation work. Many fittings have special bolts or tapped threads which are difficult to replace and must be restored. Thread burring often occurs during removal of such items and appropriate taps and dies are required. Most useful sizes are 5/8" and 3/4" BSW, though each group will need to examine the threads on second hand material available to it to determine requirements.

Pliers - Several pairs are useful, including at least one pair of long-nosed, and one pair of Fencing and Telegraph pliers. The latter incorporate a strong wire cutter, but their special feature is the bluntness of their grip grooves. This enables them to manipulate wire without nicking it or cutting of the zinc coating.

Angle Cutter and End Cutter - Both of these will be very useful for trimming and tidying after tying hitches, attaching feeders.

Bolt Cutters - These are expensive, but if large numbers of cuts have to to be made in trolley or heavy stranded wires, they save a great deal of time, taking about 5 seconds for a cut which takes a minute or more using hacksaws. The cutters cannot be used for trolley wire cuts if the profile must remain undistorted. Our particular cutters have

24" arms, can cut up to 3/8" mild steel rod and make very short work of all cuts in overhead gear. If an overhead collapse occurred and speed was of the essence, bolt cutters would be an essential overhead tool.

Hacksaw and Small portable vice - These make the best cut for trolley-wires in which preservation of wire profile is required. A small portable vice to hold items being cut is a useful fixture on a tower wagon.

Insulation Tester - "Megger" or similar. The working voltage of these will depend on standards (if any) of local electricity authorities. Our own Megger is a 500v unit. These are essential for checking insulation on old fittings to be reclaimed, and also for testing overhead fittings *in situ*. If two long connecting wires are made, one worker can make the necessary contacts up on a ladder while another, on the ground works the machine. Although these are costly items, they are almost essential. They are also necessary for checking insulation on vehicles. Second hand units are sometimes available and in our experience should be perfectly satisfactory.

Mechanical Screwdriver - These units make fitting and removal of overhead ears very simple (Figure 3). If they are not available, a large conventional screwdriver will do, but the mechanical type is much safer to use and will undo even the most obstinate machine screw without burring the slot badly (unless the screw breaks under the strain).

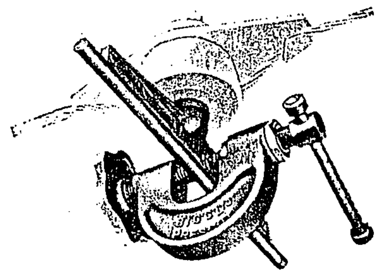


Fig. 3 - Mechanical screwdriver

G-Clamps - Various sizes. Useful for holding fittings or forcing obstinate items into place.

Graphite grease - Bolts lubricated with this remain workable for a long time. We found, when removing ex MTT fittings, that those whose threads had been greased were held firmly but could be removed easily, whereas ungreased units were generally corroded tight and sheared off.

Tool Bag - A canvas tool bag with rope loops, for hooking to ladder tops, and a cane upper rim to hold the top open will be found useful for ladder work. If tools are being used where public are passing nearby, fixing cords are desirable. These consist of stout cords, with one end fixed to the body belt and the other to the tool in use. If the tool is dropped accidentally, much time is saved in not having to climb down to get it, and the risk of striking persons below is minimized.

Safety helmets - These are essential if ground crew are working near

where overhead work is being done, and would be required by law in many places. We have found that the type with a "V" notch on top is advantageous since the "V" is able to be used to support wire, leaving both hands free for working.

Safety Cones, Flags and Signs - A supply of "Witches'hats" of the fluorescent type is useful for fencing off areas above which work is occurring. At our own museum, where several public road crossings occur, the cones can be used to divert traffic around tower wagons. Appropriate warning signs of "Half Road Closed- Drive Slowly" and other types are also desirable, though approval for their use may be required.

Safety Vests - Fluorescent vests are useful for ground crews working near traffic. As with all safety equipment, one must not assume that the wearing or placing of such items is a fail-safe action. A dictum "The best safety device is a careful man" has much to commend it.

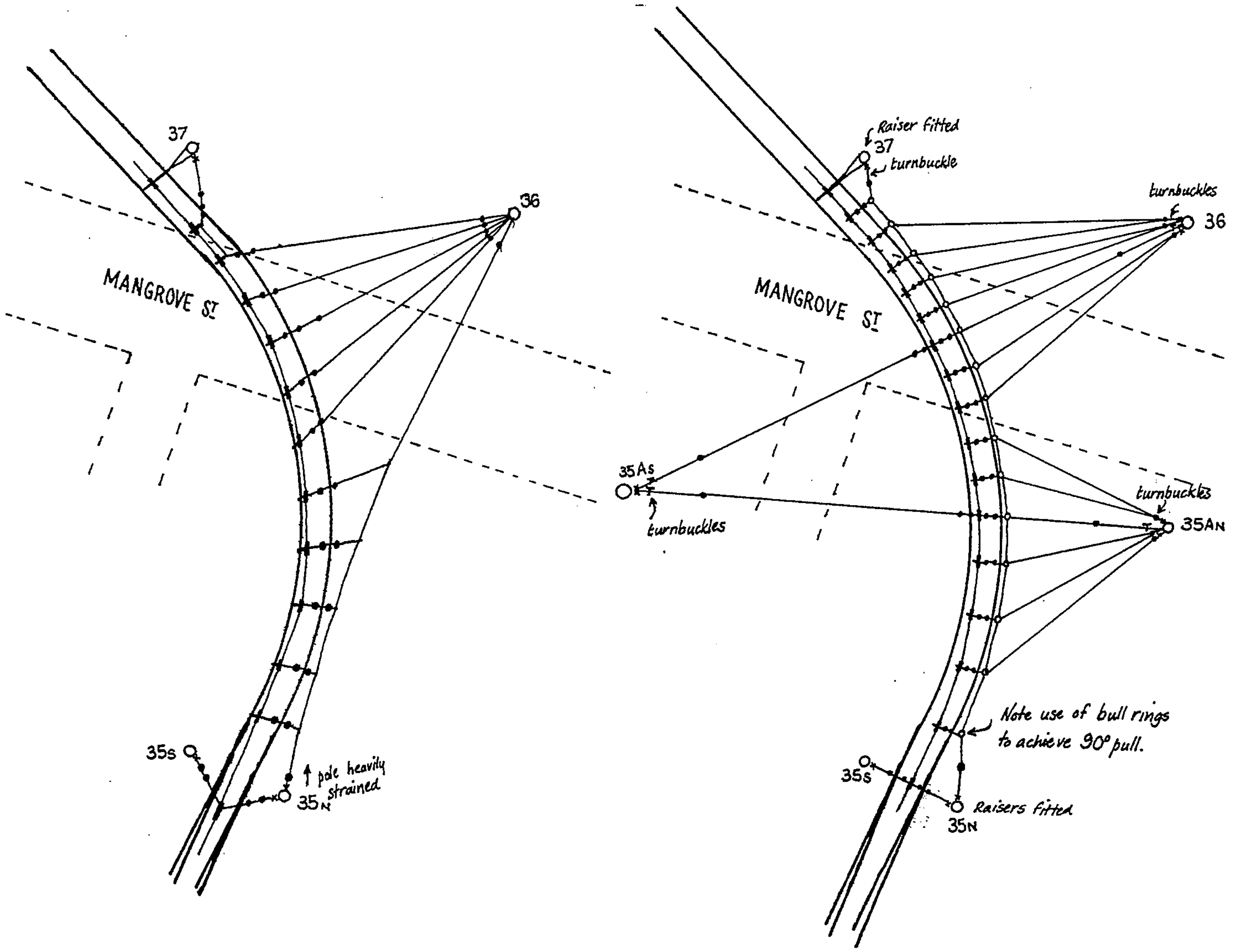
Eye Protection - Goggles should be worn during wire work to offset risks of eye injury if wire ends whip.

Other specialized fittings may be acquired from local transport authorities, or they may have to be made. It is difficult to buy new items, and they would probably be very expensive. Items in this category include kink removers, clamps for grooved fittings; frog pan clamps and cap-and-cone grips.

Design

When preparing for overhead construction, it is desirable to have a detailed track map upon which the proposed overhead plan can be superimposed. Make sure sufficient poles are provided on curves, loops and termini. It is desirable that pairs of poles be located on either side of road crossings so that they may take most of the tension on each side of the crossing. Should a road vehicle foul the wire above the crossing, risk of a major fall of overhead is minimised, especially if the trolley-wire is fixed with joining ears in such locations. Larger poles may be required on curves to take the additional strain of a complex suspension system. If the suspension system is designed first, the appropriate poles can be installed, rather than trying to design a suspension system to make the most of whatever poles have already been erected. An example of part of a designed reverse curve is shown in Figure 4.

