TS 05332:1.0

T HR SC 00006 ST

Standard

Rolling Stock Signalling Interface Requirements

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Document information

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Document history

Revision	Effective date	Summary of changes
1.0	19/12/2014	First issued as T HR SC 00006 ST on 19 December 2014.
2.0	07/07/2017	Second version issued 07 July 2017. Updates to requirements related to ATP and AEOs.
1.0	19/11/2021	Renumbered as TS 05332:1.0. Version number recommenced in line with new designation.

Preface

This standard supersedes T HR SC 00006 ST *Rolling Stock Interface Requirements* Version 2.0.

This is a first issue under the new designation.

This document defines the interface requirements between rolling stock and the signals and control systems in the TfNSW Metropolitan Heavy Rail Network.

To aid in the certification of rolling stock, additional details on proof of compliance have been provided. An acceptance process has also been included as a recommended test procedure, to allow the AEOs to test and approve rolling stock.

Changes from the previous revision include updates to the following:

- ATP to cover revisions to ETCS level 1 LS implementation
- ATP to cover revisions to ETCS level 1 implementation of selective door operation
- settings for the 50Hz on board detector
- minimum track circuit length
- reference standard used for the compatibility testing over axle counters.

Table of contents

1 Scope

This document defines the signalling infrastructure compatibility requirements for all new or modified heavy rail rolling stock that operate on the TfNSW Metropolitan Heavy Rail Network.

Refer to TS TOC 1, which defines the areas associated with the network.

The requirements reflect the interfaces between rolling stock and the signalling infrastructure, considering in particular the issues of train detection by track circuits or axle counters, traction interference by rolling stock, train dynamics (braking and acceleration) and signal spacing and indications.

It also considers the interfaces to the track and the electrical traction supply system that relate to the safe and reliable operation of the signalling system.

2 Application

This document applies to all new or modified heavy rail rolling stock operating on the TfNSW Metropolitan Heavy Rail Network. It is intended for use by rolling stock manufacturers or suppliers of rolling stock whose vehicles are intended to operate on the TfNSW Metropolitan Heavy Rail Network to ensure that the signalling infrastructure compatibility requirements are met.

3 Referenced documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

International standards

EN 50238 *Railway applications – Compatibility between rolling stock and train detection systems*

EN 50121-3-1 *Railway applications – Electromagnetic compatibility – Part 3-1: Rolling stock – Train and complete vehicle*

EN 50121-3-2 *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*

EN 50592 *Railway applications – Testing of rolling stock for electromagnetic compatibility with axle counters*

Transport for NSW standards

ESC 210 *Track Geometry and Stability*

ESC 215 *Transit Space*

ESC 220 *Rail and Rail Joints*

T HR SC 10003 ST *Signalling Design Principle – Braking Distance*

T HR SC 10004 ST *Signalling Design Principle – Overlaps*

ESR 0330 *Wheel Defect Manual*

SPG 0706 *Installation of Trackside Equipment*

T HR EL 08002 ST *Relative Positions of Signals and Open Overlaps*

T HR EL 90003 ST *Heavy Rail Traction System – Current Ratings of 1500 V dc Equipment*

T HR RS 00100 ST *RSU 100 Series – Minimum Operating Standards for Rolling Stock – General Interface Requirements*

T HR RS 00200 ST *RSU 200 Series – Minimum Operating Standards for Rolling Stock – Common Interface Requirements*

T HR RS 00300 ST *RSU 300 Series – Minimum Operating Standards for Rolling Stock – Locomotive Specific Interface Requirements*

T HR RS 00600 ST *RSU 600 Series – Minimum Operating Standards for Rolling Stock – Multiple Unit Train Specific Interface Requirements*

T HR RS 00830 ST *RSU Appendix C – Brake Performance Curves*

T HR RS 00870 ST *RSU Appendix G – Drawings*

T HR RS 04001 ST *Passenger Rolling Stock Access and Egress*

T HR SC 01610 SP *ETCS Trackside Equipment*

T HR SC 01650 SP *ETCS Onboard Equipment*

T HR SC 10031 ST *Signalling Design Principle – ETCS Level 1*

T MU AM 01001 ST *Life Cycle Costing*

TS 00003.1:1.3 *Concessions to Transport Standards Part 1 – Concession Process*

T MU MD 20002 ST *Risk Criteria for Use by Organisations Providing Engineering Services*

TS TOC 1 *Train Operating Conditions (TOC) Manual – General Instructions*

Legislation

Radiocommunications (Low Interference Potential Devices) Class Licence 2015 (Cth)

Other reference documents

ERA/ERTMS/033281 *Interfaces between control–command and signalling trackside and other subsystems*

European Commission, January 2015, Commission Decision (EU) 2015/14 amending Decision 2012/88/EU on the technical specification for interoperability relating to the control-command

and signalling subsystems of the trans-European rail system using set of specifications #2 (ETCS Baseline 3 and GSM-R baseline 0)

Network Rules NSG 600 *Running signals*

Network Rules NSG 602 *Shunting signals*

Network Rules NSG 604 *Indicators and signs*

4 Terms, definitions and abbreviations

The following terms, definitions and abbreviations apply in this document:

AEO Authorised Engineering Organisation

AMB Asset Management Branch

ATP automatic train protection

CCS control-command and signalling

consist listed order of the vehicles arranged to make up a complete train

DMU diesel multiple unit

DPU data pick-up unit

EMC electromagnetic compatibility

EMI electromagnetic interference

EMU electric multiple unit

ETCS European train control system

EU European Union

LS limited supervision

OHW overhead wiring

rail transport operator rail transport operator means –

(a) a rail infrastructure manager; or

(b) a rolling stock operator; or

(c) a person who is both a rail infrastructure manager and a rolling stock operator;

RIM rail infrastructure manager; in relation to rail infrastructure of a railway, means the person who has effective control and management of the rail infrastructure, whether or not the person –

(a) owns the rail infrastructure; or

(b) has a statutory or contractual right to use the rail infrastructure or to control, or provide, access to it

Subset an ETCS specification managed by the EU Agency for Railways

TCA track circuit actuators

train a single unit of rolling stock or two or more units coupled together, at least one of which is a locomotive or other self-propelled unit

train detection is the technology and method by which the signalling system knows where a train is (the state of occupancy of any protected section of track)

TfNSW Transport for NSW

TSI technical specification for interoperability

unit a single item of rolling stock

UPS uninterruptible power supply

VDU video display unit

vehicle general term used to describe rolling stock

5 Whole-of-life considerations

This standard defines the various interfaces between rolling stock and the signalling system. The solutions and methodologies used to meet the requirements of this standard shall, in their implementation, be considered and measured using whole-of-life principles and strategies to achieve best practice outcomes.

Whole-of-life considerations shall also include the life cycle cost. All the data and assumptions for determining the whole-of-life cost calculations of the relevant systems and equipment shall be recorded in accordance with T MU AM 01001 ST.

6 Fundamental requirements

All vehicles operating on the TfNSW Metropolitan Heavy Rail Network shall always be correctly detected by the existing signalling system.

Vehicles and trains shall generate no energy or electromagnetic interference capable of interfering with the TfNSW Metropolitan Heavy Rail Network's signalling system.

7 Rolling stock interfaces

The listed points below are key interfaces that rolling stock has with the signalling system and in which the following sections of this document outline the interface requirements. Where necessary, discussion sections have been included as informative text to allow a better understanding of the interface requirements.

- Rolling stock

  - Size, shape, gauge and profile of wheels.
  - Limits on wheel condition.
  - Braking systems, including train performance parameters for both air brake and handbrake.
  - Effective electrical conductivity between wheel-to-rail contact points on the same axle.
  - Electrical compatibility between traction system components and between traction systems, and signalling and telecommunication systems.
  - Sanding equipment and its possible effects on track circuits.
  - Train acceleration performance.
- Signalling and telecommunications systems and equipment
  - Possibility and effect of electric traction or other electromagnetic interference with the signalling and telecommunications, or any other system.
  - Operation of track-to-train automatic protection systems.
  - Required stopping distances, speeds and signal sight distances.
  - Restrictions to be applied to particular types of trains where they are signalled over track which operates mixed train types (for example, freight, loco hauled passenger and electric multiple units (EMUs) passenger).
- Onboard safety systems.

8 Risk factors

Where any new or unauthorised rolling stock requires access to the TfNSW Metropolitan Heavy Rail Network, a risk to the integrity of the signalling system exists.

The following risk factors are identified in the interface between rolling stock and the signalling systems:

- ineffective detection of train presence
- electrical interference between trains and infrastructure
- train braking performance and acceleration
- damage to signalling equipment such as facing points, due to wheel geometry
- data transfer between signalling systems and train or driver
- the ability of the driver to initiate appropriate responsive action
- the driver not adequately perceiving or responding to signalling indication.

Section 8.1 to Section 8.3 explain additional identified risk factors.

8.1 Track circuits

Train detection is the technology and method by which the signalling system knows where a train is (the state of occupancy of any protected section of track).

Track circuits are the main train detection technology currently used. The principal risks associated with track circuits are the ability of the train to make effective electrical contact between wheel and rail, and the sensitivity of adjustment of the track circuit.

Secondary risks are maintaining effective conductivity between rolling stock wheels on any axle, or the potential for electric traction systems to be the source of interference. Both of these can render the track circuits unsafe or unreliable.

8.2 Axle counters

Where axle counters are used for train detection, a different risk profile emerges. The ability of the axle counter system to reliably detect the presence of a train remains the highest risk. Secondary risks are associated with miscounts of the axle counter where an unoccupied section of track remains in the occupied state, forcing train movements to be executed manually.

Train braking poses the problem of matching signalling infrastructure design to train braking potential, so that the signalling system can provide sufficient warning for all trains approaching a stop signal to stop safely before the obstruction that it protects. Identified risk factors include the value and variability of braking effort, propagation delay in initiating braking effort throughout the length of a train, and variations in train speed.

8.3 Trip mechanism

Most forms of rolling stock used on the TfNSW Metropolitan Heavy Rail Network are fitted with trip mechanisms. The identified risk of trip mechanisms is that a misalignment between the train mounted trip gear and the ground mounted trainstop can be present. The implication of this is that the trainstop arm could fail to engage with the train mounted trip gear, allowing a train to proceed unimpeded.

An identified risk at rail junctions is that the geometry of a mismatched wheel does not effectively cause the train to follow a diverging route.

9 Train detection

The train detection system in the TfNSW Metropolitan Heavy Rail Network uses track circuits, axle counters, treadle switches and DPUs. Section 9.1 to Section 9.3 provides the requirements for the train detection system.

9.1 Track circuits requirements

The basic principle behind a track circuit lies in the connection of the two rails by the wheels and axle of a vehicle to short out an electrical circuit. This short circuit is detected by the track circuit receiver which then reports the presence of the vehicle to the signalling system.

Train detection by track circuits is the result of one or many axles on a train making effective electrical contact with the surfaces of both rails, providing a low-impedance path to the track circuit current and thereby depriving a correctly adjusted receiver of energy.

9.1.1 Track circuit compatibility requirements

Rolling stock operating on the TfNSW Metropolitan Heavy Rail Network shall meet the following requirements to be compatible with the network's track circuits and train detection systems:

- The maximum resistance between rail contact surfaces of wheels on the same axles shall be no greater than 1 mΩ.
- The total rail-to-rail resistance of any one unit shall not exceed 1 mΩ when measured on clean straight track at an open-circuit voltage not exceeding 1.0 V rail-to-rail.
- The leading and trailing axle of each diesel self-propelled unit shall be provided with the means to keep contact surfaces clear of any contaminant build-up, especially while rolling on straight track; for example, tread brakes or scrubber blocks.
- Where concern exists as to how well the leading and trailing single axle can shunt sufficient rail current, additional measures shall be employed to ensure effective track circuit shunting, for example, track circuit actuators.
- Irrespective of wheel or rail wear states, wheels shall always maintain effective rail wheel electrical contact. In particular under the following conditions:
    - centre top 10 mm of new or re-profiled rail
    - inner 30 mm of top of worn or standard profile rail.

  Note 1: Effective rail wheel electrical contact infers that even for a worn wheel tread profile, the contact point on the rail needs to be on the shiny used 'conductive' contact band and not on the rusted part of the rail head.

  Note 2: Tolerances for new and worn rail head profiles are set out in ESC 220.

  Note 3: Worst case wheel tread profiles are set out in ESR 0330.
- The vehicle shall not deposit insulating materials on the rail contact surface that interfere with the ability of the train to be detected by the signalling system.
- Vehicles that use sand to improve wheel-to-rail friction shall have de-sanding equipment fitted.

Note 4: The system requirements for the use of sand and de-sanding equipment are set out in T HR RS 00300 ST.

- The tread of a wheel shall not be allowed to be contaminated by brake residue where this can interfere with the shunting performance of the train.
- For all new vehicles, an assessment of the vehicle against those factors that affect train shunting as described in Appendix B of this document shall be required. The outcome of the assessment should indicate that the vehicle has sufficient inherent features in its design to assist shunting.

