TRACTION RETURN, TRACK INSULATION AND BONDING

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CRN SC 002

LINKING COMMUNITIES. CONNECTING CUSTOMERS.

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Document Control

Function	Position	Name	Date
Approver	A&E Manager	Lucio Favotto	25/01/2022

Revision	Issue Date	Revision Description
1.1	10/12/2021	UGLRL Operational Standards Template applied
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Summary of changes made from previous version

Section	Summary of change
All	This document is based on the previous rail infrastructure maintainer (RIM). Full revision history is available on request from UGLRL.

1 Introduction

1.1 Purpose of this document

This document sets out the requirements of the CRN for traction return, track circuit insulation and bonding, and electrolysis connections as they relate to non-electrified areas, and electrified areas using 1500 volt DC traction. Specific track circuit operating details will be found in the relevant standards for track circuits. Traction requirements are discussed in terms of “Light” and “Heavy” traction current areas.

1.2 Definitions

In this document, the following definitions of terms shall apply.

1.2.1 Principal Signal & Communications & Network Control Engineer

The person nominated by UGLRL with Engineering Authority for signalling and electrical infrastructure standards and designs.

1.2.2 Principal Electrical Engineer

The person nominated by Sydney Trains with Engineering Authority for traction supply and distribution infrastructure standards and designs.

1.2.3 Signal Engineer

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

1.2.4 Traction System Engineer

The Sydney Trains’ engineer responsible for the installation and maintenance of the 1500 volt traction supply and distribution infrastructure.

1.2.5 Hypalon

Generic term for abrasion-resistant tough synthetic rubber insulation material specified for cables installed on ballast.

1.3 Referenced Standards

This standard makes reference to the following Standards:

1.3.1 CRN Specifications

- Signalling Design Principles
- Specification CRN SE 012 Single-Phase Air-Cooled Isolating Transformers for Signalling Applications
- Specification CRN SC 021 Cable Routes and Associated Civil Works
- Specification CRN SC 020 Installation of Equipment Racks and Termination of Cables and Wiring
- Specification CRN SE 022 Solderless Terminals and Cable Lugs for Signalling Applications
- Specification CRN SD 017 – Track Circuits – Signal Design Principles
- Specification CRN SE 035 – Cables for Railway Signalling Applications

2 Traction Return System and Current Ratings

2.1 Traction System Ratings

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

All new systems are designed as 'Heavy' traction return systems as the electrical demands of electric rolling stock increases.

2.2 Traction Electrical Supply

The DC electrified area of the Sydney Trains network is electrified with 1500 volt DC traction supply.

The Sydney Trains electrified network uses a 1500 volt DC, dual 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.

2.3 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 (i.e., 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 calculation of traction return resistance is the responsibility of the Electrical Engineer, however, the Signal Engineer must use the following guidelines for all designs.

Single track	2 rails at all times
Dual track	Mostly 4 rails, but 3 are allowed within interlockings, over points
Multiple tracks	Maintain the ratio for dual track unless specific permission is obtained from the Principal Electrical Engineer.

3 Track Circuit and Traction Return

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 may be high frequency jointless, or pulse type.

3.1.2 Non-electrified Areas

Track circuits not over points may be any approved type.

3.1.3 Track Circuit Equipment

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 CRN SE 035 – Cables for Railway Signalling Applications.

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 Principal Signal & Communications & Network Control Engineer 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 50 Hz 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.

3.3 Double Rail Track Circuits

3.3.1 Description

Double Rail track circuits use both rails for traction return.

3.3.2 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

3.4 Single Rail Track Circuits

3.4.1 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 Principal Signal & Communications & Network Control Engineer for specific approval, as higher traction return resistances adversely affect DCCB settings.

3.4.2 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.

Current in Traction Rail (A)	1700	3400	5200	6800
Track Circuit Length (m)	**Voltage Drop (volts)**			
50	2.81	5.61	8.58	11.22
75	4.21	8.42	12.87	16.83
150	8.42	16.83	25.74	33.66
200	11.22	22.44	34.32	44.88
250	14.03	23.05	42.90	56.10
300	16.83	33.66	51.48	67.32

Table 1 - DC Voltage drop Impressed across Track Relay on Single Rail Track

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

Rail Size - kg/m	DC Resistance Ω/1000m	microΩ/m
45	0.0438	43.8
53	0.0368	36.8
60	0.0330	33.0

3.5 Single Rail 50 Hz AC Track Circuit

3.5.1 Use and Operation

The design of single rail 50 Hz 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 Clause 3.4. 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

- Light Traction 200 m
- Heavy Traction 100 m

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

3.5.2 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 Clause 3.4.

3.5.3 Cross Bonding of Single Rail AC Track Circuits

Cross bonding shall be provided at intervals of not more than 200 m in accordance with Clause 5.8.

3.5.4 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 Clause 5.

3.5.5 Transposition of Traction Rail

Transposition of the traction rail between Up and Down rails of contiguous 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.

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.

