Standard

# Rolling Stock - Tram - Braking Systems

Doc. No.: CE-019-ST-0026
Version: 1.01
Date: 10/09/2020

Keolis Downer

PROUD OPERATOR OF yarra trams

# Table of Contents

# 1 PURPOSE

The purpose of this document is to specify the minimum function, performance and maintenance requirements for the braking systems on the existing Yarra Trams rolling stock fleets.

# 2 SCOPE

The scope of this standard is only the function and performance of braking systems applicable for maintenance and modifications to existing trams.

This standard does not specify requirements for design and procurement of new braking systems or trams.

This standard defines the minimum requirements to support the safe maintenance of the braking systems on existing Yarra Trams rolling stock fleet.

This standard considers the differing age profiles and tram and braking system designs currently in use on the existing Yarra Trams rolling stock fleet, and any changes to the existing trams.

This standard recognises that any previous designs or modifications to a tram system will have been designed to those standards in force at the time of the tram design and manufacture. Some of the existing trams will have been designed to standards no longer in force and possibly no longer available. Accordingly, this standard only documents the known and current function and performance characteristics applicable for maintenance of each existing tram type.

The requirements in this standard are derived from the following sources:

- OEM manuals supplied at the time of manufacture
- Previous upgrades/ modifications undertaken since the time of manufacture
- The original specifications for the trams
- Standards available at the time of design
- Local Subject Matter Expert knowledge

Unless otherwise stated, application of this standard is not retrospective to existing trams that are not being modified.

Any future modifications or enhancements to trams, for example for obsolescence, safety or to improve performance, shall, so far as is reasonably practicable, seek to comply with currently accepted standards.

The design and review process shall comply with requirements of the Yarra Trams ‘Manage Design Procedure’ (CE-021-PR-0006).

# 3 COMPLIANCE

This standard shall be fully complied to when undertaking maintenance or modifications on the existing tram fleets. Deviation from this standard is only permitted when a Waiver has been sought and approved by the Engineering Design Authority at Yarra Trams.

The Yarra Trams Engineering Change Management Procedure (CE-021-PR-0020) shall be followed in all circumstances where change is proposed to the braking systems. For the avoidance of doubt this shall include, but not be limited to:

- An engineering risk assessment in accordance with the Yarra Trams Safety Management System.
- An assessment to determine the appropriate Safety Integrity Level (SIL) for any modification that has electrical/electronic/programmable electronic safety-related systems. The SIL assessment shall comply with International Electrotechnical Commission's (IEC) standard IEC 61508.
- Complying with the requirements of EN 50155 for any modification that has electronic equipment.
- A list of all applicable laws and standards to be complied with for that modification for review and agreement by Yarra Trams Engineering Design Authority.

A compliance schedule shall be completed and returned for any engineering change activities on the braking systems. Assessment of compliance shall be provided for each requirement, defined by one of three permissible responses:

- Compliant;
- Partially Compliant;
- Non-Compliant.

Absolute requirements in this standard are defined within square brackets and a tolerance level as a percentage or range e.g. [AM 4000mm ± 1%. or 3960mm to 4040mm].

Compliance terminology defined in this standard shall be adhered to with the following definitions:

- ‘Shall’ statements are mandatory in the context of compliance with requirements stipulated in this standard.
- ‘Should’ statements are considerations in the context of compliance with requirements stipulated in this standard.
- ‘Information’ statements provide additional content for clarification purposes only and are not requirements in the context of compliance with this standard.
- ‘So far as is reasonably practicable’ statements must at a minimum result in the provision of an engineering risk assessment in accordance with the Yarra Trams Safety Management System and So Far As Is Reasonably (SFAIRP) Guidance Notes (Rail Safety Regulator).

