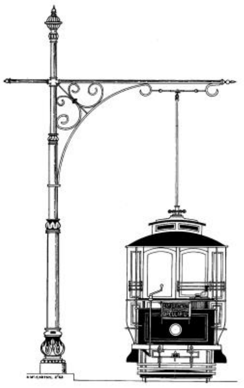


SYDNEY TRAMWAY MUSEUM

TRAMWAY OVERHEAD MANUAL

~~MARCH~~ JULY 2010

SYDNEY TRAMWAY MUSEUM

Document Control Record

1. Document Details:

Name: Tramway Overhead Manual

Number STM 6025

Version Number: 1.4~~3~~

Document Status: [ ] Working Draft

[X] Approved for Issue

[ ] Archived

Next Scheduled Review Date: ....

2. Version History:

Version Number	Date	Reason/Comments
1.0	20/01/2007	Initial issue
1.1	16/07/2007	Improve the quality of some of the drawings.
1.2	20/08/2008	Changed form STM6109 format & removed STM6108
1.3	31/05/2010	Changes made to satisfy the 2009 ITSRR audit.
1.4	31/07/2010	Minor changes to document names

Approved by .... **Signature & Date** ....

3. Distribution List

Position	Date	Copy Issued (Yes/No)	Copy No.	Received
Rail Safety Manager	31/07/2010	Y	1	

1. Purpose

To explain the various tramway overhead traction wire standards at STM. Also the purpose of this document is to set down, in printed form, a history of the construction, operation and maintenance of the STM for the benefit of future generations called upon to further the aims of the society.

2. Scope

This standard applies to the design, construction and maintenance of all tramway overhead traction wire installed by the Sydney Tramway Museum.

3. Responsibilities

The Infrastructure staff at STM must follow these processes in this manual.

4. References

This document is an update of the work done by W.M. Denham in 1994 whose work is noted with grateful appreciation.

Also grateful assistance was given by Richard Clark, Chief Engineer for the Sydney Tramway Museum in confirming the engineering details given, by David Rawlings, Overhead Supervisor for the museum in confirming the construction methods given.

STM6029 - Tramway Overhead Inspection Procedure

STM6086 - Tramway Overhead Inspection Schedule

STM6107 ~~–~~ – Overhead Pole Inspection Report

STM6108 – Tramway Overhead ~~Trolley Wire~~ Inspection Check Lists

STM6109 - Tramway Overhead ~~Trolley Wire~~ Inspection/Maintenance Report

5. Definitions

STM	Sydney Tramway Museum: the trading name of South Pacific Electric Railway Co-Operative Society Limited for tram activities, therefore references to STM.
SPER	South Pacific Electric Railway Co-Operative Society Limited
INS	*Inches*
Kg/m	*Kilograms per metre*
Km/h	*Kilo meters per hour*
Lbs	*Pounds (weight)*
Lb/yd	*Pounds per yard*
M	*Metres*
Mm	*Millimetres*
NSWGT	*New South Wales Government Tramways*

6. Table of Contents

7. Preface

One purpose of this manual is to set down, in printed form, a history of the construction, operation and maintenance of the Sydney Tramway Museum for the benefit of future generations called upon to further the aims of the Society.

While the Manual discusses the methods of design, construction and maintenance of tramway track in some detail, the information given should only be regarded as a basis for practical demonstration, observation and experience.

The Manual is based upon archival data located in the State Government Archives and those of the SPER related to the former New South Wales Government Railways (NSWGR) and the New South Wales Government Tramways (NSWGT) and observation and interpretation of the thousands of photographs of the New South Wales and other tramway systems available to SPER. It is supplemented with data from other sources, particularly of the other former and existing Tramways systems from which tramcar exhibits and spare parts for trams and track have been obtained.

Technical information has also been gleaned from: -

Electric Traction by A.T. Dover;

Electric Railway Handbook by Albert S. Richey;

Catalogues of The Ohio Brass Company, Mansfield, Ohio.

Various issues of Street Railway Journal and ***Electric Railway Journal*** in the Society's archives;

and from observations made during the demolition of in-situ railway and tramway track work for use in the museum tramway.

8. Introduction

8.1 Historical Background

Since 1888 the most successful means of supplying electric power to tramcars has been through the use of bare overhead conductor. The power is transferred to the tramcar by an underrunning rotating trolley wheel, by a sliding shoe or by the sliding pan of a bow collector or pantograph.

In this system, the power circuit is completed via the tramcar wiring, the wheels and the rails.

From the early 1900s, in New South Wales, much of the design for the overhead wiring was based on tables and details included in the catalogues of the component suppliers, initially from USA or England. Although half a world away, the effects of the pronouncements of the British Board of Trade also had some bearing on the early design.

Large stocks of fittings were initially obtained from these overseas firms but after a time locally manufactured replicas were added to the stocks of materials.

Many “rule of thumb” methods existed, for after the initial overhead works has been constructed, it appears that the overhead erection and repair crew usually continued in the manner established. Some over design existed, probably based on economics. Also, by standardising wherever possible the chance of the wrong material being used was significantly reduced.

It would appear that very little change took place in overhead construction practice on the New South Wales Government Tramways (NSWGT) after 1920 and the training of new overhead crew members may have been carried out mainly on the job.

When the Sydney Tramway Museum initially considered the construction of tramway overhead for its first demonstration tramway in the mid 1960s, a then recently retired linesman from the NSWGT explained the purpose and use of each type of fitting and how to form a wire tie. He finished the discussion with the advice that “you’ll probably do as we did – put up the wire to your best ability, try it and if dewirements happen, adjust the position of the trolley wire and fittings until it all works”!

The design of tramway overhead can be developed in a much more scientific way but the many variables which occur in construction usually result in fine tuning in a manner closely allied to the linesman’s sentiments. Even text books on tramway overhead can usually be found to express the same idea, mostly couched in terms which make it appear as a technically sound argument.

8.2 Minimum Standards

Any minimum standards for the construction and maintenance of a tramway overhead wiring network outlined herein shall apply to the whole of the tramway of the South Pacific Electric Railway Co-Operative Society Limited but shall not be taken to restrict the Society to such minimum standards nor shall the adoption by the Society of higher standards for any section of the tramway be taken to imply an offer by the Society to bring any or all of the remaining overhead network up to such higher standard.

8.3 Current Collector

In Australia, most early electric tramways used trolley pole method of current collection. The trolley pole was fitted with a fixed axis wheel and mounted in a base which had a vertical pivot to allow the pole to swing as it tracked along the overhead wire and, initially, to allow the trolley pole to be rotated through 180º at termini.

The sole exception was the Hobart system (1893-1960) which used a simplified bow collector during its entire existence.

In 1920, sliding shoe collectors to replace trolley wheels were placed on trial in Sydney but were not adopted due to the extensive mileage of round wire in use on the system supported in fouling ears. Although the sliding shoe worked with moderate success through fouling ears when new, destruction of the replaceable insert was unacceptably accelerated as the insert began to wear out. A cost comparison at the time showed that the rotating wheel then in use was a more economical solution. Regular use of collector shoes did not take place in Sydney until 1937 when they were fitted to the Kogarah electric trolley buses.

Bow collectors saw limited use in Melbourne in 1924 and 1927 and then from 1931 to 1938. In the meantime trolley shoes had been in limited use in trials from 1930 to 1940. The whole system was changed over to trolley shoe operation from 1956, and it was not until after 1976 that widespread use of pantograph type collectors was introduced with a new generation of tramcars.

When trolley buses were introduced into Australia it was desirable to fit such vehicles with swivel head current collectors to allow the buses to be able to tour through traffic and therefore to operate away from the centre line of the wiring.

Sydney Wylde Street system (1937-1948) used trolley wheels, the buses on the larger Kogarah system (1937-1959) were fitted with sliding shoes in swivel brackets. The use of swivel trolley heads allowed greater latitude in the location of the trolley wire but also necessitated the use of overhead frogs to divert the collector along the correct wire at junctions.

9. Design

9.1 Generally

The main purpose of the designer and the constructor of tramway overhead is to produce a trolley wire support network which is mechanically sound and one which provides electrical insulation integrity. Of equal importance is the production of a tramway overhead network that is aesthetically pleasing.

Tramways which run a uniform fleet of cars usually have a little trouble in constructing a working overhead wiring system. Tramway museums, on the other hand, can generally expect to have a mixed fleet in which the types and locations of current collectors can vary widely and it may not be desirable or possible, to alter these to a uniform standard.

In such cases, the overhead wiring should be adjusted to conform to the greatest number possible of regular service passenger vehicles. For the remainder of the fleet the only recourse may be the imposition of much reduced operating speeds and an acceptance of dewirements at known locations.

9.2 Design Factors

Before any overhead work is undertaken, it is desirable that a scale drawing of the track and structure layout be available to a workable scale. On this, the approximate layout of the overhead wire and poles can be plotted to allow a preliminary assessment of the materials required.

More often than not, however, the tram track is laid before design of the overhead is considered and the temptation is often present to simply plant poles at visually attractive locations. This will generally lead to extra work as additional poles are required or existing poles have to be relocated or greater quantities of span wire and fittings are needed.

Where the tramway is laid as single track in private right-of-way or along the side of a roadway then bracket construction may be used to support the overhead wire. Suitable poles are planted clear of the track and fitted with side arm brackets.

Where the tramway is laid as double track in private right-of-way then the track centres may be widened and single centre support poles erected between the tracks to support the overhead wire. Side arm brackets are fitted in pairs, one each side of the pole.

Where the required siting of the overhead pole is some distance from the track and the length of the side arm bracket might be considered excessive, or where double track is laid in the middle of a roadway or where motor vehicles might require manoeuvring, the use of side arm bracket suspension may not be desirable. In these cases it becomes necessary to change to span wire construction.

In this latter case, and on straight track, pairs of poles are planted opposite each other, one each side of the line. A span wire of steel strand or other approved material is stretched from pole to pole and supports the overhead wire at the required height. The weight of the wires will cause the span wire to sag. The sag must be taken into account when calculating the height of the wire connection to the poles.

On curves, additional poles may be required on the outside of the curve to enable pull-over span wires to be installed.

Where the tramway passes substantial buildings adjacent to the line the span wire may be fixed to the side of the building into a structural termination on the wall.

Wherever possible, poles in pairs should be located an equal distances from the outer rail each side of the tramway. This will produce an even sag in the span wire.

9.3 Type of Collector

The matter of whether a trolley pole overhead or a pantograph overhead is needed or whether a universal type is necessary must be seriously considered. The construction of an overhead network compatible to all current collectors will tax the ingenuity of the overhead designer since they are not closely compatible.

The path of the trolley head on a curve will be varied by any or all of the following functions:

(a) the location of the trolley base with respect to the tramcar length and effective wheel centres;

(b) the mounting height of the trolley base above the rails;

(c) the length of the trolley pole;

(d) the height of the trolley wire above the rails; and

(e) the superelevation, if any, of the rails on the curve.

Other factors which might enter into the special requirements of the overhead design concern the matter of the physical aspects of the wire type to be used and whether any special local requirements exist regarding the minimum legal height for the trolley wire.

It would be a useful exercise for the overhead wiring designer to endeavour to establish the tracking line of the trolley pole, by experiment or by drawing, of the various tramcar types in the fleet. The location of the wire will be required to be a compromise of these paths.

9.4 Location of Wire

The trolley wire is held above the tramway along the tracking line of the collector. Trolley pole collectors are considered in detail but additional notes will be found at the end of this document to cover pantograph collectors and networks suitable for mixed types of collector.

On straight track the path of the collector wheel or shoe will be above the centre line of the track, but on curves it will be found that as the radius of the curve decreases, the tracking line of a trolley wheel or shoe will move over towards the centre of the curve. On very sharp curves the trolley wire may be inside the line of the inner rail. Various tables can be found to direct the placement of the wire on curves but two factors will always override the most detailed formulae.

The wire must be restrained around the curve in a series of straight segments approximating the tracking line of the collector and this line may vary noticeably between different types of tram. The position of the wire can therefore only be roughly calculated and the installation will almost certainly be subject to adjustment after proper trial tram operations have been conducted.

For this reason, it is a quite acceptable practice, even occasionally a necessary requirement, to erect the trolley wire with temporary ties. On straight track the temporary ties should be at the outer ends of the span wire. On curves, it will be necessary to introduce more temporary ties and often within the length of span wires and pull-offs.

While temporary ties are approved, they must be made permanent as soon as possible to prevent the wire from going out of adjustment and to prevent the ties from failing completely and possibly dropping a live trolley wire to a dangerous level.

9.5 Supporting Structures

Supporting structures are the devices which sustain the supporting system; and may be poles, whether wood, steel or concrete; towers, buildings, or any other form of support, together with their anchors, guys, braces and similar reinforcing attachments. The type of supporting structures used will be governed largely by local conditions.

