



Minimum Rolling Stock Requirements Standard

SM-20-00046618

Metro Body of Knowledge (MBoK)

Version:	3.0
Status:	Final
Document owner:	Executive Director, EDA
System:	Health and Safety Management System
Applicable to:	Sydney Metro
Issue date:	8/02/2024
Next review date:	8/02/2026

Document Approval:

Name	Position	Date	Signature
Gabriel McGowan	ED, Engineering Design Assurance	08/02/2024	Approval via email

Table of Contents

1.	Purpose and scope	5
2.	Definitions.....	5
3.	Accountabilities.....	6
4.	Vehicle Static Acceptance Criteria	7
4.1.	Static Rolling Stock Outline Interface	7
4.1.1.	Operation on Sydney Metro North West Viaduct	7
4.2.	Measured Vehicle Wheel Loads.....	8
4.3.	Static Vehicle Twist Test Requirements	8
4.3.1.	Rail guidance vehicles with multiple rear road axles.....	11
4.4.	Static Brake Test.....	11
4.4.1.	Road/Rail Vehicles/Trolley and Trailer Emergency Recovery with Static Brakes Applied.....	11
4.4.2.	Road/Rail Vehicle: Off tracking of vehicles.....	11
4.5.	Static Vehicle to Bogie Swing Test.....	11
4.6.	Static Vehicle to Vehicle Swing Test.....	12
4.7.	Signal (PPI) Visibility Test	13
4.8.	Acceptance of Infrastructure Maintenance Vehicles for Operation under Live OHW.....	15
4.8.1.	Travel Mode.....	15
4.8.2.	Work Mode.....	15
4.8.3.	Moveable parts which can exceed 3276mm above rail	16
4.8.4.	Infrastructure Maintenance Vehicle SAD Acceptance Test Criteria.....	16
4.8.5.	Safety Signage	16
5.	Vehicle Dynamic Acceptance Criteria	17
5.1.	Ride Performance Test.....	17
5.2.	Brake Test.....	18

5.3.	Safety Equipment and System Functionality	19
5.3.1.	Speedy Indicator	20
5.3.2.	Driver Safety System.....	20
5.3.2.1.	Rail Bound Infrastructure Maintenance Vehicles.....	20
5.3.2.2.	Road/Rail Infrastructure Maintenance Vehicles	21
5.3.3.	Data Logger/Recorder.....	22
5.3.4.	Main Reservoir and Brake Pipe Pressure Indication.....	22
5.3.5.	Driver's Emergency Cock	22
5.3.6.	Emergency Equipment.....	22
5.3.7.	Communications.....	23
5.3.8.	Headlights and Warning Lights	23
5.3.9.	Horns	23
5.3.10.	Environmental Requirements.....	24
5.3.10.1.	Noise and Vibration	24
5.3.10.2.	Wastes	24
5.4.	Maintenance	24
6.	Related documents and references.....	24
7.	Superseded documents.....	25
8.	Document history	25
	Appendix A: Rolling Stock Outline Dimensions	26
	Appendix B: Twist Test.....	27
	Appendix C: Example Electricity Danger Zone	30

Figures

Figure 1: Specific Rolling Stock Outline requirements (Sydney Metro Northwest Viaduct)	7
Figure 2: Bogie Vehicle Twist Requirement	9
Figure 3: Four Wheel Vehicle Twist Requirements	9
Figure 4: Road Rail Vehicle Twist Requirements	10
Figure 5: Visibility of Signals	13
Figure 6: Visibility of Signals	13
Figure 7: Visibility of Signals	14

Tables

Table 1: Base rule performance requirements	17
Table 2: Measured average deceleration (rail bound infrastructure maintenance vehicle)	18
Table 3: Measured average deceleration (road rail vehicle vehicle)	18
Table 4: Locomotive operating work trains – stopping distance requirements	18
Table 5: Low horn requirements	23

1. Purpose and scope

The purpose of this Standard is to prescribe the minimum technical requirements for infrastructure maintenance/construction rolling stock for operation on the Sydney Metro controlled network.

This Standard applies to Sydney Metro staff required to make determinations on the acceptance and registration of rolling stock for use on the Sydney Metro controlled network and Rolling Stock Operators who intend to operate rolling stock on Sydney Metro controlled network.

2. Definitions

All terminology in this Standard is taken to mean the generally accepted or dictionary definition. Other terms and jargon specific to this Standard are defined within the SM-17- 00000203 Sydney Metro glossary. Acronyms specific to this document are listed below.

	Definitions
Accredited Rolling Stock Operator	An entity that, as an owner and operator of its own railway rolling stock and/or plant, is accredited with the ONRSR as a Rail Transport Operator (RTO) under the Rail Safety Act2012.
Heavy Self Propelled Vehicles	A rail vehicle where the braking effort is such that the vehicle cannot achieve the 1.1 m/s ² deceleration, expected of smaller vehicles (i.e. the vehicle has a braking performance equivalent to that of a locomotive).
Height Restrictor	An engineering device or control which limits the operating height of plant with lifting appliances such as a jib, boom or EWP (Elevating Work Platform).
IMS	Integrated Management System (IMS).
Independent Competent Person	An impartial person with no conflict of interest, having sufficient practical experience and theoretical knowledge of infrastructure maintenance rolling stock to enable that person to critically and capably examine vehicles to identify and assess the importance of any defects, weaknesses or non-compliances with regard to the vehicle's continued safe operation and function, and be aware of their own particular limitations with regard to the task to be undertaken.
Infrastructure Maintenance Vehicle	A vehicle designed and constructed to operate on rail for the purpose of assisting infrastructure maintainers in carrying out the construction and maintenance of rail related infrastructure (i.e. Road Rail Vehicle, Track Machine, Trolleys, etc).
MTS	Metro Trains Sydney (operator of Sydney Metro Northwest).
ONRSR	Office of the National Rail Safety Regulator.
Other RTO rail site	A rail site managed and controlled by another accredited RTO where the Safety Management System of the other RTO applies.
Rail Bound Plant	Rail vehicles for the purpose of infrastructure maintenance, specifically designed for operation exclusively on railway tracks. Some vehicles may access work sites by rail and others may be transported by road to a worksite and placed on rail.
Rail Corridor	The space on an operational rail line measured from fence-line to fence-line, or if there are no fences, everywhere within 15 metres of the outermost rails.
Rail Site	A construction site becomes a rail site from the point in time when there is potential for rolling stock to operate.
Rail Traffic	Trains, track maintenance, road-rail vehicles and any other rail mounted vehicles.
Road-rail Vehicle	A road vehicle which has been fitted with rail guidance equipment to permit it to travel safely on railway track. The traction and braking system can be provided by the road tyres and/or the rail wheels.
	The following who are accredited by ONRSR as an RTO under the Rail Safety Act

Definitions	
Rail Transport Operator (RTO)	2012: ○ A Rail Infrastructure Manager (RIM), OR ○ A Rolling Stock Operator (RSO), OR ○ A person who is both a rail infrastructure manager and a rolling stock operator
Rolling Stock	Rolling stock specifically identified as an infrastructure maintenance vehicles, plant and/or wagons, including trolleys and trailers, which are designed to operate on a railway track and participate in the construction and maintenance of rail infrastructure. Rolling stock for the purposes of this Standard does not include passenger trains.
Rolling Stock Waiver	A document issued by Sydney Metro that authorises the one off movement of a piece of (non-registered or non-conforming) rolling stock or plant on or across the Sydney Metro network based on sufficient evidence that risk control measures are in place.
Safe Approach Distance (SAD)	The required safe distance between a person or object and the 1500 Volt Overhead Contact Wire/Catenary in order to prevent an electrical discharge and/or electrocution.
Train	A locomotive or self-propelled vehicle, alone or coupled to one or more vehicles.

3. Accountabilities

The Deputy Executive Director – Engineering Projects is accountable for this Standard including approving the document, monitoring its effectiveness and performing a formal document review.

The Executive Director, Health and Safety is responsible for the System under which this Procedure and its associated documents reside.

Direct Reports to the Chief Executive are accountable for ensuring the requirements of this Standard are implemented within their area of responsibility.

Direct Reports to the Chief Executive who are accountable for specific projects/programs are accountable for ensuring associated contractors comply with the requirements of this Standard.

The following requirements are applicable to all rolling stock proposed for operation on the Sydney Metro network.

To be registered for operation on the Sydney Metro network all vehicles/plant must comply with the requirements of this standard.

The accredited Rolling Stock Operator (RSO) of the infrastructure maintenance vehicle/plant is responsible for ensuring vehicle compliance and shall submit the appropriate documentation with the application for vehicle registration.

The minimum rolling stock requirements contained within this document are reviewed and updated in accordance with the Sydney Metro IMS review cycle and as required to reflect changes to the Sydney Metro network and to include controls for new (and newly identified) risks.