9.1.2 Track circuit proof of compliance

The rolling stock supplier or operator shall demonstrate compliance to AMB requirements for new rolling stock by providing the following theoretical and empirical data:

- detailed design analysis of vehicle dimensions, bogie and braking system design, wheel profiles and wheel and axle assembly methods
- test results of single axle wheel-to-wheel and rail-to-rail resistance measurements
- results of actual track circuit shunting tests at an approved test site
- provision of rail cleaning equipment if sand or adhesion enhancers are used; for example, blowers
- wheel cleaning or shunt enhancement provisions
- an assessment on the effectiveness of electrical connections between axles and between axles on different bogies.

The submitted information shall be in the form of a risk assessment, using T MU MD 20002 ST.

9.1.3 Track circuit discussion

Effective train detection by track circuits is the result of one or many axles on a train making effective electrical contact with the surfaces of both rails, providing a low-impedance path to the track circuit current and thereby depriving a correctly adjusted receiver of energy. This relies on clean wheels making contact with clean rails on correctly adjusted track circuit equipment.

The track circuit shunting performance of a piece of rolling stock is the result of a number of factors, individually and in combination. These factors include the following:

- wheel-to-rail interface
- rail and wheel metallurgy
- rolling stock design and mass
- electric traction

- sanding
- leading and trailing axles
- vehicle dimensions
- track circuit sensitivity.

9.1.3.1 Wheel-to-rail interface

The match between rail and wheel profiles is of critical importance to the effectiveness and reliability of track circuit shunting.

Rail profiles are specified in ESC 220.

Wheel profiles are specified in T HR RS 00200 ST.

Worn wheel information is specified in ESR 0330.

The occasional presence of mismatched wheel profiles has led to cases of rail contact failure where wheels contact the rail outside of the established contact band, thereby creating an intermittent shunting effect.

A mismatch can also occur where a vehicle operates over track that is not on a regular route for that vehicle. Regular operation can result in the wheel developing the matching contact band on the rail.

9.1.3.2 Rail and wheel metallurgy

Metallurgical factors play a part in the train detection equation. The propensity of rail surfaces to oxidation, the ease with which wheel treads can pick up contaminants in rolling contact and the relative hardness of rails and wheel treads can result in different tread wear rates and profiles.

A continuing trend in the metallurgy of wheels is to increase the hardness of the wheel to maintain its profile. Harder wheel materials maintain tread profile for longer because they do not wear as much as the softer materials do.

9.1.3.3 Rolling stock design and mass

Generally, the effectiveness of rolling stock detection improves with increasing vehicle mass. Low vehicle mass is normally not a factor with freight trains, due to the mass of a typical locomotive. It can be a concern with lightweight diesel railcars.

The interaction of wheels and rail at the contact surface is very significant. Traditionally, rolling stock bogie design was relatively unsophisticated, producing large amounts of relative movement between wheels and rails, which resulted in a high degree of mutual cleaning and polishing of the contact surfaces.

Improvements in wheel and rail design, initially with passenger rolling stock and more recently with freight stock (with steering bogies) have extended the life of wheels and rails at the expense of contact surface polishing. Moreover, wheels, which roll without slippage, will pick up a layer of contaminant from the rail surface, which can degrade their shunting effectiveness, even on clean rail.

Using light short consist railcars with optimised bogie design and disc brakes can result in higher risk situations, particularly where they operate over a corridor in which they do not normally operate. Regular operation in country areas can cause wheel hollowing and a wheel-to-rail mismatch.

TCAs are the preferred method of mitigating this risk.

9.1.3.4 Electric traction

A feature of wheel-to-rail contact is that when a current flow of any kind is established, any other current can follow the same path without obstruction. Electric rolling stock has the advantage over diesel powered rolling stock in that any temporary loss of wheel-to-rail contact will be rapidly rectified by the traction return current, re-establishing an effective return path.

9.1.3.5 Sanding

Dry sand is an extremely effective electrical insulator. Using sand or similar materials to improve wheel-to-rail friction shall be applied and controlled in a manner which does not leave an insulating layer on the rail-to-wheel contact surface.

9.1.3.6 Leading and trailing axles

TfNSW uses DPUs across the TfNSW Metropolitan Heavy Rail Network for a variety of applications. DPUs are essentially a tuned rail current sensor that is influenced by the magnetic field generated by the track circuit current flowing in the rail. For correct operation, the leading and trailing axle of a train shall always be able to shunt sufficient rail current away from the area of influence of the DPU.

9.1.3.7 Track circuit sensitivity

The lower the resistance required to place a track circuit into the occupied state the less sensitive the track circuit is to train shunt.

All track circuits in use in the TfNSW Metropolitan Heavy Rail Network have a shunt sensitivity of no less than 0.15 Ω. This means that all track circuits installed in the network will show occupied when a resistance of 0.15 Ω or less is applied across the rails.

The minimum resistance of the vehicle for a rail vehicle to be safely and reliably detected by a track circuit including any resistances between wheel and rail shall be less than 0.15 Ω.

In the outer metropolitan area, the area beyond where suburban train services typically operate, some older track circuit types still exist that have a shunt sensitivity of 0.06 Ω. Where vehicles are intended to operate over these types of track circuits, the minimum resistance of the vehicle for it to be safely and reliably detected by a track circuit including any resistances between wheel and rail shall be less than 0.06 Ω.

9.2 Axle counter requirements

The basic principle of an axle counter lies in the ability of a wheel to sufficiently disturb a magnetic field produced by a rail mounted wheel sensor. The wheel needs to be of a low permeable material and of sufficient dimension so as to be reliably detected.

9.2.1 Axle counter compatibility requirements

Rolling stock operating on the TfNSW Metropolitan Heavy Rail Network shall meet the following requirements to be compatible with the network's proposed use of axle counters:

- maximum distance between axles shall be as defined in Section 10
- distance between end of train and first axle shall be as defined in Section 10
- minimum axle spacing shall be such that at line speed, the wheels can be reliably detected as required in ERA/ERTMS/033281
- wheel material shall have ferromagnetic characteristics and be electrically conductive
- rolling stock protuberances shall be kept free of the metallic influencing zone as defined in ERA/ERTMS/033281.

Where the wheel dimensions detailed in ERA/ERTMS/033281 differ from those listed in T HR RS 00200 ST the matter shall be referred to the AMB to determine whether the wheel dimensions are operationally acceptable through discussion with the supplier or manufacturer of the axle counter equipment.

Rolling stock-generated interference limits are set out in ERA/ERTMS/033281. The test process shall be performed in accordance with EN 50592.

9.2.1.1 Wheel parameters

Wheel parameters shall be in accordance with T HR RS 00200 ST and T HR RS 00870 ST.

9.2.2 Axle counter proof of compliance

The rolling stock supplier or operator shall demonstrate compliance to AMB requirements for new rolling stock by providing the following theoretical and test data:

- detailed design analysis of vehicle dimensions, wheel dimensions, bogie and braking system design
- results of actual axle counting occupancy tests at an approved test site
- results of actual interference tests by an approved method.

9.2.3 Axle counter discussion

Effective train detection by axle counters is the result of wheels passing over a sensor attached to the rail. Depending on the sensor type, accurate and reliable detection of either the wheel itself or the wheel flange passing over the sensor distorts a magnetic field produced by the sensor, which is then detected by an evaluator.

Wheels of smaller dimensions generally have smaller flanges and as such, when travelling at speed, not only do they distort the magnetic field less, but they also distort it for a shorter time. Axle counter evaluators have a minimum integration time which shall be met in order to achieve a reliable count.

Reliable detection is the result of the following:

- wheels or flanges being within the detection limits as specified for the axle counter
- protuberances on the vehicle being outside of the metallic influencing zone
- the speed of the vehicle
- distance between axles meets the minimum integration time of the wheel sensor.

Interference from rolling stock is greatly diminished as the wheel sensor is galvanically isolated from the rail; however the sensor can potentially be influenced by strong magnetic fields from traction systems and other large electromagnetic radiating sources onboard the vehicle.

9.2.3.1 Wheel-to-rail interface

For axle counters, the wheel-to-rail interface is far less of an issue than for track circuits.

For axle counters to reliably detect wheels and flanges, the detectors first need to be properly positioned on the rail, in accordance with the manufacturer's instructions. Reliable detection for both wheel and flange detector systems will require the wheels to be kept within tolerances as defined in ESR 0330.

9.3 Other methods of train detection

Track circuits are the main form of train detection used in the TfNSW Metropolitan Heavy Rail Network. However, a number of installations use alternative methods such as treadle switches and DPUs.

9.3.1 Treadle switches

Using treadle switches eliminates many of the problems associated with train detection using track circuits. However, on some forms of rolling stock, due to the size of the wheels, they cannot be reliably detected, or cannot be detected at speed.

Treadle switches are not failsafe in design, so are only used in applications where their failure modes do not result in an unsafe condition.

9.3.1.1 Treadle switches requirement

As referenced in the manufacturer's technical manual, the minimum wheel diameter for detection of the treadle switches used in the TfNSW Metropolitan Heavy Rail Network is 450 mm.

9.3.1.2 Treadle switches proof of compliance

Proof of compliance shall be determined by developing specific test cases tailored to test the vehicle against the installed items. Acceptance criteria for each test case shall be based on the detection requirements detailed in the manufacturer’s technical manual. To ensure long-term compliance, the acceptance criteria should also include a safety margin, to allow for wheel wear.

9.3.1.3 Treadle switches discussion

Treadle switches detect the passing of a wheel over a sensor mounted to rail. Some sensors are mechanical; however most detect the wheel through a change in the magnetic circuit generated by the sensor. The sensors are designed to detect the passing of a wheel with certain dimensions. Some sensors pay particular attention to the wheel flange.

9.3.2 Data pick-up units

DPUs are also known as pin point detectors or intermediate receivers. They are a tuned inductive pick-up device, and are located adjacent to the inside running rail of an audio frequency track circuit. The DPU is energised by the electrical current that flows in the rail from the parent track circuit.

The low output of the DPU is amplified by way of either a step-up transformer or an intermediate amplifier of type QAJTC1, where it is then fed into an audio frequency receiver.

As a wheel passes over the DPU, the short circuit formed by the wheel and axle to the other rail shunts the track circuit current away from the DPU, depriving it of sufficient current to maintain its output above the pick-up threshold for the receiver.

DPUs can be used to either detect the leading end of a train where they are used to typically time a train’s approach speeds or they can detect the rear of the train where they are typically used for conditional clearing of signals in the rear.

9.3.2.1 DPU proof of compliance

DPUs have been proven to be very susceptible to interference from rolling stock; particularly rolling stock that uses power electronic controlled traction systems due to the 'close up' effect described further in Section 21.

Proof of compliance shall be determined by specific test cases where the vehicle under test is to power and brake over the DPU, to ensure that noise levels detected by the DPU are within specified limits.

10 Rolling stock dimensions

Particular dimensions on rolling stock are critical to the train detection system for both track circuited and axle counter solutions.

Vehicle dimensions that have the ability to affect the signalling system include the length of vehicle overhang and the distance between inner axle centres.

Vehicle dimensions that have the ability to affect the OHW include the position of pantographs onboard an EMU and their likelihood of bridging out section overlaps for extended periods of time, particularly when standing at a signal at stop.

10.1 Vehicle overhang

To guarantee the safety of trains on converging tracks at clearance points, the extremities of any vehicle shall not extend past the outermost detectable axles by more than 3 m. Details of permitted vehicle outlines and swept paths are documented in T HR RS 00100 ST.

Where it is proposed to operate a vehicle on the TfNSW Metropolitan Heavy Rail Network with an overhang in excess of 3 m, the acceptance for approval shall assess the likelihood of a collision on converging or diverging routes.

10.2 Inner axle centres

To maintain shunting reliability, there shall always be a minimum of two axles shunting a track circuit. The minimum track circuit length used in the TfNSW Metropolitan Heavy Rail Network is 20 m. Consequently, the maximum distance between inner axles of a single vehicle is 14 m to ensure that a minimum of two axles will always be shunting the shortest used track circuit.

Details on the bogie centres for approved rolling stock types are set out in T HR RS 00100 ST.

Where a vehicle is proposed to operate on the TfNSW Metropolitan Heavy Rail Network where the inner axle spacing exceeds 14 m, the acceptance for approval shall assess the likelihood and consequence of the potential for a track circuit to energise underneath the vehicle.

Where axle counters are in use, the minimum distance of a track section shall be 15 m, the same as is for track circuits.

10.2.1 Discussion

The minimum distance stated above addresses the risk of a vehicle with a long wheel base spanning a track section. With respect to axle counters the minimum length has not taken into account other factors that may influence the minimum length of a track section such as train speeds, axle counter evaluator processing times or communication delays. Minimum track section lengths for axle counters may extend beyond this minimum distance to account for these delays.