In general, natural wood (or concrete) poles are used for all suburban construction and wherever else practicable. Steel poles may be used in streets if so desired; sawed poles and tree attachments should not be employed, and building attachments should be used only when local authorities or conditions compel such use, in which case special precautions and construction may be necessary.

9.6 Wiring Network

The trolley wire (contact wire) is suspended from the support structures by a network of simple span wires on straight track and a complex arrangement of diagonal pull-off or pull-over wires. The type of network will generally depend on the actual track layout and the type of wiring fittings available to be used.

Straight line hangers are used for supporting the trolley wire above straight lengths of track where the whole load on the hanger is vertical.

When the track begins to curve it is sometimes possible to use straight line hangers at reduced spacings for the curves down to about 100m radius. Below this, the lateral strain imposed by the curve pull-offs begins to increase significantly and the hanger is caused to tilt until the wire connection and the trolley wire are in the same horizontal line. The trolley wire ear is thus forced to overturn until it may be in a position where it can be struck by passing collectors.

On sharper radius curves bow hangers and half bow hangers are used. These have a body which loops over the top of the trolley wire and wire clamp (ear). The hanger body is provided with fixing lugs which are in line with the trolley wire and thus restrain the fitting and the ear from overturning,

9.7 Insulators

The use of a metallic tendon (usually stranded steel wire) for the span wires and pull-offs introduces the need for insulators and other fittings to be cut into the san wire. For appearance, the section of the span wire between the trolley wire fitting and the first insulator beyond the trolley wire should be of uniform length. These parts may then be constructed on a work bench at a suitable working height and at spare moments.

Standardisation of components will assist in this matter. Although construction may take longer to achieve, the results are well worthwhile as standardisation will also generally make replacement of damaged sections somewhat easier.

9.8 Span Wire Fabrication

For timber pole construction, sections of span wire of various lengths may then be prepared and connected to the centre portions. These will then be temporarily tied to the eye bolts in the poles until the overhead is fully aligned.

For curves, bow hangers may be tied to short lengths of wire with a connector ring at the other end. From the ring, a standard length of wire may then be spliced, terminating in an insulator. These may all be pre-finished on the work bench. On site, it will only be necessary to form the bridle wires and the final span section to the pole.

9.9 Hangers

Hangers are the assemblies used to connect the trolley wire with the span wire. There are two different types*:* *Insulated* and *Non-insulated*. Hangers in use on the museum tramway are mainly surplus items salvaged from tramway and electrical railway systems. They come from a variety of sources but may be summarised as Sydney Type, Brisbane type and Melbourne type.

Sydney type hangers are generally to be used on all recreations of the historic tramway scene. Due to the limited quantity of these types in stock, the Brisbane type will be used on other sections of the museum demonstration tramway with more modern (mostly Melbourne type) to be used on tourist tramway section.

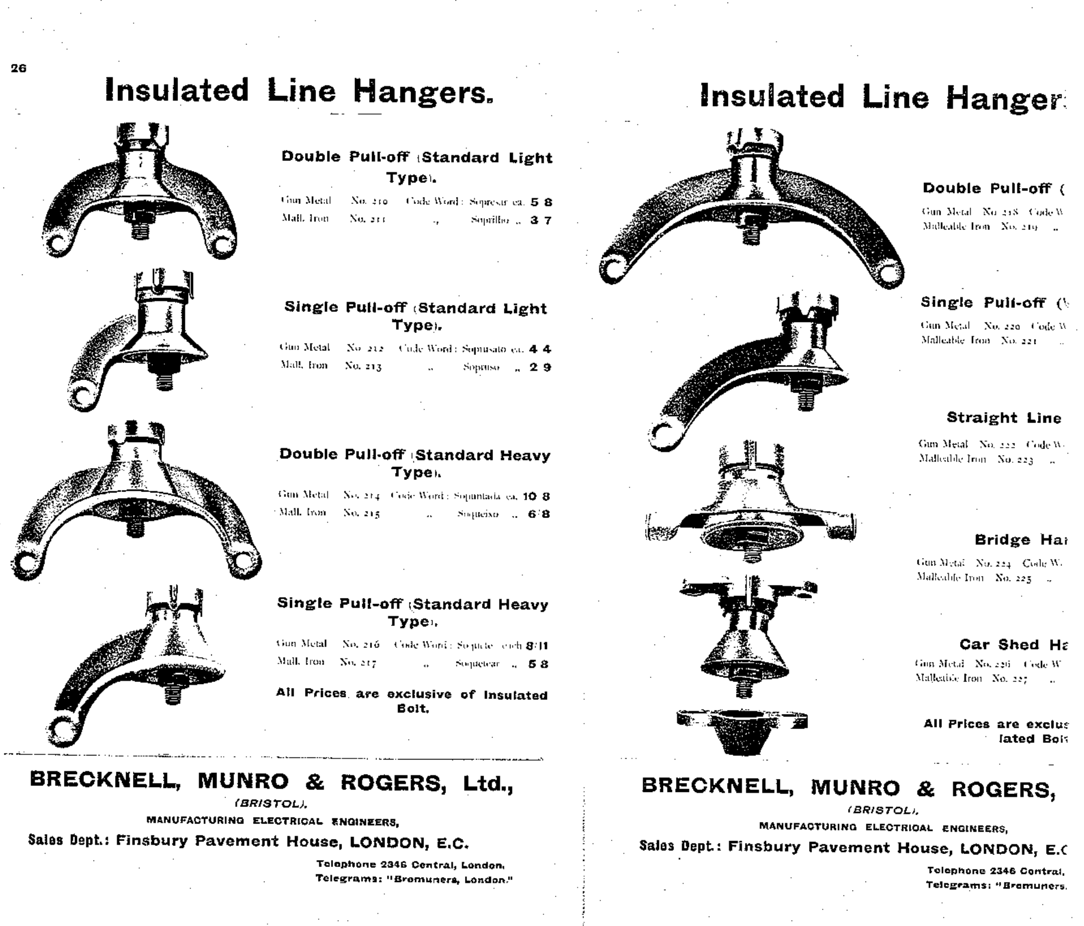
The Sydney and Brisbane hangers are generally grouped into two major types:

a) Straight line hangers;

b) Trough hangers;
c) Full bow hangers
d) Half bow hangers; and
e) Miscellaneous fittings.

The Melbourne hangers are of the non-insulating type and generally grouped as:

a) Old pattern; and
b) New pattern.



9.10 Sydney Hangers

9.10.1 Straight Line Hangers

These consist of three main components - the body, cap and insulator.

The cast body is formed with two lugs which hook around the span wire. They may be installed or removed after the tension of the span wire has been eased. A screw cap is fitted to the top to hold an insulator in place.

The insulator is moulded of insulating material around a steel or brass stud which is threaded to fit the trolley wire ear. It is dropped into the hanger from the top and screwed into the ear. The cap is then secured on the hanger. Leather or fibre disks may be required under the cap to hold the cone rigid. A clip may be attached to the hanger body to engage in a serrated edge to the cap and prevent it unwinding.

9.10.2 Trough Hangers

They are bolted to the underside of the timber trough in car sheds or under low structures, the cone being held in place by the trough into which circular poles are drilled to take the place of the caps normally installed.

9.10.3 Full Bow Hangers

These have a body similar to the straight hangers but have curved arms on each side with holes to take span wire splices. The holes are located so that the line of force in the wire is effectively carried through the centre of the trolley wire. This reduces the tendency for the hanger to tilt when the trolley wire is subjected to significant side force, such as on a curve.

A cap and insulator are installed in the same manner as for a straight line hanger.

9.10.4 Half Bow Hangers

These are similar to the full bow hanger but have only one curved arm. They are used to restrain the inner wire on a multi track curve when the span wire does not carry through.

9.10.5 Miscellaneous Hangers

Pressed metal bow and half bow hangers without insulation were used for a time in Sydney and may be used on the tramway provided that an approved insulator is inserted between the fitting and the span wire at each attachment.

Double hangers may be used when twin wires are to be supported, usually when individual wires are provided for each direction of travel over single track. Two standard hangers mounted side-by-side will usually be adequate to provide such support.

9.11 Brisbane Hangers

These complemented the Sydney type in range of style but were of somewhat different construction. The straight line, bow and half bow hanger bodies attach to the span wire in a like manner but the cap and cone are cast integrally with the cap. It is inserted from the top through a shaped insulation spacer which is held between the fitting and the top of the wire ear.

The cone is installed with the aid of a lever to which is fitted a friction clamp.

9.12 Melbourne Hangers

9.12.1 Old Type

Straight line hangers clip onto the span wire. They are provided with a central hole through which a stud passes to attach the wire ear. Curve hangers have a stepped, slotted arm one side through which the span wire passes to tilt the fitting to compensate for the tilting effect of the ear on a curve. Insulators must be inserted in the span wire each side of each fitting to provide for the level of protection afforded by the self insulating type.

9.12.2 New Type

These consist of a galvanised steel bar formed into a specific shape and drilled for wire clamps and the fixing bolt into the wire ear. The horizontal face is fixed to the underside of the span wire with a small U-bolt. The vertical face is fixed to the side of the span wire and has a number of holes to allow the fitting to be adjusted as required to keep the wire ear upright.

The fitting was primarily intended to be used on synthetic polyester tendon which is self insulating. When used with steel span wire, insulators must be inserted in the wire each side of each fitting.

9.13 Poles

9.13.1 Pole Spacing

It has been customary for many years to install span poles on straight track at 36m (120’ 0”) maximum centres. For curved track and a special work the pole spacings will generally be reduced but each curve will warrant separate investigation.

On curves, the poles will be located to allow the greater number of pull off wires to be between 90º and 60º to the trolley wire. Where the pull off wire forms an angle of less than 60º to the trolley wire then additional diagonal pull off wires and bridle wires must be introduced into the support network and it may be necessary to provide somewhat heavier poles to support the wires at these locations.

Overleaf is a scale (1:100) diagram of a 15.24m (50’ 0”) radius curve with the minimum wiring shown thereon. Poles A, B and C are placed as far from the nearest rail as possible, consistent with the available space adjacent to the tramway. The poles D, E and F should be placed as close as possible to the nearest rail consistent with required clearances.

When the distances A-B and B-C become too long then additional poles B1 and E1 are necessary to reduce this spacing.

Poles A and D, C and F are ideally to be located at the point at which the trolley wire commences to offset on the curve.

The point “G” is the design centre for the radius of the curve. From a practical point of view, the path of the wire on the curve may be taken as an arc of larger radius than the track. The distance “g-h” is the curve offset referred to in the tables.

The curve in the track, although for tramway design purposes a simple curve between two straight lines, will, during construction, most likely take up a hyperbolic shape, sharper at the centre and flatter at the ends. This will give the approximate effect of a transition curve.

For this reason, the diagonal pull-off and span wiring network shown will require temporary ties to enable the trolley wire to be accurately located after tramcars have run trial trips around the curve.

The span wires A-D, B-E and C-F (and B1-E1, if required) are included with two important functions. The weight of the trolley wire requires to be supported even if high tension is established. The inclusion of the span wires will also assist in preventing excessive damage if the wiring on the curve becomes disarranged, usually due to the current collector leaving the overhead wire.

With a sharp curve of this type, it is also important to provide tensioning wires from A and D, and C and F back to the next fitting along the straight. This will reduce the damage caused to other parts of the network in the event of major damage being caused to the wiring on the curve.

