

# Minimum Rolling Stock Requirements Standard for Infrastructure / Construction Vehicles (Southwest Section)

**SM-24-00230239**

## Metro Body of Knowledge (MBoK)

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# 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 the Sydney Metro staff required to determine 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 the 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Accredited Rolling Stock Operator</b>  | 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.                                                                                                                                                                                                                                                                                             |
| <b>Gross Vehicle Mass (GVM)</b>           | This is the maximum your vehicle can weigh when fully loaded as specified by the manufacturer.                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Heavy Self Propelled Vehicles</b>      | A rail vehicle where the braking effort is such that the vehicle cannot achieve the 1.1 m/s <sup>2</sup> deceleration, expected of smaller vehicles (i.e. the vehicle has a braking performance equivalent to that of a locomotive).                                                                                                                                                                                                                                               |
| <b>Height Restrictor</b>                  | 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).                                                                                                                                                                                                                                                                                                                          |
| <b>IMS</b>                                | Integrated Management System (IMS).                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Independent Competent Person</b>       | 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. |
| <b>Infrastructure Maintenance Vehicle</b> | 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).                                                                                                                                                                                                                              |
| <b>MTS</b>                                | Metro Trains Sydney (operator of Sydney Metro Northwest).                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>ONRSR</b>                              | Office of the National Rail Safety Regulator.                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Other RTO rail site</b>                | A rail site managed and controlled by another accredited RTO where the Safety Management System of the other RTO applies.                                                                                                                                                                                                                                                                                                                                                          |
| <b>Rail Bound Plant</b>                   | 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.                                                                                                                                                                                                                                |
| <b>Rail Corridor</b>                      | 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.                                                                                                                                                                                                                                                                                                                       |
| <b>Rail Site</b>                          | A construction site becomes a rail site from the point in time when there is potential for rolling stock to operate.                                                                                                                                                                                                                                                                                                                                                               |
| <b>Rail Traffic</b>                       | Trains, track maintenance, road-rail vehicles and any other rail mounted vehicles.                                                                                                                                                                                                                                                                                                                                                                                                 |

|                                      | Definitions                                                                                                                                                                                                                                                                                                                                             |
|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Road-rail Vehicle</b>             | 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.                                                                                                                                             |
| <b>Rail Transport Operator (RTO)</b> | The following who are accredited by ONRSR as an RTO under the Rail Safety Act 2012: <ul style="list-style-type: none"> <li>○ A Rail Infrastructure Manager (RIM), OR</li> <li>○ A Rolling Stock Operator (RSO), OR</li> <li>○ A person who is both a rail infrastructure manager and a rolling stock operator</li> </ul>                                |
| <b>Rolling Stock</b>                 | Rolling stock is specifically identified as infrastructure maintenance vehicles, plants 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. |
| <b>Rolling Stock Waiver</b>          | 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 is based on sufficient evidence that risk control measures are in place.                                                                                           |
| <b>Safe Approach Distance (SAD)</b>  | 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.                                                                                                                                                                                |
| <b>Train</b>                         | A locomotive or self-propelled vehicle, alone or coupled to one or more vehicles.                                                                                                                                                                                                                                                                       |

### 3. Accountabilities

The Deputy Executive Director – Project Engineering & Design is accountable for this standard, which includes 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 is accountable for specific projects/programs, are accountable for ensuring associated contractors comply with the requirements of this Standard.

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

To be registered for operation on the Sydney Metro network, all vehicles/plants 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 Narrow non-electric outline diagram in Appendix A, also contained in TfNSW TN 005: 20 - ESC 215 Transit Space Version 4.9

If the vehicle exceeds the permitted dimensions, 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 the gauge.

The accredited RSO's responsible for checking the vehicle for compliance and submitting the necessary documented proof of compliance with the application to Sydney Metro for vehicle registration.

### Operation on Sydney Metro

Vehicles that are required to operate on the Sydney Metro Southwest from Sydenham to Bankstown Metro Stations are required to fit within the specific gauge generated via the parameters below. Refer to Appendix A for Narrow non-electric outline

| Parameter                       | Narrow non-electric |
|---------------------------------|---------------------|
| Bogie Centres (mm)              | 16,155              |
| Car Length (over couplers) (mm) | Up to 22,900        |
| Body Overhang (mm)              | 3353                |
| Car Length (mm)                 | 22,861              |
| Nominal Train Length (mm)       | Various             |
| Car Width (mm)                  | 2970                |
| Passenger Doors                 | N/A                 |
| Body Roll Centre (ARL)          | 610                 |

## 4.2. 1 Measured Vehicle Wheel Loads

The maximum permitted wheel loads for operating on the Sydney Metro network must not exceed 10 tonnes (20 tonnes per axle) unless 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 have 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, as locomotives and self-propelled vehicles work 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 that 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 vehicle diagram 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 on 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