Designing pole locations depends, to some extent, on the type of current collection to be used. If swivel headed poles are in use, the wire can be well off track centre, though most Australian tramway systems used fixed heads, which require the wire to follow the track centre except on curves. It is important to allow as much clearance as possible between car sides and poles, to cut the risk of contact between passengers and poles. A minimum clearance standard of 4' beyond the widest car was adopted by AETM.



As built 1973

As redesigned and reconstructed December 1976

<u>Fig. 4</u> - Example of designs for curve at Mangrove St., St. Kilda. As originally constructed, excessive load was placed on poles 35N and 36. Subsequently two additional poles (35AN and 35AS) were installed, and a raiser added to poles 35N, 35S and 37 to allow the load to be better distributed and the overhead height to be raised. Curve radius 73 ft.

Poles

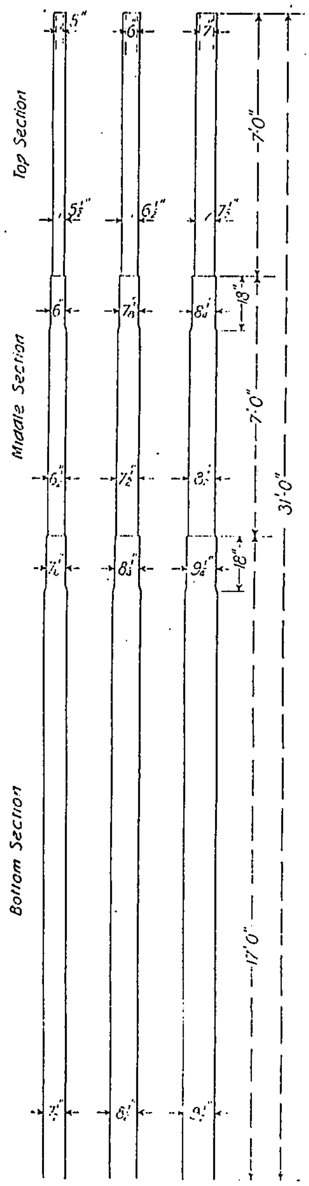


Fig. 5 - Pole types

The type of poles to be used is influenced by a number of factors, the chief ones being initial cost, ease of acquisition, ease of erection, ease of maintenance and historical links. Though some tramway systems used wooden poles throughout, most used some form of tubular steel pole with finials, collars and ornamental bases.

Unless termites, fungal attack or fires are likely to cause problems, properly treated wooden poles are probably the best items for museum work. If they are properly ferruled and capped to prevent soaking and splitting, they need little maintenance, and their initial cost is lower than that of new steel poles. Second-hand steel tramway poles were adopted for the St. Kilda tramway due to availability at low cost, and due to their historical interest when fully decorated.

Steel poles come in 3 main sizes. They are usually about 31" long, and the size difference is in the pole diameters. Strainer poles for use on curves, wide spans and at termini are of about 9½" external diameter in the base section. Medium weight poles for long bracket arms and shorter spans are 8½" external diameter in the base section, while light weight poles, which in Adelaide were used almost exclusively for centre pole construction are of 7½" external base diameter (Figure 5).

If maintenance is to be minimized with steel poles it is essential that they be well treated against corrosion before erection and touched up thoroughly afterwards. Before beginning any treatment the poles must be checked for rusting and straightness and defective ones rejected.

If possible they should be completely chipped back to the metal, using scrapers and hand tools if the worst comes to the worst, though a needle gun or a sand blaster will do a quicker and better job.

Finials, collars and bases should be removed, tapping with a mallet or a hardwood block and hammer. Since such fittings are usually of cast iron, hammering must be avoided, because the fittings may be smashed. If so, the risk of flying iron chips is high and they can cause a lot of injury.

Eye protection should be worn at all times during chipping and cleaning.

Following this treatment, a final examination for any weaknesses in a pole is needed. Welds should be examined again, and the areas which were beneath bases, collars, clamps, bracket arms and finials need to be checked especially thoroughly, since the worst corrosion usually occurs there.

Having been pronounced sound, the pole should be primed carefully and undercoated. The final coat of paint can be applied before or after erection, but touching up will be necessary in the former case.

Having restored poles it is necessary to find as cheap a way of erecting them as possible. The system used during the construction of the AETM line required a crane, welder/cutter and the provision of concrete. Reject asbestos cement pipes from a local works were used as caissons, and an auger truck was used to bore the holes. As a section of the tramway was to be constructed on a causeway, the poles on this section were erected before the track was laid in order that the augers and cranes could work from the track bed.

To erect the poles, the locations were first accurately fixed and the holes dug with an auger. The caisson was then inserted and the surrounding soil packed back with a "Whacker". The poles had had a pair of 3/4" holes cut in them some 6" from the top, and a steel loop was fitted to this to enable them to be picked up easily by a crane and suspended in position. They were lowered into the caisson, checked for height, trimmed if necessary, repositioned and then held while concrete was poured in around their bases. Finally they were raked slightly and held while the cement set. They were imbedded to a depth of about 6'.

Where cast iron ornamental bases were available, these were wired onto the poles with cables before erection so that they were well clear of the bottom and, following setting of the concrete the cables were loosened and the bases carefully lowered into position.

It is desirable to dome off the concrete above ground level so that excessive moisture build up around the base of the pole is avoided.

Finally, when the poles had settled, collars, bracket arms (where required) and finials were fitted.

I have expressed reservations about steel poles because of their maintenance requirements, and the time needed for this is considerable if the abovementioned pretreatment cannot occur. In our case, circumstances did not permit as thorough a checking of poles as we could have wished, so rust spots and even a few holes are causing us some concern.

Where we have been able to do so, we have tried to fit the poles out completely with bases, collars and finials. The bases and collars can be cut in half if they are to be fitted to poles *in situ*. The halves can either be strapped together or machine screwed with metal plates. (Some of our acquisitions have included a number of two-piece bases which simply bolt together).

We have made a simple crane which bolts to the poles using standard insulator brackets. Its chief use is in the placement of finials, which weigh some 30 kg or more each. Though it is possible to drag these up using a rope, the crane is much safer and quicker, and is considerably less exhausting to use. We have also used it to erect raisers on some poles in order to increase their height, (Raisers were often added to tramway poles by electricity and telephone authorities).

Maintenance of poles *in situ* consists of an annual check of each pole for rusting and mechanical damage. Areas where rust is most likely to occur are those where moisture is able to be trapped - chiefly under

bases, collars, bracket arm bosses and pole clamps. Bases and collars should be kept loose so that water can run away easily. Clamps and bossheads should be checked carefully and shifted if necessary to enable scaling and repainting to occur. Finials should be moved around in an effort to stop them from rusting into position, because once they do so it is extremely difficult to shift them and the tops of the poles can corrode through, creating a hazard to persons down below. If finials are not available straight away, a loose fitting galvanised cap can be used. These keep rain out of the poles and, in our case, prevent birds from nesting in them and building up a corrosion threat in the form of sodden nesting material in direct contact with the steel inside.

Suspension Fittings

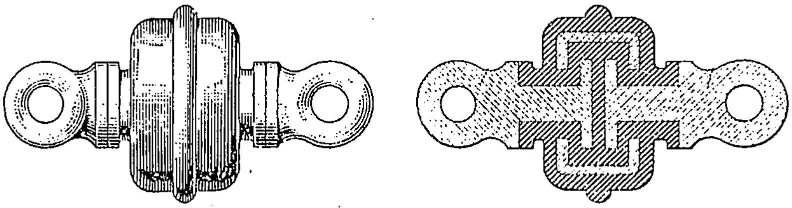
Suspension fittings are often difficult to obtain, but in many cases poles along former tram routes may still have many salvagable items years after the tramway has ceased. The AETM was able to obtain many fittings off the scrap poles it purchased, and was able to salvage others from poles being scrapped by local authorities. The fittings included steel straps and bolts, giant strain insulators and insulator brackets.

The steel straps were examined for corrosion and, if at all weakened, they were scrapped since a considerable surplus existed. Sound straps were chipped or burned back to metal and treated with hydrochloric acid to remove rust. This usually required immersion for about 15 minutes in a 1:1 solution, followed by a scrub down with sodium hydrogencarbonate solution and air or oven drying. Finally a coat of zinc paint was applied and a new galvanized 2½" x 5/8" BSW bolt attached. It usually pays to put a coat of micaceous paint over the zinc, otherwise there is a risk of flaking and consequent corrosion.

