SPG 0709

TRACTION RETURN, TRACK CIRCUITS AND BONDING

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## Document control

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<thead>
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<tr>
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1 Introduction

1.1 Purpose of this document

In areas with electric traction, the rails serve two purposes in addition to providing the path on which trains run. Rails provide a low-resistance path by which traction currents can return to the traction supply substation, and they carry the relatively small currents of the track circuits used to detect the presence of trains on the line. Due to the safety-critical nature of the last-listed purpose, Signal Engineers have the duty to provide the means for both safe operation of track circuits and safe return of traction currents.

This document sets out the requirements of the RailCorp for track circuit insulation and bonding in all areas, and traction return bonding and electrolysis connections in electrified areas using 1500 volt DC traction. Traction requirements are discussed in terms of “Light” and “Heavy” traction current areas

Specific track circuit operating details will be found in the relevant standards for track circuits.

1.2 Definitions

In this document, the following definitions of terms shall apply

Chief Signal Engineer The person nominated by RailCorp as Approval Authority for signalling infrastructure standards and designs.

Chief Electrical Engineer The person nominated by RailCorp as Approval Authority for traction supply and distribution infrastructure standards and designs.

Signal Engineer The engineer responsible for the installation and maintenance of the signalling and traction return infrastructure.

Traction System Engineer The engineer responsible for the installation and maintenance of the 1500 volt traction supply and distribution infrastructure.

Hypalon Generic term for abrasion-resistant tough synthetic rubber insulation material specified for cables installed on ballast. Refers generally to CSP insulating materials, but may include other equivalents.

1.3 Referenced Standards

This standard makes reference to the following Standards:

RailCorp Standards

Signalling Design Principle ESG 100.17 – Track Circuits
Specification SPG 0705 Construction of Cable Route and Signalling Civil Works
Specification SPG 0707 Installation of Equipment Racks and Termination of Cables and Wiring
Specification SPG 1014 Cables for Railway Signalling Applications – Traction Return and Track Connection Cables
Specification SPG 1015 Cables for Railway Signalling Applications – High Frequency Screened Track Circuit Cables
Specification SPG 1066 Solderless Terminals and Cable Lugs for Signalling Applications
2 Traction Return System and Current Ratings

2.1 Traction Electrical Supply

The DC electrified area of the RailCorp network extends from Port Kembla and Kiama on the Illawarra line; Glenlee in the South; Lithgow in the West; and Newcastle in the North. All of this area is electrified with 1500 volts DC traction supply. In the Sydney metropolitan area the only significant line that is not electrified is the goods line to Botany.

The RailCorp electrified network uses a 1500v DC, overhead conductor catenary system with traction return via the running rails. The system provided for traction supply from substations connected to line via fault sensing circuit breakers. The catenary is sectioned by air gaps which allow a section to be isolated should a fault occur.

Return current is collected by connecting the substation negative bus bar to the rails, usually by way of impedance bonds.

2.2 Traction System Ratings

Historically, the traction return system was rated for a ‘Normal’ capacity of 1000A per rail continuous, with selected areas rated for ‘Heavy’ traction of 2000A per rail continuous, where a combination of steep grades and traffic density resulted in sustained high traction currents.

The designated Heavy Traction areas extended from Rockdale to Thirroul on the Illawarra line, Emu Plains to Lithgow on the Western line and West Ryde to Hamilton Junction on the Northern Line.

With the steady increase in overall traction loadings on the system, the distinction no longer applies, and all new installations shall be rated for ‘Heavy’ traction return capacity, with ‘normal’ traction ratings now to be termed ‘Light’ traction.

DC Circuit Breaker (DCCB) settings may be 3,000A to 8,000A depending on the current loading required by train operation.

2.3 Traction Return Resistance

Track circuits used in conjunction with electric traction must provide an unbroken, low-resistance path for traction current to flow from train to substation, while the maintaining the sectioning of tracks to provide a means of determining the location of a train.

Over the whole route between each Substation and Section Hut, the traction return circuit (ie the rails and bonding) shall have a resistance not greater than the value obtained by assuming that all main line rails are 53 kg/m and all are available for traction return.

The above requirement is based on the requirements of DC Traction protective circuit breaker settings.

The DC resistance values of individual rails to be used to calculate traction return resistance are as shown in Table 2.
The calculation of traction return resistance is the responsibility of the Electrical Engineer; however, the Signal Engineer must use the following guidelines for all designs.

<table>
<thead>
<tr>
<th>Single track</th>
<th>2 rails at all times</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual track</td>
<td>Mostly 4 rails, but 3 are allowed within interlockings, over points</td>
</tr>
<tr>
<td>Multiple tracks</td>
<td>Maintain the ratio for dual track unless specific permission is obtained from the Chief Electrical Engineer.</td>
</tr>
</tbody>
</table>

2.4 **Heat Rise Calculations**

The design of the traction return system and all components must take into consideration the temperature characteristics of all the equipment, and the thermal effects of the traction currents generated by the predicted traffic patterns.

Standardised designs consider the 6 and 10 minute rating of equipment for the typical gradients and traffic patterns within the Section.

Heat rise calculations shall include an analysis of the worst case period of traffic throughout the day. The design must ensure that the operating temperature of the traction return equipment remains within the manufacturers specified limits given the heat rise and cool down characteristics of the equipment for the worst case segment of the timetable.

The recommended combinations of impedance bonds, bonding cables and traction connections are to be found in Sections 6, 8, 9 and 11 of this specification.

3 **Track Circuits**

3.1 **Track Circuits - General Requirements**

3.1.1 **DC Electrified Areas**

All track circuits within DC electrified areas shall be DC immune.

Track circuits not over points shall be high frequency jointless, or pulse type.

Track circuit types, characteristics and installation limits shall be in accordance with Railcorp Specification SPG 1858 *Track Circuit types, characteristics and applications*.

3.1.2 **Non-electrified Areas**

Track circuits not over points may be any approved type.

3.1.3 **Track Circuit Equipment Installation**

Trackside equipment shall be mounted adjacent to the rail to which it is to be connected.

The track circuit connecting cables to rail shall be duplicated except for tuning unit cables on audio frequency track circuits.

The track circuit connecting cables to rail shall be kept as short as possible.

Cables running between high voltage pulse track circuit units shall be selected to give not more than the total circuit resistance recommended by the manufacturer.
Cables between transmitters and receivers and their matching units and tuning units shall be twisted pair shielded cable constructed in accordance with Specification SPG 1015 – "Cables for Railway Signalling Applications – High Frequency Shielded Track Circuit Cables".

Impedance bonds shall be provided where a jointless track is terminated at a set of block joints in electrified areas.

Junctions between rails of different sections shall not be used for insulated joints.

### 3.1.4 Points Track Circuits

Track circuits over motor operated points shall be high voltage pulse type. In special circumstances, the Chief Engineer Signals may approve the use of audio frequency jointless track circuits over points where both legs are subject to frequent traffic.

Track circuits over mechanically operated facing points shall be high voltage pulse type.

Insulated rail joints within a set of points shall be in the least-used or slower speed route wherever possible.

Track insulated rail joints shall be positioned so that no vehicle can be foul of the points without the points track circuits being occupied.

### 3.2 Polarity of Track Circuits

On track circuits which use insulated joints for separation, the polarity of adjacent track circuits must be alternated to ensure that the integrity of the insulated rail joint is monitored.

This requirement applies to DC tracks, single and double rail 50Hz AC tracks, and single and double-rail impulse tracks. It does not apply between tracks of different kinds, but does apply between single and double-rail tracks of the same kind. Audio frequency jointless track circuits shall alternate in frequency in accordance with the manufacturer’s recommendations.

The only permitted exceptions are the two parts of a centre-fed track circuit, and interfaces where the feed ends of two similar track circuits abut. In designing a yard area, where the layout renders it impossible to maintain polarity reversal at every insulated joint, the design shall be adjusted to make the like polarities appear at a feed-to-feed interface.

On jointed track circuits which use audio frequency or coding systems to differentiate between adjacent track circuits, the manufacturer’s recommended frequency alternation schemes must be strictly adhered to.

Where jointless tracks abut both ends of a section of jointed track circuits (e.g. at an interlocking) the frequency alternation scheme should be maintained for the audio frequency track circuits that abut each end of the jointed section.

Where a short jointless track lies between two long tracks (which will have the same frequency), the long tracks should be arranged with both transmitter ends abutting the short track or, if this is impractical, with both receiver ends abutting.
4 Track Circuits and Traction Return

4.1 Double Rail Track Circuits

4.1.1 Description

Double Rail track circuits use both rails for traction return.

4.1.2 Balanced Traction Currents

Impedance bonds rely for their proper operation on traction currents remaining balanced between the rails of the track circuit. It is the responsibility of the Signal Engineer to ensure that the traction return path is properly balanced.

Jointless double rail track circuits only require impedance bonds for tie-in and substation connections, and at interfaces to non-jointless types of track circuit.

4.2 Single Rail Track Circuits

4.2.1 Description

Single rail track circuits utilise only one rail for traction current return.

Single rail track circuits are used in station areas and over points where the track circuit length is short and the provision of impedance bonds would be costly.

The disadvantages of single rail track circuits are their limited ability to provide broken rail detection of traction rails, an increase in traction return resistance and a decrease in the integrity of the traction return system due to a reduction in parallel paths available.

Short track circuits used in isolation have little effect on traction return integrity or resistance. Long single-rail track circuits should not be used in electrified areas. Where the use of single rail track circuits over long distances is unavoidable the case must be referred to the RailCorp Principal Engineer Signalling Technology for specific approval, as higher traction return resistances adversely affect DCCB settings.

4.2.2 Longitudinal Voltage Drop in Traction Rail

Care must be taken to ensure that the operation of the track circuit can be maintained under all traction load conditions (see below).

When designing single rail track circuits care must be taken that the length of the track circuit does not lead to a DC voltage drop along the signalling rail which will result in signalling equipment failure. The traffic flow, gradient and the location of the nearest substation are significant in determining both the magnitude of the problem and its solution. Table 1 sets out the expected DC voltage impressed across the relay for typical traction currents.