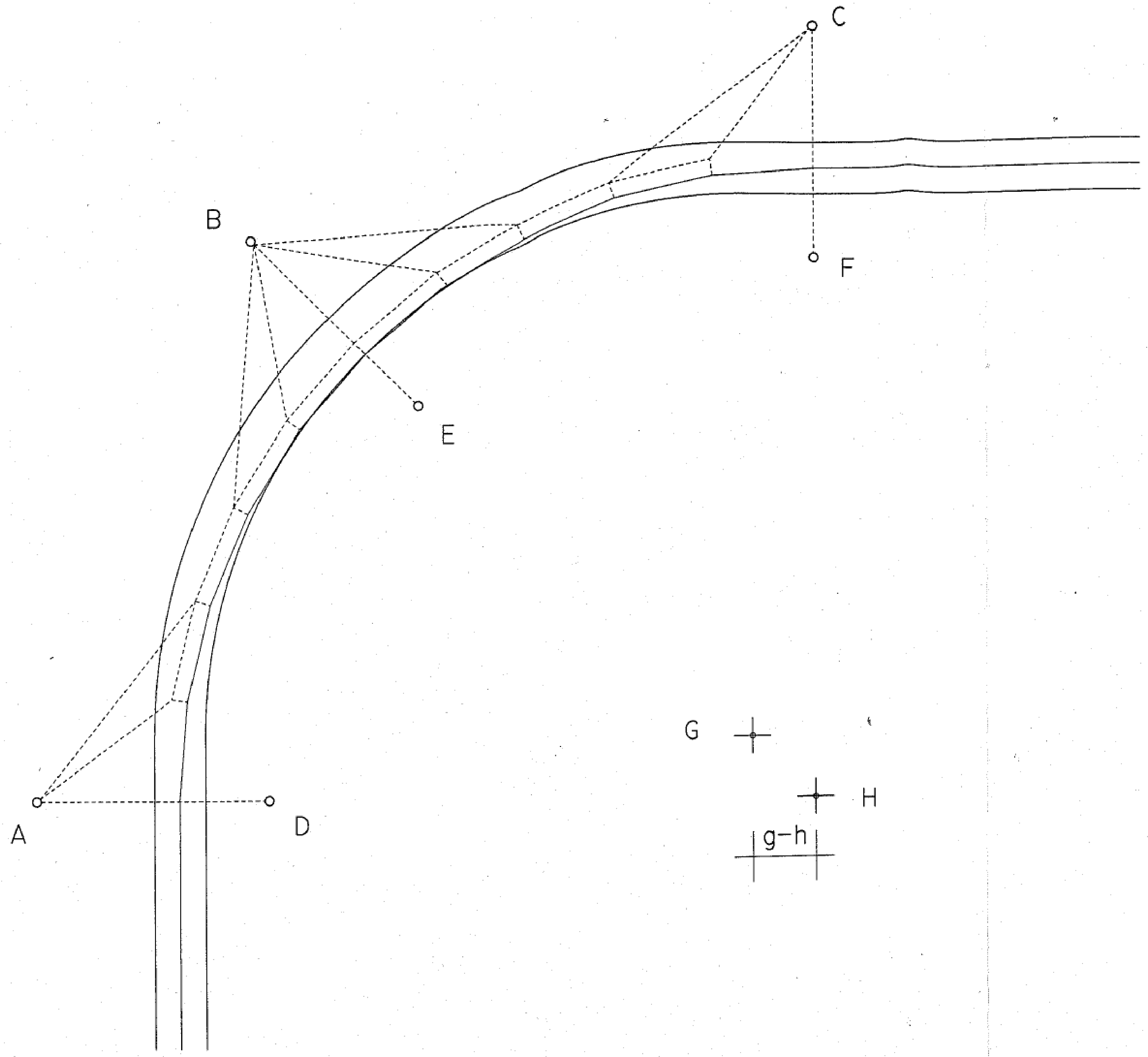
9.13.2 Pole Clearance

On private right of way and elsewhere when practicable, side supports should be set with a minimum clear distance of 2.3m (7’6”) from the centre line of the track to the face of the support at the level of the top of the rail, and centre supports should have a minimum clearance of 2.15m (7’0”) from the centre of the track, this clearance to be increased if necessary on curves to allow for rail superelevation and the tramcar overhang.

Where kerb lines are established, poles should be set just behind the kerb itself unless local ordinances or conditions prescribe another location.

9.13.3 Pole Types

In most situations, timber poles will be used to support the overhead network. These are to be of hardwood, of dimension and quality indicated under “Construction”. Ornamented and plain tapered steel poles may also be required for street scenes. These are usually reclaimed from former tramway usage.


C
B
F
E
G
H
g–h
A
D

In areas with a known history of white ant activity, it may be necessary to use steel, concrete or composite steel/concrete poles. Steel and steel reinforced concrete poles will have to be given extra consideration with respect to the provision of additional insulators in the san wire.

9.13.4 Length of Poles

The length of the pole will vary as the result of a number of factors. These are listed below and shown on the sketch.

A = total length of pole, which is made up of:

B = depth of pole to be buried *

C = height of rail level above ground.

D = height of trolley wire above rail level.

E = mounting height of side arm bracket above trolley wire.

F = height of stay wire eye bolt above side arm bracket.

G = height of eye bolt below top of pole (allow 300mm for typical calculations).

The dimension "F" will depend on:

H = distance from centre line of pole to centre line of track/trolley wire.

J = distance from trolley wire to end bracket mounting (allow 400mm minimum)

*For general calculations the depth of the pole in the ground should be assumed to be 1500mm in good ground, 7100mm in poor soil.

The angle of the stay wire to the side arm bracket should not be less than 30º otherwise the stress in the wire becomes excessive. If the angle is increased above 45º then the lengths of wire and of pole are increased without real value.

For span wire construction, the angle of the span wire from the hanger to the pole should be assumed to be 15º to the horizontal for calculating the combined value E+F. In most cases, the span wire can be satisfactorily tensioned to achieve this angle after the trolley wire has been installed.

9.14 Height of Overhead Trolley Wire

The NSWGT required a trolley wire in the 5.182m to 6.096m (17' 0" to 20' 0") range for normal operations but accepted 3.696m (12' 1½") under the Burwood Road railway overbridge and indicated 6.4m (21' 0") as the maximum service reach of trolley wheels. Other states seem to have established similar height ranges.

Although the SAA Wiring Code does not specifically mention 600 volt exposed tramway conductors, the Sydney Tramway Museum consulted in the early stages of its present development with officers of Sydney Electricity, from whom the Society obtains its electricity supply to convert to power the trams.

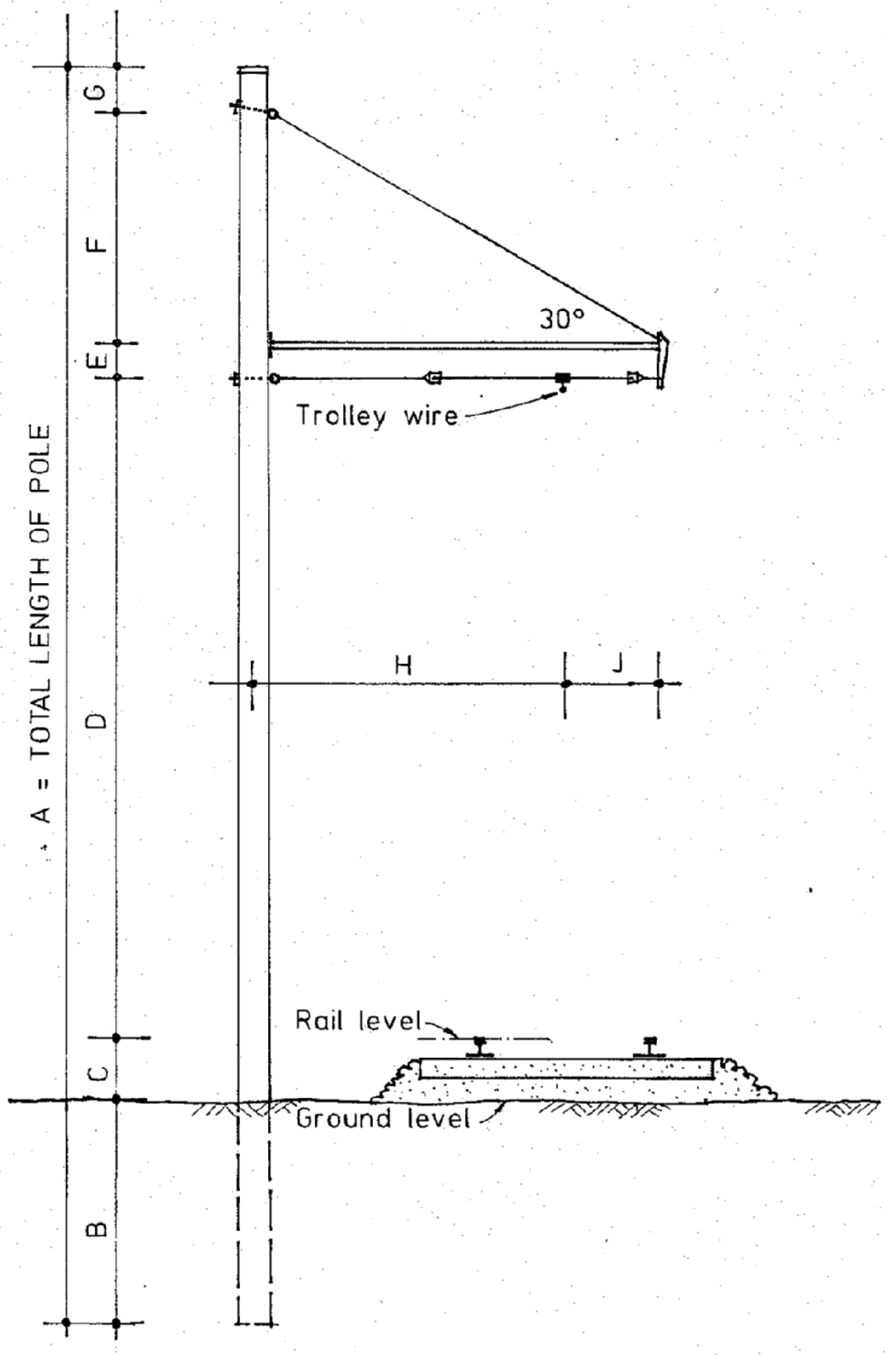
During this consultation it was suggested that, provided the structure of the overhead wiring followed the methods used by the NSWGT and the minimum height of the trolley wire above areas used by vehicles was not less that 5.5m (18' 0") nor less than 5.0m (16' 6") above any other area, then it was likely that these clearances would be considered adequate.

Therefore, the minimum height for Sydney Tramway Museum trolley wire measured art 20ºC shall be:

 5.0m (16' 6") above any area; or
 5.5m (18' 0") above any paved road along or across the tramway, whichever is the lesser.

The height shall be the vertical distance between the higher rail and the trolley wire.

Tramways to be established in other supply authority areas should consult with the authority to confirm that these dimensions are acceptable.



A = TOTAL LENGTH OF POLE
G
F
E
D
C
B
30°
Trolley wire
H
J
Rail level
Ground level

9.15 Trolley Wire - Location

As previously mentioned, the trolley wire is held in a position above the tram track, along the path taken by the current collector. On straight track this is above the centre line of the tram track but on curves the path swings over towards the inner rail of the curve.

The table below indicate suggested values for distance apart of poles around curves of various radii, the number of pull-offs per section and the approximate spacing. Other information gives suggested points to commence offsetting the overhead wire as it approaches curves.

Curves should be made up with straight line ears, attached to suitably insulated pull-over bodies (bow and half bow hangers). Support should be by span wires except where the rest of the line is carried on side arm brackets and the radius of the curve is greater than 91.5m (300’ 0”). Between supports, curves should be held to line by seven strand steel wire, with single body pull-offs (half bows) for single track or for the inside one of several tracks, and double pull-offs (full bow hangers) elsewhere. Spaced as follows:

Radius of Curve		Spacing of Pull-Offs		Number of Pull-Overs Between Supports	Distance Apart of Poles	
Feet	Metres	Feet	Metres		Feet	Metres
40	12.19	7	2.13	4	35	10.67
50	15.24	8	2.44	4	40	12.19
60	18.29	9	2.74	4	45	13.72
70	21.34	10	3.05	4	50	15.24
80	24.39	11	3.35	4	55	16.76
90	27.43	12	3.66	4	60	18.29
100	30.48	13	3.96	4	65	19.81
125	38.10	14	4.27	4	70	21.34
150	45.72	15	4.57	4	75	22.86
200	60.96	20	6.10	4	80	24.39
500	152.40	20	6.10	3	90	27.43
750	228.60	25	7.62	2	100	30.48
1000	304.80	33	10.06	2	100	30.48
1500	457.20	50	15.34	1	100	30.48
2000	609.60	50	15.34	0	100	30.48
Above 2000	609.60	100	30.48	0	100	30.48

The pull-overs in each span should have bodies and strains held radially to the curve by a lacing of seven-strand steel wire at least 4350mm (1’ 6”) away from the trolley wire, which lacing, however, may be omitted from any hanger making an angle of 60º or more with the ear to which it is attached.

With an odd number of hanger bodies the middle one should have a pull-off strand to each pole.

Intersections and complicated special work, particularly in city street recreations and depot areas, will usually require special and individual study and treatment.

9.16 Offset of Trolley Wire on Curves

Curves should be dressed with a uniform deflection at pull-overs and should offset to the inside of the centre line of the curve by an amount given by the expression:

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

Where

S = radial offset of trolley wire toward centre of curve

E = superelevation of outer rail

H = height of the trolley wire above the rail

G = track gauge

R = radius of curve

P = distance from the centre of the car to pivot of trolley base.

Q = distance from the centre of the car to the centre of the truck

L = horizontal distance from the pivot of the trolley base to point of contact between the trolley wheel and the trolley wire.

Note: all values are in terms of feet (or millimetres).

The offset should be uniformly tapered from the full value at the centre of the curve to zero offset at the outside easement point. If the track is not eased; i.e. there is no significant transition curve, start with the full offset at a distance inside the end of the curve as given below, and run to no offset at a point at an equal distance outside the end of the curve.