As with other fittings which use composition insulation, giant strain insulators (Figure 6) often crack slightly and allow moisture in to where metal parts can corrode. While this rarely caused loss of strength in any of our insulators it frequently resulted in a considerable drop in resistance. We therefore tested all of the giant strain insulators which we salvaged and baked any defective ones until they had an "infinite" resistance. We dismantled one of the more severely corroded ones to see what mechanical damage might have resulted from corrosion, but found that the slight internal corrosion had not affected the strain castings at all. Following baking and retesting, the fittings were given several coats of tarpaint. We found that fittings could be soaked in water for a week, dried off and be unaffected following the painting. After three and a half years in use the fittings are still all sound.

On most of the earlier tram routes, turnbuckles were permanently fixed to one side of the span wire, presumably to allow for retensioning of spans. We retrieved about 40 of these and, despite a very rusty appearance, they proved very easy to restore, probably because, like most of the old bolts encountered, they had had a good coating of graphite grease applied. In most cases a quick wire brushing of the exposed threads followed by a light oiling enabled the turnbuckles to be unscrewed by hand.

Though the AETM was not able to obtain hangers, ears, frogs or section insulators from the main Adelaide system at the time of its closure, we were fortunate in securing a large number of porcelain loop insulators (Figure 7). Generally these can be put into service with nothing more than a dust-off, but if it is thought necessary to remove all street-grime and wire-corrosion marks, a short boiling in caustic soda solution (≏ 500g flakes in 15 litre of water) followed by a rinse in water and dilute hydrochloric acid will be found to be a very effective cleanser. Rubber gloves, a face mask and some form of protective clothing should be worn when using caustic soda.



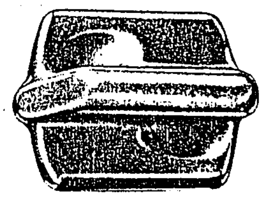


Fig. 6(a) - Giant strain insulator (b) In cross section Fig. 7 - Loop insulator

Ideally, one should try to secure a supply of straight line, double pull-off and single pull-off insulated hangers for suspending the ears and trolleywire (Figure 8), though it may be noted that much of

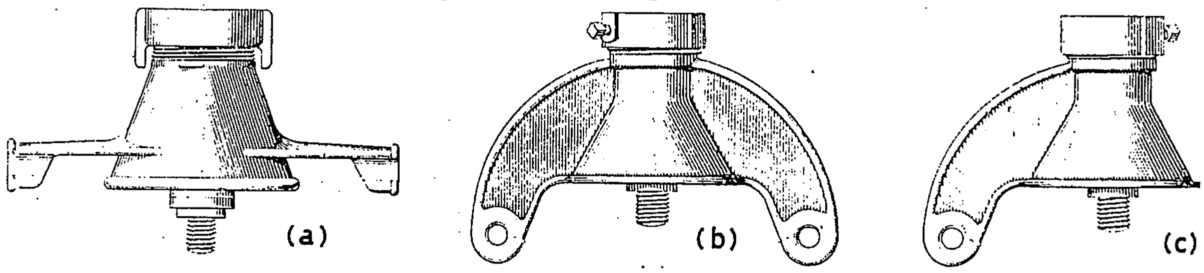


Fig. 8-Hangers (a) Straight line (b) Double pull-off (c) Single pull-off

Melbourne's overhead is suspended by simple non-insulated hangers. Although the AETM was unable to obtain any conventional hangers for its overhead work, it was able to adapt a number of porcelain hangers which had been obtained from the BHP electric railway at Iron Knob. These had been designed to hold a special variety of steel non-fouling ear, of which we had only twenty or so, leaving a surplus of some 150 hangers. An experimental adaptation of one of these "german helmets", as they were dubbed, consisted of welding a 3/4" BSW nut to the iron pedestal, protecting the porcelain from sputter by covering it with tinplate. A mechanical test was applied and, after a violent twisting, we eventually broke off part of the pedestal without being able to break the weld.

The service hangers were wirebrushed after welding and well coated with zinc paint. Corrosion of the pedestals has proved to be a minor problem in service, since it is virtually impossible to scour off the rust *in situ*. However, by keeping half a dozen spare units, we have been able to take down corroded ones and bring them back for chipping and repainting, following which they become the spares.

We have made the units in two forms. One has a 3/4" BSW nut on the pedestal and is suitable for ex-MMTB non fouling ears, most of which

are male fittings. On the few female ears of this type (Figure 9) we have used a brass grub screw for a sex-change operation.

Since most of the ex-MTT fittings which we obtained were 5/8" BSW females, we produced a second type of hanger with a 5/8" bolt welded on.

The ex-BHP steel ears mentioned above were not very suitable for our purposes outside, since they corroded badly. We have retained a number of them in the depot where weather does not affect them. (They are such coarse fittings that they can grip stranded steel wire satisfactorily without any adaptation).

When the permanent depot fan and main line wire was strung, it was necessary to obtain suitable ears. As mentioned in the introductory paragraphs, we used stranded steel wire in the fan and grooved cadmium copper on the main line.

A visit to the (then) MTT scrap bins at Hackney resulted in our obtaining a considerable number of partly worn fouling ears and several kg of countersunk-head machine screws (5/16" BSW). These have been very useful in supporting our stranded wire, and we continue to visit the stores in an effort to build up a good reserve of ears against the day when the Glenelg line overhead is converted to non-fouling fittings. We have also been able to obtain a considerable number of non-fouling ears of various designs from the STA. These are in use on the portion of the line running from the loop to the beach terminus.

During the original main line construction in 1973-74, it was apparent that there were not sufficient ears available in Adelaide for our purposes. In addition, we had no suitable frogs available for the enlarged depot fanwork and the wiring at the loop.

Here we were fortunate to receive assistance from the M. & M.T.B. in the form of some 60 support ears, 6 joining ears and five steel frog frames and pans; all for some $60. Since a new ear cost about $10 at the time, the low cost of the second-hand items can be appreciated.

The various fittings described are illustrated in figures 10 and 11.

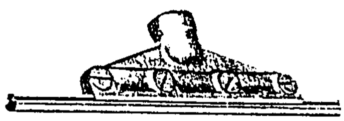


Fig. 9 - Short ear

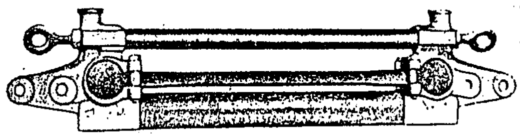
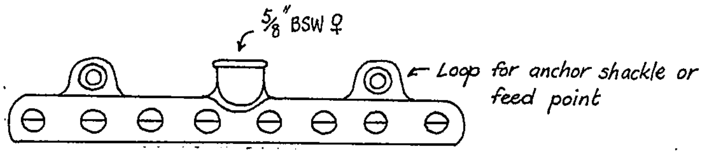
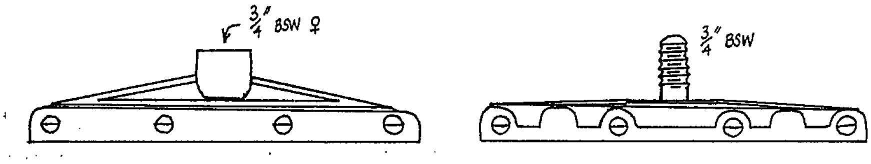


Fig. 12 - Section insulator with clevis end fittings

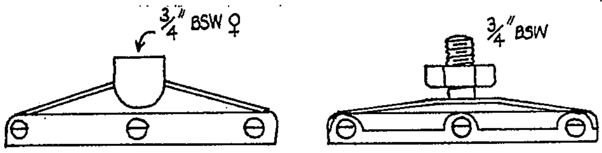
Some years previously when the Perth trolley buses closed, we had purchased an unused trolley bus turnout. The BICC type section insulators (figure 12) and joiners from this were used to isolate our depot wiring from the fanwork and the fan from the main line. In addition, the main line was divided into three sections for possible cutting back of services in an emergency. Since we do not use a feeder system on the main line, it is not possible to work sections on the beachward side of a break. The main line section insulators are presently bridged over with a long track bond, but we have some heavy insulated knife switches which we intend to install so that a section can be switched out from the ground using a long pole with a window-opening attachment. When using section insulators to isolate a section



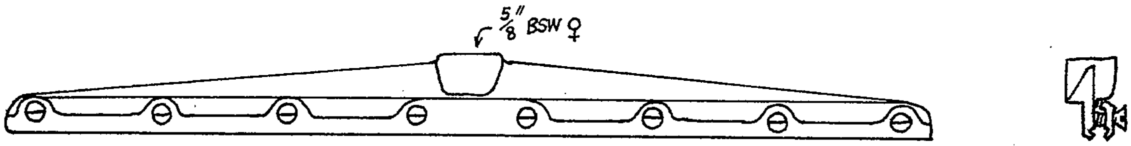
MTT non-fouling ear, suitable for support, anchor or feeder purposes.



