Standard

Infrastructure – Tram Track Construction

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1. PURPOSE

The purpose of this standard is to specify the minimum requirements for the construction of tram track for the Melbourne Metropolitan Tram Network (MMTN).

2. SCOPE

The scope of this standard includes all requirements for construction of new and replacement of existing tram track and associated infrastructure for the MMTN.

The Infrastructure elements and construction activities covered by this standard are:

- Earthworks
- Drainage
- Bonding
- Conduits and Pits
- Tram Track
- Rail installation

This scope of this standard does not include;

- Installation of poles, which are covered in the Yara Trams standard for Network Power - Overhead.
- Maintenance of track, which is described in the Yarra Trams document i601em0011 titled 'Technical specification for maintenance of tram track and tram points and crossings'.

3. COMPLIANCE

Any party who is involved in the construction, installation, test or commissioning of Infrastructure shall comply with this standard in full.

Deviation from this standard is only permitted when an application for waiver is made to and approved by the Yarra Trams Engineering Design Authority.

For the purpose of compliance, the statements below have the meanings specified:

- 'Shall' statements are mandatory in the context of compliance with requirements stipulated in this standard.
- 'Should' statements are considerations only in the context of compliance with requirements stipulated in this standard.
- 'Information' statements provide additional explanatory content for clarification purposes in the context of compliance with this standard.
- 'So far as is reasonably practicable' statements must result in the provision of a risk assessment including proposed design controls to demonstrate compliance to this standard.

Where design works are performed, the party responsible for the design shall complete and return a compliance schedule which details for each requirement one of the following responses

- Compliant;
- Partially Compliant
- Non-Compliant.

4. REQUIREMENTS

4.1 General requirements

4.1.1 Site Survey

Prior to commencement of works a current survey drawing shall be completed and made available in accordance with Yarra Trams Standard CE-021-ST-0042: Infrastructure – General – Tramway Engineering Survey.

Information: This may be provided as part of the design package.

4.1.2 Survey of underground services

4.1.2.1 The location of all underground services shall be determined prior to commencing any construction works. A safe method of work shall be implemented which provides adequate protection of underground assets.

4.1.2.2 The survey of underground services shall be carried out in accordance with the following Yarra Trams Work Instructions:

- ESSOW – Locating and Protecting YT Underground Assets – Internal YT Projects, IN-021-WI-0002
- ESSOW – Locating and Protecting YT Underground Assets – External Projects, IN-021-WI-0003

Information Note: Dial Before You Dig (DBYD) services are available to assist with the identification of underground services. Not all underground services may be accurately identified through this service. For example, VicRoads assets are not included.

4.1.3 Documentation to be provided by the Constructor

4.1.3.1 Marked up As-Built drawings shall be provided at the completion of the works to Yarra Trams. The 'As-Built' drawings must include information related to the following:

- Geofabric locations
- Concrete test results
- Compaction test results.
- Conduit locations and details
- Bonding location and detail
- Welding test records
- Installed rail dimensions, lengths, temperatures and adjustments

4.2 Civil works and earthworks

4.2.1 General

4.2.1.1 Earthworks for Tramway track shall be formed, compacted, graded, boxed, trimmed and detailed as shown on the drawings; STD_T9010; STD_T9011; STD_T9012 and any relevant detail design drawings.

4.2.1.2 Track shall be constructed on new formation.

4.2.1.3 Construction works shall be performed in such a manner as not to harm the undisturbed condition of the under-laying or adjacent soils, damage filling or prevent the proper placement of fill.

4.2.1.4 During progress of construction, the surface of all fills shall be maintained to ensure that;

- Materials are maintained in a condition suitable for their intended use
- The earthworks are kept well drained
- Trimming and final grading of surfaces is completed as work proceeds
- No damage is caused to the existing services, drainage and other works within or at the perimeter of the excavated area
- Damage to or contamination of excavated surface by construction equipment is avoided

4.2.1.5 Where required, all soil tests shall be conducted in accordance with AS 1289 by a laboratory which is NATA accredited for the required test.

4.2.2 Formation and Pavement Tolerances

4.2.2.1 All earthworks shall be finished to even and uniform surfaces in accordance with the lines, levels and cross-falls specified on the design drawings.

4.2.2.2 The finished surface level of the completed formation shall not vary by more than +25mm above or -0 mm below the levels shown on design drawings.

4.2.2.3 No point on the general finished surface level shall vary by more than +/-15mm from a 3m straight edge laid parallel to the centreline of the formation or from a template placed at right angles to the centreline.

4.2.2.4 Finished formation widths shall not vary by more than - 0mm and + 50mm from dimensions shown on drawings.

4.2.2.5 The angle of batters for embankments shall not be steeper than 1 vertical to 2 horizontals.

4.2.2.6 The angle of batters for excavations shall not be steeper than 1 vertical to 2 horizontals.

4.2.2.7 The cross fall for the surface of the new formation shall be 1 in 60 to the outside of tracks or 1 in 30 towards the sub-surface drain in the centre of tracks unless shown otherwise on the detail design drawings.

4.2.2.8 Pavement courses consisting of one or more layers of the same material shall be finished to a smooth and uniform surface, conforming to lines, grades, thicknesses and cross-sections shown on design drawings.

4.2.2.9 The top of each pavement course shall not vary by more than 10mm above or below the levels shown on design drawings.

4.2.2.10 No point on the top course of the pavement shall vary by more than 15mm from a 3m straight edge laid parallel to the centreline of the formation.

4.2.3 Geofabrics

4.2.3.1 Geofabric shall be placed under compacted fill and sub-ballast where one or more of the following conditions exists:

- the subgrade CBR value is 10% or lower, or
- proper compaction and/or drainage of the stripped area cannot be achieved, or
- excavation of soft material cannot be effected.

4.2.3.2 As built drawings shall show the extent and type of Geofabric used, refer also to clause 4.1.3.

4.2.4 Excavation

4.2.4.1 Care must be taken before excavating and removing old tracks. Any bonds removed or damaged during track repair or earthworks shall be checked back to the source of connection for damage and continuity and then reinstated as per the relevant standards drawings for Bonding.

4.2.4.2 Excavation cuts to fill zones shall be continued, in the form of transverse benching, across the cut/fill interface for a distance sufficient to ensure that a minimum thickness of fill of 600 mm is achieved across the full width of the formation. Any deviation from this requirement shall be specified and shown in the as built drawings and accepted by the relevant Yarra Trams Engineering Design Authority.

4.2.4.3 Excavation operations for track formation shall not disturb material outside the limit of the batters including adjacent road pavements.

4.2.4.4 Excavated material stockpiled and used as fill shall comply with the requirements of fill material in this standard.

4.2.4.5 Loose rock shall be removed to ensure capping and subgrade layers fully comply with the requirements of this standard.

4.2.5 Fill Material and Placement

4.2.5.1 Before backfilling is commenced, the whole area on which fill is to be placed shall be test rolled to detect any soft spots. If found, soft spots shall be removed, replaced with compliant fill, compacted in accordance with this standard and subjected to further test rolling on completion.

4.2.5.2 The formation shall be constructed in layers of uniform loose thickness not exceeding 150mm and test rolled prior to the construction of the next layer.

4.2.5.3 Test Rolling shall be performed in accordance with VicRoads Specification 173 of surface area, or an equivalent method approved by the Yarra Trams Engineering Authority, with at least one test per 500m^2.

4.2.5.4 Filling over and around pipes and culverts shall be placed to avoid unbalanced loading, movement or any undue load on the structure.

4.2.5.5 Filling over and around pipes and culverts shall be compacted by hand-controlled power-driven tampers in horizontal layers of loose thickness not exceeding 150mm.

4.2.5.6 The level of filling on either side of pipe and culvert structures shall not be more than 300mm for a distance of one and one-half times the height of the pipe or culvert away from the structure.

4.2.5.7 Fill materials shall be tested in accordance with AS 1289 prior to placement and at not less than every 5 days.

4.2.5.8 Fill shall be crushed rock pavement material shall be 20mm nominal size, Class 2 crushed rock or 20mm recycled concrete material complying with the requirements of VicRoads Standard Specification 812.

4.2.5.9 Where Fill is to be placed against an existing fill, the surfaces on or against which the fill is to be placed which have a slope greater than 1 in 4 shall be cut progressively in the form of benches over the full area to be covered by the fill.

4.2.5.10 The wide width of each bench shall be such as to permit safe and effective operation of plant but shall be not less than 1 m.

4.2.5.11 Each bench shall be sloped inwards at a slope which is not flatter than 1 vertical to 10 horizontals.

4.2.5.12 Each bench shall be filled with compacted material or the bank reinstated at the end of each day so that the distance from the toe of any bench or batter shall not be any closer than 2.0 + 1.5H to the existing track centre (where H is the height below rail level).

4.2.5.13 Before each subsequent bench is cut, new fill shall be placed and compacted in layers until the surface reaches the top of the vertical face of each bench.

4.2.6 Sub-Ballast Material and Placement

4.2.6.1 Sub-ballast material shall be basaltic fine crushed rock or equivalent material complying with the requirements below.

4.2.6.2 Sub-ballast material shall have a Plasticity Index not greater than 20 and be free from roots, sod or other deleterious matter.

4.2.6.3 Sub-ballast material grading shall conform to the following grading table:

Table 1: Sub-ballast material grading table

Sieve Size AS (mm)	% Passing (By Mass)
26.5	100
19.0	95 - 100
9.5	60 - 80
2.36	25 - 40
1.18	15 - 32
0.15	4 - 12

4.2.6.4 The sub-ballast shall be compacted in accordance with the requirements specified in section 4.2.8 of this standard.

4.2.6.5 Sub-ballast shall be provided to a uniform compacted depth of 150 mm +/- 10%.

4.2.6.6 Sub-ballast may be placed in one layer.

4.2.7 Pavement Material and Placement

Information: Pavement consists of sub-base, base and surfacing courses.

4.2.7.1 Pavement materials shall be in accordance with the requirements of Fill Material, refer to clause 4.2.5.8.

4.2.7.2 Pavement material shall be spread in even and equal layer more than 60 mm but not exceeding 120 mm in compacted thickness.

4.2.7.3 Pavement material shall be spread by means that minimize segregation of pavement material into fine and coarse components.

4.2.7.4 Each layer shall be spread and compacted before the spreading of the next layer.

4.2.8 Compaction

4.2.8.1 Compaction of each layer shall commence immediately after spreading.

4.2.8.2 Where required the spread material shall be watered to maintain the moisture content of the material to within one percent of the Modified or Vibratory optimum moisture content.

4.2.8.3 Where more than three hours after mixing have passed, surface irregularities, deficiencies in level and high areas shall be rectified by the replacing of material.

4.2.8.4 Each layer of material shall be separately compacted to a density of not less than specified below.

4.2.8.5 Compaction shall meet the following relative compaction level as determined by AS 1289.5.1.1

- Structural zone - not less than 100%
- Below structural zone - not less than 95%
- Formation within 600mm of finished surfaces – not less than 95%
- Sub-Ballast (Capping layer) – not less than 95%
- Embankments more than 3 m high, remainder of formation and stripped areas shall achieve 95% modified compaction
- Embankments less than 3 m high, remainder of formation and stripped surfaces shall achieve 95% standard compaction.

4.3 Drainage

4.3.1 General - drainage

4.3.1.1 All drainage works shall be in accordance with design drawings.

4.3.1.2 Drainage shall be provided at all low points.

4.3.1.3 Along double track where the bottom of ballast is below natural surface level, and there are no side drains, a sub-surface drain shall be constructed between the tracks unless specified otherwise in the design drawings

4.3.1.4 Track drainage covers, frames, pits, and pipework shall be in accordance with Standard Drawings STD_T9020 and Standard Drawing STD_T9021, unless specified otherwise in the design drawings or approved by the Yarra Trams Engineering Design Authority.

4.3.1.5 The drainage frames shall be adjusted if required, to suit the different Yarra Trams approved rail types.

Information note: The above referenced drawings may only refer to 60kg/m grooved rail and adjustments will be required to suit 41 kg/m T-head rail, Ri57A rails or other rail types as may be included in the design.

4.3.1.6 The installation of drainage or associated fittings shall not be achieved by cutting off rail.

4.3.1.7 The road motor box pit for automatic points shall be drained separately to the normal switch drain, taking care to ensure that water cannot flow into the road motor box pit.

4.3.1.8 Points drainage shall be constructed in accordance with Standard Drawing STD_T0304 and STD_T0305.

4.3.1.9 Drainage shall be connected to an external storm water drainage system using pipe of minimum 225mm diameter that is either UPVC or reinforced concrete in accordance with section 4.3.2 of this standard.

4.3.1.10 For drainage junctions where the angle of flow is greater than 90 degrees, a junction pit shall be installed in accordance with (drawing number needed) with a of minimum 300 x 400mm rectangular pit lid at a depth to ensure correct flow of water.

4.3.1.11 All drainage trenches shall be backfilled and compacted in accordance with clauses 4.2.5 and 4.2.8 of this standard.

Information note: sub-surface pavement drains may be specified for installation along the line between an existing pavement and a new pavement (i.e. track slab). The design should specify the location of sub-surface drains. These are usually only applicable to green field sites.

4.3.1.12 Where required, sub-surface drainage shall be constructed in accordance with VicRoads Design Guidelines Part 7, section 7.5, and VicRoads Standard Specification Section 702 – Subsurface Drainage.

4.3.2 Drainage Piping

4.3.2.1 The installation of drainage piping including back fill, shall comply with AS 3500.3

4.3.2.2 All UPVC pipes shall;

- Be in accordance with AS 1260
- Be joined utilising 'male' to 'female' ends
- Be thoroughly cleaned using an approved solvent.
- Be coated with an approved adhesive immediately prior to connection.

4.3.2.3 Unless specified otherwise in the design, reinforced concrete pipes shall be flush jointed Class 4 type in accordance with AS 4058.

4.3.2.4 All pipes shall be laid true to line and grade with the female end (where it exists) placed upstream.

4.3.2.5 Mortared joints shall be caulked with a compound of two parts fine sand and one-part cement, well tamped into the joints.

4.3.2.6 Drains shall be free of all obstructions including concrete, foam etc.

4.3.2.7 In concrete construction, SL82 reinforcing mesh shall be placed in the concrete, over any pipes, and up to 2 m in width across the pipes, with 50 mm concrete cover.

4.3.2.8 The alignment of all pipes shall not vary more than 25 mm from the design alignment.

4.3.2.9 The invert level of culverts shall be subject to a tolerance of +0 mm to -25 mm.

4.3.2.10 So far as is reasonably practical, drainage piping shall be laid perpendicular to the track alignment.

4.4 Conduits & Conduit Pits

4.4.1 Conduits – general

4.4.1.1 Conduits and associated fittings shall be manufactured from heavy duty UPVC as per AS 2053, colour coded as follows;

- Auto points (electrical)- orange,
- Feeder (electrical)- orange
- Communications – white

4.4.1.2 Conduits for Pillar boxes and Pits shall be installed in accordance with standard drawing STD_T3004.

4.4.1.3 Conduits to be installed for Autopoints shall be in accordance with the design and/or standard drawings STD_9057 and STD_9061.

4.4.1.4 Conduits to be used for communications, including the services listed below, shall comply with EMS05 Generic ICT Communication Pathways Standard, CE-021-ST-0006:

- Closed Circuit Television (CCTV)
- Passenger Information Displays (PIDS)
- Public Address (PA) and intercom systems
- Customer Help Points (CHP)
- All voice and data services, including operator Intranets and public telephones
- Security Systems
- Access Control Systems
- Radio systems
- Tram control systems
- Tram stabling displays
- SCADA systems
- Trackside Measuring systems

4.4.2 Capping of Conduits

4.4.2.1 All spare conduits shall be securely capped after installation using U.P.V.C. caps.

4.4.2.2 The location of capping must be clearly identified on as built drawings and must extend past the construction zone.

4.4.3 Conduit Installation

4.4.3.1 The conduit shall be installed to enable the smooth pulling of the cable. This includes, but is not limited to;

- ensuring conduits shall be only spigot to socket ends with the spigot end facing towards the direction of pull (generally towards the substation for feeder cables),
- ensuring conduit shall be clean and free of debris
- avoid the introduction of reverse curves
- runs shall be as straight as practical
- avoid the use of conduit elbows

4.4.3.2 A minimum bending radius of 32.5 meters shall not be exceeded when deflecting lengths of 100mm diameter conduit.

Information: This is requirement is to ensure the conduits bends will permit the pulling of feeder cable.