3.6 Double Rail Jointless Track Circuits

3.6.1 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.

3.6.2 Traction Rating of Jointless Track Circuits

Jointless track circuits are not in themselves affected by Heavy or Light traction current situations. However, the rating of impedance bonds used for connection of tie-in bonding or substation and sectioning hut connections or the termination of track circuits at insulated rail joints must be appropriate to the traction level in the section.

3.6.3 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.

Clause 5.7 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.

3.6.4 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 Clause 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 resonation necessary.

3.7 Double Rail Impulse Track Circuits

3.7.1 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 cannot be substituted with other types of impedance bonds.

3.7.2 Traction Rating of Impulse Track Circuits

The impedance bonds of the Impulse Track Circuits are rated for Light (1000A/rail) or Heavy (2000A/rail) current. In Heavy traction cases 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.

3.7.3 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.

3.7.4 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 suited for that purpose.

3.8 Single Rail Impulse Track Circuits

3.8.1 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.

3.8.2 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. For Light traction cases this permits a track circuit length of up to 500 m where traction current is light, but as little as 300 m in areas close to substations or on grades. In Heavy traction cases the maximum length is 150-200 m.

3.8.3 Cross Bonding of Single Rail Impulse Track Circuits

Cross bonding shall be provided at intervals not exceeding 250 m in accordance with Clause 5.8.

3.8.4 Connection to Substations and Sectioning Huts

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

4 Traction Supply Interfaces

Signalling traction return shall be interfaced with the Electrical Engineer’s negative bus bars in accordance with CRN SD 017 - Track Circuits - Signalling Design Principle 17.8, and Clause 6.6 of Specification CRN SC 020 – Installation of Equipment Racks and Termination of Cables and Wiring.

4.1 Substations

At substations there shall be two impedance bonds of the appropriate rating (i.e., 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 Clause 5.7 for tie-in bonds. Where the traction system has provided a separate negative busbar for each track this tie-in is not required.

Each impedance bond neutral shall be connected via cables as specified in Clause 6.1 or 6.2 as appropriate 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 Clause 6.1 or 6.2 as appropriate, to carry the full rated traction load i.e., for 2000 A in the Light traction case and 4,000 A 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 underline crossings to low-set auxiliary busbars mounted between the tracks.

4.2 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 Clause 4.2. 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 Clause 6.1 or 6.2, to the negative bus bar nearest to it by the number of cables specified for neutral connections.

4.3 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 Signal Design is required for this connection.

The Signal Engineer shall provide and install the connection to either rail or neutral point. Sydney Trains will be responsible for providing and maintaining the rail connecting cable between the isolating switch and the rail or neutral point connection.

4.4 Temporary OHW Rail Connections

At many locations on the network, Sydney Trains has requested that permanent connection points be installed close to existing overhead wiring sectioning switches, for the convenient connection of temporary OHW earthing cables.

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

5 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 CRN SD 017 - Track Circuits - Signalling Design Principles 17.6 and 17.7.

5.1 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.

5.2 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 Clause 6.1 or 6.2 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 Principal Signal & Communications & Network Control Engineer.

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.

5.3 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.

5.4 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 7/0.85 mm 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.

5.5 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 required by the Particular Specification parallel bonding may be buried in accordance with Clause 5.6.

5.6 Installation of Parallel Bonding Cables

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 600 mm intervals. Where the hypalon cables run parallel to each other they shall be tied together at not greater than 600 mm intervals to form a single unit. Hypalon cables shall never be buried direct nor be permitted to become covered with ballast.

Where the possibility of theft is high, aluminium bonding cables should be used, or cables should be installed with additional protection as described below.

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

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 600 mm intervals.

5.7 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.

5.7.1 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 Clause 6.1 or 6.2 as applicable.

5.7.2 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.

5.7.3 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 Clause 5.10.

5.8 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 circuited 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 200-250 m. 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 Clause 7. 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 Clause 5.10.

The cable numbers and dimensions for cross bonding are specified in Clauses 6.1 and 6.2 for Light and Heavy traction respectively.

5.9 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 between 20 and 50 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.

5.10 Installation of Tie-in and Cross-Bond Cables

Tie-in bond cables shall be run as surface cables in copper or aluminium 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 250 mm of rail or impedance bond. The ends of these conduits shall be sealed with concrete or an approved substitute.

6 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.

6.1 Light Traction Areas

6.1.1 Cables

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

The cables to be used in various applications are set out in Table 1 below.

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

Table 1 - Use of Bonding Cable for Light Traction Conditions

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

6.1.2 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 using a tinned copper bus of 3500 A continuous rating 160 mm x 10 mm or equivalent.

6.1.3 Bonding 'V' and 'K' Crossings and Mechanical Rail Joints

Rail joint bonds may be 2 rail head bonds, 70 mm^2. Cadweld welded bonds welded to the outer head of the running rail, or a minimum of two (2) 1250 mm lengths of copper cable as specified in Clause 6.1.1.

