Standard

Infrastructure – Overhead Network – Design and Construction

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1 PURPOSE

The purpose of this standard is to specify the minimum requirements for design and construction of overhead network infrastructure, including structures, for the Melbourne Metropolitan Tram Network (MMTN).

2 SCOPE

The scope of this standard is the design and construction of tramway overhead network elements including structures.

This standard provides the general requirements, design and construction principles, compliance obligations and considerations for designers and constructors.

The scope of this standard applies to changes to all existing and all new overhead network elements.

The requirements in this standard are derived from the following sources:

- Yarra Trams Standards
- International and Australian standards (refer to Section **Error! Reference source not found.**)
- Office of the Chief Engineer within Yarra Trams and suppliers to Yarra Trams
- Department of Transport (DoT) subject matter experts.

This standard is applicable to all entities who are involved with or provide specification, design, construction, test or commissioning services for Yarra Trams, including companies, contractors and Yarra Trams personnel, for tramway network power overhead and associated structures.

3 COMPLIANCE

This standard shall be fully complied with. Deviation from this standard is only permitted when a waiver has been sought and approved by Yarra Trams.

“Shall” statements are mandatory in the context of compliance with requirements stipulated in this standard.

‘Should’ statements are considerations in the context of compliance with requirements stipulated in this standard.

‘Information’ statements provide additional content for clarification purposes only and are not requirements in the context of compliance with this standard.

‘So far as is reasonably practicable’ statements must at a minimum, result in the provision of a technical risk assessment including proposed list of design controls to demonstrate compliance to this standard.

The design and review process shall be managed in accordance with the Yarra Trams ‘Manage Design’ procedure.

Information: This procedure requires consideration of design constructability, Safety in Design, RAM, Human Factors, design sustainability, single design platform, security in design, design competency and all relevant statutory requirements.

Any third party or contractor undertaking activities related to design and construction of overhead network infrastructure including structures shall complete and return a compliance schedule for this standard. Assessment of compliance shall be provided for each requirement, defined by one of three permissible responses:

- Compliant;
- Partially Compliant;
- Non-Compliant.

4 REQUIREMENTS

4.1 General Requirements

Information: The overhead network infrastructure consists of an electrically power trolley wire suspended from insulated frameworks over the tramway between isolated sections, providing power to trams, for the safe transportation of people to and from their destinations.

4.1.1 Unless otherwise stated all units of measure shall be per the International System of Units (SI).

4.1.2 The Yarra Trams Engineering Design Authority (EDA) shall be the ultimate authority as part of the Engineering Change Management process for all approvals via the Engineering Design Authority Procedure.

4.2 Drawing Compliance

4.2.1 All drawings provided shall conform to the Yarra Trams Standard, Infrastructure – General – Design and Drafting (CE-021-ST-0014).

4.3 Survey

4.3.1 A site survey shall be undertaken prior to the commencement of works for the construction of tramway overhead infrastructure according to the general tramways engineering survey standard to confirm all dimensions and measurements, and the accuracy of the points provided by Yarra Trams.

4.3.2 Drawings and enough survey information should be gathered in order to set out the works, such as Bench Marks, control points (at least one control point for every 200 meters of track) and drawings for the proposed works.

4.3.3 Chainages shall be marked out on site at 10 metre intervals and at tangent points as part of the works package for the construction of tramway overhead infrastructure the. Centre lines shall be marked on the ground where it intersects with span wires.

4.3.4 All relative values shall be confirmed, any discrepancies of the “Reduced Level” and or co-ordinates of such points shall be reported to Yarra Trams as soon as possible prior to any works being performed.

4.4 Setting out and Dimensions

4.4.1 If there are any discrepancies with setting out and dimensions, Yarra Trams shall be notified as soon as possible. Works cannot proceed without the expressed permission of Yarra Trams. Yarra Trams shall decide upon the method of mitigation or rectification for the discrepancies.

4.4.2 All poles shall be checked to ensure that they are correctly located against the design layout.

Information: Special care is to be taken to ensure newly installed poles are in the correct position.

4.5 Permits and Approvals

Information: New overhead infrastructure works programs may require an occupation. An occupation may disrupt tram services, pedestrian and vehicle access.

Yarra Trams operates a "T" minus process where an occupation that has service disruption requires 14 weeks' notice. Other occupation types may be less. The T minus process is illustrated below for information only. Table 1 does not form part of the compliance requirements in this standard.

Table 1 - "T" minus Process

Phase	T-weeks	Key Milestone
Planning	T-24	Scope confirmed
	T-22	Operational Planning Workshop
	T-20	Final service Plan
Delivery	T-16	Service design build
	T-12	Final Operational Plan
	T-8	Draft departmental plans
Ops Readiness	T-8	Operational Readiness Meeting
	T-2	Final Operational Readiness Meeting
	T-2	Final Operational Readiness Plan
	T-1	Handover to Operations Centre
Implementation	T-0	Occupation delivery go live
Lessons Learnt	T+2	Lessons Learnt Meeting
	T+4	Debrief Report circulated

4.5.1 All construction works that require an occupation shall not proceed without written approval from Yarra Trams.

4.5.2 All construction works shall require the obtaining of approvals and permits, for all necessary road closures including the installation of barriers required for the safe completion of the works. All necessary approvals and permits shall be obtained prior to the commencement of works from local councils and/or VicRoads or other relative authorities.

4.5.3 All construction works shall require the obtaining of all necessary road opening permits, which may affect times of working, traffic constraints, either through traffic or parking restrictions. All

necessary approvals and permits shall be obtained prior to road openings from VicRoads, local councils or other relative authorities.

4.6 Location of Underground Services and Assets

4.6.1 Underground services location and proving shall be conducted prior to design as part of an engineering survey to locate any assets at risk, and to:

- ensure the safety of personnel,
- maintain the integrity of existing underground services and assets,
- determine if any services or assets need altering or relocating to enable the works to be carried out.

4.7 Alteration or Relocation of Services

4.7.1 Yarra Trams shall be informed by the Designer or Constructor, as appropriate and as soon as possible, of the need to alter or relocate any services.

4.7.2 Yarra Trams shall be advised of details of the proposed alteration or relocation (See EMS06 Engineering Change Management Procedure).

4.7.3 Alteration of services shall be compliant with the requirements of the relevant Authorities concerned.

4.8 Temporary Works

4.8.1 All aspects of the design of any temporary structures required to support construction loads shall comply with the current Australian Standard, Specifications and Codes where such exist, or, in their absence, with British or American Standard Specifications and Codes of Practice.

4.8.2 Any temporary or additional works provided be shall adequate for the purpose and shall be properly designed and constructed for the load which they will be required to carry.

4.8.3 Details of any temporary or additional works proposed shall be forwarded to Yarra Trams for approval at least ten working days prior intended works start date.

4.8.4 Temporary support structures shall be used as required where existing poles have been assessed as to have become unstable due to construction activities such as trenching and boring.

4.9 Tramway Overhead Infrastructure Mechanical Requirements

4.9.1 Safety loading and Tensile strength of fittings (subject to wear)

4.9.1.1 A loading safety factor of 3:1 shall apply to all supports, supporting overhead structural assets unless approved otherwise via the Yarra Trams Engineering Change Management process.

4.9.1.2 Fittings which are under tension and subject to wear (e.g. splice ears and trolley wire tensioner) shall not during their projected life fail at a strain which is less than 2/3 of the Ultimate Tensile Strength of the new conductor and span material with which they are used.

4.9.2 Corrosion Prevention

4.9.2.1 Corrosion resistant metals or adequate long-term corrosion protection shall be provided in so far as dissimilar metals which would promote galvanic corrosion shall not be used in proximity to each other.

4.9.2.2 All ferrous parts shall be hot-dip galvanised upon completion of all fabrication processes including all bolts, nuts and washers. Refer to AS/NZS 1214:2016 Hot-dip galvanized coatings on threaded fasteners.

4.9.3 Wear Resistance

4.9.3.1 The fittings shall be constructed from such material and in such a manner to provide projected life delivery in service with minimum maintenance requirements.

4.9.4 Use of Composite Materials

4.9.4.1 Yarra Trams' Type Approval process shall be used to approve products manufactured from composite materials for use on Yarra Trams' network.

4.9.4.2 Tested and approved products (see 4.19.4.1) manufactured from composite materials shall be able to be used in specific applications only.

4.9.4.3 Composite materials shall be stable in Ultra-Violet Radiation.

4.9.4.4 Composite materials shall be resistant to chemicals that might be encountered in their operating environment and shall provide adequate electrical insulation levels.

4.9.4.5 Composite materials shall not sustain combustion.

4.9.4.6 Composite materials shall have good wear characteristics if subject to wear and be capable of withstanding electric arcing without deterioration.

4.9.4.7 Composite materials shall have low moisture absorption characteristics.

4.9.4.8 Composite materials shall have high impact resistance.

4.9.4.9 Composite materials shall have aesthetic considerations.

4.9.5 Projected Life

4.9.5.1 Overhead fittings and systems shall be designed for a minimum service life of 30 years.

4.10 Tramway Overhead Infrastructure Electrical Requirements

Information: The nominal voltage of the Tram Traction system is 600 volts dc.

4.10.1.1 All electrical components that make up the tramway overhead system shall be rated to 600V according to EN 50163.

4.10.2 Bonding

Information: Bonding is an electrical connection on the dc system between an asset and rail. A bond on the Traction Electrical System is the equivalent of an earth connection on an ac network.

Bonds can also be between sections of rail as well.

Pole Bonds at Aerial Switches are primarily provided for the purpose of short-circuiting power assets during isolations. Please refer to section 4.30 Arial Switches.

It is very important to recognise that pole bonds are not provided for public protection otherwise all poles supporting electrical assets would be bonded.

4.10.2.1 All electrical bonding shall comply with Yarra Trams Bonding Application Guide BAG_21_06_2017, the AS/NZS 3000 Wiring Rules and Standard Drawing, Bonding Standard Asset Bonding Layouts Drawing Number STD_T3001 and Standard Drawing 600v Supply Pole to Autopoints Cabinet Layout.

Information: Standard Drawing 600v Supply Pole to Autopoints Cabinet Layout has been included for the sake of completeness.

4.10.3 Earthing

4.10.3.1 Earthing of all Yarra Trams assets shall comply with Standard Drawing Voltage Clamp Design Earthing and Bonding Details STD_T6110 Standard Drawing, and AS/NZS 3000 Wiring Rules.

4.10.4 Conductor Sizes

4.10.4.1 Conductor sizes shall be determined by both mechanical and electrical ratings, protection and strength considerations.

4.10.4.2 Standard feeder conductor sizes, as listed in Table 2 below, shall used.

Table 2 - Standard Feeder Conductor Sizes

Description	Nominal Cross-sectional Areas In²	mm²	Conductor Material	Construction No of Strands/Size Imperial	Metric	Nominal OD mm	Remarks
Aerial Feeder Cable	0.6	400 Equivalent	Hard Drawn Copper	91/0.093"	91/2.36mm	25.96	Bare
Aerial Feeder Cable	0.5	300 Equivalent	Hard Drawn Copper	61/0.103"	61/2.62mm	23.58	Bare
Aerial Electrolysis Cable	0.3	200 Equivalent	Hard Drawn Copper	37/0.103"	37/2.62mm	18.3	Bare
Aerial Electrolysis Cable (New)	0.28	181	Hard Drawn Copper		37/2.5mm	17.5	Rail Overhead Catenary Conductor
Trolley Wire	0.2	129	Copper Tin Bearing	Solid	Solid	13.46	To Dwg. O6887 & Spec 10/Oh/01/91

Description	Nominal Cross-sectional Areas In²	mm²	Conductor Material	Construction No of Strands/Size Imperial	Metric	Nominal OD mm	Remarks
Aerial Switch and Bolted Connection Cable	0.6	400 Equivalent	Annealed Copper		61/2.85mm	35	PVC/Red/PVC Black 0.6/1kv Insulation
Feeder Tap to Trolley Cable	0.3 Equivalent	185	Annealed Copper		5510/0.2mm	31.6	UV Resistant Rubber 0.6/1kv Double Insulated. Grey or Black
Pole Bond and Surge Diverter Earth Cable	0.1	70 Equivalent	Annealed Copper		19/2.14mm	13.5	PVC/Red/PVC Black 0.6/1kv Insulation
Underground Electrolysis Feeder		120	Annealed Copper		37/2.03mm	20.4	PVC/PVC 0.6/1kv Insulation
Electrolysis Potential Leads		2.5	Annealed Copper		61/2.85mm	39	1 Core, xlpe Insulated, 37 Wire Screen, PVC Sheath
Underground Screened Feeder Cable	0.6	400 Equivalent	Annealed Copper		61/2.85mm	39	1 Core, xlpe Insulated, 37 Wire Screen, PVC Sheath
Supervisory Cable		0.64	Fibre Optic Cable	24 fibre		13	All Dielectric Self-Supporting Fibre Optic cable
				48 fibre		16	

4.10.5 Insulation Levels

Information: There are two main systems of insulation used at Yarra Trams:

One is a minimum of three levels of insulation where the three separate supports (wires) are electrically isolated by 1000V dc insulators.

