NSW GOVERNMENT

NSW Resources Regulator

TECHNICAL REFERENCE GUIDE

BRAKING SYSTEMS ON PLANT USED IN UNDERGROUND TRANSPORT

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Foreword

All mine workers who are transported or work near mobile plant rely on braking systems to work effectively and reliably to ensure a safe work environment. Braking and motion control system are essential in preventing unwanted collisions between mobile plant and fixed objects or pedestrians.

This technical reference guide (TRG) is primarily intended as the principal reference for the design, testing and performance requirements of braking systems used in underground transport for underground coal mines. This TRG is intended to be used by equipment designers and design verifiers for the development and type testing of braking systems when applying for transport braking systems (TBS) design registration in NSW. The information contained within the TRG is also a valuable tool for manufacturers, service/maintenance organisations, users and others concerned with the safe operation of transport vehicles used underground coal mines.

This TRG combines MDG39 – *Handbook for approval assessment of transport braking systems on free-steered vehicles in underground coal mines*, February 2001 and MDG39 – *Amendment No. 1*, December 2006 along with parts related to braking requirements from MDG2 – *Design Guidelines for the Construction of Locomotives*, December 1991.

Note: In NSW, braking systems used on underground transport are required to be registered under the requirements of the Work Health and Safety (Mines and Petroleum Sites) Regulation.

Contents

1. Design and construction

1.1. Scope

This document covers the general requirements applicable for the design, performance and testing requirements of braking systems on transports used in underground coal mines.

1.2. Design

1.2.1. General

All transports (except locomotives) shall be fitted with:

- a service brake system, complying with section 1.3
- a secondary brake system, complying with section 1.4
- a parking brake system, complying with section 1.5, and
- an automatic brake system, complying with 1.6.

Locomotives shall be fitted with a brake system complying with section 1.7.

1.2.2. Brake independence

The braking systems shall be sufficiently independent so that failure of one system will not prevent the operation of the other systems.

1.2.3. Number of wheels braked

Vehicles having a designed maximum operating speed of more than 15 kph, when performing their designed function, shall have the brakes operating on at least 4 wheels or 2 tracks for tracked vehicles.

a) For service brakes on vehicles that operate at speeds greater than 15 kph when performing their designed application shall have independent brake assemblies, mechanically connected to and as close as practicable to the wheelhubs or track drive hubs.

b) For service brakes on vehicles having a transit speed of more than 15 kph but which are normally operated at a speed less than 15 kph when being used for their designed application may have a lesser number of brake assemblies providing that the brakes are permanently interconnected through the drive line components including the vehicle transmission or transfer gearbox.

c) For secondary, parking and automatic brakes, the permanent interconnection of the brake unit(s) through the drive line components including the vehicle transmission or transfer gearbox, meets this requirement.

1.2.4. Holding ability

With the power train disengaged, the service, secondary and park brake systems shall be capable of holding the mobile plant motionless on the maximum operating grade in both the forward and reverse directions.

The maximum operating grade shall not be less than 25% for the purpose of this test.

Brake holding performance tests may be carried out either:

a) at a test site with the specified slope, or

b) on a tilt platform with a slip-resistant surface, or

c) by applying a pulling force to the stationary machine with the brake applied and with the transmission in neutral on a test course with no more than a 1 % slope in the direction of travel. The pulling force shall be applied horizontally near the ground to achieve a minimum force equivalent to the maximum operating grade

For testing as specified in a) and b) above the mobile plant shall be loaded to tare mass plus 120% of the manufacturer's specified payload.

For testing as specified in c) above the following formula shall be used:

$$\text{Force (N)} = mg \sin \tan^{-1}\left(\frac{\beta}{100}\right)$$

$$= mg\left(\frac{\beta}{\sqrt{100^2+\beta^2}}\right)$$

where

β = maximum designed operating grade (%)

m = tare mass plus 120% of payload (kg)

g =9.81 (m/s^2)

1.2.5. Common components

The brake systems may include common components provided that the other requirements for each individual brake contained in this TRG are satisfied and in the event of the failure of any single component, the braking system shall provide vehicle stopping capacity meeting the requirements of section 1.4.3.

Failure of a single component shall not prevent the mobile plant from being held stationary on the maximum operating grade.

1.2.6. Fail to safety

At least the automatic and park brake systems shall fail to safety. Brakes applied by compression springs, on the release of fluid pressure, satisfy this requirement.

1.2.7. Anti-locking

All braking systems should be designed to eliminate, or minimise, as far as practicable, the locking of wheels during brake application.

1.2.8. Stored pressure systems

Power assisted braking shall be capable of operation in the event of engine failure to enable the vehicle to be brought safely to rest. For brakes operated by stored pressure systems, the capacity of the stored pressure shall permit at least 5 applications of the service brakes, after the engine has stopped.

If stored pressure is used to apply the service braking system, then the system shall be fitted with a warning device that activates before the system pressure drops below the greater of 50% of the manufacturers specified maximum operating pressure level or the pressure required to meet the secondary braking requirements. The warning device shall readily attract the operator's attention by providing a continuous visual and audible warning. Gauges indicating pressure or vacuum do not meet this requirement.

or

The automatic brakes shall be applied at the pressure determined to meet the secondary brake performance requirements. (section 1.4.3)

1.2.9. Pressure gauges

Hydraulic or pneumatic, pressure applied, braking systems shall include a pressure gauge clearly marked to indicate the minimum safe brake operating pressure. The gauge shall be easily visible from the operator's seat.

Hydraulic or pneumatic, pressure released (fail-to-safety), braking systems shall include a pressure gauge or a low-pressure indicator, clearly marked to indicate the minimum brake release pressure. The gauge or indicator shall be easily visible from the operator's position.

1.2.10. Enclosure

Mechanical braking assemblies shall be totally enclosed.

NOTE: Liquid cooled brakes are preferred.

1.2.11. Surface temperatures

Mechanical brake assemblies shall be designed to limit surface temperature to a maximum of 150^{o} Celsius under conditions of normal duty cycle operation when tested to the requirements of Appendix E.

1.2.12. Wear indication

A clearly identifiable means of monitoring brake wear and the safe adjustment range should be provided.

1.2.13. Asbestos

Brakes shall not include any asbestos material.

1.2.14. Ancillary components

Interlocks, valves, logic components, associated mechanical devices shall be engineered, to minimise as far as practicable any accidental application, failure or release of any brake, by reason of system, design or component failure.

Notes: examples of avoidable design or component failure include:

a) the design of door hinges with excessive clearance, where doors are interlocked to braking systems
b) the use of pilot operated valves or devices, where direct operated valves are practicable.

1.2.15. Cables

Wire cables shall not be used to apply any part of a braking system.

1.2.16. Fluid power systems

a) Accumulators

Hydraulic accumulators shall be certified in compliance with Australian Standard AS1210 or British Standard BS7201.

Where a hydraulic system incorporates an accumulator the attachment to theaccumulator shall be by means of a minimal length adaptor and flexible hose.

Fittings shall be located or otherwise guarded to provide mechanical protection.

A manual bleed valve shall be fitted to allow pressure relief for maintenance.Fluid should return to tank.

Accumulators shall be securely installed.

A guard shall be installed between accumulators and any personnel within a vehicle. The structure of the vehicle may meet this requirement.

b) Air compressors

Air compressors shall be of a liquid cooled type in accordance with AS3584.

c) Fluid reservoirs

Liquid reservoirs shall be fitted with a robust filler cap that is rated for the maximum pressure in the reservoir system. The cap shall effectively seal the tank from any leakage and be positioned to minimise impact damage in the eventof a vehicle collision.

Reservoirs designed to operate at atmospheric pressure may include capsdesigned for breathing, provided that they include a labyrinth or similar feature tolimit spillage.

Filler caps should be self closing.

d) Hoses

Flexible hoses shall be compatible with the fluid used, maximum system pressure and temperature.

The hose factor of safety shall be a minimum of 4 to 1 based on hose burst pressure to maximum working pressure.

Hydraulic hose shall comply with the provisions of the relevant ISO/SAE standard. The requirementsfor flame resistance shall be in accordance with testing to AS1180.10B and

acceptance to AS2660 or alternately satisfy Schedule 2G of the US Bureau of Mines or comply with type 1 or 3 hose specifications as listed in ISO 6805.