10.3 Vehicle body outline

Track side signals are installed perpendicular to the track at distances that do not infringe on the requirements defined in ESC 215.

Vehicle body outlines shall comply with T HR RS 00100 ST.

10.4 Axle loads

Vehicles with light axle loads are less effective in providing a consistent shunt.

Axle loads of 10 tonnes or less shall have further consideration in the compatibility assessment with, if necessary, dynamic tests conducted to prove satisfactory shunting performance.

Appendix B details factors that affect the shunting of track circuits.

10.5 Relative positions of signals and open overhead wiring overlaps

When standing at a signal at stop, EMUs shall be of a length that the pantographs shall not bridge out switched (when the switch is open), or open overlaps in the OHW. This is in accordance with T HR EL 08002 ST.

10.5.1 Discussion

EMUs shall not stand within an open overlap section in the OHW as pantographs can electrically connect two sections of OHW through the carbon strip on the pantograph, resulting in localised heating and eventual failure of the OHW system.

For this reason, signals shall not be placed within 204 m in advance of an open overlap section (204 m being the maximum allowable distance for ten car suburban train).

10.5.2 Proof of compliance

The length of trains and the position of pantographs onboard each train shall be assessed for compliance to the requirements in T HR EL 08002 ST.

11 Track circuit actuators

A TCA is an ancillary system which can be fitted to rolling stock to assist in the shunting of track circuits.

All passenger DMUs operating with eight axles or less shall be fitted with a TCA.

Where passenger DMUs are not fitted with a TCA, their ability to maintain a reliable shunt on a track circuit shall be assessed. Where reliability of shunt cannot be guaranteed to SFAIRP level, the vehicle shall not be reliant on the signalling system. Alternate means of safe vehicle movements shall be applied; for example, block working.

11.1 Requirements for a track circuit actuator

The track circuit actuator antenna shall be fitted to the leading bogie of a vehicle. Where a vehicle can be operated from another end, a TCA antenna shall be fitted to all leading bogies. The fitment of the antenna shall be certified in all mechanical (installation and mounting) and electrical (operating) respects.

The TCA shall be type approved.

The transmitter shall have a health monitoring circuit which is indicated to the operator so that in the case of a failed system, it becomes a known fault.

The health monitoring system shall be of a fail-safe design.

The TCA system when installed and commissioned shall be certified by tests to ensure that it is functioning correctly.

The TCA shall be regularly inspected and maintained. The rolling stock operator shall determine the necessary maintenance and inspection intervals.

Before a vehicle fitted with a TCA is allowed onto the TfNSW Metropolitan Heavy Rail Network, all TCA systems shall be proven to be operating. This proof shall consist either of confirmation of no TCA fault indicated on the operator’s control panel or confirmation by visual inspection of no fault indications on the transmitter unit itself.

11.2 In service failures of the TCA

Prior to accepting a vehicle fitted with one or more TCAs, a risk assessment shall be conducted to consider the operational risk of operating the vehicle in the event that a TCA fails while in service. The risk assessment shall consider the likelihood of a loss of train detection and the protection of the vehicle from trains that follow.

The determination of the risk assessment shall form part of the vehicle acceptance criteria. The determination shall clearly state the operational procedure to be followed if there is a failure of one or more of the onboard TCA systems.

12 Train braking requirements

All trains operating on the TfNSW Metropolitan Heavy Rail Network shall have a combination of braking performance and maximum operating speeds which permit them to stop safely in the warning distances provided by the installed signalling infrastructure.

Train braking performance of a complete consist, operating at up to its permitted maximum speed at a site, shall equal or better the braking distances provided through the signal aspects.

Freight rolling stock operating on lines designated for freight or mixed traffic shall have braking performance which meets or exceeds that defined by the GW 16 braking curve at all speeds up to 115 km/h under full service braking conditions. T HR RS 00830 ST.

Service braking of passenger rolling stock that operates on passenger-only lines shall have braking performance which meets the GE 62 braking curve at speeds up to 115 km/h, and the XPT braking curves (GX4M) between 115 km/h and 160 km/h.

Passenger rolling stock fitted with trip gear for emergency trainstop operation shall have emergency trip braking performance that exceeds the GE 52 A braking curve by 15% at speeds up to 130 km/h.

All new passenger rolling stock shall have an emergency braking performance which is 15% better than the GE 52 A braking curve.

The braking performance of all new passenger rolling stock is detailed in T HR RS 00600 ST.

A consist whose braking distances does not meet those in the GW 16 curve, may be approved for operation subject to conditions to ensure that its performance will match the infrastructure.

The configuration of an approved consist shall be maintained by the rail transport operator within a range such that its braking distance, acceleration and attainable speed performance do not vary by more than 10% above those of the configuration submitted for approval. Variations in configuration include changes to train length, gross mass and the number and power of locomotives.

Further details on how the braking curves are applied to the signalling system can be found in T HR SC 10003 ST and T HR SC 10004 ST.

12.1 Train braking proof of compliance

The rolling stock supplier or operator shall, by provision of empirical test data or other means, satisfy the AMB that any new rolling stock unit or consist has been demonstrated to comply with the required braking, or that suitable restrictions are in place to ensure that the infrastructure braking limits are not exceeded.

12.2 Train braking discussion

There is a risk to the signalling system when operating trains of markedly different acceleration, speed and braking performance whose design needs to be optimised for one type of traffic.

Risk factors here are of the following two types:

- safety risk, where a train whose combined mass, speed and braking capacity make it incapable of braking to a stop before encountering an obstruction presumably protected by the signalling system, may be permitted to enter the system
- commercial risk, where poorly-braked trains have to operate under speed restrictions which make their operation uneconomic, or could even result in delays to other services sharing the corridor.

The signalling infrastructure, augmented by some local speed restrictions which have been imposed on particular train types, is generally capable of managing trains whose braking meets or exceeds the GW 16 braking curve at the permitted line speed. The GW 16 braking curve is adopted as the standard against which all new services are evaluated.

Where a rail transport operator proposes to introduce significantly longer and heavier trains on the TfNSW Metropolitan Heavy Rail Network with longer braking distances, this may require improving signal warning distances or imposing operating speed limits to meet an increased braking requirement. The potential costs incurred will become part of the commercial considerations in deciding whether to introduce the proposed service.

With long, heavy trains, the addition of more locomotives has very little effect on the train's braking capacity. In contrast, providing extra horsepower, whether by more powerful or additional locomotives, will improve the speed capability to the point where the train will be unable to brake safely. Where a particular consist has been assessed and approved for operation, its braking and speed capabilities should be maintained within close limits.

13 Facing points and wheel geometry requirement

The safe movement of trains over facing points shall be guaranteed by the rolling stock supplier or operator by ensuring that all vehicles comply with the requirements of RSU 212 in T HR RS 00200 ST.

13.1 Facing points and wheel geometry proof of compliance

Proof of compliance for facing points and wheel geometry is specified in RSU 212 in T HR RS 00200 ST.

13.2 Facing points and wheel geometry discussion

A critical factor in the safe operation of trains is their ability to pass safely through sets of points. At facing points, the combination of wheel flange dimensions, points blade design and points adjustment and detection ensure that wheels will follow the intended straight or diverging path, without 'splitting' the points or derailing.

Signalling maintenance procedures ensure that the correct points geometry is maintained; compliance with RSU 212 of T HR RS 00200 ST is to ensure that compatible flange dimensions are maintained.

14 Automatic train protection

Both trackside electromechanical trainstops with associated trip gear on the train and automatic train protection (ATP) are in operational use. The European train control system (ETCS) level 1 form of ATP is being phased into operation. The first operational ETCS level 1 installation was commissioned in the first half of 2019.

Fitment of trainstops, trip gear and ETCS is required as set out in Section 14.1 to Section 14.2.4.

14.1 Trainstops and trip gear requirements

Trainstops are provided in the metropolitan area between Emu Plains, Hawkesbury River, Bombaderry and Macarthur as well as Fassifern to Newcastle. Some high-risk locations outside of these areas also have trainstops installed.

Train-borne trip gear shall be fitted to each end (front and rear) of every passenger train on the left hand side in the direction of travel. Train-borne trip gear shall be designed and located at the front of the car (driver's cab) to engage reliably with ground-mounted trainstops. Details on the positioning of the trip gear can be found in T HR RS 00100 ST.

Ground-mounted trainstops are installed in accordance with SPG 0706.

Trains shall be able to withstand the effects of back tripping without brake application at speeds up to 25 km/h.

Trainstop arms have been tested and assessed to withstand the forces incurred in a trip event at speeds up to 140 km/h, using trip arms that are approved and fitted to the existing fleet.

Trains operating at speeds above 140 km/h and striking a raised trainstop arm have the potential to generate impact forces which could lead to the fracture of the arm or the arm face.

The impact forces on the arm or arm face of the trainstop shall be taken into account prior to the introduction of trains fitted with new trip gear designs (the train-borne trip valve) or where it is intended to operate trains at speeds greater than 140 km/h.

14.1.1 Trainstops and trip gear proof of compliance

The rolling stock supplier or operator shall provide details of the design and operation of the trip gear equipment to be provided on the proposed rolling stock, for approval by the AMB. Refer to T MU MD 00005 GU for information on type approval of products.

14.1.2 Trainstops and trip gear discussion

Mainly in areas of dense traffic, signalling system design is dependent on a measure of enforcement of trains stopping at signals and of staying below set speed limits at certain locations.

Any new rolling stock shall be equipped with the interface and control equipment to enable those enforcement functions to be effective to maintain system safety.

In sidings and other low speed routes, some trainstops may not be suppressed for signalled moves in the opposite direction.

Where this occurs, the back face of the trailing train mounted trip valve can strike the back of the trainstop arm, with the ensuing motion causing a false operation of the trip gear and the application of the brakes. This is known as back tripping.

14.1.3 Speedometer accuracy

Trains shall be fitted with accurate speedometers to permit drivers to control train speeds, in particular at timing points located throughout the system where approach speeds are between 5 km/h and 25 km/h.

The requirements for speedometer accuracy are detailed in RSU 350 of T HR RS 00300 ST for locomotives and in RSU 650 of T HR RS 00600 ST for multiple units.

14.2 European train control system

ETCS level 1 limited supervision (LS) mode trackside infrastructure is being installed in the TfNSW Metropolitan Heavy Rail Network. Planning for implementation of ETCS level 2 has commenced.

The ETCS installations comply with EU TSI relating to the CCS available on the EU Agency for Railways website. Some tailoring to European requirements are defined in T HR SC 01610 SP and T HR SC 01650 SP as described in Section 14.2.1 and Section 14.2.2.

14.2.1 ETCS trackside implementation in the TfNSW Metropolitan Heavy Rail Network

ETCS trackside equipment shall comply with T HR SC 01610 SP.

14.2.1.1 Current baseline

Trackside installations currently implement European Commission Decision 2015/14 amending Decision 2012/88/EU on the TSI relating to the control-command and signalling subsystems of the trans-European rail system. Set of specifications #2 (ETCS baseline 3 and GSM-R baseline 0) are applied. This is commonly known as ETCS baseline 3 Maintenance Release 1 (ETCS B3 MR1).

> Note: European Commission Regulation 2016/919 using set of specifications #2 (ETCS baseline 3 Maintenance Release 1 and GSM-R baseline 1) is accepted as equivalent for the ETCS level 1 implementation for level 1. This is also commonly known as ETCS baseline 3 Maintenance Release 1 (ETCS B3 MR1).

14.2.1.2 Previous baselines in use

No previous ETCS baselines are in operational use.

14.2.1.3 Specific trackside application

The trackside application design shall be in accordance with T HR SC 10031 ST. Train performance allowances and the supported static speed profiles are defined in that principle.

Level 2 is not yet implemented.

The trackside subsystem does not use Euroloop or radio in-fill.

The 'track condition station platforms' shall be implemented as needed to meet the selective door operation requirements defined in T HR RS 04001 ST. Packet 44 with a NID_XUSER value of 103 is being used for SDO. The packet contents are based on packet 69. SDO balises are not linked.

> Note: The use of packet 44 has been accepted for initial implementation based on project requirements. In the medium term it is expected that the trackside arrangement will not use packet 44.

Table 1 lists the ETCS levels not planned for implementation by the trackside subsystem that have a direct impact on onboard subsystem fitout design for a train.

Table 1 - List of unused ETCS levels

Unused levels
Level national train control (NTC)
Level 3

Table 2 lists the ETCS modes not planned for implementation by the trackside subsystem that have a direct impact on onboard subsystem fitout design for a train.

Table 2 – List of unused ETCS modes

Unused modes
Passive shunting (PS)
Reversing (RV)
National system (SN)

Table 3 lists the level 1 track to train packets not planned for implementation by the trackside subsystem that have a direct impact on onboard subsystem fitout design for a train.