4.4.3.3 Conduit elbows shall have a minimum radius of 1.5m when deviating from straight lengths, and up to surface level, except where the cable from underground to the surface is next to a pole, in such instances a minimum the minimum radius shall be 900mm.

4.4.4 Depth, Spacing and Separations of Conduits

4.4.4.1 All underground conduits shall be laid in a manner that ensures the underground wiring systems are installed in full compliance with AS 3000 and Standard Drawings STD_T3004.

4.4.4.2 All conduits located in the same run shall be separated by a minimum of 50mm with clean sand fill or approved equivalent.

4.4.4.3 All conduits shall be separated from all other underground services by a minimum clearance of 300mm, or greater if required by the relevant service authority.

4.4.4.4 The minimum cover above mechanical protection of conduits shall be 600 mm below track formation level, and 750mm cover required outside track formation, unless a higher cover is required by VicRoads or other relevant authorities.

4.4.5 Mechanical Protection and Identification

4.4.5.1 Conduits shall be provided with mechanical protection and identification that complies with either;

- 40mm think grade 15 precast concrete slabs and orange marker tape complying with AS 2648.1, or
- (preferred option) 3mm thick polymeric cover strips that extend 40mm beyond the edge of the conduit and be not more than 75mm above the conduit.

4.4.6 Back-Filling and Draw Ropes

4.4.6.1 The conduit trench shall be backfilled and compacted in accordance with the relevant section of this standard and any other relevant authority.

4.4.6.2 A draw rope shall be provided through the entire length of each run of conduit with an extra 3 meters length at each pit.

4.4.6.3 The draw rope for each run of conduit shall be continuous and without any joints.

4.4.6.4 The draw rope shall be 6mm polypropylene rope (“Telstra rope”) or equivalent and shall be installed immediately after the completion of construction.

4.4.6.5 The draw rope shall be restrained at each pit to prevent it from being pulled accidentally into the conduit.

4.4.7 Conduit Pit Sizes and Locations

Information: Pits are classified as ‘small’, ‘standard’ or ‘large’ – with dimensions and other details provided on drawing STD_3004.

4.4.7.1 Pits shall be provided wherever there is a requirement to;

- turn conduit runs,
- aid in the pulling of cables,
- allow joining of underground cables,
- where tee-offs and connection points are required

4.4.7.2 Pit dimensions shall be in accordance with STD_3004 unless specified otherwise and materials of construction shall be fibre-reinforced plastic (FRP) (eg ‘Stakkabox’) approved equivalent or constructed from concrete complying with AS 3600.

4.4.7.3 If ‘Stakkabox’ or equivalent are used the pits shall be fully encased at the sides and bottom with minimum 100mm concrete.

4.4.7.4 Pits shall be installed at a maximum interval of 400m or as specified on detailed design drawing.

4.4.7.5 The bottom pit entry of the lowest conduit shall be at least 100mm above the pit floor.

4.4.7.6 The depth of the pit shall be such that the minimum conduit cover or the 100mm clearance requirement from the pit floor is not compromised and conduit ends shall be capped.

4.4.7.7 Conduits entering the pit shall be flush with the internal walls of the pit, ensuring a minimum 50mm clearance between conduits is maintained.

4.4.7.8 Any voids between conduits entering the pit shall be firmly packed with concrete and conduit ends be capped.

4.4.7.9 Conduits exiting the pit as 'stub-ends' for future continuation shall extend a minimum of 500mm beyond the outer wall of the pit and include spigot end.

4.4.7.10 Conduits shall be clean and free of contamination.

4.4.7.11 The pit shall be constructed so that they can be covered with standard size Gatic covers.

4.4.7.12 Unless approved otherwise the pit shall be constructed to ensure the pit cover is horizontal and level with adjacent ground.

4.4.7.13 All the lid surrounds shall be clearly supported by to prevent collapse, shall not cause excessive noise when driven over and shall be well sealed.

4.4.7.14 Pits that exceed a depth of 1m shall be fitted with a step or individual rung ladder in accordance with AS 1657.

4.4.7.15 All nominated feeder pits shall allow for pre-formed holes for conduit penetration and shall be internally capped.

4.4.7.16 If an open-end pit is to be used all conduits shall be separated and grouted.

4.4.7.17 If a wall or other obstacle abuts the opening of the pit cover, the pit shall be orientated so that the cover removal can be performed parallel to or away from the obstacle.

4.4.7.18 The pit shall be orientated so that covers can be removed in the direction least likely to impact on tram operations or road traffic.

Information: The direction in which the cover can be slid out of its frame is indicated by the position of the cover edge with two or four keyholes.

4.4.8 Cover and Frame Setting

4.4.8.1 All pit covers and frames shall be filled with structural grade concrete comprised of aggregate between 10mm to 13mm to eliminate voids in, under and around the frames.

4.4.8.2 Concrete infill shall be poured and allowed to cure with the pit covers installed in frames.

4.4.8.3 An application of Gatic Manhole Sealing Compound shall be applied to all pit cover frame seatings.

4.4.9 Run-on Slabs

4.4.9.1 If the area immediately surrounding the pit is not sealed, a run-on slab shall be constructed for the removal of the pit covers.

4.4.9.2 The run-on slab shall have a minimum thickness of 150mm containing RL918 reinforcement midway.

4.4.9.3 Run-on slab dimensions shall be such that all of the relevant pit covers can be placed end to end.

4.4.9.4 Run-on slabs shall be placed according to the direction for removal of the Gatic covers.

4.5 Bonding

4.5.1 General

4.5.1.1 In order to ensure continuity of the electric circuit as well as minimizing the electrolysis effects, bonds shall be installed on the rails.

Information: Extreme care must be taken when excavating near bonds connected to electrical assets or negative feeder cables.

4.5.1.2 Bonds shall be installed in accordance with Standard Drawing STD_T3000.

4.5.1.3 Long bonds in embedded track construction shall be encased in concrete with 100mm cover in all directions, or in a trench beneath the edge of base course crushed rock.

4.5.1.4 All rail bond connections shall be welded to the foot of the rail as per Standard Drawing STD_T3000 and subject to Dye Penetrant Testing. The 'Cembre AR60N' or equivalent electric rail connector shall be used for the connection of bond to the rail in ballast track or otherwise as directed by the Yarra Trams Design Authority.

4.5.1.5 The installation of rail connectors shall be completed in accordance with manufacturer's instructions.

Information: A typical installation procedure for Cembre connectors is provided in Appendix A.

4.5.1.6 All bonds in ballast track construction shall be installed after tamping of the track as tamping will damage any previously installed bonds.

4.5.1.7 All bonds, other than rail joint bonds, shall be protected by a minimum of 300 mm ballast and shall be tarred to reduce risk of theft

4.5.1.8 The locations of all bond connections to the rail shall be marked on the top of the head of the rail on the field side (opposite side to the running edge). Each bond connection mark shall consist of 3 straight cuts (known as 'crow's foot') coming to a point at the edge of the rail head, each cut is to be 20mm long by 2mm wide by 2 mm deep.

4.5.1.9 All bonds excavated during track repair or earthworks shall be reinstated as per Standard Drawing STD_T3001, STD_T3002 and STD_T3006.

4.5.1.10 All rail connections in ballast track construction shall be achieved using the 'Cembre AR' or equivalent rail connectors.

4.5.2 Bonding at Auto points

4.5.2.1 All rail bond connections shall be welded to the foot of the rail as per Standard Drawing STD_T3000 and subject to Dye Penetrant Testing.

4.5.2.2 Pole and cabinet bonds, and surge diverters shall be installed in accordance with Standard Drawing STD_T3003

4.5.2.3 Bonds shall not be installed/welded within the safety "track circuit" automatic points installation area.

4.5.3 Rail Joint Bonding

4.5.3.1 Whenever two rails are joined by fishplates, a short electrical bond shall be provided to ensure electrical continuity of the joint in accordance with Standard Drawing STD_T3000.

4.5.4 Track and Rail Bonding

4.5.4.1 Track and rail bonds shall be installed at a maximum interval of 250m, or a pole number finishing in "0", unless specified otherwise on the Design Drawings.

4.5.5 Pillar Box Bonding

4.5.5.1 All pillar boxes shall be bonded as per Standard Drawing STD_T3001.

4.5.6 Long Bonding

Information: Special works includes features such as H-crossings, junctions, crossovers and turnouts.

4.5.6.1 Bonding shall be installed around the special works to bridge the straight tracks past either side of the special works in accordance with STD_T3002.

4.5.6.2 A copper conductor of 400 mm² shall be used to form the long bond that bond around the special works. The center of two rail bonds shall be attached by Cadweld process or approved equivalent at each end of the 400 mm² conductor to form four legs at each end.

4.5.6.3 Long bonding shall not be placed in the region of automatic track circuits, refer also to Auto point bonding section.

4.5.7 Pole Bonding

Information: Electrical equipment mounted on tramway poles includes Aerial Switches, Pillar Box Switches Sectionalising Switches and Surge Diverters

4.5.7.1 A pole bond shall be installed on every tram overhead pole which has electrical equipment mounted on it, except for wooden poles.

4.5.7.2 All pole bonds shall be installed in accordance with Standard Drawing STD_T3001.

4.5.7.3 A pole with a surge diverter shall have the surge diverter attached to the rail in accordance with Standard Drawing STD_T3001.

4.5.7.4 All pole bonds excavated during track repair or earthworks shall be reinstated using a cadwelded terminal. Welding shall only occur after Yarra Trams delegated representative has confirmed that correct bonds have been attached.

4.5.7.5 All Pole bonds removed during track repair or construction shall be re-instated using a Cadweld terminal.

4.5.8 Negative Feeders Connections

4.5.8.1 Substation negative cables shall be attached to the rail with 400 mm² cable in accordance with Standard Drawing STD_T3001.

4.5.8.2 Where bonds are welded on type two or type three track, in accordance with Drawing STD_9010D, the welds shall be tested to ensure that the rail foot is not damaged by the welding process.

4.5.9 Testing of Pole Bonds

Information: Electrical equipment is hazardous if not isolated and de-energised. Care must be taken to ensure electrical access procedures have been followed when working on or near electrical apparatus. In particular, sectionalizing switches adjacent to track construction works may contain live components.

4.5.9.1 Pole bonds identified shall be tested following an approved test procedure and test records supplied as as-built documentation (refer also to 4.1.3). A typical test procedure is provided in APPENDIX B - Typical Test Procedure for Pole Bonding.

4.5.9.2 The resistance of the bond as measured from Pole to Rail shall be less than 0.1 ohm.

4.6 Track and Points

4.6.1 General

4.6.1.1 The trackwork, including points and crossings, shall conform to the alignment, levels and cant as shown on the detail design drawings within the tolerances specified in this document.

4.6.2 Special Works

Information: Special Works is defined as any trackwork which must be pre-fabricated (i.e. bent or assembled) before it can be installed on site. This includes all switches, crossings and any trackwork which needs pre-bending.

Information: A turnout module consists of a pair of switches (including drainage boxes and all points operating mechanism), one crossing and connecting rails.

Information: A diamond module consists of four crossings and four closure rails. A diamond module weighs approximately one tonne.

Information: System and Life Cycle and Reliability modelling activities are now established as part of the CEAM work program on Asset Class Strategy and in providing support to asset management functions. *An H-crossing module may be constructed in sections to accommodate easier installation within transport, cranage and site constraints.*

4.6.2.1 Trackwork for junctions and crossovers shall be pre-fabricated into modules. Typical modules are turnouts, diamonds and H crossings.

4.6.2.2 Rails for special works shall be head hardened groove rail. A pre-bent check plate shall be fitted to Tee Head Rails prior to installation where applicable.

4.6.2.3 The modules and separate rails shall be welded together on site using the appropriate methods as specified.

4.6.2.4 All points and crossings shall be seated on the appropriate support systems and shall be firmly fastened by the fastenings specified in the Design.

4.6.2.5 Points and crossings shall be laid in a single plane and in accordance with Design Drawings.

4.6.3 Curved Trackwork

Information: Refer also the Rail Type requirements specified in the Track Design standard

4.6.3.1 Rails for curved trackwork with a radius less than 150 m shall be head hardened and pre-bent.

4.6.3.2 For T-rail (41 kg/m) a pre-bent check plate shall be fitted to the rail prior to installation.

4.6.3.3 Insulators shall be installed as required to ensure correct gauge and alignment is achieved.

Information note: this may require that insulators (or 'biscuits') of a variety of sizes are available on site during the installation process.

4.6.3.4 Tie bars shall be installed as required to ensure that gauge requirements are achieved.

4.6.4 Points Installation and Lubrication

Information: The major components of a set of points include:

- Switch Housings;
- Switches (also referred to as the blades or tongues);
- Inter-Connecting Box;
- Sump Box or drainage box.

4.6.4.1 These components are pre-assembled along with any operating mechanism for the control of switch movement.

4.6.4.2 The sump to the point's assembly shall be drained in accordance with design drawings to suit site conditions.

4.6.4.3 Points operating mechanism shall be fitted and adjusted to operate correctly in accordance with manufacturer's instructions.

4.6.4.4 If required prior to initial operation, all bearing surfaces shall be thoroughly cleaned using a non-flammable solvent followed by the application of a switch plate lubricant.

4.6.5 Autopoints Installation

4.6.5.1 Autopoints and associated equipment, including but not limited to, mass detector, track circuit equipment and motor road box shall be installed in accordance with manufacturer's instructions and Standard Drawings STD_9057 and STD_9061.

4.6.5.2 Mass detector installation shall;

- be installed in a box out section.
- be linked to the motor road box via a 32mm flexible conduit.
- be placed so the top of the coil is 30mm below the finished surface of the track.
- be covered with epoxy grout, 50 MPa.

4.6.5.3 The motor road box shall be installed in accordance with standard drawing STD_T9061, including the installation of two 50mm conduits from the road motor box to the control cabinet.

4.6.5.4 Where a check rail is installed within an Autopoints track circuit, short circuit bonds shall be installed between the check and the rail at intervals of 2m maximum.

4.6.5.5 Bonds and Conduits for Autopoints shall be installed in accordance with Section 4.5.2 of this standard.

4.6.6 Crossings

4.6.6.1 Crossings shall be fixed with all legs in true alignment to ensure that gauge and correct alignment are achieved.

4.6.7 Check Rails and Plates

4.6.7.1 Where Tee Head Rails are used at special works, or on curves up to 325m, the check plates shall be fitted in accordance with the following table:

Table 2: Check plate fitting requirements

Curve Radius / Turnout	Check Requirement	High Leg Check		Low Leg Check	
		Flange Gap	Height at Rail Head	Flange Gap	Height at Rail Head
Curve					
Up to R100m	Both Rails	30mm	-2.4mm	30mm	+3.6mm
R100m to R325m	Low Leg Rail				-2.4mm
Greater than R325m	Not Required	Not Applicable			
Turnout, Opposite V Crossing					
Zero Super Elevation	Both Rails	30mm	-2.4mm	26mm	+3.6mm
With Super Elevation		26mm	+3.6mm		

4.6.7.2 Check Rail details and construction shall comply with Standard Drawings STD_T9005, STD_T9006 & STD_T9007

4.6.7.3 The ends of Check Rail, which are elevated above rail level, shall be ramped 6mm over 250mm.

4.6.7.4 Check Rail material shall be as specified on drawings STD_T9005 and STD_9006.

4.6.8 Closure Rails

Information note: Closure rails are the rails between the parts of any special trackwork layout, such as the rails between the switch and the frog in a turnout (sometimes called Lead Rails or Connecting Rails).

4.6.8.1 Closure rails shall be cut and laid with no gaps at joints.

4.6.8.2 The closure rails shall have at least 2 supports and, unless impractical, be minimum of 2m in length.

4.6.9 Gauge

4.6.9.1 Track gauge shall be measured between the running edges of the rails at points 9 mm below the running surface, eliminating any distortion in measurement caused by rail head flow. Refer also to Yarra Trams Standard, Infrastructure - Tram Track Design (CE-021-ST-0035), section 4.2.3.

4.6.9.2 When construction requires joining new rail to existing rail, new rail profile shall meet the true existing running edge unless approved otherwise. Deviations from gauge, alignment and twist for all of the new track and up to 2m of the existing track section, shall be not be permitted without Yarra Trams approval.