Radius of Curve		Start offset easement From End of the Curve	
Metres	Feet	Metres	Feet
Up to 30.48m	Up to 100’ 0”	6.09m	20’ 0”
30.48m to 152.4m	100’ 0” to 500’ 0”	12.19m	40’ 0”
152.4m to 304.8m	500’ 0” to 1,000’ 0”	18.29m	60’ 0”
Above 304.8m	Above 1,000’ 0”	30.48m	100’ 0”

When the trolley wire is supported from long runs of side arm brackets over single track it is advisable to revert to span wire construction for curves sharper than 201.17m (10 chains) radius, the first and last span wire being located at the outer tangent points of the curve. This will provide an anchoring effect for the trolley wire should it become damaged on the curve. For the same reason, a span wire should be provided every 1.0 km in side arm bracket wiring to stabilise the overhead in the event of damage.

9.17 Isolated Wiring – Disconnected Junctions

For the most part, when trolley wheels or skids are fitted to the trams, the designer will allow for frog pans at each turnout. These are, however, usually costly to replace, are subjected to considerable burning damage and create the potential for dewirements.

With intelligent thought the number of frog pans may be reduced without detriment to the normal operations. Turnout frogs should always be considered at facing locations in main lines, but in little used sidings and at other locations the frog may be dispensed with and the main wire before being terminated. Parallel wires of at least two car lengths will suffice. In these cases it only requires that the crew stop the tram briefly and transfer the pole from one wire to the other.

In any case where 95% or more of the movements through a junction are along one leg only, the mechanically isolated wiring may be considered. If the track terminates at the stem of a Y-junction, then separate wires may be continued to the end of the track to dispense with an overhead turnout. Changing wires will automatically be part of changing poles and direction. The same condition applies at any outer terminus where a length of single track carries beyond the end of the double track or the final passing loop.

When a crossover occurs part way along a double track section and most tram movements involve short shunting at that location then an isolated wire may be provided in the facing direction the tram will take through the crossover points.

10. Construction

10.1 Span Wires

These are strung between pairs of poles located outside the track and preferably in line on straight track. They may also be shorter units strung between the outer end of side arm brackets and the bracket support pole.

Insulators must be spliced into the span wire to provide, with any insulation in the trolley wire hanger, double insulation between the live trolley wire and timber poles and triple insulation in the case of steel poles.

For calculations the sag in cross span wires, from horizontal, may be taken to be 15º. Once the trolley wire is secured the tension in the span wire may usually be taken up to provide this angle of sag.

10.2 Side Arm Brackets

The Sydney Tramway Museum originally installed steel side arm brackets salvaged from the NSWGT system and refurbished by museum members.

These brackets consist of a 38mm (1½”) diameter steel pipe fitted at one end with a flange and at the other with a purpose made bracket. The flange had been forged to a curve to fit snugly against a wooden pole to which it is attached with No. 4 off 51mm x 10mm (2” x ⅜”) coach screws.

The outer end bracket is screw fixed to the pipe and has provision at the top for connecting a stay wire and at the bottom for connecting a span wire.

The stay wire is fitted with a short 10mm (⅜”) diameter eye bolt on the lower end into the outer bracket and a standard 16mm (⅝”) diameter eye bolt at the upper end to fit into a hole bored in the timber pole. An insulated span wire is fitted between the outer end of the side arm bracket and an eye bolt in the pole.

Replica vintage side arm brackets to match the above were fabricated from 50mm diameter galvanised steel tube for the new demonstration tramway.

When called upon to restore the overhead wiring to the abandoned branch railway to The Royal National Park in a form suitable for tramway operation, the museum designed a new bracket which is functional rather than historic and which permits damaged fittings to be more readily replaced.

A spriggotted shoe is provided to bolt to the timber pole at the required height. A length of 50mm galvanised steel tube is inserted in the tube and three sleeve/bracket assembles threaded onto the tube.

The first sleeve, closet to the pole, is to support one end of a short span wire. The second, located immediately above the centre line of the track, carries a diagonal wire stay. The third fitting is outboard of the stay and supports the other end of the span wire. Once the overhead wire is adjusted to proper location, the pipe can be cut off about 300mmm beyond the third fitting and a standard pipe cap installed. The various components are secured with bolts into threaded holes.

The diagonal stay is formed out of standard span wire with a 16mm diameter eye bolt into a hole bored in the pole; the lower end is close tied directly to a hole in the centre bracket with a thimble to protect the strands.

The trolley wire is clipped to a span wire formed of synthetic polyester tendon fitted between the inner and the outer brackets.

When the side arms are connected to the remaining railway steel poles, the standard railway side arm assembly, including the 1500 volt skirt insulator, is used. The hinged railway contact wire stay is replaced with a length of 50mm pipe to which a steel flange is welded. The flange on the pipe is drilled to match that on the insulator. The pipe is bolted to the side arm assembly and supported off the upper, catenary support bracket by a triple insulated diagonal wire stay.

A similar assembly would be suitable for fitting to tramway steel side or centre poles.

Tramway overhead supported off reclaimed steel poles incorporating steel aide arm brackets and short span wires poses a special hazard to overhead linesmen unless the bracket is adequately wrapped to prevent the linesmen touching both a live overhead wire and a pert of the steel support.

If this cannot be achieved then all overhead work on such poles must be carried out with the traction power switched off.

10.3 Timber Poles

10.3.1 Used Timber Poles

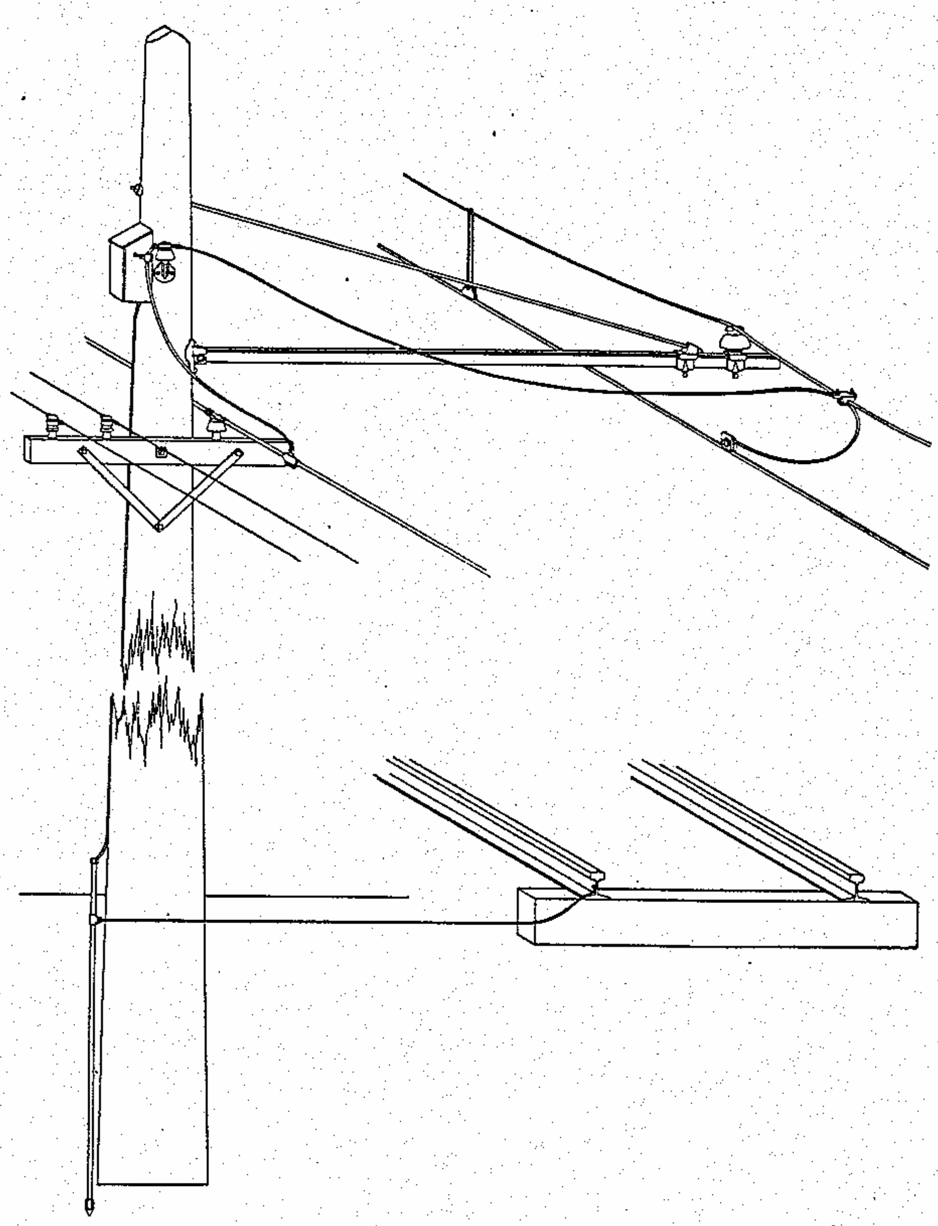
Second hand timber poles may be suitable for use along the tramway but must be closely examined for mechanical, fungal and insect damage. Poles which have a significant number of fixing holes or cross arm checks may be unsuitable for strength reasons and, occasionally, for appearance.

When a second length can be obtained from a longer pole cropped at one or both ends, it may be used.

10.3.2 New Timber Poles.

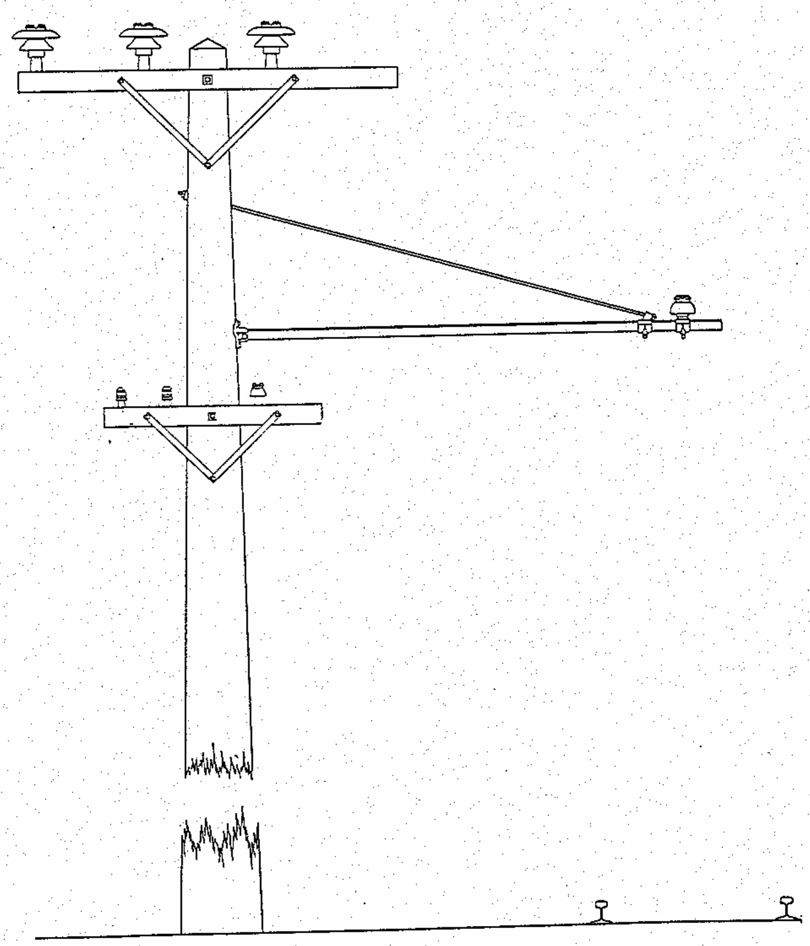
New hardwood poles may be purchased to specified lengths, diameters and grades, with or without chemical treatment. New poles should always be considered for areas exposed to general view.

CATENARY BRACKET CONSTRUCTION



Showing Lightning Arrester and Feeder Tap

CATENARY BRACKET CONSTRUCTION



Showing Typical Arrangements Including Transmission Insulators

10.4 Timber Pole Treatment

Timber poles, not otherwise pre-treated, must be treated with Creosote or other approved material for the depth of the pole to be buried and for at least 450mm above the finished ground line at the base of the pole.

Poles which have become splintered should have the loose material carefully adzed away to allow the extent of mechanical damage to be assessed and to assist in shedding rainwater.

Before any pole is planted it should have a galvanised pole cap fitted and secured with suitable size galvanised coach screws. Alternatively, the pole may be splay cut along a ridge and be fitted with a galvanised sheet steel “roof” secured with heavy duty galvanised clouts through neoprene washers.

10.5 Timber Pole Installation

When the pole is stood in the prepared hole it should stayed and set with a backward tilt of 25mm in 1200mm away from the track before the hole is refilled with excavated material in 300mm layers well rammed. The final 300mm should be sand or ash well rammed and soaked with Creosote and finished to s splay away from the pole.