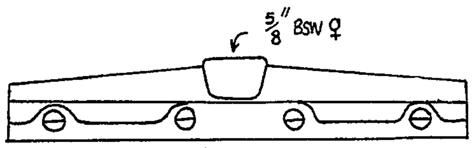
M. & M.T.B. 10" non-fouling ears. Male ears used with "L" brackets on straight or curved work. Female ears used with insulated hangers.



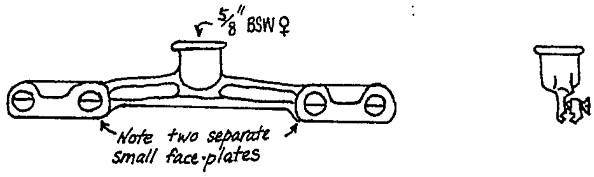
M. & M.T.B. 7" non-fouling ears (female and male).



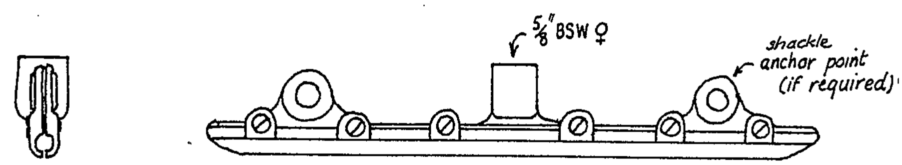
MTT 24" "Brisbane" type non-fouling ear for use on curves.



MTT 12" ear, cut down from 24" size ear.

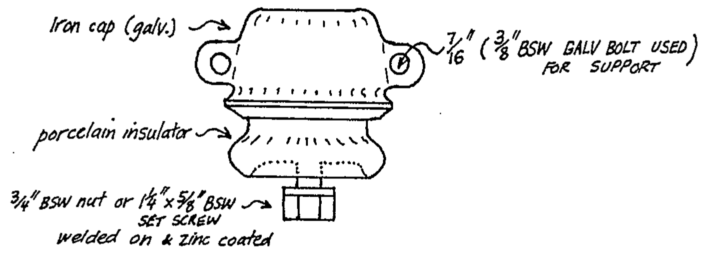


MTT Two face-plate female non-fouling ear.

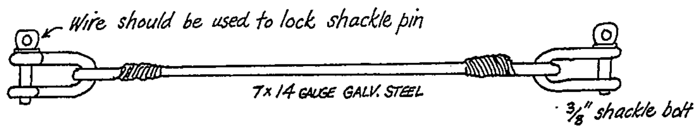


MTT fouling support ear, suitable for use as anchor ear.

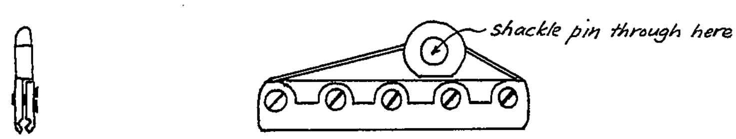
Fig.10 - Types of ears used in construction of overhead for St. Kilda Tramway (Scale 1:5).



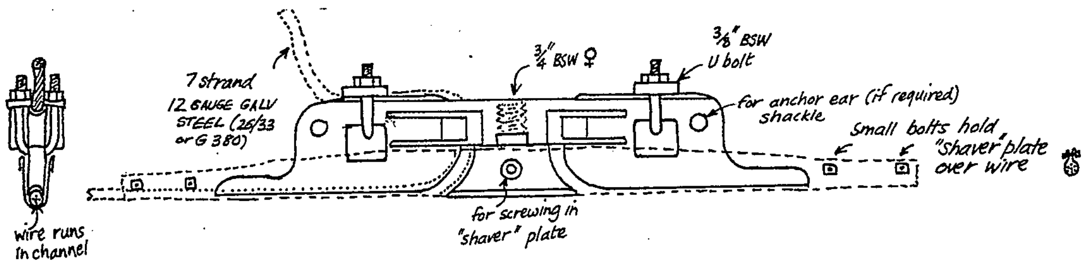
Ex-BHP type "German Helmet" type insulated hanger.



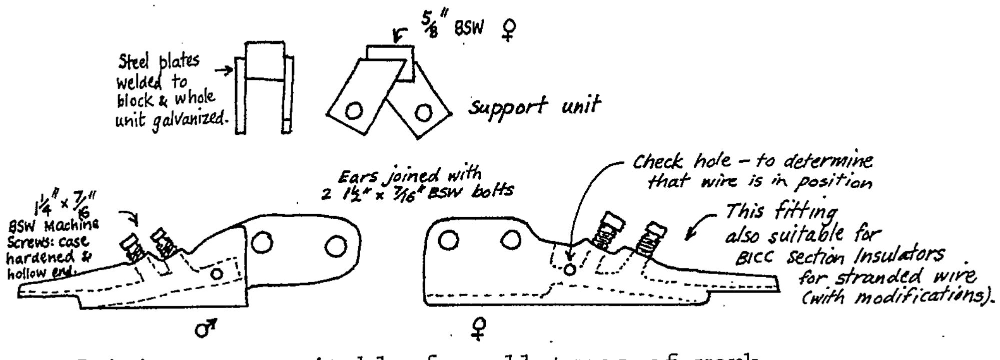
AETM anchor wire for section insulators, frogs or joining ears.



M. & M.T.B. non-fouling anchor ear.



M. & M.T.B. Joining ear, convenient to use with stranded steel wire but difficult to use with copper trolley wire.



MTT Joining ear, suitable for all types of work.

<u>Fig. 11</u> - Special fittings used in construction of overhead for St. Kilda Tramway (Scale 1:5).

of line, there is a risk of a two-pole car being driven under an insulator and bridging across it, electrifying the supposedly dead section. We use two systems to minimise this risk, the first being that the switches are so arranged that the knife section is swung across to an earthed contact when opened. We also use a heavy fluorescent stop sign which fits into a socket in the track in such a position that a car would need to demolish the sign in order to pass the insulator. By restricting the number of motormen to those persons who are aware of the risks involved in bridging out insulators, as well as by putting up notices informing workers that overhead maintenance or construction is in progress down the line, the risks are reduced to a minimum.

Where possible the power is switched off completely during such work, but where electrical maintenance or car shunts are necessary, provision has been made to feed or isolate all sections of the overhead, viz. workshop, car shed, depot fan, main line.

Since the STA uses clevis fittings appropriate to BICC type section insulators, we were able to obtain a considerable number of good second-hand ones of both fouling and non fouling types. With the appropriate male fitting, these can also be used for joining copper wire, though the use of a machine screw grip precludes them from being used for holding stranded wire. Here the M. & M.T.B. joining ears mentioned earlier are valuable, because they use a U-clamp to hold the wire. They are awkward to use with copper, but work very well with stranded steel which is more flexible. For smooth traversing the M. & M.T.B. joining ears need to be fitted with a shallow galvanised iron "envelope" which covers the gap between wire and fitting. If envelopes are not fitted, arcing and hammering causes the wire to be scalloped and severely weakened.

Bracket Arms

The next step is to put up either bracket arms or span wires for the support system. Since most of our line is single track, single bracket arms were selected for most of the suspension, span wires being used only near the loop, on the two sharpest curves, at a tensioning point and on the depot fanwork.

We had only two complete sets of bracket arms from the MTT system, both being twin-arm units which had been on centre poles. These were used at the loop. The other arms were manufactured by AETM members.

In Adelaide there had been very little clearance between the sides of cars and the centre poles, and we were determined to have a four foot clearance on our system. Accordingly our single arms were designed to achieve this, but the two double arms had to be lengthened and their wrought iron scrollwork slightly modified.

