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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 269, *Railway applications*, Subcommittee SC 2, *Rolling stock*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Railway applications — Braking system — General requirements

1 Scope

This document specifies the general requirements for brake systems. This document focuses on general principles and general requirements of brake systems.

This document is applicable for all types of rolling stock during design and whole lifetime. This document does not specify the braking performance criteria.

This document can be applied to all rolling stock with metal to metal wheel/rail contact irrespective of speed classification.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4975, *Railway applications — Braking system — Quality of compressed air for pneumatic apparatus and systems*

ISO 10516, *Railway application — Vehicle reference masses*[1)]

ISO 20138 (all parts), *Railway applications — Calculation of braking performance (stopping, slowing and stationary braking)*

ISO 24478:2023, *Railway applications — Braking — Generic vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 24478, ISO 20138-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
general operation
mode of operation of units intended to be coupled with other units in a train formation which is not defined at design stage

3.2
assessment
process of judging or deciding the amount, value, quality or importance of something

3.3
testing
process of using or trying something to see if it works, is suitable or obeys the rules

1) Under preparation. Stage at the time of publication: ISO/DIS 10516:2024.

3.4
verification
process of proving that something exists or is true, or of making certain that something is correct

3.5
nominal condition
given set of conditions (e.g. dry rail, straight and level track) used to determine the braking performance without safety margin or a confidence level

3.6
normal mode
operating condition with all expected brakes available and performing as specified

Note 1 to entry: Some brake units can be intentionally isolated.

3.7
degraded mode
operating condition where some of the brakes are not available and/or not performing as specified

EXAMPLE Equipment failure, leakage.

3.8
degraded condition
external factor adversely affecting the braking performance

EXAMPLE Low wheel/rail adhesion, wind, ice, snow.

3.9
maximum braking load
load condition corresponding to the maximum mass of payload for braking purposes

4 Design requirements

4.1 General requirements of the brake systems

The purpose of the main brake system is to ensure that the train can be slowed, the train speed can be maintained on a downhill gradient, the train can be stopped and the train/unit can be immobilized when it is stopped.

The main brake system shall enable service brake application, emergency brake application and stationary braking.

Rail vehicles/units designed and intended to be coupled and operated together shall be fitted with a compatible brake system to ensure the brake function in all vehicles/units of the train.

Additional brake systems may be included, e.g. safety brake, earthquake brake.

Brake systems may include functions which temporarily apply traction and brake at the same time (e.g. snow brake, hill start).

Self-propelled special vehicles in their running mode generally follow the requirements for locomotives. Special vehicles that are hauled in their running mode generally follow the requirements for freight vehicles.

NOTE 'Special vehicles' are machines which include infrastructure inspection machines and on-track machines (OTMs).

The brake system can incorporate the ability to adjust the braking force depending on the load of the rail vehicle/unit/train.

In brake systems using compressed air, the minimum air quality shall comply with ISO 4975.

More detailed information about automatic air brake systems is given in Annex A.

Information about certain national requirements for brake systems is given in Annex C.

4.2 General safety requirements

If a trainwide control signal for an emergency brake application is sent, no single failure in the main brake system shall result in a loss of more than 50 % of the total braking force of the train.

Any brake application signal on a service or emergency trainwide brake control line shall always cancel any traction demand.

After a control signal for a parking brake application is sent, no single failure in the brake system shall result in the complete and permanent loss of the stationary braking force of the train.

The emergency brake function of a train shall be automatic. Any inadvertent disruption of the trainwide emergency brake control line (e.g. loss of integrity resulting from an unintended train separation caused by a mechanical failure) shall immediately lead to a trainwide control signal for an emergency brake application to all vehicles from the train.

There shall be sufficient braking energy available on board the train, from the minimum stored energy distributed along the train appropriately for the design of the brake system, to ensure at least one emergency brake application capable of stopping the train from its maximum speed in any loading condition up to the maximum braking load. The local energy storage shall take into account the consumption of energy by the wheel slide protection (WSP) system under degraded conditions during emergency braking (this is sometimes referred to as inexhaustibility).

Any emergency brake demand shall lead immediately to a trainwide brake control signal for an emergency brake application and take priority over any existing brake and/or traction demand [see 4.3.2.1 a) to d)].

The cancellation of an emergency brake demand shall not lead to an automatic release of the brake. The release of an emergency brake application shall require an intentional operational demand for example by the driver or by automatic train control system.

The propagation speed of the trainwide emergency brake control signal shall be not less than 250 m/s.