Table 3 – List of unused ETCS level 1 track to train packets

Unused packet number	Unused packet name
13	Staff responsible distance information from loop
39	Track condition change of traction system
40	Track condition change of allowed current consumption
51	Axle load speed profile
68	Track condition
70	Route suitability data
71	Adhesion factor
76	Packet for sending fixed text messages
79	Geographical position information
133	Radio infill area information
134	EOLM packet
135	Stop Shunting on desk opening
138	Reversing area information
139	Reversing supervision information
143	Session management with neighbouring radio infill unit

All ETCS levels, modes and packets that are not listed in Table 1, Table 2 or Table 3 as unused may be implemented. When this occurs they shall be supported by the ETCS onboard subsystem when ETCS is fitted as part of new rolling stock procurement.

> Note: Unused levels, modes, packets and functionality provided by ETCS may be included in future trackside applications to meet business requirements.

A register of ETCS trackside subsystem implementation concessions, nonconformances and type approval conditions will be maintained for use in compatibility assessments.

14.2.1.4 Specific trackside to onboard deviations for ETCS baseline

For trackside installation to comply with the rules defined in Subset 040 paragraph 4.1.1.3, paragraph 4.1.1.5 and paragraph 4.1.2.2, the existing infrastructure will require alterations. Alterations should be made on a life cycle costing basis.

14.2.1.5 Balise installation relative to next train detection location

The installation rules for balises comply with Subset 040 with the following tailoring for TfNSW application to the installation rules for balises:

Rule 4.1.1.5:

The last switchable balise reference mark is at least 5.0 m in the rear of the location where the train could be detected for the next section. This is based on the tailoring for TfNSW application to rule 4.1.2.2. The tailored rule is defined in Section 14.2.2 of this document.

14.2.1.6 Balise installation relative to guard rails

Where installation of balises relative to guard rails have implemented arrangements that don't fully comply with Subset 036,a specific trackside guard rail compatibility test is required for the onboard equipment. This test is detailed in Section 14.2.2.

14.2.2 ETCS onboard requirements

All new rolling stock types for passenger services shall comply with T HR SC 01650 SP. The specific ETCS baseline for new or altered ETCS onboard installations is defined in T HR SC 01650 SP.

The ETCS onboard subsystem shall be compatible with the current and previous ETCS trackside baselines as implemented in the TfNSW Metropolitan Heavy Rail Network. Details are provided in Section 14.2.1.

The ETCS train category determines which speed profile provided by the ETCS trackside subsystem is selected by the train's ETCS onboard subsystem. TS TOC 1 identifies groups of train types that are associated with particular types of track speed signs. Train categories are aligned with these groups.

The trackside subsystem supports the two cant deficiency train categories. The supported cant deficiency train categories are NC_CDTRAIN = 1 and NC_CDTRAIN = 2. The NC_CDTRAIN value of '1' selects a static speed profile based on the medium track speed signs detailed in TS TOC 1 Train Operating Conditions (TOC) Manual – General Instructions. The NC_CDTRAIN value of '2' selects a static speed profile based on the high track speed signs detailed in TS TOC 1.

Passenger trains shall have a NC_TRAIN binary value of '000 0000 0000 0100'.

The basic static speed profile is based on the general track speed signs detailed in TS TOC 1 and is provided by the trackside subsystem for trains that do not match either cant deficiency train category.

Allocation of the ETCS train category for compatibility with the trackside static speed profiles shall also take into account interoperability on other rail networks that may be fitted with ETCS in the future.

ESC 210 sets the track requirements for permanent track speeds.

T HR RS 00100 ST sets the train requirements for operating speed allocation via Track interface – RSU 120.

ETCS speed profiles and train categories based on cant deficiency do not have options for the cant deficiency parameters used in the TfNSW Metropolitan Heavy Rail Network.

Operation of ETCS fitted trains from other networks on the TfNSW Metropolitan Heavy Rail Network shall take into account compatibility of the ETCS train category with the trackside static speed profiles for safe operation.

A register of ETCS onboard subsystem implementation concessions, nonconformances and type approval conditions shall be maintained for use in compatibility assessments.

14.2.2.1 Specific onboard to trackside deviations for ETCS baseline

14.2.2.1.1 Eurobalise antenna mounting location

The eurobalise antenna reference mark mounting location shall comply with Subset 040 with the following tailoring to rules for TfNSW application for the eurobalise antenna:

Subset-040 Rule 4.1.2.2:

In the first dot point, increase the minimum 2 m from the coupling face of the vehicle to at least 5 m for the primary eurobalise antenna position for level 1 operation.

In the second dot point, reduce the maximum 12.5 m in the rear of the first axle to 3.7 m.

The first dot point tailoring is to allow for existing operational stopping points at the end of a platform that do not comply with rule 4.1.1.3 of Subset 040. Use of a eurobalise antenna mounted between 2 m and 5 m from the coupling face in level 1 either requires change to the trackside infrastructure or acceptance of the potential operational impacts. Alterations are managed on a life cycle costing basis.

> Note: The tailoring to the first dot point only applies to the primary eurobalise antenna position. Fitment of a secondary eurobalise antenna should consider the operational impact of the antenna mounting location.

The tailoring of the second dot point is based on midpoint mounting not being required because individual locomotives are not being fitted currently. The distance change permits rule 4.1.1.5 of Subset 040 to be tailored to suit the existing trackside infrastructure. The tailored rule is defined in Section 14.2.1 of this document.

14.2.2.2 GSM-R frequency band

ETCS level 2 will use the DTRS which implements GSM-R in the 1800 MHz band instead of the 900 MHz band used in Europe.

14.2.2.3 Specific onboard to trackside compatibility tests

14.2.2.3.1 Non-ETCS trackside equipment

Balise transmission and odometry radar equipment have been tested for compatibility with the existing non-ETCS trackside equipment. Whether there is a requirement to perform additional specific compatibility testing will be determined as part of the type approval of new types of ETCS onboard equipment.

14.2.2.3.2 Trackside guard rail

Testing of onboard balise transmission compatibility with a noncompliant guard rail solution is required. The laboratory test is a modified onboard equipment test based on Subset 085 for guard rails cross-talk test condition as modified as follows:

- Section 5.2.2.2.3 of Subset-085
  - use test conditions as defined in B5.3.2 of Annex B modified by simulation of insulated rail joints instead of the air gap
  - test for reduced size, longitudinally mounted only with no metallic plane or steel sleepers underneath the reference loop.
- Section 5.2.9 of Subset-085
  - perform guard rails cross-talk tests in accordance with the modified Section 5.2.2.2.3 only
  - test procedure and acceptance criteria for cross-talk immunity remain unchanged
  - provide cross-talk margins for both the standard and modified B5.3.2 arrangements.

A field test may be required where there is a significant reduction in cross-talk margins.

14.2.2.3.3 Electromagnetic compatibility

ETCS onboard equipment shall have demonstrated EMC as required by ETCS baseline and GSM-R baseline. In addition, evidence of compliance with the following shall be provided as follows:

- Conducted interference (as root mean square current) from the onboard ETCS equipment onto the train power supply shall be less than one third (⅓) of the maximum permissible rail current defined in Figure 1 and Table 4 for frequencies between 40 Hz and 3000 Hz. The type test for conducted interference shall include common mode current, differential mode current and transient conditions. Transients include power on, power off and automated self-tests of the equipment that can cause interference. Exceedances of up to three times for less than 200 ms duration are permitted during power on and power off transients.

- Confirmation that ETCS equipment that fits the definition of radio transmitters (other than GSM-R equipment) is compliant with *Radiocommunications (Low Interference Potential Devices) Class Licence 2015*.

14.2.2.3.4 Balise reading and electrical traction

Train type tests shall be conducted and analysed to demonstrate that the RAMS requirements in Subset 036 are met under all conditions encountered in normal operations on the TfNSW Metropolitan Heavy Rail Network. The train type tests shall include balise reading tests on the network. The train paths selected for the balise reading tests shall include locations representative of typical EMI due to pantograph interaction with section insulators, open overlaps in the contact wire, maximum traction supply current events and equipment mounted between the rails that produce a magnetic field.

Note: The train type tests are to focus on confirming compliance with the recommendations in Section 4.4.4 of Subset-036 and the related Section 4.2.8.2 requirements will be met when the train is operating on the TfNSW Metropolitan Heavy Rail Network.

14.2.3 ETCS certification

The certification requirements for the use of ETCS subsystems in the TfNSW Metropolitan Heavy Rail Network are defined in the specification that applies to the subsystem.

Trackside ETCS subsystem certification is detailed in T HR SC 01610 SP.

Onboard ETCS subsystem certification is detailed in T HR SC 01650 SP.

14.2.4 ETCS discussion

TfNSW has adopted ETCS as its ATP system for heavy rail.

ETCS is the mandated ATP system for significant rail lines in Europe. ETCS standards and specifications are controlled by the EU Agency for Railways (formerly known as the European Railway Agency). Compliant products are produced by a number of suppliers. Interoperability between different products is verified at specific interfaces. Not all interfaces are interoperable or compatible. The EU has set a process for assuring compliance for ETCS products and implementations. This process includes the use of notified bodies to assess a manufacturer's conformity to the essential requirements listed in a directive.

Specifications, standards and documentation for ETCS are available from the EU Agency for Railways website, www.era.europa.eu. The documents are found under Activities, European Rail Traffic Management System.

The ETCS system includes a trackside subsystem and onboard subsystem. Responsibility for both the trackside and onboard subsystems rest with the signals and control systems discipline.

15 Signal sighting

Drivers and observers in cabs shall have uninterrupted vision for sighting of signals that are mounted in and about the railway corridor. T HR RS 00100 ST provides further details of this requirement which shall be met.

16 Traction return requirements

The maximum traction current drawn from the traction system shall be limited to that described in T HR EL 90003 ST.

The traction negative cabling on board a train shall be designed to allow full rated load current to be evenly distributed over all wheels so that the current is evenly distributed into both rails.

16.1 Traction return proof of compliance

The rolling stock supplier or operator shall be able to demonstrate by design, equipment specification and field tests if required, that the power rating of the train does not exceed specified limits.

The rolling stock supplier or operator shall be able to demonstrate by both design and equipment specification that the cabling and connection to axle are rated to carry the full expected designed load.

16.2 Traction return discussion

The traction return system is rated according to established known load profiles and therefore has finite limits. The capacity of the TfNSW Metropolitan Heavy Rail Network is currently under review as a result of the steadily increasing load on the network.

In areas designated as light traction, the traction return system is rated at 1000 A dc/rail continuous. Light traction areas can be typified by low to medium traffic density with no significant grades.

In heavy traction areas, the rating of the traction system is 2000 A dc/rail continuous.

Provision has been made in the design of the traction return system for the temporary overloading of the system without damage, provided that there is sufficient cool-down time between peak overloads.

In order to limit the potential difference between rail and earth, regular connections exist between tracks essentially paralleling the rails, with the net effect of reducing the overall resistance of the traction return system. With the additional tracks sharing a proportional amount of traction return current, overall system load can be increased without exceeding the specific ratings of the equipment.

Single and double rail track circuits are used in the TfNSW Metropolitan Heavy Rail Network, which refer to the number of rails used in each track circuit to carry traction return current. Any form of electric-powered rolling stock shall be so configured so that an effective electrical circuit is always maintained with the rail or rails enabled to carry traction return current.

17 Electromagnetic compatibility requirement

Trains shall not generate any form of electromagnetic interference that could interfere with the safe and reliable operation of the signalling system.

Trains shall comply with:

- EN 50121-3-1
- EN 50121-3-2.

17.1 Electromagnetic compatibility discussion

Current signalling systems are based, to an increasing degree, on microprocessors, data communications and other sensitive electronics, whose operation can be affected by electromagnetic interference. A majority of these systems predate the EMC requirements that are detailed in the EN 50121 series of specifications, so their compliance to these requirements has not been assessed.

For older analogue-based systems, their susceptibility to electromagnetic interference is even more notable.

Systems which could be susceptible include train detection systems, vehicle identification systems and transmission-based train control and signalling systems.

Potential issues include the following:

- false energisation of track circuit relays on the track that the train is operating on
- false energisation of track circuit relays on adjacent tracks
- intermittent failure of track circuits on which either the train is operating on or adjacent to
- lock out or failure of processor-based track circuits and other signalling equipment
- interlocking system shutdowns or resets due to induced or capacitive-coupled EMI.

17.2 Electromagnetic compatibility proof of compliance

The rolling stock supplier or operator shall provide evidence of testing carried out to measure the emitted electromagnetic characteristics of any new or modified rolling stock.

18 Traction system compatibility requirements

Traction system compatibility is based on the existing 1500 V dc traction power system and trackside signalling system. Using other traction power systems requires the development and implementation of compatibility requirements for that traction power system.

Trains shall not provide any means for the generation or injection into the running rails of any electrical voltage or current that can interfere with the safe and reliable operation of all forms of signalling equipment and specifically train detection systems. This requirement applies equally to currents or voltages generated by the rolling stock itself, for example traction power units or auxiliary power supplies, or to components of the traction supply finding a low-impedance path to the traction return system.