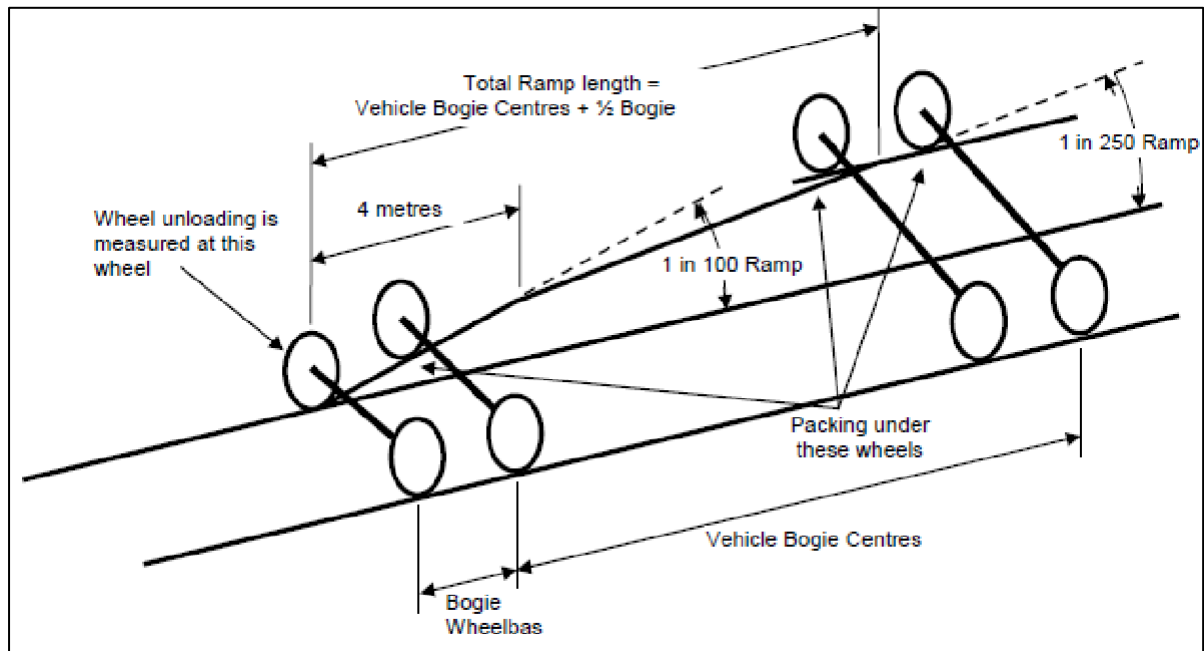


Figure 2: Bogie Vehicle Twist Requirement

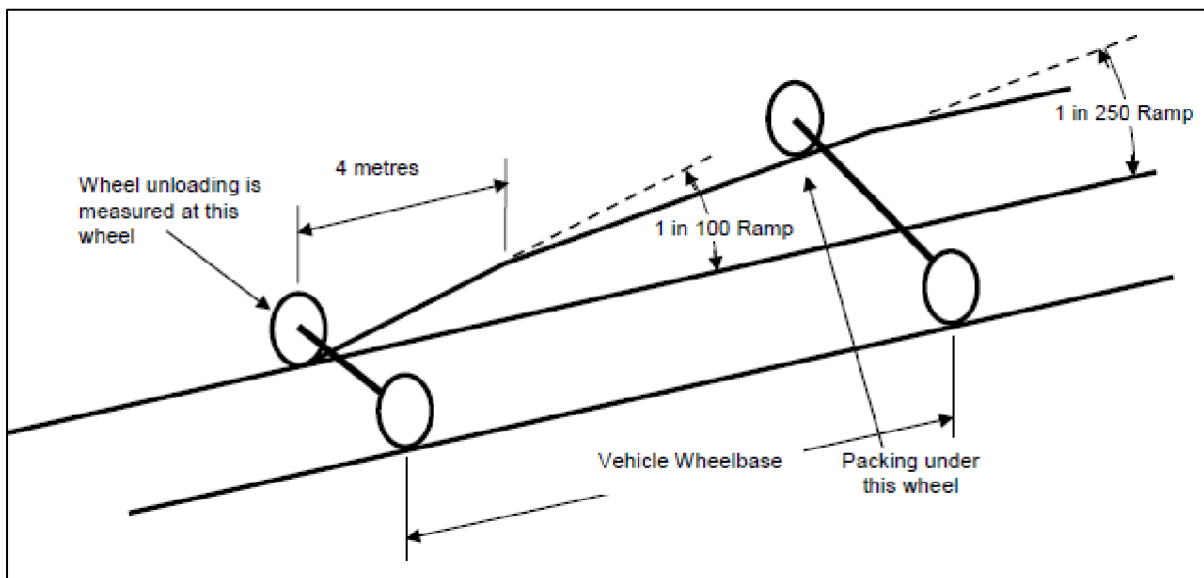
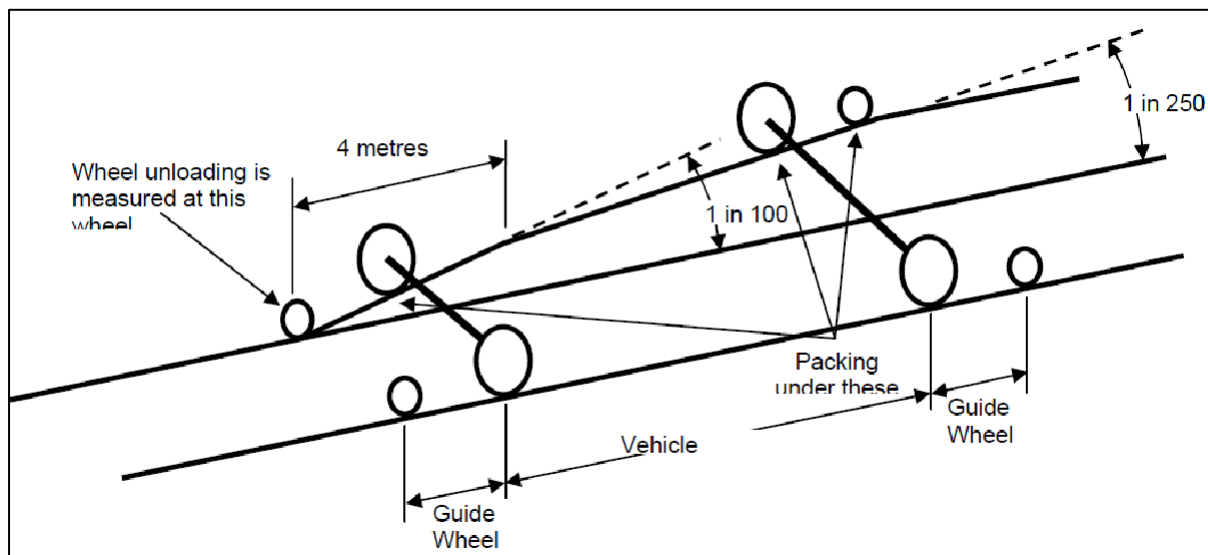


Figure 3: Four Wheel Vehicle Twist Requirements



**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 – Project Engineering & Design 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 sufficient force and release prior to the vehicle being registered to operate on the Sydney Metro network.

