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Impedance Bonds (formerly RT/E/PS/11765)

This temporary front sheet facilitates change to the new Network Rail Standards referencing nomenclature.

The Ref above will be formally allocated to this standard when it is next changed in the meantime the contents, date and issue number of this Network Rail Standard are **UNCHANGED and with immediate effect it should be referred to as “(new ref) formerly (old ref)”.**

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RAILTRACK LINE PRODUCT SPECIFICATION

IMPEDANCE BONDS

Endorsement and Authorisation

Endorsed by:



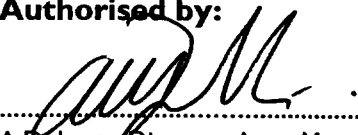
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Summary

This Line Specification states the minimum requirements for Impedance Bonds. It includes lifecycle requirements from design, safety and environmental to installation, testing and maintenance.

Issue/Revision Record

Issue	Date	Comments
I	December 2000	New Specification. The contents have been extracted from Railway Group Codes of Practice GK/RC0752, GK/RC0753 and GK/RC0754 which are to be transferred to Railtrack Line in February 2001.

Implementation

The requirements of this Specification shall apply to all impedance bonds supplied for use on Railtrack controlled infrastructure on or after 3 February 2001, It shall also apply to the alteration and maintenance of existing impedance bonds from the same date. The following documents are superseded:

Superseded documents (part only)

GK/RC0752, issue 2, December 1998 - General Information on Track Circuits

GK/RC0753, issue 1, June 1996 - Track Circuit Requirements for AC Traction

GK/RC0754, issue 1, June 1996 - Track Circuit Requirements for DC Traction

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I INTRODUCTION

I.1 PURPOSE

This Product Specification gives details of best practice in respect of impedance bonds in order to achieve the requirements of RT/E/S/11752.

I.2 SCOPE

The contents of this Product Specification apply to all impedance bonds. The more general requirements can be found in RT/E/S/11752. Safety issues specific to impedance bonds are included; general safety issues are contained in RT/E/S/11752 and other relevant Railtrack standards.

Specific requirements for each type of track circuit are given in the appropriate Product Specification:

RT/E/PS/11760 Westinghouse Signals FS2600 Track Circuits,

RT/E/PS/11761 TI.21 Audio Frequency Track Circuits,

RT/E/PS/11763 Reed Type RT Track Circuits,

RT/E/PS/11757 Phase Sensitive Track Circuits.

I.3 INTRODUCTION

High traction return currents associated with low voltage d.c. traction systems require a very low impedance path back to the substation if voltage drop is to be kept within sensible limits for reliable train operation. This is achieved by using both running rails for traction return wherever possible, as well as cross bonding between parallel tracks, thereby reducing the overall return path impedance.

This requirement causes two main problems for track circuit operation:

- Where jointed track circuits are used, traction return current needs to pass freely between adjacent track circuits, by-passing the IRJs.
- Cross bonding to parallel tracks must be achieved without providing a substantial connection from one track circuit feed to another track circuit receiver (or relay).

These problems are solved by the use of impedance bonds. An operational explanation can be found in section 3.

2 APPLICATION AND CONSTRAINTS

2.1 APPLICATION

Double rail track circuits on electrified lines require the use of impedance bonds:

- at jointed extremities of track circuits,
- for cross bonding between tracks at regular intervals within the maximum distances specified for traction return cross bonding (see section 3.2), but not closer than the minimum distances specified to facilitate track circuit adjustment,
- at electrification connections (e.g. substations, track paralleling huts, track impedance relay installations, feeder stations, track sectioning cabins, booster transformer mid-point connections), and
- for structure bond connections to structures and earth wires (on a.c. electrified lines).

The following applications are addressed:

- impedance bonds for double rail 50Hz a.c. phase sensitive track circuits on d.c. electrified lines,
- impedance bonds for double rail $83\frac{1}{3}$ Hz a.c. phase sensitive track circuits on a.c., d.c. or dual electrified lines,
- impedance bonds for T1.21 track circuits on a.c., d.c. or dual electrified lines,
- impedance bonds for double rail reed track circuits on a.c., d.c. or dual electrified lines,
- impedance bonds for FS2600 track circuits on d.c. electrified lines.