This DC voltage may be the result of steady state currents, or short term starting current.
Table 1 - DC Voltage drop Impressed across Track Relay on Single Rail Track
(Values exceeding permissible limits are shaded)

<table>
<thead>
<tr>
<th>Current in Traction Rail(A)</th>
<th>Track Circuit Length (m)</th>
<th>Voltage Drop (volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1700</td>
<td>50</td>
<td>2.81</td>
</tr>
<tr>
<td>3400</td>
<td>75</td>
<td>4.21</td>
</tr>
<tr>
<td>5200</td>
<td>150</td>
<td>8.42</td>
</tr>
<tr>
<td>6800</td>
<td>200</td>
<td>11.22</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>14.03</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>16.83</td>
</tr>
</tbody>
</table>

The DC resistance values of individual rails to be used to calculate traction return resistance and longitudinal voltage drops are as follows:

<table>
<thead>
<tr>
<th>Rail size (Kg/m)</th>
<th>DC resistance Ω/1000m</th>
<th>microΩ /m</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>.0438</td>
<td>43.8</td>
</tr>
<tr>
<td>53</td>
<td>.0368</td>
<td>36.8</td>
</tr>
<tr>
<td>60</td>
<td>.0330</td>
<td>33.0</td>
</tr>
</tbody>
</table>

Table 2 - DC Resistance of standard rails

4.3 Double Rail 50Hz AC Track Circuits

4.3.1 Use and Operation

It has been established that this type of track circuit is sensitive to interference by stray mains frequency currents, resulting in potentially unsafe situations, and special maintenance precautions are required to ensure safe operation of existing installations. This type of track circuit is being actively phased out, and no new tracks of this type shall be installed.

4.3.2 Traction Rating of 50Hz Double Rail Track Circuits

The rating of double rail A.C. track circuits is determined by the type of impedance bond and dimensions of the bonding cable used.

In Light traction areas, impedance bond types rated for a minimum 1,000A per rail and suitable for 50Hz track circuits shall be used. (The use of higher rated bonds and cabling is acceptable). Recommended impedance bond types are set out in Section 11.1.

In Heavy traction areas, impedance bond types rated for a minimum 2,000A per rail and suitable for 50Hz track circuits shall be used.

Where the expected current loadings exceed the rating of the 2000A per rail impedance bonds, jointless track circuits must be used.

Bonding cable is specified in Section 8. Section 8.1 defines the cable that is to be used in heavy traction areas and Section 8.2 defines the cable that may be used in the lighter traction areas.
4.3.3 Tie in Bonding of Double Rail Track Circuits

Tie in bonds shall be provided at intervals of between one and two kilometres. There shall be no more than one tie-in bond for every other track circuit. The dimensions of cable, type of cable to be used and the methods of connection and laying are detailed in Section 6.6.

4.3.4 Connection to Substations and Sectioning Huts

Substation and sectioning hut negative bus bars are mandatory tie-in locations. Two impedance bonds of the appropriate rating must be provided on each road for connection to the negative bus bar at the substation. Only one impedance bond for each road is required at sectioning huts.

Details regarding connections to substations and sectioning huts are to be found in Section 5.

4.4 Single Rail 50Hz AC Track Circuit

4.4.1 Use and Operation

The design of single rail 50Hz track circuits shall include arrangements to limit the maximum level of DC traction current which may be applied to the track relay.

Where the length of track circuit is excessive, the levels of DC being superimposed may result in failure of the relay protecting fuse. The design shall provide sufficient series resistance in the relay circuit to limit DC traction current to a level that will ensure continuous operation of the track circuit equipment. A minimum DC loop resistance of 1 ohm is required in the relay circuit.

The DC voltage drop expected for a given traction current is set out in Table 1. This should be used to verify that the measures provided to protect the relay and / or feed units are sufficient. Track circuit length shall be limited such that the longitudinal DC voltage drop under maximum traction conditions does not exceed 20 volts.

Typical maximum single rail AC track circuit lengths are

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy traction</td>
<td>100m</td>
</tr>
<tr>
<td>Light traction</td>
<td>200m</td>
</tr>
</tbody>
</table>

However these lengths may need to be reduced in certain cases.

4.4.2 Traction Current Rating of Single Rail AC Track Circuits

Single rail AC track circuits are rated according to length and the protection provided at the relay end of the track circuit is set out in Section 4.4.1.

4.4.3 Cross Bonding of Single Rail AC Track Circuits

Cross bonding shall be provided at intervals of not more than 200m in accordance with Section 6.7.

4.4.4 Connection to Substations and Sectioning Huts

It is preferable that single rail track circuits not be used for these connections unless adjacent siding or refuge tracks provide supporting parallel paths. However, where other
requirements dictate their location, connections are to be made between the traction rail and the negative bus by the appropriate cables as set out in Section 5.

4.4.5 Transposition of Traction Rail

Transposition of the traction rail between Up and Down rails of adjacent single rail track circuits is acceptable, but only in exceptional circumstances.

Within any one track circuit, traction return should be arranged to follow a path of continuous rail in the main line or most travelled route, without any transpositions unless absolutely unavoidable.

At a transposition, care shall be taken to position the insulated joints as prescribed in Section 6.2.1.

Where a traction transposition is installed, the number and size of cables shall be the same as are used for impedance bond neutral connections in the same area.

4.5 Double Rail Jointless Track Circuits

4.5.1 Use and Operation

Jointless track circuits are normally separated by means other than mechanically insulated rail joints. They may be used with insulated rail joints and impedance bonds where a sharp cut off is required or when interfacing with another type of track circuit.

Jointless track circuits are suitable for use in Light and Heavy traction areas as there are no traction sensitive components.

Traction current unbalances between rails are normalised at tying-in points, and by air-cored inductors in some CSEE track circuits.

The maximum length of audio frequency jointless track circuits is not limited by traction current but by the net effect of shunt resistance across the track, including the effects of any impedance bonds used for tying in or connection to substations and sectioning huts.

4.5.2 Traction Rating of Jointless Track Circuits

The traction rating of jointless track circuits is determined by the rating of impedance bonds and cables used for connection of tie-in bonding or substation and sectioning hut connections and the termination of track circuits at insulated rail joints which must be appropriate to the traction level in the section.

4.5.3 Tie in Bonding on Jointless Track Circuits

Tie in Bonding for double rail jointless track circuits is to be provided at 0.8 - 1.6 km intervals and rated according to the traction current rating of the section. There must be at least one clear track circuit between track circuits containing tie-in bonds.

Section 6.6 sets out requirements for installation of tie-in bonding.

Tie in bonding is connected between impedance bonds installed on parallel tracks. Impedance bonds used for tying-in shall be rated for the traction rating of the area where they are installed.

The air cored inductor in the tuned loop on CSEE track circuits shall not under any circumstances be used for tying-in.
4.5.4 Connection to Substations and Sectioning Huts
Connection to substations and sectioning huts shall be by impedance bonds of the appropriate rating. The impedance bonds shall be mounted mid track circuit or in any case no closer than 50 metres from the nearest track circuit tuning unit. The connections are specified in Section 5.

Impedance bonds in these situations may be resonated as required. Details in regard to this will be found in the track circuit specification. In general, bonds should be left unresonated (with resonating capacitors open-circuited) unless the track circuit length and ballast conditions make resonance necessary.

4.6 Double Rail Audio Frequency Track Circuits - Jointed
In some circumstances, audio frequency track circuits may be installed as conventional track circuits, separated by insulated rail joints and with impedance bonds to provide traction return continuity. These can consist of conventional audio frequency equipment as used in jointless track circuit arrangements, or be of a particular design intended specifically for jointed operation only.

The specified frequency alternation scheme shall be maintained between adjacent track circuits of the same type, across each insulated rail joint.

Traction return and bonding requirements for this arrangement are the same as for double rail 50Hz track circuits.

4.7 Double Rail Impulse Track Circuits

4.7.1 Use and Operation
High voltage impulse track circuits shall be used particularly over points and crossings, and infrequently used tracks where it is most important to guarantee a safe and effective shunting of the track circuit.

Double rail impulse track circuits shall be used where it is necessary to maintain a two-rail traction return resistance path.

Double rail impulse track circuit impedance bonds are specialised impulse track circuit equipment and can not be substituted with other types of impedance bonds.

4.7.2 Traction Rating of Impulse Track Circuits
Impedance bonds for Impulse Track Circuits are rated for Light (1000A/rail) or Heavy (2000A/rail) current. In Heavy traction areas the Westinghouse 2000P impedance bond shall be used. In Light traction areas Jeumont Schneider CTI 1400 CT1 or Westinghouse 2000P impedance bonds shall be used.

4.7.3 Tie in Bonding of Impulse Track Circuits
On double rail impulse track circuits the tie-in bonding shall be made at intervals of between 0.8 and 1.6 km with one clear track circuit between the tie-in bonds.

High voltage impulse track circuits are generally not suited to the connection of additional impedance bonds in mid-track, so that tie-in bonding may only occur between the ends of track circuits on adjacent lines.
4.7.4 Connection to Substations and Sectioning Huts

High voltage impulse track circuits are generally not suited to the connection of additional impedance bonds in mid-track. Connections to Substations and Sectioning Huts should be made across the junction of adjacent track circuits specifically sited for that purpose.

4.8 Single Rail Impulse Track Circuits

4.8.1 Use and Operation

Single Rail Impulse Track circuits shall be used in station areas particularly over points, and other areas where contamination is likely to affect the ability of trains to shunt the track circuit. The single rail configuration develops a higher voltage impulse than its double rail counterpart and is therefore slightly more effective in obtaining a shunt under poor conditions.

4.8.2 Traction Rating of Single Rail Impulse Track Circuits

Single Rail Impulse Track circuits can be used in Light and Heavy traction cases but the length of the track circuit must be limited by the expected DC voltage drop from the maximum traction current calculated for the particular track circuit in question.