Consideration shall be given to the wiring layout within the train to eliminate the effects of electrostatic, capacitive, inductive and conductive coupling between each circuit and the frame of the train.

18.1 Acceptable in-rail currents at signalling frequencies

Figure 1 details the signalling noise compatibility diagram. This diagram details the acceptable levels of in-rail interference currents over the frequency spectrum which is used by the installed track circuits.

ERA/ERTMS/033281 details interference limits for axle counters.

Figure 1 has been applied to testing of previously supplied electric passenger rolling stock.

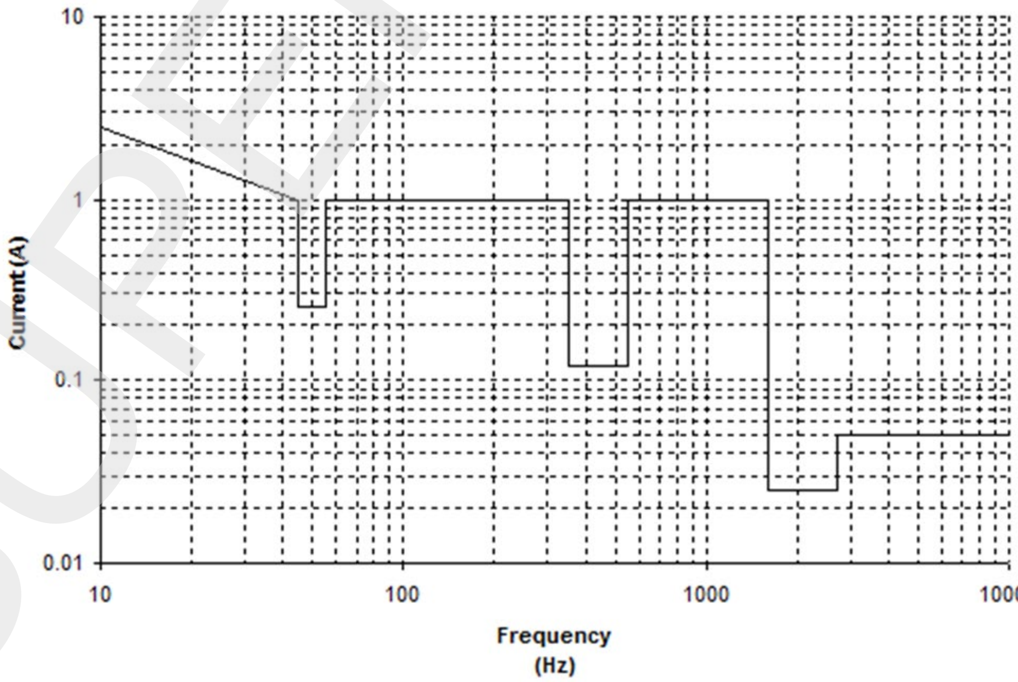


Figure 1 – Envelope of maximum permissible rail current as a function of frequency for signalling system compatibility

Table 4 provides the data set for Figure 1.

Table 4 – Data set for Figure 1

Frequency (Hz) of rail current	Maximum permitted rail current (A)
10	2.5
20	1.8
30	1.4
40	1.1
45 to 55	0.25
55 to 350	1.0
350 to 550	0.12
550 to 1600	1.0
1600 to 2700	0.025
2700 to 10000	0.05

New rolling stock that meets Figure 1 under all operating conditions is unlikely to cause interference to the signalling system; however the AMB does not assure that a train which meets this curve will not cause interference.

The train supplier is responsible for ensuring that the rolling stock is fully compatible with the TfNSW Metropolitan Heavy Rail Network signalling system under all train operating modes.

18.2 Specification for close-up effects

Close-up effects result from large inductive sources such as traction motors inducing a small voltage onto an axle. Electrical currents can flow as a consequence of axles and rails forming a low impedance circuit.

Typically the magnitudes of close-up effect currents are close to that of a track circuit clear signal. As a general rule, track circuits are not affected by close-up effect currents as the rail-to-rail voltage is very small. However, DPU coils are easily influenced by these currents and can, if the harmonic content emulates that of a track circuit transmitter, falsely energise a DPU-fed receiver.

To define acceptable criteria for the close-up effect in the audio frequency part of the spectrum the following shall apply:

- permitted levels of interfering frequencies and their magnitudes as specified in Figure 2
- for rail currents above 50 mA, no modulated harmonics shall be recorded around the following frequencies:
  - 1700 Hz ±100 Hz (200 Hz bandwidth)
  - 2000 Hz ±100 Hz (200 Hz bandwidth)

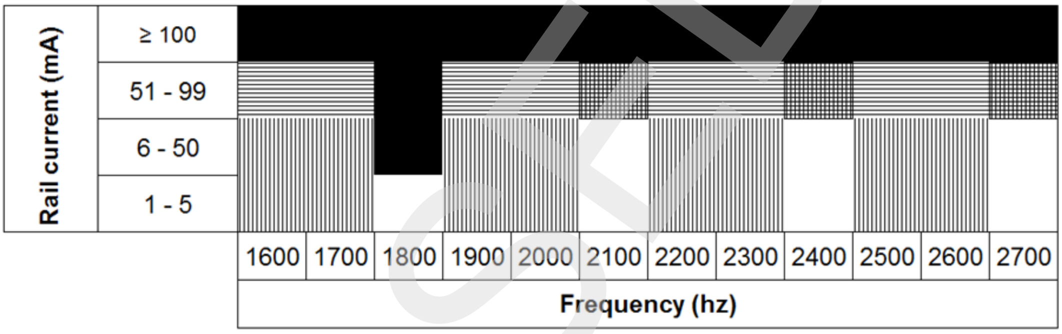
- 2300 Hz ±100 Hz (200 Hz bandwidth)
- 2600 Hz ±100 Hz (200 Hz bandwidth)

- harmonic currents in the range of 1820 Hz to 1870 Hz shall be no greater than 5 mA
- harmonics shall not be permitted for rail currents above 100 mA
- rail-to-rail volts shall be no greater than 30 mV.

For rail currents below 50 mA, harmonics may be permitted

For rail currents below 50 mA, harmonics shall not be modulated.

Note: Modulated harmonics are defined as those currents having a symmetrical upper and lower frequency component based around a real or imaginary centre frequency.



KEY

Pattern	Permitted close-up effect currents
Solid	No harmonics are permitted in this part of the spectrum except for traction supply harmonics at 1800 Hz and so forth
Cross hatch	On the provision they are not modulated, close-up effect currents may be permitted following a review
Horizontal	Close-up effect currents may be permitted following a review. No modulated effects permitted
Clear	Close-up effect currents permitted
Vertical	Close-up effect currents permitted. No modulated effects permitted

Figure 2 – Rail current versus frequency – permitted close-up effect currents

18.3 Traction equipment software

For any item of onboard equipment connected to the traction supply which is controlled by software, any modification has the potential to affect compatibility with the signalling system. The traction equipment supplier shall have in place a method of configuration control for the traction equipment software.

When type testing has begun or once the vehicle has been certified, the traction equipment supplier shall not alter the configuration without advice to the AMB.

Any changes to the traction package software may require new signalling compatibility tests to be conducted. Where the changes do not affect the traction system, the traction equipment supplier shall be able to prove that the changes made to the system do not affect those elements of the traction package that affect signalling compatibility.

18.4 Traction system compatibility proof of compliance

The rolling stock supplier or operator shall conduct a combination of theoretical design analysis, laboratory testing of prototypes and on-site testing of production versions of the rolling stock. These tests shall demonstrate that any traction current noise components, under all conditions of normal and degraded operation including component failure, are below the interference thresholds of the track circuits and detection systems in the proposed operating corridor.

18.5 Electric rolling stock system requirements for 50 Hz line current impedance and detection

Under certain fault conditions, the traction supply system can generate 50 Hz ripple frequency. For older parts of the TfNSW Metropolitan Heavy Rail Network, 50 Hz track circuits are still in use.

For these reasons, electric rolling stock is required to limit the amount of 50 Hz ripple current flowing in the traction return system where the traction return current shares a common circuit with 50 Hz track circuits formed by the traction return rails.

18.5.1 50 Hz line input impedance

The requirements in this section represent limits that are known to be compatible with the existing signalling system. The AMB will also accept other solutions that can be demonstrated to integrate successfully into the existing railway.

The 50 Hz line input impedance of the set shall be greater than those levels specified in Table 5.

Table 5 – 50 Hz line input impedance limits

Set configuration	Minimum impedance at 50 Hz
4 car set, 2 pantographs, 4 motored bogies	1 ohm
8 car set, 4 pantographs, 8 motored bogies	0.5 ohm
Other set configurations	0.5 ohm

The impedance figure shall be maintained when the set is unloaded, loaded and for any other value of conduction ratio of the traction inverter equipment.

18.5.2 50 Hz detection system

Electric rolling stock shall have a means of protecting track circuits from line ripple in the traction supply current or that which is being produced by train-borne equipment.

A 50 Hz line current detector shall be provided to isolate the relevant equipment whenever excess 50 Hz line ripple current is detected.

The filter-charging inrush current of electrical equipment shall not generate 50 Hz harmonics capable of affecting TfNSW track circuits.

Requirements of 50 Hz detection and protection are shown in Table 6.

Table 6 – 50 Hz detection and protection requirements

Detection	Level	Time
Detection system threshold level	5.5 A	2.0 seconds
Detection system operating bandwidth	47 Hz to 53 Hz	N/A

Triggering of the 50 Hz line ripple current detection system shall be logged by the rolling stock management system and reported to the driver.

The 50 Hz line current detector shall have a test function that provides a positive indication of correct operation.

Alternative solutions proposed will need to demonstrate and assure that the same function is adequately performed.

18.6 Traction system compatibility discussion

Signalling track circuits share the running rails with the electric traction return currents. Track circuits operate at currents and voltages generally less than 1 A and 3 V. In contrast, the traction system operates at a nominal supply voltage of 1500 V dc, at currents up to 6000 A. Even a very small portion (one-tenth of one percent) of the traction current is of the same order of magnitude as the track circuit current; tight control of traction noise levels is crucial to ensuring the continued safe and reliable operation of the signalling system.

19 Rolling stock approval process

The requirements in this section detail the necessary steps to approve new or modified rolling stock to operate on the TfNSW Metropolitan Heavy Rail Network. The rolling stock approval process is illustrated in Figure 3 and has been modelled from the approval process detailed in EN 50238; however due to differences between the European and TfNSW organisational structures, the approval process is tailored as outlined in this section.

Prior to allowing any new or modified rolling stock to operate on the TfNSW Metropolitan Heavy Rail Network, a compatibility case shall be provided which provides the necessary evidence that the vehicle can be safely and reliably operated on the network.

The rolling stock owner, operator or manufacturer shall engage an AEO to be accountable for assuring a vehicle's compatibility to operate on the TfNSW Metropolitan Heavy Rail Network and compliance to this standard. If the engaged AEO does not have the necessary skill set for the testing and evaluation of a vehicle, the AEO may subcontract the planning, testing and evaluation to a specialised test agency. Where this occurs, the parent AEO shall still be accountable for providing the assurance of a vehicle's compatibility and compliance.

Where the testing of rolling stock is being conducted on the TfNSW Metropolitan Heavy Rail Network, a licensed signal engineer shall be engaged to allow access and connection to the operational signalling system. Where the licensed signal engineer is not directly employed by the RIM, access to the signalling system shall be arranged through the RIM's permit to work process.

Where testing is required to be conducted using a private siding or manufacturer’s test track, a licensed signal engineer is not required unless needed for track circuit set-up and support.

When compiling the test plan, if the vehicle under test has been approved for operation in other comparable railways, it may be possible to have some aspects of the vehicle cross-accepted. The test agency shall compile all necessary information in order to create a compatibility case, based on the results of tests from other rail agencies.

The test agency shall perform a detailed review of each vehicle under test so that a comprehensive test plan can be compiled to provide proof of compatibility covering the vehicle's design and all operating characteristics.

The test plan shall be submitted to the Director Signals & Control Systems Engineering, AMB for endorsement.

Note: The intention of this step is to try and identify any shortcomings that may be in the test plan, thus avoiding the need for a further iteration of tests.

Where tests are required to be conducted on the TfNSW Metropolitan Heavy Rail Network, the test plan shall also nominate test sites and the proposed test track circuits along with test equipment connection details. This will aid in obtaining a permit to work from the RIM.

The test agency shall be responsible for the engagement of a suitably qualified licensed signal engineer and for organising the permit to work.

The test agency shall be responsible for the organising of any necessary possession/s needed for testing on the TfNSW Metropolitan Heavy Rail Network.

Depending on the complexity of the test plan, the test agency may need to have the body of work peer reviewed. For simple test cases where the outcome is clear and not in contention, the peer review is an optional step; however for more complex vehicle types or larger scale contracts, the peer review shall form part of the safety assurance in the approval process. The peer review is to obtain an assurance that the test plan has comprehensively tested the vehicle in all modes of operation; that the tests were executed properly; and that the results obtained from those tests have been interpreted correctly. Further, that any identified noncompliance has been properly managed through the concession process.