10.6 Pole Setting – Depth of Holes

Pole holes in level ground should have the depths as follows:

LENGTH OF POLE		DEPTH OF HOLE			
		In Rock or Concrete		In earth	
Imperial	Metric	Imperial	Metric	Imperial	Metric
30’ 0”	9.14	5’ 0”	1.52	6’ 0”	1.83
35’ 0”	10.67	5’ 6”	1.69	6’ 0”	1.83
40’ 0”	12.19	5’ 6”	1.69	6’ 6”	1.98
45’ 0”	13.72	6’ 0”	1.83	6’ 6”	1.98
50’ 0”	15.24	6’ 6”	1.98	7’ 0”	2.13
55’ 0”	16.76	6’ 6”	1.98	7’ 6”	2.29
60’ 0”	18.29	7’ 0”	2.13	8’ 0”	2.44
65’ 0”	19.81	7’ 0”	2.13	8’ 6”	2.50
70’ 0”	21.34	7’ 0”	2.13	9’ 0”	2.74

In very compact soil pole holes may have depths intermediate between those for the same lengths in rock or concrete, and in earth.

The depth of a hole on sloping ground should be measured from the lower side of the hole; and in very steep slopes and in loose or otherwise doubtful material the depth should be increased over the standard depth by an amount to be determined for each case on the ground.

10.7 Anchors

These may be required to take the strain of a trolley wire termination or on sharp curves and complicated special work. Anchors in earth should consist of a wooden deadman 1.219m (4’0”) long, at least 152mm (6”) thick, and having a cross-section not less than 30.968m² (48 sq.in.), buried at least 1.219mm (4’0”) below the surface with not less than 610mm (2’0”) of rock, if reasonably obtainable, well packed into the hole, and the earth filling above thoroughly tampered.

The anchor should pass through the centre of the deadman, and must lie in the line of pull of the guy to prevent bending. Patent anchors of holding capacity equal to the breaking strain of the stranded wire to be used with them, and having rugged parts sufficiently large to allow a reasonable amount of corrosion with reduction in holding capacity, may be used in place of rod and deadman where conditions are favourable.

Anchors in rock should consist of an eye-bolt securely leaded or sulphured for the entire length of shank in the hole, inclined at right angles to the pull of the guy. In rock of sufficient strength to safely withstand the action, mechanical wedge type eye-bolts may be used, and the lead or sulphur omitted.

Where practicable, guys may be anchored to an adjacent pole at a point not less than 2.13m (7’0”) above the ground.

10.8 Guy Wires

Guy wires may be used where necessary on wood poles on curves of radius less than 274.32m (900’0”) on poles to which are attached strain plate guys, trolley guys and head guys; and wherever any side strain exists. They should be of galvanised seven-wire steel strand with thimble end at the anchor attachments, and two-turn wraps at proper height for attachment.

The lead or horizontal distance from the pole at ground line to a guy wire at the same level, whenever practicable, should be equal to the distance from the ground line at the pole to the guy wire wrap.

Guy wires located where there is a liability of persons or animals running into them should be made conspicuous by a piece of pipe 50mm (2") or more in diameter and 1.83m (6')") long, slipped over the guy wire, resting on the anchor rod eye and painted white. Where the guy wire is already installed, a wooden casing, 75mm (3") diameter or square and 1.83m (6'0") long, may be used in place of the pipe. The halves should be well white leaded, and should clamp the guy tightly when screwed together, the bottom resting on the anchor rod eye.

Guy hooks attached one on each side of the pole at the level of the guy wrap by 16mm (⅝") through-bolt at right angles to the line of pull should be used where local conditions compel the use of a lead less than one-fourth the distance from the ground line at the pole to the guy wrap. Where the guy wires cannot be run directly to secure attachments they may be carried high on adjoining poles to a point where anchorage can be obtained.

10.9 Steel Poles – Generally

Steel poles are usually set in concrete, brought to ground level and sprayed off away from the pole. They shall be stayed until the concrete is poured and set. A backward rake of about 25mm in 2400mm is generally sufficient for steel poles.

Where poles are fitted with ornamental bases and collars, these should be caulked to prevent water penetrating behind the fitting and shall be lifted at specified intervals for inspection and rust removal

Steel poles are usually painted and shall be repainted every five years unless badly weathered in a shorter time. Normal procedures for preparing and painting steelwork in accordance with the paint manufacturer's recommendations shall be adopted. Paint shall not be allowed to come in contact with the overhead wiring.

Final painting should be left until the pole is standing when damage to the surface caused by handling can be rectified.

10.10 Painting Poles

10.10.1 Timber Poles

Except in the region of tram stop notices, timber poles should be left untreated from 450mm above ground up to the pole caps.

10.10.2 Used Steel Poles

Reclaimed poles shall be examined for rust and other damage and shall be thoroughly cleaned and given the necessary pre-treatment for painting of exposed surfaces before being set into the ground.

10.10.3 New Steel Poles

New poles, if possible, should be heavily galvanised after fabrication, or treated as for reclaimed poles before being set into the ground.

10.11 Trolley Wire Suspension – Generally

It is customary to support the overhead trolley wire from poles planted on one or both sides of the tram track. The most common material for overhead support poles is hardwood, the tree trunk being stripped of bark and generally shaved to a round or multi-faced section. Poles are always inserted with the largest diameter (butt end) down.

In certain locations, such as recreated street scenes and areas of known severe white ant infestation, poles of steel, concrete or composite types are used. Where substantial buildings exist near to the "kerb line" of a "street" the pole may be dispensed with and the wire may be connected to the structure of the building.

10.12 Trolley Wire Clamps (EARS)

The usual method of attaching the trolley wire to the hangers is by means of a mechanical clamp, often referred to as an ear. The typical clamp is cast in two parts, the castings being joined with machine screws, there being from two to six screws per unit depending on type and length. The clamp consists of a body and clamp plate.

The clamp body has either a spigot formed in the top which is tapped for the connector thread or a threaded stud may be provided. The clamp may also have a lug cast on for the attachment of a feeder wire. The keeper is generally, in effect, the lower half of clamp body.

On straight wire the clamp body may be on either side of the wire, but on curves should always be on the inside of the curve to facilitate lifting the wire in place and restraining it there while the clamp is attached.

The screws used to join the two halves of the ears should be countersunk to avoid being struck by the passing collector and project about 5mm beyond the fitting on the opposite side. If the studs are drilled part way along their length they may be slightly expanded to prevent their working loose and allowing the wire to fall away.

Trolley wire ears should be of the non-fouling top attaching type for grooved trolley wire but fouling ears may be used for grooved wire and must be used for round wire. Grooved wire held in fouling ears may be found to twist. Although this is not a serious mechanical problem it usually creates more noise from the trolley wheel and can accelerate wear on the wheel.

Purpose made strainer and joiner ears compatible with the above shall be used as required to stabilise the trolley wire and join the wire as necessary.

16

Line Material.

Gun Metal Trolley Wire Ears (Mechanical) for Grooved Wire.

Reference Number.	Code Word.	Length.	Size of Wire.	Each. s. d.
84	Runzelig	4 in.	1/0 and 2/0	2 4½
85	Runzellos	4 in.	3/0 „ 4/0	2 4½
86	Runzeln	5 in.	1/0 „ 2/0	2 4½
87	Ruodgaud	5 in.	3/0 „ 4/0	2 4½
88	Ruodland	6 in.	1/0 „ 2/0	2 7½
89	Ruodlieb	6 in.	3/0 „ 4/0	2 10
90	Ruolo	9 in.	1/0 „ 2/0	3 0½
91	Ruolzer	9 in.	3/0 „ 4/0	3 4
92	Ruother	12 in.	1/0 „ 2/0	3 5½
93	Ruotina	12 in.	3/0 „ 4/0	3 8
94	Ruotone	15 in.	1/0 „ 2/0	4 1
95	Rupellary	15 in.	3/0 „ 4/0	4 5½
96	Rupeorum	18 in.	1/0 „ 2/0	4 5½
97	Ruperto	18 in.	3/0 „ 4/0	4 10
98	Ruperunt	20 in.	1/0 „ 2/0	5 1
99	Rupestre	20 in.	3/0 „ 4/0	5 8
100	Rupfen	24 in.	1/0 „ 2/0	6 8
101	Rupferin	24 in.	3/0 „ 4/0	7 2
102	Rupfhase	30 in.	1/0 „ 2/0	11 1
103	Rupftest	30 in.	3/0 „ 4/0	13 8

BRECKNELL, MUNRO & ROGERS, Ltd.,
(BRISTOL),
MANUFACTURING ELECTRICAL ENGINEERS,
Sales Dept.: Finsbury Pavement House, LONDON, E.C.
Telephone 2346 Central, London.
Telegrams: "Bremuners, London."

10.13 Insulators and Insulation

10.13.1 Generally

In accordance with the NSWGT design principles and electrical safety requirements, a minimum to two insulators must be provided between the live trolley wire and timber support poles, or three insulators between the trolley wire and steel poles or building structures.

Insulators are to be of porcelain or other approved material designed to provide effective insulation for a nominal 600 volts DC.

Insulation in accordance with statutory requirements may be provided by a standard insulating cone fitting within the trolley wire hanger and by other insulators along each span wire.

A 600mm length of synthetic polyester tendon (“Parafil” or similar approved material) is deemed equivalent to one insulator.

10.13.2 Strain Insulators

These are to be inserted into the span wire at required locations in such a manner that the span wires are looped through the insulator body and will remain connected even if the insulator body disintegrates for any reason. The wire ties are to be formed so that the insulator body lies along the wire axis when tension is applied to the span wire.

10.13.3 Strain Insulator and Clevis Assembly

The small diameter triple groove (“Sydney” type) insulator which will generally be used in historic recreation areas is fitted into the span wire with one extended tie to allow for easy replacement of damaged insulators. The insulator is connected into the continuation of the span wire with a galvanised clevis and pin assembly, the pin being held captive with a suitable diameter cotter pin opened out.

Large single groove insulators are installed into clamp collars around steel poles, or between straps when used in a double insulator assembly at the trolley wire terminations, the span wire being fitted with an extended tie to allow replacement.

10.13.4 Miscellaneous

Other types of fittings such as globe insulators may be used in overhead wiring provided they satisfy the requirements of electrical resistance and mechanical strength for the duty for which they are to be used. Reclaimed insulators should be carefully examined for damage which might destroy the electrical integrity of the fitting and should be carefully cleaned of all surface contamination before being installed.

10.14 Span Wires and Wire Ties – Generally

Although synthetic polyester tendon may be used in some instances in the trolley wire network, it is generally unsuited to curves and pull-offs. For these locations and in historic recreations, stranded steel span wire will be used and will necessitate wire ties of several forms.

The spans and pull-offs will generally be a 7 strand x 2mm galvanised steel wire.

In historic sections the tie should be of the wire wrap form, in other areas mechanical ties using Crosby clips or metal swages will be approved.

Span Insulation

THREE kinds of insulation are used for trolley bus overhead cross spans; wood, porcelain and composition. All of these insulations are excellent in their place, however there are some locations where certain of them are to be avoided. The span wire insulation is usually a secondary insulation, however is often subjected to full voltage between positive and negative contact wires. This may be brought about due to the failure of the hanger or due to a smoke or dirt deposit on the primary insulation.

The span insulator is subjected to deterioration from two electrical sources; namely, leakage and galvanic action. Leakage may be started through a dirt deposit or through the deterioration of the insulation. In the case of composition insulation, a leakage current soon destroys the insulator by first developing a carbon path from live section to dead section. This is similar to the break-down performance of the wood stick insulator. In the case of the porcelain insulator there is very little deterioration of the surface except where extremely heavy cur-

FIGURE 35

rents flow. Light leakage over a porcelain surface usually causes a deposit of the span wire metal on the insulator as is illustrated in Figure 35. In addition to straight leakage over insulators, there is always a possibility of galvanic action taking place where two dissimilar metals are in contact with an electrolyte, which in the case of overhead materials is usually a dilute sulphuric acid. The galvanic action is similar to the action in the ordinary wet battery, where one pole of the battery is eventually eaten away. In the case

FIGURE 36

of the span insulator, the strand is eaten away as illustrated in Figure 36.

In locations along the seacoast where salt fogs and salt sprays prevail, a coating of salt may be deposited on the insulation. In the dry state the salt is a fair insulator but under conditions of moisture it becomes a very good conductor, resulting in considerable leakage over the insulator. Wood or composition insulation will not withstand this severe leakage very long but will burn up as illustrated in Figure 37. Porcelain insulation in sufficient quantity will withstand the leakage but will not completely eliminate it. Insulation of spans in salt sections is a prob-

FIGURE 37

lem of using sufficient insulation to provide a high resistance in the leakage circuit, thus cutting down the amount of current flowing through the span.