2.2 CONSTRAINTS

2.2.1 Maximum Number of Impedance Bonds in a Track Circuit

There is some loading of the track circuit by each impedance bond and the maximum number of impedance bonds in a track circuit must not be exceeded. Reference shall be made to the maximum length of track circuit in the appropriate Product Specification.

2.2.2 Electromagnetic Emission in High Current D.C. Electrified Areas

On high current d.c. electrification systems, impedance bonds are not permitted within 3.5m of an AWS (automatic warning system) inductor in either direction and, generally, they are not permitted within 75m beyond the inductor in the direction(s) for which the AWS is effective. In cases of difficulty, the latter distance may be relaxed to that which is covered in 1.5 seconds at permissible speed.

2.2.3 Structure Bonding on A.C. Electrified Lines

On a.c. electrified lines with double rail track circuits, lineside structures shall be earthed to the centre point of impedance bonds, via a separate earth conductor.

2.2.4 Cross Bonding

On electrified lines, track-to-track cross bonding with double rail track circuits must be provided via the centre point of impedance bonds, as shown in Figure 1. The maximum interval between cross bonding is given in section 3.2.

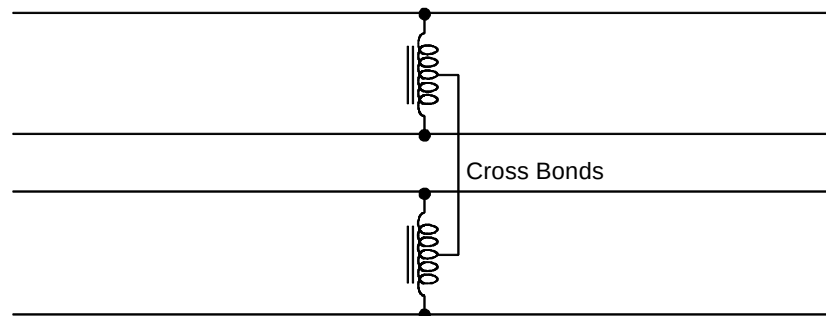


Figure 1

2.2.5 A.C. Phase Sensitive Track Circuits

The following rules apply:

- It has been found that particular combinations of relay type and impedance bond type are inherently more difficult to set up correctly and shall be avoided, as they are likely to be more susceptible to traction interference. In particular the combination of G4 relay and either type 2 or type 3 impedance bonds must not be used.
- Two impedance bonds in the same track circuit less than 100m apart must be avoided wherever possible, since resonance between the two impedance bonds makes adjustment of the track circuit very difficult.

2.2.6 TI.2I Track Circuits

The following rules apply:

- Impedance bonds must not be fitted in a tuned zone.
- Where there is only a single impedance bond within a track circuit, then this must not be fitted within 20m of a tuned zone or centre feed.
- Where there are 2 or more impedance bonds within a track circuit, they must not be fitted within 100m of a tuned zone or centre feed.
- There must be a minimum distance of 100m between impedance bonds in the same track circuit.
- In a.c. electrified areas, a maximum of 3 intermediate impedance bonds are permitted in an end fed track circuit. In d.c. electrified areas, a maximum of 2 intermediate impedance bonds are permitted. The same figures apply to each half of a centre fed track circuit.
- Impedance bonds shall be fitted with an internal capacitor tuned to the track circuit frequency.

2.2.7 Reed Type RT Track Circuits

The following rules apply:

- No loop is to be positioned over an impedance bond or a traction transposition.
- Not more than 4 impedance bonds shall be installed in any centre or end fed track circuit (a centre fed track circuit counts as a single track circuit for the purposes of this restriction).
- Only style DE, MR, P3, S or WH3 impedance bonds shall be used in d.c. electrified areas. Only style DD, DF, S or WH3 impedance bonds shall be used in a.c. electrified areas.
- Impedance bonds shall be fitted with an internal capacitor tuned to the track circuit frequency.