4. Vehicle Static Acceptance Criteria

The following sections cover the static test/inspection requirements for infrastructure maintenance vehicle/plant acceptance for operation on the Sydney Metro network.

4.1. Static Rolling Stock Outline Interface

Vehicles proposed for operation on the Sydney Metro network must comply with the Rolling Stock Outline Dimensions contained within the drawing NWRL System Wide Location Permanent Way Transit Space NWRL Structure Gauge – Platforms (NWRLOTS-NRT-SWD- PW-DRG-550634) provided in Appendix A.

If the vehicle exceeds the permitted dimensions then it shall be treated as an out-of-gauge vehicle which shall, if approved for operation, be subject to specific operating conditions. Refer to the Sydney Metro Rail Operating Conditions Standard.

Any movable parts and elements that can exceed the outline gauge should be identified including how the associated item can be secured and locked in the stowed position for travel and kept within gauge.

It is the accredited RSO's responsibility to check the vehicle for compliance and submit the necessary documented proof of compliance with the application to Sydney Metro for vehicle registration.

4.1.1. Operation on Sydney Metro North West Viaduct

Vehicles which require to operate on the Sydney Metro North West Viaduct located in- between Tallawong and Rouse Hill Metro Stations, are required to comply with the specific gauge requirements below.

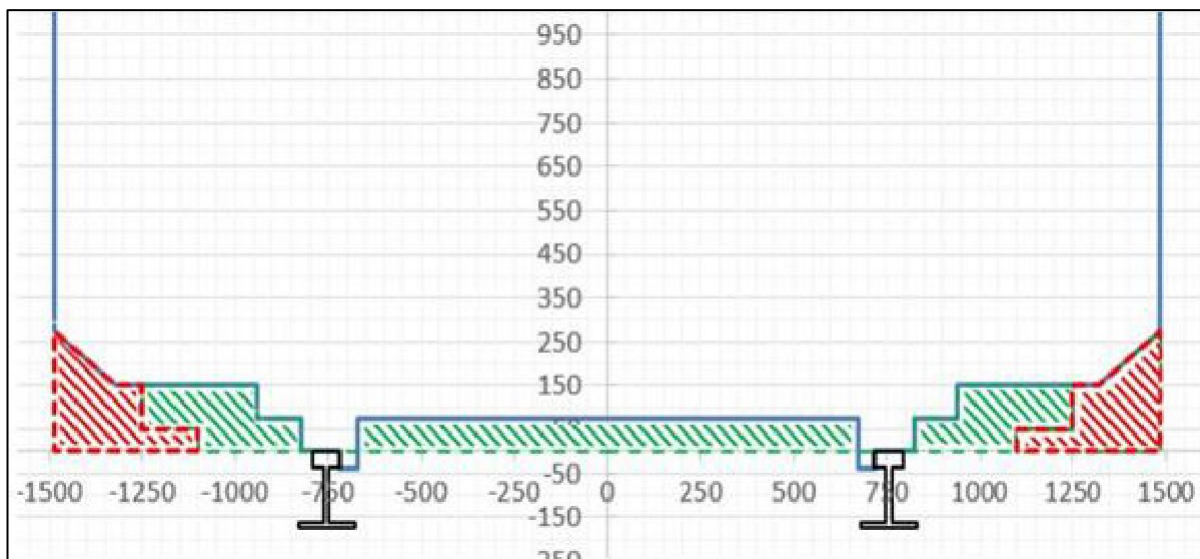


Figure 1: Specific Rolling Stock Outline requirements (Sydney Metro Northwest Viaduct)

The vehicle width on rail is <2200mm wide at 0-50mm above top of rail and < 2500mm wide for 50+ mm above top of rail, otherwise not suitable for viaduct operation (conditional)

4.2. Measured Vehicle Wheel Loads

The maximum permitted wheel loads for operating on the Sydney Metro network must not exceed 12.5 tonnes (25 tonne per axle), unless otherwise specified for specific worksites.

Wheel loads and wheel load distribution are critical for reliable and safe rolling stock operation on Sydney Metro managed rail infrastructure. This is particularly important where track top and alignment has not been finished to the required normal operating standard. In such cases wheel load imbalance can be crucial for operating safety. Axle and bogie load imbalance is also critical for traction where locomotives and self-propelled vehicles are working close to their adhesion limit.

Wheel and axle loads shall be measured whilst the vehicle is in its normal empty (tare) condition. Where a vehicle is designed to be evenly loaded, the design loading can be added and distributed evenly over the empty (tare) wheel loads. In the case of a vehicle which can be unevenly loaded such, as a crane or excavator, the expected maximum wheel loads and load distribution shall also be provided.

The accredited RSO is responsible for providing a table of wheel and axle loads, including a diagram of the vehicle showing the wheel arrangement and axle spacings, with the application to Sydney Metro for vehicle registration.

4.3. Static Vehicle Twist Test Requirements

Vehicles proposed for operation on the Sydney Metro network shall be twist tested in accordance with the requirements specified in Figures 2, 3, or 4, whichever is applicable. A twist test is designed to simulate the vehicle sitting a local twist defect superimposed on a superelevation ramp. The maximum permitted wheel unloading of any wheel is 60%.

All vehicle types or modified versions thereof shall meet the requirements of this standard before being registered for operation on the Sydney Metro network.

A twist test shall also be performed on any Sydney Metro registered vehicle that has been modified or has been derailed following registration, where the torsional stiffness of the vehicle may have changed due to any of the following:

- Increased suspension spring rates
- Suspension damage
- Increase in bogie frame torsional stiffness
- Reduction in minimum side-bearer clearance
- Increase in side-bearer preload (where applicable)
- Increase in underframe torsional stiffness
- Change in vehicle equipment, and/or mass distribution.