6.2 Heavy Traction Areas

6.2.1 Cables

In Heavy traction areas the standard cable size is 300 mm^2 aluminium. This may be provided as either 1525/0.5 mm (300 mm^2) aluminium (or 3 by 925/0.5 mm aluminium for each pair of copper cables), 962/0.5 mm CSP90 Hypalon or equivalent insulated copper, or 3 by 37/2.03 mm 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 Table 2 below.

Cable Application	185 mm^2 Copper 962/0.5 mm	300 mm^2 Aluminium 1525/0.5 mm	120 mm^2 Copper 608/0.5 mm 37/2.03 mm	185 mm^2 Aluminium 925/0.5 mm	70 mm^2 Rail head bond
Side leads	2	2	3	3	-
Neutral leads	4	4	6	6	-
Tie in bonds	2	2	3	3	-
Cross bonds	2	2	3	3	-
Neutral to substation neg. bus connection	6	6	9	9	-
Neutral to sect. hut neg. bus connection	4	4	6	5	-
Mechanical joint bonding	2	2	2	2	2
Bonding out IRJ	2	2	2	2	2

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

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 Table 3 below.

Cable Application	185 mm² copper	300 mm² aluminium	120 mm² copper	185 mm² aluminium	70 mm² Rail head bond
Side leads	4	4	4	4	-
Neutral leads	6	6	8	8	-
Tie in bonds	3	3	4	4	-
Cross bonds	2	2	3	3	-
Neutral to substation neg. bus connection	8	8	12	12	-
Mechanical joint bonding	2	2	2	2	2
Bonding out IRJ	2	2	2	2	3

Table 3 - Use of Bonding Cable for Heavy-Class 2 Traction Conditions

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

6.2.2 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 by a tinned copper bus 3500 A continuous rating 160 mm x 10 mm or equivalent.

6.2.3 Bonding 'V' and 'K' Crossings and Mechanical Rail Joints

Rail joint bonds may be 3 rail head bonds, 70 mm². Cadweld welded bonds welded to the outer head of the running rail, or a minimum of two (2) 1250 mm lengths of copper cable as specified in Clause 6.2.1.

7 Rail Connections

7.1 Rail Connection Methods

For bolted connection to rails, cables shall be terminated in suitable connection lugs as set out in Clause 7.2 below.

Rail connections shall be by one of the following methods dependant on the type of cable used.

7.1.1 Steel Hypalon

Connected to rails by means of grooved channel pins.

7.1.2 Copper Hypalon (84 x 0.3 mm)

Connected to rails by means of either the stainless steel tapered bolt, nut and washer, or 6 mm welded stud.

7.1.3 Copper Hypalon (37/1.78 or equivalent)

Connected to rails by means of either direct welded connection to the rail web, 12 mm welded stud or bifurcated rail head welded connection.

7.1.4 Aluminium Hypalon (454/0.50 mm)

Terminated using bimetallic crimp lug to a copper Cadweld tail, connected to the rail web, or using bifurcated copper tails with palm lugs on 12 mm studs connected to the rail.

7.2 Connection Lugs

The details of connection lugs to be used are specified in Specification CRN SE 022 Solderless Terminals and Cable Lugs for Signalling Applications.

8 Impedance Bonds

8.1 Traction Rating of Impedance Bonds

There are two ratings of impedance bonds in use in New South Wales. Those for Light traction are rated at 1000 A per rail continuous current while those for Heavy traction are rated at 2000 A 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 1000 A per rail continuous current.

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

8.2 AC Impedance of Impedance Bonds

The impedance of the impedance bonds on double rail AC 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 older style impedance bonds have an impedance of 0.3 to 0.4 ohms at 50 Hz AC, which limits the maximum shunt characteristic to 0.15-0.2 ohms.

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

The 50 Hz impedance of the resonated impedance bonds approaches 2.5 ohms.

8.3 Installation of Impedance Bonds

8.3.1 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 CRN SC 021 – Construction of Cable Routes and Associated Civil Works.

8.3.2 Connection of Impedance Bonds

The connection of side lead cables to rail shall be in accordance with Clause 7.1.

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 Clause 7.2. 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.

8.3.3 Side Leads

There shall be a minimum of two side leads from the impedance bond to each rail. Clauses 6.1 and 6.2 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.

8.3.4 Neutral Connections

The neutral connections between adjacent impedance bonds shall preferably consist of a tinned copper busbar as specified in Clauses 6.1 and 6.2. 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. Clauses 6.1 and 6.2and 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.

9 Electrolysis Protection

9.1 Connection of Electrolysis Bond to Track

The traction return system shall include the connection of electrolysis bonds as required.

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 50 m 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 CRN SE 012– 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.

- One 7/1.70 PVC/PVC/Nylon insulated cable, which carries the traction current from the electrolysis bond to the neutral point connection.
- 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 84/0.3 mm copper hypalon insulated cables. These are connected to rail by copper crimp lugs and tapered bolts or 6 mm welded studs.

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

10 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.

A Sydney Trains' representative will provide 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 Clause