2.2.8 FS2600 Track Circuits

The following rules apply:

- The minimum distance between impedance bonds is 10m and the maximum distance is 800m.
- Not more than one intermediate impedance bond is permitted in a track circuit.
- Impedance bonds shall be fitted with an internal capacitor tuned to the track circuit frequency.

3 FUNCTIONAL REQUIREMENTS

3.1 PRINCIPLES OF OPERATION

3.1.1 Introduction

Impedance bonds are devices which allow traction current (d.c. or a.c.) to pass through, whilst limiting the track circuit current. They are necessary wherever double rail traction return and IRJ dependent track circuits co-exist.

An impedance bond is configured to provide a very low impedance path to double rail a.c. or d.c. traction return currents (typically less than $0.4\text{m}\Omega$ per coil) whilst presenting a high enough a.c. impedance between the rails (typically greater than 15Ω) to allow the operation of track circuits. It also provides a centre connection for cross bonding, which minimises the passage of track circuit current between circuit currents.

The winding connected between the rails is comprised of heavy gauge copper, fitted with a centre tap connection and wound on a heavy iron or ferrite core. Provided that each running rail carries equal amounts of traction return current, the current from each rail passes in opposite directions through the coil from the rail to the centre tap connection. The net flux in the magnetic circuit will be zero and the impedance to traction current (d.c. or a.c.) will be very small, as shown in Figure 2.

Air cored bonds work in a similar manner.

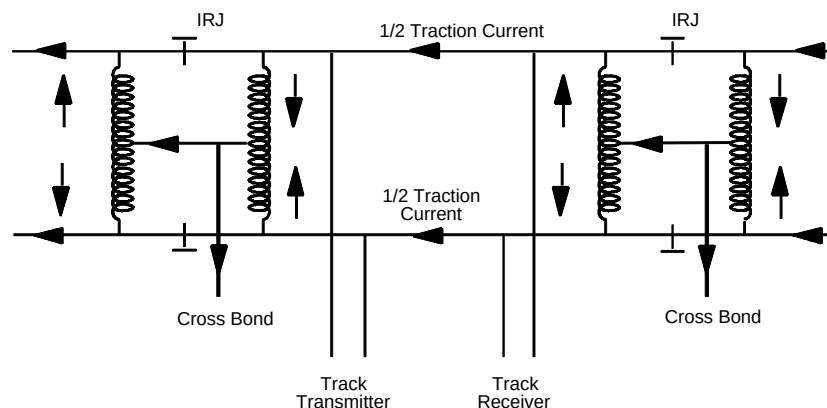


Figure 2 (Illustrative Only)

The a.c. track circuit current attempts to flow between the two rails and is therefore in the same direction through the two halves of the winding, resulting in the track circuit current seeing a larger, albeit still relatively small, impedance.

3.1.2 Auxiliary Winding

The impedance available from the simple impedance bond remains a handicap. It is therefore usual to enhance the impedance by parallel resonance of the traction winding, use being made of a step-up (approximately 50:1) transformer to reduce the value of the necessary capacitance to realistic levels. Another solution is to connect the resonating winding to form an auto transformer, as described in section 3.1.2.2.

Auxiliary windings are not provided on ferrite cored or air cored bonds. These bonds are provided with internal tuning capacitors for use on T1.21 track circuits.

3.1.2.1 Resonated Impedance Bonds

The induction of the traction winding is tuned to resonance at or near the track circuit operating frequency by use of a parallel capacitor, which raises the rail to rail impedance at the track circuit frequency, and thereby reduces the bond's effect on the track circuit.

For power frequency track circuits (e.g. 50 Hz), the value of capacitance required to attain resonance is reduced to an achievable magnitude, by applying the capacitance via an auxiliary winding, as shown in Figure 3.