Note: For twist test packing requirements, refer to the Table B1 in Appendix B

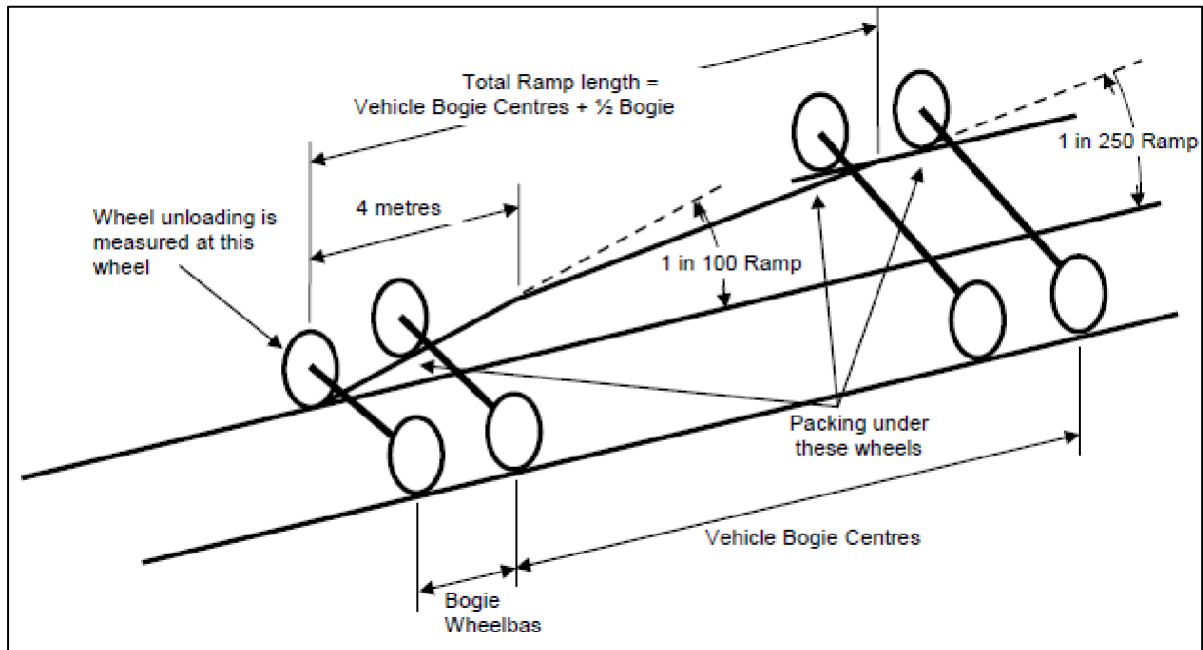


Figure 2: Bogie Vehicle Twist Requirement

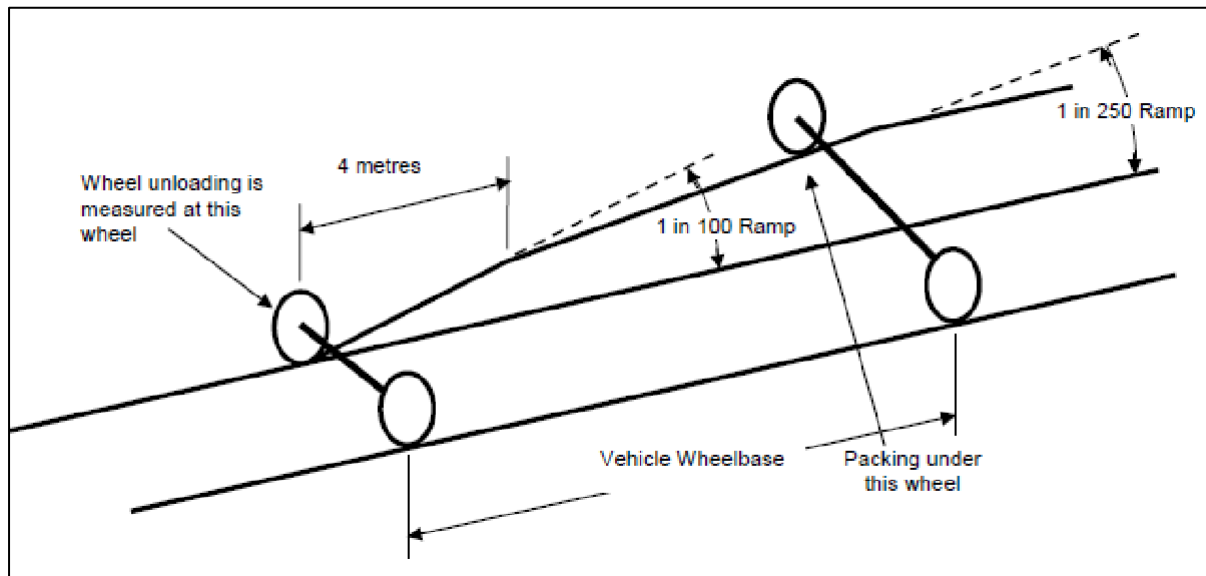


Figure 3: Four Wheel Vehicle Twist Requirements

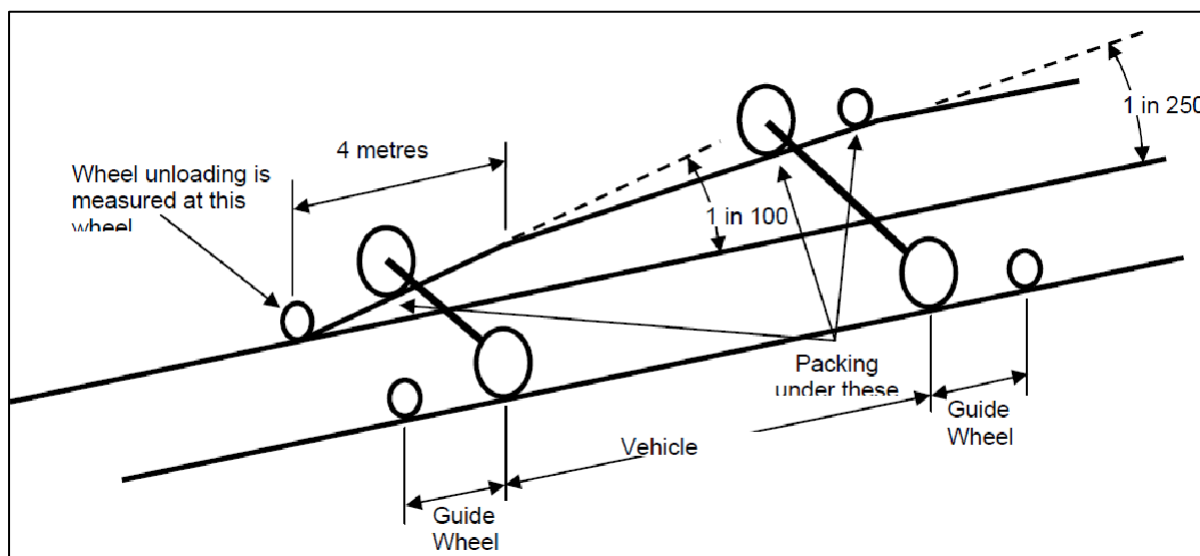


Figure 4: Road Rail Vehicle Twist Requirements

Sydney Metro reserves the right to request and have a twist test carried out by the accredited RTO/RSO where, in Sydney Metro's opinion, there is doubt as to a vehicle's twist capability.

Vehicles equipped with standard three-piece bogies and gapped side bearers having 10- 14mm clearance may be exempted from a static vehicle twist test, with the written approval of the Sydney Metro Deputy Executive Director – Engineering Projects or their nominated Sydney Metro representative. Torsionally stiff vehicles; such as tank vehicles; and high centre of gravity vehicles may not necessarily be exempt and may still require testing.

A vehicle with a floating axle that pivots about its centre on the vehicle longitudinal centreline does not require a twist test. A certified weighbridge, or other approved calibrated load measuring device shall be used to verify compliance with the above requirements.

Vehicles shall be twist tested in the operating configuration tending to give the highest wheel unloading. This will require the test to be undertaken with the vehicle at minimum tare condition. For locomotives this means minimum fuel and sand. For vehicles with symmetrically located tanks, the tanks shall be empty. For eccentrically located tanks, the worst loading case shall be tested.

For vehicles which are not fully symmetrical, the twist test shall be performed such that the wheel unloading is measured at each of the four outer wheels in turn, (i.e. all four corners of the vehicle). For vehicles equipped with air springs, the twist test shall be performed with air springs in both the deflated and the inflated condition.

For vehicles with moveable gantries, buckets, cranes or other plant, the twist test shall be performed with that plant positioned to give the maximum wheel unloading, for any operating condition when set up for travelling.

The accredited RTO/RSO is responsible for arranging the static vehicle twist test by an accredited person and shall provide evidence of the test results with the application for Sydney Metro vehicle registration

4.3.1. Rail guidance vehicles with multiple rear road axles

For vehicles operating on the Sydney Metro network with dual rear road axles driving on rail, the nominal flange angle of the rear rail wheels shall be 80deg, average surface roughness no more than 12µm, and re-profiled rims shall have no witness grooves remaining.

4.4. Static Brake Test

A static parking brake force test is designed to ensure that the brakes on a vehicle apply with sufficient force and release, prior to the vehicle being registered to operate on the Sydney Metro network.

The parking or handbrake shall be capable of holding the fully loaded vehicle stationary on a grade of 1 in 22 (4.5% or 2.6 degrees) for an indefinite period.

Sydney Metro gradients are significantly steeper than those generally found on the Sydney Trains network. An operator should not assume that provisions (notably braking) that are suitable for use on the Sydney Trains network will be acceptable for use on the Sydney Metro network.

For road rail vehicles, the brake system shall comply with section 14 of AS 7502.

For other rail bound infrastructure maintenance vehicles, the brake system shall comply with T HR RS 00700 ST – RSU 712 (Brake and pneumatic equipment) requirements.

When there is conflict identified between the nominated AMB / TfNSW standards and the Sydney Metro Minimum Operating Standard, the accredited RSO shall notify Sydney Metro for determination.

4.4.1. Road/Rail Vehicles/Trolley and Trailer Emergency Recovery with Static Brakes Applied

Calculations or an appropriate test report should be provided to demonstrate that the vehicle can be recovered braked in the event of a breakdown.

If the Brakes must be released and vehicle towed unbraked, then the vehicle must have a suitably rated tow bar and secondary securing device (e.g. chain). Otherwise, not approved for tunnel operation.

4.4.2. Road/Rail Vehicle: Off tracking of vehicles

During transition (on-or off tracking), the Road/Rail vehicle shall remain braked sufficiently to hold on a 1 in 22 gradient (minimum one axle) at GVM. An appropriate calculation / test report shall be provided to demonstrate this requirement to Sydney Metro.

4.5. Static Vehicle to Bogie Swing Test

A static vehicle to bogie swing test is designed to ensure adequate bogie to underframe / body clearance when negotiating the most extreme track curve radius. The swing test is required for bogie vehicles only and is classified as a type test. That is, vehicles of the same design are covered by one vehicle test.

The vehicle to bogie swing test consists of a practical simulation whereby the vehicle body is rotated relative to the bogie such that the angle of bogie rotation is equivalent to that attained when the vehicle is negotiating a 70 metre curve radius. This simulated relationship may be achieved by using a turntable or traverser, or by slewing one end of the vehicle body using a crane.

The vehicle is not expected to negotiate this curve radius whilst in service. The test is purely to ensure adequate running clearances during normal operation. When a vehicle is subjected to a swing test its suspension system shall be simulated in the solid condition. This may be achieved by replacing the springs with suitable packers, equivalent to the spring's solid height.

The vehicle shall be tested in the new wheel condition (full diameter wheels), complete with all equipment such as brake rigging, hoses, etc. Vehicles equipped with air springs shall be tested with these in the deflated condition as well as the inflated condition.