The parking or handbrake shall hold the fully loaded vehicle stationary on a grade of 1 in 30 (3.4% or 1.9 degrees) indefinitely.

Sydney Metro gradients can be steeper than those generally found on the Sydney Trains network. An operator should not assume that provisions (notably braking) 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 a conflict is 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 brakes must be released and the vehicle towed unbraked, the vehicle must have a suitably rated tow bar and secondary securing device (e.g. chain).

### 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 30 gradient (minimum one axle) at Gross Vehicle Mass (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 160-metre minimum 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 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), 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 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 160m radius, without transition between the two curves 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 Visibility Test

The Signal 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 from their driving positions. The driver or operator in a normal seated driving position behind the controls shall have a 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 equipment is 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.

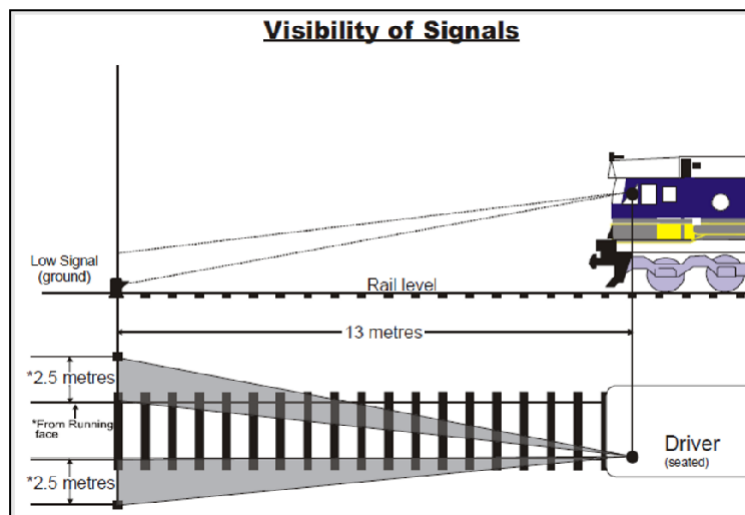


Figure 5: Visibility of Signals

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.

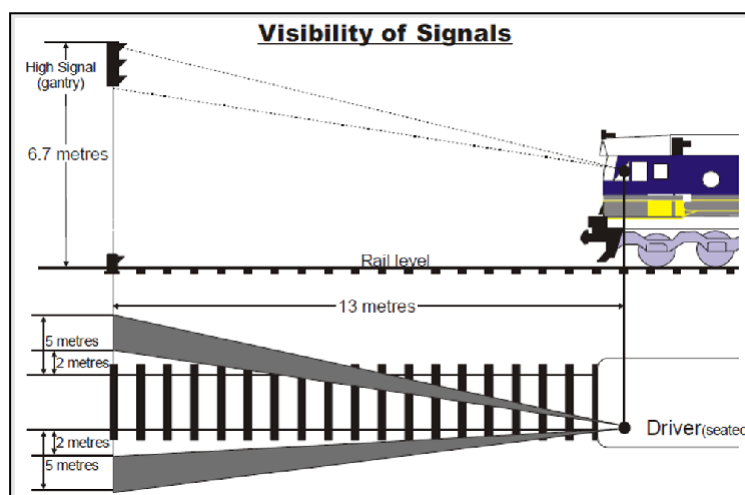
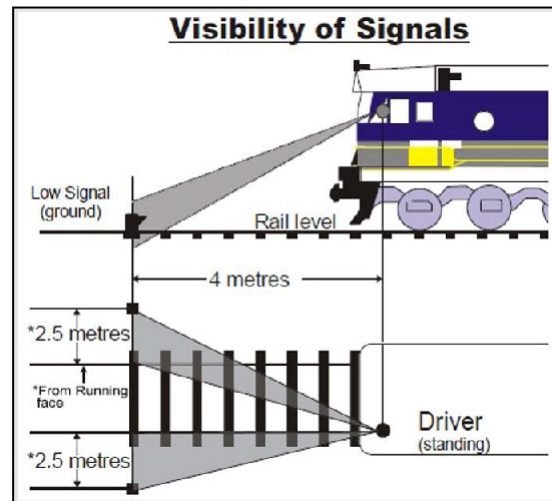


Figure 6: Visibility of Signals

The driver in a standing position behind the controls shall have a 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 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 Northwest 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 to be permitted to 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 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 exclude a temporary vehicle lift when its rail guidance equipment is being deployed or retracted, where it is required to pass over the 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 that have elevating equipment, such as 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 that would infringe on 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 is to be proven as part of the registration approval process.

Infrastructure Maintenance vehicles that 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 that 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

## 4.9. Elevated Work Platform (EWP)

This section applies to elevating work platforms (EWPs), including telehandlers, boom lifts, cherry pickers, and scissor platforms mounted to road/rail vehicles. In addition, this section also applies to EWP vehicles fitted with rail guidance gear.

Some vehicles do not meet the definition of EWPs in accordance with SafeWork NSW for design registration, for example, vertical lifting platforms or vehicles with slide-out side platforms. These vehicles shall be treated as EWPs and meet the EWP engineering, stability and test requirements in this standard.

#### **4.9.1. SafeWork NSW design registration**

All EWPs, with designs completed after 1 September 2001, shall be design registered with SafeWork NSW.

All EWPs shall have their design verified (in accordance with the normal SafeWork NSW design registration process) regardless of the date of the design, or exception status.

The design registration shall be based on the stability tests and reports associated with the testing detailed in this standard and shall be associated with the final vehicle configuration.

#### **4.9.2. Road/rail EWP General requirements**

All Elevated Work Platforms (EWPs) must adhere to the standards outlined in AS/NZS 1418.10. It's important to note that the requirements stated here do not encompass all EWP requirements.