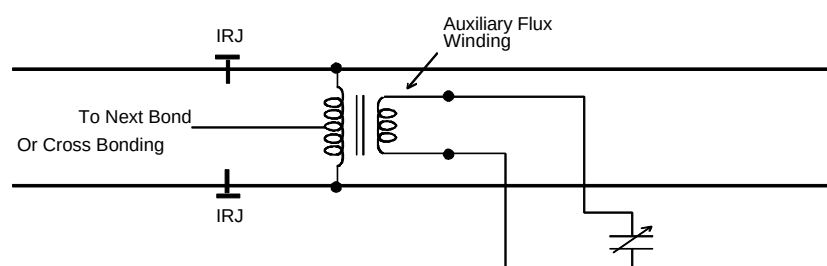


Figure 3

The value of capacitance required to achieve resonance depends on the following:

- Traction winding inductance, which may differ between designs. The capacitance required will vary inversely to the inductance.

- b) Auxiliary turns ratio, which may differ between designs. The capacitance required will vary inversely as the square of the turns ratio.
- c) Track circuit frequency, where the capacitance required will vary inversely as the square of the frequency.

Resonated impedance bonds are used at the feed and relay ends of jointed audio frequency track circuits and for all intermediate bonds associated with traction cross bonding.

3.1.2.2 Auto-Coupled Impedance Bonds

The method used to couple the feed and relay ends of certain designs of track circuit into the track as shown in Figure 4. At the feed end, the reduced voltage appearing across the traction winding is applied to the rails whilst at the relay end, the current from the track circuit passing through the traction winding is usefully employed to drive the relay.

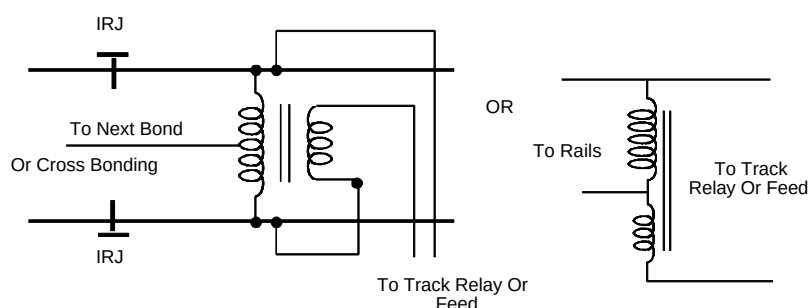


Figure 4

A double rail a.c. track circuit with auto-coupled impedance bonds is shown in Figure 5.

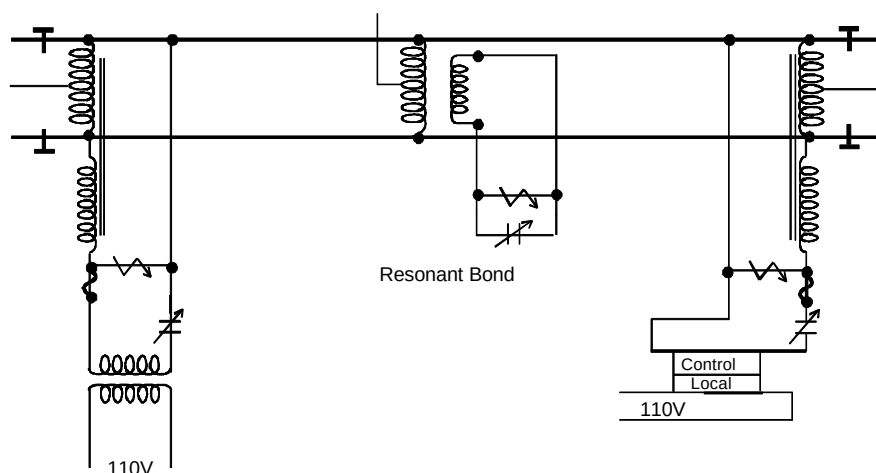


Figure 5

If the traction current in each rail is not equal, the imbalance results in a net flux in the iron circuit, and if that flux is sufficient to saturate the iron core, the track circuit current will be presented with a short circuit. It is therefore important to make the bond as tolerant as possible of traction current imbalance and this is done by creating an air gap in the magnetic circuit. Such bonds will tolerate 20% imbalance before saturation.