In determining adequate clearances, there shall be no interference or contact between any bogie component and any vehicle underframe/body/structure/component after allowances for all possible modes of vehicle bogie/body relative movement. These allowances will depend on the vehicle design. Brake rigging travel shall be taken into account when estimating clearances.

The accredited RSO is responsible for arranging the static vehicle to bogie swing test by an accredited person and shall provide evidence of the test results with the application for Sydney Metro vehicle registration.

4.6. Static Vehicle to Vehicle Swing Test

This test is designed for vehicles that operate coupled together or for vehicles that are likely to be coupled to another vehicle such as a locomotive or a freight vehicle where the test vehicle may be transferred as part of a train consist. A static vehicle to vehicle swing test is designed to ensure adequate inter-vehicle clearances and inter-vehicle coupling compatibility when negotiating the most extreme track curve radii under normal operation. This test is classified as a type test, that is, vehicles of the same design are covered by the one test.

The vehicle to vehicle swing test consists of a practical simulation whereby one vehicle body is rotated relative to another coupled vehicle such that the body rotation/displacement is equivalent to that attained when the two vehicles are negotiating the curve radii specified below. This simulated relationship may be achieved by using a turntable or traverser, or by slewing the vehicle body using a crane.

The test may be conducted either as a practical test or by CAD simulation. The CAD simulation must take into account coupler length and travel, air brake coupling hose lengths, jumper coupling length, diaphragms, etc.

When a vehicle is subjected to a vehicle to vehicle swing test, allowance shall be made for the extremes in different vehicle heights, vehicle overhangs and coupler lengths on adjacent vehicles. All inter-vehicle connections including brake hoses, control cables, power cables, etc. shall be correctly fitted and coupled during this test.

Vehicles shall be capable of successfully negotiating the following track curvatures without interference or contact between any vehicle-to-vehicle components:

- A horizontal curve of 100m radius while coupled to a vehicle with a total lateral coupler offset (from the vehicle centreline) of 90mm at the coupler line; the vehicle path shall be through the curve from tangent track
- A reverse horizontal curve of 120m radius, without transition between the two curves, while coupled to an identical vehicle.

These curve radii are tighter than those which vehicles would normally be required to negotiate in service and thus are designed to ensure there is adequate clearance under normal operating conditions.

The accredited RTO/RSO is responsible for arranging the static vehicle to vehicle swing test by an accredited person and shall provide evidence of the test results with the application for Sydney Metro vehicle registration.

4.7. Signal (PPI) Visibility Test

The signal (PPI) visibility test is designed to ensure that drivers or operators of all self-propelled vehicles including locomotives and multiple unit engineering vehicles can clearly see trackside signals (PPI) from their driving positions. The driver or operator in a normal seated driving position behind the controls shall have direct line of sight to signalling as depicted in Figures 5, 6 and 7. The normal driving position is on the left hand side of the cab however on some vehicles it may be in the centre or on the right hand side.

Dwarf or ground signalling (PPI) equipment located at all distances greater than 13 metres from the driver's eye position and to a width of 2.5 metres from the adjacent rail running face on either side of the track. Refer to Figure 5.

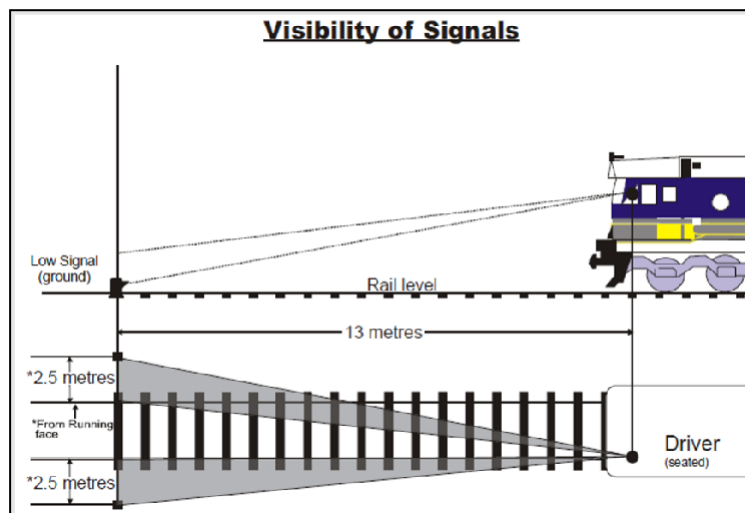


Figure 5: Visibility of Signals

High or gantry signalling equipment located at all distances greater than 13 metres from the driver's eye position at a normal height of 6.7 metres above rail level and within a width of two to five metres from the adjacent rail running face on either side of the track. Ref. Figure 6.

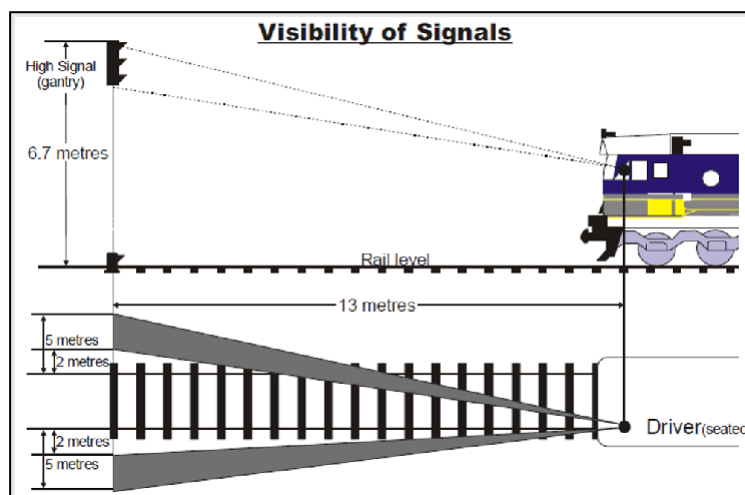


Figure 6: Visibility of Signals

The driver in a standing position behind the controls shall have direct line of sight to dwarf and ground signalling equipment located at all distances greater than 4 metres from the driver's eye position and to a width of 2.5 metres from the adjacent rail running face on either side of the track. Refer to Figure 7.

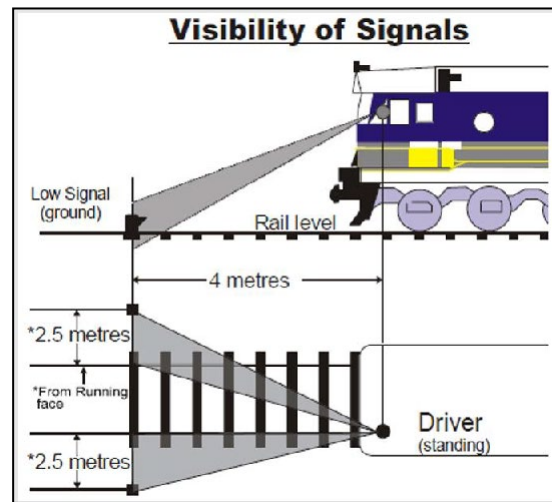


Figure 7: Visibility of Signals

In the case of vehicles where the driver is not seated at the front of the vehicle, such as in locomotives running long end leading, steam locomotives, or with some infrastructure maintenance vehicles, the driver must be accompanied by a second person who is appropriately qualified in safe working to convey unsighted signal information to the driver.

The accredited RTO/RSO is responsible for arranging the signal visibility test by an accredited person and shall provide evidence of the test results with the application for Sydney Metro vehicle registration.

Note: absence of signal (PPI) visibility testing will result in a Possession Area Only restriction being applied, limiting the operation of the vehicle to an Local Possession Authority (LPA).

4.8. Acceptance of Infrastructure Maintenance Vehicles for Operation under Live OHW

The minimum height of 1500V Overhead Wiring on the existing Sydney Metro North West network is 4276mm above rail, taking into account the maximum permitted contact wire sag and 10% tension reduction. The Safe Approach Distances (SADs) specified below must be maintained at all extremities of the transit envelope of approved road/rail vehicles, including but not limited to such items as load, exhaust pipes and radio aerials.

4.8.1. Travel Mode

Infrastructure Maintenance Vehicles whilst mounting or dismounting railway track or travelling under a live 1500V OHW system, where an Electrical Permit has not been issued for the operation, shall maintain a minimum Safe Approach Distances (SAD) of 900mm under all conditions of operation and loading. That is, the maximum height of their transit envelope at any point shall not exceed 3376mm above rail.

Infrastructure Maintenance vehicles such as excavators, elevating work platforms, cranes, etc, with moveable components or equipment capable of being elevated, such that any portion of the equipment can infringe the SAD, shall have such equipment stowed for travel and be fitted with an approved height restricting control.