Considerations regarding EWP operation on rail include:

- EWP mounted to road/rail vehicles shall be permanently mounted on the road/rail vehicle in accordance with the base vehicle manufacturer's chassis and subassembly mounting specifications. EWPs chained to flatbed trucks are prohibited from use on the Sydney Metro Network.
- The minimum braking performance of EWPs differs to that of the brake functionality performance detailed in this standard and requires a higher performance.
- The maximum allowable speed of EWPs is lower than those permitted within a Worksite (Sydney Metro Restriction SMR3) and more than likely lower than the base vehicle speed.
- EWPs require additional features to the rail guidance system to provide obstacle deflection for the rail wheels (rail guards) and derailment containment to provide guidance and promote stability in the event of derailment (derailment containment device).
- EWPs with pivoting axles shall be adequately interlocked to ensure stability is maintained for EWP operation and wheel unloading performance is maintained for vehicle travel on rail.
- EWPs shall ensure its operation is restricted if it exceeds the maximum allowable conditions that the EWP can operate on (for example excessive grade or superelevation).
- Static work mode EWPs shall ensure its vehicle travel on rail operation is restricted if the EWP is not locked in the stowed travel position.
- Some aspects of the rail guidance system may require additional features or functions that are required for EWP vehicles. For example, hydraulic cylinders used in rail guidance system or pivoting axle lockouts may require additional features to form part of the EWP load-holding or support system.
- Stability testing is outlined in Section 6 of this document which specifies the minimum fore/aft and side slopes for the network, along with additional stability requirements and operational constraints linked to these parameters.

- When road/rail vehicles operate with the EWP deployed outside the stowed travel position (Mobile Work Mode), they must adhere to twist test requirements and maximum wheel unloading under various loading conditions (including super elevation, grade, and worst-case scenarios). If wheel unloading surpasses set limits, the vehicle must either cease movement or limit EWP operation to ensure compliance. Refer to Section 6 for detailed guidelines.

All testing and design evaluations for multi-gauge vehicles must be conducted in standard gauge configuration.

#### **4.9.3. Travel Mode only (no EWP working)**

Travel mode exclusively refers to the absence of EWP utilization when the vehicle is on rail tracks. EWP operation hasn't been engineered or verified (e.g., stability testing) for rail usage. To employ the EWP, the vehicle must be taken off the rail or supported by stabilizers to lift the wheels off the rail.

This condition is specified in Sydney Metro Restriction SMR63 (AMB Restriction T24). The vehicle must comply with all other provisions of this standard to facilitate travel mode on rail.

#### **4.9.4. Static work mode**

In static work mode, the Elevated Work Platform (EWP) is utilized while the vehicle remains stationary on the rail; any movement with the EWP in operation is prohibited.

The vehicle must pass a stability test following AS/NZS 1418.10 standards, considering maximum grade and superelevation as specified in Section 6.1.1 of this document, without lifting rail wheels.

Note: Lifting of rail wheels during the stability test is not permitted on Sydney Metro Network

The vehicle shall meet all other aspects of this standard to allow travel mode on rail.

The vehicle's interlocking system must ensure that EWP usage is permitted only when the vehicle is stationary and that vehicle movement is allowed solely when the EWP is securely stowed, as indicated in Sydney Metro Restriction SMR64 (AMB Restriction T25).

EWP must comply with Section 6 of this document (Elevating Work Platforms (EWP) requirements).

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

#### **4.9.5. Mobile work mode**

Mobile work mode is defined as EWP use whilst the vehicle is travelling on rail (vehicle in motion with rail wheels rotating).

The vehicle shall undergo a stability test that complies with AS/NZS 1418.10, at the maximum grade and superelevation as outlined in Section 6.1.1 of this document and meet its requirements for static work mode.

Note: Lifting of rail wheels during the stability test is not permitted on Sydney Metro Network

The vehicle shall undergo a twist test at the maximum grade, superelevation, and most unfavourable EWP slew or reach as outlined in Section 6.1.1 of this document and meet its requirements for mobile work mode.

It is expected that the reach or loading (or both) of the EWP will need to be reduced to meet these requirements for mobile work mode compared to the static work mode.

The vehicle shall meet all other aspects of this standard to allow travel mode on rail.

If the EWP has different range or loading conditions for static and mobile work modes, then the vehicle's

interlocking, to only allow vehicle travel when the EWP is restricted to the mobile loads and ranges, shall be confirmed.

For EWP vehicles meeting the mobile work mode requirements are described as EWP in the Sydney Metro Acceptance certificate for the vehicle. No EWP-specific restrictions are associated with this operating condition.

#### **4.9.6. EWP impact on vehicle design**

The addition of an EWP to a road/rail vehicle may impact its design in terms of loading the vehicle chassis, guidance gear, and components in travel and work modes. The loads due to the EWP shall be considered in the vehicle's design, including the maximum worst-case loading of the EWP in any possible loading and position).

ICP assessment is required for all relevant load cases, including offset loadings applied when the EWP is deployed.

This requirement is applicable to all road/rail vehicles fitted with EWPs.

If the requirement in this section is not met, but the vehicle meets Sydney Metro SM-20-00046618 Standard – Minimum Rolling Stock Requirements in all other respects, the vehicle may continue operating on Sydney Metro Network. However, the EWP shall not be used on the rail.

## 5. Vehicle Dynamic Acceptance Criteria

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

### 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 tankvehicles 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 are 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 Sydney Metro vehicle registration application.

## 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.

The vehicle shall be tested on a dry-level track and have an average deceleration within the specified limits. 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.

The measured average deceleration for rail-bound infrastructure maintenance vehicles and road-rail vehicles is shown in Table 2 and Table 3, respectively.