Single rail impulse track circuits can withstand a longitudinal DC voltage drop of 30 volts. In Heavy traction areas this permits a maximum track circuit length of 150m to 200m. In Light traction areas the maximum permissible length is 500m, but may be as little as 300m in areas close to substations or on grades.

The use of single rail track circuits in close proximity to substations should be avoided, due to the known risk of intermittent points failures caused by magnetisation of switches by high traction return currents.

4.8.3 Cross Bonding of Single Rail Impulse Track Circuits

Cross bonding shall be provided at intervals not exceeding 250m in accordance with Section 6.7.

4.8.4 Connection to Substations and Sectioning Huts

Connections to substations and sectioning huts are to be made to the traction rail in accordance with Section 5.

5 Traction Supply Interfaces

Signalling traction return shall be interfaced with the Electrical Engineer's negative bus bars in accordance with Track Circuits - Signalling Design Principle ESG 100.17.8, and Section 9 of this Specification.

5.1 Substations

At substations there shall be two impedance bonds of the appropriate rating (ie. 2 x 2000A/rail impedance bonds for Heavy traction areas or 2 x 1000 A/rail impedance bonds for Light traction areas) for each track.

Where there is more than one road, the neutrals of the impedance bonds shall be tied together with cables in accordance with Section 6.6 for tie-in bonds.
Each impedance bond neutral shall be connected via cables as specified in Section 8 to the negative bus bar nearest to it.

Where single rail track circuits are in use the traction rail shall be bonded directly to the negative bus bar by cables as specified in Section 8.1, to carry the full rated traction load i.e. for 2,000A in the Light traction case and 4,000A in the Heavy traction case.

The neutral points of the impedance bonds of adjacent track circuits shall be bonded together with cables or busbar in the usual manner, as well as to the substation negative busbar.

In cases where impedance bonds mounted between adjacent tracks would be foul of structure gauge, they may be mounted adjacent to the negative busbars and connected via underwire crossings to low-set auxiliary busbars mounted between the tracks.

### 5.2 Sectioning Huts

The negative bus of the sectioning hut is used to provide a reference point for DCCB operation. It may also be used for automatic earthing of the overhead conductors for maintenance and must be able to carry high fault currents for a short period of time.

At a sectioning hut where there are two or more tracks, these shall be tied-in in accordance with Section 6.6. Where the Traction system’s negative bus connects to each track this tie-in is not required.

The connection to the negative busbar of the sectioning hut shall be similar to that of the substation excepting that only one impedance bond per road is required. Each impedance bond neutral shall be connected via cable as specified in Section 8 to the negative bus bar nearest to it by the number of cables specified for neutral connections.

### 5.3 OHW Rail Connecting (Earthing) Switches

Where overhead wiring sectioning switches are required which can both isolate the overhead supply and connect the isolated overhead to a permanent rail connection, a design is obtained from the Signal Design office for this connection.

The Signal Engineer shall provide and install the connection to either rail or neutral point.

The Electrical Engineer will be responsible for providing and maintaining the rail connecting cable between the isolating switch and the rail or neutral point connection.

### 5.4 Temporary OHW Rail Connections

At many locations on the network, the Electrical Engineer has requested that permanent connection points be installed close to existing overhead wiring sectioning switches, for the convenient connection of temporary OHW earthing cables. This serves the dual purpose of speeding up the process of applying OHW earths, and of ensuring that the OHW earth is not connected to a signalling rail, which can result in damage to the signalling equipment.

When requested, the Signal Engineer will install a single 12mm Cadwelded stud, to which the Electrical Engineer will attach a small, highly visible identification plate.

### 6 Track Circuit Bonding and Track Insulation

At points and crossings, insulated rail joints and bonding shall be provided to ensure that track circuits operate effectively, traction return path is maintained, train detection is
maintained over all parts of the track circuit, and broken rail protection is maintained to
the extent required by Track Circuits - Signalling Design Principles - ESG 100.17.6 and
ESG 100.17.7.

6.1 Bonding at Points and Crossings

On main lines, bonding of points shall be arranged to provide maximum broken rail
detection of both rails in the main line and maximum assurance of train detection in the
turnout. On double rail track circuits this shall be achieved by the use of separate
receivers on each leg of the turnout. Where this is not practicable, special parallel
bonding arrangements for the turnout leg of the track circuit shall be applied. Where a
track circuit configuration requires two or more receivers, a minimum of two bonding
cables shall be used for the ‘series’ bond connecting each rail of a turnout to its
respective rail on the main line.

Elsewhere, single rail track circuits with series/parallel bonding shall be used over points
in preference to full parallel bonding, subject to the requirement that three rails out of four
be available for traction return.

Where the preferred methods are not practicable, for instance in crossovers between
main line tracks, double rail track circuits with full parallel bonding over points may be
used. Rails connected by parallel bonding shall not exceed 50 metres in length and the
track circuit parameters must conform to the manufacturer’s recommendations.

Insulation of points and crossings shall be arranged to place insulated joints in the less-
used path as far as possible. Bonding shall be arranged to minimise, as far as
practicable, the length of all parallel and series bonds.

Track insulation should be designed to use the minimum number of insulated joints
needed to comply with all other requirements.

The use of complex, multi-branched track circuits shall be avoided - any track circuit
which branches three or more ways should be subdivided into two or more simple track
circuits. Due to the diagrammatic nature of track insulation drawings and their inability to
accurately reflect the relative positions of items on track, bonding layouts which appear
feasible on paper may be complex and unmanageable in the field.

6.2 Bonding of Single Rail Track Circuits

The signalling rail of the single rail track circuit shall be bonded to the same standards as
the traction rail with exception of series bonds, which need not be used or rated for
traction return current.

Bonding cable used shall be in accordance with Section 8.1 or 8.2 as applicable.

Traction rails in single rail track circuits shall be as direct and continuous as possible,
including between contiguous track circuits.

Transitions, where insulated joints and bonding are provided to swap the traction rail
between the up and down rails of one track circuit, or between contiguous track circuits,
are not permitted except subject to prior specific individual design approval by the Chief
Signal Engineer, and in accordance with the following Section.

6.2.1 Arcing at Insulated Joints

When traction current is flowing through a wheel to rail interface, any interruption to that
contact is likely to draw an arc. Large arcs can damage the rail surface.
The potential to draw an arc exists when a traction rail finishes and the current flow has to find an alternative path.

This occurs at single rail track circuit interfaces where there is a gap between traction rails. If the insulated joints are located so as to not overlap, there is a loss of the current path, and an arc is drawn.

These locations are typically where the traction rail may change sides, in turnouts and usually with single rail track circuits.

When the traction rail changes from one side to the other, at transitions, or in turnouts, care must be taken to ensure the blockjoints are so arranged that a continuous traction return path is provided for each axle on the train over the transition.

Where a small overlap cannot be achieved, the Signal Design Office should be consulted.

The following shows the preferred installation arrangements.

![Diagram showing blockjoint arrangements to minimise arc erosion](image)

Figure 1 – Blockjoint Arrangements to Minimise Arc Erosion

### 6.3 Bonding of Double Rail Track Circuits

For the purpose of improving broken rail detection it is preferable to use additional receivers rather than full parallel bonding. Where parallel bonding is used in double rail track circuits are over points and crossings shall connect both ends of the parallel rails unless multiple receivers are used.

Where multiple receivers are used a minimum of three bonds shall be used to connect each rail of a turnout to its respective rail on the main line. No other parallel bonds are to be used.

Where full parallel bonding is used, rails connected by parallel bonding shall not exceed 50 metres in length and the track circuit parameters must conform to the manufacturer’s recommendations.
6.4 Series Bonding

Series bonding shall not be used for traction current return purposes. The sole exception to this requirement is the ‘series’ bond connecting the turnout leg of a set of points with double receivers.

Series bonds shall be duplicated cables of at least 7/0.85mm conductors, installed in buried route between potheads adjacent to each extremity. Connection from pothead to rail shall be by duplicated steel (7/19/0.23 mm) or copper (84/0.3 mm) Hypalon cables.

6.5 Parallel Bonding

All parallel bonds shall be at least duplicated at each connection point. Parallel bonds shall be installed at both ends of any parallel bonded section of rail.

Parallel bonding shall be fully visible throughout its length, and not be permitted to become hidden or buried by ballast. Where specified for the particular project, parallel bonding may be buried in accordance with Section 6.10.

It is essential that bonding cables be installed so that continuity can be checked visually.

All Hypalon insulated cables shall be laid directly on the ballast and secured to the sleepers or foot of the rail with suitable clips at not greater than 600mm intervals. Where the Hypalon cables run parallel to each other they shall be tied together at not greater than 600mm intervals to form a single unit.

Hypalon cables shall never be buried direct nor be permitted to become covered with ballast.

When surface run, PVC insulated bonding cables shall be installed in heavy duty, orange coloured flexible PVC conduit laid on the ballast and secured to the sleepers with suitable clips at not greater than 600mm intervals.

6.6 Tie-In Bonding

Tie-in bonding may also be referred to as cross-bonding. It refers to the practice in double rail track circuited areas, of connecting together traction neutral points on adjacent tracks, to increase the parallel return paths available for traction current in both normal and fault conditions, and thereby to minimise the traction return voltage drop.

In electrified areas, parallel roads shall be tied together as frequently as practicable subject to the restrictions imposed, to minimise the traction system return resistance and to ensure the availability of a traction return path.

6.6.1 Tie-In Bonding Interval

In open track, tracks shall be tied-in at substations and sectioning huts, and between these at intervals of between 0.8 and 1.6 kilometres. There shall be at least one track circuit clear of tie-in bonding between track circuits which have tie-in bonds. The first tie-ins on either side of a substation shall be placed as close as possible within those limits.

Tie in bonds, cable quantities and dimensions are set out in Section 8.1 or 8.2 as applicable.
6.6.2 Rating of Tie-in Bonding

Tie in bonding is normally responsible for passing one third to one half of the traction current generated on one road to the parallel road. In fault conditions the tie-in bonding may have to carry the full traction load.