No worker shall be permitted to travel on top of or on a platform or tray of a road/rail vehicle whilst the vehicle is travelling under the live 1500V OHW system.

4.8.2. Work Mode

Where an Infrastructure Maintenance vehicle is approved for planned work under a live 1500V OHW, and where an Electrical Permit has not been issued for the operation, the work envelope of the vehicle shall maintain a minimum Safe Approach Distances (SAD) of 1000mm under all conditions of operation, irrespective of where the vehicle is positioned on the worksite. That is, the maximum height of the vehicle work envelope at any point shall not exceed 3276mm above rail.

Infrastructure Maintenance Vehicles such as excavators, elevating work platforms, cranes, etc, with moveable components or equipment capable of being elevated, such that any portion of the equipment can infringe the SAD to the live 1500V OHW system, shall be fitted with an approved height restricting control.

The approved specific vehicle concerned must be uniquely identified on the Safe Work Method Statement (SWMS)/ Work Activity Advice (WAA) or Task Based Risk Assessments (TRA) and pre-work briefing documents, for the work, so that it is clear to all concerned that the work must not be performed by any other vehicle, and prior to the commencement of work each shift, the person in charge of the work must ensure that the specific vehicle identified on the SWMS and pre-work brief is the actual vehicle to be used for the work.

No person shall be permitted to climb on top of or work from a platform or tray of an Infrastructure Maintenance Vehicle if the SAD from the person to the 1500V OHW system is less than 1000mm.

4.8.3. Moveable parts which can exceed 3276mm above rail

Moveable parts on the rail vehicle which can exceed 3,276mm above rail in work mode shall be identified to Sydney Metro including the associated controls / mechanisms which will ensure these moveable parts do not exceed the SAD during work under the live 1500VOHW system.

The vehicle must be fitted with a double redundant height limiting system as or not approved for work under live OHW.

If the vehicle is fitted with height limiting equipment, details shall be provided of the maximum height set limit including if these can be programmed through a Human Machine Interface (HMI).

4.8.4. Infrastructure Maintenance Vehicle SAD Acceptance Test Criteria

The following test criteria is to be used to determine the SAD acceptability for all Infrastructure Maintenance Vehicle to travel on or work under a live OHW on the Sydney Metro network

- When a vehicle is required to perform work on the rail network, the maximum height at any component or structural part of the vehicle, shall not exceed 3276mm above the rail plane
- When a vehicle is required to only travel (i.e. NOT work) on the rail network, the maximum height at any component or structural part of the vehicle shall not exceed 3376mm above the rail plane
- The above limits excludes vehicle temporary lift when its rail guidance equipment is being deployed or retracted, where it is required to pass over centre to lock in position. The maximum temporary lift shall not exceed 75mm
- All vehicles required to travel under live overhead must have all moveable equipment stowed such that it does not encroach on safe approach distances
- All vehicles required to perform work under live OHW on the network which have elevating equipment such as, that on an elevating work platform, a boom on an excavator, a jib on a crane, a bucket on a front end loader or a powered wireless aerial, for example, shall be fitted with a RSO approved height limiting system.

Any vehicle which would infringe the identified safe approach distances must be restricted from operating under live overhead (whether travelling or working) or must be able to demonstrate that the vehicle has an acceptable method of bonding to the rail track head. The effectiveness of this bonding to be proven as part of the registration approval process.

Infrastructure Maintenance vehicles which fail to comply with section 4.8 will receive a condition – Height Restricted (Not to TRAVEL or WORK under live 1500V OHW).

Infrastructure Maintenance vehicles which comply with 4.8.1 but fail to comply with 4.8.2 will receive a condition – Height Restricted (TRAVEL under live 1500V OHW only).

4.8.5. Safety Signage

Vehicles should be fitted with Appropriate Electrical Danger Zone signage / stencilling (See Appendix C) to warn personnel not to climb on the vehicle when under the overhead wires. Signage should be installed in an appropriate location on the vehicle in general view of all personnel using / operating the vehicle

5. Vehicle Dynamic Acceptance Criteria

This section covers the dynamic test requirements for infrastructure maintenance vehicle acceptance for operation on the Sydney Metro Northwest.

5.1. Ride Performance Test

A ride performance test is designed to ensure vehicle compatibility with the track and to establish the optimum vehicle safe operating conditions.

In the case of infrastructure maintenance vehicles a ride performance test is only required where it is proposed to operate the vehicle at speeds in excess of 30 km/h for vehicles up to and including 5 tonnes gross mass, or at speeds in excess of 15 km/h for vehicles over 5 tonnes gross mass.

Vehicles equipped with standard three piece bogies and gapped side bearers having 10-14 mm clearance may be exempt from a ride performance test for operation up to 80 km/h, subject to written approval from Sydney Metro. Torsionally stiff vehicles, such as tank vehicles, and high centre of gravity vehicles may not necessarily be exempt and may require testing.

Sydney Metro reserves the right to request and have a ride performance test carried out by the accredited RTO/RSO of any vehicle, for the following reasons:

- Proposed modification to the suspension characteristics
- Proposed change in bogie rotational resistance
- Proposed change in wheel profile
- Proposed change in bogie type
- Proposed change in vehicle operating conditions
- Any proposed vehicle modification which may affect the vehicle ride performance
- Significant change or redistribution in the vehicle tare or gross mass
- Where, in the opinion of Sydney Metro, there is suspected poor ride performance.

The base ride performance requirements for all vehicle types operating on the Sydney Metro network is as shown in Table 1.

Table 1: Base ride performance requirements

Parameter	Limit
Maximum lateral acceleration	+/- 0.5g
Average lateral acceleration	+/- 0.35g
Maximum vertical acceleration	+/- 0.8g
Average vertical acceleration	+/- 0.5g

Ride performance shall be measured using vertical and lateral accelerometers positioned on the vehicle body as near as possible to the trailing bogie/axle centre. All measured accelerations shall be filtered at 10 Hz low pass.

Average acceleration shall be taken as the mean peak acceleration measured about the zero axis. The mean peak acceleration shall be calculated from the 10 Hz low pass filtered acceleration.

Sustained hunting is not permitted. In this case, hunting is defined as sinusoidal lateral oscillations of the wheelset resulting in greater than 0.5 Hz lateral vehicle body accelerations measured at the bogie centre of greater than 0.35g sustained for 10 seconds or longer.

The accredited RTO/RSO is responsible for arranging the vehicle ride performance test by an accredited person and shall provide evidence of the test results with the application for Sydney Metro vehicle registration.

5.2. Brake Test

All self-propelled infrastructure maintenance vehicles shall pass an on-track brake performance test before being considered for operation on the Sydney Metro network.

The fail-safe brake system shall be mandatory for all vehicles. Existing road/rail vehicles that are not compliant shall be modified to be compliant by 01 November 2020.

The vehicle shall be tested on dry level track and have an average deceleration within the limits specified below. Tests shall be conducted with the operator applying the brake and not releasing the brake until the vehicle comes to a stand. The vehicle shall be tested at normal operating speed (typically 15 km/h in tare condition for operation during possessions), and up to the maximum allowable speed. The wheels must not skid during the test.

Measured average deceleration for rail-bound infrastructure maintenance vehicle and road rail vehicles shall be as shown in Table 2 and Table 3 respectively.

Table 2: Measured average deceleration (rail bound infrastructure maintenance vehicle)

	Tare Condition	Loaded Condition
Air brake	1.1 m/s ² minimum	0.8 m/s ² minimum
Vehicles with trailers	1.1 m/s ² minimum	0.8 m/s ² minimum
Heavy Self Propelled Vehicles	0.8 m/s ² minimum	0.8 m/s ² minimum

Table 3: Measured average deceleration (road rail vehicle vehicle)

	Minimum deceleration	Loaded Condition
Steel wheel on rail	0.9 m/s ²	All
Rubber wheel on rail	1.1 m/s ²	All

Parking brake performance test shall be as per section 4.4 of this Standard.

A heavy infrastructure maintenance vehicle with brake performance less than 1.1 m/s² may only operate as the leading vehicle in a convoy with other infrastructure maintenance vehicles, otherwise this vehicle shall not be permitted to operate in convoy.

Locomotive operating work trains on the Sydney Metro network shall meet the stopping distance requirements shown in Table 4.

Table 4: Locomotive operating work trains – stopping distance requirements

Speed (km/h)	Stopping distance (metres) (GW16)
20	94
40	281

Vehicles towing unbraked trailers must meet the deceleration specified in Tables 4a and 4b, and the permissible loaded mass of the unbraked trailer shall be specified and stencilled on the side of the towing vehicle.

Load compensating valves shall be required where the tare to gross mass ratio of a vehicle exceeds 1:3. The vehicle shall comply with the above specified deceleration requirements.

The accredited RTO/RSO is responsible for arranging the vehicle brake performance test by an accredited person and shall provide evidence of the test results with the application for Sydney Metro vehicle registration.