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

|                                     | Tare Condition               | Loaded Condition             |
|-------------------------------------|------------------------------|------------------------------|
| Vehicle with pneumatic brake system | 1.1 m/s <sup>2</sup> minimum | 0.8 m/s <sup>2</sup> minimum |
| Vehicles with trailers              | 1.1 m/s <sup>2</sup> minimum | 0.8 m/s <sup>2</sup> minimum |
| Heavy Self-propelled vehicles       | 0.8 m/s <sup>2</sup> minimum | 0.8 m/s <sup>2</sup> minimum |

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

|                      | Minimum deceleration | Loaded Condition |
|----------------------|----------------------|------------------|
| Steel wheel on rail  | 0.9 m/s <sup>2</sup> | All              |
| Rubber wheel on rail | 1.1 m/s <sup>2</sup> | 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/s<sup>2</sup> 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 a 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 Table 2 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 Table 2 and 3 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 certification or recertification.

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 safety equipment:

- Speed indicator
- Driver safety system (see Clause 5.3.2)
- Data logger/recorder
- Main reservoir and brake pipe pressure indication (where equipment is fitted)
- Driver's emergency cock
- Emergency equipment
- Communications
- Headlights and warning/marker lights (Red/White)
- Horn
- Fit for purpose electrical earthing system 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.

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

- Speed indicator (may not apply to excavators)
- Driver safety system (see Clause 5.3.2)
- Data logger/recorder (for vehicles operating in excess of 30 km/hr on rail)
- Head lights and warning/tail lights
- Horn
- Reversing Squawker (Alarm)
- 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. Speed 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.

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 (kNm) 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 600kNm metres, based on the above formula, shall have a driver safety system incorporating the following:

- A Vigilance system
- An Authorised 2<sup>nd</sup> 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 kNm, 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 degraded 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.

Regarding 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 the pressure of the 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 a 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.

Road Rail vehicles shall comply with Australian Design Rules (ADR) requirements.

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.

#### 5.3.8.1. 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.

#### 5.3.8.2. Reversing Lights and Alarms

All road/rail vehicles with full road registration shall be fitted with a reversing light.

All road/rail vehicles with full road registration shall be fitted with a reverse alarm, which is clearly audible and automatically activated when reverse gear is selected.

Road/rail plant, such as excavators and dump trucks, with restricted operator vision in both forward and reverse directions shall be fitted with a travel alarm, which operates in both directions. Alternatively, two alarms may be fitted.

Travel alarms fitted in road/rail plant shall be activated automatically in both directions.

The alarm's output shall vary in response to changes in the surrounding noise level, (for example, 'Smart Alarm'). The alarm's noise level range shall be 87 dB(A) to 112 dB(A) measured at a distance of 1 m from the vehicle. Self-adjusting type alarms shall be mounted with an unobstructed 'vision' to the rear of the vehicle. Fixed output reverse alarms originally fitted by the equipment manufacturer are acceptable.

### **5.3.9. Environmental Requirements**

#### **5.3.9.1. 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.

#### **5.3.9.2. 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 that rolling stock is maintained in accordance with manufacturer requirements and legal duties and in compliance with standards relevant to the rolling stock type.

## **6. Testing requirements for elevated work platform (EWPs)**

This section covers the stability and wheel unloading requirements of EWP road/rail vehicles. A report shall be prepared which provides evidence of compliance. A copy of this report shall be submitted to SMA as part of document submissions.

### 6.1.1. Stability test for static EWP – static work mode

All EWPs or vehicles fitted with EWPs, both on-track (rail bound) and road/rail vehicles, shall be tested for stability on rail.

Testing shall be in accordance with the requirements in AS/NZS 1418.10.

The test track conditions shall be as follows:

- minimum fore/aft slope shall be 1 in 30 grade (approximately  $\pm 2.0$  degree)
- minimum side slope shall be 160 mm super elevation (approximately  $\pm 6.4$  degrees).

The testing shall include the EWP or specific road/rail vehicle fitted with an EWP on test track conditions, with the EWP loaded in accordance with AS/NZS 1418.10, with the EWP extended and positioned in an arrangement that would give the worst stability.

AS/NZS 1418.10 shall be complied with regarding requirements of additional inclination of the test track in general, additional inclination of the test track based on the type of suspension fitted, and additional testing when using pneumatic tyres.

Note: Consideration should be given to all working positions, such that the vehicle's centre of gravity is closest to the theoretical tipping point. This position may be with the boom fully extended vertically so that the basket load and vehicle's counterweight are on the same side of the rail centreline.

Although the lifting of wheels or stabilisers alone does not indicate a condition of instability, as detailed in AS/NZS 1418.10, the loss of contact between rail and rail wheels during the stability test is considered a test failure.

EWP vehicles that have not carried out a stability test but meet Sydney Metro SM-##-#### Standard - Minimum rolling stock requirements in all other respects may operate on the Sydney Metro Southwest Network; however, the EWP shall not be used on rail.

### 6.1.2. Twist test for mobile EWPs – mobile work mode

The EWP vehicle shall meet the requirements for static work mode in accordance with Section 4.9.2 of this standard.

The mobile EWP twist test is considered a type test that is carried out similarly to the EWP stability type testing. This only applies if all vehicles are the same type (including any base vehicles).

EWP vehicles operating on rail in a mobile work mode shall undergo a twist test in accordance with Section 4.3 of this standard; however, the normal level test track and vehicle travel/loading condition shall be replaced with the following test track and vehicle conditions for each test wheel/corner:

- minimum fore/aft slope shall be 1 in 30 grade (approximately  $\pm 2.0$  degree)
- minimum side slope shall be 160 mm super elevation (approximately  $\pm 6.4$  degrees)
- EWP loaded (per stability testing in AS/NZS 1418.10) and positioned in reach/slew/elevation to minimise test wheel load.

The side slope or superelevation may be reduced from the specified 160 mm so that the combined maximum twist test packing and super elevation packing equate to 160 mm.

For example, a vehicle that requires 40 mm of twist test packing may be tested on a test track with only 120

mm of superelevation (instead of 160 mm) for a total of 160 mm superelevation and twist test packing.