Our manufactured arms were all built to a standard design from salvaged street light brackets purchased from the Electricity Trust of S.A. The bracket arms consisted of the 2" galvanised tubular arm itself, a cast iron cap (mainly for a tidy end fitting), an eyebolt, a truss rod collar, a small iron plate (for wire support), two 5/8" truss rods, an angle iron and U-bolt and a main support collar. (Figure 13).

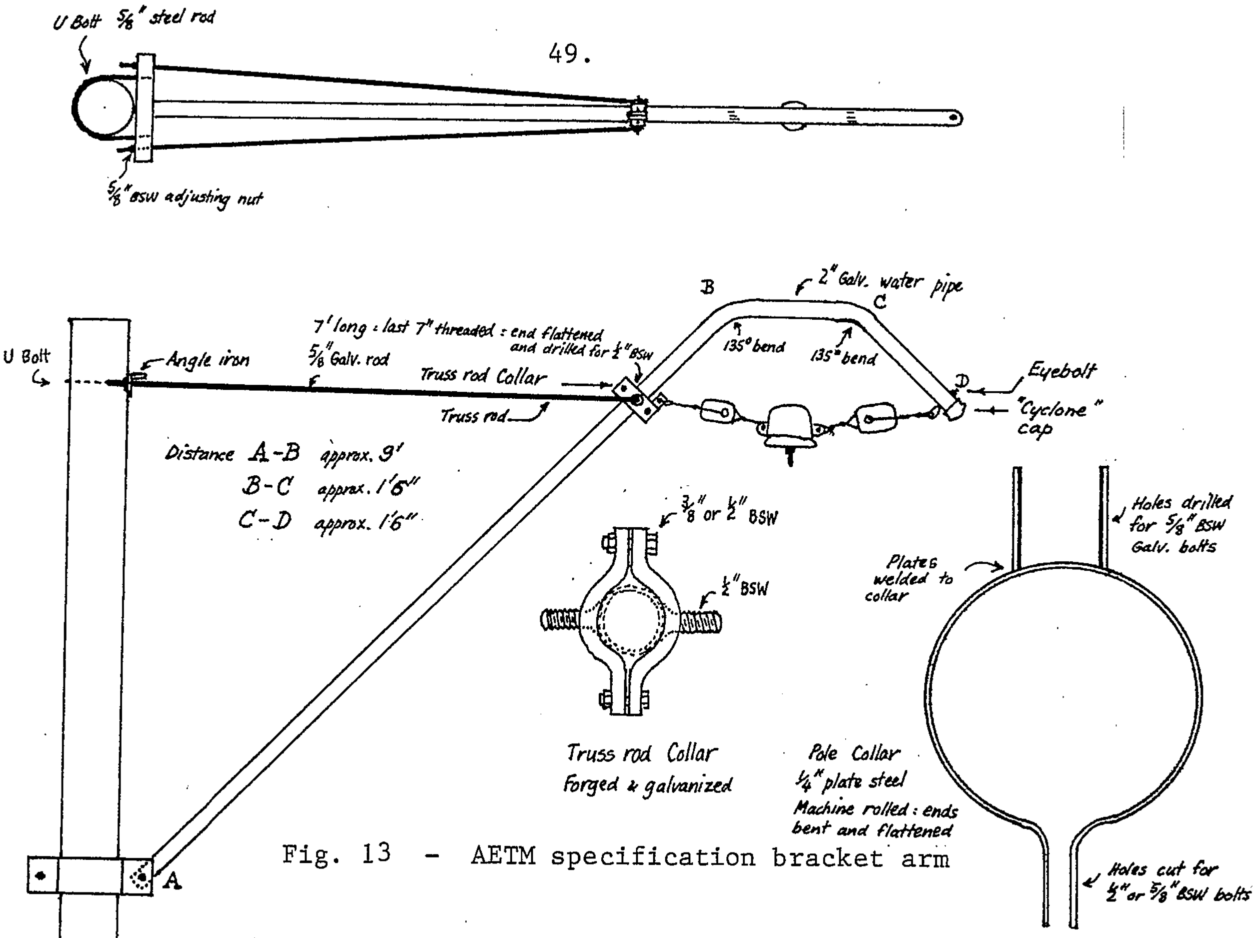


Fig. 13 - AETM specification bracket arm

Since the arms were built to a standard design it was possible to prefabricate the wire support units as well. Each required the cutting of two standard lengths of span wire, some two hundred cuts being required. In these situations a bolt cutter really saved time.

About 100 porcelain loop insulators were also required to be cleaned, and three tramway hitches had to be tied. As with the bracket arms, a team of four or five members made the units, which were designed for use with a special type of wire hanger originally used by the BHP on its Iron Knob and Rapid Bay electric ore railways. With the aforementioned modification, these support all of the ears and fittings.

The completed units - two short support wires with insulators and a "german helmet" - were put in position by two members using a tower wagon. (The bracket arms had previously been put up by the line construction gang, using a ladder and the tower wagon). The insulator units were attached to the helmet using two 1½" x 3/8" BSW galvanised bolts. While one member of the construction team held the "helmet" at track centre (marked on the wagon top) the other tied two tramway hitches, one through the collar plate and the other through the eyebolt which was then screwed tight. This left the system with a slight amount of slack. It is important to allow this when using non-fouling fittings with trolley wheel collection, otherwise hammering and excessive wire wear occurs at the ears. At the ex-MTT centre poles it was necessary to use conventional insulated double pull-offs, and we were grateful for the donation of these by the Sydney and Brisbane Tramway Museum groups.

The bracket arms are able to be used on gentle curves, though our lack of insulated double pull-off units was a problem at the time of construction, since there was not sufficient room to fit two loop insulators and a pull-off unit of the type which we made.

Our single and double pull-off brackets were made of 1½" x ¼" mild steel strip. After being cut to a suitable length, the metal was bent cold, though we did hot-bend one or two fittings when time permitted. A 5/8" or 3/4" hole was drilled 1" from the other end (for single units) or in the middle of the arch for double units. The iron was then cleaned, using the hydrochloric acid treatment, and one or two coats of zinc paint were applied. The end holes were fitted with cable thimbles (Figure 14), chiefly to avoid the cutting which occurs if the pull wires are used straight onto the fitting.

Where necessary inside bracket arms, a single pull-off was installed between the hanger and ear, insulation being provided by two loop insulators. All pull-offs used 7/16 SWG, G380 low tensile stranded wire. A small strap of the same design as that used for span wire support is clamped onto the bracket arm to provide the anchor for the pull-off.

Span Wires

Where span wires were used, we put these up using the steel collars salvaged from steel tramway poles. A giant strain insulator was put onto the collars, which were attached to the poles at the appropriate height. The span wire (7/14 SWG, G380 low tensile galvanized steel wire) was measured out on the ground by laying it between the two poles. About 1½ metres out from each pole a porcelain loop insulator was provided so that triple insulation existed between pole and wire. (We decided not to depend on the strain insulators for insulation, hence the use of the porcelain loops). Having measured off the wire and tied the tramway hitches to the insulators, a slight excess of wire between the loop insulators and the ends was allowed. Having put up one end of the span (usually holding it with a "U" clamp first, to allow for adjustment), the other end of the wire was attached to a rope or a piece of light 7/20 SWG wire and taken up the ladder. It was pulled as tightly as possible by hand, and either turnbuckles or the chain hoist used for final tensioning.

Where pull-offs occur in a span, the wire between the loop insulators should be left long and held with "U" clamps. It can then be put up as for an ordinary span and the required position of the pull-off marked on. The excess wire can then be shifted back from the loop insulators and tramway hitches tied. The wire is then cut between the positioning marks and the pull off wired in using bull rings (Figure 15), after which it can be slung in position. If some doubt about the pull off's final position exists, the pull off ties should be made with "U" clamps and the unit bridged over by a turnbuckle. Very accurate positioning is then possible, and the hitches can be tied from the tower wagon. The complete pull off unit is shown in figure 16. The technique for tramway hitches is shown in figure 17.