The use of nylon, polyurethane, PVC or similar plastic piping for pneumatic braking control systems will be acceptable only in cases where loss of pressure within these systems cause the system to fail to safety. All such piping shall be adequately protected and shielded from contact with hot and /or sharp surfaces.

Air hoses shall be in accordance with AS2660 unless specified otherwise.

Where hoses are directly attached to a compressor delivery port, they shall be PTFE, steel wire reinforced, braided construction.

e) Pressure vessels

All pressure vessels of capacity greater than 30 litres shall comply with AS1210 -Unfired Pressure Vessels.

Pressure vessels having a capacity of 30 litres or less which do not comply with AS1210 shall comply with at least one of the following;

- AS2971 Serially Produced Pressure Vessels
- SAE.J10 Automotive and Off - Highway Air Brake Reservoir
- Performance and Identification Requirements.

A drain line with a manual valve shall be provided to drain the lowest point of allair receivers. This line and valve should be suitably protected against damage.

f) Filters

Fluid filters shall be fitted to remove contaminants from the fluid system.

1.2.17. Control forces

Control forces shall not be greater than those quoted in Table 1 when achieving the stopping distances required in 1.3.4 (service brakes), 1.4.3 (secondary brakes) and 1.6.4 (automatic brakes).

Table 1 Control forces

Control forces	
Method of activation	**Maximum control force** **N**

Finger grasp	20
Hand grasp: Upwards Downwards Fore-aft Sideways	 400 300 300 300
Foot pedal: End pivoted Centre pivoted	 700 350

1.2.18. Maximum operating grade

The maximum longitudinal operating grade in which:

a) the service and secondary brakes are able to pull up and hold the mobile plant stationary on, and

b) the park brake is able to hold the mobile plant stationary on, at maximum gross vehicle mass (GVM) shall be:

i. stated by the manufacturer

ii. not less than 25% for general purpose mobile plant such as personnel transporters and load haul dumpers (LHDs)

iii. not less than 20% for any other mobile plant

iv. not less than 15% for a particular case and confirmed in writing as safe by the equipment manufacturer or a competent person.

A particular case means required for a once off particular application only.

1.2.19. Integrity of brake controls

The integrity of all braking systems shall be subject to a design risk assessment.

This design risk assessment shall be in the form which systematically analyses the failure modes and integrity of each brake system and associated warning devices.

Note:

1. A failure modes and effects analysis (FMEA), fault tree analysis, quantitative risk assessment, or similar analytical systematic methods are suitable
2. Guidance can be found in AS/NZS 4024.1201 & AS/NZS 4024.1302 and the National Minerals Industry Safety and Health Risk Assessment Guideline

Safety related functions, which keep the transport under control by use of braking systems, must be designed and assessed using the following functional safety standards, as amended from time to time:

(a) For PL – to AS 4024.1503 and AS/NZS 4024.1502; or ISO 13849-1 and ISO 13849-2.
(b) For SIL – to AS 61508.1 or AS 62061.

All safety-related functions identified in 1.2.19 must be tested and validated in accordance with the applicable functional safety standard.

1.2.20. Integrity of components beyond the brake control system

Components that do not form part of a safety related control function must be designed and analysed using failure modes effects analysis, fault tree analysis or other similar methods to determine:

(a) all reasonably foreseeable failure modes and to verify that the required level of reliability has been achieved, and
(b) lifecycle inspection, maintenance, test and discard requirements, as required for lifecycle functionality.

Consideration must be given to fatigue testing or analysis, where applicable.
Note: In order for the transports to come to a stop, components which are servants of the control system or transfer forces to the ground via tyres or track should be designed to perform reliably for the intended operating environment, design loads and period between lifecycle maintenance activities.

1.2.21. Single pilot operated valves

A single line pilot operated control valve shall not be used for the application of dual braking systems, unless it can be reasonably demonstrated that the:

a) required system integrity or category level is determined and maintained, refer section 1.2.19, and
b) probability of failure upon demand of the valve has been established, and
c) valve is installed in accordance with the conditions specified by the valve manufacturer, and
d) there is an appropriate lifecycle maintenance regime specified.

1.2.22. Wheeled towing loads

The maximum (gross) un-braked wheeled towing load shall not exceed the rated payload of the prime mover or 50% of the weight of the prime mover unless additional testing is carried out or the mobile plant is being used for a particular case as specified in writing by the OEM or a competent person. Where additional testing is carried then the braking system shall be tested with the maximum trailer/load combinations and the following shall be specified:

a) Maximum braked towing load.
b) Maximum un-braked towing load.
c) Maximum combination of payload and towing load for the mobile plant.

1.2.23. Trailer labels

All trailers shall be labelled with:

a) The gross weight of the trailer.
b) The unladen or tare weight of the trailer.
c) The safe working load for the trailer (SWL).
d) If brakes are fitted, identification of the braking systems (TBS) to which the trailer can safely attach and the TBS which covers the prime mover – trailer combination.

1.2.24. Slow moving track driven mobile plant

Track driven mobile plant, which transport one or more persons traveling at 4 kph or less shall be fitted with the following:

a) A mechanical braking system that is fail safe and capable of bringing the mobile plant to a controlled stop with the mobile plant traveling at maximum speed down a 1:3 grade.
b) An oil immersed multi disc spring applied brake on each traction drive assembly.
c) An interlock to ensure that traction cannot be energised with the brakes applied.
d) Note: An emergency override of this interlock requirement may be permitted provided its inclusion is justified and that it is not convenient to use it during normal cutting operations.
e) A deadman control to apply the brake(s).

1.3. Service brakes

1.3.1. Brake system recovery

For service brake systems that are pressure applied, the engine speed control shall be set to obtain 75% of the maximum rated engine speed (rpm) or at the mean speed at which the engine normally operates, whichever is the lower.

The service brake system shall be capable of delivering at least 70% of the pressure measured during the first brake application after the service brakes have been fully applied in the following manner:

- 20 times at the rate of six applications per minute.

The upper and lower governed set pressures for brake control systems shall be recorded at the pressure storage vessel.

1.3.2. Hydrostatic braking

1.3.2.1. The only service brake system

Hydrostatic service braking systems are permitted as the only service brake system for skid steer, tracked or other vehicles having a maximum designed road speed of less than 10 kph provided dual traction/braking circuits are used so that the failure of one circuit, including the bursting of a hose, will not prevent the other circuit from acting as a brake. or

Hydrostatic service brake systems are permitted as the only service brake system for skid steer, tracked or other vehicles having a maximum designed road speed of greater than 10 kph, provided that the failure of any part of the system, including the breaking of a hose applies the automatic brakes.

1.3.2.2. Combined with other systems

Vehicles fitted with both hydrostatic and mechanical (friction) brakes, designed to operate together, shall meet the performance requirements of section 1.3.4 for either the hydrostatic braking system or the mechanical friction brake system when operated singularly. The other system must meet the minimum performance requirement of 1.4.3. Mechanical (friction) service brakes are preferred.

1.3.3. Response time

Service braking systems shall be constructed so that the response time between initiation and commencement of braking does not exceed 0.7 seconds (excludes human response time). The braking is considered to have commenced at a deceleration rate of 0.1 g.

Note g = acceleration due to gravity = 9.81 mtrs/sec^2

1.3.4. Stopping distance

The service brakes shall bring the vehicle loaded at its vehicle mass (gross) to rest from maximum achievable speed in both directions of travel in the distance calculated from the following formula, when tested under the conditions nominated in Appendix C & D.

The measured deceleration of the machine shall be greater than the following:

$$a_{\text{brake-test}} = (a_{\text{safe-nett}} + g\,(D\text{-}T))$$

Where

$$D = \frac{\beta}{\sqrt{100^2+\beta^2}}$$

$$T = \frac{a}{\sqrt{100^2+a^2}}$$

$a_{brake\text{-}test}$ = the mean minimum acceptable deceleration for the vehicle when measured alongthe test grade (m/s^2).

g = acceleration due to gravity (m/s^{-2})

β = maximum designed operating grade as a percentage, e.g. β = 25 for a 25% grade

α = test grade as a percentage

$a_{safe\text{-}nett}$ = the mean minimum safe nett deceleration to pull up the machine in the safest andshortest practicable time. (m/s^2).

The minimum $a_{safe\text{-}nett}$ (service brake application when a new machine is type tested) is = 0.75 m/s^2

Where mean decelerations are not measured then the maximum allowable stopping distance shall be based on the following formula:

$$s = \left(\frac{v^2}{25.92\left[a_{safe-nett}+g(D-T)\right]}\right)$$

where

v = machine speed in km/hr

s = stopping distance in metres

Note: For slow moving mobile plant travelling at 10km/hr a pull test to simulate the same energy absorption is considered satisfactory.