The packing for the fore/aft slope (grade) and the packing for the side slope (superelevation) shall be arranged/oriented to minimise the wheel load on the test wheel.

The EWP shall be loaded in compliance with the test requirement specified in AS/NZS 1418.10 for stability testing, and the EWP shall be extended and positioned (reach, slew, and elevation) in such a position as to minimise the wheel load for the test wheel.

**Note:** Consideration should be given to all working positions, so the vehicle wheel loading is minimised at the test wheel.

The twist test shall then follow as normal with the static wheel load recorded, required track twist profile (packing) applied and wheel unloading measured and assessed in accordance with Section 4.3 of this document. The test is then repeated at all four corners.

**Note:** The mobile EWP twist test closely follows the standard twist test. However the intent of adding grade packing, superelevation packing, and loaded EWP positioning prior to twist testing is to minimise the static wheel load on the test wheel/corner (or wheel of interest).

Wheel unloading performance is at its worst when the static wheel load is minimised and is, therefore, the intent behind the additional grade packing, superelevation packing, and EWP loading/position. The packing orientation may not coincide with expected track curvatures and transitions on the network.

Each test corner/wheel will have associated grade packing, superelevation packing, and loaded EWP position oriented specifically to minimise the static wheel load. In general, it is expected the wheel load is minimised when the test wheel is on the high side for a grade, the high side for superelevation, and loaded EWP is positioned at maximum reach in the opposite direction to the test wheel, although counterbalances may dictate a different position).

Figure 13 illustrates the expected packing (grade and superelevation) and position of the EWP such that the test wheel load is minimised prior to twist testing.

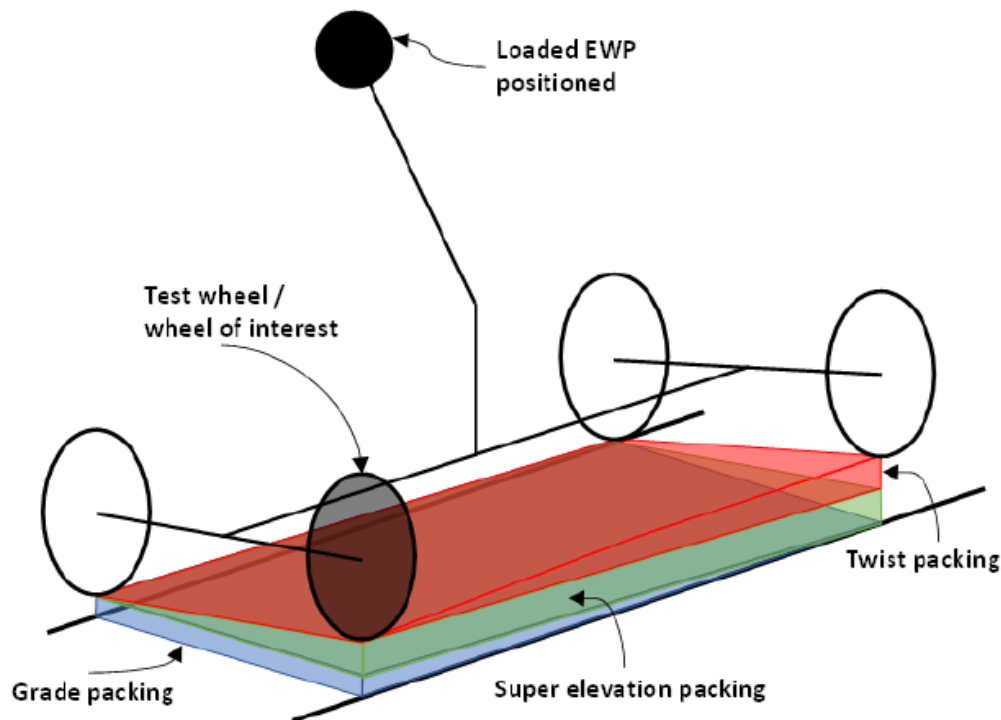


Figure 8 EWP Mobile twist test – Example showing expected packing requirements

### 6.1.3. Infrastructure maintenance vehicles with wireless control

The requirements for any infrastructure maintenance vehicles which utilise wireless communications for control of the vehicle or its work functions are detailed in this section.

Examples of use of wireless systems include remote control of vehicles, control of base vehicle from EWP basket, and control of various moveable elements on vehicles such as cranes.

Australia has a specific regulatory framework regarding telecommunications, radio communications, electromagnetic compatibility (EMC) and electromagnetic energy (EME), which in many instances are not able to be cross accepted from other jurisdictions including Europe.

Refer to AMB standard TS 03948 (T MU MD 81001 ST), which details requirements for wireless communications and directs the suppliers to the ACMA requirements.

If the wireless system does not comply with the regulatory framework set by the ACMA requirements, it cannot be supplied to Australia, and therefore cannot be used on the Sydney Metro network.

Wireless systems shall be fail-safe and bring the vehicle to a stand if there are any issues with communications between the vehicle and controller. These may include signal strength, signal interference or corruption, and malicious interference. For further information refer to IEC 62280.

Wireless systems may operate with a Class License as specified by Radiocommunications (Low Interference Potential Devices) Class Licence 2015 or later. Refer to the ACMA website for further information.

## 7. Vehicles with cranes and lifting attachments

This section applies to all infrastructure maintenance vehicles that are fitted with cranes or capable of lifting loads as either a primary or secondary function (for example, truck-mounted cranes, earthmoving equipment, telehandlers, rail cranes).

Due to the fitment of rail guidance gear and vehicle operation on track geometry and tipping lines, the centre of mass of machines and the resultant working load limits may change from the original base vehicle. This section provides requirements for the stability testing of infrastructure maintenance vehicles capable of lifting loads.

### 7.1. Stability test requirements

This test is considered a type test. This only applies if all vehicles are the same type (including any base vehicles).