6.6.3 Track Circuit Integrity Considerations

Tie in bonding may, under certain bonding fault conditions, allow circulating signalling currents to interfere with the safe operation of the track circuit. It is for this reason that tie-in bonds must be separated by a clear track circuit.

Where insulated rail joints are in use, the tie-in is made between the impedance bonds at the end of the track circuits. In some cases where the type of track circuit permits it, an additional impedance bond can be fitted mid track circuit for the purpose of tying-in to a parallel track. Jointless track circuits require impedance bonds to be provided mid track circuit.

On multiple-track lines, tie-in bonds must not be installed between track circuits of the same frequency.

Tie in bonds shall be as short as possible and tie-in points shall be as near as practicable directly opposite each other. Connections shall be made between the neutral points of impedance bonds on both tracks.

Cables shall be installed as specified in Section 6.10.

6.7 Cross Bonding of Single Rail Track Circuits

Cross-bonding refers to the tying-in of traction rails at more frequent intervals in single-rail track circulated areas.

Single rail track circuits provide a reduced traction path, with consequent increased traction return resistance. Parallel traction rails shall be bonded together by appropriately rated traction cables, to form a common traction return ‘grid’. The typical cross bonding interval is 200-250m. Cross-bonding may also include connections to sidings or impedance bond neutral points on adjacent double-rail track circuits.

The cross bonding cables shall be connected to rail as specified in Section 9. The cables shall be surface run over the ballast to allow the continuity of the cable and condition of the insulation to be inspected easily. However, where cable theft is known to be a problem, or the cable run is long the customer may require an under-track crossing to be provided. Installation shall be as specified by Section 6.10.

The cable numbers and dimensions for cross bonding are specified in Sections 8.1 and 8.2 for Heavy and Light traction respectively.

6.8 Bonding at Friction Buffer Stops

Friction buffer stops rely on being clamped to both rails to achieve their frictional sliding characteristics. Where friction buffer stops are provided on track circulated lines, insulated joints are to be provided before the buffer stops to ensure the correct operation of the track circuit.

Bonding shall be provided to ensure the rails that the buffer stops are mounted on are connected to the traction return system.
Where tracks are wired for electric traction but not track circuited, their rails shall be bonded together and tied into the adjacent traction return system at their extremities and at intermediate points, depending on the length of the track involved.

6.9 Tying-in Non-Track Circuited Tracks

Where tracks are wired for electric traction but not track circuited, their rails should be bonded together and tied into the adjacent traction return system at their extremities and at intermediate points, depending on the length of the track involved. Traction return bonding shall also be maintained for a short distance past the end of the overhead wiring, at any location where an electric locomotive or train might over-run the end of electrification and render an unbonded return rail ‘live’ at traction supply voltage. This additional traction bonding shall extend for 100 metres past the last point of electrified overhead.

Non-electrified, unbonded tracks shall be isolated from rails bonded to the traction return system with insulated joints in both rails, to minimise electrolysis effects, as detailed in Section 7.2.

6.10 Installation of Tie-in and Cross-Bond Cables

Tie-in bond cables shall be run as surface cables in aluminium or copper Hypalon, or as V75 PVC cables in underline crossings.

Due to their increased attraction and vulnerability to theft, the preferred installation method for copper tie-in bonds between off-track impedance bonds is in underline crossings.

Where there is a particular requirement for mechanical protection of the bonding cables, PVC insulated copper bonding cable shall be installed, buried in class 12 rigid PVC conduit to within 250mm of rail or impedance bond. The ends of these conduits shall be sealed with concrete or an approved substitute.
7 Electrolysis Protection

7.1 Electrolysis Protection - General
DC traction return systems will inevitably have a percentage of the traction return current leak from the rail into the surrounding earth. This leakage current will find its way through earth, back towards the originating substation. Along the way, the current may encounter buried metallic services, especially pipelines, whose low resistance compared to the surrounding earth makes them a preferred path for the stray current. Where the current exits from the buried service to return to the traction rails, it can cause serious erosion of the metal of the buried service. This erosion caused by stray current is called electrolysis.

As the source of the damaging stray currents, RailCorp is obliged to limit the presence of stray currents, and to mitigate its electrolysis effects. This is achieved by, firstly, restricting traction current to rails where a traction current return is needed and, secondly, by providing for the managed return of stray currents to the rails in a way that does not give rise to electrolysis.

7.2 Electrolysis Protection - Restriction of Traction Currents
On wired tracks (tracks with overhead traction supply), care shall be taken to maintain as high as possible the electrical contact resistance between rails and earth, by ensuring that traction return rails are kept clear of excessive ballast and especially spoil or other moisture-retaining soil.

Insulated joints shall be provided in all traction rails at all interfaces between wired track and unwired branches or sidings, to restrict DC traction return currents to areas of ‘wired’ track.

Traction return bonding shall be maintained for a short distance past the end of the overhead wiring, at any location where an electric locomotive or train might over-run the end of electrification and render an unbonded return rail ‘live’ at traction supply voltage. This additional traction bonding shall extend for between 20 and 50 metres past the last point of electrified overhead.

7.3 Connection of Electrolysis Bond to Track
The traction return system shall include the connection of electrolysis bonds as required.

The Chief Electrical Engineer, with the New South Wales Electrolysis Committee, determines the location at which electrolysis bonding facilities are required, and the type of bonds to be used together with the bond conductance and expected maximum operating voltage and current.

The Signal Engineer is responsible for connecting the electrolysis bond to rail at the specified location.

Electrolysis bond connections shall be made to a convenient traction neutral point close to the utility’s electrolysis bond. The electrolysis bond should not be more than 50m from the rail connection. Suitable neutral points are existing impedance bond neutral point connections, SI units (air-cored inductors) on CSEE track circuits, and the traction rail of any single rail track circuit.

Where suitable existing neutral points are not available a Store 54 centre tapped inductor unit may be used on double rail AC and audio frequency track circuits. The Store 54 choke is not suitable for connection to double-rail impulse track circuits. Details of the
Store 54 choke are given in Specification SPG 1133—“Single-Phase Air-Cooled Isolating Transformers for Signalling Applications”.

Two cables shall be provided for the connection from the electrolysis bond to the traction neutral point:

- a) One 7/1.70 PVC/PVC/Nylon insulated cable, which carries the traction current from the electrolysis bond to the neutral point connection.

- b) One 7/0.85 PVC/PVC/Nylon insulated cable, which is connected to a voltage sensing test terminal at the electrolysis bond.

For double rail track circuits the SI or impedance bond shall be connected in the usual manner to rail. If a Store 54 unit is used it shall be connected to each rail by twin 84/0.3mm copper Hypalon insulated cables. These are connected to rail by copper crimp lugs and tapered bolts or 6mm welded studs.

Connection to a single rail track circuit shall be via bootleg riser or junction box and then by twin 84/0.3mm Copper Hypalon insulated cables to the traction rail of the track circuit.

8 Cables and Busbars

Cables are used to connect impedance bonds and negative bus bars to rail and between neutral points of impedance bonds mounted in-track. They are also used for tie-in bonds, cross bonds, bonding of mechanical rail joints, “out of service” insulated rail joints, and the connection of electrolysis bonds to rail. Bus bars should be used between neutral points of adjacent impedance bonds when they are mounted externally to the track.

The current rating of cables and busbars shall be matched to the defined traction current rating of the installation area. Specified crimp lugs are designed to carry the full traction rating.

Because of the prevalence of theft of copper cable, aluminium bonding cables should be used wherever practicable. If it is necessary to install copper cables, they should be installed with additional protection as described below.

8.1 Heavy Traction Areas

8.1.1 Cables

In Heavy traction areas the standard cable size is 300mm² aluminium. This may be provided as either 1525/0.5 mm (300mm²) aluminium (or 3 by 925/0.5mm aluminium for each pair of copper cables), 962/0.5mm CSP90 Hypalon or equivalent insulated copper, or 3 by 37/2.03mm V75 PVC insulated cables for each pair of 962/0.5mm cables, when it is to be buried. The cables to be used in various applications are set out in the table below.

<table>
<thead>
<tr>
<th>Cable Conductor Application</th>
<th>300mm² aluminium 1525/0.5mm</th>
<th>185mm² aluminium 925/0.5mm</th>
<th>185mm² copper 962/0.5mm</th>
<th>120mm² copper 608/0.5mm 37/2.03mm</th>
<th>70mm² Rail head bond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side leads</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Neutral leads</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Tie in bonds</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Cross bonds</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>
In certain circumstances a combination of particularly high traction currents, steep grades and frequent traffic may exceed the 2000 amp per rail continuous current rating of Heavy traction areas. Where calculations show that such circumstances may be encountered, an upgraded rating of traction cables (Heavy Class 2) shall be used. Impedance bonds rated for 2000 A/rail may be used in this application.

The cables to be used for extra-Heavy traction (Heavy Class 2) applications are as set out in the table below.

<table>
<thead>
<tr>
<th>Cell</th>
<th>Application</th>
<th>300mm² aluminium</th>
<th>185mm² aluminium</th>
<th>185mm² copper</th>
<th>120mm² copper</th>
<th>70mm² Rail head bond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side leads</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Neutral leads</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Tie in bonds</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cross bonds</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Neutral to substation neg. bus connection</td>
<td>8</td>
<td>8</td>
<td>12</td>
<td>12</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Mechanical joint bonding</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Bonding out IRJ</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 - Use of Bonding Cable for Heavy-Class 2 Traction Conditions (combinations shown shaded are not preferred)

Track insulation and bonding plans may augment these minimum standards in special circumstances.

8.1.2 Neutral Bus Bar

Where the impedance bonds are mounted on stands next to the track, the connection between adjacent impedance bond neutral points should be made by a tinned copper busbar 3500A continuous rating 160mm x 10mm or equivalent.
8.2 Light Traction Areas

8.2.1 Cables

In Light traction areas the standard cable size is 185mm$^2$ aluminium. This may be provided as either 925/0.5mm Hypalon insulated aluminium 608/0.5mm CSP90 Hypalon or equivalent insulated copper, or 37/2.03mm PVC insulated copper when it is to be buried. Larger size cable may be used, as well as 70mm$^2$ ‘Cadweld’ head bonds. The cables to be used in various applications are set out in Table 5 below.