4.3 Requirements for the main brake system

4.3.1 General requirements

A main brake system shall provide, as a minimum, the following functions:

— emergency brake application and release;

— service brake application and release;

— stationary brake application and release.

A brake demand for a brake application shall always have priority over a brake demand for a brake release that can have already been initiated.

To achieve these functions, a main brake system generally incorporates the following features:

— trainwide brake control device(s);

— brake demand devices (driver's cab equipment, control command signalling equipment, etc.);

— trainwide brake control line(s);

— local brake control device(s);

— brake units;

— monitoring and display of the brake status;

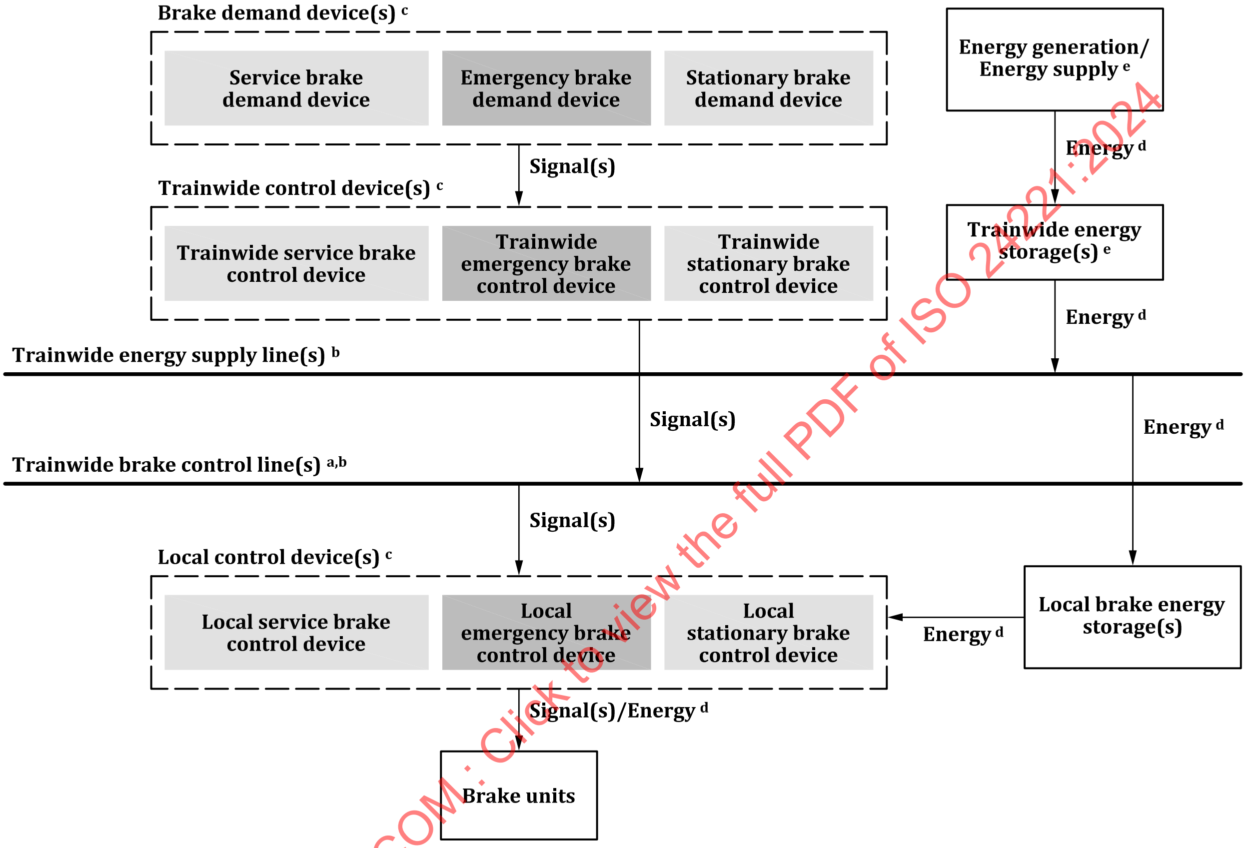
— distributed energy storage for braking force generation.

For further explanations on devices and signals, see ISO 24478:2023, Annex D.

When a trainwide energy supply line is used that is separate from any trainwide brake control lines, it is permitted for this energy supply line also to supply energy to other systems.

The energy in a trainwide brake control line and local brake energy storage shall not be used for other purposes than for the brake.