Two is a minimum of two levels of insulation where a boom is installed and is electrically isolated (both ends) at the pole support and the trolley wire support.

4.10.5.1 There shall be a minimum of three levels of insulation between the contact wire clamp and the supporting pole or structure system.

4.10.5.2 All the support spans shall be insulated in such a manner that, should they break, live parts will be maintained at a height no less than 3m above ground level.

4.10.5.3 Electrical installations mounted on or suspended off tram poles such as signal booster, CCTV cameras, light luminaries mobile phone antennas and telecommunications infrastructure shall be double insulated and comply with AS 3000 and Electrical Safety Installations regulations

2009 (latest amendment) and VicTrack's TS-SP 066 Engineering Specification: Attachments to Tram Poles.

4.10.6 Electrical Clearances

4.10.6.1 All electrical clearances from any conductor or part energised at 600V dc, shall be in accordance with the Electrical Safety Act 1998, Electricity Safety (installations) Regulations 2009 (ESR2009) and Yarra Trams' Electrical Infrastructure Safety Rules.

4.10.7 Electrical Separations

4.10.7.1 The relative position and separations between conductors and circuits shall be in accordance with the Electricity Supply and Construction Regulations, Yarra Trams' Electrical Infrastructure Safety Rules and Electrical Safety (installations) Regulations 2009 (ESR2009).

4.10.8 Current carrying Capacity

4.10.8.1 The current carrying capacity of switches or isolators shall not be less than that of the highest rated conductor(s) connected to each of its terminals.

4.10.8.2 Only fittings approved by Yarra Trams to join conductors or to provide electrical connection or tapping shall be used.

4.10.9 Cleaning and Greasing of Current Carrying Connections

4.10.9.1 All joint assemblies which are designed to permit the transfer of current from one conductor to another shall be prepared as follows and to the satisfaction of Yarra Trams.

4.10.9.2 The conductors, clamps and fittings shall be thoroughly dried and then cleaned with a suitable scratch brush to remove all dirt and surface oxide from the conducting surfaces of the joint.

4.10.9.3 Before the clamps are tightened, a liberal film of Shell Ensis CB compound or other acceptable electrical jointing compound shall be applied to the conducting surfaces to seal the joint against moisture ingress.

4.10.10 Interfacing with Existing Equipment

4.10.10.1 The integrity of items that are not to be replaced but are worked upon or handled in the process of installing or replacing mating parts or assemblies shall be preserved when installing a new system or rehabilitating an existing system. Any defects in these assemblies shall be brought to the attention of Yarra Trams.

Information: All 'due care' is be taken to ensure the integrity of these items is not compromised.

4.10.10.2 During the process of trolley wire tensioning, the relative position of components and wire stagger at other locations upstream and downstream shall not be affected adversely. Prior to terminating in any fittings, the trolley wire tension is to be checked by Yarra Trams. Special care shall be exercised at cable connections and supports.

4.10.10.3 Upstream and downs stream locations shall be checked to ensure that the overhead integrity is maintained.

4.11 Tramway Overhead Infrastructure Line Geometry Requirements

4.11.1 Structure Gauge

4.11.1.1 The structure gauge specified in STD_T9000 shall be observed for all works associated with designed for the construction of tramway overhead infrastructure.

4.11.2 Trolley Wire Height on Straight Track

4.11.2.1 Where there are no restrictions such as bridges, civil engineering works or electrical separations the height of the trolley wire shall between 5.00 to 5.64 metres at the support points at an ambient temperature of 20 deg Celsius.

4.11.2.2 An exemption to the requirements of clause 4.11.2.1 may be granted where conflicting infrastructure, i.e. bridges and support structures or electrical infrastructure, do not allow those requirements to be met. In this instance a minimum trolley wire height of 3.6M, -0mm is required.

4.11.3 Trolley Wire Sag

Information: Trolley wires sag between adjacent supports. Trolley wire sag is mainly dependent on trolley wire tension, span lengths, ambient temperature and the type of fittings being used.

There are three types of fittings used by Yarra Trams Elastic, Semi-Elastic and Non-Elastic (also called rigid fittings).

Weight tensioning on trolley wire consists of a weighted pully system within an overhead section that provides a constant tension regardless of the ambient temperature changes and hence creates less sag and minimal sag variation. These are also called auto-tensioners.

For AUTO Tension - Where existing boom with non-elastic or semi elastic fittings are existent, the boom tube may need to be changed to a longer one depending on the direction of the stagger and the type of fittings used (Delta with steady arm or steady arm only or delta only).

4.11.3.1 Where an auto tensioned trolley wire crosses an intersection, the wire shall be anchored on both side of the intersection.

4.11.3.2 Where existing semi elastic fittings are changed to elastic fittings to allow for Auto Tension, the existing stagger shall be plumb first and marked on the ground (do this only if the wire has stagger. Not required if no stagger is present) before unclipping existing fittings.

4.11.3.3 The tolerance for weighted tension sag shall be ±25mm.

Information: Fixed tension systems have the trolley wire fixed and tensioned to prescribed values given specific ambient temperatures and span distances.

4.11.3.4 For fixed tension systems, the sag of the trolley wire shall be in accordance with the Tension – Sag Table 3 below.

Table 3 - Tension – Sag

Wire Temperature in Degrees Celsius	15m Span		20m Span		25m Span		30m Span		35m Span	
	Sag mm	Tension kN	Sag mm	Tension kN	Sag Mm	Tension kN	Sag mm	Tension kN	Sag mm	Tension kN
0	32	10.0	56	10.0	88	10.0	127	10.0	172	10.0
5	36	8.7	64	8.8	100	8.8	143	8.9	193	8.9
10	42	7.5	75	7.6	115	7.7	163	7.8	218	7.9
15	51	6.3	88	6.4	133	6.6	186	6.8	246	7.0
20	62	5.1	104	5.4	154	5.7	212	6.0	277	6.2
25	76	4.2	124	4.6	179	4.9	242	5.3	310	5.6
30	94	3.4	147	3.8	206	4.3	273	4.7	345	5.0
35	113	2.8	171	3.3	234	3.8	304	4.2	380	4.5
40	133	2.4	195	2.9	262	3.4	336	3.8	416	4.2
45	153	2.1	219	2.6	290	3.0	367	3.5	450	3.8
50	171	1.9	241	2.3	417	2.8	397	3.2	484	3.6

4.11.4 Change in Trolley Wire Levels

4.11.4.1 Loss of contact, defined as separation between the current collection equipment and the trolley wire and fittings, shall not exceed 1% at normal service speeds. Dramatic change in trolley wire levels can cause loss of contact.

4.11.4.2 Due attention shall be paid to ensure smooth transition of trolley wire levels.

4.11.4.3 The desired max. trolley wire gradient shall be determined by the formula below:

Desired max. Gradient = 1 in (5 X Practical Speed in km/h).

4.11.4.4 The absolute maximum gradient shall be 1 in 75.

4.11.5 Not in use

4.11.6 Tangent track (Straight Track)

4.11.6.1 On tangent or straight tracks, the stagger shall alternate on either side of the centre line in a zigzag pattern reaching a maximum offset of 230mm from the centre line before crossing back to the other side.

4.11.6.2 A mirror gauge or laser panto-gauge shall be utilised to set the trolley wire offset/stagger with respect to the centre line of the track.

4.11.7 Curved track

4.11.7.1 For pantograph only operations, trolley wire shall be allowed to be staggered to maximum of 300mm towards outside of the curve with the support of suitable fittings approved by Yarra Trams.

4.11.7.2 A mirror gauge or laser panto-gauge shall be utilised to set the trolley wire offset with respect to the centre line of the track.

4.12 Other Tramway Overhead Infrastructure Requirements

4.12.1 Pantograph only Operation

4.12.1.1 Only fittings type approved by Yarra Trams and suitable for pantograph only operations shall be used on new or renewed lines.

4.12.1.2 All overhead fittings shall be Type Approved through the Yarra Trams Type Approval process.

4.12.1.3 The design and installation of overhead fittings shall ensure smooth transition from the trolley wire to the fitting and vice versa.

4.12.1.4 For pantograph passage, a flat surface shall be provided over the entire length of the fitting.

4.12.2 Assembly Methods

4.12.2.1 All components shall be assembled in a manner which ensures that fasteners are tightened to the correct torque and they will not work loose due to vibration or other factors. It shall be possible to dismantle fittings for adjustment, maintenance or replacement.

4.12.2.2 For proprietary items the manufacturer's installation procedure and specifications shall be adhered to. All such details shall be provided to Yarra Trams prior to implementation of said proprietary items.

4.13 Tramway Overhead Infrastructure Component and Assembly Details

4.13.1 Poles

4.13.1.1 Poles shall be constructed to comply with Standard Drawing STD_T0316 Steel Tram Pole in Ground Mounted Rating 6.5./11, 12/11, 22/12.

4.13.1.2 The poles shall be constructed from two diameters of circular hollow steel section in accordance with Table 4, Pole Anchors, Footings, Specifications and PTC Drawings, below and shall comply with AS/NZS 1163:2016 Cold-formed structural steel hollow sections. Structural steel plate shall be grade 250 and the yield stress shall be not less than 340MPA. All welding shall comply with AS/NZS 1554 SET: 2014 Structural Steel Welding Set

4.13.1.3 Galvanized steel poles shall be used to support the overhead system and comply with AS/NZS 4792:2006 Hot dip galvanized (zinc)coatings on ferrous hollow sections, applied by continuous or specialized process.

4.13.1.4 If the position given on concept drawings interferes with any of the above and necessitates the relocation of the pole, the revised position shall not vary from the original in a way that jeopardises the layout of the network or interferes with vehicles, pedestrians or council standards.

Information: In some instances, the location and number of poles to be installed may vary, due to external factors such as the planning process and the presence of underground services or encumbrances.

4.13.1.5 No assets shall be attached to the poles for a minimum period of 7 days after pole installation.

Table 4 - Pole Anchors, Footings, Specifications and PTC Drawings

Description	Footing	Specification	Section		PTC Drawing No.
			Upper	Lower	
Span Pole (6.5 kN/11m)	Planted	i022ts0002	219.1x8.2CHS x 5m	273.1x9.3CHS x 6m	STD_T0316
Light Anchor Pole (12 kN/11m)	Planted	i022ts0002	273.1x9.3CHS x 5m	323.9x9.5CHS x 6m	STD_T0316
Heavy Anchor Pole (22 kN/12m)	Planted	i022ts0002	273.1x9.3CHS x 4m	323.9x12.7CHS x 8m	STD_T0316
Slim Anchor Pole (11 kN/11.8m)	Planted	i022ts0002			STD_T0317
Span Pole (6.5 kN/9m)	Base Mounted for Spread Footing	i022ts0002	219.1x8.2CHS x 5m	273.1x9.3CHS x 4m	o15-168-B
Light Anchor Pole (12 kN/9m)	Base Mounted for Spread Footing	i022ts0002			o15-168-B
Heavy Anchor Pole (22 kN/9m)	Base Mounted for Spread Footing	i022ts0002			o15-168-B
Centrally Mounted Span & Lighting Pole (8 kN/14m)	Planted	i022ts0002	219.1x8.2CHS x 6m	273.1x9.3CHS x 8m	o14-339
Anchor Pole with Dual Cantilever Capacity (17 kN/14m)	Planted	i022ts0002	273.1x9.3CHS x 6m	323.9x12.7CHS x 8m	o14-346

4.14 Installation and Removal of Tram Overhead Support Poles

4.14.1 When installing or removing tram overhead support poles the Yarra Trams Process Control Document, Installation and Removal of Tram Overhead Support Poles, Number i601wi0384 shall be referred to and the procedure followed.

4.14.2 Pole Inspection and Testing

4.14.2.1 Yarra Trams shall reserve the right to request appropriate testing be carried out as required or to obtain appropriate documentation proving that the pole quality and pole strength is satisfactory in the network.

4.14.2.2 In all cases the testing and inspection authority shall refer to and follow the procedure documented in the Yarra Trams Process Control Document, Overhead Support Structure Examination, Number i022wi1000.

4.14.3 Lighting Arms

4.14.3.1 The attachment of lighting arms to Tram Poles used and maintained by Yarra Trams shall be in accordance with the VicTrack's TS-SP 066 Engineering Specification: Attachments to Tram Poles.

4.14.3.2 Installation of the lighting arms onto the poles shall occur at least seven days after pole installation.

4.14.3.3 A 3mm diameter galvanised steel soft wire (fencing wire) shall be used to provide a draw wire for the arms to allow installation of the lighting cable through each of the arms. Also, a length of the same draw wire shall be provided through the centre of the pole to enable the lighting cable to be pulled up through the hollow section of the pole entering through the 50mm hole drilled 500mm from ground level.