Note: The fail-safe nature of spring applied hydraulic release brake systems rely on the hydraulic fluid venting from disconnected or severed hoses, fittings, or couplings. Since venting may be suppressed when 'Dry Break' or 'Quick Connect' type couplings are used, these styles of connections are not suitable. *Ref T HR RS 00700 Series clause 22.7.1– Minimum Operating Standard for Rolling Stock – Infrastructure Maintenance vehicle specific interface requirements*

5.3. Safety Equipment and System Functionality

All rail bound infrastructure maintenance vehicles shall be fitted with the following safetyequipment:

- Speed indicator
- Driver safety system (see Clause 6.4.2)
- Data logger/recorder
- Main reservoir and brake pipe pressure indication (where equipment is fitted)
- Driver's emergency cock
- Emergency equipment
- Communications
- Head lights and warning/marker lights (Red/White)
- Horn
- Fit for purpose electrical earthing system is installed on the vehicle
- All associated emergency stop systems shall be failsafe and designed in such thatany loss of power, fluid, pressure or other system fault results in a brake application.

All road-rail infrastructure maintenance vehicles shall be fitted with the following safetyequipment:

- Speed indicator (may not apply to excavators)
- Driver safety system (see Clause 5.4.2)
- Data logger/recorder (for vehicles operating in excess of 30 km/hr on rail)
- Head lights and warning/tail lights
- Horn
- Fit for purpose electrical earthing system is installed on the vehicle
- All associated emergency stop systems shall be failsafe and designed in such that any loss of power, fluid, pressure or other system fault results in a brake application

5.3.1. Speedy Indicator

All rail bound infrastructure maintenance vehicles shall be fitted with an operative speed indicating device.

All road/rail vehicles capable of travelling in excess of 15 km/h shall be fitted with an operative speed indicating device located in all driving cabs. GPS Speed Indicating devices are only permitted for use in non-tunnel environments.

Vehicles with a GPS Speed Indicating Device will be issued with a condition restricting them to walking pace in tunnel environments.

5.3.2. Driver Safety System

Infrastructure maintenance vehicles having the potential to operate with a kinetic energy exceeding 600 kNm, shall be fitted with an approved driver safety system as specified below. The driver safety system must operate while the vehicle is in travel mode.

Infrastructure maintenance vehicle's having the potential to operate with a kinetic energy of 600 kNm or less, are not required to have a driver safety but must carry a 2nd person competent to stop the vehicle in the event of an emergency.

The following equation is used to determine the vehicle's kinetic energy "E"

$$E = 0.0386 MV^2$$

Where E = Kinetic Energy (kiloNewton metres) and M = Maximum vehicle/train mass (tonnes) V = Maximum vehicle speed (km/hr).

5.3.2.1. Rail Bound Infrastructure Maintenance Vehicles

On-Track (rail bound) infrastructure maintenance vehicles (with a driver's position), operating in travel mode, alone or as a motive power unit, hauling or controlling other infrastructure maintenance vehicles between and within worksites, with the potential for having a total kinetic energy (E), exceeding 600 kiloNewton metres, based on the above formula, shall have a driver safety system incorporating the following:

- A Vigilance system
- An Authorised 2nd Person competent to stop the vehicle/train in the event of an emergency
- An Emergency Cock or alternate suitable device for stopping the vehicle in an emergency. This device shall apply the brakes and remove traction power.
- An on-board control system that shall not allow the vehicle to power up, move or continue in motion with the driver safety system isolated, except under degraded and specifically defined operating conditions
- An approved process to enable suppression of the vigilance system whilst the vehicle is in work mode within a worksite.

Or in the case of Driver Only Operation:

- A Vigilance System
- An Operator Enable System
- An Emergency Cock or alternate suitable device for stopping the vehicle in an emergency. This device shall apply the brakes and remove traction power
- An on-board control system that shall not allow the vehicle to power up, move or continue in motion with the driver safety system isolated, except under

degraded and specifically defined operating conditions.

- An approved process to enable suppression of the vigilance system whilst the vehicle is in work mode within a worksite

Note: Where it is not possible to incorporate a suitable driver safety system within the vehicle, the vehicle/train maximum allowable speed must be reduced to bring the value of “E” below 600 kNm

5.3.2.2. Road/Rail Infrastructure Maintenance Vehicles

Road-rail infrastructure maintenance vehicles operating in travel mode, alone or as a motive power unit, hauling or controlling other infrastructure maintenance vehicles between and within worksites, with the potential for having a total kinetic energy (E), exceeding 600 kiloNewton metres, based on the above formula, shall have a driver safety system incorporating the following:

- A Vigilance system
- An Authorised 2nd Person competent to stop the vehicle/train in the event of an emergency
- An Emergency Cock or alternate suitable device for stopping the vehicle in an emergency. This device shall apply the brakes and remove traction power
- An approved process to enable suppression of the vigilance system whilst the vehicle is in work mode within a worksite.

Or in the case of Driver Only Operation:

- A Vigilance System
- An Operator Enable System
- An Emergency Cock or alternate suitable device for stopping the vehicle in an emergency. This device shall apply the brakes and remove traction power
- An on-board control system that shall not allow the vehicle to power up, move or continue in motion with the driver safety system isolated, except under degraded and specifically defined operating conditions
- An approved process to enable suppression of the vigilance system whilst the vehicle is in work within a worksite.

Note: Where it is not possible to incorporate a suitable driver safety system within the vehicle, the vehicle maximum allowable speed must be reduced to bring the value of “E” below 600 kNm.

Road/Rail Prime Motor Vehicles Authorised to Operate as a Locomotive Only, within a Worksite

Road-rail prime mover vehicles operating in travel mode, alone or as a locomotive hauling/controlling rail bound rolling stock, exclusively within a worksite, shall meet the following requirements.

The driving position controlling the operation of the vehicle/train shall include a driver safety system incorporating the following:

- A Driver suitably qualified to operate the vehicle both on road and as a locomotive on rail
- A Brake Controller compatible with the brake system on the vehicles to be hauled/controlled
- A Vigilance System
- A Second Person
- An Emergency Cock or alternate suitable device for stopping the vehicle in an emergency. This device shall apply the brakes and remove traction power

- An on-board control system that shall not allow the vehicle to power up, move or continue in motion with the driver safety system isolated, except under downgraded and specifically defined operating conditions

Or in the case of Driver Only Operation:

- A Driver suitably qualified to operate the vehicle both on road and as a locomotive on rail
- A Brake Controller compatible with the brake system on the vehicles to be hauled/controlled
- A Vigilance System
- An Operator Enable System
- An Emergency Cock or alternate suitable device for stopping the vehicle in an emergency. This device shall apply the brakes and remove traction power
- An on-board control system that shall not allow the vehicle to power up, move or continue in motion with the driver safety system isolated, except under degraded and specifically defined operating conditions.

Note: Such vehicles shall be fitted with a suitable Air Compressor and Main Reservoir system to meet the duty requirements for a main reservoir and train brake air supply.

5.3.3. Data Logger/Recorder

All vehicles capable of operating above 30 km/hr shall be fitted with a functioning, reliable and accurate data recording device to record at least the following:

- Time
- Speed
- Brake application.

In the case of road-rail vehicles, data shall be recorded when the vehicle is in rail mode only. The system shall meet the requirements of the ONRSR Data loggers code of practice guideline. This guidance material is available via the ONRSR website

5.3.4. Main Reservoir and Brake Pipe Pressure Indication

Each vehicle shall have a means of indicating pressure of main reservoir, brake pipe, spring brake and brake cylinder where applicable. Gauges shall be clearly labelled and calibrated in kPa.

5.3.5. Driver's Emergency Cock

All vehicles fitted with automatic pneumatic brakes shall be fitted with an emergency cock near each driving position. The cock when opened shall directly vent the brake pipe, apply the brakes and remove traction power.

Vehicles not fitted with an automatic pneumatic brake but fitted with spring parking brakes shall be fitted with an emergency cock near each driving position. The emergency cock when opened shall directly vent main reservoir air from the spring parking brakes and remove traction power.

5.3.6. Emergency Equipment

Each infrastructure maintenance vehicle must be equipped as a minimum with working two-way radio communication.

5.3.7. Communications

All self-propelled rolling stock operating on or across the Sydney Metro network must be equipped with radio communication, sufficient to allow radio communications between the operator and the Possession Protection Officer or competent person delegated by the Possession Protection Officer

5.3.8. Headlights and Warning Lights

All infrastructure maintenance vehicles shall be fitted with headlights in accordance with Australian Standards for Railway Rolling Stock, AS 7531-4, Lighting and Rolling Stock Visibility – Infrastructure Maintenance Rolling Stock Section 2, Headlights.