3.2 IMPEDANCE BOND SITING

3.2.1 D.C. Electrified Areas

To allow the traction return current to pass freely around the IRJs defining the limits of a jointed double rail track circuit, impedance bonds are connected across the rails, as shown in Figure 6.

If impedance bonds are placed too close together within the same track circuit, they can upset each other's operation, normally making it difficult or impossible to adjust the track circuit correctly. A minimum separation of 100m is required to overcome this.

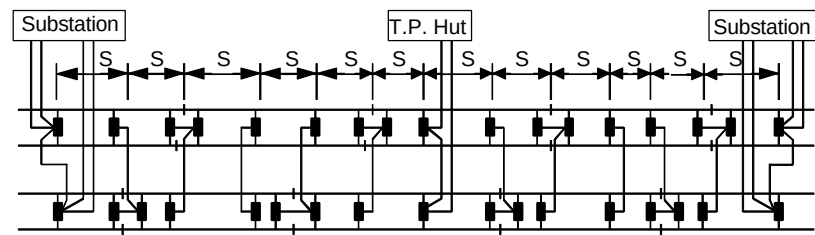
In deciding the position of impedance bonds and traction cross bonds, account must be taken of the necessity for providing them where double rail track circuits occur opposite substations, track paralleling (TP) huts, track impedance relay installations, feeder stations, track sectioning cabins and booster transformer mid-point connections, etc., generally within 45m of the centre lines.

In order to ensure a robust traction return system, the return rails must be periodically cross bonded between adjacent lines. To achieve such cross bonding in double rail track circuit territory, it is usually necessary to provide extra intermediate impedance bonds, in addition to the track circuit end bonds, connected across the rails as shown in Figure 6. The centre connections of the intermediate bonds on adjacent lines are cross bonded together. The cross bonds shall be as short as possible (approx. 46m max.).

3.2.2 A.C. and Dual Electrified Areas

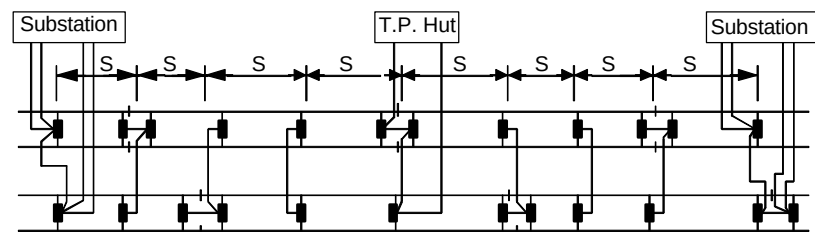
Similar considerations apply in a.c. and dual electrified areas.

The maximum intervals between successive track-to-track bonds in a.c. electrified areas are given in Appendix C of RT/E/S/21085.



Southern Region Arrangement from 1957 to 1962

Most schemes designed to this specification have now been reconfigured to the design below.



Southern Region Arrangement from 1962

Notes:

- 1 Distance (S) between cross bonds must not exceed 1100m nor be less than 100m. The average distance (S) must not exceed 825m, considering each substation section.
 - 2 One set of cross bonds to be installed at each substation and TP hut.
 - 3 A substation section is the distance between adjacent substations and usually includes one set each of substation and TP hut cross bonds.
 - 4 Use of the following table ensures that the above limits are not exceeded:
- | Substation section | Number of sets of bonds to be installed
(including substation at one end only) |
|--------------------|---|
| Up to 4800m | 6 |
| 4801m to 6500m | 8 |
| Above 6500m | 10 |
- 5 No more than two adjacent intermediate bonds per track circuit, with not less than 100m between adjacent bonds.
 - 6 Red sleeve or tape to be attached to track end of substation/TP hut traction return bond to indicate cable must not be disconnected without permission of the electrification infrastructure organisation, and warning labels must be attached (see Figure 41).