**Note: All standards referred to within this document are correct at the time of writing. It is the responsibility of the user to always ensure the most current version of any standard is referred to when applying any given standard.**

# 4 REQUIREMENTS

## 4.1 Maintenance of Existing Trams

### 4.1.1 Braking Modes and Systems

The fleet of Yarra Trams has an array of braking systems to achieve specified braking modes. The requirements for the current modes and systems and their interdependence are set out in this section.

4.1.1.1 Braking modes dependent on each other or interfacing to other modes shall not affect the operation of other brake sub-systems on failure or loss of any braking mode or sub-system.

4.1.1.2 Trams operating on the Yarra Trams network shall utilise braking modes or functions with the following industry and local terminology:

- **Service Brake:** Braking used normally either under control of the tram driver and / or automatic driving equipment to control the tram's speed.
- **Emergency Brake:** (Also referred to as Hazard Brake on E class) Actuation may be by:
    a. **Driver**
    b. **Passenger**
    c. **System initiated:** When actuated by a vigilance system the term **Safety Brake** may be used. (Also referred to as Force Brake on E class).
- **Holding Brake:** Brake holding a tram stationary with passengers for a defined time and load.
- **Parking Brake:** (Also referred to as fail safe park brake on W class) Brake which can permanently hold a tram with a defined load on a defined gradient.

4.1.1.3 Trams operating on the Yarra Trams network shall utilise braking systems or techniques with the following industry and local terminology:

- **Electro-Dynamic Braking** (Also referred to as Electric Braking) with two types:
    - Rheostatic (when braking current is fed into a resistor)
    - Regenerative (when braking current is returned into the overhead contact wire)
- **Friction Braking:** (Also referred to as Mechanical Braking and Electro-Hydraulic Braking) Braking achieved by the application of brake blocks to the wheel tread or application to brake pad disks. For hydraulic braking, braking effort is generated by spring force regulated by hydraulic fluid pressure.
- **Magnetic Track Brake:** (Also referred to as Electromagnetic Brake and Track Brake) Braking is achieved using the friction between the magnetic shoes and rails.
- **Wheel Slide Protection (WSP):** System to optimise braking performance, and to provide protection against wheel set damage during braking in poor wheel / rail adhesion conditions.
- **Brake blending:** The interaction between two (or more) systems of braking to attain a required level of retardation (Most often used in service braking with the dynamic and friction brakes blended together).
- **Load Control:** The adjustment of the braking force on a brake system in accordance with the load experienced on the tram.
- **Sanding Systems:** The use of sanding equipment to improve the adhesion between wheels and rail during traction and braking.

4.1.1.4 Each braking mode shall use the following systems as tabled below.

*Table 1: Braking Modes and Systems Actuation*

| Braking Modes | Braking Systems | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Actuator | Electro – Dynamic Braking | Friction Brake | Magnetic Track Brake | Wheel-slide protection | Brake blending | Load Control | Sanding Systems |
| Service Brake | Drive/brake controller | Automatic | Automatic | Driver Operated | Automatic | Automatic | Yes | Driver Operated / Automatic |
| Driver Emergency Brake | Drive/brake controller | Automatic | Automatic | Automatic / Optional (Depending on tram class) | Automatic | Automatic | Automatic | Automatic / Driver Operated |
| Passenger Emergency Brake | Door emergency egress | Automatic | Automatic | Automatic / Optional (Depending on tram class) | Automatic | Automatic | Automatic | Automatic / Driver Operated |
| System initiated Emergency Brake | Door (safety) loop circuit / Vigilance monitoring System | Automatic | Automatic | Automatic / Optional (Depending on tram class) | Automatic | Automatic | Automatic | Automatic / Optional |
| Holding Brake | Driver Actuator - Mechanical brake | No | Yes | No | No | No | No | No |
| Parking Brake | Driver Actuator - Spring applied brake | No | Yes | No | No | No | No | No |

**Note:** Section 5 sets out the modes and systems currently in operation for each fleet type.

### 4.1.2 Braking Hierarchy

4.1.2.1 Where available Electro-Dynamic Braking shall be the primary source of braking.

4.1.2.2 Braking modes shall have the following hierarchy:

- Driver's Emergency Brake: This brake mode can override the modes listed below;
- Passengers Emergency Brake: This brake mode can override the modes listed below;
- Door Safety Loop Emergency Brake: This brake mode can override the modes listed below;
- Service Brake. This brake mode can override the modes listed below;
- Hold Brake. This brake mode can override the mode listed below;
- Park brake: This brake system must only be operational in the "Parking", "Sleep" and "Dead" modes.