To determine the working load limit in rail mode, the vehicle shall undergo a stability test in compliance with the relevant part of AS 1418, on a minimum side slope of 6.4 degrees (superelevation of 160 mm) and grade of 2.0 degrees (1 in 30 grade).

During stability testing, lifting rail wheels during the test is not permitted. This contrasts with the content in AS 1418. As such, the wheel load on the rail wheels may require monitoring during the test.

Multi gauge vehicles shall be tested using standard gauge configuration.

The working load limit may be defined for slewed over the side positions and slewed forward/aft positions.

P/D limits shall be met with the rated load defined in AMB document RSU 120 Section 3.4 for a Track Class 2.

Results of the testing shall be included in the Engineering report.

### 7.2. Marking and identification

Rated capacity charts shall be fitted to the vehicle in the driver's cab (and included in the operations manual).

Rated capacity charts shall display information in accordance with the relevant part of AS 1418.

In addition to the requirements in AS 1418, the following shall also be displayed on the rated capacity chart:

- the rail track gauge relevant to the rated capacity
- the maximum permitted side slope (superelevation) of the rated load
- whether stabilisers require deployment to meet the rated capacity.

### 7.3. SafeWork NSW design registration

Mobile cranes with a rated capacity of greater than 10 tonnes shall have their design verified (in accordance with the normal SafeWork NSW design registration process).

The design registration shall be associated with the final vehicle configuration.

## 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](#)
- [SM-24-00230260 Template - Minimum Rolling Stock Requirements Assessment Template \(Southwest Section\)](#)
- [SM-20-00046618 Standard - Minimum Rolling stock requirements](#)
- [SM-20-00046299 Template - Minimum rolling stock requirements assessment](#)

Note: All SM documents available on request via TeamBinder

Note: All AMB documents available at <https://standards.transport.nsw.gov.au/>

## Superseded documents

### Superseded documents

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

## Document history

| Version   | Date           | Notes                                                                |
|-----------|----------------|----------------------------------------------------------------------|
| Draft 0.1 | 1 May 2024     | Document Draft Steven Mok, Andrew Ho, Andrew Parker, Phil Boyd       |
| Draft 0.2 | 25 June 2024   | Document Final Draft Steven Mok, Andrew Ho, Andrew Parker, Phil Boyd |
| 1.0       | 21 August 2024 | Final approved version                                               |

# Appendix A: Rolling Stock Outline Dimensions

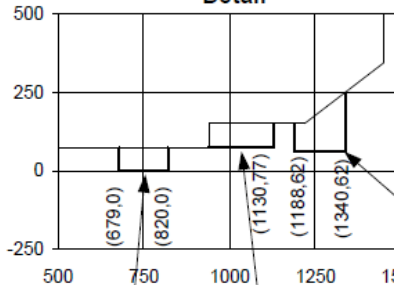
## "Narrow Non-Electric" Rollingstock Outline Dimensions

Bogie Centres: 16155 mm  
Body Overhang: 3353 mm

### Coordinates

| Point | Lateral | Vertical |
|-------|---------|----------|
| A     | 0       | 75       |
| B     | 940     | 75       |
| C     | 940     | 152      |
| D     | 1220    | 152      |
| E     | 1450    | 345      |
| F     | 1450    | 1120     |
| G     | 1485    | 1120     |
| H     | 1485    | 3580     |
| I     | 1250    | 3916     |
| J     | 1065    | 4040     |
| K     | 760     | 4190     |
| L     | 455     | 4270     |
| M     | 0       | 4270     |

### Detail

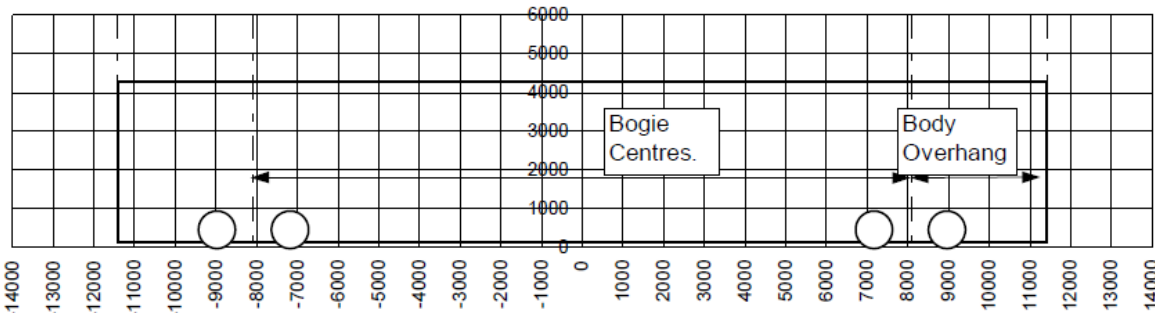
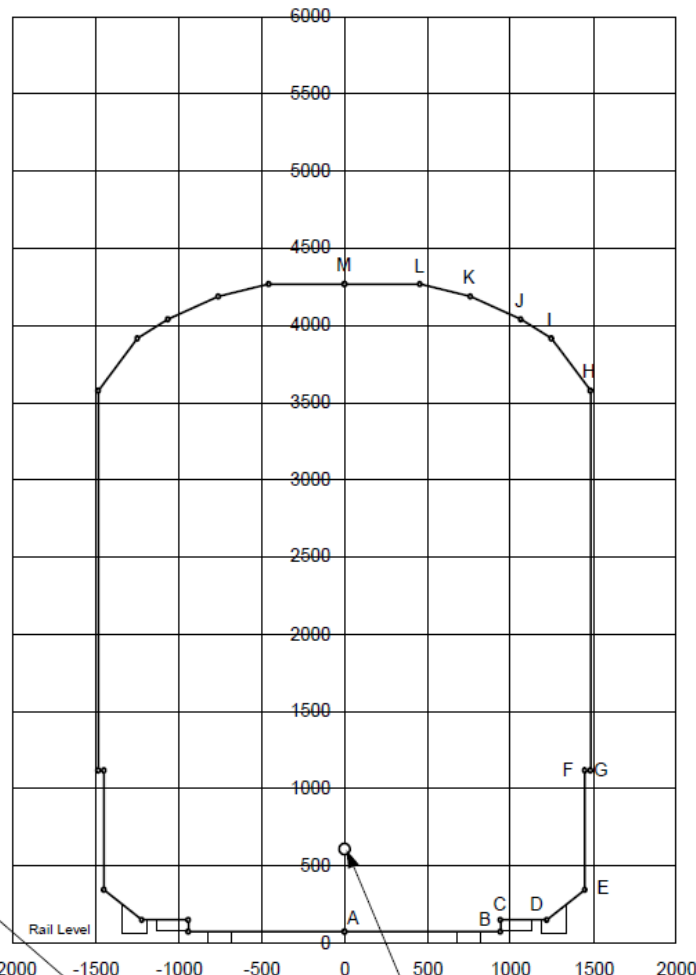