The test agency shall submit a formal compatibility case to the AMB that clearly demonstrates compliance to the requirements detailed in this standard, with a recommendation for operation. Depending on the outcome of the test results, the recommendation shall be one stating a full compliance, a temporary approval or a restricted approval. The latter two recommendations shall also detail any necessary operating restrictions. Restricted recommendations for operation shall also take into account complexity, as complex operating conditions may be unworkable and unacceptable to the TfNSW Metropolitan Heavy Rail Network controllers.

The AMB will review this report and obtain an agreement with the RIM that the findings of the report and recommendations are acceptable.

On the provision that the report and recommendations are accepted, the AMB will compile a train operating conditions waiver.

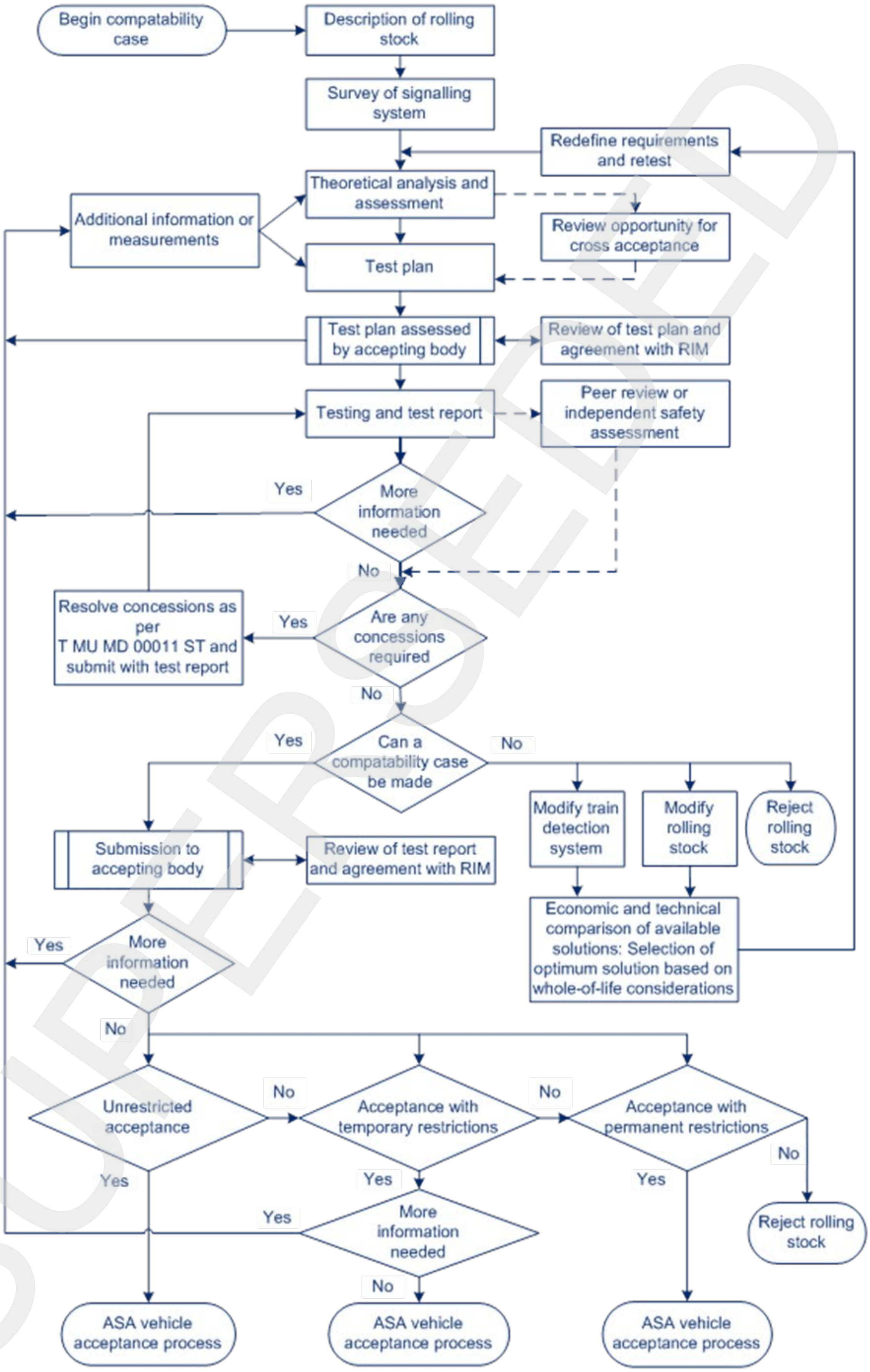


Figure 3 – Rolling stock approval process

19.1 AEO utilisation

AEOs that have been authorised to perform the testing and approving of any new or modified rolling stock shall have systems engineering in their scope of services, with additional notes added to further define their range of capabilities in this particular field of expertise.

An AEO may subcontract the planning, testing, evaluation and approval phases of a test programme to a specialised test agency which may not be authorised as an AEO.

Where the test agency is not an AEO, the test agency shall adhere to the AMB authorised process and procedural framework of the parent AEO. The parent AEO shall be responsible for providing the overall assurance of the work being undertaken.

The AEO and the test agency shall have joint responsibility for the compliance testing to this standard and the compilation of the compatibility case. The parent AEO provides the assurance of vehicle compatibility to operate on the TfNSW Metropolitan Heavy Rail Network.

19.1.1 AEO test agency required qualifications

Test agencies for this work shall have a comprehensive understanding on the operational characteristics of the diverse range of track circuits installed on the TfNSW Metropolitan Heavy Rail Network. They shall also have experience in the following:

- identifying test equipment appropriate for the proposed tests
- the setting up and conducting of tests in the rail corridor
- technical understanding of rolling stock traction systems
- capability to evaluate results and equate these to compliance to this standard and others
- an understanding of the hazards that the new or modified rolling stock presents to the safe and reliable operation of the TfNSW Metropolitan Heavy Rail Network.

Experience in the testing of axle counters may need to be considered but is dependent on the scope of the test program.

19.2 Roles and responsibilities

The testing of rolling stock involves the following diverse range of groups within industry:

- rolling stock owners, operators or manufacturer (including traction equipment suppliers)
- test agency
- RIM
- the AMB acting as the approving body.

For this reason, it is necessary to support the test program by identifying roles and responsibilities in the planning, testing and approval process.

Section 19.2.1 to Section 19.2.5 is based on EN 50238-1; however it has been tailored to suit TfNSW.

19.2.1 Rolling stock owner, operator or manufacturer

The rolling stock owner, operator or manufacturer (including the traction equipment supplier) shall support the test program by providing a properly configured vehicle that is ready for testing. This infers a vehicle built to specification that meets the vehicle performance requirements and has addressed the requirements detailed in this and other applicable standards. Additionally, the rolling stock owner, operator or manufacturer shall provide the required crew to operate the vehicle during the testing. As vehicle testing can take place at numerous locations on the TfNSW Metropolitan Heavy Rail Network, the road knowledge of the operators should be reviewed.

During the planning phase, the rolling stock operator should also arrange the necessary possessions for on-track testing as well as the required work site protection officers.

Once testing has begun, no changes shall be made to the traction system unless this is done in full consultation with the AEO or the subcontracted test agency.

19.2.2 Test agency accountabilities

The test agency is wholly responsible for the testing and certification of the vehicle under test and providing the assurance of a vehicle's compatibility to operate on the TfNSW Metropolitan Heavy Rail Network. The AEO or the subcontracted test agency shall be responsible for the following:

- conduct a detailed review of the vehicle and its operating characteristics
- conduct a survey of the signalling system to identify the scope of tests required to satisfy the compatibility case
- detail the test plan and test locations
- coordinate the various bodies needed to conduct these tests
- provide the test equipment
- execute the tests as necessary
- evaluate results
- identify and manage any nonconformance through the concession process
- have test results peer reviewed if and when necessary
- provide the compatibility case to the accepting body.

19.2.3 Rolling stock operator and AEO or test agency

In preparation for the request to test, the rolling stock operator and the test agency shall produce a document which details the proposed schedule of tests. This shall include the locations of test sites, the types of tests which will be conducted, the limits of possession, the details of any signalling equipment to be booked out during testing, schematic circuits for the connection of the test equipment and a risk assessment on the operation of the rolling stock for each test site and the test program overall.

Access to the TfNSW Metropolitan Heavy Rail Network shall be organised through the RIM, and the test agency shall obtain a permit to work to access the signalling equipment.

19.2.4 Railway infrastructure manager

The RIM is responsible for the operation and maintenance of the TfNSW Metropolitan Heavy Rail Network. Any rolling stock testing shall be appropriately undertaken so that the following are achieved:

- test sites are set up without impacting on train services
- test sites are set up without damage to infrastructure
- testing is executed without damage to infrastructure.

At the conclusion of testing, test sites shall be re-certified ready for the resumption of train services.

For any testing conducted on a network that is under the control of a RIM, it may be necessary to obtain a permit to work. After receiving a request from the test agency (or the licensed signal engineer), the RIM shall assess the request and if found satisfactory, issue a permit to work.

As the RIM has a role in accepting the new rolling stock on the TfNSW Metropolitan Heavy Rail Network, the AMB will also provide the RIM a copy of the test plan. The aim being to confirm that all track circuit types have been identified and that the selection of tests sites is appropriate.

As part of the approval process, the AMB will provide the RIM with a copy of the final report detailing the compatibility case and will seek their consensus on the findings of the compatibility case.

19.2.5 Accepting body

The AMB is the accepting body, which provides the final certificate of acceptance. The AMB's limit of approval extends only to the TfNSW Metropolitan Heavy Rail Network.

The AMB will grant a full acceptance, temporary acceptance or an acceptance with restrictions. The compatibility report supplied by the test agency is to provide a recommendation of one of these acceptance types along with appropriate justification.

The AMB will review the report and provide a copy to the RIM. An internal process will aim to seek a consensus on the findings of the report.

Where a consensus cannot be made, the AMB will request further information as required from the test agency.

Where a consensus can be made the Director Signals & Control Systems Engineering, AMB shall provide advice to the Director Fleet Engineering, AMB.

19.3 Managing nonconformances

When evaluating results, it may be necessary to address a nonconformance to this standard. The parent AEO or the test agency shall be responsible for the submission and management of a concession request to AMB in accordance with TS 00003.1:1.0.

19.4 Managing transient events

This standard does not cite a permitted period or duration for any test result that exceeds the limits defined in this standard.

A transient event shall be treated as a nonconformance and managed accordingly.

20 Cross-acceptance

The AMB recognises the benefit to rolling stock owners and manufacturers of cross-acceptance by accepting the results of any evidence-based approval work done by a recognised organisation. Acceptance of prior approvals shall be evidence-based, on the following criteria:

- The vehicle being offered is identical in all respects.
- The vehicle has operated on a similarly-sized rail network without incident.
- The class of track circuit being accepted is identical in all respects, for example, model number, firmware revision and so on.
- The configuration of the traction system is identical in terms of traction return (return current is via the running rails), traction supply ripple, substation impedances and so on.
- The pass or fail criteria used in the originating safety case are assessed as being identical. Where a difference exists, the opportunity to take this up with the train detection equipment supplier or manufacturer for confirmation and rationalisation of the differences can be negotiated.
- The results of tests are in a similar format; for example, units of measure are currents or voltages as nominated in this standard, and not in decibel-milliwatts. Where a difference exists, translation to the defined units of measure may be accepted on the provision that the accuracy of the results is maintained.

- The results indicate what level of interference is being impressed onto the track circuit equipment and does not just measure the electrical noise being produced by the train.
- The test results detail degraded modes of operation of the vehicle under test, for example, traction inverter modules cut-out.
- The test results detail degraded modes of track circuit operation, for example, a simulated broken rail in a double rail track.

21 Rolling stock test procedure

Section 21.1 to Section 21.5 provides details on various aspects on the testing of rolling stock.

The test AEO has licence to create the test plan and manage the test procedure as they see fit so as to obtain the desired outcome. However, the information in Section 21.1 to Section 21.5 should be considered in the development and execution of the test plan and in the evaluation of test results.

21.1 Test outcomes

As a minimum, the test plan shall establish the following:

- the vehicle under test can be safely and reliably detected by the detection system
- the vehicle under test does not cause a wrong side failure of the signalling system
- the vehicle under test does not cause a right side failure of the signalling system
- the vehicle under test does not cause a right side failure (with lock-up) of the signalling system
- the vehicle under test does not generate electrical interference which may result in one of the above failure modes
- the vehicle under test complies with the requirements of this standard.

21.2 Devising a test plan

The test agency shall devise a test plan which will ultimately provide sufficient evidence that the test outcomes in Section 21.2 have been considered and satisfactorily answered.