4.14.3.4 All lighting fittings and associated wiring shall be double insulated from the pole.

4.14.3.5 No Earth connection shall be connected to Yarra Trams' poles.

4.15 Trolley Wire Support via Straight Steel Cross Span

4.15.1 Steel Cross Span

4.15.1.1 Where there is no curvature in the track, straight support spans shall be constructed using 8mm stainless steel wire rope to Specification TMO20/OH/09/07, with insulators complying to requirements of this standard.

4.15.1.2 The wire rope shall be terminated using preformed terminations to Specification TMO21/OH/09/07 or swaged fittings.

4.15.1.3 The swaged fittings shall be aluminum alloy for machine swaging or copper for hand swaging and shall be sized to suit 8mm wire rope.

4.15.1.4 Swaged terminations shall not fail at a load lower than the minimum breaking load of the wire rope.

4.15.1.5 The construction of straight cross spans shall be carried out as per Drawings No. o15-194.

4.15.1.6 Starting at the end of the trolley wire fitting, the cross span shall slope upwards from the horizontal and towards the pole or wall attachment. This upward gradient shall be approximately 1 in 10 for 129mm² trolley wire depending on the actual fittings and wire loading.

4.15.1.7 To prevent excessive sag and overturning of trolley wire fittings, span wire shall be pre-tensioned by applying 2-3 kN lateral force before loading up trolley wire and fittings.

4.15.1.8 Span wires made of composite materials, such as Kevlar Type F ropes, shall not be used on curved tracks unless approved by Yarra Trams.

4.15.2 Detailed Steel Cross Span Construction (Refer Drawings)

4.15.2.1 The standard steel wire rope cross-span shall be composed of eight (8) lengths of 8mm wire rope, and seven (7) silicon loop insulators. Refer to Standard Drawing o15-194 for detailed span construction.

4.15.3 Pole Attachments

4.15.3.1 End of the span wire shall be attached to the pole via a standard type pole band to Drawing No. o6897 Type 2, sized to fit the diameter of the pole.

4.15.4 Wall Attachments

4.15.4.1 New wall attachments shall not be installed without the expressed approval (in writing) of the building owner.

4.15.4.2 15/12.5mm high/wide lettering shall be impressed on all new wall attachment brackets, indicating manufacture month and year.

4.15.4.3 New wall attachments shall be tested as per existing wall brackets but only when the manufacturer's specified curing time for the chemical anchor has elapsed and prior to the attachment of any other loads.

4.15.4.4 All existing wall attachments shall be proof tested by the application of a load of 18kN. A load cell or equivalent equipment shall be utilised to measure the load. Wall attachments that withstand the designated proof load shall be re-used subject to approval from Yarra Trams.

4.15.4.5 Standard new and replacement wall attachments shall be per Drawing No. o14-308; Non-standard wall bracket design may be required to suit special site conditions.

4.15.4.6 End of the cross span or pull-off shall be attached to the wall attachment via a standard “U” shackle per Drawing No. Q3362 type 1 or 2 depending on application requirements.

4.15.4.7 If a shackle of other type is used it shall have a minimum breaking load of 20 kN or a Working Load Limit of 12 kN and be approved by Yarra Trams.

4.15.4.8 Any wall attachment that fails the proof test shall be replaced.

4.16 Suspension Systems for Cross Span Support

4.16.1 Hanger and Ear Suspension

4.16.1.1 Hanger and Ear trolley wire suspension systems shall not AFAIRP be installed on new or upgraded network. Existing Hanger and Ear systems shall be replaced with elastic systems using pendulums and steady arms.

4.16.1.2 For curved networks fixed hanger and ear systems shall be avoided.

4.16.2 Single Pendulum or Double Pendulum

4.16.2.1 The Single Pendulum and Double Pendulum assemblies supported on cross spans shall be in accordance with Drawing o14-500.

4.16.3 Trolley Wire Support via Boom Tube

4.16.3.1 Supported on boom tubes, the installation of the Single Pendulum or Double Pendulum or Pull-off Arm elastic suspension assemblies shall be in accordance with Drawings o14-545 (typical), Q6060, and o14-531.

4.16.4 Boom Tube

4.16.4.1 The steel boom tube shall be manufactured to Drawing No. F12075. Where applicable the boom tube shall be manufactured of:

- Elektroline (or equivalent) GRP 55mm solid rod; or
- Steel tube, having been “Type Approved” via the Yarra Trams Type Approval process.

4.16.4.2 The specifications of the Boom Tube material are:

- Welded mild steel tube;
- Outside Diameter of 60.3mm;
- Wall Thickness of 5.4mm to A.S. 1163; or alternately
- Refrigerant pipe, to identical specifications.

4.16.4.3 Mild steel boom tubes shall be hot dipped galvanised to AS4792. The external surface shall be smooth and free of 'run off'. The internal diameter of the tube shall be no less than 47mm after galvanising.

4.16.4.4 For each location, the length of the boom shall be appropriate to the overhead support / track layout geometry.

4.16.5 Boom Tube Insulation

4.16.5.1 Elektroline GRP boom tubes shall be suitably insulated to nominal system voltages.

Information: GRP booms should not be used in or near to salt water environments “Seaside” routes.

4.16.5.2 The steel boom tube shall be connected to and insulated from the pole by a polymeric strut type insulator.

4.16.5.3 The insulator shall have the following Mechanical characteristics:

- Minimum Tensile Breaking Load 40kN
- Minimum Compression Failing Load 40kN
- Minimum Bending Breaking Load 270kN

4.16.5.4 The insulator shall have the following Electrical characteristics:

- Minimum Creepage Distance 370mm
- Power Frequency Wet Withstand Voltage 50kV
- Impulse Withstand Voltage (12/50 us wave) 125kV

4.16.6 Boom Tube Tie

4.16.6.1 The boom tube tie shall be constructed from Kevlar Type “F” rope with a 2 Tonne minimum breaking load Drawing No. D4465.

4.16.6.2 The Kevlar Type “F” rope tie shall be terminated in accordance with Drawing No. D4466.

4.16.6.3 The termination used shall be to Drawing No. D4464, Reference D4464/201 or D4464/204, or approved equivalent.

4.16.6.4 The boom tube tie shall be attached to the boom tube via a boom connector bracket, manufactured to Drawing No. D4953, retained and located on the boom tube by two 'U' bolts to Drawing No. D3933, Reference D3933/1.

4.16.7 Boom Tube Attachment to Pole

4.16.7.1 Two pole band assemblies shall be attached to each pole to enable the attachment of the boom tube and the boom tube tie.

4.16.7.2 The band assembly on centre pole structures with back-to-back single track cantilever arms, shall be per Drawing D5076.

4.16.7.3 The single cantilever, the band assembly shall be to Drawing No. D5075.

4.16.7.4 The boom tube insulator shall be attached to the lower band assembly pivot.

4.16.7.5 The boom tube tie shall be attached to the upper band assembly pivot.

4.16.7.6 The pole band shall be sized to suit the pole diameter for each location.

4.16.7.7 Alternatives to the above stated construction methods shall be subject to approval by Yarra Trams.

4.17 Suspension Systems for Boom Tube Support

4.17.1 Single Pendulum Fittings (Pantograph Only Operation)

4.17.1.1 A primary insulator shall electrically insulate the boom tube from the trolley wire.

4.17.1.2 All new systems shall use Electroline fittings

4.17.1.3 Single pendulum fitting shall be selected for locations where angle of trolley wire deviation is between 0 – 4 degrees.

4.17.1.4 The K&M single pendulum assembly No. 101678 shall be mounted to the boom tube as per Drawing No. o14-500/3 or and Electroline equivalent.

4.17.1.5 The assembly shall be adjusted to ensure the trolley wire seats horizontally and is without any twists, or kinks.

4.17.1.6 The Manufacturer's installation and adjustment instructions for the single pendulum equipment shall be followed.

4.17.2 Pull Off Arm Fittings

4.17.2.1 Single steady arm shall be selected for locations where angle of trolley wire deviation is between 4 – 9 degrees; where angle of trolley wire deviation is greater than 9 degrees, double steady arms shall be utilized.

4.17.2.2 The K&M single steady arm assembly No. 102660 and double steady arm assembly No. 102661 shall be mounted to the boom tube as per Drawing No. O16-103 or Electroline equivalent.

4.17.2.3 The assembly shall be adjusted to ensure the trolley wire seats horizontally without any twists, or kinks.

4.17.2.4 The Manufacturer's installation and adjustment instructions for the single pendulum equipment shall be followed.

4.17.3 Trolley Wire Support Beneath Bridges and within Depot Buildings

4.17.3.1 Where a trolley wire is installed adjacent to other structures such as bridges or with depot buildings, insulation provision shall be made to ensure the pantograph does not create an electrical bridge between the trolley wire, trolley wire supporting infrastructure and the structure (bridge or building etc).

4.17.3.2 The insulating provision used in clause 4.17.3.1 shall be adequate to provide protection against electricity injection and shall protect authorised “live line” personnel.

4.17.3.3 The insulation shall be attached to the bridge or building by framework or brackets. There shall be no exposed earthed components in the vicinity of the trolley wire

4.17.3.4 The height of the supporting framework shall be as compact so that the standard trolley wire height of 5.64 metre can be maintained.

4.17.3.5 The framework shall be designed to ensure that the insulation is solidly supported, and its joints are level and straight.

4.17.3.6 The framework shall be designed to prevent inadvertent earthing or flashover of resilient fitting mounts.

4.17.3.7 Where a bridge superstructure is more than 1.0 metre above the trolley wire, alternative protection shall be provided by the installation of durable sheeting made from insulating materials adequately affixed so that it maintains a minimum lateral coverage of 750mm on each side of the trolley wire.

Information: 4.27.3.7 above now applies uniformly across the network

4.17.3.8 No earthed fastenings shall project below the inverted insulated surfaces of the insulators.

4.18 Electrical Protective Troughing and Flat Type Protection

4.18.1 Flat type protective system

Information: Various flat type protective systems mainly made from fiberglass materials have been developed for Pantograph only operation.

4.18.1.1 Flat type protective system shall be able to:

- Achieve separation between trolley wire registration and protective panel;
- Utilise elastic trolley wire registration fittings
- electrically insulate against a 600V dc nominal working voltage.

4.18.2 Troughing

Information: Troughing has been included in this standard for the sake of consistency and practicality where tram infrastructure reconstruction and heavy maintenance is required on existing structures such as bridges and depots. No new systems use troughing please refer to 4.27.3.7 above.

4.18.2.1 The fibreglass troughing shall:

- be supplied in 3 m lengths
- be electrically insulating against a 600V dc nominal working voltage.
- be UV stabilised (gelcoat UV stabilised).
- not support combustion (fire retardant resin).
- have high resistance to impact.
- have good surface finish, especially the inside.

4.18.2.2 The fibreglass walls of the troughing shall have a minimum thickness of 6mm.

4.18.2.3 Multiple lengths troughing shall be where applicable, joined to form one continuous length. In such applications, galvanised steel "Unistrut" channel shall be used to provide support of troughing being attached to above structures

4.18.2.4 The "Unistruts" shall be 41mm by 21mm with a wall thickness of 2.5mm and shall run the full length of the troughing.

4.18.2.5 To protect the troughing side walls against impact, steel plate ribs 50mm wide by 3mm thick shall be formed to follow the profile of the side wall.

4.18.2.6 The ribs shall be spaced at 500mm intervals and shall be welded to the "Unistrut".

4.18.2.7 The steel ribs shall be embedded in the fibreglass in a manner that ensures there are no protrusions on the inside of the troughing whilst maintaining a minimum fibreglass cover of 4mm on each side of the steel plate.

4.18.2.8 The plate shall extend horizontally 75mm from the "Unistrut" channel at the upper end of the wall of the troughing.

4.18.2.9 To ensure proper keying between the fibreglass and the steel plates several 5mm holes shall be drilled on the plate.

4.18.2.10 The troughing installation shall be level and without sag.

4.18.2.11 Individual troughing lengths shall be joined together using two 40mm wide x 12mm thick x 185mm long galvanised steel flats and four galvanised M12 hexagon headed structural bolts per flat.

4.18.2.12 The troughing shall protrude a minimum distance of 600mm beyond each side of the bridge.

4.18.3 Troughing Support

4.18.3.1 The ends of consecutive lengths of troughing shall be butted together and a pair of galvanised steel plates shall be used to splice the "Unistrut" channels of consecutive lengths of troughing.

4.18.3.2 Each plate shall be attached to the "Unistrut" channel of each butted length of troughing by using two M10 structural screws and spring loaded "Unistrut" nuts.