Physical Interface  
for wheels only.

Outline Extension for  
bogie components only.

Physical Interface for  
trip valve arm only.

Roll Centre  
at 610 mm.

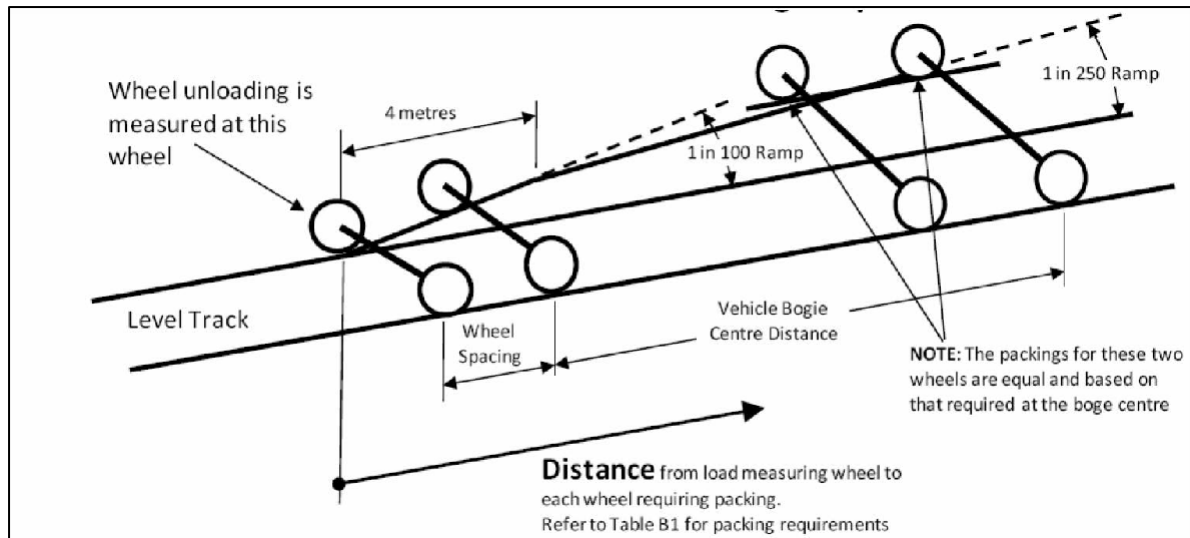


- All cross-section dimensions are symmetrical about the vehicle centreline.
- The origin for all horizontal coordinates is the vehicle centreline.
- The origin for all cross-section vertical coordinates is the rail level.
- The origin for all pantograph vertical coordinates is the contact position with fully worn contact brushes.
- All dimensions are in millimetres.

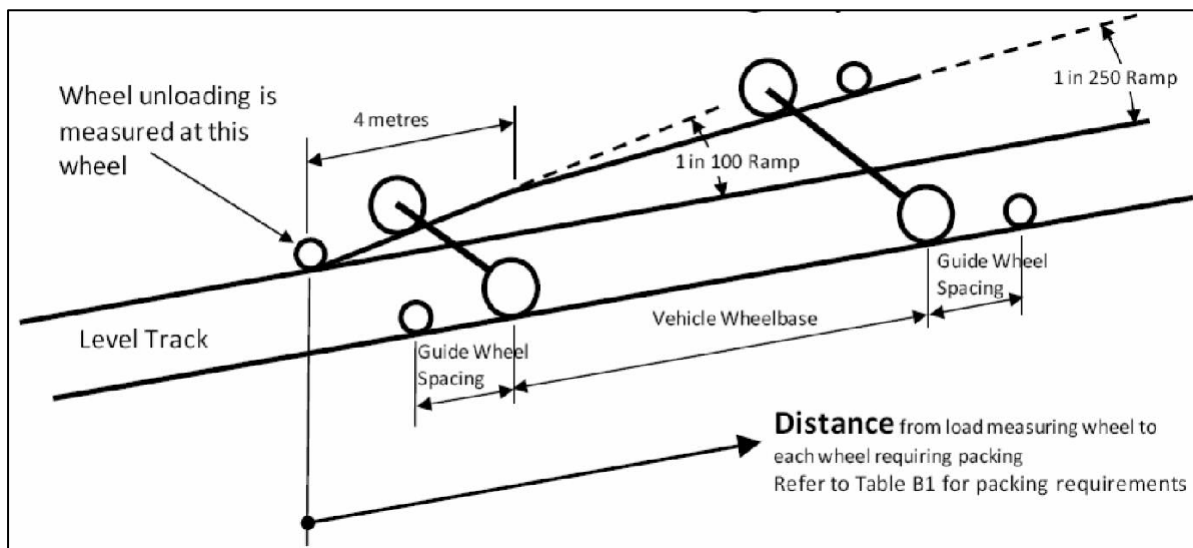
Refer to TfNSW TN 005: 20 - ESC 215 Transit Space Version 4.9

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## 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