All infrastructure maintenance vehicles shall be fitted with tail and marker lights in accordance with Australian Standards for Railway Rolling Stock, AS 7531-4, Lighting and Rolling Stock Visibility – Infrastructure Maintenance Rolling Stock Section 3, Tail and Marker Lights. Marker lights shall be displayed as follows. In travel mode, white lights shall be lit on the leading (forward) end and red lights lit on the Trailing (rear end). In work mode, white lights shall be lit at both ends of the vehicle/train.

All infrastructure maintenance vehicles shall be fitted with an orange flashing light in accordance with Australian Standards for Railway Rolling Stock, AS 7531-4, Lighting and Rolling Stock Visibility – Infrastructure Maintenance Rolling Stock Section 6, Flashing Beacons. Trolleys and trailers need not display any lights during daylight. When operating at night, in heavy fog, or in tunnels, suitable front and rear lights (e.g. hand lamps) must be displayed.

Trolleys may operate without lights however will receive a condition. Condition requires the Safe Work Method Statement (SWMS) / Work Activity Advice (WAA) or Task Based Risk Assessment (TRA) to appropriately control the trolley not having lights.

5.3.9. Horns

All infrastructure self-propelled maintenance vehicles shall be fitted with an operating horn. Horns shall be used for signalling proposed vehicle movements. Road-rail vehicles shall be fitted with a multi frequency broadband audible warning device to operate when the vehicle is reversing or is about to reverse.

The device tone must be distinct and clearly audible in the working environment where there may be other sources of noise. Vehicles with a maximum speed of 30 km/h or more shall be fitted with a horn that meets the requirements for the low horn as specified in Table 5.

Table 5: Low horn requirements

	Low horn
Speed	Stationary
External location	100 m
External noise limit	85 dB(A) min

Vehicles with a maximum speed of less than 30 km/h shall be fitted with a horn at least equivalent to an automotive horn.

5.3.10. Environmental Requirements

5.3.10.1. Noise and Vibration

All infrastructure maintenance vehicles (including rail bound vehicles) shall be selected to represent the quietest practically available. Start-up inspections shall include checking that all mufflers and noise mitigation devices are in place and operational.

For more general information on construction noise management and assessment please refer to Sydney Metro's Construction Noise and Vibrations Standard.

5.3.10.2. Wastes

Infrastructure maintenance vehicles shall comply with all the requirements of the Protection of the Environment Operations Act 1997 as amended in relation to the discharge, intentional or otherwise, of wastes on the rail corridor.

The accredited RTO/RSO must have a positive means to prevent spillages (for example: fuel, oil or coolant) plus manage, contain and clean-up all environmental incidents resulting from their activities to ensure compliance with all requirements of the Protection of the Environment Operations Act 1997 as amended.

Toilets fitted to infrastructure maintenance vehicles shall be of the chemical type and/or be provided with holding tanks and decanting facilities. The toilet system shall not discharge treated or untreated waste to track.

5.4. Maintenance

The RSO and vehicle owner will ensure rolling stock is maintained in accordance with manufactures requirements, legal duties and in compliance with standards relevant to the rolling stocks type.

6. Related documents and references

Related documents and references

- [SM-18-00058177 Rail Operating Conditions Standard](#)
- [SM-20-00046300 Rolling Stock Acceptance Procedure](#)
- [SM-18-00039121 City & Southwest Rail Safety Accreditation Strategy](#)
- [SM-20-00046218 Application for Rolling Stock Registration Form](#)
- [SM-20-00047229 Rolling stock acceptance – Rolling stock type file note Template](#)
- [SM-20-00046299 Minimum Rolling Stock Requirements Assessment Template](#)
- [SM-20-00047230 Cover Letter for Rolling Stock Acceptance Template](#)
- [SM-20-00046222 Accepted Rolling Stock Register Template](#)
- [SM-17-00000203 Sydney Metro glossary](#)

Note: All documents available on request via TeamBinder

7. Superseded documents

Superseded documents

There are no documents superseded as a result of this document.

8. Document history

Version	Date of approval	Notes
1.0	24 April 2020	New IMS document.
2.0	Xx October 2022	Scheduled review
3.0	19 Dec 2023	Scheduled review – Minor updates

© Sydney Metro 2024

OFFICIAL

Appendix B: Twist Test

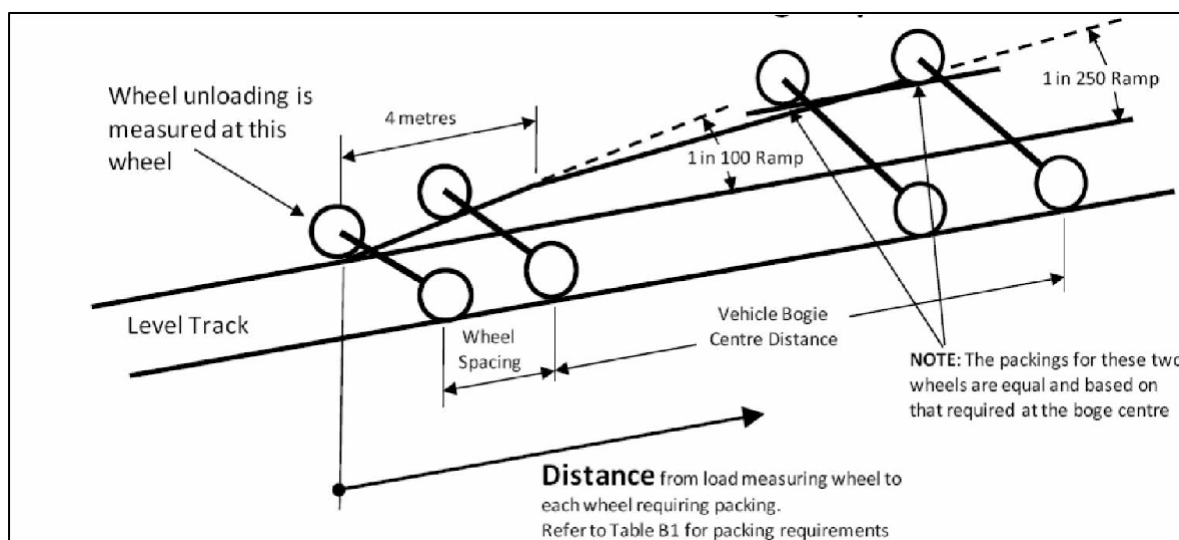


Figure B 1 - Rail Vehicle Twist Test Packaging Requirements

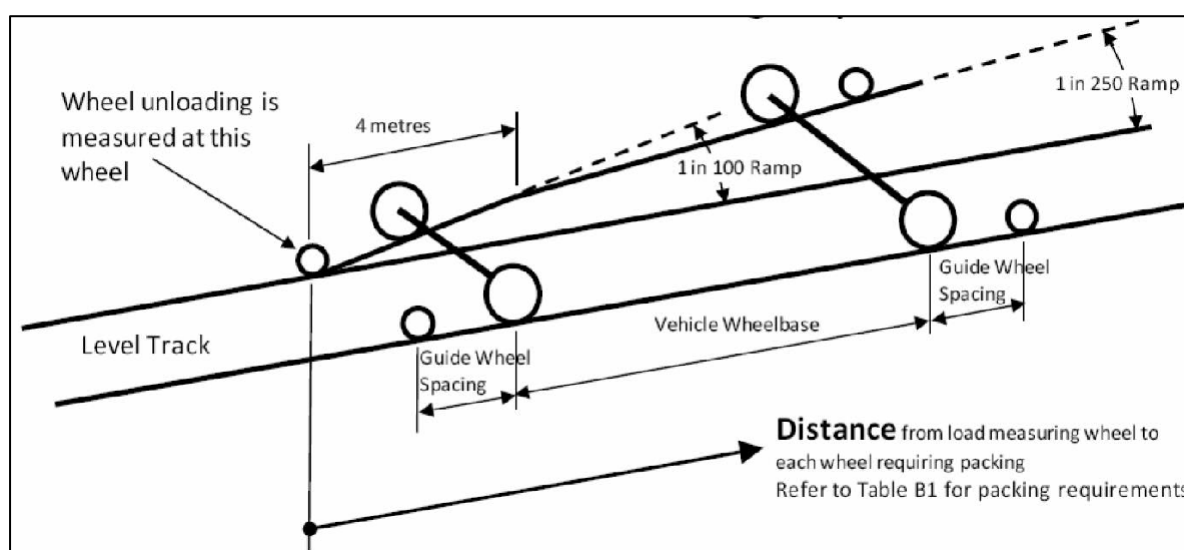


Figure B 2: Rail Vehicle Twist Test Packaging Requirements

Note:

- For wheel packing requirements refer to table B1.
- Where the distance falls between the dimensions shown in the table, round the specified packing thickness up to the next size