4.18.3.3 Troughing shall not have an unsupported span length of more than 1.0 metre.

4.18.3.4 At intervals not exceeding 1.0m, the troughing shall be supported from the support frame structure above, by bolting to each of its encased "Unistrut" channels.

4.18.3.5 A 75SHS central steel spine with transverse flats welded to its upper and lower surfaces at appropriate intervals shall be used for fixing to the superstructure (upper) for adequate troughing support (lower).

4.18.3.6 To support the troughing beneath bridges, a steel framework spine shall be designed for attachment to the underside of the bridge.

4.18.3.7 The frame shall be galvanised and have attachment for troughing support at intervals of not more than 1.0 metre.

4.18.3.8 The frame shall be attached to steel bridge girders approximately perpendicular to the trolley wire by "Type A M12" Lindapters or other suitable non-drilling required fasteners approved by Yarra Trams' Engineering Change Management process.

4.18.4 Steel bridge girders approximately perpendicular to the trolley wire.

4.18.4.1 Z" type brackets designed for the support of troughing shall be provided to Yarra Trams for approval.

4.18.4.2 Each bracket shall be comprised of a piece of 40mm x 12mm flat, bent so that each end is horizontal and parallel and with a short vertical step between.

4.18.4.3 The height of the step shall be less than the thickness of the flange. The lower level shall have 2 x 14mm diameter holes drilled for M12 bolts.

4.18.4.4 The brackets shall be erected with the underside of the upper level atop the beam flange so that when the bolts through the lower level holes to the troughing are tightened, the troughing "Unistruts" will bear firmly beneath the underside of the flange.

4.18.5 Steel Bridge Girders approximately parallel to the trolley wire.

4.18.5.1 A suitable attachment detail for the "Z" type brackets shall be provided.

4.18.5.2 This shall consist of a series of structural steel flats or angles which are firmly clamped or fastened to the flanges of the girders.

Information: Welding is not permitted or drilling of bridge members or any other modification is permitted without the written approval from the Department of Transport's Manager of Structural Engineering and/or from the owner of the bridge.

4.18.5.3 The troughing shall be attached to the angle flange or flat by using "Z" type (step) brackets or by bolting directly to them.

4.18.6 Concrete Bridges

4.18.6.1 For concrete bridges suitable troughing attachment detail shall be provided.

4.18.6.2 The attachment shall consist of a structural steel flat which is sufficiently wide to straddle the troughing and which has another short length of structural flat welded to each end to "step" the plate.

4.18.6.3 The lower dropped plate shall have 2 x M14 holes drilled for M12 structural bolts into the "Unistruts" and the (upper level) end plates shall be drilled for attachment to the concrete bridge soffit.

4.18.6.4 The height of the step shall be such that the M12 structural bolt heads do not bear directly against the bridge soffit.

Information: Fabrication or field works or any modification, to attach to any part of a bridge is not permitted without the written approval from the owner of the bridge and any other related authorities.

4.18.7 Semi-Elastic Support Arms (Resilient Fittings)

4.18.7.1 In all new constructions and replacements, only YT Type Approved fittings shall be used.

4.18.7.2 Under structures the trolley wire shall be supported by elastic support arms. The semi-elastic support arms shall be attached to the underside of the troughing.

4.18.7.3 For the standard trolley wire height of 5.640 metres, the spacing of the elastic support arm shall
be 6.0 metres.

4.18.7.4 Where the height of the trolley wire drops to below 5.64 metres, the spacing of the elastic support arms shall be less than 6m to compensate for the increased upward force exerted by the pantograph of the tram.

4.18.7.5 If the track beneath is curved, the spacing of the elastic support arms shall be reduced to a spacing of not more than 2.0metres.

4.18.7.6 The elastic support arm shall be attached to the troughing via the cranked plate (Siemens m8WL 3575-0) supplied with it or Electroline equivalent.

4.18.7.7 At the point of installation 2 x 18mm diameter holes shall be drilled at 105mm centres through the upper wall along the longitudinal centre line of the troughing.

4.18.7.8 A spreader plate shall be manufactured by drilling 2 x 18mm diameter holes at 105mm centres for M16 structural bolts in a steel plate of dimensions 80 x 3 x 210.

4.18.7.9 To prevent rotation the inserted bolts shall be welded to the plate which is then fibreglass coated for electrical insulation purposes.

4.18.7.10 The structural bolts from the spreader plate shall be inserted through the holes in the troughing and through the cranked plate beneath the troughing and the entire assembly tightened by using the nuts and spring washers supplied.

4.18.7.11 The structural bolts used to secure the elastic support arms to the troughing shall be kept clear, by a minimum distance of 80mm, from any part that can electrically bridge the structure which supports the troughing.

4.18.7.12 The holes shall also be clear from the steel troughing ribs by a minimum of 100mm.

4.18.7.13 The resilient fitting shall be installed with the main support arm pointing in the direction of tram travel.

4.18.7.14 Each end fitting shall be installed such that the trolley wire support point projects beyond the end of the troughing.

Information: Since the first resilient fitting encountered by an approaching tram is an end fitting, its orientation would be non-standard i.e. point opposite to the direction of tram travel.

4.18.8 Crossovers

Information: To enable trams to move from one tram track to another a crossover system is used.

The three basic variations of crossovers are:

- *Left Hand Cross Over*
- *Right Hand Crossover*
- *Scissor Crossover (Combination of Left and Right Hand)*

Whilst it is usual to have four (4) x poles to support the crossover, a greater number may be required depending on the location and offset of the poles and the width of the track centres.

4.18.8.1 Two (2) of the four (4) or more poles shall be light anchor poles, rated at 12kN/11m as per Drawing No. STD_T0316 or 11kN/11.8m and Drawing No. STD_T0317, to provide termination for cross over trolley wire.

4.18.8.2 Turnbuckles shall be used for wire terminations

4.18.8.3 The crossover trolley wire shall run centrally over the curved track within the limits of the pantograph pan running surface, the stagger limits being ±230 mm.

4.18.8.4 At the point of intersection, the crossover trolley wire shall cross above the main wire. The crossover wire shall then be lifted slightly and go out of running.

4.18.8.5 The intersecting trolley wires shall be adjusted to ensure smooth pick up of incoming trolley wire by the pantograph.

4.18.8.6 The straight and intersecting trolley wires shall be connected electrically utilising jumper cables assembly as per the trolley wire equaliser at both intersections.

4.18.8.7 Four (4) x Jumper cables shall be installed onto the trailing sides of the intersecting points between trolley wires of the cross over and the main lines.

4.18.8.8 Cross contact bar to Drawing No. O14-572 shall be installed at the intersecting points of the two trolley wires.

4.18.8.9 The crossing trolley wire shall extend past the transition point and be terminated and anchored to the two light anchor poles via termination legs as shown in Drawing No. o15-194/DN.

4.18.8.10 The trolley wire termination shall be anchored higher than the straight trolley wire.

4.18.8.11 Crossing trolley wire shall be terminated and anchored.

4.18.8.12 The wire rope tension members shall be attached to the pole in the same manner as the standard cross spans via a standard anchor band to Drawing No. o923

4.18.8.13 Kevlar 'Type F', rope with a minimum breaking load of 6 tonne shall be allowed to be used for trolley wire terminations.

4.18.9 Turnouts

Information: In some locations, such as at the termini, the two tracks merge into one.

4.18.9.1 This is called a turnout and shall be described, designed and constructed as a single ended crossover. At the intersecting point a contact bar to Drawing O14-572 assembly shall be installed as per crossover detail. The curved wire shall cross over the straight wire.

4.18.10 Intersection Crossings

4.18.10.1 Where tracks intersect, crossing fittings are required to facilitate crossing over of trolley wires. Crossing Pans, which have been used for a long time, shall be gradually phased out from the system due to their heavy weight and unsatisfactory performance.

4.18.10.2 In this standard Kummler & Matter Kudisc (assembly no. B1303) is listed and shall be used as replacement for crossing pan. Equivalent compatible designs must be Type Approved through the Yarra Trams' Type Approval process.

4.18.10.3 The angle of the Kudisc shall correspond correctly to the angle of intersection of the tracks. The angles of Kudisc ranges from 55 degrees to 90 degrees.

4.18.11 General Installation Requirements for Crossing Pans

4.18.11.1 The intersecting wires cross above the crossing pan and shall be bent ('crowed') correctly to ensure the Kudisc does not distort during the installation process.

4.18.11.2 The Kudisc shall be adjusted to sit level in both the longitudinal and transverse directions.

4.18.11.3 The crossings shall be located centrally to the track crossings (using a mirror gauge).

4.18.11.4 The Kudiscs shall be installed and adjusted to provide a smooth interface with the trolley wire and shall provide a smooth passage for pantographs without loss of contact.

4.18.11.5 The Kudisc shall be supported via a dedicated support network located above the crossings and connected to the crossings via stainless steel wires or approved alternative materials such as Kevlar Type "F" ropes.

4.18.11.6 Manufacturer instructions shall be followed during installation and maintenance.

4.18.12 Heavy Fittings Locations

4.18.12.1 When crossovers are renewed from old heavy fittings like frogs to new cross contact bars "elastic system", at least three (3) bays past the crossover on each side of the crossover shall be renewed to elastic fittings.

4.18.12.2 Where spans are renewed to elastic fittings and ends 3 bays before a crossover which has heavy fittings like frogs, the crossover and 3 bays past the crossover shall also be renewed to elastic systems during the same occupation.

4.18.12.3 The same principles shall apply to the following overhead assets class:

- Crossings (H-Crossings, Curves onto straight) and include:
    - Circular crossings
    - Kumax crossing
    - Frogs

- Crossovers including:
    - Frogs
- Turnouts including:
    - Frogs

4.18.12.4 The asset and spans three bays either side of the assets shall be converted to flexible fittings.

Information: It is not acceptable to finish rigid fittings up to flexible suspended assets or to have rigid support systems integrated with flexible systems.

4.18.12.5 In conjunction with this requirement poles shall also be upgraded as necessary to facilitate this requirement.

4.18.12.6 Poles shall be upgraded for the following reasons:

- Inadequate height
- Sleeved poles with limited life
- Poles not in a serviceable condition and will require changing in less than 2 years
- Poles not strong enough to hold the new tension of elastic system
- Location does not suit span wire arrangement

4.19 Trolley Wire

Information: Kevlar rope spans are not to be used in salty environments

4.19.1 Installation Requirements

4.19.1.1 The trolley wire to be installed shall be straight, free of kinks, twists and other defects and the cross-section profile shall not be deformed along the entire length of the wire.

4.19.2 Trolley Wire Standard

4.19.2.1 Cross sectional area of the standard trolley wire utilised by Yarra Trams shall be 129mm^2.

4.19.2.2 The trolley wire shall be tin bearing copper wire and shall conform in all aspects of Specification No. i601ts0001.

4.19.2.3 The profile of the trolley wire shall be as per Drawing O6887 Rev.B for 0.2 sq.in. trolley wire (129mm^2). For clarity Drawing O6887 has been reproduced below.

4.19.3 Trolley Wire Termination

4.19.3.1 The trolley wire shall be terminated to a Forked Collar Socket to Drawing No. D5480/3;

4.19.3.2 An eye-clevis type polymeric insulator shall then connect to the forked collar socket.

4.19.3.3 Then the trolley wire shall be terminated to anchor pole band mounted on the designated pole(s) or structure(s) using an 8mm stainless steel span wire with two (2) silicon insulators inserted or a 6 Tonne, Kevlar Type “F”, rope with a minimum breaking load of 6 Tonne.

4.19.4 Trolley Wire Splicing (Joining)

4.19.4.1 The trolley wire shall be run with the minimum number of joints.

4.19.4.2 To join two lengths of trolley wire, the splice ears utilised shall be of a proven design, comply with Specification TMO/02/06/92 and shall be approved by Yarra Trams.

4.19.4.3 The transition from trolley wire to the splice shall be smooth in both directions.

4.19.4.4 The surface where pantographs run shall be smooth and flat.

4.19.4.5 For new trolley wire installations, splices shall only to be installed within 1.50 metres of cross support spans.