1.3.5. Heat and fade

The service brake system when tested under the conditions specified in this section shall be capable of stopping the vehicle five times at intervals between successive stops of not more than 20 minutes and provided that the entire test shall be completed in 40 mins.

The stopping distance of any stop shall not be more than 125% of the stopping distance of the first stop.

The surface temperature of the service brakes shall not exceed 150 ^oC when tested to the requirements of Appendix D.

Note 125% derived from ISO 3450

1.4. Secondary brake

1.4.1. Operation

The secondary brake system may apply automatically on the loss of service brake system pressure or be manually applied by the operator.

1.4.2. Response time

Secondary braking systems shall be so constructed that the response time between initiation and commencement of braking does not exceed 1.0 seconds (excludes human response time). The braking is considered to have commenced at a deceleration rate of 0.1 g.

1.4.3. Stopping distance

The secondary brakes shall bring the vehicle loaded to its vehicle mass (gross) to rest from maximum achievable speed in both directions of travel in the distance calculated from the following formula, when tested under the conditions nominated in Appendix C & D.

The minimum $a_{safe\text{-}nett}$ (service brake application when a new machine is type tested) is = 0.40 m/s^2 when calculated in accordance with the formulae in section 1.3.4.

The secondary brake system shall be tested to simulate the performance condition when the service brake system has failed under the worst-case failure as identified by the risk assessment, refer section 1.2.19. If the secondary brake system forms part of the service brake, then the service brake must be modified and separated from the secondary brake, so that secondary brake system can be operated alone for the test.

Secondary brake performance shall be able to be achieved after the following events occur simultaneously:

i. A failure of the retarder if fitted.

ii. A failure of a single component of the braking system that provides the worst condition for braking as identified by the design risk assessment.

iii. For pressure applied systems:

- After the system pressure reaches alarm level and using only the dedicated fluid reservoir for the brake system being applied, and
- Following five applications of the operator's brake foot pedal.

The secondary system shall have sufficient energy to stop the machine on the maximum operating grade on the sixth application of the foot pedal with one brake circuit disabled.

The pressure prior to the application of the foot pedal shall be the alarm level.

The pressure following the 5th application shall be the minimum pressure to achieve the secondary brake performance. This pressure and the alarm level pressure shall be recorded.

1.4.4. Severity

To ensure minimal risk of injury to personnel within the vehicle, the maximum deceleration rate should not exceed 0.7 g.

1.4.5. Hydrostatic systems

Secondary braking systems shall not utilise hydrostatic braking.

1.4.6. Controls

The secondary brake control shall be clearly identified and readily accessible to the operator.

1.5. Parking brake

1.5.1. Operation

The parking brake system shall apply automatically on the loss of parking brake system pressure (fail to safety).

1.5.2. Common components

The parking braking system may use common components that also form part of other braking systems, provided that the requirements of section 1.2.2 are met.

1.5.3. Hydrostatic systems

Parking brake systems shall not use hydrostatic braking.

1.5.4. Control button

The parking brake control shall be a red button, ≥40 mm in diameter, readily visible which is pushed to apply the brakes. This button shall be located in a position readily accessible to the operator.

Once applied, the brake may only be released by the manual resetting of the brake button (pull). The system shall be arranged so that it cannot be released unless immediate reapplication is possible from the operator's position.

Once applied, the park brake shall not be capable of being released by the operation of controls governing any other function of the vehicle.

Where a control system includes more than one operating button, then all buttons must meet the requirements of this clause.

Personnel carrying vehicles having more than one passenger compartment, shall be fitted with brake operating control buttons in each compartment.

1.5.5. Interlocking

An effective interlock shall be fitted to prevent the vehicle being driven with the park brake applied.

a) *Notes: A brake providing more braking effort than the maximum tractive effortmeets this requirement.*

b) *An interlock disabling the transmission may meet this requirement.*

1.6. Automatic brakes

1.6.1. Operation

The automatic brake system shall fail to safety.

Automatic brakes shall comply with the following:

i. The braking system is designed to be applied at the vehicle speed at the time of application.

ii. The operator is made aware the automatic brakes have applied.

iii. The deceleration rate applied by the automatic application will not cause the vehicle to become out of control.

1.6.2. Common components

The automatic braking system may use common components that also form part of other braking systems, provided that the requirements of clause 1.2.2 are met.

1.6.3. Hydrostatic systems

Automatic brake systems shall not utilise hydrostatic braking.

1.6.4. Stopping distance

The automatic brake shall bring the vehicle loaded to its vehicle mass to rest from maximum achievable speed in both directions of travel in the distance calculated from the following formula, when tested under the conditions nominated in Appendix C & D.

The automatic brake performance shall meet the secondary performance criteria specified in section 1.4.3.

Park brakes shall not be applied automatically at speed unless they are designed dynamically for the speed of the vehicle at the time of application.

1.6.5. Control

Automatic brakes shall apply:

a) whenever the operator leaves the driving position, or

b) whenever the engine is stopped by the operator, or

c) whenever the engine stops for any reason. (e.g. the operation of the automatic engine protection system)

Once applied, the brake may only be released by the manual resetting of the brake.

1.6.6. Response time

Automatic braking systems shall be constructed so that the response time between initiation and commencement of braking does not exceed 1.0 seconds (excludes human response time) for 1.6.5 (a) & (b). The braking is considered to have commenced at a deceleration rate of 0.1 g.

For an engine stoppage as 1.6.5.(c), the response time should not exceed 2.0 seconds from the time the engine ceases rotation.

or,

If the transmission drives the engine while ever the vehicle is moving then the response time between initiation and commencement of braking shall not exceed 3.0 seconds (excludes human response time)

Note: g = acceleration due to gravity = 9.81 mtrs /sec^2

1.6.7. Interlocking

An effective interlock shall be fitted to prevent the vehicle being driven with the automatic brake applied.

Notes (a) A brake providing more braking effort than the tractive effort meets this requirement.

(b) An interlock disabling the transmission may meet this requirement.

1.7. Locomotive traction braking requirements

At least three braking systems shall be available for use on any locomotive. These systems are classified as:

- service brakes - to be used as the primary braking system
- emergency brakes - to be used in the event of a failure of the service brakes
- parking brakes.

1.7.1. Brakes general

A deadman control shall be fitted. This control shall be designed to minimise the possibility of being defeated. When activated the deadman control shall either cut or reset automatically to zero the traction power and apply either the spring applied section of the service brakes where applicable or the emergency brake at a controlled rate. (refer section 1.7.8)

Brake systems may use common components, but any one failure in the common components shall not reduce the capability of the emergency brakes to stop the locomotive safely. '

At least one of the braking systems must be operated by direct mechanical action by the driver. Brakes applied by springs on the release of fluid pressure satisfy this requirement.

All braking systems should be designed to eliminate or minimise so far as practicable, locking of the wheels.

No power-assisted mechanical or fluid systems shall be rendered ineffective by non-rotation of the engine.

Where the operation of a braking system depends on accumulated hydraulic or pneumatic power, the system must include a reservoir capable of sustaining at least five consecutive applications of the brakes

with the power source inoperative. Devices shall be provided to prevent the locomotive or vehicle being moved under its own power unless the braking system is in operating condition.

Hydraulic or pneumatic braking systems shall include a pressure gauge clearly marked to indicate the minimum safe brake operating pressure. The gauge shall be easily visible from the driver's seat. A warning light should also be used to indicate the state of the brake pressure systems.

Hydraulic braking systems shall use approved fire-resistant oil or fluid except where hydrostatic service braking is used, or oil-immersed brakes are used.

The emergency and park brake once applied should require the control to be reset before the breaks may be released.

An effective interlock should be provided to protect against the locomotive being driven with the brakes applied full stop.

All mechanical brakes other than dump shoes or shoes applied directly to the wheels or rail track shall be oil immersed and fully enclosed and shall include a means of limiting maximum surface temperature to less than 150^{o} Celsius.

A clearly identifiable monitoring brake wear and range shall be displayed.

Any braking system relying on adhesion between wheel and track shall have that braking system acting on all wheels.

Service and emergency braking systems shall be so constructed that the response time between initiation and commencement of braking does not exceed 0.7 second. (excludes human response time).