4.6.9.3 Measurements of track dimensions shall be taken and recorded on as-built drawings for all new track and at interfaces with existing track up to at least 4 m into the existing track section.

4.6.10 Track Geometry and Tolerances

4.6.10.1 Track shall be constructed to the tolerances shown in the following table:

Table 3: Track construction tolerances

Parameter	Dimension / Tolerance
Centreline location	± 3mm
Level	± 3mm
Gauge, straight and curved track	1435mm, + 3, - 0mm
Gauge, straight track through Diamonds and H crossings	1430mm +2mm, -0mm
Gauge, Turnouts (opposite crossings)	1435mm, + 2mm, - 0mm
Guard rail gauge (back to back)	1390mm, Tolerance +3mm, -0mm
Guard rail (Check) flangeway gap	30mm, + 2mm, - 0mm
Guard rail (Check) flangeway gap – opposite crossings	28mm, +/- 2mm
Line measured over a 10 m chord	± 3mm
Twist (1.8 m chord)	± 2mm
Cant	± 3mm however, must not exceed twist parameter above
Top (10 m chord)	± 3 mm
Sleeper spacing	± 50 mm
Gauge - where super elevation is applied at turnouts, (turnout move) opposite V Crossings	1435mm, +3mm, -0 mm

4.6.10.2 Cant shall be applied uniformly over the full length of transitions.

4.7 Track – Embedded

4.7.1 Types of Embedded Track

Information: There are six types of embedded track construction in concrete:

- Type 1 - Rigid track structure, concrete to surface, sleepers at 3000mm spacing on straight track (CTS);
- Type 2 - Semi resilient track structure, crushed rock and top layer of asphalt, sleepers at 700mm spacing on straight track (SR/CR/A);
- Type 3 - Same as type 2 but with full depth asphalt (SR/A);
- Type 4 - Concrete to surface with tie bars - (CTS TB);
- Type 5 - Direct fixation between rails and existing paving. This track type is used where minor excavation for blue stones, conduits and drainage (DF) is involved and is only undertaken when a specific design is available.
- Type 6 – Semi resilient with rail with Rubber boot encased, concrete to surface (RB).

4.7.2 Special Works

4.7.2.1 Special works in embedded track construction shall include an additional 100mm depth of concrete to support the track.

4.7.3 Tie Bars

4.7.3.1 Tie bars shall conform to Standard Drawing STD_T9003 and Australian Standard AS 1302 unless shown otherwise on the approved Design drawings.

4.7.3.2 Tie bars shall be placed a minimum of five per full rail length (approximately every 3 metres for straight track and at 1.5 metres spacing for curved track).

4.7.3.3 Tie bars shall be adjusted and tightened to keep the rails to gauge.

4.7.3.4 Tie bar sizes shall be as follows;

- 22mm - for junctions or curves with radius less than 325m
- 18 mm - straight track or curves with radius greater than 325 metres.

4.7.3.5 Tie bars are to be used in junctions and crossovers in accordance with an approved design for the location.

4.7.3.6 Where tie bars are used in track circuits for Autopoints, they shall be insulated or removed prior to concreting.

4.7.4 Rail Supports

4.7.4.1 Rail shall be supported to achieve line and level by blocks placed at appropriate intervals. Blocks shall be either;

- concrete mono block sleepers, or
- concrete dual block sleepers

4.7.4.2 Packers shall be placed at regular intervals under the rail in accordance with STD_9010D and including under each end of switches, and under the centre of crossings.

4.7.5 Concrete

4.7.5.1 Unless approved otherwise, the concrete type shall be 'Special 50 MPa' which meets the compressive strength requirements specified in the table below.

Table 4: 'Special 50 MPa' concrete compressive strength requirements

Concrete Type	Curing Time	Compressive Strength (MPa)
Special 50	5 hours	5
	24 hours	14
	7 days	40
	28 days	50

4.7.5.2 Tram traffic shall not be permitted on the track within 5 hours of final concrete pour.

Information: A shorter timeframe may be approved by Yarra Trams for concrete in the section between the two tracks.

4.7.5.3 No motor traffic shall be allowed on to the concrete until a minimum strength of 14 MPa has been achieved.

4.7.5.4 The manufacture and supply of concrete shall comply with the requirements of AS 1379 and the standards referred to in Clause 1.2 of AS 1379.

4.7.5.5 Cement used shall be general purpose Portland cement Type GP complying with AS 3972. The minimum cement contents shall be 460 kg/m3 for Special 50 MPa mix.

4.7.5.6 Fine and coarse aggregate for concrete shall comply with AS 2758.1 and the coarse aggregate shall have nominal size of 20 mm.

4.7.5.7 Concrete slump shall be a maximum of 75 mm slump determined from a test in accordance with AS 1012.3.

4.7.5.8 Concrete shall be manufactured, transported and handled in accordance with the requirements of AS 3600.

4.7.5.9 Notwithstanding the provisions of AS 1379, all concrete shall be completely discharged in position in the forms within 60 minutes of the introduction of the mixing water to the mix.

4.7.5.10 The concrete shall be placed and compacted within 20 minutes after discharge from the mixer.

4.7.5.11 The working surfaces of platforms and conveying equipment shall be cleaned of all foreign material and set concrete immediately prior to commencement of each placing run.

4.7.5.12 Prior to and during the placing of concrete, the formwork and the space to be occupied by the fresh concrete, and all embedded items, including reinforcement, shall be maintained in a clean condition, free of mud, oil and other deleterious materials. All debris shall be removed from places to be filled with concrete.

4.7.5.13 Concrete shall be handled from the supply truck to the place of final deposit as rapidly as possible by methods that shall prevent the separation, segregation or loss of ingredients. It shall be deposited as near as possible to its final position in order to prevent re-handling or flowing. Concrete shall not be dropped from a height of greater than 1.2 metres.

4.7.5.14 If an interval between placing of any two consecutive loads of concrete should occur in which the concrete starts to harden, the concrete shall be removed from under the rail and a transverse construction joint shall be made as specified.

4.7.5.15 No concrete which has partially hardened or has been contaminated by foreign materials shall be deposited in the work. Concrete shall not be re-tempered.

4.7.6 Preparation for Concrete Placing

4.7.6.1 Concrete shall be placed outside each of the tracks before placing the concrete between the rails (the “4 foot”). Each part shall be poured as a monolithic section in one continuous operation unless otherwise approved.

4.7.6.2 The sub-base shall be dampened, and concrete shall be deposited on the dampened sub- base in such a manner as to minimise segregation and re-handling. The placing shall be rapid and continuous between planned construction joints and it shall be distributed so that when consolidated and finished, the slab thickness, surface shape and levels shown will be achieved at all locations.

4.7.6.3 Dowels shall be used where concrete hardens between pours and shall comply with the requirements of clause 4.7.8.

4.7.6.4 Concrete shall not enter the working compartments of switches.

4.7.6.5 There shall be a minimum of 125 mm under the foot of the rail for the placement of new concrete, or if this cannot be practically achieved, SL82 reinforcement shall be placed under the foot of the rail with at least 50 mm coverage.

4.7.6.6 Where the track is being laid on a concrete foundation slab, such as a bridge deck, the reinforcement mesh may be omitted.

4.7.7 Concrete to Surface Track Formation-Reinforcement

4.7.7.1 Reinforcement shall be laid on the tie bars and/or approved supports and shall be securely held in its correct position during the concrete placing operation and until the concrete has hardened.

4.7.7.2 Steel reinforcement shall comply with the requirements of AS 1302, AS 1303, AS 1304, AS 3600.

4.7.7.3 Welding, including tack welding, of hard-drawn steel wire reinforced fabric shall not be permitted.

4.7.7.4 Any welding of hot-rolled steel reinforced bars shall be in accordance with Australian Standard AS 1554, Part 3, Welding of Reinforced Steel, including all preheated requirements specified therein.

4.7.7.5 All placed reinforcement shall be clean and free from grease, tar, oil, paint, mud, loose mill scale, loose or thick rust, etc.

4.7.7.6 Reinforcing fabric sheets shall be handled so that they remain free from distortion. They shall be lapped so that the two outermost wires of one sheet of fabric overlap the two outermost wires of the adjacent sheet. Lapped portions shall be tied with wire at a maximum spacing of 500 mm.

4.7.7.7 Reinforcement shall be terminated 75 to 80 mm from dowelled contraction joints. Reinforcement shall terminate at least 40 mm and not more than 80 mm from longitudinal construction joints, or pavement edges.

4.7.7.8 Reinforcement bars shall be bent by machine or other approved means producing a gradual and even bend. Bars shall be bent cold. After being bent and straightened, steel reinforcing bars shall not be re-bent within 500 mm of the previous bend.

4.7.7.9 At corners and bends in main reinforcement, the internal radii of bends shall be not less than five times the diameter of the bar unless detailed otherwise on the drawings. Placing bars on layers of fresh concrete as the work progresses and adjusting bars during the progress of the concreting will not be permitted.

4.7.8 Dowels

4.7.8.1 Dowels shall be one-piece, straight, plain/ribbed round steel bars complying with the requirements of AS 1302 and of the size shown on the design drawing.

4.7.8.2 Dowels shall be cut to length prior to delivery to the site and the ends shall be cut square and free from burrs.

4.7.8.3 Dowels shall be clean and free from mill scale, loose rust or oil.

4.7.8.4 Ribbed dowels shall be used where new concrete is to be placed adjacent to existing concrete, or concrete that has hardened and no other means of vertical support in place to prevent differential settlement. Eg. where a new pit is constructed between the rails.

4.7.8.5 Dowels shall be placed at approximately 300 mm centres and approximately 200 mm below top of concrete level.

4.7.8.6 Dowels shall penetrate the old and new concrete by 150 mm in a diameter of 20mm.

4.7.8.7 Dowels shall be securely held in their correct position until the concrete has set.

4.7.9 Formwork

4.7.9.1 Formwork shall be of straight, seasoned timber or steel, and shall be free from warps, bends or kinks.

4.7.9.2 Formwork shall be of adequate cross section and strength and secured to resist the pressure of the concrete when placed and the impact and vibration of any equipment it supports without yielding, springing or settlement. The method of connection between sections shall be such that the joints do not move.

4.7.9.3 The formwork shall be placed true to alignment, grade and level, and checked by the Contractor immediately before placing the concrete.

4.7.9.4 The formwork shall be cleaned and oiled prior to use.

4.7.9.5 Formwork shall be used where required and shall conform to the shapes, lines and dimensions of the concrete shown on the Drawings.

4.7.9.6 Forms shall be supported independently of freshly poured concrete. Timber separators, if used, shall be removed before being encased to concrete.

4.7.9.7 Any surplus moisture shall be removed from the formwork prior to placing of concrete. Formwork for exposed concrete surfaces ("off form concrete") shall be dressed or shall be approved tampered "maisonette" or "resoply" or steel formwork or other approved dressed formwork material, to give a fair face concrete. Any projections shall be chipped off and ground smooth.

4.7.10 Weather Conditions

4.7.10.1 When ambient air temperature is below 5 degrees Celsius, the concrete shall have a temperature not lower than 10 degrees Celsius when placed in the forms. Precautions shall be taken to prevent the concrete from freezing at any time during the curing period. Salts and chemicals shall not be used to prevent freezing.

Information: High-dose concrete accelerant as use in Special 50 MPa mix may not work effectively below 5 degrees Celsius.

4.7.10.2 The sub-base course shall be prepared and protected and shall be entirely free of frost when the concrete is deposited.

4.7.10.3 Any concrete damaged by freezing shall be removed to the full depth to the nearest contraction or construction joints and replaced.

4.7.10.4 When concreting in hot weather, precautions may be required to avoid premature stiffening of the fresh mix and to reduce water absorption and evaporation losses.

4.7.10.5 Concrete shall be protected from rain as required and in accordance with 4.7.15.

4.7.11 Chuting

4.7.11.1 Where used, chutes shall not be inclined at more than 30 degrees to the horizontal plane.

4.7.11.2 Where concrete is placed by chuting, the whole of the plant shall be arranged to give a continuous flow of concrete without segregation and so as to deliver the concrete close to the point of deposit.

4.7.11.3 The whole of the plant shall be flushed with clean fresh water before the pouring commences and after each stoppage of operations exceeding fifteen minutes. The water used for this purpose shall be discharged outside and clear of the forms.

4.7.12 Compacting

4.7.12.1 All concrete shall be thoroughly compacted during and immediately after placing. Care shall be taken to fill every part of the forms, to force the concrete under and around the rails and reinforcement without displacing it, to work back coarse aggregate from the face, and to remove all air bubbles and voids.

Information: This requirement is critical around switches and special works.

4.7.12.2 External faces of formwork shall be vibrated sufficiently to ensure that the exposed surfaces of concrete shall be smooth and free from air bubbles and voids. All compaction shall be carried out by use of approved immersion (poker) vibrator.

4.7.13 Bonding Fresh and Hardened Concrete

4.7.13.1 Before depositing new concrete on or against concrete which has set, the surface of the set concrete shall be roughened, cleaned of foreign matter and laitance and thoroughly moistened with water. Excess water shall be removed prior to placing of the concrete.

4.7.14 Concrete to Surface Track Formation/Construction Joints

4.7.14.1 Construction joints shall be installed in accordance with the Design drawings, unless approved otherwise.

4.7.15 Curing

Information: Proper curing is considered vital to the long term durability and surface toughness of the slab.

4.7.15.1 Concrete less than 4 hours old shall be protected by covering with waterproof covers where appropriate (Concrete to surface).

4.7.16 Tolerances

4.7.16.1 All concrete shall finish true to the dimensions, lines and levels shown on the Drawings. The following tolerances shall be observed:

Table 5: Concrete tolerances

Parameter	Tolerance
Plan dimension of slab	± 10mm
Thickness of slab	- 0mm
Cover to reinforcement	+ 5, - 3mm
Finished level of slab	± 3mm
Foundation Level of slab	+ 0, - 20mm

4.7.17 Slab Finish

4.7.17.1 Slab surface for Track Structure Type 1 in accordance with Standard Drawing STD_T9010D shall be uniformly level, flat and free from bumps, hollows and other irregularities. All exposed

concrete surfaces shall be true, even and free from stone pockets, depressions and projections.

4.7.17.2 A groove shall be formed along the running edge of each rail in accordance with Standard Drawing STD_T9010 Rev. D Track Structure Type 1 and Tee rail.

4.7.17.3 The slab surfaces shall be broomed to provide a non-slip finish.

4.7.17.4 All concrete vertical surfaces shall be "off form finish" unless otherwise specified, and shall be neat, smooth, and regular in appearance. All exposed edges shall have 10mm x 45 degree Chamfers.

4.7.17.5 Upon completion, the surface shall be protected against damage.

4.7.18 Concrete Testing

4.7.18.1 Concrete testing shall be conducted by a NATA certified laboratory.

4.7.18.2 Concrete test sample records shall include location and pour details(quantity and date).

4.7.18.3 Concrete test samples shall be obtained in accordance with AS 1012, Part 1, Methods for Sampling Fresh Concrete.

4.7.18.4 The minimum number of composite samples shall be taken based on the concrete volume to be poured during any continuous phase of casting operation, in accordance with the table below:

Table 6: Concrete sample testing minimum requirements

Volume cast in one continuous operation (m^3)	Minimum number of samples
0-25	1
25-50	2
50-100	3
Each additional 50	1

4.7.18.5 Concrete test specimens shall comply with AS 1012, Part 8, Method for Making and Curing Concrete Compression, Indirect Tensile test specimens.

4.7.18.6 For Special 50 MPa concrete each composite sample of concrete shall comprise four standard cylinder test specimens.

4.7.18.7 Concrete testing shall be in accordance with AS 1012, Part 9, Methods for Determination of Compressive Strength of Concrete Specimens.

4.7.18.8 For Special 50 MPa concrete, two standard cylinder test specimens shall be tested for compressive strength at 24 hours and the remaining two shall be tested at 7 days.

4.7.18.9 The test strength of the concrete at 24 hours and at 7 days shall be deemed to be the average of the strengths of the two standard cylinder test specimens used for each respective test.

4.7.18.10 The test strength of the concrete at 28 days shall be deemed to be the average of the two standard cylinder test specimens used for the test.

4.8 Track – Ballasted

4.8.1 Supply, Placement and Compaction of Ballast

4.8.1.1 The whole of the material supplied shall be basalt or other approved material and shall be clean, free from clay, dirt and other deleterious matter or weathered pieces of rock and free of dust.