## 4.2 Modifications to Existing Trams

### 4.2.1 General

4.2.1.1 Any modifications to the tram braking system shall be carefully considered using an engineering risk assessment in accordance with the Yarra Trams Safety Management System.

4.2.1.2 Any modification to tram braking shall require a trial of the modification on a sample of the fleet before full fleet roll out. The method and size of the trial is to be agreed with Yarra Trams Engineering Design Authority.

4.2.1.3 Any modifications to the tram that significantly changes the weight of the tram shall include an engineering risk assessment in accordance with the Yarra Trams Safety Management System and ensure that the braking performance requirements in Section 5 are maintained.

4.2.1.4 Any modification to the braking systems, braking equipment or braking modes shall ensure the performance of the tram after the modification complies with the requirements specified in Section 5 and should comply with EN 13452.

4.2.1.5 Braking system shall be designed such that it fails to safe i.e. the braking system shall bring tram to standstill in a failure scenario.

### 4.2.2 Service Brake

4.2.2.1 The operation of the service brake system shall be under the control of the driver with the following functions:

- Brake the tram in normal service.
- Brake the tram to address line speeds.
- Brake the tram to bring the tram to a standstill.

4.2.2.2 Any modifications to the braking components, settings or configurations shall ensure instantaneous jerk rates for service braking do not exceed 1.2m/s$^2$.

4.2.2.3 Any modifications to the braking components, settings or configurations shall minimise adverse environmental effects (e.g. noise, dust).

### 4.2.3 Emergency and Safety Brake

4.2.3.1 To ensure passenger comfort any modifications to the braking components, settings or configurations shall ensure instantaneous jerk rates for emergency and safety braking do not exceed 1.6m/s$^2$.

4.2.3.2 Emergency braking may include Track Brakes.

4.2.3.3 If the passenger emergency brake activator has been used to initiate the emergency brake system, then it shall not be capable of being released until the tram comes to a standstill.

4.2.3.4 If the driver has initiated the emergency brake system using the traction/brake controller then it shall be possible to cancel the operation of the emergency brake system with the tram in motion using the traction/brake controller.

### 4.2.4 Holding Brake

4.2.4.1 The function of the holding brake shall be to secure the tram with passengers at standstill during a stop in a station and to secure the tram on at least an 8.5% gradient during a hill start.

4.2.4.2 Holding brake must be applied automatically and may be applied by the driver.

4.2.4.3 Tram roll back prevention shall limit roll back against the direction of travel as selected by the driver to not more than 250 mm.

### 4.2.5 Parking Brake

4.2.5.1 The function of a parking brake shall be to permanently hold a crush loaded tram on an 8.5% gradient or steepest gradient on the network.

4.2.5.2 The parking brake system shall hold the tram stationary when the tram is not in power, coast or braking mode as selected by the driver.

### 4.2.6 Electro-Dynamic Brake

4.2.6.1 Regenerating Electro-Dynamic Braking shall have the capability of transferring electrical energy to the overhead contact wire.

4.2.6.2 All modifications shall be designed, so far as is reasonably practicable, to ensure that the Electro-Dynamic Brake system maximises energy recovery.

4.2.6.3 Where dynamic braking cannot be regenerated the electrical energy shall be expelled rheostatically where the braking current is fed into a resistor.