(This may be increased to 1.0 seconds while locomotives are operated and controlled in tandem).

The mechanical brake installations shall be designed so that the same breaking effort can be delivered in both driving directions.

a) For operational service, the loads and speed shall be limited so that an adhesive coefficient of 0.17 during braking will bring the locomotive at its load safely to rest in a safe distance. As a guide, a distance not exceeding 60 metres may be used (assuming steel wheels on steel track).
b) The theoretical maximum possible breaking force shall be less than the theoretical maximum possible adhesive force but by no more than 5%.

Electrical regenerative or hydrostatic braking should be capable of a maximum effective brake force as per the paragraph above.

All mechanical braking systems except service brakes shall fail to safety.

All locomotives utilising pneumatic operated braking systems shall have a compressor and receiver capacity adequate for immediate or future train braking. This requirement does not apply to man cars that are not designed to haul other wheeled loads.

Compressed air operated brake cylinders and systems shall be designed to ensure an adequate service life by including:

a) suitable protective coating of the cylinder walls to prevent corrosion
b) effective an adequate draining of the water from the air system.

Consideration should be given to providing air or hydraulic energy storage for service brake application independently from the requirements of other consuming systems.

Braking systems must be designed to eliminate or minimise so far as practicable, the generation, in any part of the system, of temperatures capable of igniting combustible material likely to be present in the vicinity of that part. Brake blocks and or brake linings must be of a type designed to minimise incendive sparking by frictional contact and shall not contain asbestos.

Locos that normally rely on rail to wheel adhesion but do not have shoe brakes applied directly to the wheels shall be provided with a means of removing any build-up of solid materials which may affect the addition between rail and wheels.

All braking performance requirements shall be verified both by calculation and testing. (see Appendix I)

If brake performance varies with wear, then consideration should be given to design of an automatic adjusting system that maintains braking performance.

Consideration should be given to the installation of a grade and load sensitive speed limiter.

1.7.2. Service brakes

The service brake systems shall consist of either:

a) a full mechanical system or
b) an electric regenerative system in addition to a mechanical system or
c) a hydrostatic system in addition to a mechanical system.

1.7.3. Mechanical service brakes

It is preferred that the mechanical service brake system be a dual circuit such that the failure of one circuit will not prevent the other circuit from acting to apply braking effort. This applies particularly to locomotives with only 1 means of service braking. This provision is not necessary if the dead man brake system automatically applies when pressure to the service brakes fails.

At least one brake actuator shall be provided for each axle.

For locomotives designed for use with captive rail traction systems the mechanical service braking system must be capable of providing effort at least equal. to the maximum tractive effort which the locomotive is capable of developing.

1.7.4. Electric regenerative braking

Electric regenerative braking is permitted providing that it can readily be replaced or supplemented by mechanical service breaking during normal driving.

Automatic application of the regenerative braking during overspeed should be considered, particularly for man cars.

In addition, automatic braking should be considered for locomotives hauling loads where the control system includes a means of compensating for variations in grade.

Before the automatic braking system speed is reached, a warning light should indicate to the driver that he is approaching that speed at which the brakes apply automatically.

A means of detecting wheel slip and correcting automatically should be considered.

1.7.5. Hydrostatic service brakes

Hydrostatic service brakes are permitted provided they can be replaced or supplemented by mechanical service braking during normal driving.

Hydrostatic service braking should be provided with dual circuits such that the failure of one circuit will not prevent the other circuit from acting to apply the respective break.

Hydrostatics service braking shall include adequate factors of safety in the design of the system and components.

Automatic application of the hydrostatic brakes when the locomotive exceeds its safe speed should be considered, particularly for man cars.

In addition, automatic brake application should be considered for locomotive hauling loads where the control system includes a means of compensating for variations in grade.

1.7.6. Emergency brakes

Emergency braking shall operate independently of the adhesion between wheels and track.

- Emergency braking shall meet deceleration criteria as per results of section 1.7.1.
- A satisfactory means of emergency braking includes track dump braking.
- The emergency brake shall remain capable of being applied from any compartment regardless of which drive station has been selected.
- Clearance between dump pod and rail shall be such that contact does not normally occur when negotiating undulating track.

Operation of the emergency brake should be by a large red button readily accessible to the seated driver and to passengers in any other compartment.

1.7.7. Parking brake

A fail to safety park brake shall be provided. The park brake shall keep the locomotive and its maximum permissible load at a standstill on the maximum operable gradient that the loco is designed for.

It must be possible for the park brake to be activated while the locomotive is moving.

The parking brake may use components of the deadman brake, but the means of application must be by a separate control of the operating device.

1.7.8. Deadman brake

The deadman brake shall be fail-to-safety and not require stored fluid pressure energy for its application. (Spring applied brakes may be used).

The deadman brake shall be capable of safely bringing to rest the maximum load on the maximum grade that the loco is designed for.

The deadman valve shall be sufficiently clear off the floor to prevent a build-up of dirt preventing its operation.

The rate of application of the deadman brake shall be such that it doesn't tend to cause the locomotive to skid on unsanded track.

A deadman control shall be provided at each driver's position and shall only be capable of releasing the brakes from the cabin selected for drive control.

2. Marking

2.1. Plates and labels

Labels shall not be manufactured from light metal. Labels shall be permanently fixed and indelibly marked. Engraved or etched and filled stainless steel labels are preferred.

2.2. Compliance plate

A plate giving the following information shall be permanently affixed to each vehicle in an easily seen position.

a) The braking system approval/certification number

b) The name of the manufacturer of the braking system

c) The date of manufacture of the braking system

d) The drawing number, issue number and date of the schematic and arrangement drawing(s)

e) The minimum acceptable mean deceleration rates at speed for the vehicle at tare mass, calculated from type testing, and the maximum acceptable response time, for each of the braking systems.

f) The minimum acceptable mean deceleration rates at speed for the vehicle at tare mass shall be nominated by the manufacturer and may not be less than those required to meet the requirements of 1.3.4, for service brakes and 1.4.3 for secondary brakes and 1.6.4 for automatic brakes.

g) The minimum acceptable peak deceleration rates at speed for the vehicle at tare mass, calculated from type testing, and the maximum acceptable response time, for each of the braking systems.

h) The maximum gross vehicle mass.

i) The maximum gross unbraked towing capacity.

j) The maximum holding grade for the parking brakes.

Notes.

a) The information required above may be included on a general vehicle compliance plate.

b) See table 2 for an example of a compliance plate.

Table 2 Compliance plate example

Braking system compliance plate	
Approval /certification No.	
Manufacturer	
Date of manufacture	
Approval/certification drawing	
Max. (vehicle) gross mass	

Max. (trailer) gross mass				
Minimum acceptable brake performance for in-service testing				
	At speed (km/hr)	Mean deceleration rate (m/s^2)	Peak Deceleration rate (m/s^2)	Response time (s)
Service brakes				
Secondary brakes				
Automatic brakes				
Maximum holding grade (%)				
Parking brakes				

2.3. Specification plate

A plate giving the following information should be permanently affixed to each free-steeredvehicle in an easily seen position.

a) Wear indicator location and meaning (if fitted).
b) Any special oils used in braking systems.
c) Any limitations on use or grade.

Note

The information required above may be included in a general vehicle compliance plate and/or added to table 2 above.

2.4. Warnings

Warning labels shall be fitted as required to each braking system or component, in clearly visiblelocations, to identify hazards which may cause injury to persons.

Example: Labels warning of high hydraulic pressures, stored pressure accumulators and the like.

3. Testing

3.1. Type testing

The following information for each new type and model of braking systems shall be determined.

a) A statement of compliance or variation to each of the clauses of this TRG.

b) Compliance by audit of the braking systems to the documents, including the approval/certification drawing, provided by the manufacturer.

The following testing shall be undertaken for each new type and model of braking system.

Each system shall be tested to the requirements of Appendix D, E and I and the test results reported.

All type testing shall (excluding locomotives) be carried out within 10% or 2km/hr (whichever is the greater) of the maximum attainable speed for the particular loaded test condition.

3.2. Modified components

Where a component within the braking systems is modified, the regulatory authority or certifying body, may, upon request from the manufacturer, allow the component to be tested individually or may require a complete re-test of the vehicle braking systems.

3.3. Routine testing

The integrity of each type tested, approved/certified vehicle braking system shall be confirmed by the braking system manufacturer as complying with the performance established during type testing for approval/certification.

Routine testing shall meet the requirements of Appendix F.