4.8.1.2 Following the completion of the formation and prior to laying sleepers, one or more layers of ballast shall be placed, graded and compacted to a total minimum depth of 150 mm.

4.8.1.3 Compaction shall be by a smooth wheeled vibrating roller as specified for earthworks.

4.8.1.4 After track construction and prior to tamping, cribs and shoulders are to be filled to the top of the sleepers with extra ballast.

4.8.1.5 The depth of ballast following tamping shall be 200 mm from top of sub ballast to bottom of sleepers.

4.8.1.6 Ballast shall not be excessively segregated.

4.8.1.7 Ballast shall be tested for conformity by a NATA certified laboratory.

4.8.1.8 Ballast shall be tested in accordance with AS 1141 – Methods of Sampling and Testing Aggregates.

4.8.1.9 Ballast shall not contain friable particles in excess of 0.3% by weight when tested in accordance with Part 32 of AS 1141.

4.8.1.10 Ballast shall have a particle density of not less than 2600 kg/m3 on a dry basis when tested in accordance with Part 6 of AS 1141.

4.8.1.11 Ballast percentage of wear shall not exceed 30% when tested in accordance with Part 23 of AS 1141: Los Angeles Value.

4.8.1.12 Ballast shall have a crushing value that does not exceed 30% when tested in accordance with Part 21 of AS 1141.

4.8.1.13 Ballast material shall have misshaped particles at 2:1 ratio that does not exceed 30%, when tested in accordance with Part 14 of AS 1141.

4.8.1.14 Ballast shall meet the sieve analysis requirements specified in the table below;

Table 7: Ballast sieve analysis requirements

Sieve Size AS (mm)	% Passing By Mass
63.0	100
53.0	90 – 100
37.5	35 – 70
26.5	0 – 15
13.2	0 – 5

4.8.1.15 A ballast sample shall be taken from the first 100 m^3 of ballast produced.

4.8.1.16 All samples and test results shall be documented and recorded.

4.8.2 Sleepers

4.8.2.1 Concrete sleepers shall be used for all open track in ballast.

4.8.2.2 Concrete mono-block sleepers for open track shall conform to the Design, AS1085.14 and manufacturers drawings. Concrete dual-block sleepers shall be in accordance the Design and manufacturers drawings.

4.8.2.3 Sleepers shall be handled and moved into position in such a way as to avoid damage or bruising. Sleepers shall not be subjected to blows from a hammer or any other tool or appliance.

4.8.2.4 Sleepers shall be stored and stacked in a manner which will prevent warping and twisting of concrete sleepers or damage to "Pandrol" shoulders .

4.8.2.5 Sleepers shall be laid central to the track and at right angles to the centreline of the track unless otherwise specified. Timber sleepers for turnouts shall be aligned on one end as specified on drawings.

4.8.2.6 Sleeper spacing shall be at the following centres:

- Open track – 685 mm + 25 mm, with a minimum 1460 sleepers per km;
- Turnouts – as specified on relevant drawings, with a general tolerance ± 10 mm;

4.8.2.7 Sleeper spacing shall be adjusted to ensure that:

- Welded joints are suspended centrally between sleepers (spaced at 685 mm);

4.8.2.8 All sleepers shall be lifted, lined and tamped after installation and fastening of rails.

4.8.3 Fastenings

4.8.3.1 The rail fastening system shall consist of the "Pandrol" or approved equivalent components as below :

- For Ri57A Grooved rails:
    - Resilient Rail Clips
    - Rail Foot Insulator
    - Rail Pad Rubber
- For 41kg T Head rails:
    - Resilient Rail Clips
    - Rail Foot Insulator
    - Rail Pad Rubber.

Information: The fastenings specified comply with relevant sections of AS 1085.

4.8.3.2 The components shall be installed strictly in accordance with manufacturer's instructions eg. 'Pandrol' Installation Manual'.

4.8.3.3 A Panpuller, or equivalent, shall be used for installing or removing the – use of a hammer or the like shall not be permitted.

4.8.4 Track Adjustment

4.8.4.1 For ballast track with continuously welded rail (CWR – rails joined with flash butt or aluminothermic) the track shall be adjusted (tensed) in accordance with a method approved by the Yarra Trams Design Authority.

4.8.4.2 Each rail length subject to adjustment shall be anchored in accordance with Standard Drawing STD_T9008.

Information: In hot weather, it may be necessary to anchor the track temporarily to avoid expansion while the next section is laid or adjusted. This will prevent creep affecting the designed adjustment.

4.8.4.3 A record of location, rail length installed, rail temperature and adjustment shall be prepared and provided as part of the as-built drawing and document set in accordance with section 4.1.3 of this standard.

4.8.5 Marking Tangent Points and Cant Values

4.8.5.1 For all ballast track, tangent Points shall be stencilled in white paint on the outside of the low leg rail web reading from the Melbourne end of a curve as follows:

- T.S. (tangent-spiral) at the beginning of the transition;
- S.C. (spiral-curve) at the end of the transition/start of the circular curve;
- C.S. (curve-spiral) at the end of the circular curve/beginning of the transition;
- S.T. (spiral-tangent) at the end of the transition;
- Cant values shall be stencilled on the inside of the high leg rail web or check plate, at each 10 mm increment through the transitions.

4.9 Rail

4.9.1 General

Information: The rail profile will be specified in the design. Rail may include serviceable sections of used rail with flame cut ends. Typical profiles for rail are:

- *57kg/m grooved rail for all embedded track;*
- *60kg/m grooved rail for embedded track;*
- *41kg/m standard T rail for ballast.*

4.9.2 Handling and Removal

4.9.2.1 Rail shall not be handled in any manner which is detrimental to the rail, trackwork, trackwork components or structures.

4.9.3 Laying

4.9.3.1 In ballast track formation serviceable rail shall be laid such that the worn face (former running edge) is utilised as the running edge of the re-laid track unless otherwise specified. If rail is required to be transposed, the rail head and/or welds may require regrinding to conform to true rail head profile.

4.9.3.2 All rails shall be straight and true prior to laying. Any crippled, deformed or damaged rail shall not be used.

4.9.3.3 The bottom of the rail, the sleeper plate and the bearing surface of the sleeper, as applicable, shall be clean before the rail is laid.

4.9.4 Cutting

4.9.4.1 The cutting of rails shall be minimised.

4.9.4.2 Cutting of rail shall be carried out to ensure conformance to detailed specifications for rail end condition (cutting), proximity of welds (minimum closure lengths), head matching (joint alignment) and requirement for square or staggered joints (position of joints).

4.9.4.3 Rails shall only be cut with an approved rail saw or friction saw. Flame cutting of running rail is prohibited for ballast track.

4.9.4.4 As supplied rail ends shall be re-sawn if the condition does not comply with the tolerance. Flame cut rail ends shall be re-sawn a minimum distance of 25 mm from the flame cut.

4.9.4.5 Cuts shall be square to the rail within a tolerance of 2.0 mm over the width and/or height of the rail.

4.9.4.6 Cutting compound should be used for cooling and lubrication when a rail saw is used. Cutting compound shall not be used with friction saws. When cutting rails under tension the contractor must ensure that all persons are removed from potential spring zones of the rail to avoid injuries to staff. All persons cutting rail must check that other persons are not in movement paths

4.9.5 Minimum Closure Lengths

4.9.5.1 Unless specified otherwise on the design drawings, minimum rail lengths for normal straight and curved track shall be:

- for jointed ballasted track, 6.0 metres,
- for CWR ballasted track, 3.0 metres
- for concretes track, 2.0 metres,
- for Track junctions, as specified in the design drawings

4.9.6 Rail Joints – General

4.9.6.1 Rail joints can be either:

- Aluminothermic welds
- Manual Arc Welds (ie. Kirby Joint).

4.9.6.2 Rails of same profile shall be joined using Aluminothermic welds, unless approved otherwise.

4.9.6.3 Rails joined by aluminothermic welds are considered as continuously welded rail (CWR). CWR in ballast must be tensioned to prevent buckling of rails. CWR in concrete does not require tensing.

4.9.6.4 Rails of different sizes shall be joined with approved aluminothermic welds or alternatively with Manual Arc welds (Kirby weld) . Rail joints shall have top and running edge match up at each joint. Any misalignment of rail heads caused by the existing rail being worn shall be rectified by building up the worn rail to line, level and gauge using appropriate weld material to create a 1 in 25 ramp.

4.9.6.5 Fishplates with fishbolts shall only be used for temporary joints.

4.9.6.6 Manual Arc welds shall be avoided for permanent installation in tensioned ballast track. Where use in unavoidable they, shall be protected against movement by either, anchoring, for 40 m on each side of the joint, or burying the track in concrete, for a minimum of 1 m on each side of the joint.

Information: Situations where permanent Manual Arc welded joints may be specified include:

- *Joints in concrete track;*
- *Joining of dissimilar rail sections;*
- *Joining of rails to castings if the castings are constructed in an unsuitable manner for fish plating;*
- *Joining of manganese castings.*

4.9.7 Position of Joints

4.9.7.1 In straight track, joints shall be square across the track and at a change of rail section.

4.9.7.2 In curved track, joints may be staggered, and the stagger shall be squared up with the first joints into the straights. Curved track of less than 150m radius shall have staggered joints in accordance with detail design drawings.

4.9.7.3 Joints shall not be located within 3.0 m of the approach of rigid track construction, eg. concrete track construction or direct fixation on bridges.

4.9.8 Aluminothermic Welds

4.9.8.1 Aluminothermic welds shall be performed in accordance with an approved weld procedure. Refer to APPENDIX C – Aluminothermic Welds, for a typical specification/procedure.

4.9.9 Manual Arc Welding

4.9.9.1 Manual Arc welds shall be performed in accordance with an approved weld procedure. Refer to APPENDIX D – Manual Arc Welding (Kirby Joints), for a typical specification/procedure.

5. RELATED LEGISLATION & DOCUMENTS

Name	Document number
Technical specification for maintenance of tram track and tram points and crossings	i601em0011
Infrastructure – General – Tramway Engineering Survey	CE-021-ST-0042
ESSOW-Locating and Protecting YT Underground Assets-Internal YT Projects	IN-021-WI-0002
ESSOW-Locating and Protecting YT Underground Assets-External Projects	IN-021-WI-0003
Standard Conduit Depth and Layout (Contract Spec)	E14-265
EMS05 Generic ICT Communication Pathways Standard	CE-021-ST-0006
Methods of Testing Concrete	AS 1012
Railway Track Materials	AS 1085
Methods for Sampling and Testing Aggregates	AS 1141
High Strength Steel Bolts with Associated Nuts and Washers for Structural Engineering	AS 1252
PVC-U pipes and fittings for drain, waste and vent application	AS 1260
Methods of Testing Soils for Engineering Purposes	AS 1289
Geometrical Product Specifications (GPS)-Indication of Surface Texture in Technical Product Documentation	AS 1302
Steel reinforcing wire for concrete	AS 1303
Welded wire reinforcing fabric for concrete	AS 1304
Specification and Supply of Concrete	AS 1379
Carbon and Carbon-Manganese Steel-Cold-Finished Bars	AS 1443
Chemical Admixtures for Concrete, Mortar and Grout	AS 1478
Structural Steel Welding	AS 1554
Fixed Platforms, Walkways, Stairways and Ladders	AS 1657
Conduits and Fittings for Electrical Installations	AS 2053
Underground Marking Tape	AS 2648
Aggregates and Rock for Engineering Purposes	AS 2758
Electrical Installations	AS 3000
Plumbing and Drainage Set	AS 3500
Concrete Structures	AS 3600
General Purpose and Blended Cements	AS 3972
Precast concrete pipes (pressure and non-pressure)	AS 4058

Name	Document number
Steel Structures	AS 4100
Examination and Testing Of Materials And Work	Section 173-VicRoads
Subsurface Drainage	Section 702-VicRoads
VicRoads Standard Specification for Roadworks and Bridgeworks, 2006.	
VicRoads Design Guidelines Part 7, section 7.5-2003.	
Fishplate Type Rail Joint 41Kg/m or 47Kg/m Tee Head Rail with Swage Lock Fastenings	STD_T0007
Points Drainage General Arrangement	STD_T0304
Points Drainage General Arrangement Isometric Views	STD_T0305
Bonding Standard Connection Details	STD_T3000
Bonding Standard Asset Bonding Layouts	STD_T3001
Bonding Standard Long Bonding Layouts	STD_T3002
600V Supply Pole To Autopoints Cabinet Layout	STD_T3003
Pillar Box and Pit Arrangement	STD_T3004
Installation of Bonds to Existing Track Double Track Arrangement	STD_T3006
Standard Tie Bar Standard Tie Bar Clip Arrangement	STD_T9003
Standard Check Plate Block&Assembly-41Kg Rail Block&Assembly-41Kg Rail	STD_T9005
Track Curve Construction Special Check Plate Block& Assembly-41Kg Rail	STD_T9006
Track Construction at Crossing for Turnouts Special Check Plate-41Kg Rail	STD_T9007
Destressing Procedure for 41Kg Tram Rail Gauge-Lock Clip Arrangement	STD_T9008
Typical Track Structures	STD_T9010
Ballast Construction Track Design Track Design	STD_T9011
Ballast Construction W/Centre Poles Track Design	STD_T9012
Track Drainage Trench Grate Arrangement	STD_T9020
Track Drain Triangular Pit For 41, 60 & Ri57 Kg/m Rail Assembly Details	STD_T9021
Track Structures Transition	STD_T9060
Autopoints Construction Details	STD_T9061

6. DOCUMENT VERSION CONTROL

Version History	Date	Detail
1.0	25/06/20	First publication

7. GLOSSARY

Word	Definition
Austenitic Manganese Castings	Points, crossings and closure rail castings manufactured from a typically 14% manganese steel.
Ballast	The crushed rock supporting the sleepers and forming part of the track. Requirements for ballast are covered in other parts of this Standard.
Base Plate	A steel plate placed under the foot and across the two rails being joined and welded to the rails.
Batter	The uniform side slope of a cut or fill.
CBR	California Bearing Ratio, Standard Compaction expressed as % of the actual load causing the penetrations of 2.5 mm or 5.0 mm to the standard loads on standard crushed rock.
Check rail	
Check	The guarding portion opposite and parallel to the head of a tramway rail. The flangeway between the rail head and guarding check of a grooved tramway rail.
Connector Kit	A package containing all CEMBRE materials necessary to enable a cable lug to be electrically connected to the track.
Dead Line Work	The condition where Power has been removed from the overhead trolley wire network, automatic points as well as other components that may need to be worked on. A permit will be issued for dead line working.
Design	A set of documents including drawings and other information which has been developed and approved in accordance with the Yarra Trams, Manage Design Procedure
Extruded Bush	A process whereby a flanged bush of soft, tin plated copper is expanded from inside so that it moulds itself to the inside of a hole in the rail to exclude moisture and give very good, reliable electrical contact. This expansion also causes the bush to become longer.
Feeder Cable	To be defined.
Fill	The material used for filling the earthworks up to design surface level as indicated on the Drawings, but not including sub-ballast material.
Formation	The layer the track is laid on after completion of earthworks, including the sub-ballast course but excluding any cut or fill batters.
Grooved Rail	Special tramway section rail comprising rolled section foot, web and head with a guarding check. A flangeway groove exists between the head and check of the rail.
Head Hardened Rail	Plain carbon or pearlitic manganese rail on which heat treatment has been carried out on the head of the rail during manufacture to significantly increase the hardness of the rail head surfaces.
Head Weld	A vee butt weld which may be employed to join the rail heads.