With the objectives of the test plan stated, the following should be considered when preparing the plan:

- type of vehicle being tested
- types of tests to be undertaken to prove compliance (see the following)
    - static test or dynamic test

  - shunt test
  - signal interference test
- track circuits the vehicle needs to be tested over
- worst-case configuration of the vehicle – tare or crush loaded
- degraded modes of operation for the vehicle; for example, reduced motoring
- worst-case for the track circuit – for example, an unbalanced track circuit
- location of the track circuits on the TfNSW Metropolitan Heavy Rail Network
- location of a suitable test site, taking into account the following:
  - position of the test site relative to the location of the nearest traction substation so as to capture all traction return currents
  - test site receptivity for regen braking
  - the possibility of noise from an adjacent track circuit masking results for example, a Tx on a jointless track circuit
- the pass or fail criteria
- design of circuit schematics
- test equipment is needed
- calibration requirements
- if TfNSW Metropolitan Heavy Rail Network access is required, and when
- formation of a test team
- is the vehicle in use in other comparable railways
- is there sufficient evidence for cross-acceptance
- what are the differences or deltas that need to be tested
- are there elements of the vehicle that can be assessed by way of a desktop audit.

In addition to the aforementioned tests, the following aspects of train design shall also be tested and confirmed as meeting specification, so as to ensure that all aspects of the vehicle are tested. Tests such as the following shall be included as applicable in any test plan:

- 50 Hz impedance tests
- 50 Hz detector tests
- testing of other noise-generating sources for example, static inverters
- acceleration and braking characteristics

- any other aspects of the vehicle that have the potential for interference to the signalling system.

21.2.1 Test team

The test team shall comprise members competent to undertake the following:

- identify suitable test sites or locations
- arrange for the necessary possessions and coordinate the planning of the possession
- set up the worksite protection for the test site
- perform any necessary booking out and isolation of signalling equipment
- connect test equipment to the working signalling system as defined by the test schematics
- execute the tests in accordance with the test plan
- manage the recording system
- maintain detailed test logs
- liaise with the operator of the vehicle.

At the conclusion of testing re-certify the signalling system once the test equipment has been disconnected and equipment has been restored.

The test team shall also be capable of evaluating and interpreting results to demonstrate compliance to this standard.

21.2.2 TfNSW Metropolitan Heavy Rail Network access

A licensed signal engineer shall be engaged to access the TfNSW Metropolitan Heavy Rail Network and work on the live signalling equipment, as would be the case when the test equipment is to be connected.

To access the TfNSW Metropolitan Heavy Rail Network, permission needs to be granted by the RIM. Permission is granted by way of a permit to work. A detailed scope shall be submitted when requesting the permit to work.

Any other relevant details that may affect the operation of the TfNSW Metropolitan Heavy Rail Network should be included in this request.

21.2.3 Vehicle test matrix

Table 7 to Table 10 provides an overview of the range of tests that should be conducted against various types of vehicles.

This list does not exclude any other tests needed to verify the compatibility of a particular aspect of the vehicle not captured in the tables below

Table 7 – Vehicle tests against possible vehicle types – vehicle design

Tests	Assessment criteria	Diesel unit no electric traction	Diesel unit dc electric traction	Diesel unit (power electronic controlled traction – ac or chopper)	EMU
Cab sighting	Meets specification	✓	✓	✓	✓
Acceleration	Meets specification	✓	✓	✓	✓
Braking	Meets minimum braking curve	✓	✓	✓	✓
Vehicle overhang	Meets specification	✓	✓	✓	✓

Table 8 – Vehicle tests against possible vehicle types – bogie design

Tests	Assessment criteria	Diesel unit no electric traction	Diesel unit dc electric traction	Diesel unit (power electronic controlled traction – ac or chopper)	EMU
Brake types	Provide detail	✓	✓	✓	✓
Trip gear	An approved type	As required	As required	As required	✓
Wheel diameter	Provide detail	✓	✓	✓	✓
Wheel profile	To an approved wheel profile – WPR 2000	✓	✓	✓	✓
Axle spacing	Provide detail	✓	✓	✓	✓
Inner axle spacing	Meets specification	✓	✓	✓	✓
Axle resistance	Meets specification	✓	✓	✓	✓
Wheel back to back	Meets specification	✓	✓	✓	✓
Sand blowers fitted	Fitted as required	✓	✓	✓	N/A
Axle loading	Meets specification	✓	✓	✓	✓

Table 9 – Vehicle tests against possible vehicle types – train detection tests

Tests	Assessment criteria	Diesel unit no electric traction	Diesel unit dc electric traction	Diesel unit (power electronic controlled traction – ac or chopper)	EMU
Shunt test	Residual volts less than prescribed in **Error! Reference source not found.**	✓	✓	✓	✓

Table 10 – Vehicle tests against possible vehicle types – signal interference

Tests	Assessment criteria	Diesel unit no electric traction	Diesel unit dc electric traction	Diesel unit (power electronic controlled traction – ac or chopper)	EMU
Signal interference testing	Meets specification	None (on the assumption there are no other electrical noise sources)	None (on the assumption that no other electrical noise sources are present)	✓	✓
Regen braking	Interference currents meet specification	N/A	✓	✓	✓
Train start up or shut down	Interference currents meet specification	N/A	N/A	N/A	✓
Degraded mode 1 for example 75% traction	Meets interference current limits	N/A	N/A	✓	✓
Degraded mode 2 for example broken rail	Meets interference current limits	N/A	N/A	✓	✓
50 Hz impedance tests	Meets specification	N/A	N/A	N/A	✓
50 Hz detector	Functions to specification	N/A	N/A	N/A	✓
Special test case	As nominated	As identified	As identified	As identified	As identified

When preparing a test plan it is important to ensure that:

- all modes of vehicle operation are tested for and;
- for each test, there shall be an assessment (pass / fail) criteria.

21.2.4 Data pick-up configurations

Table 11 details the range of DPUs in use on the TfNSW Metropolitan Heavy Rail Network and the method of interfacing to its receiver. For each configuration, any of the four base frequencies may be used.

Table 11 – Audio frequency DPU configurations

Track circuit type	QAJTC1 amplifier	TI21 amplifier	MTU	T121 DPU	CSEE DPU	WBS FS2500 DPU
CSEE T1	X	-	X	-	X	X
CSEE T2	-	-	X	-	X	-
MLTI21	X	X	-	X	X	X
FS2500	X	-	-	-	X	X

21.2.5 Managing vehicle movements

Vehicles that are not registered to operate on a network shall not rely on the signalling system for movement authorities or protection from following trains. Where this is the case, a method of manual block working shall be instituted. The basis of block working assumes that the vehicle cannot be reliably detected by the signalling system and does not address the potential for signal interference with unknown consequences.

If the test vehicle has an unknown potential to cause interference to the signalling system, then an even more restrictive practice is required. This would typically entail the test vehicle travelling in a de-energised state and hauled to each test site by an approved vehicle. Only when the section of line is protected from other trains, can the test vehicle move under its own power.

21.2.6 Possessions

A possession of the line is usually the most effective way of conducting a series of tests. When requesting a possession, the limits of the possession have to be defined. The limits of the possession shall be well away from the test site allowing sufficient distance for the vehicle to speed up and slow down without nearing the end of the possession.

When requesting the possession, permission shall be arranged to operate the test vehicle bi-directionally on the line. This offers far greater flexibility in achieving all the required tests in a block possession period.

The duration of the possession should allow for the setting up of the worksite protection, booking out and rendering safe any signalling equipment (for example, clipping points), and sufficient time to complete the required test runs.

21.3 Execution of the test plan

The execution of the test plan shall take into account the following:

- obtaining access to the signalling system through the RIM's permit to work procedure
- establish work site protection
- connection of test equipment to working circuitry
- calibration of the test site
- booking equipment out of order
- management of test vehicle while testing – adhering to appropriate safe working methods
- execution of tests – achieving test aims
- re-certification of signalling system at the conclusion of testing
- booking equipment back in.

21.4 Evaluation of test results

The evaluation of results shall:

- determine results against test objectives – whether the test achieved its aim
- determine results against pass or fail criteria
- look for any unforeseen results which could lead to a noncompliance
- manage any nonconformances to a base level for acceptance
- determine findings
- compile results into a report
- peer review test plan, tests and results.

21.4.1 Maximum permitted residual voltages

Table 12 details the maximum permitted residual voltage of a track circuit as a vehicle traverses it. Attention is also drawn to the residual voltages with a single axle occupying the track circuit.

These residual voltages shall not be exceeded for vehicle shunt tests.

Table 12 – Typical and maximum train shunt values

Track circuit type	Test point	Unit of measure	Typical value	Maximum train shunt
DC with shelf relay	relay coil	V dc	<10% of drop away test value	<30% of drop away test value
DC with plug-in relay	R1/R2	V dc	<10% of drop away test value	<30% of drop away test value
50 Hz ac	control terminals	V ac	<10% of drop away test value	<30% of drop away test value
UM 71 CSEE	receiver R1 R2	mV ac (with filter)	<30	<90
ML TI 21	input resistor (1 ohm) terminals	mV ac (with filter)	(mV x gain) <35	(mV x gain) <100
ET200	Receiver TP1&TP2	mV ac (with filter)	30% of threshold current	50% of threshold current
WBS FS2500	receiver monitor	mV ac	<135	<400
HVI Jeumont Schneider[1]	C+/C1 (RVT-600) 3/C1 (BRT-CA2)	V dc (with integrator)	<35	<100
USS Microtrax coded track circuit	slave end			
- track interface panel terminals	mV dc	<50 mV (pulse)	<80 mV (pulse)	
WBS FS2600	receiver monitor	mV ac	<100	<500

Note 1: Due to the long-time constant of the capacitors inside an integrator, the recording of voltages using this device is problematic as transient events can be missed. An alternative test point is on each of the relay coils V1+/-, V2+/ measuring VDC. Pass or fail limits have not yet been developed for this test point; however, satisfactory train shunt and interference levels can be easily seen and an assessment made from these readings.

21.4.2 Managing nonconformances

When a nonconformance is found, it is necessary to carefully evaluate the issue. This may mean understanding the mechanism generating the nonconformance, and identifying the boundaries of the noise being recorded in terms of frequency and magnitude. Other factors may include, but are not limited to, how often the event occurs and for what duration.

Once the nature of the nonconformance is understood, it can then be further evaluated. The evaluation is to quantify what impact, if any, the nonconformance has on the signalling system and if there is cause for concern, which can then be further investigated.

Investigations can include theoretical modelling and bench testing.

The nonconformance shall be thoroughly investigated to clearly establish whether it can be accepted or accepted with conditions, for example a route clearance. Otherwise it will result in the vehicle under test being rejected.

Once the nonconformance has been fully investigated, the findings are to be documented and a concession request submitted to the AMB in accordance with TS 00003.1:1.0. The approved concession shall then form part of the compatibility case.

21.4.3 Transient events

This standard does not cite a permitted period or duration for any test result that exceeds the limits defined in this standard.

This omission is deliberate, as any exceedance needs to be fully understood in the context of track circuit operation where once it has been investigated and understood, the test AEO can assess any likely impact to the safe and reliable operation of the train detection system.

A transient event, once assessed, shall be managed as a nonconformance.

21.5 Recommendations following assessment

Following the review of test reports, a recommendation will be made based on the findings of the assessment.

The recommendation for any approval shall accompany the compatibility case and detail any restrictions that should be applied to the operation of the vehicle.

Recommendations can take the form of the following:

- Incremental approvals which can be used during a large test program where a compatibility case has been established for certain types of signalling equipment while other types are still being confirmed. The benefit of these incremental approvals is that it allows a large test program greater flexibility and access in the TfNSW Metropolitan Heavy Rail Network. The incremental approvals generally take the form of route clearances.
- Final approval – unrestrictive or restrictive approval which is issued once a compatibility case has been satisfied for the complete TfNSW Metropolitan Heavy Rail Network. Restrictions may apply as identified during the compatibility case.
- Route clearances or exclusions – where the compatibility case has identified a nonconformance, a permanent route clearance may be granted where the vehicle is permitted operation over certain routes only.

After receiving a compatibility case complete with recommendations, the AMB shall review the case and, where satisfied, endorse the findings and update TS TOC 1 accordingly.

Appendix A Description of the signalling system

The following sections provide a high level description of the signalling system in the TfNSW Metropolitan Heavy Rail Network.

The signalling system in the TfNSW Metropolitan Heavy Rail Network comprises many elements including the following:

- track circuits
- points
- signals
- trainstops
- interlockings
- level crossings
- cabling
- power supplies
- surge protection
- telemetry, communications
- control systems.

A.1 Track circuits

The existing track circuits used in the TfNSW Metropolitan Heavy Rail Network are as follows:

- 50 Hz ac double and single rail
- audio frequency jointless track circuits operating at 1700 Hz, 2000 Hz, 2300 Hz and 2600 Hz
- audio frequency jointed track circuits operating at frequencies between 380 Hz and 510 Hz
- high voltage impulse track circuits.

Outside of the metropolitan area, dc and coded dc track circuits are also used.