**Figure 6 - Arrangement of Cross Bonds
on D.C. Electrified Lines with Track Circuits**

4 PHYSICAL REQUIREMENTS

Iron cored impedance bonds shall generally conform to specification BR863.

4.1 FITTING

Impedance bonds and rail connections at adjoining track circuit ends typically require ten clear sleeper bays for fitting and care shall be taken to ensure the space is available in S&C areas.

Further details are given in section 9, Installation Procedures.

4.2 CONFIGURATION

The difference between auto-coupled (series resonated) and parallel resonated (also known as resonated) impedance bonds is explained in section 3.1.2. Impedance bonds must be capacitor resonated to present a significant impedance to the appropriate track circuit frequency.

See the appropriate Product Specification for further details and typical wiring:

- RT/E/PS/11760 Westinghouse Signals FS2600 Track Circuits,
- RT/E/PS/11761 TI.2I Audio Frequency Track Circuits,
- RT/E/PS/11763 Reed Type RT Track Circuits,
- RT/E/PS/11757 A.C. Phase Sensitive Track Circuits.

4.2.1 Auto-Coupled Mode

Impedance bonds at the extremities of a.c. and FS2600 track circuits (feed and relay ends) must be connected in the auto-coupled mode and series capacitor resonated via the track circuit connections.

A.C. track circuits use an external capacitor, whilst FS2600 use an internal one.

4.2.2 Resonated Mode

Intermediate bonds on a.c. track circuits must be parallel capacitor resonated, using an external capacitor.

All impedance bonds on TI.2I and reed track circuits, and intermediate bonds on FS2600 track circuits, must be parallel capacitor resonated, using an internal capacitor.

5 PERFORMANCE REQUIREMENTS

General performance requirements are given in RT/E/S/11752.

5.1 MAINTAINABILITY

When choosing the type of impedance bond (see section 9, Installation Procedures), the weight shall be considered for ease of replacement, in addition to the other factors listed in Figure 10.

Maintenance and local stock holding will generally be made easier if different styles of impedance bond are not intermixed within a track circuit.

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6 ENVIRONMENTAL REQUIREMENTS

6.1 ENVIRONMENTAL CONDITIONS

Impedance bonds shall comply with specification BR967, category F.

They are mounted two sleeper bays from any associated IRJs to prevent excessive vibration.

6.2 ELECTROMAGNETIC INTERFERENCE SUSCEPTIBILITY

The following explanation applies to iron cored bonds. Air cored bonds are less susceptible to interference from traction current imbalance as they do not saturate.

6.2.1 Interference Caused by D.C. Traction Current Imbalance

Traction return currents flowing through double rail track circuits are shared between the running rails. 50Hz a.c. double rail track circuits using auto-coupled impedance bonds are inherently immune to high levels (many hundreds of Amps) of 50Hz interference in the traction current where this is balanced between the running rails and the half windings of the relay end impedance bond. There are however a number of reasons why interference currents flowing through the track circuit may be, or become, imbalanced:

- Presence of check rails
- Track curves
- Earthing of one rail
- Bonding differences
- Asymmetric position of conductor rail
- Broken rails
- Disconnected impedance bond sideleads

When the track circuit becomes unbalanced any 50Hz interference in the traction return current due either to ripple in the supply, or generated by traction units, will result in a 50Hz signal being presented to the relay. The magnitude of this interference voltage is largely independent of the length of the track circuit, but is proportional to the imbalance of 50Hz currents flowing through the relay end impedance bond. Therefore, with a train occupying the track circuit, a 50Hz voltage can be applied across the track relay control coil, which if of sufficient magnitude and in the required phase relationship with the local supply, will operate the track relay and cause a wrong side failure of the track circuit.

With a completely imbalanced track circuit (broken rail or impedance bond side leads disconnected), as little as 1.5A of 50Hz traction interference could cause a wrong side failure. The susceptibility of imbalanced double rail track circuits is worsened if they become over resonant (on the capacitive side of resonant). Track circuits fitted with the more modern type 2 and type 3 impedance bonds can be at greater risk when this occurs due to a lower auxiliary coil resistance providing less damping of the resonant response. Measures that can be applied during track circuit set-up, to avoid track circuits becoming over resonant, are included in the Testing Requirements section of RT/E/PS/11757 (A.C. Phase Sensitive Track Circuits).