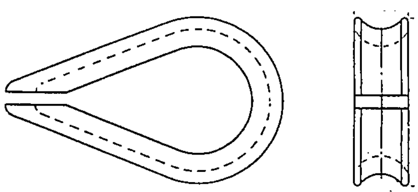


Fig. 14 - Cable Thimbles

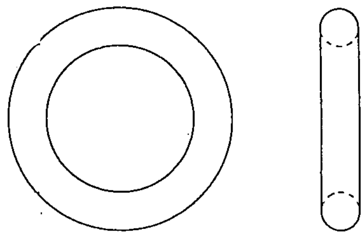


Fig. 15 - Bull rings

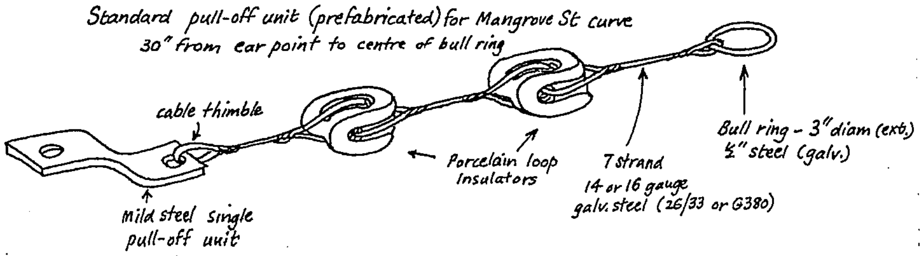


Fig. 16 - Prefabricated pull off unit

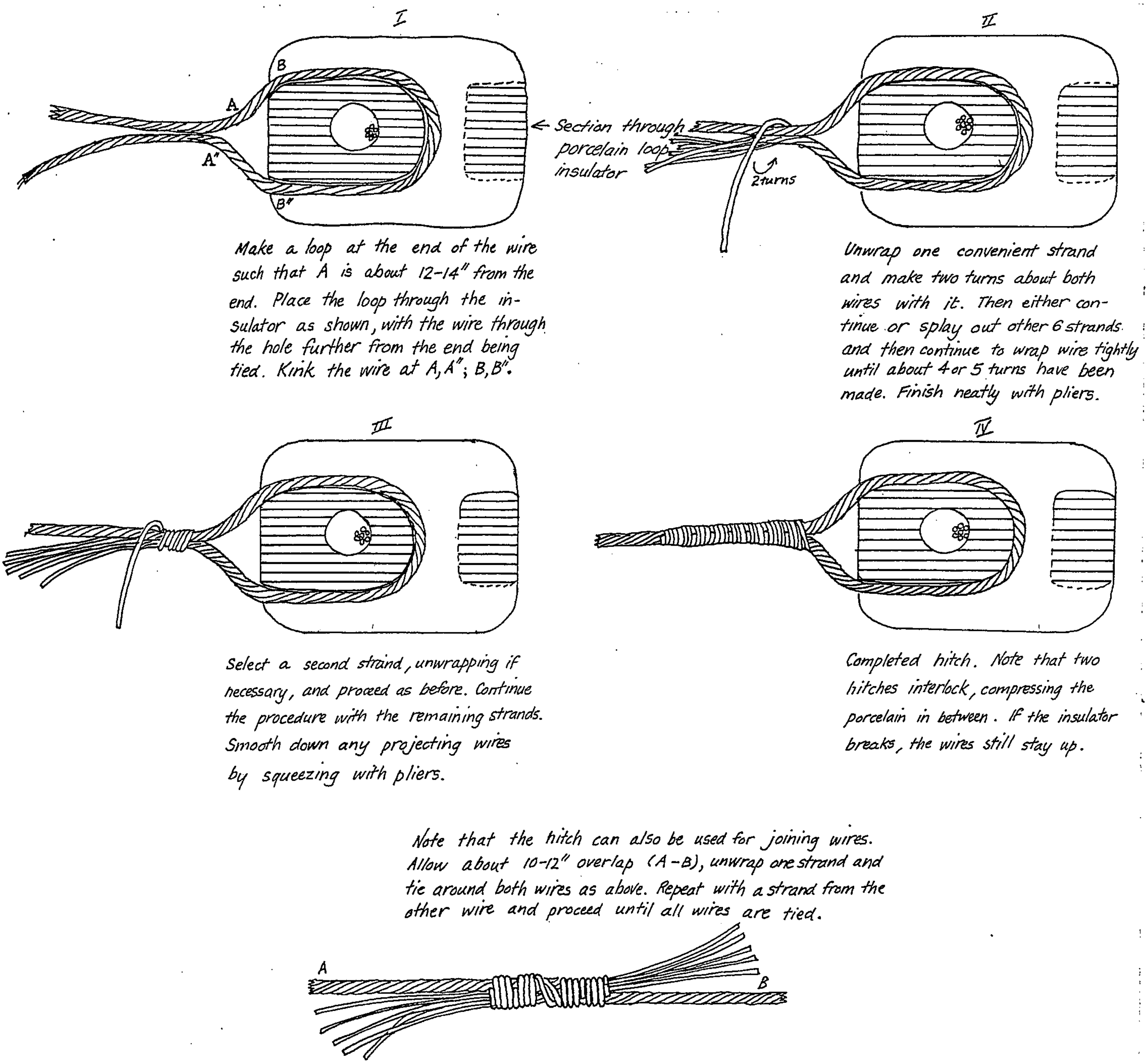


Fig. 17 - Technique for tying a "Tramway Hitch"

Pull off units for use between the span poles were put up after the trolley wire on the St. Kilda tramway.

The final item of construction before putting the trolley wire in position was the manufacture of several stout wire hooks, which served to support the wire while it was being tensioned. These were made either as hooks from ¼" steel rod, or as loops from pieces of 8g fencing wire containing a reel insulator which served as a roller and allowed wire to move freely along.

Steel Trolleywire

Though all of our main line overhead was put up in 1973-74, we had had stranded steel wire on our depot fan and in two roads of the running shed for a little over a year before-hand. Provided that low tensile wire (26/33 or G380) is used, stranded steel is much easier to work with than copper, especially on curves. Having put up the span wires on the depot fan, we simply reeled out the steel trolleywire, lifted it up using either the tower wagon or a ladder and, having tied it off to a support wire at the back of the first running road, tensioned it at a strainer pole.

When tensioning the wire, we took up the tension on two poles using a "V" shaped 7/14 SWG wire. A turnbuckle was hooked to the "V", and a triple insulated straight wire attached. The end of the trolley wire was clamped to this using three "U" clamps, with one road being erected at a time.

A number of factors must be allowed for when tensioning the wire, the chief ones being the day temperature and the distance of the span to be covered. It pays to consult a wire manufacturer's specification if an accurate sag is to be left.

Once the wire was strung and partly tensioned, the pull-off bridle wires were put up and the requisite pull-off ears attached. The wire should be set slightly towards the inner rail on curves if fixed head trolley wheels or skids are to be used for current collection. We simply put up the pull offs with plenty of spare wire to allow for adjustment, and ran cars under the wire. Where adjustments were needed they were made until the smoothest possible tracking was obtained. Final tension was made at the turnbuckle, and the positioning of section insulators and frogs could then be made.

We standardized the positioning of section insulators just outside the car shed doors - some two feet from the front of the depot. These insulators were provided so that power could be on in the shed but off on the fan or vice-versa.

The BICC pattern section insulator is very easy to fit, though its end support units must be drilled out to allow stranded wire to be attached.

We simply positioned the tower wagon below the place where the insulator was to go and carried the insulator fitting aloft. While one member held the fitting in its final position, another marked the exact spot where it was to go on the wire. The trolley wire was then bridged over with a turnbuckle and come-along clamps and tension taken up. A cut was made half way between the two marks on the trolley wire and the end pieces attached so that they corresponded exactly with the wire marks. Finally the insulator was bolted on and the turnbuckle loosened.

A small eyebolt was put through the timber door beam of the depot and the insulator unit was supported using a double insulated guy wire between this eyebolt and the eye of the insulator unit. It is necessary for these wires to be tight enough to hold the section insulator upright, but not so tight that the trolley wire is pulled out of the horizontal. If roll-a-doors or any other fittings which will not permit a continuous wire to be strung are used, this suspension system will not work. We have found it to be very suitable for use with paired wood framed swing doors, though it was necessary to make sure that no metal shed components came anywhere near the wire. The insulator support relied on two porcelain loop insulators and with our outward-opening doors care had to be taken that enough clearance was available between loop insulators and door edges.

Frogs

Since we originally had only two wired roads on the fan, only one frog was required. At this stage we had not obtained any MMTB frogs (which are actually of the type used by the DGT on the Sydney Tramways and, in fact, had pans pressed by the DGT who own the dies). No tramway frogs were available in Adelaide, so we used a galvanised iron, single piece trailing frog from the MTT trolleybus system. Though there was little free running space in which wheels could adjust their tracking, it worked quite satisfactorily and is still in service.