There are many sections in the country where climatic conditions and local conditions demand the use of definite types of insulation. For instance, the Cuban district is infested with a worm which destroys the interior of the wood stick insulator. The varnished surface on the outside is not attacked by this worm. To the eye the insulator looks perfect, but a slight bending moment will break the wood with the interior appearing as in Figure 38. This condition has been slightly bettered by the use

Publication No. 403G, Page 23

10.15 Wire Wrap Ties – Close Ties

The span wire should be terminated in each fitting as follows:-

The wire is to be cut to a length of 1.2m longer than the distance between the two fittings or points of attachment. Each end is then to be turned back to from a wrapping tail about 500mm long. The loop in the end of the tie must then be dressed down onto the fitting and the tail unravelled and held along the main wire.

One strand is then to be wrapped around the remaining wires and the main part for 7 turns, and then bent away from the fitting along the main wire. A second strand is then to be wrapped, capturing the first strand on the first turn after which the first wire is to be bent away from the strands and the wrapping completed for seven turns.

Each strand is then to be wrapped in turn until the last. This will be wrapped to its end and dressed onto the main wire. The projecting ends are then cut off close to the wrapping.

10.16 Wire Wrap Ties – Extended Ties

Extended ties are used mainly in conjunction with grooved insulators and allow the insulator to be replaced without dismantling the span.

They are formed in a manner similar to a closer tie but the tail is cut about 300mm longer.

The first strand is wrapped completely onto the remaining strands and the main wire. The second strand wrapping is commenced about 300mm from the fitting and the remainder are finished beyond this as for a close tie.

In the event that the insulator requires replacement, wire clamp plates and a block and tackle are used to take up the strain in the wire. The first tie is then unwrapped. This will allow the lage loop to be opened out to allow the insulator to be replaced. The loop is then closed down and secured with the unwrapped strand or a new strand or wire.

10.17 Crosby Clips

When Crosby clips are used the tail of the span wire is bent around the terminated as for a wrapped tie but the strands are left twisted. Three clips are the attached to the wire. Clips with an internal diameter equal to the nominal wire diameter are to be used, the U-bolt holding the tail captive, the clamp plate being fitted against the main part of the wire.

Some references state that the centre one of three clips should face the opposite direction. There seems to be no hard and fast rule in this matter.

One clip will be positioned as close to the fitting as possible, one will be located about 100mm from the end of the tail, the third will be midway between the other two.

After the clips are tightened the end of the tail is to be bent away from the main wire to prevent the clips slipping along the wire if they work loose.

Crosby clips enable the span wire to be dismantled as necessary to replace or alter fittings or attachments. They may also be used in historic scenes to restrain temporary ties until the overhead is correctly aligned when permanent ties should be made.

10.18 Metal Swages

In non-historical recreations of tramway overhead, metal swages of a size suitable for the span wire may be used. The tail of the wire will require to project about 100mm beyond the fitting. Swaging thimbles are usually provided with a figure of eight” hole which provides a sliding over the wire and tail. They are then compressed onto the wire by (usually) a hydraulic press. The tail projecting from the swage is then to be turned away from the main wire to hold the thimble captive should it work loose.

10.19 Thimbles

When the span wires are to be terminated around fittings with sharp edges to be fixing holes or when the span wire is required to be bent over to a U-shape with the inner radius of less than twice the nominal diameter of the wire then a metal sleeve thimble is to be inserted in the loop.

10.20 The Wire – Generally

As explained below, most new tramway overhead construction will use grooved contact wire. If non-fouling wire clamps are used, then a construction suitable for both trolley wheels and shoes will result. With certain modifications this form of overhead will also allow for the operation of pantograph collectors.

10.21 Used Wire

Any proposal to use trolley wire reclaimed from existing or abandoned electric systems will generally be impractical. In most cases it will be found that such undertakings are reluctant to dispose of trolley wire for further use. It would appear that this is based on health risks.

For many years trolley wire was milled from a copper-cadmium alloy. In recent years cadmium has been declared a contaminant and copper-cadmium is being progressively removed from use.

Any supplies of surplus unused wire on offer should be examined before delivery is taken of such material to ensure that the wire has not been manufactured from copper-cadmium.

10.22 New Wire

Since the cost of new wire is proportionately high for the tramway museum budgets, every effort should be made to determine the exact quantity required before an order is placed. The wire is now usually drawn to order (as “trolley rod”).

To reduce the cost as far as possible, the tramway purchasing officer should discuss the order with the manufacturer as to the grade of wire to be supplied and the cross section. Any special requirements placed upon the order will often incur cost penalties which could have been eliminated with a little prior investigation.

The wire will usually be supplied on standard cable drums and to a minimum lead time of four weeks.

The standard (minimum) size trolley rod manufactured at present appears to be No. 4/0 (100mm or 0.4 in) diameter of “Melbourne” grooved section. Heavier section wire is usually not considered economically or structurally desirable; wire lighter than round section No. 3/0 (8mm or 5/16 in. diameter) is generally to light to be mechanically sound and often requires extra feeder wires over long distances.

10.23 Wire Installation

Whenever possible, the wire should be fed from the cable drum which is fitted to an arbour on which it can freely run. The arbour cradle is generally fitted to a purpose made works tram or to a suitable road motor vehicle. Tension on the overhead wire may then be induced by providing a screw brake on the cable drum arbour.

One end of the new wire is secured to the terminal assembly and the trolley wire then is fed out slowly, being secured to each span wire by temporary pulleys, shackles or wire ties. As each length is strung out it should be temporarily terminated.

The work gang should then return to the commencement of the length and progressively install the wire grips (ears), and tension the trolley wire as necessary. A permanent terminal assembly with turnbuckle should then be installed at the outer end of the length.

10.24 Wire Tension and Sag

The wire should be pulled to the correct sag and temporarily tied to brackets or spans by rope or other soft insulating ties. Particular care should be taken to prevent twisting, kinking or bruising the wire. Parallel faced clamps should be used; chains, cam come-alongs or other short grip devices should not be employed. According to the *American Electric Railway Engineering Association* the sags should be as follows, and in pulling up the wire great care should be taken that the corresponding tensions are not exceeded:

SAG AND TENSION OF TROLLEY WIRE 30.48m (100’ 0”) spans													
GAUGE		00				000				0000			
Temp.		Sag		Tension		Sag		Tension		Sag		Tension	
ºF	°C	Ins.	mm	Lbs	Kg.	Ins.	mm	Lbs	Kg.	Ins.	mm	Lbs	Kg.
0	-17.8	3	76.2	2020	916.3	2¾	69.85	2780	1261.0				
30	-1.1	3½	88.9	1730	784.7	3¼	82.55	2350	1065.9	3¼	82.55	2960	1342.6
60	15.6	4¼	108.0	1420	644.1	4¼	107.95	1800	816.5	4¼	107.95	2260	1025.1
90	32.2	5½	139.7	1100	499.0	5¼	133.35	1450	657.7	5¼	133.35	1830	830.1
120	48.9	7¾	196.9	760	344.7	7¼	184.15	1050	476.3	7¼	184.15	1330	603.3

The table values are for spans of 30.5m (100’ 0”); for any other span the sag for the tension given in the table is as the squares of the lengths. For example, for a span of 15.25m (50’ 0”) the sag for a given temperature is equal to 50 squared divided by 100 squared, or one-quarter of the corresponding table value for that temperature.

After the trolley wire has been temporarily tied up with the proper sags, and has been anchored, the support ears and hangers may be accurately located and attached, clinch ears and fittings being thoroughly closed down to give a secure grip and smooth running surface, and the mechanical ears well seated in the grooved wire, the clamp screws then being slightly upset to prevent them backing out.

10.25 Trolley Wire Terminations

At terminal poles the wire should continue as far as practicable to the limit of the collector, and then be provided with a close tie around a single groove insulator. The wire is wrapped around the insulator and a tail of 450mm is laid against the main wire and wrapped for about 100mm with copper wire in three locations – against the insulator, to within 150mm of the end of the tail and midway between the two.

The tail should then be bent through 90º away from the main wire. This will prevent the wire ties from sliding away from the tail should they work loose. The copper windings may be soldered in place provided excessive heat is not conducted to the trolley wire or the insulator.

The insulator is then joined to a similar unit with straps or shackles and extended to the pole with stranded steel span wire to terminate at an eye bolt or collar. A turnbuckle may be included in the assembly if required.

Where the trolley wire is terminated in a fitting such as a section insulator, this fitting usually requires the wire to be bent to a particular shape and be looped through the body of the fitting and held captive by U-bolts and clamp plates.

10.26 Tension on Trolley Wire

There are at least two schools of thought regarding the tension to which trolley wire should be stressed. Where the trolley pole collectors are used and service speed is relatively low the wire may be erected with a minimum tension and allowed maximum sag consistent with the minimum clearance height.

Where high speeds are to be encountered or pan-fitted collectors are to be used the level of the trolley wire should be more consistent. This may be achieved by a high tension on the wire or by the use of a catenary form of overhead.

The tramway overhead must be erected with a degree of flexibility to reduce wear. In operation, the collector device pushes a wave in the wire along ahead of the wheel, shoe or pan. When it reaches a fitting, the overhead network must be flexible enough for the fitting to ride over the wave. If the fitting is too heavy or is too rigidly fixed, it becomes an anvil onto which the collector hammers the wave in the wire.

This rapidly causes the wire to be bent upwards where it enters the fitting and each pass of a collector then rapidly increases the damage. When it hits the end of the wire in the fitting the collector will often bounce away from the wire causing arcing. It then hammers the wire once more and arcs when making further contact beyond the fitting.

The trolley wire must therefore not to so tightly strung that it is liable to be overstressed and break in cold weather, nor so loose that the wave preceding the collector is excessive.

Heavy fittings should be supported by secondary span wires and, where possible, slightly above the general level of the wire to absorb the shock of the approaching collector.

Provision of counterweight tension devices is generally not considered desirable for tramway overhead wiring.

10.27 Wire Joiners

The trolley wire should be erected in long lengths, preferably in single lengths between termination fittings.

When it becomes necessary to join a contact wire, the joints should be made in special wire joiner fittings or other fittings suitable to the purpose and the joints dressed to provide the minimum of obstruction of the collector.

At particular points on the tramway, the trolley wire may fail due to overstressing, to continual electric arcing or to other structural damage and it would not be economical proposition to renew the whole section. A short section of the trolley wire at terminals and turn back locations will be subject to arc burning as the trolley collector is removed from and returned to the wire. This can be reduced by following the opening provisions that poles are not removed from the wire while a compressor on the tram is operating.

In such cases it would be desirable to insert a new piece of wire in the damaged location. The insert should be at least 5.0m long to avoid the effect of the splice amplifying the damage already caused to the wire.

Round wire is usually joined in a purpose made tubular fitting into which the adjoining ends of wire are inserted. Small serrated wedges are installed into the fitting from a port in the side and hammered home. Tension on the wire will tend to draw the wedges even tighter.

One piece joiner ears for grooved wire have a groove along the bottom into which the ends of the wire are inserted and the wire ends are held captive by studs screwed in from the top. The studs are at an angle towards the centre of the fitting to provide additional grip as the wire is tensioned. The ends of the trolley wire should be slightly rounded to provide a smooth path for the collector.

These joiners are usually not provided with stabiliser attachment points so should be located between 750mm and 1500mm from a wire grip otherwise they have a tendency to overturn as the collector approaches and may cause dewirements.

Joiner ears similar to section insulators but usually shorter and without the centre insulator section are available but if not located near the permanent attachment point of a long section of wire may not allow sufficient longitudinal movement of the trolley wire during adjustment of line and tension.

10.28 Section Insulators

Where necessary, purpose made section insulators shall be inserted in the trolley wire to enable it to be deadened in any one section without affecting the adjoining sections. The section insulator shall be provided with trolley wire terminating blocks and renewable collector guides attached to the trolley wire and the insulator body for wheel and skid overhead and/or guard wires to depress the collector pan below the joint on pan type overhead.

Because of the weight of the assembly, an additional span wire, strung 400mm above the main span wire, should be provided to support the insulator. Rings should be inserted in the main span wire about 500mm each side of the section insulator and in the auxiliary wire directly above. Dropper wires will then be inserted between the rings to take the load.

Any feeder cables to the section insulator should be attached to the auxiliary cable, neatly taped or wired to prevent the feeder from sagging and becoming entangled in the current collector.

Reclaimed section insulators should be carefully examined for damage and repaired if necessary before use. They should be thoroughly cleaned and insulating material given a liberal coating of approved insulating varnish.

10.29 Junction Rings

Where three or more span wires come together they should be spliced to a galvanised steel ring. This ring will be a closed loop of 10mm steel rod with an internal diameter of between 50mm and 70mm. The use of the ring allows for flexibility in the overhead network and ease of removing/repairing any section of the span wire network without disturbing the adjoining wiring.

10.30 Turnouts and Crossings

At turnouts (frogs) and crossings the trolley wire is clamped into purpose made backing plate using specially forged U-bolts, flattened at the base of the “U”. The wire must be seated in the locating lugs on the underside of the plate before the U-bolts are tightened.