Word	Definition
Installation Tool Kit	The set of equipment necessary to fit the CEMBRE Connector Kit into a hole which has already been drilled in the rail.
Junction joints	A joint comprising rail of differing profile, particularly with respect to height.
Kirby Joint	The joining of two rails by fillet welding of a steel base plate to the bottom of the foot of the rails and straps on the tops of the foot of the rails and side of the web, if appropriate. A vee butt weld may also be employed to join the rail heads in defined situations. At junctions of different rail profiles, the joint utilises steel spacer blocks or packers.
Metal Flow	Extrusion or flow of steel with sharp edges on the running surface of the rail head.
Neutral Axis	The position in the web of the rail where a hole may be drilled without weakening the rail. This position is given in AS 1085.1 for rail to Australian Standards, in Ri57A rail this is 39.7mm above the foot of the rail.
No-fines concrete	No fines concrete shall consist of B4 filter of granular filter material as defined in VicRoads Table 702.051 and mixed with 4.0% by mass of cement and 3.5% by mass of water in a mixing plant. Granular filter material shall consist of hard, durable and clean sand, gravel or crushed rock, free from clay balls and organic matter, and shall have a pH value greater than 6.0 and less than 8.0
Pearlitic Manganese Rail	Also known as medium manganese rail. It is typically used by tramways. Carbon content is in the order of 0.4 - 0.6% and manganese in the order of 1.2 - 1.6%.
Plain Carbon Rail	Rail typically used by railways but also used in smaller quantities by tramways. It contains carbon in the order of 0.6 - 0.8% and manganese in the order of 0.6 - 1.0%.
Preheating	The action of heating rail ends to a specified temperature prior to commencement of welding.
Public Transport Corporation	Public Transport Corporation (PTC) documents, including drawings, are referred to in this document. The PTC documents shall be utilised unless superseded by Yarra Trams documents.
Reinforcement Tie Bar	A steel reinforcing bar which had been welded to the top surfaces of the gauge side of the foot and across the two rails being joined. Reinforcement fabric was laid on this bar. This bar is no longer used.
Spacer Blocks	Steel blocks or packers utilised between the rails and base plate or straps to permit vertical and/or lateral alignment of the running and gauge surfaces of the rails being joined.
Straps	Steel plates welded to the top surfaces of the foot and also the web across the two rails being joined.
Sub-ballast	The trimmed and graded crushed rock or similar material forming the portion of the formation on which the ballast is laid.
Surfacing (Pad) Weld	A pad weld used at the step or alignment deviation in the rail groove or inside edge of the check of grooved rails.

Word	Definition
Technical Definitions	Refer to PTC document ENG- ESTD-2101, Track Technical Definitions.
Track	Consists of rails, sleepers, fastenings and ballast laid on the formation in continuity to line and grade.
T-Head Rail	Common section rail comprising rolled section foot, web and head without a guarding check.
Tramway Rails	T-head and grooved rails which may be pearlitic (medium) manganese, plain carbon or head hardened steel and which are used solely for running of trams and light rail vehicles.
Track Safety Circuit	A safety interlock for Autopoints installations, consisting of a transmitter and receiver fitted between the tracks for a length of approximately 10 - 20 m before the automatic points.

8. APPENDIX A - CEMBRE CONNECTOR - TYPICAL INSTALLATION PROCEDURE

Information note: The procedure below has been taken directly form the superseded standard VRIOGS 005.2 – Part3, Tram Track Construction, section 3.3. This is intended for information only and the information should be verified for suitability prior to use.

General

This instruction deals with the installation of the AR series track bonding device manufactured and patented by Cembre SpA of Brescia, Italy.

The Cembre AR60N connector is suitable for traction bonding, earth bonding & impedance bonding to track in all cases where an extremely low, constant electrical resistance is required.

It is suitable for use on rail having a web thickness from 12 to 13mm, including most types of grooved tramway track and AS41 kg/m rail.

Employees Required

The Supervisor ensures that all employees involved in installing Cembre AR60N connectors are competent in the areas of bonding installation and trackside protection. He/she determines and allocates the correct number of employees required to safely complete the task.

Materials Required

The Supervisor determines and allocates sufficient connector kits for the job in hand.

The following materials are required to make one track connection. Sealed Plastic Bag labelled 'Cembre AR60N' containing:

(a) One tin plated, flanged copper bush to fit hole diameter 19 mm;
(b) One 12 mm plated steel bolt with hollow hexagon head;
(c) One 12 mm Nyloc type anti vibration nut;
(d) One 12 mm flat washer.

Equipment Required

The Supervisor ensures that each work group is equipped with a CEMBRE installation tool kit with the necessary attachments for installing the Cembre AR60N connector.

Equipment required to fit an AR65 connector into a 19 mm hole already drilled in the rail:

(a) CEMBRE hydraulic tool HTEP consisting of pump, hose and head connected together, normally stored in a blue steel case marked 'Cembre' by embossing on the lid;
(b) CEMBRE "Go/No Go" gauge CAL 19.20 to test hole 22 mm diameter;
(c) CEMBRE calibrated plunger OG 13.20, which is used to extrude (expand) the bush in the hole.

Methodology

(Refer to Exhibit A at the end of this section for installation diagrams)

Trackside Protection

The Work Leader ascertains whether trackside protection is necessary, and if so puts it in place in accordance with the PTC book of rules and operating procedures, Section 15.

Reconditioning of Hole

It is possible to fit a Cembre AR60N connector into an existing 19 mm hole in the rail, provided the hole is thoroughly cleaned using a reamer and that the diameter of the cleaned hole does not exceed 20 mm as per the test in Clause 3.5.12.

Drilling of Hole (Ref Fig. 1)

Using a suitable drilling machine, drill a 19 mm diameter hole through the rail web at the neutral axis, ensuring that the hole is straight and level. Remove any burrs or swarf.

Testing of Hole (Ref. Fig. 2)

Insert the 'Go/No Go" gauge CALI9.20 provided into the hole. If the green part only passes, the hole is correct. If the GREEN and RED parts pass through the hole, the hole is too large and may not be used. In this case another hole of the correct diameter must be drilled.

Insertion of Bush (Ref. Fig. 3)

Insert the tin plated copper bush into the hole in the rail web with the flange on the sale of the rail to which connection is to be made.

Note that the bush does not protrude right through the hole.

Insertion of Plunger (Ref. Fig. 4)

Insert the calibrated plunger OG13.20 through the bush from the flanged side.

Attachment of Tool (Ref. Fig. 5)

Ensure that the plunger of the hydraulic tool is fully retracted (if not, press down the lever on the side of the pump until it is) and that the adaptor M9M5 is fully retracted. Using the socket head in the end of the 'Go/No Go' gauge, screw the plunger fully into the head of the hydraulic tool.

Note that if the plunger is not screwed fully in, damage may occur to the screw threads.

Operation of Pump (Ref. Fig. 6)

Operate the hydraulic pump by opening and closing the handles until the plunger has been drawn completely through the bush and the head becomes free of the rail.

Inspection of Bush (Ref. Fig. 7)

Inspect the bush to ensure that this has extruded right through the rail and ‘mushroomed' on the reverse side.

Note: This will indicate that the bush has been correctly installed. If the bush has not extruded correctly, this means that the hole size was incorrect, or the rail web is beyond the allowable tolerance. In this case the connection must be re-made.

Connection of Cable (Ref. Fig. 9)

Insert the hollow head bolt through the bush from the side opposite to the flange on the bush. Fit the lug, washer and nut. Tighten the nut until it grips the lug and then tighten a further one quarter turn to achieve the recommended torque.

Exhibit A

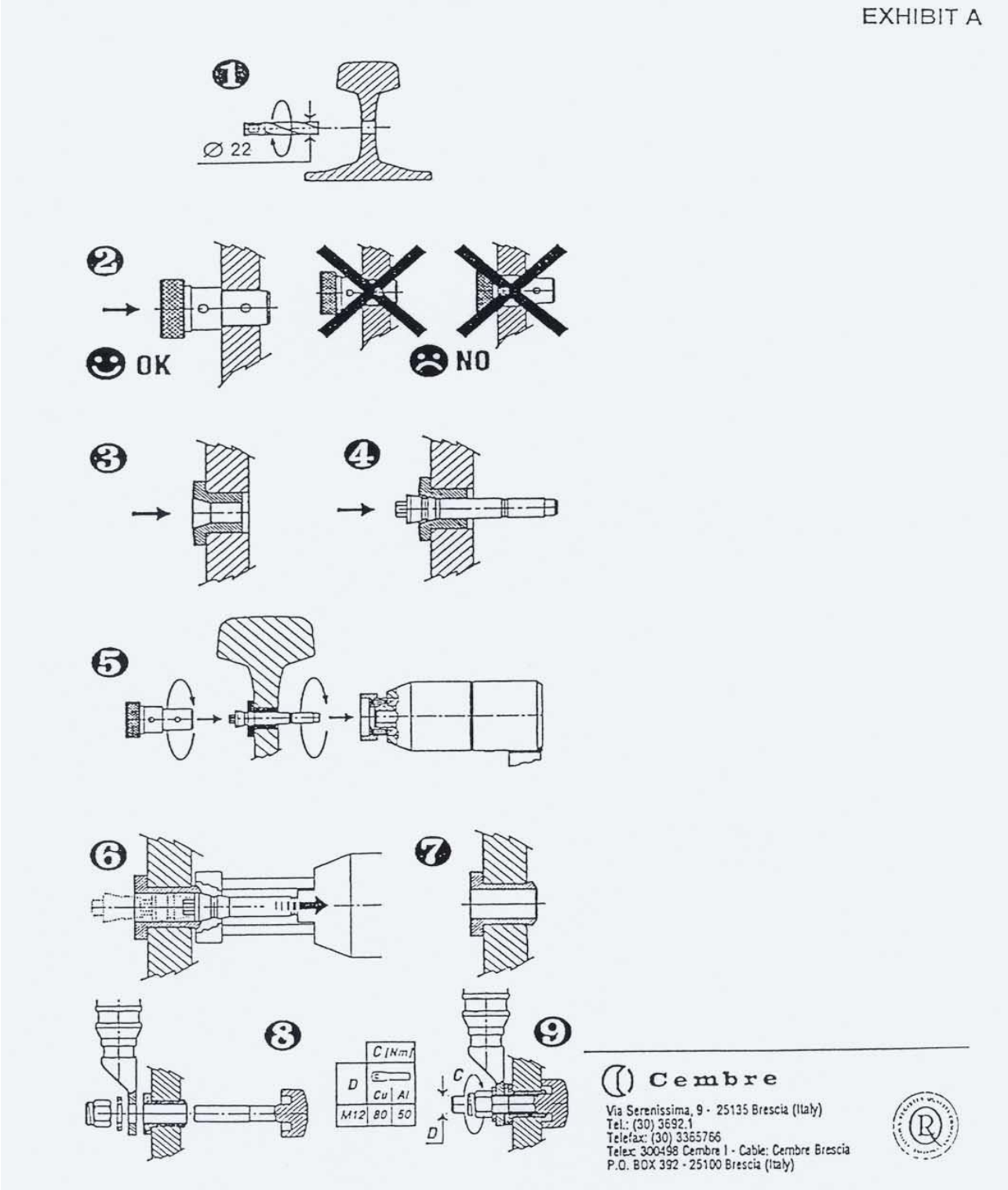
EXHIBIT A
1
Ø 22
2
OK
NO
3
4
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Cu Al
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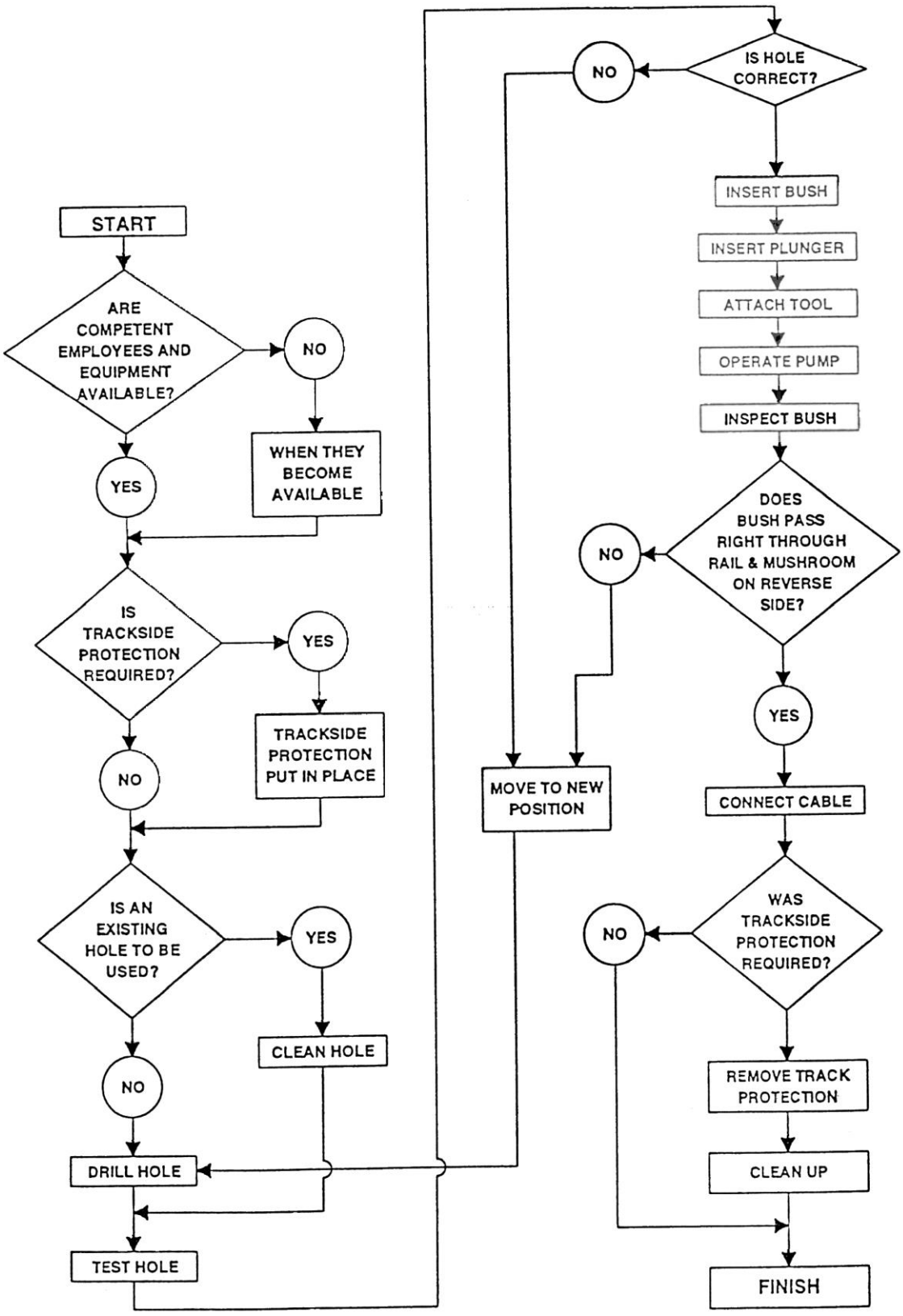
Cembre
Via Serenissima, 9 - 25135 Brescia (Italy)
Tel.: (30) 3692.1
Telefax: (30) 3365766
Telex: 300498 Cembre I - Cable: Cembre Brescia
P.O. BOX 392 - 25100 Brescia (Italy)

Flowchart


START
ARE COMPETENT EMPLOYEES AND EQUIPMENT AVAILABLE?
NO
WHEN THEY BECOME AVAILABLE
YES
IS TRACKSIDE PROTECTION REQUIRED?
YES
TRACKSIDE PROTECTION PUT IN PLACE
NO
IS AN EXISTING HOLE TO BE USED?
YES
CLEAN HOLE
NO
DRILL HOLE
TEST HOLE
IS HOLE CORRECT?
NO
MOVE TO NEW POSITION
INSERT BUSH
INSERT PLUNGER
ATTACH TOOL
OPERATE PUMP
INSPECT BUSH
DOES BUSH PASS RIGHT THROUGH RAIL & MUSHROOM ON REVERSE SIDE?
NO
YES
CONNECT CABLE
WAS TRACKSIDE PROTECTION REQUIRED?
NO
REMOVE TRACK PROTECTION
CLEAN UP
FINISH

9. APPENDIX B - Typical Test Procedure for Pole Bonding

Information note: The procedure below has been taken directly form the superseded standard VRIOGS 005.2 – Part3, Tram Track Construction, section 3.2. This is intended for information only and the information should be verified for suitability prior to use.

9.1.1.1 The pole bond conductor shall be disconnected at the pole and the resistance of the conductor between the pole terminal lug and the rail connection shall be measured. The test shall be conducted by a qualified electrician or qualified Technical Officer.

9.1.1.2 Yarra Trams shall approve the equipment as well as the method utilised to perform the test.

9.1.1.3 The results of the bond testing shall be submitted in writing to the Yarra Trams. The location, pole number, original cable resistance reading and final pole bond resistance reading after reinstatement shall be included in the test results. Depending on the test results obtained one of the procedures below shall be undertaken.