### 4.2.7 Friction Brake

4.2.7.1 All motorised and trailer bogies shall be equipped with a Friction Brake.

4.2.7.2 The Friction Brake sub-system shall continue to operate in the event of a failure of the traction power supply.

4.2.7.3 In the event of a failure of the Electro-Dynamic Brake, the Friction Brake shall take over in the affected bogie(s).

4.2.7.4 Brake blocks and brake pads shall not contain asbestos.

### 4.2.8 Magnetic Track Brake

4.2.8.1 All motorised and trailer bogies shall be equipped with a Magnetic Track Brake.

4.2.8.2 The Magnetic Track Brake shall continue to operate in the event of a failure of the traction power supply for as long as there is power in the battery.

4.2.8.3 The Magnetic Track Brake shall be compatible with the infrastructure so that is does not cause incorrect operation of signaling or any communication systems.

### 4.2.9 Wheel-slide protection

4.2.9.1 Wheel slide protection equipment shall limit the increase in the stopping distance during full service braking under degraded adhesion conditions in relation to the maximum service braking permitted by the adhesion level.

4.2.9.2 The wheel slide protection equipment shall also ensure the absence of any wheel locking when adhesion remains greater than or equal to 6%.

### 4.2.10 Brake blending

4.2.10.1 The function of brake blending, if available, shall be used when two (or more) systems of braking are required to attain a specified level of retardation. This is most common for service braking with dynamic and friction brakes being blended together.

### 4.2.11 Load control

4.2.11.1 The function of load control, if available, shall be maintained to adjust the braking force in accordance with the load, with the objective of maintaining the deceleration rate demand irrespective of load.

### 4.2.12 Sanding

4.2.12.1 To achieve the performance required for service and emergency braking, an improvement of the adhesion between wheels and rails shall be provided by the sanding system.

4.2.12.2 Sanding systems on Yarra Trams rolling stock must comply with the requirements described in Yarra Trams Standard, Rolling Stock - Tram – Sanding Systems (CE-021-ST-0016).

# 5 MAINTENANCE PARAMETERS

*Table 2: Tram class braking parameters (Class W8 to C1)*

| Parameter | | Class W8 | Class Z3 | Class A1 /A2 | Class B1/ B2 | Class C1 |
|---|---|---|---|---|---|---|
| Braking Modes | **Service Brake**[1] | Mechanical brake applied up to a pressure of 40 psi. | Electric brake that operates down to 7 km/h.<br>The mechanical brake then takes over to bring the tram to a standstill. | Electric brake that operates down to 7km/h (10km/h for A2).<br>The mechanical brake then takes over to bring the tram to a standstill. | Electric brake that operates down to 10 km/h.<br>The mechanical brake then takes over to bring the tram to a standstill. | Electric brake that operates down to 3 km/h.<br>The mechanical brake then takes over to bring the tram to a standstill. |
| | **Emergency Brake** | Mechanical braking applied at full air pressure (Greater than 60 psi), Track Brakes and sand.<br>≥ 3.0 m/s$^2$ | Highest level of electric brake down to 7 km/h, Track Brakes and the application of sand.<br>≥ 3.0 m/s$^2$<br>The mechanical brake takes over at 7 km/h. | Highest level of electric brake down to 7km/h (10km/h for A2), Track Brakes and the application of sand.<br>≥ 3.0 m/s$^2$<br>The mechanical brake takes over at 7 km/h (10 km/h for A2). | Highest level of electric brake down to 10 km/h, Track Brakes and the application of sand.<br>≥ 3.0 m/s$^2$<br>The mechanical brake takes over at 10 km/h. | Highest level of electric brake, Track Brakes and the application of sand.<br>≥ 3.0 m/s$^2$ |
| | **Safety Brake** | Mechanical brake applied at a pressure of 40psi and the application of sand.<br>≥ 2.5 m/s$^2$ | Higher level of electric brake down to 7 km/h, Track Brakes and sand.<br>≥ 2.5 m/s$^2$<br>The mechanical brake takes over at 7 km/h. | Higher level of electric brake down to 7 km/h (10 km/h for A2), Track Brakes and sand.<br>≥ 2.5 m/s$^2$<br>The mechanical brake takes over at 7 km/h. | Full service brake, and sand. | Full mechanical braking, Track Brakes and automatic sanding. |
| | **Holding Brake** | Spring applied park brake. | Full mechanical brake is applied at standstill. | Full mechanical brake is applied at standstill. | Full mechanical brake is applied at standstill. | Full mechanical brake is applied at standstill. |
| | **Parking Brake** | Fail safe park brake. | Hold brake acts as park brake.<br>Full mechanical brake is applied at standstill. | Hold brake acts as park brake.<br>Full mechanical brake is applied at standstill. | Hold brake acts as park brake.<br>Full mechanical brake is applied at standstill. | Hold brake acts as park brake.<br>Full mechanical brake is applied at standstill. |
| Brakin | **Electro-Dynamic Brake** | N | Y<br>1.7 m/s² ±0.05 | Y<br>1.6 m/s² ± 0.05 | Y<br>1.55 m/s² ± 0.05 | Y<br>1.5 m/s² ± 0.05 |