3.4. In-service testing

In-service testing shall be undertaken by the user of any approved/certified braking system. In- service testing shall be undertaken at intervals no greater than that recommended by the manufacturer of the braking systems.

As a minimum, dynamic braking of the mobile plant shall be carried out annually using the formula below.

Mean brake decelerations shall not decrease by more the 125% from those result obtained from the type test result unless the manufacturer has carried out further brake testing to confirm a larger variance is safe to use.

$$a_{\text{brake-test}} = (a_{\text{safe-nett}} + g(D\text{-}T)) \left(\frac{m_{GVM}}{m_{actual}}\right)$$

$$s = \left(\frac{V^2}{25.9[\, a_{safe-nett} + g(D-T)]}\right)\left(\frac{m_{actual}}{m_{GVM}}\right)$$

Where

$\left(\frac{m_{GVM}}{m_{actual}}\right)$ = ratio of gross vehicle mass to actual mass of the machine = 1 for type testing

m_{GVM} = gross vehicle mass of the machine

m_{actual} = actual mass of the machine being tested

The minimum values for $a_{\text{safe-nett}}$ when the machine is being operated in service are:

i. Service brake application = 0.60 m/s2

ii. Secondary brake application = 0.30 m/s2

A guide for the development of in-service testing is provided at Appendix G.

Notes

a) Operating hours based, in-service testing is preferred to calendar intervals.

b) Manufacturers and users should develop testing intervals with regard to the operating conditions at each mine. In-service brake testing should be included in the Standards of Engineering Practice for each mine.

4. Documentation

4.1. General

The designer of the braking system must keep records of the design to fulfil the duties of a designer, to provide ongoing support for the design and provide necessary information to manufacturers, persons conducting testing, end users and regulatory authorities.

Braking system design records should include but, not limited to:

1) A description of the intended purpose of the design.
2) Limitations of use of the design.
3) Circumstances the design should or must not be used.
4) Detailed drawings and Bills of materials.
5) Calculation, analysis, testing and examination reports.
6) Compliance assessment reports.
7) Design verification reports.
8) Arrangement drawings and schematic diagrams.
9) Commissioning checklists or inspection and test plans (ITPs).
10) Safety critical checks, settings and adjustments.
11) Parts and servicing information.
12) Maintenance and repair information.
13) Performance data.
14) Purchaser information.

Much of the above mentioned will be required in the preparation and support of an application for design registration of transport braking systems.

4.2. Arrangement drawings and schematic diagrams

Arrangement drawings and circuit diagrams should include:

a) all part numbers or component specifications
b) hose, pipe or tube sizes where length or bore size may affect performance of the system
c) the maximum vehicle mass and maximum achievable speed of the vehicle for which the braking system has been designed
d) an illustration of the mechanical brakes, noting the highest surface temperature and its location. (see appendix E service brake system performance)
e) a written description of the operation of the braking systems.

4.3. Maintenance, inspection and testing information

Maintenance, inspection and testing information should include:

a) frequency of in-service testing
b) in-service brake testing procedures
c) in-service testing performance limits demonstrating the range of safe braking performance.
d) adjustment procedures for the braking systems

4.4. Purchaser information

The braking system manufacturer should supply, or may be required to supply the following to each purchaser of a braking system:

a) Information regarding the intended use and limitations of use of the design.
b) Notice of registration – transport braking system.
c) Arrangement drawings and schematic circuit diagrams.
d) A certificate of conformance for the braking system to the notice of registration signed by an authorised representative of the design registration holder including any supporting routine test requirements.
e) Plant safety file including any relevant serial numbers of safety critical components and test certificates (e.g. hose pressure test certificates, pressure vessel certificates etc).
f) Details of maintenance and operational requirements, specifications and any other drawings required to maintain the braking system in compliance with this TRG or designers and manufacturers duties.
g) Parts manuals, service manuals and other product related information.

Appendices

Appendix A – References

Definitions

For the purpose of this TRG, the following definitions apply;

Automatic brakes	Brakes which apply automatically.
Braking system	Includes all components which combine to stop or hold the transport.
Light metal	Aluminium, magnesium, titanium or an alloy containing an aggregate of more than 15% by mass of aluminium, magnesium and titanium, or an alloy containing an aggregate of more than 6% by mass of magnesium and titanium.
Mean deceleration, (a)	Average rate of change of the speed of the vehicle from the instant the brake control actuation begins until a full stop is achieved. Mean deceleration may be determined from the formula; $a = \frac{v2}{2s}$ Where: a - is the mean deceleration, in metres per second squared. v - is the speed of the vehicle immediately prior to the brake control being activated, in metres per second. s - is the stopping distance in metres.
Mobile plant	Means plant capable of being driven, moved or relocated under its own power and includes track mounted machines which travel at slow speeds. Vehicle may be taken as reference to mobile plant.

Parking brakes	Used to prevent movement of a stationary vehicle for prolonged periods.
Secondary brakes	A system applied by the operator in the event of a failure of the service brakes.
Service brakes	A system used to stop and momentarily hold a vehicle.
Tare Mass	The tare mass of a vehicle including the heaviest combination of cab, canopy and protective structures (ROPS/FOPS). It also includes components, mountings and equipment which are approved by the vehicle manufacturer, one 120kg operator, full fuel, water, oil and lubricant tanks. For materials, equipment/stores transporters and LHD's the vehicle shall be fitted with the heaviest combination of attachments recommended by the manufacturer. The attachments shall not be loaded. For vehicles designed to haul un-braked trailers, the tare mass shall include the unladen mass of the trailer.
Transport	Transport means mobile plant used for the purpose of transporting persons, materials, coal or stone, whether by carrying, towing or otherwise and includes: (a) a locomotive, or (b) a rubber tyred or tracked vehicles (including a shuttle car) propelled by electrical and/or mechanical means. Note : The following plant is required to have design registered braking systems: Locomotive, shuttle car, Hauler-electric (battery), Load-Haul-Dump, Shearer Carrier, Chock Carrier, Personnel Transporter, Grader/Dozer, Skid-Steered Loader. Note: The plant which do not require transport braking registration is plant which does not carry a person or materials and does not perform its primary function while moving such as:

	Continuous miners, mobile bolting machines, breaker line supports, feeder breakers etc.
Vehicle	A free-steered vehicle, having a maximum speed of more than 4 km/hr, not operating on rails, powered by a diesel engine system or batteries and/or electric motors and driven by wheels or tracks, used for the transportation, handling or manipulation of personnel and/or equipment and/or material. Does not include machines or equipment fitted with tracks or wheels for the purpose of relocation but which do not perform their normal function while moving.
Vehicle Mass (gross)	The operating mass of a vehicle including the heaviest combination of cab, canopy and protective structures (ROPS/FOPS). It also includes components, mountings and equipment which are approved by the vehicle manufacturer, an 120kg operator, full fuel, water, oil and lubricant tanks. For personnel carriers, a mass equivalent to the designed maximum number of persons multiplied by 120 kg shall be added. For materials, equipment/stores transporters and LHD's the vehicle shall be loaded to its' maximum rated payload at the specified axle distribution. For vehicles designed to haul un-braked trailers, the operating mass shall include the mass of the trailer and the maximum rated load of the trailer.

Abbreviations

AS	Australian Standards
AS/NZS	Australian / New Zealand Standard
Km/h	Kilometres per hour
TRG	Technical reference guide
WHS	Work, Health and Safety

Max.	Maximum

Relevant Australian Standards

AS1210	Pressure Vessels
AS2971	Serially produced pressure vessels
AS3584	Diesel engine systems for underground coal mines.
AS/NZS 4024.1201	Safety of machinery - General principles for design - Risk assessment and risk reduction
AS/NZS 4024.1302	Safety of machinery - Risk assessment - Reduction of risks to health from hazardous substances emitted by machinery - Principles and specifications for machinery manufacturers
AS4024.1501	Safety of machinery - Design of safety related parts of control systems - General principles for design
AS4024.1502	Safety of machinery - Design of safety related parts of control systems
AS61508.1	Functional safety of electrical/electronic/programmable electronic safety-related systems - General requirements
AS61508.2	Functional safety of electrical/electronic/programmable electronic safety-related systems -Requirements for electrical/electronic/programmable electronic safety-related systems
AS61508.3	Functional safety of electrical/electronic/programmable electronic safety-related systems - Software requirements
AS61508.4	Functional safety of electrical/electronic/programmable electronic safety-related systems - Definitions and abbreviations

AS61508.5	Functional safety of electrical/electronic/programmable electronic safety-related systems - Examples of methods for the determination of safety integrity levels
AS/NZS 62061	Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems
AS 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
AS/NZS ISO 9000	Quality management systems - Fundamentals and vocabulary
AS/NZS ISO 9001	Quality management systems - Requirements
AS/NZS ISO 9004	Quality management - Quality of an organization - Guidance to achieve sustained success

International Standards

MSHA, 30 CFR part 75	Braking Performance - underground vehicles
CAN/CSA-M424.3-M90	Braking Performance, Rubber tyred self-propelled underground mining machinery.
SAEJ10	Automotive and off-highway air brake reservoir performance and identification requirements
ISO6805	Rubber hose and hose assemblies for underground mining, wire reinforced types for coal mining - specification.