6.2.2 Impedance Bond Saturation

Provided that each rail is perfectly bonded and of equal resistance, the traction current will be equally divided and the impedance bonds will be perfectly balanced with no direct current flux in the cores. However, imperfect bonding or disparity of resistance will unbalance the bond, lowering its permeability and decreasing the impedance presented to the a.c. track circuit current.

An imbalance of as little as 5% (difference between rail currents / sum of rail currents) can cause distortion of the track circuit current waveform, resulting in possible right side failure of the track circuit. However, although correct set-up of the track circuit should enable imbalance to be detected, this cannot be relied upon; even completely imbalanced track circuits due to broken rails or disconnected side bond leads may not be automatically detected. One mechanism whereby imbalance is detected, is due to saturation of the impedance bond iron core. As the difference between the d.c. currents flowing through the impedance bond s half windings increase, the transformer action of the impedance bond becomes less efficient as it is driven into saturation, thereby suppressing the track circuit relay voltage. The operation of the relay will become unreliable, but some protection against wrong side failure of the track circuit is provided.

In order to improve the bond s tolerance to d.c. traction imbalance, an air gap is provided in the iron circuit, although this reduces the impedance presented to the a.c. track circuit current.

6.2.3 Remedy for Traction Current Imbalance

The level of imbalance current required to saturate impedance bonds is roughly proportional to their rating, with higher rated type 3 bonds able to withstand greater imbalance current levels than type 2 bonds for example (see the section 3). Therefore, care shall be applied when replacing one type of bond for another, as the tolerance to imbalance may be increased, but at the expense of detection of situations where track circuits become exposed to traction interference which could lead to wrong side failure. Similarly the introduction of additional cross bonding between track circuits may reduce the probability of the detection of imbalanced impedance bonds, by reducing the saturation effect. Whilst bonding between parallel tracks will reduce the concentration of traction interference in any particular track circuit, it may conversely allow it to propagate undetected through a completely imbalanced track circuit.

The unbalanced traction return currents usually result from defective bonding but can also occur on long curves where the low rail is shorter and therefore offers less resistance. The effect is particularly aggravated by the presence of a check rail. The usual remedy is the provision of transposition joints and bonding as shown in Figure 7.

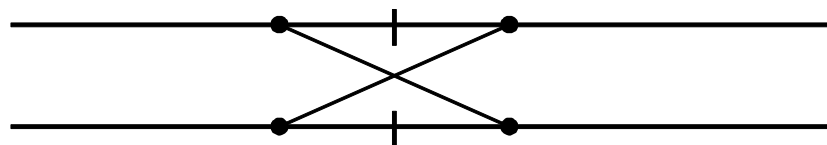


Figure 7

The position of these joints is determined within any individual track circuit and between any two impedance bonds by measuring the total length of check rail in each running rail and positioning the transposition joints so that the length of check rail in each leg of the track circuit is equal, as depicted in Figure 8.

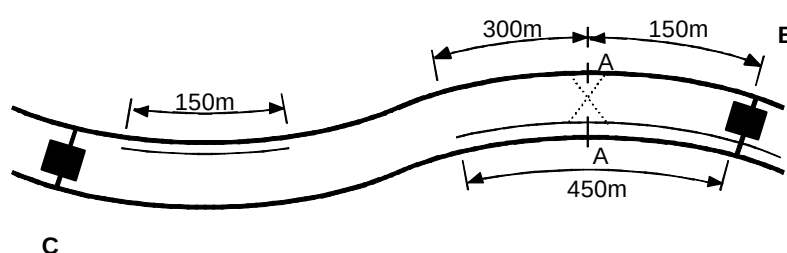


Figure 8

The position of the transposition joints (AA) is 150m from bond B. Therefore, the length of the check rail is 300m in each leg of the track circuit.