9.1.1.4 The cable shall also be visually inspected for damage along its length and adjacent to the rail connections. If any conductors are damaged, the cable shall be replaced.

9.1.1.5 If the cable resistance exceeds 0.1 Ohm, then:

9.1.1.6 If the pole carries underground feeder cables, an aerial switch or a sectionalising switch then a new 120 mm² double insulated conductor shall be run between the pole and the rail as per Standard Drawing STD_T0008. On completion of the cable installation the resistance between the pole and the rail shall be retested and shall not exceed 0.1 Ohm;

9.1.1.7 If the pole carries a surge diverter then three new 120 mm² double insulated cables shall be installed between the pole and the rail as per Standard Drawing STD_T3001 and STD_T3003, except that the cable to the surge diverter must extend all the way to the surge diverter and not stop 300 mm above ground level;

9.1.1.8 On completion of the cable installation the resistance between the pole and the rail, and the surge diverter earth cable and the rail shall be retested and shall not exceed 0.1 Ohm;

9.1.1.9 If the pole does not carry underground feeder cables, an aerial switch, a sectionalising switch or a surge diverter, the Superintendent's advice shall be sought whether to replace the pole bond cable or not;

9.1.1.10 If the bond cable is to be replaced it shall be done as per Standard Drawing STD_T3000;

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

9.1.1.12 If the bond cable is not to be replaced, then it shall be disconnected from the pole cut at or below ground level. At the track end the cable shall be cut as far away as possible from the rail and abandoned.

9.1.1.13 If the cable resistance does not exceed 0.1 Ohm then:

- The cable bond connections shall be reinstated at the rail and the pole as per drawing No. STD_T3000;
- On completion of the cable installation the resistance between the pole and the rail shall be retested and shall not exceed 0.1 Ohm.

10. APPENDIX C – Aluminothermic Welds

Information note: The procedure below has been taken directly form the superseded standard VRIOGS 005.2 – Part5, Tram Track Construction, Section 3. This is intended for information only and the information should be verified for suitability prior to use.

General

This procedure sets out the supply, manufacturing process and testing for joining of rails by aluminothermic welding.

The Contractor shall submit to the Yarra Trams for review and approval the source of supply of welding materials and equipment, compliance certificates, detailed procedures for welding, weld testing and rail de-stressing, qualifications of welders and ultrasonic testers and fire prevention management plan prior to the commencement of works.

Occupational Health & Safety

Yarra Trams is currently developing its own Hazcom Registration and this section will be updated once the process is finalised. Current registration to remain pending revised system.

Registration No. T-11543, (28/7/95) for Thermit Australia products. Registration No. R-11569, (21/2/97) for Railtech Australia products.

Material Safety Data Sheets:

Item	Thermit Aust. Reference	Railtech Aust. Reference
Moulds	Chemwatch 42022	Railtech Int. Feb 93/Rev 2
Portions	Chemwatch 41926	Railtech Int. Feb 93/Rev 2
Igniters	Chemwatch 41928	Railtech Int. Feb 93/Rev 2
Crucible Thimbles	Chemwatch 41927	Railtech Int. Feb 93/Rev 2
Luting Sand	Chemwatch 42023	N/A
Luting Paste	Chemwatch 42024	US Dept.Labr. OMB1218- 0072
Clay Cement	N/A	Railtech Int. Feb 93/Rev 2
Crucible (one - shot)	N/A	Railtech Int. Feb 93/Rev 2

Responsibilities

The Contractor and the Superintendent are responsible for conformance to this standard.

Weld Type Requirements

Aluminothermic welds shall suit the relevant rail sections, rail hardness and chemistry, and shall be either:

(a) standard gap, long preheat, for welding non head hardened rails (standard carbon & pearlitic manganese)
(b) standard gap, short preheat, for welding non head hardened rails (standard carbon & pearlitic manganese) to head hardened rails.
(c) standard junction, short preheat, for welding rail junctions (rails of different sections)

The use of wide gap welds (rail gap over 25 mm) is not permitted without the approval of the Superintendent.

Materials and Equipment

All welding materials and equipment, including safety equipment appropriate to the activity, shall be supplied by the Contractor and may be reviewed by the Superintendent prior to use.

Consumables shall be compatible with rail chemistry, including hardness.

Equipment shall be suitable for the relevant processes.

Aluminothermic welding materials shall comply with AS 1085.15 and the requirements of this standard. In particular the Contractor shall ensure that:

(a) All weld processes, including consumables, equipment and procedures shall be subject to Type Testing in accordance with AS 1085.15, Clause 6.2.
(b) All consumables shall be subject to proof testing in accordance with AS 1085.15, Clause 6.3.
(c) Supplier's Certificates of Compliance and certificates, as applicable, shall be provided to the Superintendent before the commencement of welding to demonstrate compliance with:
    (a) AS 1085.15, Clause 6.3, “Proof Testing of Batches” of portions;
    (b) Relevant standards, specifications and drawings for other consumables;
    (c) Relevant standards, specifications and drawings for equipment.

Operator Qualifications – Welders

Welders shall be trained and qualified for the brand and each type of weld used, e.g. standard gap, long preheat, short preheat, junction etc.

Certification shall be provided to and approved by the Superintendent prior to commencement of welding. The date of certification shall be within twelve months of commencement of contract unless documentary evidence of suitable experience and recent equivalent welding is provided to and approved by the Superintendent.

Welder training and certification by the welding materials suppliers or an Australian government railroad system are acceptable.

The Superintendent reserves the right to retest welders.

Operator Qualifications – Ultrasonic Testers

Ultrasonic testers shall be trained and qualified to AINDT Technician level and shall be experienced in rail weld testing.

Certification shall be provided to and approved by the Superintendent prior to commencement of testing.

The Superintendent reserves the right to retest ultrasonic testers.

Quality Assurance

General

For ballasted track, the Contractor shall develop and maintain a Quality System for the Works. The proposed Quality System including Certificates of Compliance and Production Control Test Reports shall be submitted to the Superintendent for review and approval prior to work commencing.

Certificates of Compliance and Production Control Test Reports shall be provided to the Superintendent immediately following each series of inspections/tests.

Quality System

The Contractor shall maintain detailed production control records, including submission of test reports which as a minimum include:

(d) Contractor's name;

(e) Contractor's I.D. or trademark (as marked on weld);

(f) Weld identification number (as marked on weld);

(g) Welder name and I.D;

(h) Date and time of rail welding;

(i) Location (e.g. line and kilometrage);

(j) Rail (e.g. up or down - up rail is the left rail when facing Melbourne);

(k) Rail Section (e.g. 47, 53, 60 kg);

(l) Brand of aluminothermic weld (e.g. Thermit, Railtech);

(m) Weld gap (e.g. 20 mm, 25 mm);

(n) Weld preheat (e.g. Long - LPH, Short – SPH);

(o) Weld type (e.g. Standard - AP, PL, SmW-F, SkV-F, Junction);

(p) Weld batch No (Portion batch number);

(q) Nature of weld (e.g. free, closing, tensioned);

(r) Whether closure rail utilised;

(s) Tense length;

(t) Rail temperature;

(u) Weather (e.g. Fine, Overcast, Wet);

(v) Test results (Visual, Alignment and Ultrasonic.);

(w) Signature of Contractor's Quality Assurance Officer.

A separate Quality Assurance certificate for Ultrasonic testing is required if the Production Control Report is not signed by an Authorised Officer for the Ultrasonic Testing Authority.

Defective Welds During Defects Liability Period

During the currency of the Contract or within the defect liability period, as defined in the Contract, any weld provided by the Contractor which does not conform to this standard, shall be cut out and a new portion of rail shall be welded in its place.

The Contractor shall be liable for the cost of providing the 3.0 m section of rail and all associated costs to reinstate the rail in the required specified condition.

Fire Prevention

The Contractor shall comply with all statutory requirements and prepare a management plan for the prevention of fires during welding and associated operations.

The fire prevention management plan shall be reviewed by the Superintendent prior to the commencement of operations.

The Contractor shall take all necessary precautions to prevent fires being started by hot metal, slag, waste products and grinding, and shall be solely responsible for meeting the cost of any damage should a fire occur.

Each welding team shall be equipped with suitable fire fighting equipment.

Methodology

General

All welds shall be manufactured strictly in accordance with suppliers' current codes of practice and recommendations.

Detailed welding procedures for all applicable processes shall be provided to and approved by the Superintendent prior to commencement of welding.

Location of Welds

No field weld shall be located within:

(a) 3 m of a bridge abutment or on a bridge;
(b) 3 m of a level crossing;
(c) 3 m of another weld;
(d) 3 m of a rail end (joint);
(e) 1.5 m of the end post of a glued insulation joint assembly;
(f) 65 mm of the edge of any rail hole unless approved by the Superintendent.

Field welds shall be located within + 50 mm from the centre of the bay between sleepers, unless otherwise approved by the Superintendent.

Rail Junctions

The heads of different classes of rail may be brought to the same gauge and level by use of aluminothermic junction welds.

Direct junctioning from Ri57A to Ri60 grooved rail or 41kg T rail are permitted as well as any other section of existing rail.

Head Hardened Rails

Head hardened rails shall be welded with portions to suit the hardness of the rail head.

Where a head hardened rail is welded to a non-head hardened rail, the portion hardness shall suit the head hardened rail.

Rail End Preparation

Rail ends for welding shall be even and square in both the vertical and transverse planes in conformity with weld supplier's code of practice.

Rail end preparation shall match, i.e. flame cut - flame cut or saw cut - saw cut. Rails may be saw cut or flame cut.

Any cracks or rail defects detected during a cutting operation shall be removed. Water shall not be permitted to contact a hot, oxy cut rail end.

Preparation of Joint and Welding

The heads of rails to be welded shall be vertically peaked and the gauge faces aligned in conformity with the weld supplier's code of practice using a 1 metre steel straight edge.

The preparation of the rail joint and the welding procedure shall conform strictly with the weld supplier's code of practice.

Preparation and welding operations shall be suitably protected from quenching as may occur in rainfall.

Weld Protection

Welds shall be protected in accordance with the following:

(a) From commencement of rail preheating until after completion of trimming, the rails being welded shall be protected from movement, shock and vibration.
(b) If it is necessary for a tram to travel over the new weld, the weld shall be sheared and risers bent back sufficiently to permit safe passage. The weld shall be rough ground, if necessary, to ensure a maximum weld protrusion of 2 mm. The steel wedges shall be removed from under the rail and sleepers packed, if necessary. The tram shall be supervised over the unground weld at low speed.
(c) The hot weld and rail shall be protected from quenching as may occur in rainfall.
(d) If a rail tenser is being utilised, it must remain effectively in place for a minimum of twenty minutes after completion of weld trimming.

Trimming of Welds

The hot weld excess head and sides shall be trimmed with hot sets and double acting shears. Care shall be taken to avoid notching the weld surfaces. Pipes (runners) shall be broken off when cold.

Grinding of Welds

The weld shall be ground smooth to the exact rail head profile after it has sufficiently cooled (not earlier than one hour after pouring). The grinding stroke should not exceed 500 mm to each side of the weld. A collar shall be left below the rail head. Particular attention must be given to grinding grooved rail and only a purpose built grinder and grinding stone must be used with suitably qualified staff to undertake this task.

Alignment of Welds

Alignment of the rails at welds shall be within the following limits:

(a) Running Surface
When a straightedge, 1 m long, is laid on the top surface of the rails symmetrically about the weld, any deviation between the straightedge and the rails shall not exceed, for mainline tracks:

(x) 0.5 mm peak or convex variation over the rail, i.e. a maximum deviation of 1.0 mm at the end of the straightedge with the other end in contact with the rail surface or;

(y) 0.0 mm dip or concave variation at the weld.

For siding and yard tracks:

(z) 1.0 mm for a convex variation or;

(aa) 0.5 mm for a concave variation.

No step or abrupt variation in alignment is permitted.

(b) Gauge Face

When a straightedge, 1 m long, is held against the gauge sides of the rails, symmetrically about the weld, 9 mm below the running surface of rails in the running surface of rails in tramway tracks, for mainline tracks:

(bb) The lateral misalignment shall be such that the maximum deviation from the straight edge shall not exceed 0.5 mm.

For Siding and Yard Tracks:

(cc) The lateral misalignment shall be such that the maximum deviation from the straight edge shall not exceed 1 mm.

Alignment inspection shall be carried out on each weld and the results recorded on the Production Control Test Report.

Cleaning of Welds

Welds shall be cleaned of sand and cast metal residues to permit a thorough visual inspection.

Marking Of Welds

For ballasted track all welds shall be clearly and legibly marked for identification purposes with:

(a) Contractor's initials or trademark;
(b) Date of weld manufacture (dd/mm/yy);
(c) Unique weld number.

The identification markings shall be in white paint, of minimum 20 mm height and, after exposure to normal weather conditions, shall remain legible for a minimum period of two years.

Two identification markings shall be painted for each weld. The markings shall be located on the rail web within 300 mm of the weld and shall be on diagonally opposite sides of the weld.

Sleeper Adjustment and Tamping

On completion of the grinding, the sleepers adjacent to the weld shall be adjusted to 685 mm maximum and tamped.

Cleaning Up

All slag shall be disposed of clear of the ballast and all surplus materials and containers removed from the site after each weld.

Visual Inspection

Each weld shall be visually inspected after completion of grinding and removal of pipes.

Visual Weld Inspection shall cover the entire weld surface and adjacent areas of the rails, with particular attention to the rail foot.

The rail and weld shall not exhibit any visible defects, including porosity, notching, grinding burns or other defects.

Welds exhibiting defects which may be detrimental to service shall be removed. Other defects shall be rectified to the satisfaction of the Superintendent.

Results of visual inspection shall be recorded on the Production Control Test Report.

Alignment Inspection

Each weld shall be inspected for conformance to alignment specifications. Results of alignment inspection shall be recorded on the Production Control Test Report. Welds which do not conform shall be removed.

Ultrasonic Testing

The Contractor shall carry out ultrasonic testing of each weld after completion of the grinding and the results shall be recorded on the Production Control Test Report.

Details of testing equipment, procedures and calibration shall be provided to and approved by the Superintendent prior to commencement of testing.

The cross section of the area of the head and web shall be completely scanned. The foot area shall be scanned in accordance with AS 1085.11, Figure C2. Welds shall be scanned in both directions.

A 70°probe shall be used to scan the head and a 35°probe to scan the web and flange from the head. The nominal frequency of probes shall be between 2 and 2.5 MHz.

Reference blocks similar to AS 1085.11, Clause C2.3 but with side drilled holes shall be used to establish test sensitivity. The reference holes shall be drilled in a similar rail adjacent to a similar weld. Test sensitivity shall be established by testing through the weld to the reference holes. Alternatively, an approved attenuation allowance shall be used.

Weld rejection criteria shall be in accordance with the following Table:

Segment	Probe	Rejection Criteria
Head	70°	2% i.e. 60 mm² total
Web	35°	25 mm maximum total
Flange	35°	Any defect indication
Head Or Web	70°	Any internal defect extending to the surface of weld
	35°	
Head Or Web	70°	Two defects, of half rejectable size or greater, in the one weld
	35°	

All welds found defective shall be removed.

Inspection and Additional Tests By Superintendent

The Superintendent reserves the right to carry out detailed inspection of the welding operation and request tests, additional to those required under this standard, to be performed by the Contractor at the Superintendent's cost.

The Contractor shall afford the Superintendent access at all times to the work site and to all welding and testing records.

De-Stressing

For all ballasted track, the Contractor shall de-stress all track to a stress free temperature of 38°C.

De-stressing shall strictly comply with PTC Circular CEC 3/87.

11. APPENDIX D – Manual Arc Welding (Kirby Joints)

Information note: The procedure below has been taken directly form the superseded standard VRIOGS 005.2 – Part5, Tram Track Construction, Section 4. This is intended for information only and the information should be verified for suitability prior to use.

SECTION 4.0 KIRBY JOINTS

Occupational Health & Safety Warning

NOTE : This section is under review by Yarra Trams. Policy requires all chemical substances to be registered by the Hazardous Chemicals Committee (HAZCOM) for specific processes and Designated Workgroups.

The aim is to ensure that the safest, technically acceptable products are used, and adverse environmental effects are minimised.

Applications for HAZCOM registration shall be made to Manager Health, Safety & Environment.