The U-bolts in the plates should not be fully tightened until the exact location of frog or turnout is determined. This can usually only be done by running a variety of trams both ways through the fitting.

Tight clamping of the fitting will put a kink in the trolley wire. If the fitting has to be moved afterwards, the kink must be carefully dressed out using a rubber or soft metal mallet and a solid backing piece.

In turnout frogs, the main wire will run continuous through the plate; at crossing both wires will be carried through. Special renewable pans are required to clamp below the plate and around each trolley wire to guide the trolley wheel or shoe onto the correct path. Alternatively, purpose made one piece units may be used.

The method of determining the exact position for the frog pan to be secured has as many complicated expressions as people who have endeavoured to produce the definitive formula. Most agree, however, that above the heel of the point blade or 1/3rd of the distance between the toe of the blades and the crossing (or somewhere in between) are the most suitable starting points.

The frog is then moved backwards and forwards along the wires until the most suitable location is found. At points, both the main wire and the

The frog pan frame is usually provided with lugs to which pull-off wires may be attached to stabilise the unit. It is important that the frog and pan are fitted horizontal to the overhead wires otherwise wheels and shoes may continually dewier when the tram is travelling towards the low point of the fitting.

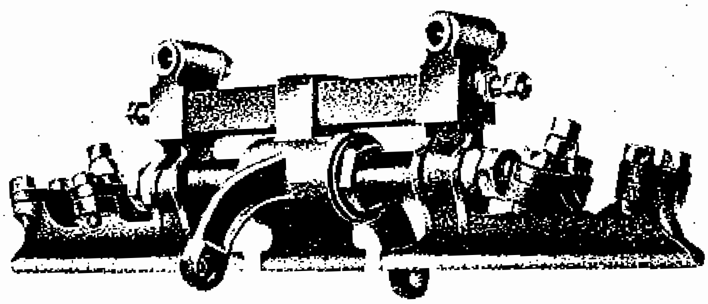
It should be noted that the frog and crossing pan assemblies are alive and additional insulators must be provided in guy wires to ensure that the minimum level of insulation is maintained.

Crossing plates and pans are usually located at the true point of intersection of the two wires. If the unit is a fixed angle, then it should be within 1° or 2° of the exact wire crossing angle to obviate dewirements. If adjustable crossing units are available then these must be firmly secured after the wire is correctly positioned.

The renewable frog crossing pans are provided with lugs which are bent over slightly onto the plate until the whole assembly is correctly positioned and are then hammered down flat to secure the pan. Sleeves are formed at each end of the pan to be wrapped tightly around the trolley wire. These should also be lightly crimped until the fitting is correctly positioned then crimped tightly around the wire to provide the minimum obstruction to the path of the collector.

Line Material.

Section Insulators.



No. 228. Code Word: "Sorbetto."

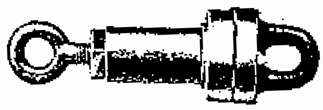
Prices for either span wire or bracket arm suspension. Length over all 21½ inches.

£3 3s. 0d.

These insulators can be made **continuous feeding** if desired.

The ordinary insulator may be fitted with a small connection to keep car lights in whilst going over "break."

Brooklyn Strains.



					Gunmetal.		Malleable Iron		Prices on applicatn.	
Extra Large Size,	9"	"Take-up,"	1"	Eye Bolt.	220.	"Sorbais."	233.	"Sorbigno."		
						Code Word		Code Word	s. d. Gunmetal	s. d. Mall. Iron
Large Size	6"	"	¾"	" "	230.	"Sorbiamos."	234.	"Sorbique."	20 0	13 0
Medium "	4"	"	⅝"	" "	231.	"Sorbieron."	235.	"Sorbitira."	9 4	6 6
Small "	1½"	"	½"	" "	232.	"Sorbieses."	236.	"Sorbition."	6 6	5 3

Gun Metal, with hard drawn bolt. Malleable Iron Insulated Body.

Galvanized Malleable Iron, with drop steel forged galvanized bolt.

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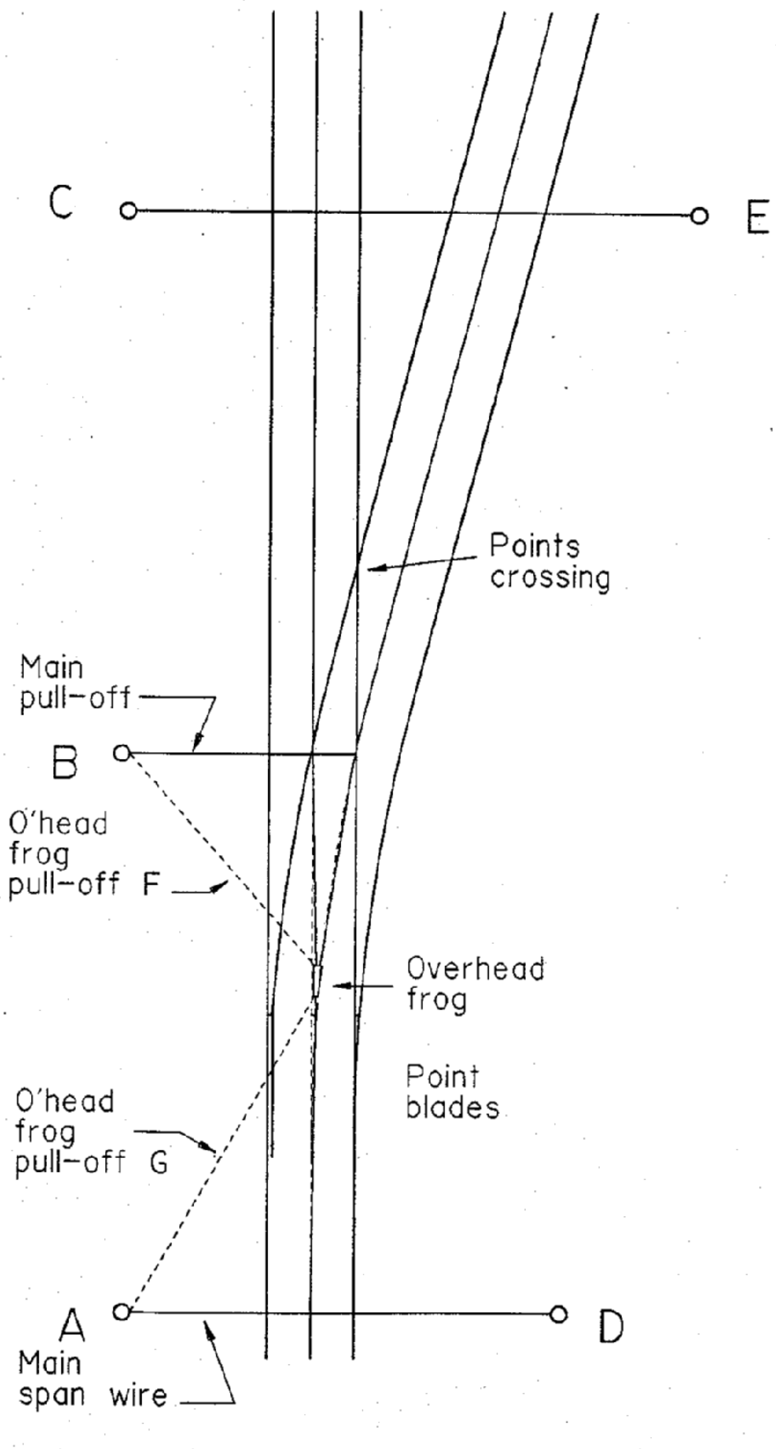

C
E
Points
crossing
Main
pull-off
B
O'head
frog
pull-off F
Overhead
frog
Point
blades
O'head
frog
pull-off G
A
D
Main
span wire

11 Maintenance

11.1 Overhead Inspection Schedule - Generally

The overhead wiring shall be visually examined at intervals from the tram driver's view point and tram drivers are to report after each trip to the Officer-in-Charge any apparent defect in the overhead wire and the location and circumstances of dewirements to allow any defect to be examined as soon as possible.

Specific details about overhead inspections, etc are covered in the Tramway Overhead Inspection Procedure (STM6029)) in section 6.12 (Defect Reporting)..

11.2 Pole Maintenance and Replacement

a) Existing Timber Poles

Existing poles are to be inspected on a regular basis at which time the pole is to be examined for insect attack, decay and mechanical damage. Poles which exhibit major defects are to be listed for prompt replacement.

On a 3 year cycle poles are to be excavated for a depth of 300 mm below the surrounding surface and this excavated length of the pole and for 450 mm above the ground is to be liberally coated with wood preservative. The excavation is then to be filled with sand, well rammed and rakes at the top away from the pole.

Poles which have become splintered shall have the loose material carefully adzed away to allow the extent of mechanical damage to be assessed and to assist in shedding rainwater.

b) Timber Pole Replacement

Where a timber pole is to be replaced, a pole of similar size is to be obtained and erected about 1 metre to the side of the existing pole.

If there is any likelihood of the new pole tipping towards the excavation then a temporary guy wire shall be installed on the new pole before the old pole is removed.

c) Existing Steel Poles

Existing poles are to be inspected on an annual basis at which time the pole is to be examined for rust decay and mechanical damage. Poles which exhibit structural deficiency must be listed for immediate replacement.

11.3 Trolley Wire

The wire is to be examined annually from a purpose made road tower wagon or tower tram to ensure that no significant damage has occurred. The wire should be measured at selected locations to determine the annual wear. Control locations should be identified and examined at each annual inspection. Suitable control locations include the approach side and the exit side of overhead fittings such as frog pans and section insulators, major change of grade of the wire and at each end and at the centre of major curves.

11.4 Wire Fittings, etc.

a) Ears/Grips

Each ear is to be examined for excessive wear, damage and loose clamping screws, the screws must be tightened as required. Examination of previous inspection schedules shall be made to ascertain whether any fittings are giving a poor performance.

b) Span Wires and Insulators

Each span wire and pull-off wire is to be examined for its full length and repairs or replacements effected as necessary. All wire clamps are to be checked for tightness and swages and wire ties examined to ensure integrity of the joint.

Insulators are to be examined and where electrical or mechanical integrity is lost they must be scheduled for replacement as soon as possible.

c) *Terminations*

Eye bolts in timber poles, collars to steel poles, turnbuckles and shackles at span wire and trolley wire terminations are to be examined and tightened where necessary. Where adjustments reach the limit of the fitting without achieving the desired tension then the fitting and as much of the associated wiring as necessary are to be replaced with a new assembly.

11.5 Electrical Safety

Work on live tramway overhead wiring may be carried out from insulated platforms such as on a tower wagon, where live and earthed metal cannot be touched simultaneously, i.e. there must exist a vertical separation of 2.5m and a horizontal separation of 1.2m.

If this cannot be achieved then the work shall be undertaken with the traction power isolated from the section under examination. In this case, the overhead wire shall be earthed with a heavy duty strap clamped to the overhead trolley wire(s) and clamped to a running rail or to a heavy block laid along the head of fully paved rail. The earthing device must be maintained within the view of the overhead line crew supervisor.

On the active side of the overhead section insulators red flags (or red lamp at night) are to be positioned in the four foot warn any approaching tram driver not to proceed into the section.

If, for any reason, a tram must pass the section insulator, the driver must ensure that all power collectors are removed from the overhead wire when the tram may be coasted past the section insulator.

This is necessary to prevent the brief bridging by the current collector between live and dead wires and the possibility of electric shock to the overhead crew or damage to the power supply through short circuit.

When, for any reason, it is necessary to work on overhead wiring which is energised, special care must be taken to ensure that members of the overhead crew do not receive an electric shock. Work should not be undertaken in rain or mist and all equipment must be kept as dry and clean as possible.

It should be noted that a new timber poles may contain enough moisture to conduct sufficient electricity to give a severe shock and a similar situation exists with span wires and pull-offs which come in contact with trees located between the track and the overhead poles.

Insulation sleeves shall be installed on earthed wires when there is any likelihood of the overhead crew touching such wires while in contact with an energised section of the overhead wiring.

METAL LADDERS MUST NOT BE USED in electrical work associated with overhead wiring. Timber ladders must be of the type reinforced with nylon rope; ladders with metal wire reinforcing shall not be used.

Persons not immediately engaged in the overhead wiring work shall be directed to remain well away from the area to reduce the risk of electric shock.

11.6 Pole vs Pan Collector

Trolley wire set for sliding shoe collectors will usually accommodate wheels without any modification. When a mixture of poles and collector pans is to be run then complications arise due to the difficulty in ensuring the location of the wire is suitable for both. On straight track the wire collector pans must run in a zig-zag fashion between adjacent supports to avoid excessive wear in the centre of the pan. This offset in the wire must not be excessive when trolley poles are to use the same wire.