<table>
<thead>
<tr>
<th>Cable Application</th>
<th>185mm$^2$ aluminium</th>
<th>120mm$^2$ copper</th>
<th>185mm$^2$ copper</th>
<th>70 mm$^2$ Rail head bond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side leads</td>
<td>2</td>
<td>2</td>
<td>N/A</td>
<td>-</td>
</tr>
<tr>
<td>Neutral leads</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Tie in bonds</td>
<td>2</td>
<td>2</td>
<td>N/A</td>
<td>-</td>
</tr>
<tr>
<td>Cross bonds</td>
<td>2</td>
<td>2</td>
<td>N/A</td>
<td>-</td>
</tr>
<tr>
<td>Neutral to substation neg. bus connection</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Neutral to sect. hut neg. bus connection</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Mechanical joint bonding</td>
<td>2</td>
<td>2</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>Bonding out IRJ</td>
<td>2</td>
<td>2</td>
<td>N/A</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 5 - Use of Bonding Cable for Light Traction Conditions

Track insulation and bonding plans may augment these minimum standards in a particular installation.

8.2.2 Neutral Bus Bar

Where the impedance bonds are mounted on stands next to the track, the connection between adjacent impedance bond neutral points should be made using a tinned copper bus of 3500A continuous rating 160mm x 10mm or equivalent.

8.3 Bonding ‘V’ and ‘K’ Crossings and Mechanical Rail Joints

‘V’ and ‘K’ crossings shall be bonded using single 127mm$^2$ Cadweld bonds welded to the neutral web of the rail, in accordance with drawing M04-123. This is in preference to the previous practice of bonding with duplicated 70mm$^2$, long Cadweld head bonds welded to the outer head of the running rails.

Rail joint bonds may be 2 x 70mm$^2$ Cadweld rail head bonds, welded to the outer head of the running rail, or a minimum of two (2) 1250mm lengths of copper cable as specified in the Table 3 above.
9 Rail Connections

9.1 Track Circuits

The track circuit trackside equipment shall be installed on mounting posts in accordance with Specification SPG 0705 Construction of Cable Route and Associated Civil Works and Cable Laying.

The cables from the trackside equipment boxes or bootleg risers to rail shall be

a) 95mm² copper or equivalent cable for audio frequency track circuits

b) Steel or copper Hypalon cables for all other track circuits. The choice of steel or copper Hypalon cable will depend on cable lengths and resistance considerations.

All new track circuit connections to rail shall be installed using Track Cable Protector (TCP) plates to positively locate and protect cables within the rail zone, and detailed in Section 9.9 and Procedure G.

Where this is not practicable, and as a minimum, cables shall be secured to the rail foot using a suitable proprietary strain relief clip, at a point not more than 300mm from the rail connection.

Steel and copper Hypalon cables shall be laid directly on the ballast and secured to the sleepers with suitable clips at not greater than 600mm intervals.

Note: Hypalon insulated cables shall never be direct buried.

Where the Hypalon cables run parallel to each other from trackside equipment boxes or bootleg risers, the cables shall be tied together with non-metallic UV stabilised cable ties at not greater than 600mm intervals to form a single unit.

The rail connecting procedures listed below are detailed in Section 13 of this specification.

Connections to rails for the different types and sizes of cable shall be:

a) Steel Hypalon: Connected to rails by means of the grooved channel pins installed as in Procedure B

b) Copper Hypalon (84 x 0.3mm): Connected to rails by means of either the stainless steel tapered bolt, nut and washers installed as in Procedure C, or 6mm welded stud installed as detailed in Procedure D

c) Copper Hypalon (37/1.78 or equivalent): Connected to rails by means of either direct welded connection to the rail web as detailed in Procedure E, 12mm welded stud installed as detailed in Procedure D, or bifurcated rail head welded connection as described in Procedure F.

d) Aluminium Hypalon (454/0.50mm) – Terminated using bimetallic crimp lug to a copper Cadweld tail, connected to the rail web as detailed in Procedure E, or using bifurcated copper tails with palm lugs on 12mm studs connected to the rail as detailed in Procedure D.
9.2 Traction Bonding

Connections to rails for the different types and sizes of traction bonding shall be, for copper Hypalon 608/0.50mm and 962/0.50, bonding cable 37/1.78mm, aluminium Hypalon 962/0.50mm and 1524/0.50; 12mm welded studs as detailed in Procedure D, direct Cadweld to rail web connection as detailed in Procedure E, or bifurcated-link Cadweld connection as described in Procedure F.

9.3 Impedance Bonds

Impedance bonds shall be mounted as described in Specifications SPG 0705 Construction of Cable Route and Associated Civil Works and SPG 0706 Installation of Trackside Equipment.

Bonding cables between adjacent impedance bonds, from impedance bonds to rail and from impedance bonds to negative busbars shall be as indicated on the track bonding plan.

Bonding cables sizes from signalling equipment to impedance bonds shall be as detailed in Section 8.

All side lead cables to any one impedance bond shall be of equal length.

Aluminium Hypalon covered cables shall be laid directly on the ballast as detailed and fixed to sleepers as detailed in Section 9 and Procedure G.

Copper Hypalon cables shall be encased in a rigid or semi-rigid non-metallic conduit to within 250 mm of rail or impedance bond, except where the Particular Specification states that this is not required, in which case the bonds shall be laid directly on the ballast. The ends of these conduits shall be sealed with a hard setting sealant.

Impedance bonds used for traction tie ins or sectioning hut and substation connections shall not be installed within 50 metres of a audio frequency track circuit tuned loop, except with specific prior approval.

Traction cables shall be fixed to impedance bonds with stainless steel bolts, nuts and washers. Bolt threads shall be treated with anti seize compound before assembly.

9.4 Rail Bonds, V&K Crossing Bonds

The bonding cable sizes and types shall be as indicated in Section 8.

Bonding cables shall be fitted with crimped lugs in accordance with the provisions of Section 10.3 except for steel Hypalon cable ends which shall be connected to the rail using the stainless steel grooved channel pin method of connection.

All bonds shall be duplicated except in areas subject to heavy traction currents when additional bonds may be required between adjacent impedance bonds and between impedance bonds and rails, as shown on the track bonding plans.

In general, all rail bonds shall be kept as short as possible. Parallel and short series bonds (less than 8m) shall be surface mounted. Long series bonds (greater than 8m) shall be buried in accordance with the provisions of Specification SPG 0705 Construction of Cable Route and Signalling Civil Works.
Hypalon covered bonding cables shall be laid as detailed in Section 9.1. Other bonding cables, except those around rail joints and within V-crossings, shall be installed in heavy duty, orange coloured flexible PVC conduit laid on the ballast.

Rail joints in non electrified areas shall be bonded using copper Hypalon, steel Hypalon or 7/1.40 steel signal wire as appropriate for the type of track circuit in use. The connections to the rails shall be made using steel, grooved channel pins installed as detailed in Procedure B, tapered bolts as detailed in Procedures A and C or welded studs as detailed in Procedure D as applicable to the type of cable.

Rail joints in electrified areas shall be bonded using cables as nominated in Section 8. The connections to the rail shall be made welded studs installed as detailed in Procedure D or Cadweld 70mm² head bonds welded as described in Procedure E.

Where parallel bonding is approved, the bonds on the parallel leg of a points track circuit in an electrified area shall be installed not more than 50 metres apart.

9.5 Rail Connection for Spark Gap Arrestor Bond

Spark gap arrestors are provided on some overhead wiring masts (generally at or near stations) and on all steel bridge structures. Connection is made using a PVC sheathed steel bonding cable from the spark gap terminated in a suitable crimp lug and connected to the rail using 12mm welded stud rail connections as detailed in Procedure D.

For single rail track circuits the spark gap arrestors shall be connected to the common (traction) rail.

For double rail track circuits spark gap arrestors shall, in general, be connected to one rail for one half of the track circuit and to the other rail for the remainder of the track circuit.

9.6 Connections from Traction Negative Busbars to Rails

For single rail track circuits the bonds from the negative busbar shall be connected directly to the common (traction) rail.

For double rail track circuits, including audio frequency track circuits, the bonds from the negative busbar shall be connected to the rails via the neutral points of paired impedance bonds on each track.

The size and quantity of the bonds shall be as shown in Section 8.

The bonds shall be fitted with crimp lugs in accordance with the provisions of Section 10.3 and the rail connections shall be made as detailed in Section 10.

9.7 Tie-in Bonds Between Tracks

For single rail track circuits the common (traction) rails shall be bonded directly together at the tie-in points.

The size and quantity of bonds shall be as indicated in Section 8.

The bonds shall be fitted with crimp lugs in accordance with the provisions of Section 10.3 and the rail connections shall be made as detailed in Section 10.
9.8 Electrolysis Bond Connections

Electrolysis bonds shall be as specified in Specification SPG 1184 Centre tapped electrolysis bond chokes (30a per rail).

Electrolysis bond connections shall be by twin copper Hypalon (84/0.3mm) cables to each rail connected as detailed in Procedure C or 6mm welded stud installed as detailed in Procedure D.

Cables shall be to Specification SPG 1014 Cables for Railway Signalling Applications – Traction Return and Track Connection Cables

For bolted connection to rails, cables shall be terminated in suitable connection lugs as set out in Section 10.3.

9.9 Track Cable Protectors

All new track circuit connections to rail shall be installed using Track Cable Protector (TCP) plates to positively locate and protect cables within the rail zone, making the installation compatible with the operation of track tampers and ballast regulators.

Figure 3 – Track Cable Protector with tuning unit cables, installed on concrete sleeper

Figure 4 – Track Cable Protector and rail connections, on timber sleepers

The TCP plates and cables shall be installed as detailed in Procedure G.
10 Rail Connection Methods

The preferred method for making cable connections to rail is the aluminothermic welding process known colloquially by the commercial name Cadweld.

The CADWELD product is the current approved rail bond welding method.