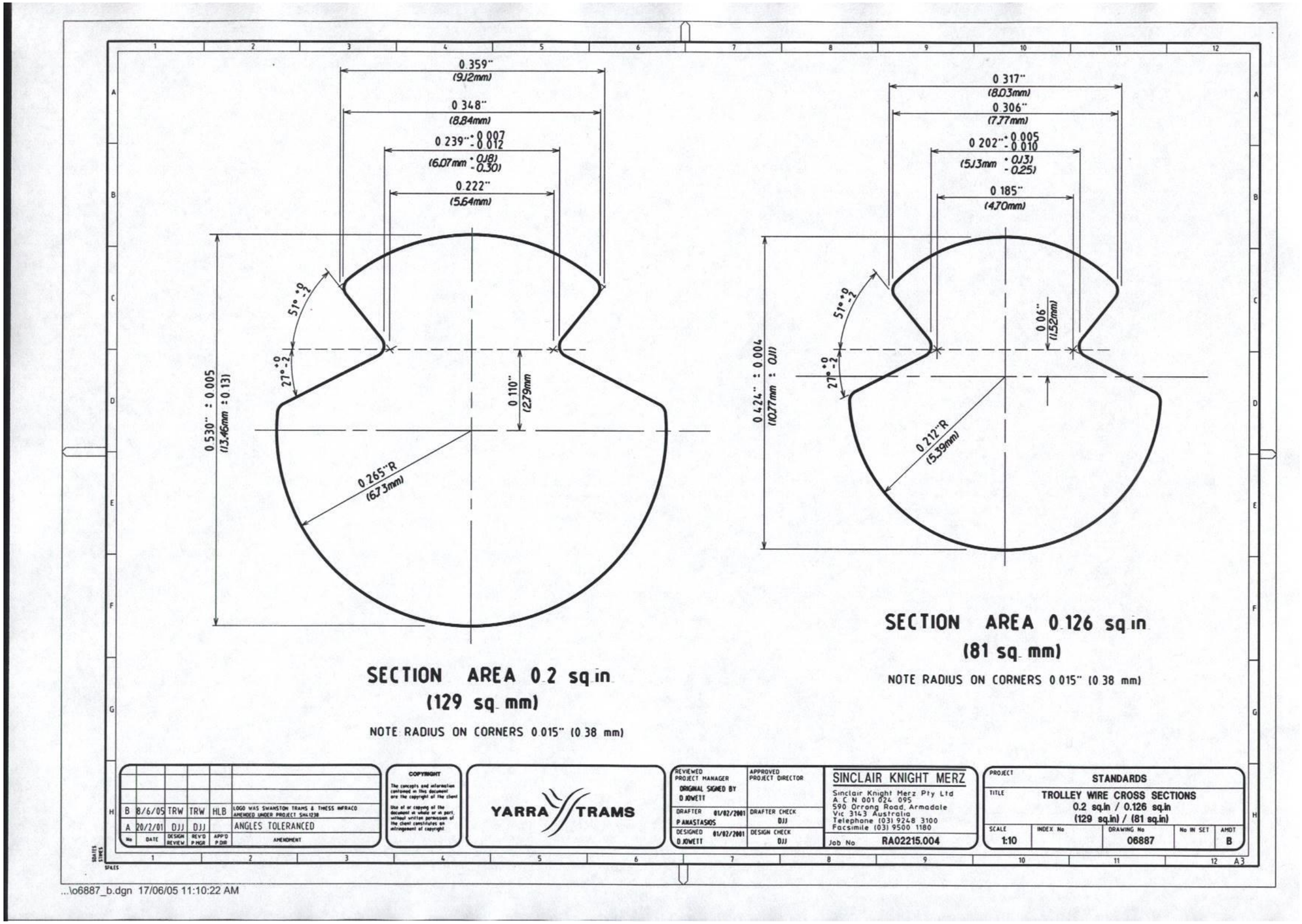

Figure 1. Drawing O6887 Rev.B for 0.2 sq.in. trolley wire (129mm²) and 0.126 sq.in. trolley wire (81 mm²)

4.19.5 Trolley Wire Current Equalizer

4.19.5.1 To bridge the up and down trolley wires, a trolley wire equaliser shall be installed every five poles / bays.

4.19.5.2 The equalizer shall comprise a feeder ear attached to each trolley wire and connected via a length of 185mm^2. double insulated flexible cable (specified in the Clause "Feeder tap to trolley wire cable") which is supported on an independent Kevlar Type “F” cross span located above the standard cross span as per Drawing No. O14-606.

4.19.5.3 The flexible cable shall be supported on the cross span by wrapping, in a spiral form, 1.50 metres, 7/0.50mm insulated copper building wire over the entire supported length.

4.19.6 Trolley Wire Anchoring for Sharp Radius Curves

Information: In some cases, straight runs of trolley wire are tensioned to a higher tension (10kN at 0°C) than that for trolley wire on curves (8kN at 0°C).

4.19.6.1 To compensate for differential in tension, a trolley wire anchor shall be installed to transfer the tension imbalance to adjacent poles.

4.19.6.2 For the lower tension of trolley wire applied in this instance the 8mm stainless steel wire rope utilised for the cross spans should be used.

4.19.6.3 Each trolley wire anchor assembly shall consist of two separate legs anchored to poles on either side of the track. Typical legs assembly is shown on Drawing No. O14-599 with GY1 insulator replaced by silicon loop insulators.

4.19.6.4 The wire or Kevlar Type “F” rope tension members shall be attached to the pole in the same manner as the standard cross spans with loop insulators via a standard pole band to Drawing No. o6897.

4.19.6.5 In each trolley wire anchor leg loop insulators shall be incorporated at approximately 1.5m from attachment points of the trolley wire anchor bar and the additional 2 no. loop insulators at 1.55m and 0.35m off the pole.

4.19.6.6 Additional insulators shall be required where the anchor wire runs above other live conductors. Positions of these insulators shall be offset by 1.0m from track centres.

4.19.6.7 The wire, Kevlar Type “F” rope shall be terminated with aluminum or copper swaged ferrules or galvanised steel preformed helical terminations, using galvanised steel thimbles where applicable.

4.19.6.8 The detensioner installation shall be provided with guard bars, located between the legs of the anchoring arrangement, to ensure the Pantograph does not become entangled.

4.19.7 Trolley Wire Anchor Assembly (Hanger & Ear Suspension)

4.19.7.1 Each anchor assembly shall be comprised of a galvanised steel anchor bar as per Drawing O7466, two standard 10" (254mm) line ears, a hanger as per Drawing O13-983, an 8mm alloy Dee shackle, quality grade S and a 12mm bull ring.

4.19.7.2 The male line ears shall be attached to the anchor bar with 3/4" brass nuts each fitted with a spring washer.

4.19.7.3 The hanger shall be attached to the ear closest to the bent end of the anchor bar via the 3/4" screw. The shackle shall be threaded through the bull ring and attached to the 7/16" diameter hole of the anchor bar.

4.19.7.4 The legs (pull offs) transferring the tension to adjacent poles shall attach to the bull ring.

4.19.7.5 The assembly shall be located on a cross span.

4.19.7.6 If this is not possible, the assembly shall be installed on a centre between cross spans (i.e. mid pole bay) with span anchors to locate it.

4.19.8 Trolley Wire Anchor Assembly (Pendulum/Pull Off Arm Suspension)

Information: Trolley wires supported by pendulum are tensioned to a higher tension than that for trolley wire supported by fixed cross span system or by curved cantilever with ear and hanger system.

4.19.8.1 To compensate for this differential in tension, a dual running trolley wire tensioner shall be installed to transfer the tension imbalance to adjacent poles utilising 11mm, 6X25(12/6+6/1) RHOL 1 WRC G2070 galvanised 'Tirfor' wire rope.

4.19.8.2 Each tensioner assembly shall consist of two separate legs anchored to poles on either side of the roadway. Typical legs assembly is shown as per Drawing O14-315.

4.19.8.3 The angle between the trolley wire and any anchoring leg shall not exceed 45 degrees.

4.19.8.4 Trolley wire supported by standard hanger and ear suspension is tensioned to a lesser tension than for pendulum suspension and the anchorage detensioning system employed shall be in accordance with PTC Drawing No. O14 - 599.

4.19.9 Trolley Wire and Boom tube Anchoring (Pendulum/Pull Off Arm)

4.19.9.1 With pendulum installations, the trolley wire and the boom tubes shall be anchored to adjacent poles at 400 metre intervals, this is to minimise the adverse effects of possible trolley wire breakage.
(See Drawing No. O14-546).

4.19.10 Boom Tube Anchoring

4.19.10.1 At the point of anchoring, the boom tubes of two consecutive poles shall each be anchored to the adjacent poles thus preventing excessive movement of the tubes towards the space between the two consecutive poles (Boom Anchor Leg).

4.19.10.2 A steel wire rope tie or Kevlar Type “F” with a minimum breaking load of 6 Tonne shall be strung between the boom tubes of the consecutive poles preventing excessive movement of the boom tubes away from each other thus forming an 'Anchoring Catenary'.

4.19.10.3 The Boom Anchor Legs and Anchoring Catenary shall be made from 11mm, 6X25(12/6+6/1) RHOL 1 WRC G2070 galvanised 'Tirfor' wire rope or alternatively from, Kevlar Type “F” rope with a minimum braking load of 6 Tonne.

4.19.10.4 A load test certificate shall be provided for brackets supporting boom tubes.

4.19.10.5 Insulators shall be inserted in line with the Tirfor wire as per Drawing O14-546.

4.19.10.6 The following describes how the boom anchor legs shall be attached to the pole:

- An anchor band as per Drawing No. O923 shall be attached to the pole.
- A piece of 13mm galvanised steel chain, 350mm long, shall connect the anchor band to a silicon loop insulator. Another piece of 1.20 metres long steel wire chain shall connect the loop insulator with another one. The wire rope is then connected to the second insulator.
- In each boom anchor leg a loop insulator shall be incorporated at approximately 1.75m from the attachment point of the disc insulator.
- The boom anchor legs and anchoring catenary shall be attached to the boom tube as described below:
- Two boom connector brackets, to Drawing No. D4953, shall be attached back to back the boom tube.
- A clevis thimble shall be attached to each boom connector bracket.
- A GY2 insulator shall be incorporated in the Tirfor wire 1.75m from the boom connector bracket.
- The wire rope shall be terminated with galvanised steel preformed helical terminations using galvanised steel thimbles where necessary.
- A loop insulator shall be inserted 1.0 metre on either side from the midpoint of the anchoring catenary.
- At 2.0 metres from the centre of the loop insulator a 16mm bull ring, per Drawing D3885 Reference D3885/2, shall be included in line with the wire rope.
- A Rebosio tension type insulator per Drawing No. D3677 shall be connected between the bull ring and the wire rope of the anchoring catenary.
- Should an adjacent pole, to which boom tubes are anchored, have inadequate load capacity in the event of wire failure, the pole shall be stabilised by the provision of a back anchor to the next external adjacent pole.

4.19.11 Trolley Wire Mid-bay Anchoring

4.19.11.1 The trolley wire shall be anchored mid-bay below the Anchoring Catenary. An approved trolley wire splice shall be placed on top of the trolley wire mid-way between the consecutive poles where anchoring is to occur.

4.19.11.2 Construction of the mid-bay anchor shall be as per detail ‘4’ in Drawing No. o14-546.

4.19.11.3 Alternative mid-bay anchor construction methods may also be accepted but details shall be submitted to Yarra Trams for approval via the Engineering Change Process.

4.19.11.4 Mid-bay anchors and or detentioners shall be attached to new poles that can support loads of at least 12kN.

4.19.12 Bull Rings

4.19.12.1 Galvanised steel bull rings shall be utilised where two or more wire rope members in tension (such as pull-offs, lacing or cross spans) act radially through a common point.

4.19.12.2 There are three sizes currently utilised and they shall be correctly chosen for each application with consideration given to the number of fittings and the magnitude of forces acting at the point where the bull ring is used. Standard Drawing No. D3885, shall be used for the following common applications:

- D3885/1 12.7mm thickness, would be used for linkage points.
- D3885/2 15.9mm thickness, would be used for holding 2 to 3 legs.
- D3885/3 12.7mm (heavy duty) thickness, would be used for network spine applications.

4.19.12.3 Bull rings shall be manufactured in accordance with Standard Drawing No. D3885.

4.19.13 Curves and Junctions – Fixed System

4.19.13.1 Span networks shall be erected to provide support and restraint for the trolley wire and all the associated components required to make up the curve or junction.

4.19.14 Span Network

4.19.14.1 Spans shall not go through trees for new overhead network design.

4.19.14.2 Where trees must be considered, extra pole/s shall be installed, or the use of V-pulls shall be considered.

4.19.14.3 The attachment structure or pole shall be insulated from the cross spans by using two loop insulators at 350mm and 1.55 metres from the pole.

4.19.14.4 If required more than one pull-off span shall be attached to the pole via 350mm and 1.20 metres wire-insulator links and bull ring.

4.19.14.5 The number of pull off spans to be attached on each bull ring shall be determined by the loads applied in each specific situation and shall not exceed three.

4.19.14.6 Spans extending straight across two poles shall be attached to the poles independently from other pull-off spans.

4.19.14.7 All wire rope parts of the network shall be terminated using corrosion resistant Aluminium alloy or copper swaged fittings or preformed helical terminations to Specification TMO/05/07/92.

4.19.14.8 The installation shall be machine crimped with machine crimped fittings except where hand crimping necessary.

4.19.14.9 Hand crimping with hand crimp fittings shall only be used on single wire support spans which are not under excessive loading.