Further safety information may be obtained from the Occupational Health & Safety Adviser and Material Safety Data Sheets (MSDS) for the products:

US-CW155 dated 6 / 1 / 89 for Lincoln NR 311 wire electrodes. For approved equivalent electrodes, refer to relevant MSDS.

Welding Wire Electrodes

(a) HAZCOM Registration (Yarra Trams is reviewing this process):
Registration is not applicable to these products.

(b) Material Safety Data Sheets:
Refer to relevant electrode Material Safety Data Sheets (MSDS) for detailed information.

(c) Storage, Transport and Disposal:
Store in a cool, dry, well-ventilated area.

Dispose of damaged welding electrodes, residues etc. in waste skip.

(d) Personal Protection:
Use in well ventilated areas or provide suitable mechanical ventilation or welding fume respirator or air supplied respirator;

Avoid breathing fumes;

Welder shall wear a welding helmet;

Welder, assistants and supervisor shall wear anti flash safety glasses. Shield others by using a suitable screen;

Welder and assistant should wear appropriate PPE for welding tasks, which may include overalls, welding gloves, leather apron and leggings or spats and safety footwear to avoid spatter injuries.

(e) Health Effects And First Aid
Swallowing - Extremely unlikely due to nature of product;

Eye - Arc rays can cause injury. Fumes evolved during welding may cause irritation. Do not remove embedded particles – apply pads to BOTH eyes and obtain URGENT medical attention;

Skin - Arc rays can burn the skin. In the event of skin irritation, wash effected area with soap and water or use waterless hand cleaners. If irritation persists, obtain medical attention;

Inhalation - Fumes evolved during welding may cause a health hazard. Short term acute overexposure may result in discomfort such as irritation of nose and throat, dizziness or nausea. Remove from further exposure. If discomfort persists, obtain medical attention.

Personal Safety

For the safety of operators, assistants and bystanders, the procedures for gas cutting and welding, and arc welding as detailed in Tram Track Maintenance Department Welding Safety Procedures.

Welding, oxy cutting, preheating and grinding, produce hot metal. Care shall be exercised to avoid burns.

Metal flow on worn rails may have sharp edges. Care shall be exercised to avoid cuts and gashes.

Safe Working

Track safe working requirements shall be complied with. Maintenance work shall be carried out under track occupation or track/road protection conditions.

Electrical Safety

For maintenance and construction works where all rails are removed simultaneously, works shall be carried out in consultation with Yarra Trams Power Control Centre.

Fire

Before any cutting, preheating or welding is commenced, suitable fire protection equipment shall be available, properly located and manned.

During the Fire Danger Period, fireproof and spark shields shall be used where there may be a risk of fire.

A permit is required to conduct welding operations on Total Fire Ban days. This permit is issued on an annual basis upon application by Yarra Trams to the Metropolitan Fire Brigades Board, Melbourne. On days of Total Fire Ban, welding supervisors shall contact the M.F.B. and quote the permit number to allow the welding works to proceed.

Arc Welding, Gas Cutting and Preheating

The instructions relating to safety procedures and use of safety equipment for arc welding, gas cutting and gas preheating.

Welding shields shall be utilised, as appropriate, to protect nearby personnel and property from sparks, hot slag and arc burn etc.

Additional precautions are required when gas cutting, preheating and arc welding are carried out in close proximity to concrete, which will explode when overheated. These procedures should not be carried out within 600 mm of concrete. Additionally, steel plates or other heat shields shall be utilised to absorb heat and prevent heat radiating into the concrete.

The process of welding manganese steel produces fumes which are harmful to the central nervous system. The fumes are also irritating to eyes and the respiratory system. Skin sensitisation may be caused by contact.

Cutting, gouging, grinding and welding must be carried out only in well ventilated areas. Mechanical ventilation is recommended.

Welders must wear welding helmets with suitable filters and assistants must wear suitable disposable respirators. Personnel not involved in the process must keep clear of fumes.

Grinding

Suitable safety equipment and clothing shall be used when grinding: overalls, safety footwear, leather gloves, eye protection, dust mask (disposable), hearing protection etc.

A spark shield should be utilised where a fire hazard exists.

Personnel, equipment and materials shall be kept out of the path of grinding particles.

Care shall be exercised to ensure that no cuts or notches are produced on rails. Any damage shall be reported to the Tram Track Welding Supervisor.

General

Metal flow may have very sharp edges. Care shall be exercised when working on worn rails and track components.

Work Practices

Work practices shall comply with this instruction, including the use of the relevant safety equipment, suitable work clothing and specified equipment and materials.

General

This standard provides direction for the joining, by welding, of pearlitic manganese, plain carbon and head hardened tramway rails which will be embedded in concrete. The welding method employed is flux cored arc welding (FCAW) self -shielded. This method of joining rails is commonly referred to as a “Kirby Joint”.

The procedure incorporates preheating of the rail ends to prevent the formation of cracks in welded rail and subsequent brittle fractures.

This instruction does not cover welding of austenitic manganese steel castings to austenitic manganese steel castings or austenitic manganese steel castings to pearlitic manganese or carbon rails.

Responsibilities

The Track Engineer is required to assign the responsibility for supervision of weld preparations and welding procedures, use of approved equipment and consumables, employment of approved safety procedures and use of safety equipment.

The officer nominated by the Track Engineer shall be responsible for ensuring welder qualification and compliance with this standard.

The welder shall be responsible for use of approved equipment and consumables and for compliance with preparation and welding in accordance with this standard.

Records

Records of rail joining by welding shall be maintained. The records shall include information on the location of welded joint, rail section/s welded, preheating carried out, whether a head weld was employed

and also whether the rails were head hardened. The format of records shall be approved by the Track Engineer.

Qualification and Approval of Welders

This weld procedure shall be performed only by welders qualified and specifically approved for the process.

The Track Engineer shall be responsible for Training and approval of welders. Welders shall be subject to re-approval if not engaged in this procedure for a period of six months and at the discretion of the Track Engineer.

Inspections

The Track Engineer shall be responsible for regular auditing of the welding preparations and procedures.

The completed welds shall be carefully inspected visually for defects and alignment.

Any cracks or other defects shall be ground out and repaired by welding to this standard and re-inspected.

Equipment and Materials Required

(a) **Equipment:**

DC Welding power source complete with leads;

Wire feeder and welding gun for flux cored wire electrodes;

Oxy cylinders;

LPG cylinders;

Hose (oxy & LPG);

Regulators (oxy & LPG), High flow rate;

Flashback arresters;

Cylinder keys;

Preheating torch, 36 mm diameter rose burner;

Blowpipe handle with mixer;

Lighter, oxy welding and flints;

Rail profile grinder;

Friction saw or heavy duty large disc grinder;

Spindle (straight) or disc grinder;

Straight edge, 1 m;

Wire brush;

Chipping hammer;

Rail puller;

Rail clamps;

Thermometer contact type or temperature crayons.

(b) **Safety Equipment for Preheating and Welding:**

Arc welding helmet;

Preheating and oxy cutting goggles;

Anti-flash safety glasses (for all personnel in immediate area);

Welding screen;

Overalls, welding gloves, leather apron, leggings or spats and safety boots;

Mechanical ventilation and/or welding fume respirator or air supplied respirator if ventilation in work area is not adequate.

(c) **Safety Equipment for Grinding:**
Overalls, leather gloves, eye protection (grinding goggles), dust mask (disposable), hearing protection and safety boots;

Grinding shield.

(d) **General Safety Equipment:**
First aid kit including portable eye wash bottles;

Drum of fresh, clean water and soap (preferably liquid);

Firefighting equipment for grinding, cutting or welding.

(e) **Consumables:**
Lincoln NR311, 2.4 mm diameter flux cored welding wire electrodes;

Base plates, straps and spacer blocks;

Grinding wheels to suit rail profile grinder;

Cutting discs to suit friction saw or large disc grinder;

Grinding discs or stones to suit hand grinders (spindle or disc);

Oxygen & LP gas.

(f) **Consumables (Manganese Castings):**
Stainless Steel electrodes to AS 1553.3, e.g. CIG Satincrome 309 Mo shall be used for welding dissimilar metals, i.e.;

Austenitic manganese steel castings and mild steel;

Austenitic manganese steel and rail;

Rail and mild steel.

Manganese electrodes to AS 2576, Type 1215-A4, e.g. CIG Cobalarc Mangcraft shall be used for welding austenitic manganese castings to austenitic manganese castings.

Methodology

Welded Component Description

(a) Base Plate
The base plate is used at all locations where rails are joined using this procedure. The plate is packed or clamped to the underside of the rail foot centrally at the joint. After preheating of the rail ends of the joint, the plate is fillet welded to the foot on each side of each rail. A stepped or packed base plate shall be used when joining rails of dissimilar section (junction joints). Refer to rail preheating requirements, weld procedure worksheet 625TTW- KIRBY01 and relevant drawings for details.

(b) **Straps**

Foot straps are used at all locations where rails are joined using this procedure. Web straps are used where rail web alignment and clearance permits. The straps are fillet welded centrally at the joint to the top of the rail foot and side of the web. Stepped or packed straps shall be used when joining rails of dissimilar section (junction joints). Refer to rail preheating requirements, weld procedure worksheet 625TTW-KIRBY01 and relevant drawings for details.

(c) Spacer Blocks

Spacer blocks or packers are used where dissimilar rail sections (junction joints or rails with significantly different amounts of head wear) are welded using this procedure. The spacer blocks are fillet welded to the base plate and foot of the rail or strap(s) and foot or web of the rail. Refer to rail preheating requirements, weld procedure worksheet 625TTW-KIRBY01 and relevant drawings for details.

(d) Reinforcement Tie Bar

A reinforcement tie bar is no longer used where rails are joined using this procedure. The tie bar had been fillet welded to the top of the rail foot of each rail centrally at the joint.

(e) Rail Heads

The heads of rails are vee butt welded together only in the following circumstances:

Joining of non-head hardened, pearlitic (medium) manganese and plain carbon rails of identical section on curves of radius equal to or less than 350 m.

Joining of non-head hardened, pearlitic (medium) manganese and plain carbon rails of identical section where the gap between rails exceeds 1 mm.

Joining of non-head hardened, pearlitic (medium) manganese and plain carbon rails to head hardened rails of identical section where a gap between the two rails on the running surface at any point exceeds 1 mm.

Joining of non-head hardened, pearlitic (medium) manganese and plain carbon rails of dissimilar section (junction joints or significantly different amounts of head wear) to close any rail head gap and/or step or misalignment. Refer to rail preheating requirements, weld procedure worksheet 626TTW-KIRBY02 and relevant drawings for details. Unless otherwise approved, the head weld shall not be used to join head hardened (commonly referred to as S900 in Ri60) rails, as a significant reduction in hardness of the running surface of the rails will be produced. Rail heads shall be butted together such that no gap at any point exceeds 1 mm. Angle cutting of the rail head and undercutting of the web and foot of the rails utilising a friction saw or angle grinder may be required to reduce full running surface contact.

(f) Rail Grooves and Checks

Surfacing or pad welds shall only be used for transitions in the groove and also on the inside edge of the check of grooved rails where the misalignment exceeds 3 mm.

Transition lengths shall be ground to a slope not greater than 1:10.

The welds shall be produced immediately after head welding, if applicable, and while the joint is still hot.

Surfacing or pad welds shall not be used at the joint of head hardened to head hardened rails.

Welding parameters (voltage, amperage and welding consumable) shall conform to weld procedure worksheet 625TTW-KIRBY01.

If a head butt weld is not used, then the groove and check shall be preheated in accordance with weld procedure worksheet 625TTW-KIRBY01 prior to being welded in accordance with weld procedure worksheet 626TTW-KIRBY02.

Refer to grinding for misalignments of less than 3 mm.

Rail End Preparation

(a) Cutting

Rail ends shall be saw or friction cut. The cut ends of each rail shall permit butting of the rail heads to within 1 mm across the full head of the rail. Angle cuts may be dressed with a grinder.

Undercutting of the rail end by 1 mm, from the head to the foot, is recommended to provide no gap when the rails are butted together.

If, due to special circumstances, it is necessary to flame cut a rail end, 3 mm of material shall be removed by grinding whilst the rail end is still hot. A rail end which has been flame cut earlier and which has cooled to "touch warm" shall be recut a minimum of 25 mm from the cooled flame cut end.

Flame cutting of head hardened rail for use in track is prohibited except for preparation for a vee butt weld where a head hardened rail is joined to a pearlitic (medium) manganese or plain carbon rail.

The rail head preparation for the vee butt weld on non-head hardened rails may be flame cut immediately before commencement of the preheating and welding procedures. The preparation shall include removal of 3 mm of flame cut material by grinding before commencement of welding.

The prepared surfaces shall be visually inspected for cracks and reground if any are detected.

The grinder should not be used in a cutting action and care shall be taken not to notch the rail. Any accidental notches of less than 2 mm may be carefully dressed smooth by grinding. Deeper notches in rail ends shall be removed by recutting. Repair of notches in rails by welding is not permitted.

(b) Butting and Aligning

Rail ends to be welded shall be butted together as closely as possible, preferably with no gap between rail heads. (A tirfor or similar hand winch may be utilised. Attachment to the rail shall be with suitable eye bolts as close as practical to the joint, preferably utilising existing holes.) Care shall be taken to ensure that the rails are not pulled together excessively, forcing the feet of the two rails together and producing a peaked or high joint.

Refer to “Additional requirements for inserting of closure rails” for closure rail gaps.

The rail heads at the joint shall be aligned on the running and gauge surfaces and assembled with the base plate and base spacer block, if applicable, by utilising clamps or support packers.

(c) Preheating

Rail ends shall be butted and aligned, and assembled with base plate and spacer blocks, if applicable, prior to commencement of pre-heating.

Pre-heating shall not be carried out in rain.

Pre-heating shall not be carried out on the heads of the rails or checks , except as specified in preparation for surfacing or pad welds.

A correctly adjusted (neutral flame), suitable oxy-LPG pre-heating torch shall be used. The preheating torch shall not be applied closer than 30 mm to the rails being pre-heated.

Both sides of each rail end shall be evenly pre-heated from the rail ends to 150 mm beyond the rail ends. Pre-heating shall be confined to the top surface of the foot of each rail and to half the height of the web. Pre-heating shall be such that at all times during the welding process, relevant parts of the rail (foot and web) to be welded shall be at a temperature of between 270°C and 350°C.

Rail temperatures shall be measured on the foot and web of each rail at a minimum distance of 50 mm from the point of direct flame contact. A contact thermometer or temperature crayons may be used to check temperatures.

Temperature shall be measured not earlier than one minute after completion of preheating on similar profile rail joints and two minutes on dissimilar profile joints.

Precautions are required when preheating is carried out in close proximity to concrete, which will explode when overheated. Preheating should not be carried out within 600 mm of concrete. Steel plates or other heat shields should be utilised to absorb heat and prevent heat radiating into the concrete.

Concrete shall be cleaned from in-track rails by chipping and or grinding to provide clean surfaces prior to preheating of rails.

Weld Preparation and Welding Procedures

The welding procedure is based on preheating of rail ends, in accordance with this standard, prior to welding. Welding to rails without preheating is prohibited, unless otherwise specified.

Rail ends requiring head welding, in accordance with this standard and relevant drawings, shall be prepared by:

blade or friction saw cutting beforehand or

friction saw or grinder cutting immediately after welding of web straps or

flame cutting grinding of a minimum of 3mm depth of cut material, immediately after welding of web straps.

Rails and components shall be clamped in position in preparation for welding.

Rails, components for welding and consumables shall be kept dry and welding shall not be carried out in rain.

Preparation of rails and components and welding shall be carried out strictly in accordance with the relevant drawings and procedures as detailed in the following welding procedure worksheets:

Exhibit B - Procedure No. 625 TTW-KIRBY01, Pre-heating and fillet welding of straps and base plate, Revision No. 2.

Exhibit C - Procedure No. 626 TTW-KIRBY02, Rail head butt weld, Revision No. 1

The sequence of welding a rail joint (two rail ends), after rail end preheating, shall be:

(a) Base plate and spacer block, if applicable, to the foot of the rail from the end of the plate toward the rail end. Repeat for the opposite rail and overlap previous weld.