Cadwelding is extensively used to attach bonding and track circuit cables to rails. Incorrectly done, Cadwelding can present an increased risk of broken rails. Process Control is vitally important to control weld quality. The following requirements apply to all use of Cadwelding for signalling connections to rails.

10.1 Rail Connection Options

Signalling and traction connections to rail shall be by one of the following three methods (listed in order of preference)

a) Caweld connection welded directly to the neutral axis in the web of the rail, as detailed in Procedure E.

b) stainless steel stud ‘Cadwelded to the neutral axis of the web of the rail, as detailed in Procedure D.

c) bifurcated Cadweld connection to the outside of the head of the rail, as detailed in Procedure F.

d) (This shall only be used with the specific prior agreement of the responsible Track and Signalling maintenance managers.)

Note: Welding to the rail head is only permitted where the rail is supported (eg within the area of a fishplate) or to a non load bearing rail, such as a check rail, and is for bonding only.

It is preferred that all connections that form part of a track circuit are welded directly to the rail web. This includes track circuit leads and impedance bond connections.

Where track circuit leads are to be connected to the rail web using studs, a bifurcated tail is to be provided connecting to two studs. When directly welded only a single connection is required.

When deciding on the method of attachment, consideration must be given to whether the cable needs to be easily removed for mechanised track maintenance, ballast cleaning or other purpose.

10.2 Cadweld Rail Connecting Method

The following are general requirements for making rail connections using the Cadweld process. Specific rail connecting procedures are detailed in Section 13.

10.2.1 Cadwelding Operators to be Trained

Only persons trained by the manufacturer/supplier or RailCorp licensed Rail Bond Welders are to use the Cadweld process. Each 12 months, every operator is required to complete a mandatory refresher by the performance of a successful demonstration weld under the observation of a RailCorp licensed Rail Bond Welder. Contractors may also be accredited in Cadwelding, but the accreditation will apply only for the duration of the particular project for which it has been granted.
10.2.2 Requirements for Cadwelding

The manufacturer's recommendations for Rail Bond Welding must be strictly followed. Particular attention is drawn to the warming of the mould and rail, to dispel moisture, and the correct fitting of the mould to the rail. Worn moulds must not be used. The usual life of a mould is 50-70 uses.

For web welds, the mould must be located so that the weld is placed at the neutral axis of the rail web, to an accuracy of ±2mm. For 53 kg rail this is 79mm from the underside of the rail foot, 79mm for 60kg rail, and 68mm for 47kg rail.

The correct positioning of mould at the neutral axis shall be achieved by use of a locating gauge matched to the rail profile.

Mould locating gauges shall be obtained from the supplier of Cadweld materials, as Template Mould Rail p/n NRT5360, Erico Dwg No.B806A02

To remove the risk of metallurgical damage to the rail, the operator shall prevent any possibility of molten weld metal spilling onto the foot of the rail. A suitable shield is to be placed on the rail foot to protect it from any spillage of molten material. Additionally, and where practical, thermal putty is to be applied at the base, and up both sides of the mould to prevent the leakage of weld metal.

Should any leakage of weld material occur, and especially if it is deposited on the rail foot, the civil representative must be advised immediately. Where a civil representative is not immediately available, the IOC shall be advised.

Where additional connections are required, they must be at least 50mm away from any previous weld, and from any hole in the rail. For this reason, old weld nuggets are not to be removed from the rail.

10.2.3 Review of Rail Bond Welds

Whenever a Cadweld connection is made, the weld is to be identified with the initials of the welder marked on the foot of the rail, using an indelible marking pen.

When each weld or group of welds, is completed, the welder shall submit a form “Notification of Rail Bond Welding” (Appendix A) to the Team Manager, Team Leader, Work Group Leader Signals or Signal Engineer.

The Team Manager, Work Group Leader Signals or Signal Engineer shall arrange for the welds to be reviewed for quality and effectiveness by an accredited person other than the person who performed the weld. Quality issues with the welding shall be noted on the “Notification of Rail Bond Welding” form, and brought to the attention of the welder and Team Manager immediately.

Following the review, the form shall be signed by the Reviewer and forwarded to the Maintenance Engineer Signals for the area.

10.3 Cable Terminations

Crimp lugs are used to terminate bonding cables for connecting to impedance bonds, neutral busbars and rails.

For bolted and stud connections, cables shall be terminated with cast copper compression crimp lugs as specified in SPG 1066 Solderless Terminals and Cable Lugs for Signalling Applications.
Aluminium cables shall be terminated with bimetallic crimp lugs as specified in SPG 1066 \textit{Solderless Terminals and Cable Lugs for Signalling Applications}.

In-line crimps for termination of cables to Cadweld tails shall be as specified in Procedure F.

11 \hspace{1cm} \textbf{Impedance Bonds}

11.1 \hspace{1cm} \textbf{Traction Rating of Impedance Bonds}

There are two ratings of impedance bonds in use in New South Wales. Those for Heavy traction are rated at 2,000A per rail continuous current, while those for Light traction are rated at 1,000A per rail continuous current.

The air cooled Light traction impedance bonds, Westinghouse MJS, ABW/Macolo 1000 and the GEC Alsthom / Jeumont Schneider CIT 1400 are suitable for 1000A per rail continuous current.

For Heavy traction current areas the Westinghouse 2000R and 2000P, Macolo 2000 and ABB B3 4000 bonds are used.

11.2 \hspace{1cm} \textbf{50Hz Impedance of Impedance Bonds}

The impedance of the impedance bonds on double rail AC and audio track circuits becomes a limiting factor in setting the length of the track circuit and the maximum shunt value at which the relay will drop.

The air cooled impedance bonds have an impedance of 0.5 ohms at 50Hz AC, which limits the maximum shunt characteristic to 0.25 ohms.

On audio frequency track circuits, this equates to an impedance of 20 ohms at a frequency of 2000Hz, and proportionate values at other frequencies.

The 50Hz impedance of the resonated impedance bonds is about 0.25 ohms unresonated, and approaches 2.5 ohms resonated.

On audio frequency tracks these bonds have an unresonated impedance of around 10 ohms. This allows them to be used unresonated on shorter track circuits, with resonance generally only required for track lengths above 400 metres.

11.3 \hspace{1cm} \textbf{Installation of Impedance Bonds}

11.3.1 \hspace{1cm} \textbf{Mounting}

New impedance bonds shall be installed on steel frames mounted outside the track and not between rails. Impedance bonds on contiguous track circuits should be mounted on a common frame.

Mounting shall be in accordance with Specification SPG 0705 \textit{Construction of Cable Route and Signalling Civil Works}.

11.3.2 \hspace{1cm} \textbf{Connection of Impedance Bonds}

The connection of side lead cables to rail shall be in accordance with Section 10.1.
The connections of cables to impedance bonds i.e. side leads, neutral leads and tie-in bond leads shall be with crimped cable lugs specified in Section 10.3. Where the type of impedance bond does not permit direct connection of the nominated cables suitable tinned copper adapter plates shall be provided to permit correct termination of the nominated cables and lugs.

Side, neutral and tie-in lead terminations shall be accessible for examination and disconnection with the impedance bond lid or cover in place but shall not be unduly exposed to damage. Where required, cables shall be mechanically supported to reduce the load on the termination point and cable lugs.

### 11.3.3 Side Leads

There shall be a minimum of two side leads from the impedance bond to each rail. Sections 8.1 and 8.2 and the track bonding plans specify the number of side leads required in particular situations.

Side lead connections to rail shall be made as close as practical to the insulated joint. Where the insulated joint has been ‘Thermit’ welded in place, the side leads shall be connected between the joint and the weld.

To minimise traction return system resistance, all side leads should be kept as short as possible, while maintaining a tidy and safe installation.

To avoid unreliable operation of the impedance bond due to traction current imbalance, all side leads on any individual impedance bond shall be of equal DC resistance. Generally, this requirement will be satisfied by making all leads of equal length. Where impedance bonds are mounted off track, the upper or farther side lead shall be connected to the near rail, and the lower or nearer side lead shall be connected to the far rail. To facilitate the use of equal side lead lengths, side lead rail connections shall be to the inside face of each rail and the upper side leads on vertical frame-mounted impedance bonds should be terminated to the bond from above. Where welded head-bond connections are used, these shall be connected to the outside of the rail.

### 11.3.4 Neutral Connections

The neutral connections between adjacent impedance bonds shall preferably consist of a tinned copper busbar as specified in Sections 8.1 and 8.2. This busbar should also be used for terminating any cables for tie-in bonds or connections to substation or sectioning hut busbars.

Where the copper bus connection is not practical, such as with mid track mounted impedance bonds, there shall be a minimum of four neutral leads between the impedance bonds. Sections 8.1 and 8.2 and the Particular Specification may require additional cables and specify cable cross sections. Neutral leads between impedance bonds shall be kept as short and straight as possible.

Where the impedance bond is used to change from a single rail to a double rail track circuit, the total number of neutral leads specified shall be connected to the common (traction) rail of the single rail track circuit.

### 12 Spark Gap Arrestors

Spark gap arrestors are provided on some overhead masts, for example near stations and level crossings, and on all steel or reinforced concrete bridge structures. They are installed at locations where there is a significant probability of persons touching a metallic structure supporting the overhead traction supply, generally to protect against electric
shock or electrolysis in the event of an insulator failing and rendering the structure ‘live’ at traction voltage.

The Traction System Engineer provides a PVC sheathed steel bonding cable from the spark gap for connection to the rail by the Signal Engineer. A suitable crimp lug shall be fitted to the steel cable and connection to the rail shall be made by an appropriate method set out in Section 9.

13 Procedures for Cable to Rail Connections

13.1 Procedure A - Copper Bush and Tapered Bolt Style Rail Connection

The copper bush style rail connections were historically used for the connection to rails of cables at track circuit tuning units, impedance bonds, rail joint bonds (electrified areas), traction negative busbars, and tie in bonds.

This type of connection has been replaced by stud or direct Cadwelded connections, and is no longer approved for use.