4.19.14.10 Except for wire rope sections of the network that are shorter than 700mm, at least one end of every wire rope section shall be fitted with a preformed helical termination to provide adjustment.

4.19.14.11 The distance and alignment of centre spans on curves shall be determined such that:

- The trolley wire is always within the allowable stagger envelop.
- Radial load exerted from trolley wire angle of deviation shall not exceed maximum allowable load permitted by supporting wire and fittings.
- The span shall be as close as possible to be perpendicular to the trolley wire support point to prevent fitting roll over.

4.19.15 Trolley Wire Suspension

4.19.15.1 The trolley wire shall be suspended in the manner described for the straight span (clause 4.19.14) with the following exceptions:

- Fittings of solid suspension type such as holders can be used to achieve levelling between two or more trolley wires.
- Where usage of steady arms is restrained by confined space.

4.19.15.2 Solid suspension type fittings shall only be used when the design can prove that it is not practicable to use flexible suspensions.

4.19.15.3 Flexible suspensions shall not be used, as they are impractical in the arrangement.

4.19.15.4 There shall be no more than two (2) rigid fittings in any curve.

4.19.15.5 Rigid fittings shall not be used on any weight tensioned curve.

4.19.16 Trolley Wire Anchoring

4.19.16.1 If required by Yarra Trams, a trolley wire anchor shall be installed on each trolley wire at either end of each curve to maintain the tension on the straight section at the approaches to the curve and limit the tension of the trolley wire within the curve.

4.19.16.2 The remaining tension on the curve trolley wire must be adequate to ensure that the curve wire remains tight and that the flexible fittings remain at the correct height without down pull.

4.19.16.3 The tension on curved trolley wire shall be no less than 8kN.

4.19.17 Curves and Crossings

4.19.17.1 All fittings used on curves and at junctions shall comply with the relevant clauses in this standard.

4.19.17.2 Heavy fittings developed for dual running shall not be used.

4.19.18 Trolley Wire Offset

4.19.18.1 A mirror gauge or laser panto-gauge shall be correctly utilised to set the trolley wire offset with respect to the centre line of the track.

4.19.18.2 Plumb bobs shall be used for construction only where it can be demonstrated that no super-elevation exists on the track.

4.19.18.3 For fixed registration points, trolley wire shall be staggered to ±230mm for tangent tracks and ±300mm for curved tracks respectively.

4.19.19 Section Insulator Assembly

4.19.19.1 Section insulators shall be used to enable electric isolation of sections of the overhead system from adjoining sections.

4.19.19.2 Suitable type of section insulators shall be selected to achieve isolation of different electrical sections whilst providing smooth passage to pantographs.

4.19.19.3 The insulation runner for the section insulator shall be manufactured from materials with high resistance to arcing and mechanical wear.

4.19.19.4 Section insulators shall be either bridging or non-bridging type, subject to operation requirements and approval by Yarra Trams.

4.19.19.5 Bridging section insulator, the ears shall be outside the 340mm zone. This shall prevent annealing and shall allow for the capturing of the wire if the wire fails.

4.19.19.6 Where installed adjacent to a bridge, the section insulators shall be of the shear pin type.

4.19.19.7 Bridging insulators shall not be used where trams stops especially at platforms or areas where trams get stuck under such insulators.

4.19.20 Installation of the Section Insulator

4.19.20.1 Whenever a new pair of section insulators are to be installed, two new 12 kN poles shall be installed. However, if there are existing 12kN poles at the location an assessment shall be performed to confirm that the poles are fit for purpose.

4.19.20.2 The section insulator shall be supported from a standard steel cross span in a manner that enables the section insulator to 'float'. Refer to standard Dwg No. 995317_301.

4.19.20.3 The cross span shall be constructed as per the detailed construction of the steel cross span of this standard with the trolley wire registration fittings being replaced with the nominated section insulator.

4.19.20.4 The section insulator shall be adjusted to provide a smooth passage for pantographs. Final adjustment shall be completed on site using turnbuckles.

4.19.21 Section insulator and adjacent span wires

4.19.21.1 When installing new elastic fittings or installing a new section insulator designers and maintainers shall ensure that the overhead support system does not transition between elastic and rigid fittings within three pole bays of the section insulator.

4.19.21.2 If Elastic support systems are used, it shall be installed at least three bays either side of the section insulator to ensure that the heavy fitting is in a flexible suspension system.

4.19.21.3 The section insulator shall also be installed on a flexible support system. Where existing poles do not allow for this change, new poles shall be installed.

4.19.21.4 In a situation where the existing Section insulator is suspended on a span with ears, the section insulator shall be renewed to one that is approved for elastic system.

4.19.21.5 Some adjustment/modification to the span wire shall be needed as the existing span wire may not be suitable for the new section insulator.

4.19.21.6 The adjustment/modification shall:

- Increase or decrease mechanical tension on the existing span wire
- Increase or decrease pole bands height
- Replace the span that's not in a good condition, example: rust, frayed, old porcelain insulator.
- Use Kevlar Type "F" rope with a minimum breaking load of 6 Tonne or 8mm stainless wire (preferred for use in salty environments) for new or replacement spans.

4.20 Aerial Switch (Isolator)

4.20.1.1 The aerial switch shall be utilised to enable:

- The bridging and isolation between underground feeder cables and overhead cables.
- The bridging and isolation between two sides of a section insulator.
- The bridging and isolation between two aerial feed cable termination points.

Information: Various applications of the aerial switch are shown on Drawing No. O14-930.

4.20.1.2 The pole on which the aerial switch is mounted shall be bonded to the tracks as per Drawing No. STD_T3001.

4.20.2 Aerial Switch

4.20.2.1 The standard switch installed shall be a 2,000 Ampere at 1000Vdc Panel Mounted Isolator (switch).

4.20.3 Aerial Switch Operating Gear

4.20.3.1 The aerial switch operating gear shall comprise of:

- An operating handle to Drawing No. O14-312, Items 4, 7 and 9. It shall include a length of 1/2" pipe to suit the height of mounting the switch box at each location.
- The locking band to Drawing No. O14-312 Item 6 (diam. to suit pole)
- The guide band to Drawing No. 014-312 Item 3 (diam. to suit pole)
- The fibreglass upper, operating insulated rod as per Drawing No. O14-312, Item 2 shall be sealed with a suitable adhesive at the interface of the fibreglass tube to the steel tongue at the ends to prevent water ingress.
- A locking clamp to Drawing No. O14-312 Item 5.

4.20.3.2 Assembly of the above components and the aerial switch box onto the pole shall be required.

4.20.3.3 The aerial switch shall be mounted at a height that is above and as near as possible to the span or aerial component that the switch is servicing.

4.20.3.4 The aerial switch shall be mounted as near as possible to the cross-span attachment point.

4.20.3.5 It shall be the responsibility of the designer to assess the pole assets and determine whether it is acceptable to relocate some of these to another position on the pole so that the switch can be thus installed.

4.20.3.6 To ensure that the switching linkage system does not fail, all mechanical linkages shall have split pins or other suitable devices installed that cannot come loose.

4.20.4 Aerial Switch Box

Information: The Aerial switch box comprises the backing plate and the front cover.

4.20.4.1 The backing plate shall incorporate a wooden 'V' block.

4.20.4.2 The switch assembly shall be attached to the backing plate of the switch box.

4.20.4.3 All the counter bored holes accommodating bolt heads or nuts shall be filled with electrical insulating material that will inhibit moisture ingress once the fasteners have been fully tightened.

4.20.4.4 The front cover shall be manufactured from fire retardant fibreglass and it shall incorporate a commercially available, corrosion resistant, adjustable type toggle latch.

4.20.4.5 The Switch box shall be mounted on the pole using two bands to Drawing No. O14-312 Item 1.

4.20.4.6 The switch shall include a visual indicator to identify the location of the blade within the box.

4.21 Surge Diverter (Arrester)

4.21.1 Surge Diverter Characteristics

4.21.1.1 The diverter shall have the following characteristics:

- Rated Voltage 1kV dc / 2kV dc
- Nominal Discharge Current 10kA
- Permissible Short Circuit 20kA/0.2s
- Pressure relief Class 4

Information: DEHN is the type of Surge Diverted now used by Yarra Trams

4.21.2 Mounting and Connecting Details

4.21.2.1 The surge diverter shall be mounted above other tram assets.

4.21.2.2 The pole on which surge diverters are mounted shall be bonded to the track (Rail Bond).

4.21.2.3 The diverter shall be insulated to a level of 10kV from the pole or structure to which it is attached.

4.21.2.4 The installation of the surge diverter on a wooden cross arm shall be as per Drawing No. O14-312.

4.21.2.5 The surge diverter shall fit onto the standard Yarra Trams mounting bracket.

4.21.2.6 The earth terminal of the diverter shall be connected to a Rail Bond by a continuous length of single core, annealed, stranded copper cable.

4.21.2.7 The cable shall have a cross sectional area of 70mm^2 with no less than 19 strands.

4.21.2.8 The level of insulation shall be:

- 0.6/1 kV and the outer sheath shall be heavy duty.
- resistant to chemicals including petrochemicals.
- unable to sustain combustion.
- stabilised against UV radiation.

4.21.2.9 The cable shall comply with AS/NZ 5000. 1:2005 and its outer sheath shall be Black or Grey in colour.

4.21.2.10 One end of the cable shall be connected to the earth terminal of the surge diverter via a crimped type terminal lug having a stud hole to accept a 10mm screw.

4.21.2.11 The other end shall be connected by 'CADWELD' to the 91/2.14mm bare conductor of a standard track bond which has been welded to the rail (See Drawing No. E14-557).

4.21.2.12 The conduit shall be extended to a minimum height of 3m above the ground level.

4.21.2.13 The conduit shall be attached to the pole by a 19mm stainless steel strap in at least three positions.

4.21.2.14 The cable extending above the conduit shall also be supported on the pole using 19mm stainless steel strap at intervals not exceeding 2 metres.

4.21.2.15 To prevent the stainless steel band cutting into the cable sheathing and insulation at the point of attachment, a rubber or PVC cover with a minimum thickness of 5mm shall be placed and secured between the band and the cable sheath.

4.21.2.16 The rubber or PVC cover shall extend for a minimum distance of 30mm from either edge of the stainless steel band.

4.21.2.17 The positive terminal of the surge diverter shall be connected via a single core, annealed, tinned, finely stranded copper cable to whatever is being protected e.g. feeder cable, trolley wire, etc.

4.21.2.18 The cable shall have a cross sectional area of 16mm^2 and shall have no fewer than 224 strands.

4.21.2.19 The level of insulation shall be:

- 1.8/3 kV and the outer sheath shall be heavy duty
- resistant to chemicals including petrochemicals shall not sustain combustion and shall be stabilised against UV Radiation.
- The cable shall comply with Standard IEC 502 and its outer sheath shall be Black or Grey in colour.

4.21.2.20 If the DEHN diverter is utilised its disconnector device shall be used for the positive connection and will indicate the operation of the diverter by tail lead having been blown off when there has been a lightning strike.

4.21.2.21 The diverter shall be suitably mounted and clamped on the wooden cross arm to ensure that this tail lead cannot come into contact with other metallic components or conductors.

4.21.2.22 The installation method of the arrester shall be in accordance with the manufacturer's installation instructions unless otherwise instructed by the Yarra Trams Engineering Design Authority.

4.21.3 Section Insulator Bridging via an Aerial Switch

4.21.3.1 To enable power feed from the adjacent electrical section, in case of power supply loss, quick electrical bridging across section insulators shall be provided via an aerial switch in certain locations.

4.21.3.2 The aerial switch shall be installed onto one of the poles supporting the section insulator.

4.21.3.3 Dual Flexible, 185mm^2 feeder taps to the trolley wire cable shall be used to make the necessary connections.

4.21.3.4 At the bridging insulator/s (Dual Track), cables from the same side of the insulator/s one from each trolley wire shall connect to the bottom terminal of the aerial switch. Cables from the other side (second section side) of the bridging insulator/s one from each trolley wire shall connect to the top terminals, one to the left-hand side terminal the other to the right-hand side terminal of the aerial switch.

4.21.3.5 A current equaliser shall connect 2 x 185mm^2 cables to the section insulator closest to the aerial switch to the same end of the second section insulator.

4.21.3.6 Another cable shall connect the other end of the aerial switch to the other side of the section insulator closest to the aerial switch.

4.21.3.7 Again, a current equaliser shall connect this end of the section insulator closest to the aerial switch to the same end of the second section insulator.

4.21.3.8 All the flexible cables shall be supported along their entire length onto a 2-tonne cross span located above the standard cross span in the same manner as the feeder tap to trolley wire as per Drawing No. O14-605. To prevent unravelling in the event of cable end strand failure, lock ties shall be installed at 1m intervals.