Appendix B Means of demonstrating continued compliance with this TRG

Introduction

A manufacturer or supplier has an obligation to ensure that any braking systems supplied as conforming to this guideline are manufactured to a design that has been type tested and certified/approved as conforming to this guideline. All further braking systems of the type, if tested in accordance with the guideline, shall conform to the requirements of the Handbook.

This appendix sets out the following different means by which compliance with this guideline can be demonstrated by the manufacturer or supplier:

a) The use of a product certification scheme e.g. the certification for electrical explosion protected apparatus.

b) Assurance using the acceptability of the supplier's quality system.

c) Other such means proposed by the manufacturer or supplier and acceptable to the customer.

Supplier's quality system

Where the manufacturer or supplier can demonstrate an audited and registered quality management system complying with the requirements of the appropriate or stipulated Australian or International Standard for a supplier's quality system or systems, this may provide the necessary confidence that the specified requirements will be met. The quality assurance requirements need to be agreed between the customer and supplier and should include a quality or inspection and test plan to ensure product conformity.

Guidance in determining the appropriate quality management system is given in AS/NZS ISO 9001 and AS/NZS 9000.

Other means of assessment

If the above methods are considered inappropriate, determination of compliance with the requirements of this Handbook may be assessed from the results of testing coupled with the manufacturer's guarantee of product conformance.

Irrespective of acceptable quality levels (AQLs) or test frequencies, the responsibility remains with the manufacturer or supplier to supply products that conform with the full requirements of the Handbook.

Appendix C Type testing – test conditions (normative)

Test course

For deceleration tests

The test course on which braking tests are carried out shall have sufficient length to enable them to be carried out safely.

The grade of the test course:

a) at right angles to the direction of travel, shall be not more than three percent from horizontal; and
b) in the direction of travel, shall be not more than one percent from the horizontal.

The surface of the test course shall be hard, reasonably smooth and supported by a well compacted base. A sealed, paved surface is preferred. Surface or ground moisture may be present to the extent that it does not adversely affect braking performance.

Note It is the intent that the test course should provide a co-efficient of adhesion of ≥ 0.95.

For holding tests

A ramp having a 25% grade and surface meeting the requirements of above. or

Equipment to provide sufficient pulling force and a calibrated tension gauge.

Vehicle

Any burnishing of brakes (i.e. conditioning of frictional surfaces before testing), (which is permissible) shall comply with the manufacturer's recommendations.

The physical parameters that affect braking (e.g. tyre size, tyre pressure and brake adjustment) shall comply with the manufacturer's recommendations. Where manual adjustments are made during tests, all tests prior to the adjustments being made shall be repeated.

Operation

Any precautions given by the manufacturer shall be observed.

At the commencement of any test, operating fluids (e.g. engine oil and transmission oil) shall be at normal operating temperatures.

Blades, buckets, dozers and other equipment shall be carried in the transport position recommended by the manufacturer.

Any manually selected gear ratio shall be suitable for the speed of the vehicle just prior to the brake test.

The power train may be disengaged just prior to completing the stop.

Test report

As transparency of testing is of great importance, test report should have a full description of testing including any applicable descriptive drawings and plans. The test report shall include the following:

a) the name of the test organisation and key personnel involved .

b) descriptions of the components/assemblies/vehicle tested.

c) a statement that the test course meets the requirements of this appendix.

Appendix D Type testing – Performance (normative)

Scope

This appendix sets out the procedure for the type testing of braking systems to determine that the performance meets the requirements of this TRG.

Principle

The tests simulate the braking systems being operated under conditions from which an assurance of safe operation conforming to this TRG may be determined.

Apparatus

The testing shall be carried out with instruments meeting the requirements of Appendix G.

Accuracy

The calibration of all measuring instruments shall be traceable to national/international Standards and should be controlled through an accredited Quality Management System to AS/NZS ISO 9001.

Procedure

Normalisation

The free-steered vehicle, loaded to its vehicle mass, shall be operated over a range of speeds and loads for a sufficient length of time to ensure that operational stabilisation hasoccurred and that the temperature of oils, hydraulic fluids and the like have reached normal operating temperatures.

Burnishing

The burnishing (conditioning) of the brakes before testing is permissible. The burnishingprocedures indicated in manuals for the vehicle shall be verified with the manufacturer.

Information to be recorded

For each test, measure and record:

i. The stopping distance (m)
ii. The speed immediately prior to the application of the brakes (km/hr)
iii. The maximum deceleration rate (m/s2)

iv. The mean deceleration rate (m/s2)
v. The response time between the application of the brakes and the beginning of retardation. The beginning of retardation is considered to be 0.1 g.
vi. The operating force applied to the pedal/button/lever by the operator. (N)
vii. Evidence that the minimum stopping distances are achieved with operating forces less than the maximums nominated (see Table 1)

Service brake system - performance

(a) **Forward (at vehicle mass)**
Drive the vehicle, loaded to its vehicle mass, on a test course meeting the requirements of Appendix C at the maximum attainable speed in the forward direction. Apply the servicebrakes. Test.

Test five times with not more than 20 mins between each test. Record the results applying to the longest recorded stopping distance in Table 3.

(b) **Reverse (at vehicle mass)**
Drive the vehicle, loaded to its vehicle mass, on a test course meeting the requirements of Appendix C at the maximum attainable speed in the reverse direction. Apply the service brakes. Test.

Test five times with not more than 20 mins between each test. Record the results applying to the longest recorded stopping distance in Table 3.

(c) **Forward (at tare mass)**
Drive the vehicle, with minimum load (tare), on a test course meeting the requirements of Appendix C at the maximum attainable speed in the forward direction. Apply the servicebrakes. Test

Test five times with not more than 20 mins between each test. Record the results applying to the longest recorded stopping distance in Table 3.

(d) **Reverse (at tare mass)**
Drive the vehicle on a test course, with minimum load (tare), meeting the requirements of Appendix C at the maximum attainable speed in the reverse direction. Apply the servicebrakes. Test

Test five times with not more than 20 mins between each test. Record the results applying to the longest recorded stopping distance in Table 3.

(e) **Holding**
At vehicle mass, drive the vehicle onto a ramp or slope having a grade ≥ 25%.Apply the service brakes. Ensure that the brakes hold the vehicle for a period of not lessthan 5 mins without any further application or re-application of the brakes.

or,

If the above requirement is impractical for test purposes, then the following alternative may be employed. Apply a pulling force to the vehicle with the brake set and with the transmission in neutral under test conditions meeting the requirements of Appendix B. The pulling force shall be applied horizontally near to the ground. The force required shall be calculated as follows:

F = SIN Grade x M x 9.81 where

F = pulling force on the machine in Newtons

Grade = the maximum operating grade in degrees

M = 1.1 X Machine operating mass in kg

Secondary brake

Repeat the tests nominated in service brake system – performance (a) & (c) above. Record the results in Table 3.

Note The secondary brake may be combined in function and/or components with other braking systems in which case, performance must comply with the requirements nominated for each of the systems.

Automatic brake

Repeat the tests nominated in service brake system – performance (a) & (c) above. Record the results in Table 3.

Note The automatic brake may be combined in function and/or components with other braking systems in which case, performance must comply with the requirements nominated for each of the systems.