13.2 Procedure B - Grooved Channel Pin Rail Connection

Grooved channel pin rail connections shall be used only for the connection of steel Hypalon or 7/1.4mm un-insulated steel cables to rails and shall be installed in accordance with the following procedure:

   a) Drill hole in the centre of the web using a sharp accurate 7.1mm (9/32″) machine twist drill and using a water lubricant. (Oil shall not be used as part of the drilling process).

   b) Bare 80mm in length of the insulation from the end of the steel Hypalon cable.

   c) Insert the flexible steel conductors directly into the hole from the outside of the rail until the insulation (where present) is 10mm from the rail.

   d) Insert the grooved channel pin with groove facing downward from the inside of the rail ensuring that the steel strands of the cable are bunched together and placed in the groove of the channel pin.

   e) Hammer the channel pin into the hole as far as possible.

Note: To prevent rusting of the hole, the cable and channel pin shall be installed immediately the hole is drilled.

13.3 Procedure C - Stainless Steel Tapered Bolt Rail Connection

Copper Hypalon cables (84 x 0.3mm) shall be connected to rails using stainless steel tapered bolts, nuts and lock washers installed in accordance with the following procedure:

   a) Drill hole in the centre of the web using a sharp accurate machine 7.1mm (9/32″) machine twist drill and using a water lubricant. (Oil shall not be used as part of the drilling process).

   b) Hammer the tapered stainless steel bolt into the hole as far as possible, from the inside of the rail.

   c) Fit the track connections as shown on Standard Drawing No. E08179/3.
13.4 Procedure D - Cadwelded Stud Rail Connection

The following procedure details the installation of Cadweld welded stud rail connections, in compliance with the requirements of Section 9.2:

Qualified Personnel

The connection of cable to rail using welded stud rail connections shall only be performed by persons who have been trained and accredited in the application of welded stud rail connections by the supplier of the material being used or by a recognised signalling training organisation.

Safety

The Cadweld process produces a quantity of molten copper hot enough to melt rail steel. The presence or moisture or contaminants may cause a charge to react extremely vigorously, sufficiently to splatter weld metal from an uncovered mould.

a) Persons involved in the installation of welded stud rail connections shall wear appropriate protective clothing.

b) Equipment designed and constructed for welded stud installation shall be used.

c) Ensure the mould and the welding materials are free of moisture and contaminants. Contact of molten weld metal with moisture or contaminants may cause the weld metal to spurt out of the mould.

d) Do not attempt to perform Cadweld connections in wet weather.

Weld Preparation

Before commencing the weld ensure that:

a) The mould is not worn or broken. Worn or broken moulds may cause leakage of molten weld metal and result in safety problems and unsatisfactory weld connections.

b) The mould is fitted with a fully functional safety lid. Use of a mould with a missing, makeshift or damaged safety lid may leave the operator at risk of injury from spattering weld metal.

c) The mould fits the weld area and closes correctly. (If necessary apply thermal putty at the base and sides of the mould to ensure a perfect seal and prevent the leakage of weld metal.).

d) The mould is securely attached to the rail using the manufacturer’s recommended rail clamp.

e) The mould is clean of slag from previous welds. (Foreign material shall be removed with a short haired brush. Wire brushes or sharp implements shall not be used as these will shorten the life of the mould).

f) The mould is not wet or damp. (Wet or damp moulds will result in porous welds). Remove moisture from the mould using a hand operated butane torch before making the desired weld.

g) The stud is completely clean. Studs must be stored in a clean container with an airtight lid.

Rail Preparation
a) Select the area on the rail for attachment of the stud. New welds are to be a minimum of 50 mm away from any other weld. Where multiple welds are to be installed an additional distance may be required to prevent the two connections fouling each other.

b) Do not attempt to apply a stud over raised lettering on the rail web.

c) Grind off all mill scale and rust from the rail surface over the required area of the neutral axis of the rail such that the area is bright, clean and dry.

d) Warm the weld area and remove any moisture using a gas torch.

**Igniter**

Use a flint gun to ignite the cartridge. Ensure the flint gun is in good working order and will produce enough spark to ignite the cartridge. Clean fouled up flint guns by soaking gun in household ammonia.

Use of an extended igniter gun will eliminate any risk of burns by flaring-up of the weld metal.

**Welding Procedure**

a) Insert the clean bright stud into the mould making sure there is a minimum of 1mm between the stud and the rail. If this distance cannot be achieved, the mould is uneven or worn and should be replaced.

b) Secure the mould to the neutral axis of the rail making sure the mould is firmly against the clean bright web section of the rail. Use the locating gauge to ensure that the weld is properly located on the neutral axis of the rail.

c) Ensure the spillage shield is properly fitted under the mould, to prevent any spilled weld metal from dropping on the foot of the rail.

d) Insert the steel disk, dished side up, directly centred over the hole in the bottom of the crucible.

e) Pour the correct weld powder cartridge size into the crucible being careful not to disturb the steel disk. The initial powder material will flow out of the container easily. Do not attempt to scrape the material out of the container. **Note** - Use the correctly sized charge for the mould – do not use two smaller charges to make up the required charge amount.

f) Tap the bottom of the cartridge to loosen all the starting powder and spread the powder evenly over the top of the weld powder.

g) Close the safety lid.

h) Check the mould and crucible ensuring the arrangement is secure and safe for ignition. Stand upwind of the arrangement and aim the flint gun to the opening in the safety lid and ignite.

i) As soon as the charge ignites, withdraw the flint gun quickly.

j) Check that molten metal is not escaping from the mould during the welding process.

k) Allow approximately 20-30 seconds for the weld metal to solidify before opening the mould.
l) Loosen the mould securing devices and remove the mould pulling directly and squarely from the rail. Remove the sprue and any excess slag from the top of the rail.

m) Check that there has been no excess overflow of weld metal which indicates an unsatisfactory porous weld. This can also be recognised by observing the end of the broken-off sprue, which will be very obviously porous in the case of a porous weld. Check also that the surface of the copper button around the stud is smooth and clean.

n) Mark operator initials at foot of rail. Enter details in Notification of Rail Bond Welding form, and arrange for independent check/review of welds.

o) Where there has been an overflow of weld metal, or any other indication of a defective weld, the civil representative shall be informed immediately, to permit an assessment to be made on whether the integrity of the rail has been affected.

Fixing Cables to Studs

Always ensure the copper contact surfaces of the weld and cable lug are perfectly clean before fitting the lug.

Fit the cable lugs onto the studs, treat the threads with anti-seize and tighten nuts and locknuts to 50 ± 5 Nm.
13.5 Procedure E - Cadwelded Head or Web Direct-to-Rail Connections

Traction and tuning unit cables can be installed by connecting to 127mm² Cadweld tails welded directly to the rail web, in accordance with the following procedure.

The procedure also covers the application of 70mm² Cadweld head bonds.

Qualified Personnel

The connection of cable to rail using welded direct-to-rail connections shall only be performed by persons who have been trained and accredited in the application of Cadwelded rail connections.

Safety

The Cadweld process produces a quantity of molten copper hot enough to melt rail steel. The presence or moisture or contaminants may cause a charge to react extremely vigorously, sufficiently to spatter weld metal from an uncovered mould.

a) Persons involved in the installation of welded rail connections shall wear appropriate protective clothing.

b) Equipment designed and constructed for Cadwelding direct to rail shall be used.

c) Ensure the mould and the welding materials are free of moisture and contaminants. Contact of molten weld metal with moisture or contaminants may cause the weld metal to spurt out of the mould.

 d) Do not attempt to perform Cadweld connections in wet weather.

Weld Preparation

Before commencing the weld ensure:

a) The mould is not worn or broken. Worn or broken moulds may cause leakage of molten weld metal and result in safety problems and unsatisfactory weld connections.

b) The mould is fitted with a fully functional safety lid. Use of a mould with a missing, makeshift or damaged safety lid may leave the operator at risk of injury from spattering weld metal.

c) The mould is clean of slag from previous welds. (Foreign material shall be removed with a short haired brush. Wire brushes or sharp implements shall not be used as these will shorten the life of the mould).

d) The mould is not wet or damp. (Wet or damp moulds will result in porous welds). Remove moisture from the mould using a hand operated butane torch before making the desired weld.

e) The mould fits the weld area and closes correctly. (If necessary apply thermal putty at the base and sides of the mould to ensure a perfect seal and prevent the leakage of weld metal.)

f) The mould is securely attached to the rail using the manufacturer’s recommended rail clamp.
g) The Cadweld tail is clean and undamaged, with completely dry, clean and bright ferrule at the weld end. Unused tails must be stored in a clean protective container with an airtight lid or cover.

Rail Preparation

a) Select the area on the rail for attachment of the weld. New welds are to be a minimum of 50 mm away from any other weld. Where multiple welds are to be installed an additional distance may be required to prevent the two connections fouling each other.

b) Do not attempt to apply a stud over raised lettering on the rail web.

c) Grind off all mill scale and rust from the rail surface over the required area of the head or neutral axis of the rail such that the area is bright, clean and dry.

d) Warm the weld area and remove any moisture using a gas torch.

Igniter

Use a flint gun to ignite the cartridge. Ensure the flint gun is in good working order and will produce enough spark to ignite the cartridge. Clean fouled up flint guns by soaking in household ammonia.

Use an extended igniter gun to avoid any risk of burns by flaring-up of the weld metal.