Significant operating parameters of these track circuit types are shown in Table 13.

Table 13 – Track circuit operating parameters

Track circuit type	Frequency	Modulation	Operating track voltage	Receiver or relay minimum operation	Receiver or relay maximum drop away	Receiver or relay normal working level	Maximum track circuit length double rail	Maximum track circuit length single rail	Nominal shunt value
dc using QT1 4 Ω relay	dc	N/A	0.8 V to 1.2 V	103 mA	68% of working	146 mA	2000 m @ 1.5 ohm.km ballast resistance	N/A	0.25 Ω
dc ac immune using QTA1 9 Ω relay	dc	N/A	2 V to 5 V	120 mA	68% of working	140 mA	N/A	600 m @ 1.5 ohm.km ballast resistance	0.5 Ω
ac	50 Hz	Nil	1 V to 3 V	0.5 V	0.3 V	1.3 V	1600 m	300 m	0.06 Ω to 0.5 Ω
Audio frequency jointless	1700 Hz, 2000 Hz, 2300 Hz, 2600 Hz	Fsk ±10 Hz to 15 Hz	3 V to 5 V	200 mV	180 mV	400 mV	900 m or 2000 m (compensated)	N/A	0.15 Ω to 0.5 Ω
Audio frequency jointed	380 Hz to 510 Hz	Fsk ±10 Hz to 15 Hz	3 V to 20 V	1.7 V	1.5 V	3 V to 12 V	400 m	250 m	0.5 Ω
HV impulse	Bipolar dc pulse (3 pulse / second)	N/A	40 V to 120 V	35 V	20 V	40 V to 120 V	1000 m	500 m	0.25 Ω to 0.5 Ω
Microtrax	2 second coded pulse train at 6 second intervals	N/A	~1 V	Margin at 100%	Margin <100%	Margin ~175%	Typically 7000 m @ 1.5 ohm.km ballast resistance	N/A	0.25 Ω

A.2 Points

Several forms of points machines are used across the TfNSW Metropolitan Heavy Rail Network. A majority of the mechanisms are electric-powered, driving a reduction gear train. Others use compressed air or hydraulics to move the switch rails of the points. Some mechanically operated points still exist in the network.

All facing points are fitted with a facing point lock that mechanically locks the points into position. Where point mechanisms such as Claw Lock and Spherolok are used, the locking of the points is achieved in conjunction with the driving of the points.

Facing point locks come in a variety of forms depending on the type of drive to the points and the era when they were installed.

Some point machines are trailable, which allows train movements through the points where the points are set in the opposite position without damaging the mechanism.

The switch rails in the points also differ across the TfNSW Metropolitan Heavy Rail Network from short, conventional forms on 53 kg rail to asymmetrical long flexible switches on 60 kg rail.

In addition to facing and trailing points, other point configurations referred by this standard include single-bladed catchpoints, independent switches and derailers of various types.

A.3 Signals

Signals in the TfNSW Metropolitan Heavy Rail Network use either incandescent dual filament globes in conjunction with a focused lens system or LED based inserts.

Running signal indications provided to the driver are of either a single or double light indication. Single light indications typically start on the outskirts of the Sydney metropolitan area, in areas beyond where suburban services typically operate. Signal indications consist of main or subsidiary signal indications.

Running signals can be post-mounted, mounted low on the ground, mounted against a tunnel or wall or on signal bridges or gantries. Network rules NSG 600 and NSG 602 provide further details on the range of running and subsidiary aspects displayed to operators of rail vehicles.

Indicators and signs are used to supplement signal indications and to aid in providing additional information to the operator. NSG 604 provides further information on the range of indicators and signs used.

A.4 Trainstops

The function of a trainstop is to operate a trip arm, which, in its raised position, will actuate a brake valve of a passing train. When the associated signal is cleared, the signal control circuitry applies power to the trainstop, driving the arm down into its cleared position.

Three models of trainstop are used across the TfNSW Metropolitan Heavy Rail Network as follows:

- pneumatic
- electric
- electro – hydraulic.

The trip arm is proved in its raised and lowered position. In the event of a trip arm breaking, spring loading on the contacts within the train stop 'centre', leaving all contacts open.

Trainstops are rated to withstand an impact from a train trip arm at speeds up to 140 km/h.

Trainstops can also be used to enforce speed control of trains.

A.5 Interlocking equipment

The types of interlocking equipment used across the TfNSW Metropolitan Heavy Rail Network range from mechanical to relay based through to computer controlled.

Most relay-based interlocking systems use Westinghouse Q series vital signalling relays. Older interlockings use shelf relays and are being phased out.

Three types of computer based interlockings are used across the TfNSW Metropolitan Heavy Rail Network as follows:

- solid state interlockings (SSI) including Westlock and Smartlock
- Microlok II
- Westrace.

In some areas, mechanical levers and associated rodding control signalling equipment are used.

A.6 Level crossings (including pedestrian crossings)

Approach warning time at level crossings vary from 25 seconds to 30 seconds depending on local rail and road traffic conditions. Where booms are fitted upon activation of the lights, there is a 10 seconds to 12 seconds delay before the booms begin to descend providing a period of time for motorists to clear the level crossing.

Warning lights to the crossing are flashing red and are focussed for short and long approaches to the crossing.

Where deemed necessary, flashing yellow advance warning lights have been installed to warn motorists of the level crossing being activated.

Power to the crossings is derived from either council or railway supply. At some installations, a backup signalling supply is used. All level crossings have an additional battery backup in case of a loss of mains supply.

An approaching train is detected by track circuits. The strike-in point to activate the crossing is determined by calculating the line speed and the desired warning time for road motorists. In double line areas, when the crossing is activated, the approach distance on the other line is extended for checking for an approaching train. This additional functionality prevents the crossing from excessively short clearing times, with the booms rising and then falling without the crossing being open for a practical period of time.

A.7 Cabling

Cabling for the signalling system comprises power cabling and signal circuit cabling.

A.7.1 Power cables

Signalling distribution is generally at 120 V ac 50 Hz nominal and 50 V dc with some mains at 415 V ac and 480 V ac. Cable cross-sectional sizes vary from 4 mm^2 to 120 mm^2. The feeders are installed in ducting, troughing or buried. Cable runs are generally parallel to the lines.

Power distribution cables are not screened.

A.7.2 Fibre optic cables

Modern signalling installations use fibre optic cables to connect lineside equipment. The fibre optic cable carries both vital and non-vital signalling information. The links are typically duplicated.

As a general rule, this cable is run alongside the signalling copper cables and is not treated as a communications cable.

A.7.3 Signalling circuits

Signalling circuits are run in multicore cable installed in ducting, or troughing, or they can be buried. Individual conductors are generally installed in either ducting or troughing.

Circuits in multicore cables generally operate at 50 V dc double switched, not ac-immunised. Conductors are normally 7/0.5 mm (not balanced pairs or quads). On the suburban lines, audio frequency track transmitters and receivers are connected to the trackside equipment by up to 1500 m of single pair 7/0.5 mm aluminium foil screened cable, laid in trackside ducts or troughing.

Some installations still contain single switched 120 V ac control circuits.

A.8 Power supplies

A.8.1 Mains power

The main form of electrical power used for signalling applications is 50 Hz ac at a nominal voltage of 120 V.

For general signalling purposes, ac supplies are always duplicated with separate supplies derived from independent high voltage feeders.

The common normal and emergency supply arrangements are as follows:

- railway normal and railway emergency
- railway normal and council emergency.

Switching between normal and emergency supplies is usually done by an automatic mechanical changeover contactor. At critical supply points, seamless changeovers between supplies are required. At these locations, an UPS or static switches are used.

At newer locations, UPSs have been installed. The configuration of this newer system has an automatic transfer switch, switching between the two incoming supplies, which then feeds via an essential services board to the input to the UPS. To ensure availability of supply in case of a catastrophic failure of the UPS, a bypass contactor is also provided. One leg of the bypass contactor is fed from the UPS supply and the bypass contactor is biased to this supply. The second alternate supply leg of the bypass contactor is fed from the essential services board. In the event of a UPS failure, the bypass contactor will drop out and feed the load directly from the essential services board.

In these newer locations, reticulation at 415 V to outlying signalling locations is also used. The supply is a 415 V IT distribution scheme. To ensure the integrity of the mains wiring insulation, earth leakage monitors are installed at the feed locations.

Downstream locations have step-down transformers stepping the voltage down from 415 V to 120 V for use by the signalling equipment.

A.8.2 Direct current power supplies

The signalling system uses many different types of dc power supplies. Power supplies range from small low current linear supplies to sophisticated rack-mounted switch mode supplies.

The following are used where the application requires it:

- power supplies are duplicated and run in parallel for increased availability
- power supplies could also have either a battery or capacitor bank to supply the load in the advent of a brief interruption on the mains
- low voltage alarms are fitted, monitoring the charge voltage on a battery bank.

All power supplies are rated at 120 V nominal input. Typical output voltages are 12 V dc, 24 V dc and 50 V dc at different current levels ranging from 2 A to 90 A.

A.8.3 Surge protection

The design of the surge protection system follows standard industry principles of primary, secondary and tertiary protection.

Surge protection equipment is provided at all interface points to signalling locations including mains cabling, sub mains cabling, signal control and communication cabling.

Care is taken to minimise the effects of earth potential rises propagating to remote earths via the signal control and communication cable network.

A.9 Railway telephone and radio systems

Railway analogue telephone and communications circuits operate in the range of 150 Hz to 108 kHz and are used across the TfNSW Metropolitan Heavy Rail Network.

With the introduction of newer technologies, there is an increasing need for digital based communications systems being installed across the network, interconnected with fibre cabling schemes.

Train working and emergency telephones are used in some tunnels.

Future communications equipment and systems are designed to meet the Australian Communications and Media Authority requirements.

A.10 Telemetry and remote control

A variety of signalling remote control and indication systems SCADA and RTU telemetry are used in the TfNSW Metropolitan Heavy Rail Network.

Information is transmitted typically through communications type cable; however, some systems use untwisted cable cores in a signalling cable.

A.11 Control systems

Across the TfNSW Metropolitan Heavy Rail Network, the types of signal control systems in use are widely varied. This is as a result of the age of the signalling system in use at a particular location and also of the varying complexities.

Control systems in use range from a ground frame of only a few mechanical levers, to local signal boxes where either mechanical or power operated signalling is in use.

More modern signal control systems are of a centralised traffic control concept where they have control and indication of a larger area of the TfNSW Metropolitan Heavy Rail Network. Within these larger complexes, telemetry systems link the control system to the remote field equipment. Control panels can be either hard-wired or by way of a VDU system.

Appendix B Factors that affect shunting of track circuits

The following tables outline the factors that affect shunting of track circuits. Table 14, Table 15 and Table 16 include factors that assist and work against shunting of track circuits.

Table 14 – Track factors that affect shunting of track circuits

These things assist train shunt	Item	These things work against train shunt
Track not well-aligned causes wheels to scrub	Clean rails	Well-aligned track, wheels that track on a narrow rail head band
Dry environment	Corrosion on rail head	Damp corrosive environment, especially near the coast
Wide rail contact band	Clean part of wheel on clean part of rail	Narrow rail contact band
Well-worn rail	Clean part of wheel on clean part of rail	Newly ground rail head profile
Good ballast (lower leakage current)	Improves train shunt sensitivity	Poor ballast (higher leakage current)
Clean rail head	Clean rails	Rail head contamination such as leaves, leaky product from wagons and rust

Table 15 – Signalling factors that affect shunting of track circuits

These things assist train shunt	Item	These things work against train shunt
Impulse type track circuit (needs block joints)	Train detection to overcome poor rail or wheel resistance	Low voltage, non-impulse track circuits
High shunt sensitivity of track circuit	Train detection	Low shunt sensitivity of track circuit
Axle counters (no rail or wheel contact required)	Train detection	Track circuits
Each track circuit individually in signal control	Probability of shunt	Cut track circuit
Time delay on track circuit	Momentary loss of shunt	No time delay

Table 16 – Operational factors that affect shunting of track circuits

These things assist train shunt	Item	These things work against train shunt
Consistent operational pattern	Wheel or rail contact	Changed operation pattern

These things assist train shunt	Item	These things work against train shunt
No use of sand to improve adhesion	Wheel or rail contact	Use of sand to improve adhesion
More carriages or longer trains	Probability of good shunt	Less carriages or shorter trains
Loaded vehicles	Rail wheel contact resistance	Unloaded vehicles
Frequently used line	Rail wheel contact resistance	Infrequently used line
Wide mix of vehicle or traffic type	Rail wheel contact resistance	Low mix of vehicle or traffic type
Regular use of each types of vehicles	Rail wheel contact resistance	Intermittent use of a particular type
Longer or slower trains	Block skip (See Note 1)	Short or fast trains

Note 1: Block skip is a situation where the track circuit on which a train is leaving picks up before the next track shunts, resulting in a momentary situation where the train is lost to the system.