[1] **Note:** The transition between electric and friction braking occurs over a small speed range to allow for the build-up of mechanical braking effort. This varies between tram classes.

| Parameter | | Class W8 | Class Z3 | Class A1 /A2 | Class B1/ B2 | Class C1 |
|---|---|---|---|---|---|---|
| | **Friction Brake** | Air applied mechanical wheel tread brake.<br>1.7 m/s² ±0.05 | 2 step disc brake; spring applied, hydraulically released.<br>1.4 m/s² ± 0.1 | A1:<br>2 step disc brake; spring applied, hydraulically released.<br>1.4 m/s² ± 0.1<br>A2:<br>Proportional disc brake, spring applied, hydraulically released<br>1.4 m/s² +0.3,-0.1 | Proportional disc brake, spring applied, hydraulically released.<br>1.5 m/s² ±0.1 | Mechanical disc brake. |
| | **Magnetic Track Brake** | Y<br>Mushroom push button can apply the Track Brakes at any speed. | Y | Y | Y | Y<br>Mushroom push button can apply the Track Brakes at any speed. |
| | **Wheel-slide protection** | Y | Y – on electric brake | A1 –Y on electric brake<br>A2 Y | Y | Y |
| | **Brake blending** | N | Y | Y | Y | Y |
| | **Load Control** | N | N | Y | Y | Y |
| | **Sanding** | Y | Y | Y | Y | Y |
| | **Roll Back detection** | Y | N | N | N | Y |

*Table 3: Tram class braking parameters (Class C2 to E)*

| Parameter | | Class C2 | Class D1 | Class D2 | Class E |
|---|---|---|---|---|---|
| Braking Modes | **Service Brake[2]** | ≥1.5 m/s² | ≥ 1.35 m/s² average<br>≥1.61 m/s² max | ≥ 1.25 m/s² average<br>≥ 1.47 m/s² max | Combination of Dynamic and disc brakes used in normal service operation.<br>Min deceleration of 1.22m/s² @ 40km/hr |
| | **Emergency Brake** | Y<br>≥ 3.0 m/s² | Y<br>≥ 3.0 m/s² | Y<br>≥ 3.0 m/s² | Referred to as Hazard Brake.<br>Emergency Brake with traction braking controller - Combination of dynamic, disc brakes & Track Brakes used in an emergency operation, min deceleration of 2.4m/s² @ 40km/hr.<br>Max ≥ 3.0 m/s² |
| | **Safety Brake** | N/A | N/A | N/A | Referred to as Force Brake.<br>Combination of Dynamic and disc brakes used when braking application is triggered by the tram.<br>Min deceleration of 1.64m/s² @ 40km/hr |
| | **Security Brake** | N/A | N/A | N/A | Mushroom button - A hard wired brake, combination of disc brake and Track Brake.<br>Also drops the lifeguard/body catcher.<br>Min deceleration of 1.86m/s² @ 40km/hr |
| | **Holding Brake** | Y | Y | Y | Does not roll back at standstill or on an incline of 8.5% in any load conditions. |
| | **Parking Brake** | Y | Y | Y | Hold Brake |
| Braking Systems | **Electro-Dynamic Brake** | Y<br>1.5 m/s² ± 0.05 | Y<br>1.61 m/s² ± 0.05 | Y<br>1.47 m/s² ± 0.05 | Y<br>1.4 m/s² ± 0.05 |
| | **Friction Brake** | Y<br>1.0 m/s² ±0.1 | Y | Y | The electro-hydraulic (EH) spring-loaded disc brake system consists of 10 Hydraulic Brake Callipers. These are supplied with oil pressure from four electrically operated Hydraulic Units.<br>Each motor bogie has two Callipers while the trailer bogie has four.<br>The braking force is available in three graduated steps. These are applied according to the amount of braking force applied by the driver. |