4.21.3.9 The flexible cables shall be kept clear from the pole or conductive fittings attached to the pole, cables ties are unacceptable and shall not be used.

4.21.4 Aerial Feeder Cables

4.21.4.1 Aerial power feeder cables shall be 400mm^2, 91/2.36mm, hard drawn, bare, insulated, concentric, copper conductor and shall be capable of being self-supporting.

4.21.4.2 The feeder shall be supported on SLP/11/180 pin type porcelain insulators, to A.S. 2947 .1-.3, fitted to wooden cross arms.

4.21.4.3 The feeder cable shall be held onto the insulator by a cable tie wire made from a 3.15mm solid, annealed copper wire.

4.21.4.4 The pins used to attach the insulators to the cross arm shall be to AS 1154.2.

4.21.5 Cross Arm Construction

4.21.5.1 The wooden cross arms shall be manufacture from durable wood types suitable for outdoor use with a lifespan of forty (40) years and according to:

- Drawing No. 014-427 for one or two feeder arrangement.
- Drawing No. 014-428 for three or four feeder arrangement.

4.21.5.2 The cross arm shall be attached to the pole using a 'U' Band as per Drawing No. O9653 and steadied by two cross arm braces manufactured to:

- Drawing No. O13-195 for the two feeder cross arm.
- Drawing No. O13-196 for the four feeder cross arm.

- The braces shall be attached to the pole, below the cross arm by a pole band fitted with a 1/2" B.S.W. stud as per Drawing No. O13-490.

4.21.6 Aerial Power Feeder Conductor Termination

4.21.6.1 The feeder conductor shall be terminated as per standard Drawing No. STD_T9502, using compression dead-ends to the pole via anchor pole band as per Drawing No. O923 for single feeder and steel anchor cross arm as per D4950 or D4938 for multiple feeders.

4.21.6.2 400mm² concentric feeder cable shall be directly terminated into compression dead-end (reference no. EEI-2122R1).

4.21.6.3 For aerial feeders constructed in other way and sizes, a suitable cable splice and 1m length 400mm² shall be required to enable termination by compression dead-end.

4.21.7 Aerial Power Feeder Conductor Joining

4.21.7.1 A crimped type full tension copper sleeve shall be used to join feeder cables.

4.21.7.2 A specially designed crimped type full tension copper sleeve shall be used to join 400mm² concentric feeder cables to existing feeder cables that have a cross section/configuration other than 400mm² concentric i.e. 323mm² or 400mm². (equivalent) rope lay and 323mm². concentric.

4.21.7.3 The mechanical strength of the sleeves shall be in accordance with A.S. 1154.1.

Information: The feeder cables details are shown in Table 5 below.

Table 5 is the same content as Table 2. and it has been repeated here for the sake of convenience.

Table 5 - Feeder Cable Details

Description	Nominal Cross-sectional Areas In²	mm²	Conductor Material	Construction No of Strands/Size Imperial	Metric	Nominal OD mm	Remarks
Aerial Feeder Cable	0.6	400 Equivalent	Hard Drawn Copper	91/.093"	91/2.36mm	25.96	Bare
Aerial Feeder Cable	0.5	300 Equivalent	Hard Drawn Copper	61/0.103"	61/2.62mm	23.58	Bare
Aerial Electrolysis Cable	0.3	200 Equivalent	Hard Drawn Copper	37/0.103"	37/2.62mm	18.3	Bare
Aerial Electrolysis Cable (New)	0.28	181	Hard Drawn Copper		37/2.5mm	17.5	Rail Overhead Catenary Conductor
Trolley Wire	0.2	129	Copper Tin Bearing	Solid	Solid	13.46	To Dwg. O6887 & Spec 10/Oh/01/91

Description	Nominal Cross-sectional Areas In²	mm²	Conductor Material	Construction No of Strands/Size Imperial	Metric	Nominal OD mm	Remarks
Aerial Switch and Bolted Connection Cable	0.6	400 Equivalent	Annealed Copper		61/2.85mm	35	PVC/Red/PVC Black 0.6/1kv Insulation
Feeder Tap to Trolley Cable	0.3 Equivalent	185	Annealed Copper		5510/0.2mm	31.6	UV Resistant Rubber 0.6/1kv Double Insulated. Grey or Black
Pole Bond and Surge Diverter Earth Cable	0.1	70 Equivalent	Annealed Copper		19/2.14mm	13.5	PVC/Red/PVC Black 0.6/1kv Insulation
Underground Electrolysis Feeder		120	Annealed Copper		37/2.03mm	20.4	PVC/PVC 0.6/1kv Insulation
Electrolysis Potential Leads		2.5	Annealed Copper		61/2.85mm	39	1 Core, xlpe Insulated, 37 Wire Screen, PVC Sheath
Underground Screened Feeder Cable	0.6	400 Equivalent	Annealed Copper		61/2.85mm	39	1 Core, xlpe Insulated, 37 Wire Screen, PVC Sheath
Supervisory Cable		0.64	Fibre Optic Cable	24 fibre		13	All Dielectric Self-Supporting Fibre Optic cable
				48 fibre		16	

4.21.8 Feeder Tap to Trolley Wire

4.21.8.1 Feeder taps shall be used to connect the 600Vdc power feeder cables, to the trolley wire at predetermined locations.

Information: The distance between successive feeder taps is dependent on the type and number of trams likely to be in the section at the same time, the location of tram stops and the pertaining terrain. This distance is determined by the power systems designer

4.21.8.2 This distance shall be specified for each location on systems design drawings.

4.21.8.3 However, the distance between feeder taps shall be nominally 300 metres or 10 successive poles assuming the poles are no more than 30 meters apart. Feeder taps shall not exceed 400 metres distance.

4.21.8.4 Feeder tap points shall be in line with the support pole.

4.21.8.5 The tap to trolley wire cable shall be supported along its entire length onto a 2-tonne Kevlar Type “F” rope cross span located above the standard cross span as per Drawing No. O14-605.

4.21.8.6 The flexible cable shall be supported from the Kevlar Type "F" rope by wrapping, in a spiral form, 1.5mm^2, 7/0.50mm insulated copper building wire over the entire supported length or other approved approaches.

4.21.8.7 The feeder tap to trolley wire cable shall be kept clear from the pole or conductive fittings attached to the pole.

4.21.8.8 A separate feeder tap shall be provided for each trolley wire. The feeder tap shall be 185mm² cross section.

4.21.9 Underground Feeder Cable Taps

4.21.9.1 Feeder taps connecting to an underground feeder cable shall be connected to the feeder using an electro-tinned crimp type terminal lug designed for 185mm^2. cable and provided with a 20mm stud hole.

4.21.9.2 An aerial switch (isolator) shall be used to enable isolation of the feeder tap from the underground feeder and act as a terminal block for the feeder tap to trolley cable and the underground cables.

4.21.10 Feeder Tap Terminal (T Clamp) to Overhead Feeder Cable.

4.21.10.1 Feeder tap terminals shall be attached to the hard drawn bare aerial feeder conductor to provide the termination for the feeder tap to trolley cable.

4.21.10.2 The terminal shall be attached close to the cross arm.

4.21.10.3 The tap terminal (clamp) shall be manufactured as per Drawing No. O792 and sized correctly for the size of the feeder conductor to which it is attached.

4.21.10.4 Surfaces in contact with conductors or fittings that provide current path shall be tin plated.

4.21.11 Feeder Ears

4.21.11.1 Only parts that has been Type Approved by the YT Type Approval process shall be used.

4.21.11.2 The feeder ear shall be clamped onto the trolley wire.

4.21.11.3 The tap to trolley cable shall attach to the feeder ear via a crimped lug at the connection tabs provided for this purpose.

4.21.11.4 Where a feeder tap to trolley wire is installed at a span, supporting section insulators, the feeder tap cables shall be electrically connected to the trolley wire by being attached to a feeder ear mounted adjacent to the section insulator.

4.21.12 Feeder Tap to Trolley Wire Cable

4.21.12.1 The feeder tap to trolley cable, shall be a single core, annealed, finely stranded, copper, double insulated, highly flexible cable.

4.21.12.2 The feeder tap to trolley cable level of insulation shall:

- be 0.6/1 kV.
- be heavy duty, resistant to chemicals including petrochemicals.
- not be able to sustain combustion.
- be stabilised in Ultra-violet Radiation.
- comply with AS/NZS 5000. 1:2005 and its outer sheath shall be Black, Grey in colour.

4.21.13 Cross Arm Replacement

Information: Timber cross arms installed on poles, over time, are subject to rot, splitting, cracking and the results of fair wear and tear. Consequently, some in-service timber cross arms will need to be replaced with new.

4.21.13.1 New cross arms shall be resistant to rot, splitting and cracking and must be insulated design.

4.21.13.2 Cross arms should have a design life expectancy of at least 40 years.

4.22 Electrolysis Feeder Conductor Support

4.22.1.1 The aerial electrolysis feeder conductor shall be supported on SLP/11/180 pin type porcelain insulators, to AS 2947.1-3, fitted to wooden cross-arms.

4.22.1.2 The feeder cable shall be held onto the insulator by a cable tie made from a 3.15mm solid, annealed copper wire. The pins used to attach the insulators to the cross arm shall be to AS 1154.2.

4.22.1.3 The cross arm shall be attached to the pole using a 'U' Band as per Drawing o9653.

4.22.1.4 The cross arm shall be steadied by two cross arm braces manufactured to:

- Drawing No. 013-195 for the two feeder cross arm.
- Drawing No. 013-196 for the four feeder cross arm.

4.22.1.5 The braces shall be attached to the pole, below the cross arm by a pole band fitted with a 1/2" B.S.W. stud as per Drawing No. 013-490.

4.22.2 Support of supervisory Cable on Pole

4.22.2.1 The supervisory cable shall be supported on poles utilising shackle porcelain insulators type SHLV8.

4.22.2.2 The insulator shall be attached to a 'Band-it' stainless steel sign mounting bracket by a 5/16" stainless steel set screw.

4.22.2.3 The set screw shall be inserted through the back of the bracket and screwed all the way onto the bracket. The insulator shall be secured onto the bracket using a stainless steel washer and nut.

4.22.2.4 The complete assembly shall then be attached to the pole using a 19mm stainless steel strap and buckle.

4.22.2.5 At the point of cable support the galvanised wire bearer (catenary), incorporated in the cable, shall be separated from the cable for a length of 150mm.

4.22.2.6 Care shall be taken to ensure the cable, or its insulation are not damaged.

4.22.2.7 The separated bearer wire shall be suspended over the insulator.

4.22.2.8 The cable and the bearer wire shall be secured to the insulator by a cable tie made from 1.5mm^2 insulated building wire.

4.22.2.9 The building wire shall hold the bearer wire and the cable together in a manner that prevents the bearer parting from the cable further than the 150mm described above.

4.22.3 Support of Supervisory Cable on Kevlar Type "F" Cross Span

4.22.3.1 The supervisory cable shall be supported on a two tonne Kevlar Type "F" cross span located above the standard steel cross span.

4.22.3.2 The supervisory cable shall be located no less than 2 metres from the primary insulator and nearest the pole or wall support.

4.22.3.3 At the point of cable support, the galvanised wire bearer (catenary), incorporated in the cable, shall be separated from the cable for a length of 50mm.

4.22.3.4 Care shall be taken to ensure the cable, or its insulation is not damaged.

4.22.3.5 A 'U' bolt as per Drawing No. O13-983 shall be inserted between the separated bearer wire and the supervisory cable.

4.22.3.6 The Kevlar Type" F" cross span shall be placed within the 'U' bolt, also.

4.22.3.7 A 40mm x 40mm x 6mm galvanised plate, with 2 x 8mm diameter holes, centrally located, at 20mm apart shall be used to clamp the bearer wire and Kevlar Type "F" rope together.

4.22.3.8 The cable and the bearer wire shall be secured to each other by a cable tie made from a 1.5mm^2 insulated building wire in a manner that prevents the bearer parting from the cable further than the 50mm.

4.22.3.9 The supervisory cable height shall be kept to a maximum, especially at road intersections.

4.22.3.10 The supervisory cable shall be kept well clear of the possible deviations and deflections of a detached tram pole.

4.22.4 Underground Supervisory Cable Installation

4.22.4.1 The Supervisory cable shall be installed in 50mm conduits in the manner specified for the underground feeder cables.

Information: A higher level of care shall be exercised to prevent damage to the supervisory cable given that its lower mechanical strength and thinner insulation.

4.22.5 Supervisory Cable Protection on Pole

4.22.5.1 When the supervisory cable emerges from underground onto a pole it shall be enclosed in a 25mm hot dip galvanised steel conduit for protection.

4.22.5.2 The conduit shall be extended up to the junction box. In at least two positions, the conduit shall be attached to the pole by a 19mm stainless steel strap.

4.22.6 Supervisory Cable Connection

4.22.6.1 All connections of the supervisory cables shall be made in junction boxes attached to a pole at a height 3-4 metres above ground level.