If possible, frogs which do not require that the main wire be cut should be used, because a fair amount of shifting around is possible without much damage to the trolley wire. Proper positioning is vital, otherwise dewirements due to wrong tracking will occur. In our case, where trams in public service run onto and off the depot fan all the time, a minimum of dewirements is desirable, though members of the public seem to find them entertaining. However the risk of a wildly-flexing pole smashing insulators, bringing down wires or tearing a catwalk or trolleybase loose from a car is too great to permit imperfect frog installation.

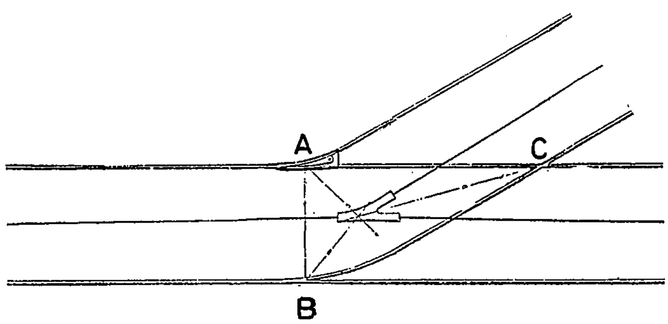


Fig. 18 - The Frog pan should be located at the intersecting point of the lines bisecting the angles of the triangle A B C.

Figure 18 indicates one way to position the frogs, though the units which we obtained from the MMTB were symmetrical rather then directed to the left or right, and they need a little more displacement to work properly than would a directional frog.

The M & M.T.B. frogs are of the more conventional tramway type, with a steel frame which is clamped to the wire permanently, and a pan which fits over the top and is able to be replaced when it wears out. Since we have experienced corrosion problems with the plain steel pans, we have had the next set zinc plated, but none of the latter have yet been installed, so a comparison of corrosion effects of plated or unplated pans is not possible as yet. The significant wearing agent however, seems to be running through the frogs under power, which causes severe arcing away of the edges of the pan and also pits the edges of the trolley wheels.

(The M. & M.T.B. use gunmetal frogs on all of their permanent work, and the steel units are only used for temporary track, since they damage the carbon skids which are used in Melbourne. The gunmetal frogs require that the wires be cut, so very accurate positioning is necessary, and this is not practicable with temporary track).

The steel frog frames have four support eyes on them, and the number of supports required depends on the position. It is usually possible to use a single span wire, with a short spur leading to the other support eye, on each side of the frame. The frog angle can be varied using a permanently attached turnbuckle on each side of the frame. However, where three or four span poles are nearby as at a passing loop, separate wires can be led to each corner of the unit, allowing for more flexibility in positioning.

Copper Trolleywire

Copper trolleywire is customarily used on all commercial tramways, 3/0 or the heavier 4/0 SWG being the main gauges adopted. Historically round wire with envelope ears was used, but modern practise is to use grooved wire with non-fouling ears. Standard details of BICC grooved 4/0 trolleywire are given in table 1.

The erection of copper wire requires more care than is needed for stranded steel. The St. Kilda main line uses 4/0 SWG cadmium copper wire, which came on three spools - two holding 0.5 miles and one smaller spool of some 600 yds. Though the copper overhead may seem to be flexible and thin when viewed from the ground, it proves to be very stiff and heavy when one works with it.

We began by carefully unreeling about 10 metres of wire and attaching one end to our stranded steel using a section insulator. A team of three members then began rolling the cable drum along between the rails, leaving a trail of overhead. This was carried back over the tray of the tower wagon which was pushed slowly along the track and thus acted as an automatic lifting device. Each time the wagon reached a span wire or bracket arm it was chocked in position, and the wagon gang climbed aloft and suspended the wire using the aforementioned insulator loops. Since the unreeling process involved moving under the 415V electric lines, the trolley wire was earthed to the rail using some clamps and a section of cable near the crossing point. A rope was also held over the line to stop any flexing and looping which might have caused the trolleywire to contact the mains.

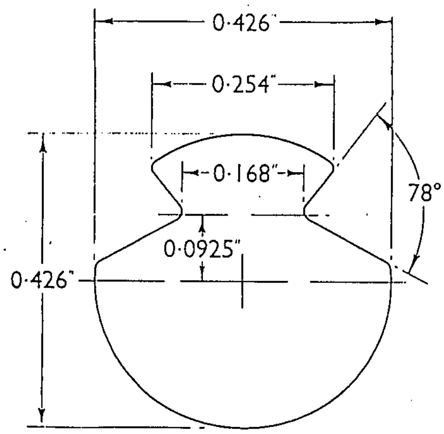


FIGURE 5

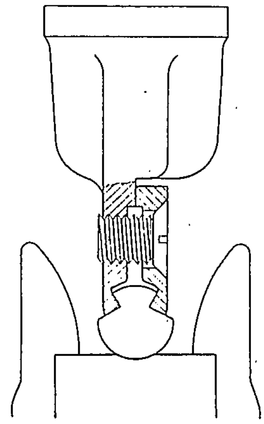


FIGURE 6

(Left) *Dimensions* 0·125 *sq inch* (4/0 *s.w.g.*) *standard grooved trolley wire*
(Right) *The clamping groove of the standard trolley wire ensures adequate clearance between the trolley head and line fittings, even with maximum wear*

TABLE 1 : **Standard Grooved Trolley Wires—Data**

		0·125 SQ INCH (4/0 S.W.G.) (B.S. 23 : 1949)	
		COPPER (HARD-DRAWN)	CADMIUM-COPPER
Cross sectional area	*sq inch*	0·125	0·125
Diameter	*inch*	0·426	0·426
Minimum tensile stress	*tons/sq inch*	22·5	26·5
Breaking load	*lb*	6335	7400
Maximum working load at minimum temperature	*lb*	2000	2500
Elongation on 10 inches	*per cent*	3·0	3·0
Minimum number of turns in 10 inches		6	6
Maximum resistance at 60 F (15·6 C)	ohm/1,000 *yd*	0·198	0·228
at 68 F (20 C)	ohm/1,000 *yd*	0·201	0·231
Weight (approximately) per foot	*lb*	0·482	0·485
per 1,000 yd	*lb*	1445	1454
per mile	*lb*	2544	2559

Basic Data

		Copper (hard-drawn)	*Cadmium-copper*
Modulus of elasticity	*lb/sq inch*	18×10^6	18×10^6
Coefficient of linear expansion between 32°F and 86°F (0°C and 30 C) per °F		$9{\cdot}222 \times 10^{-6}$	$9{\cdot}222 \times 10^{-6}$
Density at 60°F (15·6°C) gm/cc		8·89	8·945
Conductivity	*per cent*	97·3	84 (minimum)
Resistivity at 60°F (15·6°C)			
lb/mile-ohm		886·4	1024
ohm/sq inch/1,000 yd		0·02468	0·02876
Resistance temperature coefficient (constant mass)			
at 60°F (15·6°C) per °F		0·00212	0·00169
at 20°C per °C		0·00381	0·00300

Copper which has a resistivity at 20°C *of* $\frac{1}{58}$=0·017241 *ohm/mm²/m is said to have a conductivity of* 100 *per cent*

Since the first section insulator on the main line was required on the edge of the museum's leased land, and the team had begun by using the smallest lot of wire, a cut was allowed for in the appropriate place, which left some 200m of wire on the drum. The wire was not yet cut however. The tower wagon approached to within one pole length of the insulator position and stopped while the museum tractor was connected to the wire. (As the wagon had passed, the trolleywire had hung down in large loops behind it, so a lot of tension needed to be taken up). The wagon was now pushed up to the section pole and chocked in position. The tractor took up the tension slowly until the wire was hanging in loops with perhaps 1 metre sag between poles. A tensioning wire was run

from the next support pole back to the wagon position and clamped tightly to the copper with "U" clamps. The tractor was released and the wire leading to the drum slackened and held with a rope while being cut. As mentioned previously it pays to wear eye protection when making cuts just in case the steadying provisions fail and the wire whips.

Finally a second tensioning wire, with double insulation, was attached to the temporary strainer pole and the chain hoist used to draw the overhead to its correct tension. Our spans are of approximately 90 feet, and we allowed a sag of some 9", which is sufficient to permit cars to pass below the wire without a very obvious lifting of the wire at mid-span.

The tower wagon was now run back to the start of the wire and pushed along steadily with one man aloft watching the wire to make sure that no twists had occurred. Any twists were turned out of the wire before attaching the support ear, so that at the end of the run a twist-free overhead with ears permanently attached was at hand. Two bays of pull-offs were attached where the wire rounded a gentle curve, and our first long power run was possible. Accordingly, once the earth clamps and other superfluous fittings had been removed, the power was connected and car No. 1 made a number of trips to pole 11 and back.