[2] Note: The transition between electric and friction braking occurs over a small speed range to allow for the build-up of mechanical braking effort. This varies between tram classes

| Parameter | | Class C2 | Class D1 | Class D2 | Class E |
|---|---|---|---|---|---|
| | | | | | |
| | **Magnetic Track Brake** | Y | Y | Y | Operated by the driver's "Track Brake" button on the armrest, controls the Track Brakes.<br>Min deceleration of 0.65m/s² @ 40km/hr |
| | **Wheel-slide protection** | Y | Y | Y | Y<br>Under all circumstances, the tram will automatically drop sand to assist with regaining traction. |
| | **Brake blending** | Y | Y | Y | Y |
| | **Load Control** | Y | Y | Y | Y |
| | **Sanding** | Y | Y | Y | Y |
| | **Roll Back detection** | Y | Y | Y | Y |

# 6 RELATED LEGISLATION & DOCUMENTS

| Document Number | Name |
|---|---|
| CE-021-PR-0006 | EMS04 Manage Design Procedure |
| CE-021-PR-0020 | EMS06 Engineering Change Management Procedure |
| CE-021-PR-0004 | EMS05 Deviation from Standards Procedure |
| SS-005-MA-0003 | Yarra Trams Safety Management System |
| IEC 61508 | Functional Safety |
| EN 50155 | Railway Applications - Rolling Stock - Electronic Equipment |
| EN 13452-1 | Railway Applications - Braking - Mass Transit Brake Systems - Part 1: Performance Requirements |
| EN 13452-2 | Railway Applications - Braking - Mass Transit Brake Systems - Methods of Test |
| CE-021-ST-0016 | Rolling Stock – Tram – Sanding Systems |

# 7 DOCUMENT VERSION CONTROL

| Version History | Date | Detail |
|---|---|---|
| 1.0 | 17 Mar 2020 | Original approved issue |
| 1.01 | 10 Sep 2020 | Correction of minor typographical errors |

# 8 GLOSSARY

| Term | Definition |
|---|---|
| Actuation | To put a device or machine into mechanical action |
| Crush load | Condition of passenger loading in which passengers are “crushed” against one another |
| Engineering Design Authority | The person or position designated by the Franchisee with the authority to approve engineering design changes, modifications and the TMPs under a system which complies with AS/NZS ISO 9001 Quality Management Systems or similar standard and AS4292 Railway Safety Management as applicable to rolling stock providers. |
| IEC | International Electrotechnical Commission |
| Jerk rate | The rate of change of acceleration or deceleration |
| OEM | Original Equipment Manufacturers |
| SIL | Safety Integrity Level |
| Standstill | The condition where all movement and activity has stopped |

| Term | Definition |
|---|---|
| Stationary | Not moving or movable |
| Waiver | Waiver process as per EMS05 Deviation from Standards Procedure. |
| WSP | Wheel Slide Protection |