Welding Procedure

a) Fit the clean bright ferrule into the mould making sure that it is fully inserted into the ferrule ‘tunnel’ and is a close fit in the tunnel. If this cannot be achieved, the mould is uneven or worn and should be replaced.

b) Secure the mould to the head or web of the rail making sure the mould is firmly against the clean bright web section of the rail. For web welds, use the locating gauge to ensure that the weld is properly located on the neutral axis of the rail.

c) Ensure the spill shield is properly fitted under the mould, to prevent any spilled weld metal from dropping on the foot of the rail.

d) Insert the steel disk, dished (concave) side up, directly centred over the hole in the bottom of the crucible.

e) Pour the correct weld powder cartridge size into the crucible being careful not to disturb the steel disk. The initial powder material will flow out of the container easily. Do not attempt to scrape the material out of the container.

f) Note – Use only the correctly sized charge for the mould – do not use two smaller charges to make up the required charge amount.

g) Tap the bottom of the cartridge to loosen all the starting powder and spread the powder evenly over the top of the weld powder.

h) Close the safety lid.

i) Check the mould and crucible ensuring the arrangement is secure and safe for ignition. Stand upwind of the arrangement and aim the flint gun to the opening in the safety lid and ignite.

j) As soon as the charge ignites, withdraw the flint gun quickly.
k) Check that molten metal is not escaping from the mould during the welding process.

l) Allow approximately 20-30 seconds for the weld metal to solidify before opening the mould.

m) Loosen the mould securing devices and remove the mould pulling directly and squarely from the rail. Remove the sprue and any excess slag from the top of the rail.

n) Check that there has been no excess overflow of weld metal which indicates an unsatisfactory porous weld. This can also be recognised by observing the end of the broken-off sprue, which will be very obviously porous in the case of a porous weld. Check also that the surface of the copper button around the stud is smooth and clean.

o) Mark welder’s initials at foot of rail. Enter details in Notification of Rail Bond Welding form, and arrange for independent check/review of welds.

p) Where there has been an overflow of weld metal, or any other indication of a defective weld, arrange for the civil representative to be informed to permit an assessment to be made on whether the integrity of the rail has been affected.
13.6 Procedure F - Bifurcated Cadwelded Rail Connection

General

This method of connection is used to connect a single cable to the rail using duplicated ‘Cadweld’ 70mm² tails, approximately 160mm long, applied to the outside of the head of the rail and joined to the 120mm² or 185mm² bonding cable by means of a suitable in-line crimp.

This shall only be used with the specific prior agreement of the responsible Track and Signalling maintenance managers.

Applicability

This method of connection may be used with the following traction bonding cables:

a) 962/0.5 Aluminium
b) 493/0.5 Aluminium
c) 608/0.5 copper
d) 962/0.5 copper

Materials required

<table>
<thead>
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<th>Cable</th>
<th>Cadweld Bond</th>
<th>Crimp Link</th>
<th>Heat Shrink Tube</th>
<th>Crimping Die</th>
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<td>962/0.5 Aluminium</td>
<td>355mm</td>
<td>BLK 182/199</td>
<td>40/12 TK-125</td>
<td>HT-150/185 A1</td>
</tr>
<tr>
<td>493/0.5 Aluminium</td>
<td>355mm(half only)</td>
<td>BLK 97/70 RSA</td>
<td>34/7 TK-100</td>
<td>HT-95/120 A1</td>
</tr>
</tbody>
</table>

Description

For 962/0.5 aluminium and 608/0.5 and 962/0.5 copper cables the connection consists of the 355mm Cadweld bond cut in half with the two ends inserted into the nominated crimp link and crimped to the end of the bonding cable. The nominated heat shrink sleeve is placed over the link and cable (not over the Cadweld bond). The Cadweld bonds are then welded to the rail head using the Cadweld process.

For the 493/0.5 aluminium cable the connection consists of one half of a 355mm Cadweld bond inserted into the nominated crimp link and crimped to the end of the bonding cable. The nominated heat shrink sleeve is placed over the link and cable (not over the Cadweld bond). The Cadweld bond is then welded to the rail head using the Cadweld process.

The procedure for the welding shall be otherwise as per Procedure E, for 70mm² Cadweld head bonds.
13.7 Procedure G – Installation of Track Cable Protector Plates

The following procedure outlines the steps to be followed when installing Track Cable Protector plates with new cables.

A more detailed description of how connections and cables are to be laid out, together with details of the TCP plate sleeper drilling template, is provided in TMG G1470 Track Cable Protection Installation Guidelines.

13.7.1 Cable Check

Before commencing site work check track cables for visible signs of damage. Under no circumstances are plates to be installed on track cables that show visible signs of damage.

13.7.2 Site Selection

Determine the sleeper bay and particular edge of sleeper for the cable installation and protection plates. To minimise risk of damage to the cable, the cables running parallel to the sleepers should be located on the trailing side edge of the sleeper recognising normal train running. Whilst the general location is predetermined the precise location should be determined following an inspection of the sleeper condition and any other site conditions. Plates should not be installed on defective/damaged sleepers.

Carefully remove ballast from the edge of the sleeper and dig a groove in the ballast adjacent the sleeper to accommodate the cables such that the top cable (or top of the top cable where multiple cables) is level with the top of sleeper. The groove should extend across the ‘four foot’ area and the cess side of the sleeper where the cable(s) will be connected to the stanchion, tuning or matching unit etc. Remove excess ballast in the vicinity of track cables. It is recommended to use a pelican pick to perform this work.

13.7.3 Cable Installation

Install the cables. The cables running parallel to the sleepers should be located on the trailing side edge of the sleeper recognising normal train running whilst cables running parallel to the rail should be located between the rail sleeper fastenings (ie immediately alongside the web of the rail). Depending upon the size, up to four cables may be stacked vertically. Cables ties are used to tie the cables together as a unit and the unit attached to the protector plate through the two holes located on the curved section of the plate.

A maximum of four 185 mm² orange traction cables may be stacked vertically as shown above.
A maximum of two large cables including orange traction cables (300 mm²) may be stacked vertically. Consecutive sleepers are used to accommodate larger numbers of cables.

Avoid excessive slack in the cables. Once the cables have been positioned, check the slack. Removal of the excessive slack may involve carefully pulling the cable under the rail.

Do not run cables over rail fastening clips and do not connect cables where they could interfere with the removal of the clips. The connection of the cable to the rail should be located in the bays between sleepers.

Typical Track Cable Protector Installations for the various track cables are shown in Appendix B of TMG G1470.

Figure A details Typical Track Circuit Cable Installation,

Figure B details Typical Traction Return Bonding Cable Installation (Cable flow in the same direction.)

Figure C details Typical Traction Return Bonding Cable Installation (Cable flow in both directions), and

Figure D details Typical Spark Gap Arrestor Cable Installation.

Connection of the cables to the rail is unaffected by the use of the Track Cable Protector with the cables Cadwelded to the centre of the web of the rail. To minimise the risk of damage to the cable whilst complying with the signalling equipment requirements, the connections should be located as shown on the typical cable installation figures and as described below.

For track circuit connections, Cadweld studs should be located within 100mm from the edge of the sleeper. Where Cadwelds are directly applied as the connection, they should be located 200mm from the edge of the sleeper.

For traction return bonding cable connections, the first Cadweld stud should be located within 100mm from the edge of the sleeper and the second weld a further 100-150mm from the first weld.

Where multiple cables connections are located near an insulated rail joint the track circuit cable should be connected closest to the joint. This will allow the track circuit to detect any cracks in the rail, should they occur.

13.7.4 Protector Plate Installation

a) Position the Cable Protector Template on the sleeper. The steel angle on the template must be placed against the trailing side edge of the sleeper recognising normal train running and accurately positioned on the sleeper. The template is then restrained to prevent movement during the drilling process. All holes can then be marked and drilled through. Ensure template is centred on sleeper. (Note: Provided the template is centred on the sleeper, the template correctly locates the fastening holes for any sleeper type).

Generally four plates per sleeper are required - three between rails and one on the sleeper end. The exemption to this is the Spark Gap cable connection with connection on the stanchion side of the near rail, where only one plate is
required, on the sleeper end. Bolt holes must not be closer than 30mm from the ends of the sleeper.

The three plates to be installed in the four foot should be installed using the template. The aim is to have the cable located immediately adjacent the vertical face of the sleeper and protected by the plates. The plate to be installed in the cess/six foot should be installed using the manual positioning method such that the cable is located immediately adjacent the vertical face of the sleeper and is protected by the plate.

b) Drill holes 45mm deep, using an 8mm diameter tungsten drill bit and depth gauge, in locations shown on template (in four foot) and manually determined (in six foot). All holes shall be drilled within 5mm of the centre line of the sleeper.

c) Remove template and brush down surface of sleeper with paintbrush or similar. With the nozzle of a hand operated rubber bulb blower inserted into the hole, press on the rubber bulb to eject the dust out of the hole. This type of blower is sufficient to clear the hole of any concrete dust that settled during the drilling process, without providing any significant risk to operator safety.

d) Select cable protector plates and locate them in their approximate position across the sleeper. Choose the required holes and place plates in position accordingly, insert bolts (as is, do not unscrew, tighten or take washer off) in drilled holes and tap down as far as possible without forcing, using a flathead hammer. Note that some sleepers have brandings on the top surface of the sleeper but do not require packing washers under the plate to ensure a firm fit.

e) Tighten bolts with a spanner, ratchet or cordless electric impact wrench to secure the plates to the sleeper.

f) Secure cables under lip of plates with nylon cable ties. Steel cable ties must not be used.

g) Refill the previously removed ballast in the sleeper bays to a level in line with the top surface of the sleeper and restore the original design ballast profile. Ensure that at the end of the plate installation process, no ballast obstructs any track equipment functioning and enables safe train operation according to RailCorp standard.
Appendix A  NOTIFICATION OF RAIL BOND WELDING

<table>
<thead>
<tr>
<th>Date:</th>
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<tr>
<td>Location:</td>
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<tr>
<td>Kilometrage(s):</td>
<td></td>
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<tr>
<td>Track Name: (eg: Up Illawarra)</td>
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<tr>
<td>Points No.:</td>
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<table>
<thead>
<tr>
<th>Track Circuit Name(s):</th>
<th>No. of Welds</th>
<th>Feed End</th>
<th>Relay End</th>
<th>Bonding</th>
<th>Head Weld</th>
<th>Web Weld</th>
<th>Stud Weld</th>
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<tr>
<th>Name of Welder:</th>
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<td>(Print) (Signature)</td>
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To: Team Manager, Team Leader, Work Group Leader, Signals or Signal Engineer

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The above listed welds have been inspected and are:

- □ Satisfactory
- □ Not Satisfactory

Remedial action undertaken:

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To: Maintenance Engineer Signals

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