6.3 ELECTROMAGNETIC EMISSION

Impedance bonds impart no impact on the environment, except to trainborne AWS receivers, as detailed in section 2.2.2.

7 SAFETY REQUIREMENTS

7.1 SYSTEM SAFETY

The following features are fully described elsewhere in this specification:

- Impedance bonds must be sufficiently highly rated and tuned to suit the type of electrification system and the track circuit frequency.
- The configuration of impedance bonds must be series or parallel capacitor resonated, as required by the specific type of track circuit.
- Impedance bonds must not be mounted in the vicinity of AWS inductors on high power d.c. electrified lines, such that interference from the traction current could affect the train mounted AWS receiver.

7.1.1 Exposed Terminals

Exposed terminals must be prevented from making electrical contact with other terminals where there is a risk of a component becoming loose or tools being dropped. The preferred method is by shrouding.

7.2 OCCUPATIONAL SAFETY

Caution must be observed to avoid trapping fingers when handling impedance bonds.

Care should be taken when handling oil filled impedance bonds (types 0 and 1) to avoid any hazard from physical contact with the oil.

Special precautions shall be taken to protect personnel from the high voltages present on impedance bond coils and other terminals, as well as from traction voltages under fault conditions, including fusing, insulation and labelling. These shall generally be based on BS 7671.

Installation Procedures require impedance bond primary coils to be shorted out before changing capacitors.

7.2.1 Protective Fusing

A fuse, preferably fully enclosed to BS 88, is to be provided in the leg of track cables connecting to the impedance bond winding, as protection against traction faults.

7.2.2 Insulation of Terminals

Track circuit tail cable terminations shall be fully shrouded or situated in dedicated enclosures, as described in Code of Practice RT/E/C/11600. The terminals of all track circuit equipment shall be shrouded or enclosed, except when using the safety procedures for work on electrical equipment.

7.2.3 Safety Labelling

Due to the high voltage present on impedance bonds and other track circuit equipment, it is necessary to install warning signs on the outside of all lineside apparatus housings containing track circuit equipment.

The "Caution, risk of electric shock" warning sign depicting a yellow triangle with lightning flash, as described in Part J of RT/E/S/11752, shall be fitted to the outside of the auxiliary coil terminal box cover.

A label with the legend **TRACTION VOLTAGE - DO NOT REMOVE THIS LEAD** (see Figure 41) must be attached to all impedance bond leads at substations, track paralleling huts, track impedance relay installations, feeder stations, track sectioning cabins, booster transformer mid-point connections and spur feeders. These leads may only be disconnected under an absolute electric traction isolation, as detailed in section 12.4.2.

8 DESIGN REQUIREMENTS

8.1 SPECIAL DESIGN REQUIREMENTS

There are no special design requirements, apart from those given in the preceding rules.

8.2 GENERIC DESIGN REQUIREMENTS

The generic design requirements in RT/E/S/11752 include:

- interfaces with the track circuit (auto-coupled or resonated mode),
- interfaces with the permanent way (impedance bond fitting),
- interfaces with the electric traction infrastructure (cross bond positioning).

8.3 GENERIC DESIGN DELIVERABLES

The design deliverables associated with impedance bonds that are specified in the Signalling Design Handbook (Code of Practice RT/E/C/11701) include:

- signalling/scheme plan,
- track circuit schedule,
- location area plan,
- bonding plan (or track plan),
- location layout and wiring.

8.3.1 Bonding Plans

The impedance bond rail connections and the bond to bond connections must be shown on bonding plans, using symbols to RT/E/S/11004. Cross bond connections are the responsibility of the electrification infrastructure organisation and need not be shown on track plans for the former Southern Region, but are required on bonding plans for traction systems elsewhere.

The style or type of impedance bond is not required to be shown, unless a specific type is required, e.g. BR863 type 3 at substations on lines where high current trains run (presently classes 92, 373 and 465).

The impedance bond symbol must be shown filled in if the bond contains an internal resonating capacitor, as required by TI.21, reed and FS2600 track circuits.