(b) repeat for base plate and spacer block, if applicable, to the foot of each rail on the other side of the joint rails
(c) web strap and spacer block, if applicable, in accordance with the relevant drawings, to the web of each rail on the field side (opposite side to check, if applicable), with a continuous weld on the top of the strap,
(d) foot strap and spacer block, if applicable, in accordance with the relevant drawings, to the top of the foot of each rail on the gauge side (under the check, if applicable), with a continuous weld all around the strap commencing in the middle of the strap and overlapping the start of the weld
(e) repeat for foot strap and spacer block, if applicable, on the field side (opposite side to check, if applicable),
(f) where necessary, surface or pad weld in the groove and also the inside edge of the check of grooved rails.

For welding of half joints (one rail end), as may be required during fabrication, the rail end shall be pre-heated, as specified, and each side of the base plate welded in accordance with welding procedure worksheet 625TTW KIRBY01.

For rail junctions only welding of spacer blocks to base plates may be completed before commencement of rail preheating.

Welding of the joint shall be carried out as a continuous operation. A disruption to the procedure may require additional preheating.

All weld ends shall be welded using an overlapping back welding technique over the weld for a minimum length of 20 mm to ensure that all craters are fully filled to the full cross section of the weld.

On base plates and foot straps where fillet welds run into an existing fillet joint, the weld shall continue a further 20 mm onto the existing fillet joint.

The welded rails shall not be permitted to cool rapidly. Heat blankets shall be used to cover the welded portions of rails (i.e. web and foot on each side of the rail ends. The blankets shall extend a minimum distance of 300 mm beyond the extremities of the welds, i.e. minimum length 900 mm.

The heat blanket shall remain in place for a minimum period of 15 minutes after completion of welding.

The heat blankets should not be draped over the heads of head hardened rails as surface hardness may be reduced by prolonged heating. The softening effect is time/temperature dependant and typically one hour should be regarded as a maximum for a temperature of 150°C.

Additional Requirements for Inserting of Closure Rails

The welding in of closure rails in concrete track involves additional requirements.

The minimum closure rail length shall be 2 m.

Closure rails shall be cut as close to the required length as possible. The maximum rail gaps at the ends of the closure shall not exceed 3 mm. Where possible, one rail end should be butted up to eliminate the need, unless otherwise specified, for a vee butt head weld.

Concrete shall be excavated and removed for a minimum distance of 600 mm beyond the rail end to be welded and to the sides of the rail to permit preheating of the rail end. Concrete shall be cleaned from the in-track rail by chipping and or grinding to provide clean surfaces for preheating and welding and even surfaces for the base plate and straps. Steel plates or other heat shields shall be utilised to absorb heat and prevent heat radiating into the concrete which is in close proximity.

Base plate and strap welding shall be completed on one joint before commencement of welding on the second joint.

Vee butt head welding, if required due to head gaps exceeding 1 mm, shall be commenced after completion of base plate and strap welding on both joints. The first head weld shall be permitted to cool to below 50°C before commencement of head welding of the second joint.

Surfacing or pad welds, if required, shall be produced immediately after head welding.

Closures shall be continuously supported with concrete after being welded in track.

If closures are left open for tram operation, each welded joint shall be adequately supported using a red gum timber block with two sets of wedges supporting the joint at two points. Additionally, similar supports shall be installed to ensure that unsupported spans do not exceed 500 mm. The integrity of these supports shall be maintained during operation of the service.

Welding Precautions

(a) Weld Cooling

Hot welds shall be protected from rapid cooling such as may occur during rain and no water shall be permitted to flow in the rail groove.

Concreting shall not be carried out at the site of the welded joint for a minimum period of 30 minutes after completion of the weld.

(b) Arc Strikes

Arc strikes outside of the weld zone shall be avoided due to the possibility of producing cracks. Any such strikes shall be dressed smoothly from the surface to a depth of 1 to 2 mm.

(c) Tack Welds

Tack welding to rails is prohibited without rail preheating. Tack welds shall be 6 mm fillets of minimum 50 mm length. Tack weld craters shall be filled to 6 mm weld profile. The tack welds shall be completely welded over during the final welding procedure.

Instead of tack welds, it is preferred that rails and components be clamped in position in preparation for welding.

Grinding of The Weld

Grinding of the rail head, as applicable, shall be performed only after the rail head has cooled to below 50°C.

A rail profile grinder shall be used to grind the rail head weld. A spindle (straight) or disc grinder shall be used to grind the rail check and groove.

A 1 m straight edge shall be used while grinding the rail head (wheel running surfaces) to ensure a good straight surface and profile.

The standard of finish of the completed joints shall be within the following limits on both the running surface and gauge faces 8 mm below the top surface:

Hollow maximum of 0.5mm under the centre of a 1m straight edge;

Peaking maximum of 1 mm at the end of a 1 m straight edge when placed centrally on the weld;

Localised steps or scallops not permitted.

Misalignment of rail heads on the running and gauge surfaces, due to different amounts of rail wear, shall be rectified by grinding. The slope of transition shall not be greater than 1:25.

Misalignments of the groove and check not exceeding 3 mm shall be rectified by grinding. The slope in transition shall not be greater than 1:10.

Any grinding required to make joints flush shall extend to 500 mm each side of the joint.

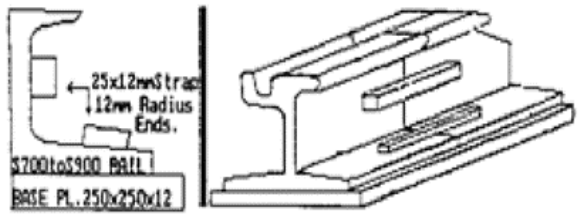
Head, groove and check welds shall be ground to the required finish before the conclusion of shift and before any traffic at normal speed is permitted to pass over the welds.

4.5 Welding Procedure Worksheet 25TTW-KIRBY01

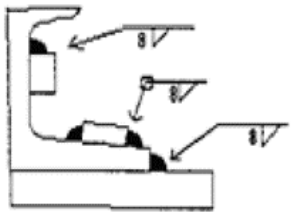
Catalogue number 0625	P.T.C. WELDING SERVICES WELDING PROCEDURE WORKSHEET	Test record (PQR) No. KIRBY 01
Manufacturer's name TRAM TRACK WELDERS	Procedure (WPS) no. 625TTW-KIRBY01	Revision no. 2

Welding Process FCAW -semi auto Root run process FCAW -semi auto Joint type Tee - fillet welded Welding position Horizontal-vertical Welding technique BACKHAND	PARENT MATERIAL Thickness 12 to 12 Type C-Mn steel Alloy PEARLITIC MANGANESE & Standard Grade S900 / S700 CARBON RAIL

WELD PREPARATION



RUN SEQUENCE



Method of prep'n SAW CUT OR FLAME & cleaning CUT & GRIND 3mm. min. DEPTH.	POST-WELD HEAT TREATMENT Specification: SLOW COOL Method: HEAT BLANKET Control: MINIMUM 15 MINUTES Soak temp: N/A Soak time: N/A
WELDING CONSUMABLES Filler material Make/type LINCOLN INNERSHIELD NR-311 Specific ETD-Nn-W500H Size(s) 2.4mm Shielding gas/flux Make/type Composition	Baking treatm't N/A

	Preheat	Interpass
Side 2 treatment N/A	Temp 270-350°C Method LP TORCH C/trol HEAT CRAYON	270-350°C RESIDUAL HEAT CRAYON

WELDING CONDITIONS	UNITS
Run number(s)	all
Electrode polarity	dc-ve
Consumable diameter	2.4mm
Current	320
Voltage/Arc length	26
Gas flow rate(s) (Shielding/Purging)	n/a
Travel speed	265mm/m
Wire feed rate	120in/m

Rail Vehicle Maintenance Engineering Group

COPY No. 1

Other Info.
AUTHORISED BY: S Martin
DATE: 23-2-97

NOTE:
THIS IS AN UNQUALIFIED INTERIM PROCEDURE. TO BE QUALIFIED BY TESTING BY SCIENTIFIC SERVICES.

"TRIAL" KIRBY TYPE TRAM RAIL JOINT.
FILLET WELDING OF BASE PLATE & STRAPS TO S900 HEAD HARDENED & S700 RAIL (FOOT & WEB). REF: JOINING OF TRAMWAY RAILS BY ARC WELDING. DOC.No.TS 96002

NOTES:

1. BASE PLATE JOINT: WELD FROM END OF BASE PLATE TOWARD RAIL END. WELD OPPOSITE RAIL FROM END OF BASE PLATE TOWARD THE PREVIOUS WELD & CONTINUE WELDING OVER PREVIOUS WELD FOR Min. LENGTH OF 20mm.

2. RAIL WEB STRAP: WELD CONTINOUSLY FROM ONE END OF STRAP TO OTHER END & FILL CRATER TO FULL CROSS SECTION OF THE WELD BY BACKWELDING TECHNIQUE.

3. RAIL FOOT STRAPS: START WELD IN MIDDLE OF STRAP & CONTINUE TO WELD AROUND RADIUS ENDS WITHOUT STOPPING. COMPLETE JOINT BY WELDING OVER THE START.

4. TACK WELD TO BE Min.50mm LENGTH & 6mm FILLET SIZE. FILL ALL CRATERS. NOTE: TACK WELDING OF HEAD HARDENED TYPE S900 RAIL "NOT PERMITTED".

Rev.1: 4/9/96 . Rev.2: 28/2/97 INTRODUCE PREHEAT & DELETE TIE BAR.

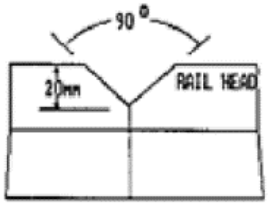
WELDSPEC PLUS TWI Software , Abington , Cambridge. Telephone (0223) 891162

4.6 Welding Procedure Worksheet 626TTW-KIRBY02

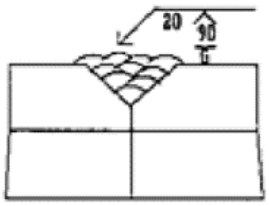
Catalogue number 0626	P.T.C. WELDING SERVICES WELDING PROCEDURE WORKSHEET	Test record (PQR) No. KIRBY 02
Manufacturer's name TRAM TRACK WELDERS	Procedure (WPS) no. 626TTW-KIRBY02	Revision no. 1

Welding Process FCAW -semi auto Root run process FCAW -semi auto Joint type Butt-1 sided/backed Welding position Horizontal-vertical Welding technique BACKHAND	PARENT MATERIAL Thickness 30 to 30 Type C-Mn steel Alloy PEARLITIC MANGANESE & Standard Grade S900 / S700 CARBON RAIL

WELD PREPARATION



RUN SEQUENCE



Method of prep'n SAW CUT OR FLAME & cleaning CUT & GRIND 3mm. min. DEPTH.	POST-WELD HEAT TREATMENT Specification: N/A Method: Control: Soak temp: Soak time:		
WELDING CONSUMABLES Filler material Make/type LINCOLN INNERSHIELD NR-311 Specific ETD-Nn-W500H Size(s) 2.4mm Shielding gas/flux Make/type Composition	Baking treatm't N/A		
		Preheat	Interpass
Side 2 treatment N/A	Temp Method C/trol	NONE	

WELDING CONDITIONS	UNITS
Run number(s)	all
Electrode polarity	dc-ve
Consumable diameter	2.4mm
Current	320
Voltage/Arc length	26
Gas flow rate(s) (Shielding/Purging)	n/a
Travel speed	265mm/m
Wire feed rate	120in/m

Rail Vehicle Maintenance Engineering Group

COPY No. 1

Other Info.
AUTHORISED BY: S. Mustin
DATE: 27-2-97

NOTE: THIS IS AN UNQUALIFIED INTERIM PROCEDURE. TO BE QUALIFIED BY TESTING BY SCIENTIFIC SERVICES.

"TRIAL" KIRBY TYPE TRAM RAIL JOINT.
BUTT WELDING OF RAIL HEAD.
TYPE S900 HEAD HARDENED RAIL TO TYPE S700 RAIL JOINT.
ALSO TO BE USED FOR TYPE S700 RAIL HEAD JOINT & OTHER RAIL TYPES HEAD JOINTS.
REF: JOINING OF TRAMWAY RAILS BY ARC WELDING. DOCUMENT No. TS 96002.

NOTES:
1. "NOT" TO BE USED FOR RAIL HEAD WELDING OF TYPE S900 TO TYPE S900 HEAD HARDENED RAILS.
2. FILL ALL CRATERS TO FULL SECTION HEIGHT.

Rev.1: 28/2/97. INCLUDE Ref. to PEARLITIC Mn. STEEL & DELETE Drg.No.

WELDSPEC PLUS TWI Software , Abington , Cambridge. Telephone (0223) 891162

Joining Rails To Manganese Castings - Methodology

General

This joining methodology is specific to welding of:

an austenitic manganese casting to an austenitic manganese casting and;

an austenitic manganese casting to a pearlitic manganese rail which will be embedded in concrete.

The procedure involves the welding of:

a mild steel base plate (also referred to as a sole plate) to the underside of the castings or casting and rail;

mild steel side straps to join the castings or casting and rail, and;

the sides and top of the castings or interfacing edges of the casting and rail.

Additionally, the welding of reinforcement bar stirrups to the casting is included.

Preparation

Electrodes in hermetically sealed metal cans which are known to be air tight on initial opening should be placed in an electrode drying oven at more than 100°C and taken directly from the oven for use as required.

Electrodes from any other source must be thoroughly dried by heating in a drying oven, to manufacturer's specifications, then maintained at a temperature of more than 100°C and taken directly from the oven for use as required.

Joint faces shall be a flush fit and/or butt neatly together. This may be carried out by the use of mild steel spacer blocks or by metal removal from the casting.

End joint faces of castings and rails for vee butt welding shall have a 60° included angle weld preparation.

Welding

Electrical settings on the welder shall comply with the electrode manufacturer's specifications.

A low heat input is required for welding of austenitic manganese steel. The maximum interpass temperature shall not exceed 250°C (i.e. it should be possible to place a hand on the job, a palm width away from the weld bead).

A stringer bead technique shall be employed where the weave is no greater than 2.5 times the electrode width.

It is preferred that prior to welding, rails are preheated generally in accordance with clause 4.4.4.c of this document or other approved method. However, rail preheating may be omitted if it can be demonstrated that weld toe cracking does not occur.

Tack welding of the base plate and also side straps at diagonally opposite corners is recommended to reduce stresses. Tack welds on rails shall conform to clause 4.4.7.c of this document.

Where possible, all weld runs shall be continuous. All weld ends shall be welded using an overlapping back welding technique over the weld for a minimum distance of 20 mm to ensure that all craters are fully filled to the full cross section of the weld.

All fillet welds shall have a minimum of 3 bead runs and be in the form of a 10 mm radius.

Welds shall be visually inspected for quality. Any imperfections shall be removed by grinding and re-welded.

Sequence of Welding

Joining austenitic manganese castings:

(a) Castings shall be accurately aligned on the top and running surfaces to ensure that the final standard of finish conforms to section G.3.6;
(b) Weld the base plate, and spacer block if required, centrally to the base of the castings;
(c) Weld the side strap centrally to each casting on each side of the casting;
(d) Weld the side sections of the casting from the underside of the side strap supports to the base plate on each side of the castings;
(e) Weld the top surfaces of the castings, ensuring slight overfill to permit subsequent flush grinding;
(f) Grind the top surfaces flush to ensure conformity with section G.3.6;
(g) Visually inspect welds for defects and repair by grinding and re- welding if required.

Joining an austenitic manganese casting to rail Refer to clause G.3.2 (c) regarding rail preheating:

(a) The casting and rail shall be accurately aligned on the top and running surfaces to ensure that the final standard of finish conforms to section G.3.6;
(b) Weld the base plate, and any spacer block if required, centrally to the base of the casting between the casting and the rail;
(c) Weld the side strap, and any spacer block if required, centrally to the casting between the casting and the rail;
(d) Weld the base plate, and any spacer block if required, to the foot of the rail on each side;
(e) Weld the side strap, and any spacer block if required, to the field side (opposite to check) of the rail with a continuous weld on the top of the strap;
(f) Weld the rail web and foot to the end of the casting, and spacer block if applicable, on both sides;
(g) Weld the rail head top and (check) side to the casting;
(h) Grind the top surfaces flush to ensure conformity with section G.3.6;
(i) Visually inspect welds for defects and repair by grinding and re- welding if required.

Attaching reinforcement bar to castings:

(a) Insert 25 mm diameter, 360 mm long deformed reinforcement bars to casting in holes provided and fillet weld the top of the bars to the casting on each side.