Table B 1: Rail Vehicle Twist Test Packing Requirements

Distance	Packing	Distance	Packing	Distance	Packing	Distance	Packing	Distance	Packing	Distance	Packing
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
350	3.5	2550	25.5	4750	43	6950	51.8	9150	60.6	11350	69.4
400	4	2600	26	4800	43.2	7000	52	9200	60.8	11400	69.6
450	4.5	2650	26.5	4850	43.4	7050	52.2	9250	61	11450	69.8
500	5	2700	27	4900	43.6	7100	52.4	9300	61.2	11500	70
550	5.5	2750	27.5	4950	43.8	7150	52.6	9350	61.4	11550	70.2
600	6	2800	28	5000	44	7200	52.8	9400	61.6	11600	70.4
650	6.5	2850	28.5	5050	44.2	7250	53	9450	61.8	11650	70.6
700	7	2900	29	5100	44.4	7300	53.2	9500	62	11700	70.8
750	7.5	2950	29.5	5150	44.6	7350	53.4	9550	62.2	11750	71
800	8	3000	30	5200	44.8	7400	53.6	9600	62.4	11800	71.2
850	8.5	3050	30.5	5250	45	7450	53.8	9650	62.6	11850	71.4
900	9	3100	31	5300	45.2	7500	54	9700	62.8	11900	71.6
950	9.5	3150	31.5	5350	45.4	7550	54.2	9750	63	11950	71.8
1000	10	3200	32	5400	45.6	7600	54.4	9800	63.2	12000	72
1050	10.5	3250	32.5	5450	45.8	7650	54.6	9850	63.4	12050	72.2
1100	11	3300	33	5500	46	7700	54.8	9900	63.6	12100	72.4
1150	11.5	3350	33.5	5550	46.2	7750	55	9950	63.8	12150	72.6
1200	12	3400	34	5600	46.4	7800	55.2	10000	64	12200	72.8
1250	12.5	3450	34.5	5650	46.6	7850	55.4	10050	64.2	12250	73
1300	13	3500	35	5700	46.8	7900	55.6	10100	64.4	12300	73.2
1350	13.5	3550	35.5	5750	47	7950	55.8	10150	64.6	12350	73.4
1400	14	3600	36	5800	47.2	8000	56	10200	64.8	12400	73.6
1450	14.5	3650	36.5	5850	47.4	8050	56.2	10250	65	12450	73.8
1500	15	3700	37	5900	47.6	8100	56.4	10300	65.2	12500	74
1550	15.5	3750	37.5	5950	47.8	8150	56.6	10350	65.4	12550	74.2
1600	16	3800	38	6000	48	8200	56.8	10400	65.6	12600	74.4
1650	16.5	3850	38.5	6050	48.2	8250	57	10450	65.8	12650	74.6
1700	17	3900	39	6100	48.4	8300	57.2	10500	66	12700	74.8
1750	17.5	3950	39.5	6150	48.6	8350	57.4	10550	66.2	12750	75
1800	18	4000	40	6200	48.8	8400	57.6	10600	66.4	12800	75.2
1850	18.5	4050	40.2	6250	49	8450	57.8	10650	66.6	12850	75.4
1900	19	4100	40.4	6300	49.2	8500	58	10700	66.8	12900	75.6
1950	19.5	4150	40.6	6350	49.4	8550	58.2	10750	67	12950	75.8
2000	20	4200	40.8	6400	49.6	8600	58.4	10800	67.2	13000	76
2050	20.5	4250	41	6450	49.8	8650	58.6	10850	67.4	13050	76.2
2100	21	4300	41.2	6500	50	8700	58.8	10900	67.6	13100	76.4
2150	21.5	4350	41.4	6550	50.2	8750	59	10950	67.8	13150	76.6
2200	22	4400	41.6	6600	50.4	8800	59.2	11000	68	13200	76.8
2250	22.5	4450	41.8	6650	50.6	8850	59.4	11050	68.2	13250	77
2300	23	4500	42	6700	50.8	8900	59.6	11100	68.4	13300	77.2
2350	23.5	4550	42.2	6750	51	8950	59.8	11150	68.6	13350	77.4
2400	24	4600	42.4	6800	51.2	9000	60	11200	68.8	13400	77.6
2450	24.5	4650	42.6	6850	51.4	9050	60.2	11250	69	13450	77.8
2500	25	4700	42.8	6900	51.6	9100	60.4	11300	69.2	13500	78

Continued

Distance	Packing	Distance	Packing	Distance	Packing	Distance	Packing	Distance	Packing	Distance	Packing
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
13550	78.2	15750	87	17950	95.8	20150	104.6	22350	113.4	24550	122.2
13600	78.4	15800	87.2	18000	96	20200	104.8	22400	113.6	24600	122.4
13650	78.6	15850	87.4	18050	96.2	20250	105	22450	113.8	24650	122.6
13700	78.8	15900	87.6	18100	96.4	20300	105.2	22500	114	24700	122.8
13750	79	15950	87.8	18150	96.6	20350	105.4	22550	114.2	24750	123
13800	79.2	16000	88	18200	96.8	20400	105.6	22600	114.4	24800	123.2
13850	79.4	16050	88.2	18250	97	20450	105.8	22650	114.6	24850	123.4
13900	79.6	16100	88.4	18300	97.2	20500	106	22700	114.8	24900	123.6
13950	79.8	16150	88.6	18350	97.4	20550	106.2	22750	115	24950	123.8
14000	80	16200	88.8	18400	97.6	20600	106.4	22800	115.2	25000	124
14050	80.2	16250	89	18450	97.8	20650	106.6	22850	115.4	25050	124.2
14100	80.4	16300	89.2	18500	98	20700	106.8	22900	115.6	25100	124.4
14150	80.6	16350	89.4	18550	98.2	20750	107	22950	115.8	25150	124.6
14200	80.8	16400	89.6	18600	98.4	20800	107.2	23000	116	25200	124.8
14250	81	16450	89.8	18650	98.6	20850	107.4	23050	116.2	25250	125
14300	81.2	16500	90	18700	98.8	20900	107.6	23100	116.4	25300	125.2
14350	81.4	16550	90.2	18750	99	20950	107.8	23150	116.6	25350	125.4
14400	81.6	16600	90.4	18800	99.2	21000	108	23200	116.8	25400	125.6
14450	81.8	16650	90.6	18850	99.4	21050	108.2	23250	117	25450	125.8
14500	82	16700	90.8	18900	99.6	21100	108.4	23300	117.2	25500	126
14550	82.2	16750	91	18950	99.8	21150	108.6	23350	117.4	25550	126.2
14600	82.4	16800	91.2	19000	100	21200	108.8	23400	117.6	25600	126.4
14650	82.6	16850	91.4	19050	100.2	21250	109	23450	117.8	25650	126.6
14700	82.8	16900	91.6	19100	100.4	21300	109.2	23500	118	25700	126.8
14750	83	16950	91.8	19150	100.6	21350	109.4	23550	118.2	25750	127
14800	83.2	17000	92	19200	100.8	21400	109.6	23600	118.4	25800	127.2
14850	83.4	17050	92.2	19250	101	21450	109.8	23650	118.6	25850	127.4
14900	83.6	17100	92.4	19300	101.2	21500	110	23700	118.8	25900	127.6
14950	83.8	17150	92.6	19350	101.4	21550	110.2	23750	119	25950	127.8
15000	84	17200	92.8	19400	101.6	21600	110.4	23800	119.2	26000	128
15050	84.2	17250	93	19450	101.8	21650	110.6	23850	119.4	26050	128.2
15100	84.4	17300	93.2	19500	102	21700	110.8	23900	119.6	26100	128.4
15150	84.6	17350	93.4	19550	102.2	21750	111	23950	119.8	26150	128.6
15200	84.8	17400	93.6	19600	102.4	21800	111.2	24000	120	26200	128.8
15250	85	17450	93.8	19650	102.6	21850	111.4	24050	120.2	26250	129
15300	85.2	17500	94	19700	102.8	21900	111.6	24100	120.4	26300	129.2
15350	85.4	17550	94.2	19750	103	21950	111.8	24150	120.6	26350	129.4
15400	85.6	17600	94.4	19800	103.2	22000	112	24200	120.8	26400	129.6
15450	85.8	17650	94.6	19850	103.4	22050	112.2	24250	121	26450	129.8
15500	86	17700	94.8	19900	103.6	22100	112.4	24300	121.2	26500	130
15550	86.2	17750	95	19950	103.8	22150	112.6	24350	121.4	26550	130.2
15600	86.4	17800	95.2	20000	104	22200	112.8	24400	121.6	26600	130.4
15650	86.6	17850	95.4	20050	104.2	22250	113	24450	121.8	26650	130.6
15700	86.8	17900	95.6	20100	104.4	22300	113.2	24500	122	26700	130.8

Appendix C: Example Electricity Danger Zone