On curves, the offset required for the trolley pole collector to work efficiently may well cause the wire to move beyond the limit of the collector pan. In such cases, a secondary contact wire may be required on curves. Frog pans and crossing pans are generally required for pole operation but need not be used for collector pans. When dual operation is required, special runner wires are necessary set parallel to the special work to depress the collector pan below the fitting.

In trolley pole operation, curves are usually restrained by the use of bow and half bow hangers. These are designed to have the span wire attached at the level of the trolley wire. They are therefore likely to foul the collector pan in most instances. Extended cones would provide extra clearance but cause the fitting to tilt on sharper curves, thus defeating the object of providing clearances.

Special adjustable wire clamps are therefore required to compensate for the overturning factor on curves but still provide sufficient clearance for the pan collector to clear the clamp and the span wire.

11.7 Pull-Off Wires

Where a significant components of the load of the trolley wire at fittings is horizontal i.e. generally curves, the trolley wire must be held in position with diagonal pull-off wires.

On sharp curves, the pull-offs and fittings are required to reduce wire offset to about 7½º. On gradual curves, pull-offs may be required to reduce the distance of the centre of the chord to within acceptable limits although the angle of the wire through the suspension fittings does not exceed 7½º.

Pull-offs which join the trolley wire at greater than 60° are usually acceptable as a direct connection. Where then angle between the trolley wire and the pull-off is less than 60° or where a number of pull-offs are provided between span wires then they should be connected to a bridle wire inserted about 600mm outside the proposed curve of the trolley wire. The bridle is constructed with rings opposite the hangers, the hangers being connected with short pull-off wires.

The use of the jointed bridle equalises the tensions in the curve wiring making adjustment of individual pull-offs easier and reducing the possibility of the curve working out of line.

11.8 Insulation and Insulators

The overhead system is generally designed so that no earthed metal is in an overhead worker’s reach of live wire. This is achieved by use of timber poles, triple insulation of metal parts, timber sheathing of the ornamental pole brackets and insulated trough within buildings.

Insulators shall be of porcelain or other approved material designed to provide effective insulation for a nominal 600 volts DC.

11.9 Hangers

Purpose made hangers shall be used to connect the trolley wire ears to span wires or other suspension. Simple “straight wire” hangers shall be used where the trolley wire is subject only to its own weight. On curves or at other places where the wire is subject to lateral tension special “bow hangers” shall be used to hold the ear vertical.

Purpose made hangers incorporating an insulated bolt may be used to provide one level of required insulation. Hangers which do not include an insulated bolt shall require one insulator each side of the fitting.

Where a single track trolley wire is provided at curves, “half bow” hangers are used to restrain the wire. Where double track trolley wires are provided, then a “full bow” hanger is provided on the outer wire in the curve and a short pull-off wire taken across to a "half bow" to restrain the inner wire.

Since the trolley wire will dip when only restrained by side pull-offs, full span wires must be provided at intervals around curves to support the trolley wire generally at the required height. "Full bow" hangers are required to be installed in these span wires.

11.10 Check Sheets and Schedules

Check sheets and schedules shall be prepared in accordance with the detail shown on the diagrammatic layout or, alternatively, with provision for the manual insertion in each sheet of this detail. Copies of these sheets shall be provided to the Overhead Inspection Supervisor each day that inspections are to take place.

The sheets shall be filled in as the inspection work progresses and at the end of each day shall be inserted in a "Current" file. When all repair work has been carried out the sheet shall be suitably annotated and transferred to an "Archive" file where it will remain to form history of the examination and maintenance of the tramway overhead.

11.11 Recording Any Inspections, Maintenance and Replacement

All inspections and maintenance performed on the tramway overhead traction wire on the STM network must be recorded in the following forms:

a) Overhead Inspection ~~–~~ – Overhead Pole Inspection Report (STM6107);

- *Date* – the date that the inspection was performed;
- *Sheet* – the sheet number and if more than 1 sheet the number of sheets;
- *Inspector* – the name of the person inspecting the poles;
- *Membership No.* – the member number if the inspector was a Museum member;
- *Pole number* – the pole numbers inspected;
- *Type* – the pole type (eg wood, steel, etc);
- *Pass* – tick is passed;
- *Fail* - Tick if failed; and
- *Comments* – a brief description of the inspection performed and any necessary repairs.

b) Tramway Overhead Inspection Schedule (STM6086) shows the schedule of inspections during a calendar year,

c) Overhead Inspections - Tramway Overhead ~~Trolley Wire~~ Inspection Check Sheets (STM6108). There are a number of sheets covering all of the Museum lines. These are:

- TW Inspection Schedule 2008;
- 1 Pitt St - North Term;
- 2 Pitt St - Hwy. Lev.Cross.;
- 3 Hwy. Lev. Cross. - N. P.Term;
- 4 Depot Junc – Depot; and
- 5 Cross Street.
- .

d) Overhead Inspection - Tramway Overhead ~~Trolley Wire~~ Inspection/Maintenance Reports (STM6109). There are a number of sheets covering all of the Museum lines. These are:

- Trolley Wire; and
- Support System.

11.12 Prioritisation of Defects

Attention to defects is prioritised by the Infrastructure Manager in consultation with other managers and the Board, based on the likelihood and consequences of any adverse safety outcomes potentially arising from the particular defect

11.13 Notfcation, Imposition and Removal of Protection/Restriction Signs

The only people to place, and remove a protection or restriction sign are the Overhead Supervisor or the Chief Engineer.

These signs will be posted as the result of a defect being reported and unable to be fixed immediately or the overhead work not being completed in time before traffic resumes.

It is the responsibility of the Overhead Supervisor to remove the protection/restriction signs once the repairs have been completed, inspected and cleared for normal operations. The Overhead Supervisor is to check any work done (whether by that officer personally or under supervision or independently) and be satisfied that the overhead is safe for use without temporary protection, before removal of the temporary protection notice.

Each year, the Overhead Supervisor reviews all current protection/restriction signs during the annual preparation of the Tramway Overhead Inspection Schedule (STM6086) to ensure that they are all still valid.

11.14 Type of Protection/Restriction Signs

These signs must be placed on the nearest poles on either side of the defect or uncompleted work.

The signs are:

Speed restriction inforce at speed nominated on the sign	As per the Australian Standard
End of Speed restriction	As per the Australian Standard

APPENDIX A – INSPECTION REPORT SHEETS

See forms:

- STM6086 – Tramway Overhead Inspection Schedule
- STM6107 – ~~Tramway Maintenance –~~Overhead Pole Inspection Report
- STM6108 – Tramway Overhead~~Trolley Wire~~ Inspection Check Lists
- STM6109 - Tramway Overhead~~Trolley Wir~~e Inspection/Maintenance Report

APPENDIX B – CATENARY OVERHEAD

Where the unsupported span of the trolley wire would exceed 36m (120' 0") then other means of support must be introduced. The most common is the catenary structure.

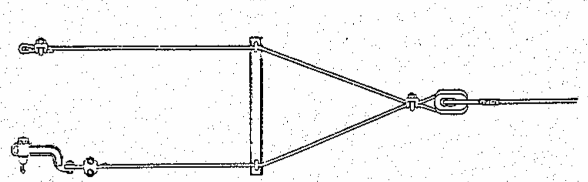
Simple catenary construction involves the erection of a heavy duty support cable slung between supports which may be up to 72m (240' 0") or more apart. This support cable is allowed to sag between supports almost to the level of the contact wire. Dropper wires are attached to the cable at intervals and connect to the trolley wire with approved wire grips. When thus loaded, the support cable takes up the geometric shape referred to as a catenary curve.

The trolley wire will be held closer to horizontal than can be achieved with normal single span supports, the accuracy depending on the spacing of the dropper wires.

Catenary construction is usually recommended in cases of high speed operation of either trolley poles or pantographs. It is almost mandatory in high speed pantograph operation to prevent the pan from skipping across the undulations in the wire and causing excessive arcing.

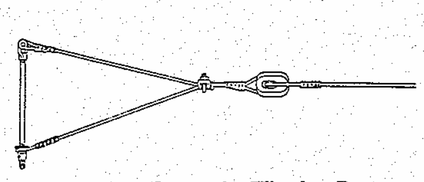
The catenary cable can double as an electric feeder and over longer distances is usually of a large cross section stranded copper cable. At intervals, usually at least once between supports, heavy straps are connected from the catenary to the trolley wire to act as feeders and to significantly reduce the voltage which is passed through the light gauge droppers.

CATENARY CURVE PULL-OFF CONSTRUCTION



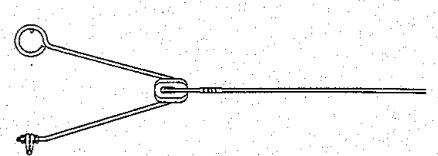
Pull-Off Spreader with Pull-Over Yoke for Trolley Wheel

See pages 433 and 280 for listing.



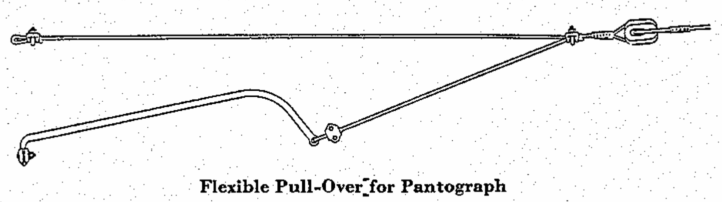
Type CA Pull-Off Hanger for Wheel or Pantograph

See page 432 for listing.



Type CB Pull-Off Hanger for Wheel or Pantograph

See page 431 for listing.

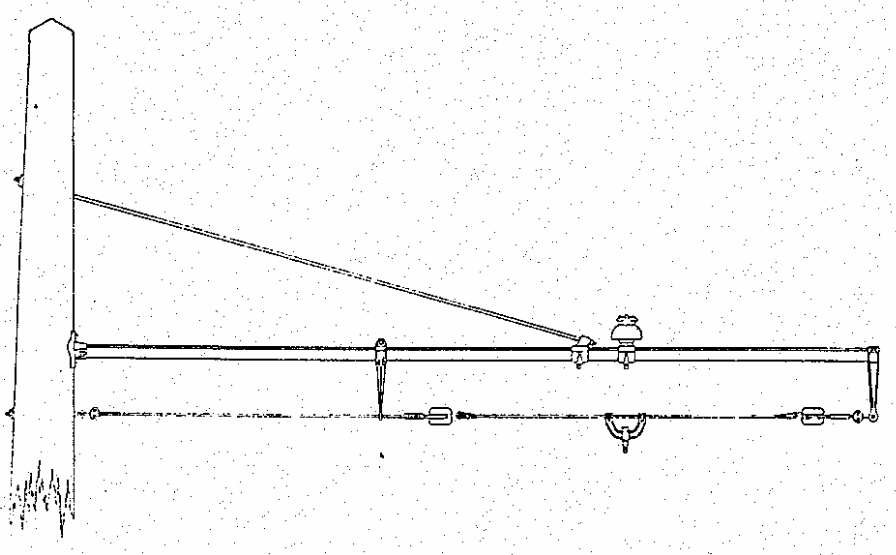


Flexible Pull-Over for Pantograph

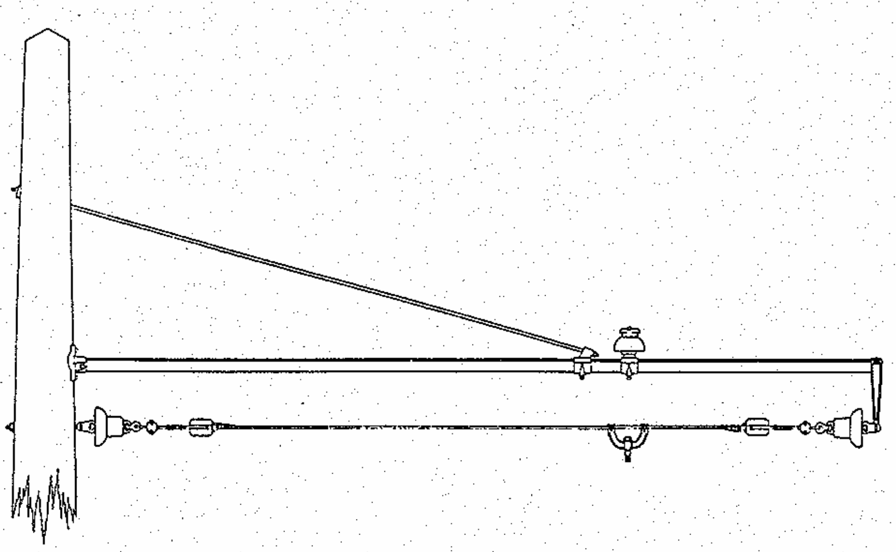
See page 433 for listing.

CATENARY STEADY CONSTRUCTION

Tangent or Curve



Up to 1,500 Volts



11,000 Volts