The most tedious part of the process had been the unreeling from the cable drum, so a workshops dolly was modified to act as a cable car. A stout iron frame was bolted on and a 2" waterpipe axle fitted. The axle could be lifted out, pushed through the cable drum and the drum in use mounted on the frame.

It was a simple matter to attach the end of the wire to the previous overhead end and trundle the cable car off down the track, leaving a trail of wire behind. Our copper wire was eventually put up on five working sessions; viz. museum fan - pole 11, pole 11 - pole 17 (end of first cable drum), pole 17 - pole 35 (loop), pole 35 - pole 41 (end of second cable drum, and including two sharp curves), pole 41 to pole 57 (terminus) including a long curve, and finally the 'D' of the loop, which required the installation of two frogs.

The terminus was tensioned against only one pole initially but we have subsequently had an extra pole put in and tied the wire off to a V-support with turnbuckles. Another improvement has been the rehanging of the sharpest curve on the system, which also required the erection of two poles.

One source of concern to us had been the relatively low height of the overhead across roadways. This was due mainly to the fact that the Electricity Trust, when removing steel poles, simply held them with a crane and cut them off at ground level, thus leaving poles of about 26' length instead of the usual 31'. Since we had imbedded them to a depth of about 6', the maximum overhead height attainable with span wires was only about 17'6". We therefore recreated some 31' poles by using offcuts from bent or rusted poles in our store. These pieces were inserted into the bases of the 26' poles and welded on. With the addition of raisers to three of the existing poles, we have been able to achieve an overhead height of 21' at the road crossing, and this allows sufficient clearance for yacht masts and other over-height loads.

Telephone Line

Another overhead item which we intend to install shortly is a telephone line. This will allow the tram crews to contact the despatcher more satisfactorily than they can with the present set up of using two-way radios, especially with the impending legalization of competing C.B. radios. We have an abundance of "U" brackets, insulator spikes, cross arms and insulators and the steel poles are very easily able to be fitted with them. It would also be possible to provide a feeder wire if necessary, but we have no plans for this at the moment. Since the capacity of our power unit is small, a feeder wire is superfluous and, in any case, the low capacity of the sub station prevents high speed running with its consequent effects of track and vehicle strain and associated dangers.

Routine Maintenance

Maintenance of the overhead is carried out as required. Firstly, by having a "hard ticket" policy on appointing motormen, it is possible to have all regular tram drivers aware of what constitutes wire defects, and these are reported to despatchers or repair staff when they occur. One of the desirable habits to develop in motormen is the looking ahead at both track and overhead so that defects have a better chance of being seen and avoided.

In addition to this reporting system, which takes the place of weekly routine inspections from the ground, a 6 monthly check of the entire system, including car sheds, feeders, fan and main line wires is made using the tower wagon and tractor.

The main work which has been required so far is the tightening of plate screws on ears, the varnishing of fibre components on section insulators and the cleaning of hangers. In addition the zinc painted steel pull offs have needed recoating. Because of the piecemeal construction of the pull offs, it was not possible to have them zinc plated at the time of manufacture. Other museums who use such fittings and can make them in advance of requirements could well consider the worth of having them galvanized or zinc plated.

On the depot fan section, we have kept a careful watch on the stranded wire and the fouling ears. As yet no significant corrosion has occurred, though the running side of the wire has been worn down to some extent, probably by the severe arcing which occurs.

Wear on the non-fouling ears has been unnoticeable so far, and no significant thinning of the wire beneath such fittings has occurred, though the STA has experienced problems with this on the Glenelg tramway.

Vandalism has been minimal - three loop insulators have been smashed - probably by rocks. Fortunately all of these insulators were on the one pole and were replaced as part of rehanging of the Mangrove Street curve.

Reference works

Manufacturers catalogues, electrical engineers' handbooks from the period 1900-1930 and tramway construction texts from this period provide useful additional information.

Lightning Protection

Some form of lightning protection should be provided on the overhead and feeder system (Figure 19). Solid state power supplies usually have a protection system incorporated in the rectifier, but we have provided further protection in the form of a tramway-type choke coil and spark gap. This is connected in the feeder line from the sub-station, the equipment being located within the station itself. The coil is wound in a heavy (19/064) double insulated cable on a wooden former, and a GE spark gap from a tramcar is connected on the overhead side of the coil, the earth side being run to a number of earth stakes.

We intend to install further spark gaps along the line, possibly with choke coils at section insulators.

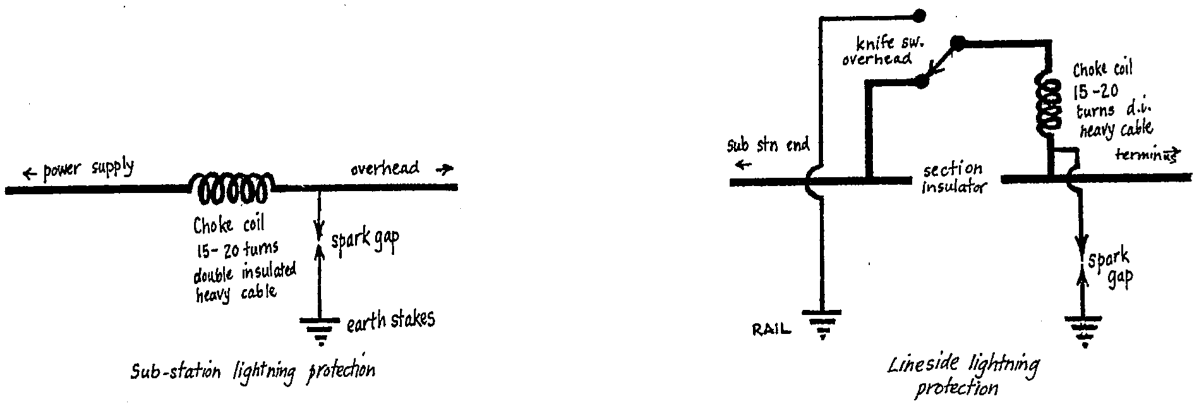


Figure 19. - Lightning protection ciruits

Safety belt use

Safety must be the keynote of any overhead construction, and the greatest safety aid is to learn the correct use of the safety belt (Figure 20).

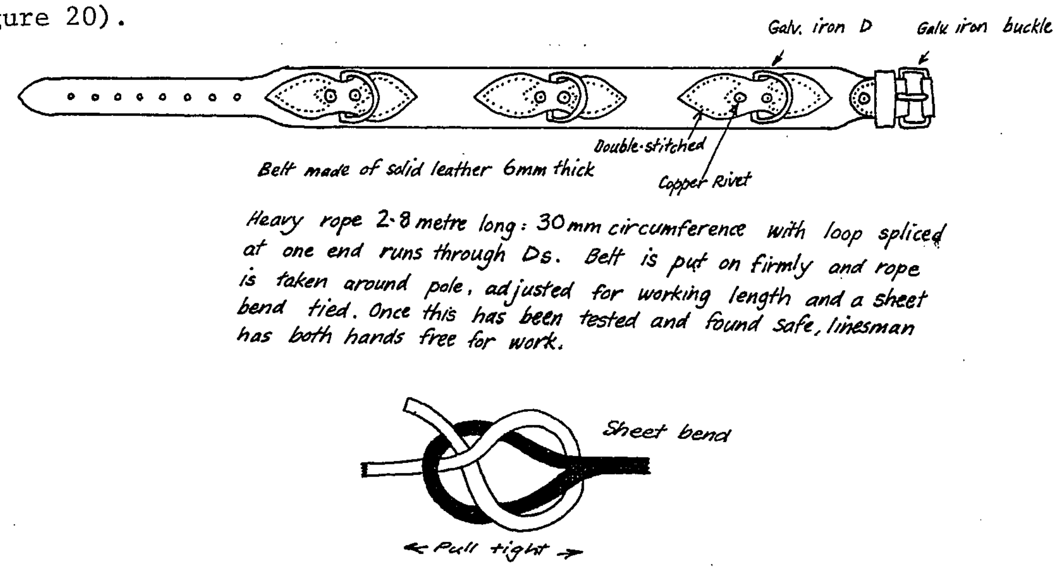


Figure 20 - Correct use of safety belt

Conclusion

Not only must the overhead be structurally and electrically sound in design and construction, but it is desirable that as much effort as possible be put into achieving a tidy and aesthetically pleasing job as the overhead is always visible whether the tramway is operating or not.