(a) Drive the vehicle onto a ramp or slope have a grade ≥ 25%. Apply the automatic brakes.Ensure that the brake holds the vehicle.
or,

If the above requirement is impractical for test purposes, then the following alternativemay be employed. Apply a pulling force to the vehicle with the brake set and with the transmission in neutral under test conditions meeting the requirements of Appendix C. The pulling force shall be applied horizontally near to the ground. The force required shall be calculated as follows:

F = SIN Grade x M x 9.81 where

F = pulling force on the machine in NewtonsGrade = the maximum operating grade in degreesM = 1.1 X Machine operating mass in kg

(b) Confirm that each of the possible methods of automatic initiation of the automatic brake meets the requirements of 1.6.5 and 1.6.6 for operation and response time.

Note Pressure gauges or other indicators of correct brake operation may be employedfor this test.

Parking brake

Drive the vehicle at 110% of vehicle mass onto a ramp or slope having a grade ≥ 25%. Apply the park brakes. Ensure that the brake holds the vehicle.

or,

If the above requirement is impractical for test purposes, then the following alternative may be employed. Apply a pulling force to the vehicle with the brake set and with the transmission in neutral under test conditions meeting the requirements of Appendix B. The pulling force shall be applied horizontally near to the ground. The force required shall be calculated as follows:

F = SIN Grade x M x 9.81 where

F = pulling force on the machine in Newtons

Grade = the maximum operating grade in degrees

M = 1.1 X Machine operating mass in kg

Ensure that the Parking Brake holds the vehicle for a minimum period of 5 mins.

Note The parking brake may be combined in function and/or components with other braking systems in which case, performance must comply with the requirements nominated for each of the systems.

Table 3 Braking system test results

Braking system test results						
Manufacturer						
Date of test						
Drawing reference						
Name & model of vehicle						
Brake Performance	**Stop Distance.** (m)	**At speed** (km/hr)	**Max Decel. rate**(m/s^2)	**Mean Decel. rate**(m/s^2)	**Response time** (s)	**Operating force** (N)
Service brakes – forward (at vehicle mass)						
Service brakes – reverse (at vehicle mass)						
Service brakes – forward (at tare mass)						
Service brakes – reverse (at tare mass)						
Secondary brakes (at vehicle mass)						

Secondary brakes (at tare mass)						
Automatic brakes (at vehicle mass)						
Automatic brakes (at tare mass)						

Brakes – holding ability		
Method of test	**Grade (%), or**	**Force (N)**
Service, holds 5 minutes?		
Auto, holds?		
Park, hold 5 minutes?		

Test report

The test report shall include the following:

a) The name of the test organisation.

b) Descriptions of the components/assemblies/vehicle tested, including;

   i. Burnishing procedure (if any)

   ii. Tyres fitted during test (specification)

   iii. Any other information considered relevant by the test organisation which may have affected the test results.

c) The tests carried out.

d) The test results.

e) A statement as to whether or not the tests carried out satisfy this appendix.

Appendix E type testing – temperature (normative)

Scope

This appendix sets out the procedure for the type testing of braking systems for surface temperature and the effects of temperature on brake performance.

Principle

The tests simulate the braking systems being operated under conditions from which an assurance of safe operation conforming to this TRG may be determined.

Apparatus

The testing shall be carried out with instruments meeting the requirements of Appendix H.

Accuracy

The calibration of all measuring instruments shall be traceable to national/international Standards and should be controlled through an accredited Quality Management System to AS/NZS ISO 9001.

Procedure

1) **Normalisation**

The free-steered vehicle, loaded to its vehicle mass, shall be operated over a range of speeds and loads for a sufficient length of time to ensure that operational stabilisation hasoccurred and that the temperature of oils, hydraulic fluids and the like have reached normal operating temperatures.

2) **Burnishing**

The burnishing (conditioning) of the brakes before testing is permissible. The burnishingprocedures indicated in manuals for the vehicle shall be verified with the manufacturer.

3) **Service brake system - performance**

a) For a vehicle designed to be driven primarily in the forward direction, drive the vehicle, loaded to 110% of vehicle mass, on a test course, meeting the requirements of Appendix C at the maximum attainable speed in the forward direction. Apply the service brakes.

Test five times at intervals between successive stops of not more than 20 minutes and provided that the entire test shall be completed in 40 minutes.

For vehicles designed to operate equally in both forward and reverse directions, the tests shall be repeated for the reverse direction.

b) Measure and record:

i. The stopping distance (m)

ii. The speed immediately prior to the application of the brakes (km/hr)

iii. The maximum deceleration rate (m/s^2)

iv. The mean deceleration rate (m/s^2)

v. The highest surface temperature of any part of the braking system. The location of the highest surface temperatures shall be described and added to arrangement drawing(s). (^0C) (see 4.2.1)

vi. The ambient temperature (^0C)

Record the test results at Table 4.

Optical thermal imaging systems should be employed for the measurement of temperatures, providing the instrument is:

a) calibrated

b) corrected for colour temperature

The stopping distance of any stop shall not be more than 125% of the stopping distance of the shortest stop.

The highest surface temperature of the service brakes shall not exceed 150 ^0C.

Table 4 Braking system test results

Braking system test results					
Manufacturer					
Date of test					
Approval / Cert. No. **Drawing**					
Name & model of vehicle					
Ambient temperature					
Brake Performance	**Stop Distance.** (m)	**At speed** (km/hr)	**Decel. rate (max)** (m/s^2)	**Decel. rate (mean)** (m/s^2)	**Highest surface temp.** °C
Test 1					
Location of highest temp					
Test 2					
Location of highest temp					
Test 3					
Location of highest temp					
Test 4					
Location of highest temp					

Test 5					
Location of highest temp					

Test report

The test report shall include the following:

a) The name of the test organisation.

b) Descriptions of the components/assemblies/vehicle tested,

i. including burnishing procedure (if any)

ii. tyres fitted during test (specification)

iii. any other information considered relevant by the testing organisation which may have affected the test results.

c) The tests carried out.

d) The test results.

e) A statement as to whether or not the tests carried out satisfy this appendix.

Appendix F Routine testing (normative)

SCOPE

This appendix sets out the procedure for the routine testing of serially produced approved/certified braking systems as installed in free-steered vehicles.

Principle

The tests indicate that serially produced braking systems provide performance indication within an acceptable tolerance of the results measured by the test organisation during type testing. The tests indicate that the configuration and function of brake controls conform to the design approved/certified.

Apparatus

The testing should be carried out with instruments meeting the requirements of Appendix H.

Accuracy

The calibration of all measuring instruments shall be traceable to national/international Standards and should be controlled through an accredited Quality Management System to AS/NZS ISO 9001.

Procedure

1) **Normalisation**

The free-steered vehicle, at tare mass, shall be operated over a range of speeds and loadsfor a sufficient length of time to ensure that operational stabilisation has occurred and that the temperature of oils, hydraulic fluids and the like have reached normal operatingtemperatures.

2) **Burnishing**

The burnishing (conditioning) of the brakes before testing is permissible. The burnishing procedures indicated in manuals for the vehicle shall be verified with the manufacturer.

3) **Service brake testing**

a) Forward (at tare mass)

Drive the vehicle, with minimum load (tare), on a test course meeting the requirements of Appendix B at the maximum attainable speed in the forward direction. Apply the service brakes. Test

Test three times with not more than 20 mins between each test. Record the results applying to the longest recorded stopping distance in Table 4.

b) Reverse (at tare mass)

Drive the vehicle on a test course, with minimum load (tare), meeting the requirements of Appendix C at the maximum attainable speed in the reverse direction. Apply the service brakes. Test

Test three times with not more than 20 mins between each test. Record the results applying to the longest recorded stopping distance in Table 4.

c) Holding

Drive the vehicle at vehicle mass (gross) onto a ramp or slope having a grade ≥ 25%. Apply the service brakes. Ensure that the brakes hold the vehicle for a period of not less than 5 mins without any further application or re-application of the brakes.

or,

If the above requirement is impractical for test purposes, then the following alternative may be employed. Apply a pulling force to the vehicle with the brake set and with the transmission in neutral under test conditions meeting the requirements of Appendix B. The pulling force shall be applied horizontally near to the ground. The force required shall be calculated as follows:

F = SIN(Grade) x M x 9.81 where

F = pulling force on the machine in Newtons

Grade = the maximum operating grade in degrees

M = 1.1 X Machine operating mass in kg

4) **Secondary brake testing**

Repeat the tests nominated in service brake testing - forward & holding above. Record the results in Table 4.

Note *The secondary brake may be combined in function and/or components with other braking systems in which case, performance must comply with the requirements nominated for each of the systems.*

5) **Automatic brake testing**

a) Repeat the tests nominated in service brake testing - forward and holding above . Record the results in Table 4.