4.22.6.2 Joints shall not be made within the cable. The cable glands of the junction box shall be sized to suit the supervisory cable used.

4.22.6.3 On the poles adequate spare cable shall be left to enable connections at the predetermined locations.

4.22.6.4 The cable ends shall be sealed against moisture ingress by a heat shrink type end cap.

4.22.6.5 At the substation, the supervisory cables shall be brought and secured onto the pole nearest to the substation or into the substation pit allowing adequate spare cable to enable connections inside each substation.

4.22.7 Testing and Reinstatement of Pole Bonds

4.22.7.1 For poles that carry sectionalising switches the pole bond cable shall not be disconnected or have tracks removed for combined track/overhead works programs unless the sectionalising switch is isolated and the permission from Yarra Trams has been obtained.

4.22.7.2 To test the pole bond, the bond conductor shall be disconnected at the pole and tested against the test bond (where applicable) or measured to rail.

4.22.7.3 The conductor resistance shall be measured between the pole terminal lug and the rail. High current should be used when there is doubt on conductor integrity.

4.22.7.4 The test shall be conducted by a qualified and registered electrical tradesperson or Technical Officer.

4.22.7.5 The equipment as well as the method utilised to perform the test shall be approved by Yarra Trams.

4.22.7.6 The results of the bond testing shall be submitted in writing to Yarra Trams.

4.22.7.7 The location, pole number, original cable resistance reading, final pole bond resistance reading after reinstatement shall be included in the test results.

4.22.7.8 Depending on the test results obtained, one of the following procedures shall be undertaken.

4.22.8 If the cable resistance exceeds 1.0 Ohm

4.22.8.1 If the cable resistance exceeds 0.1 Ohm a new bond cable shall be run.

4.22.8.2 On completion of the cable installation the resistance between the pole and the rail shall be retested and shall not exceed 0.1 Ohm.

4.22.9 If the cable resistance does not exceed 0.1 Ohm

4.22.9.1 The cable bond connections shall be reinstated at the pole as per Drawing No. STD_T3000.

4.22.9.2 On completion of the cable installation the resistance between the pole and the rail shall be retested and shall not exceed 0.1 Ohm.

4.22.10 Poles with Surge Diverter

4.22.10.1 If the pole carries a surge diverter, an additional 70mm^2 double insulated cable shall be run between the pole and the rail as per Drawing No. STD_T3001 to connect the surge diverter earth directly to the rail.

4.22.10.2 The installation shall be carried out as described in the section dealing with surge diverters.

4.22.10.3 On completion of the cable installation the resistance between the surge diverter earth cable and the rail shall be retested and shall not exceed 1 Ohm.

4.22.10.4 Any road opening permit and service proving that may be necessary for the installation of new pole bonds or Surge Diverter connections shall be obtained by the contractor.

4.22.10.5 Any roadway or footpath excavated for new pole bond installation or Surge Diverter connection shall be reinstated to a standard that is acceptable to the local authorities and/or VicRoads as applicable.

4.22.10.6 All bond cables shall be installed to a minimum depth of 450mm and shall be protected by PVC protection shields or other suitable means.

4.22.10.7 All bonds must be inspected by Yarra Trams prior to reinstatement.

5 DIAGRAMS AND GUIDANCE

5.1 Referenced Drawings

Table 6 - Referenced Drawings

Title	Drawing No	Rev
Insulator Polymeric, Tension (Rebosio Type)	D3677	C
Bull Rings Component, Style Variable	D3885	C
"U" BOLTS COMPONENTS	D3933	D
PARAFIL (Kevlar Type “F”) ROPE TERMINATION FITTINGS	D4464	A

Title	Drawing No	Rev
PARAFIL (Kevlar Type “F”) ROPE COMPONENT, STYLE VARIABLE	D4465	A
2-TONNE PARAFIL (Kevlar Type “F”) TIE WITH CLEVIS TERMINATION FITTINGS	D4466	A
Anchor Cross Arm For (4) Feeder Cables on Circular Poles Component, Non-Variable	D4938	B
Anchor Cross Arm For (2) Feeder Cables on Circular Poles Component, Non-Variable	D4950	A
Boom Connector Bracket Casting, Component, Non-Variable	D4953	B
SINGLE PIVOT TYPE CANTILEVER ARM BRACKET, ASSEMBLY, DIAMETER VARIABLE	D5075	E
Back-to-Back Pivot Type Cantilever Arm Bracket Assembly, Diameter Variable	D5076	E
CONTACT CONDUCTOR FITTINGS ARTHUR FLURY	D5480	B
BOOM TUBE, 60.3 O.D.,5.4 WALL, COMPONENT LENGTH VARIABLE	F12075	K
Feeder Tap Terminal Clamp to Pole	o792	H
Anchoring Bands	o923	C
Trolley Wire Cross Sections 129mm²/81mm²	o6887	E
Pole Bands	o6897	C
Double Anchor Bar	o7466	B
"U" Band (For Cross Arm)	o9653	D
Cross Arm Brace - 2 Feeder Arm	o13-195	A
Cross Arm Brace - 4 Feeder Arm	o13-196	A
POLE BAND CROSS ARM BRACE	o13-490	A
Hanger (For Line Ear)	o13-983	G
Pole Bands	o14-308	D
Aerial Switch Operating Mechanism & Surge Diverter Mounting	o14-312	A
Overhead Wiring Curve Network	o14-315	G
Centrally Mounted Span & Lighting Pole 8kn/14m	o14-339	F
Anchor Pole with Dual Cantilever Arm Capacity 17kn/14m	o14-346	F
2 FEEDER WOODEN CROSS ARMS	o14-427	C
4 FEEDER WOODEN CROSS ARMS	014-428	C
Single Pendulum Trolley Wire Support Assembly, Style Variable	o14-500	C
SINGLE TRACK CANTILEVER SINGLE PENDULUM TROLLEY WIRE SUPPORT ASSEMBLY, STYLE VARIABLE	o14-531	C

Title	Drawing No	Rev
Back-To-Back Single Track Cantilevers Single Pendulum T.W. Support Assembly, Style Variable	o14-545	B
STANDARD COMBINED TROLLEY WIRE/ BOOM TUBE ANCHORING PANTOGRAPH ONLY OPERATION	O14-546	B
Cross Contact Bar - Type 1 Assembly	o14-572	B
Trolley Wire Anchor - Low Tension	o14-599	B
FEEDER TAP TO TROLLEY CONNECTIONS FROM UNDERGROUND CABLE USING AERIAL SWITCH, GENERAL ARRANGEMENT	o14-605	B
CURRENT EQUALIZER CABLE SUPPORT ON INDEPENDENT PARAFIL (Kevlar Type "F") CROSS SPAN FROM POLE TO POLE	o14-606	A
Span Wire & Leg Assembly	o15-194	A
K&M BOOM & CROSS SPAN SINGLE & DOUBLE STEADY ARM PANTOGRAPH ONLY	o16-103	
Standard "U" Shackles	Q3362	
TWO TRACK CANTILEVER PENDULUM TROLLEY WIRE SUPPORT ASSEMBLY, STYLE VARIABLE	Q6060	A
Steel Span Pole 6.5kn/11m, 12kN/11m and 22kN/12m	STD_T0316	
Steel Anchor Pole 11kN/11.8m	STD_T0317	
Standard Drawing Pole to Track Bonding	STD_T0008	
Standard Drawing Bonding Standard Connection Details	STD_T3000	
Standard Drawing Bonding Standard Asset Bonding Layouts	STD_T3001	
Standard Drawing 600V Supply Pole to Autopoints Cabinet Layout	STD_T3003	
Standard Drawing Steel Tram pole in Ground Mounted Rating 6.5./11, 12/11, 22/12.	STD_T0316	
Surge Diverter Earth Connection And Pole To Track Bonding Maintenance Work	E14-557	
Fittings Switch & Feeder Arrangements T & O	D4953	
	014-930	
Tramway Structure Gauge	STD_T9000	
Voltage Clamp Design Earthing And Bonding Details	STD_T6110	
	995317_301	
	STD_T9502	

5.2 Safety Acts and Regulations

5.2.1 Rail Safety Acts

The Rail Safety National Law sets out the legislative requirements for any persons operating in the network. All workers involved in any rail safety work must hold the appropriate certificate of competency for the task undertaken.

5.2.2 Rail Safety Work

Rail Safety Work means:

- Design, construction, certify, maintain, repair, monitor,
- Signalling and signalling operations,
- Rolling stock and rail infrastructure,
- Driving/shunting,
- The development and management of safe working systems.

Safe Working is the controlled movement of rail traffic to protect workers, infrastructure and other rail traffic.

6 RELATED LEGISLATION & DOCUMENTS

Name	Document number
Department of Transport: Infrastructure Drafting Standards (dated 15 Sept 2015)	Version 1
Application and Approval to place an Electrical Installation into Service	IN-023-WI-0002
Insulator and Conductor fittings for overhead power lines Part 1: Performance, material, general requirements and dimensions	AS/NZS 1154.1
Insulator and Conductor fittings for overhead power lines Part 2 Dimensions	AS/NZS 1154.2
AS/NZS Cold-formed structural steel hollow sections	AS/NZS 1163:2016
AS/NZS Hot-dip galvanized coatings on threaded fasteners.	AS/NZS 1214:2016
AS/NZS Structural Steel Welding Set	AS/NZS 1554 SET: 2014
Insulators-Porcelain and glass for overhead power lines-Voltages greater than 1000 V a.c. Test methods- Insulator units, Characteristics, Couplings	AS/NZS 2947.1-3
Electrical Installations (known as the Australian/New Zealand Wiring Rules)	AS/NZS 3000
Road safety barrier systems	AS/NZS 3845
AS/NZS Hot dip galvanized (zinc)coatings on ferrous hollow sections, applied by continuous or specialized process.	AS/NZS 4792:2006
Electric cables-Polymeric insulated	AS/NZS 5000.1-3
Clearance for Electrical Apparatus to be Placed into Service	IN-019-FO-0020
Aerial Switch Check list	IN-023-FO-0001
Electricity Safety (Installations) Regulations 2009	
Elektroline a.s. Geometry of Delta suspension.	
Elektroline a.s. SECTION INSULATOR TRAM 13 R – 400 DUO User Guide	Cat No: 227770
Elektroline a.s. SECTION INSULATOR TRAM 13 RM – 400 User Guide	Cat No: 227772

Elektroline a.s. TRAM SECTION INSULATOR UDT 96	
IEC Standard: Degrees of Protection provided by enclosures (IP Code)	IEC 60529 (2001)
EN Railway Applications – Supply Voltages of Traction Systems	EN 50163 (2004)
Installation and Removal of Tram Overhead Support Poles	IN-023-WI-0023
Occupational Health & Safety Act 2004,	
Occupational Health & Safety Regulations 2007,	
Overhead Support Structure Examination	IN-023-WI-0032
PTV Infrastructure Drafting Standards Version 1.0	
Rail Safety National Law	
Standard Drawing, Bonding Standard Long Bonding Layouts	STD_T3002
Standard Drawing 600V Supply Pole to Autopoints Cabinet Layout	STD_T3003
Yarra Trams Bonding Application Guide	BAG_21_06_2017
Yarra Trams Electrical Infrastructure Safety Rules	IN-002-ST-0002
EMS Engineering Design Authority Procedure	CE-021-PR-0019
EMS06 Engineering Change Management Procedure	CE-021-PR-0020
EMS Engineering Management Framework	CE-021-PL-0008
Yarra Trams Adjusting Elektroline Section Insulator (SI) Blades or Horns	
Yarra Trams Interim Standard for Transitions between rigid and flexible overhead support systems	Overhead 20/04/2018
Yarra Trams Tram Overhead Construction Specification – 2016	LR-600-OH-C-011
	Spec 10/Oh/01/91
Engineering Specification: Attachments to Tram Poles Telecommunications	TS-SP 066
	TMO/02/06/92
	TMO/05/07/92
Specification for Galvanized Steel 8mm Wire Rope	TMO 20/OH/09/07
Specification For Preformed Helical Termination For 8mm Wire Rope	TMO 21/OH/09/07

7 DOCUMENT VERSION CONTROL

Version History	Date	Detail
1.0	17 Mar 2020	Original approved issue

8 GLOSSARY

Word	Definition
Engineering Design Authority (EDA)	EDA is defined within the Franchise Agreement as the person or position designated by the Franchisee with authority to approve engineering decisions, processes, changes and plans. Yarra Trams is required to have the necessary competence to complete engineering design and development with acceptable levels of risk. The scope of engineering authority extends to the preparation and approval of specifications, detailed design proposals, construction and maintenance processes and standards, as well as products and systems used within the engineering support task. The procedure that states the limits of the EDA and states the process for the delegation of the EDA within Yarra Trams is Engineering Design Authority Procedure