Note *The automatic brake may be combined in function and/or components with other braking systems in which case, performance must comply with the requirements nominated for each of the systems.*

b) Drive the vehicle onto a ramp or slope having a grade ≥ 25%. Apply the automatic brakes. Ensure that the brake holds the vehicle.

or,

If the above requirement is impractical for test purposes, then the following alternativemay be employed. Apply a pulling force to the vehicle with the brake set and with the transmission in neutral under test conditions meeting the requirements of Appendix C.The pulling force shall be applied horizontally near to the ground. The force required shall be calculated as follows:

F = SIN(Grade) x M x 9.81 where

F = pulling force on the machine in Newtons

Grade = the maximum operating grade in degrees

M = 1.1 X Machine operating mass in kg

6) **Parking brake testing**

a) Drive the vehicle at vehicle mass onto a ramp or slope have a grade ≥ 25%. Apply the park brakes. Ensure that the brake holds the vehicle.

or,

If the above requirement is impractical for test purposes, then the following alternative may be employed. Apply a pulling force to the vehicle with the brake set and with the transmission in neutral under test conditions meeting the requirements of Appendix C. The pulling force shall be applied horizontally near to the ground. The force required shall be calculated as follows:

F = SIN(Grade) x M x 9.81 where

F = pulling force on the machine in Newtons

Grade = the maximum operating grade in degrees

M = 1.1 X Machine operating mass in kg

Note The parking brake may be combined in function and/or components with other braking systems in which case, performance must comply with the requirements nominated for each of the systems.

7) **Information to be recorded**

For each test, the measure and record:

i. the speed immediately prior to the application of the brakes (km/hr)

ii. the mean deceleration rate (m/s^2)

iii. the response time between the application of the brakes and the beginning of retardation. The beginning of retardation is considered to be 0.1 g.

iv. the operating force applied to the pedal/button/lever by the operator. (N)

8) **Test report**

The test report shall include the following:

(a) The name of the organisation undertaking the testing, and the name of the person responsible for the testing.

(b) Descriptions of the components/assemblies/vehicle tested, including;

i. The serial number of the vehicle
ii. The date of manufacture and the date of test (may be the same)
iii. Burnishing procedure (if any)
iv. Tyres fitted during test (specification)
v. Any other information considered relevant by the testing organisation which may have effected the test results.

(c) The tests carried out.

(d) The test results.

(e) A statement as to whether or not the tests carried out satisfy this Appendix

Appendix G in-service testing procedure (informative)

Scope

This appendix sets out a procedure for evaluating and monitoring the performance of braking systems fitted to free-steered vehicles, in service. This procedure is a guide only.

Operators of vehicles with approved/certified braking systems should develop unique maintenance and testing procedures within their maintenance management systems to ensure the safe and effective continued operation of braking systems.

Note Users should develop maintenance management systems in consultation with the manufacturer.

Principle

The tests simulate the braking systems being operated under conditions from which an assurance of safe operation conforming to this TRG may be determined.

The test results are compared to the manufacturer's recommendations as noted on the Compliance Plate. (See table 2)

Apparatus

The testing should be carried out with instruments meeting the requirements of Appendix G.

Accuracy

The calibration of all measuring instruments should be traceable to national/international Standards and should be controlled through an accredited Quality Management System to AS/NZS ISO 9001.

Performance

1) **Information to be recorded**

For each test, measure and record:

(i) the speed immediately prior to the application of the brakes (km/hr)
(ii) The mean deceleration rate (m/s^2)
(iii) The peak deceleration rate (m/s^2)
(iv) The response time between the application of the brakes and the beginning of retardation. The beginning of retardation is considered to be 0.1 g.
(v) The operating force applied to the pedal/button/lever by the operator. (N)

Note *The peak deceleration rate is an indicator of the ability of brakes to hold on a grade. A rate of less than 2.8 m/s^2 indicates that the brakes may not hold on a 25% grade.*

2) **Service brakes**

Service brakes shall be tested while the vehicle is unladen, at tare mass, and travelling on a surface and grades as close as practicable to the requirements of Appendix B. at the recommended testing speed for the vehicle, subject to a maximum of 30 kph. Retarders or hydrostatic systems may be used during the test.

Tests should be repeated a minimum of three times and the lowest deceleration rate recorded.

Note: Where a test course is not available, meeting the requirements of Appendix B, then operators should select a test course for in-service testing which will be maintained and consistent for long periods. The results from the same test course may then be used to indicate performance trends which may then be employed within the maintenance management system to predict service/repair requirements. Testing should always be done in the same direction of travel on the test course.

The mean deceleration rate shall not be less than that recommended by the manufacturer and included on the Compliance Label. (see table 2)

Note Decreases in the mean deceleration rate for subsequent in-service tests will indicate a reduction of service brake performance and a requirement for maintenance, service, adjustment or repair.

3) **Secondary and Automatic brakes**

Secondary braking systems shall be tested in accordance with the manufacturer's specification.

4) **Park brakes**

Parking brakes shall be capable of holding the vehicle stationary in a fully loaded condition on the steepest grade that it will encounter in both the forward and the reverse directions, subject to a minimum incline of 25%.

NOTES:

(a) This test should not submit the operator or observers to any danger.
(b) The test can be a live test or a stall test that will apply an equivalent braking force.

Test report

The test report shall include the following:

(a) The name of the organisation undertaking the testing, and the name of the person responsible for the testing.
(b) Descriptions of the components/assemblies/vehicle tested.
(c) The tests carried out.
(d) The test results.
(e) A statement as to whether or not the tests carried out satisfy this appendix.

Appendix H Specification of test instruments (normative)

Scope

This appendix sets out the performance requirements for instruments used in the measurement ofbrake performance parameters.

Brake testing instrument

Any brake testing instrument employed to demonstrate compliance with this TRG shall becalibrated.

Accuracy	± 1.5% g
Repeatability	± 2.0% g
Range	0 - 140% g (g = 9.81 m/s^2)
Pedal force transducer	0 - 2000 N
Calibration	± 0.1% g

General instrumentation

In general terms, the permissible deviations of instruments/sensors/transducers, when combined with power supplies and converters, for engine related parameters shall be as shown in Table 5 (based on ISO 8178-1)

Table 5 General instrumentation parameters

No.	Item	Permissible deviation	
		based on maxvalues	Repeatability
1	Mass	+/- 2 %	+/- 1 %
2	Power	+/- 4 % (calc)	+/- 2 %
3	Temp (surface)	+/- 2 K	+/- 0.5 K
4	Force	+/- 4%	+/- 2%
5	Oil temp	+/- 2 K	+/- 0.5 K
6	Ambient temperature	+/- 2 K	+/- 1 K
7	Atmospheric pressure	+/- 1 %	+/- 0.5 %
8	Relative humidity	+/- 2 %	+/- 0.5 %

Appendix I locomotives brake performance verification

The performance of all brake systems shall be verified by both calculations and by practical tests as follows.

Calculations should include those leading to:

1) available braking force assuming an adhesion coefficient of 0.17
2) maximum possible adhesive braking force - best conditions
3) maximum possible braking force that the brakes can apply.

Practical tests

These tests require use of a suitable automatic device to monitor brake response time and to coordinate this with actual loco retardation relative to the track. This requires the use of a separate non braked wheel applied to the track but supported by the loco to ensure that any skidding is catered for.

Test results will include:

1) Brake system response time from each driver's compartment and also for tandem operation.
2) Average deceleration.
3) Maximum deceleration.
4) Operation of the interlock which prevents a loco being driven with the brakes applied.
5) Operation of the automatic brake systems where fitted.
6) Maximum surface temperature of brakes (for oil immersed type brakes only) NOTE this may require a non-braked load to be applied to increase the load on the braking system.
7) Number of effective brake operations that can be achieved from any stored energy system, where fitted.
8) Ability of brake system to defeat the maximum tractive effort of the loco (requires temporary defeat of interlock).
9) All brake tests are to be conducted with and without the sanders operating.
10) Level track is preferred but results can be corrected if necessary, to allow for some grade.
11) Tests should be conducted with both the loco loaded and unloaded.
12) Check to ensure that operation of the service brake doesn't interfere with the operation of the dump brake.
13) Brake tests should be conducted in both directions and repeated. The suggested number of operations is at least 3 service, 3 dump brake tests and 1 deadman brake test in each direction.
14) Variations to this test procedure are permitted subject approval by the Resources Regulator.