The general structure of a main brake system is shown in Figure 1.



a Discrete trainwide brake control lines for service brake control, emergency brake control and stationary brake control are also possible.

b For some applications, the trainwide energy supply line and the trainwide brake control line can be combined (e.g. brake pipe).

c Depending on technological implementation, one or more boxes can be combined and correspond to a single device.

d Different types of energy can be used simultaneously, e.g. pneumatic, electric, hydraulic.

e Energy generation / energy supply and trainwide energy storages are not dedicated to braking purpose only and are not considered as part of the brake system.

Figure 1 — General structure of the main brake system

4.3.2 General functions on train level

4.3.2.1 Brake control functions

The brake control functions on train level are as follows.

a) The train shall be equipped at least with one trainwide emergency brake control line (e.g. pneumatic brake pipe, electrical emergency brake loop).

b) The train shall be equipped with local brake control devices which are connected to the trainwide brake control line.

c) All brake units intended to be used for emergency braking shall be controlled by each trainwide emergency brake control line.

d) Brake units intended to be used for service braking shall be controlled at least by a trainwide service brake control line (e.g. hard wired, data bus). A trainwide service brake control line can be combined with a trainwide emergency brake control line.

It is permitted to use brake units for both emergency and service braking.

4.3.2.2 Automatic brake application

In order to achieve the automatic brake function, the main brake system shall be designed using a "fail-safe" principle for an emergency brake application. This is generally achieved by de-energizing the trainwide emergency brake control line to command the emergency brake application.

If a separate trainwide brake control line is used for service brake control only, this does not need to achieve the automatic brake function.

4.3.2.3 Graduable brake application and release

The main brake system shall be capable of transmitting a graduable trainwide service brake control signal.

If the train is equipped with several service brake demand devices (e.g. several driving cabs, ATO system), no more than one service brake demand device shall be able to transmit a demand on the trainwide brake control device at any time in operation.

The main brake system shall be capable of achieving at least seven levels of increasing service brake application (from brakes released up to and including full service brake application).

The provision of direct release or graduable release of the service brake applications depends on local applicable regulations.

NOTE The graduability can be realized by a time- or position-dependent service brake demand device.

4.3.2.4 Emergency brake demand devices

The main brake system can include different emergency brake demand devices dedicated to specific purposes, for example, derailment detection system, on-board temperature monitoring of axle bearings, "dead man" system.

The emergency braking performance shall be assessed with the emergency brake demand device that is the slowest to generate the trainwide emergency brake control signal(s). It applies to all emergency brake demand devices that can be used by the driver and to train control systems or to train protection systems but not to passenger activated systems.

If a type of emergency brake demand is realized by the action of multiple trainwide emergency brake control devices, then the emergency braking performance shall be assessed in the least favourable configuration allowed in operation without restriction. For example, with a train equipped with a pneumatic trainwide emergency brake control line and an emergency brake demand is done by opening two valves and if the train is allowed to operate with one of these two valves isolated without restrictions, the emergency braking performance is assessed with only one valve opening.

NOTE The slowest device to generate the trainwide emergency brake control signal is the one for which the stopping distance is the longest.

4.3.2.5 Stationary braking

4.3.2.5.1 General

Stationary braking shall provide the functions to keep a train stationary either for a certain period of time or permanently when it is not in operation, with or without any energy replenishment.

Stationary braking is used for the following functions:

— holding (see ISO 24478:2023, 3.4.5);

— immobilizing (see ISO 24478:2023, 3.4.6);

— parking (see ISO 24478:2023, 3.4.7).

4.3.2.5.2 Holding

The holding function shall be able to:

— secure the train at standstill during a temporary stop (e.g. in a station, in front of a signal),

— secure the train on a gradient during a hill start (anti-roll back brake).

NOTE 1 The holding function is only intended to be active when the train is at standstill following an application of the service brake or emergency brake.

NOTE 2 The holding function can be provided by either the leading rail vehicle or the locomotive alone, or both, or multiple vehicles along the train.

NOTE 3 The holding function can be simultaneously applied with a traction demand (anti-roll back brake, hill start).

NOTE 4 The brake system energy used can be replenished while the holding function is in use.

4.3.2.5.3 Immobilizing

The immobilizing function shall be able to hold a train stationary under specified load conditions for a defined period of time and on a defined gradient using just the brake system energy stored on the train without replenishment.

NOTE 1 The immobilizing function is active when the train is at standstill following an application of the service brake or emergency brake.

NOTE 2 The immobilizing function is normally considered with a train at its maximum load, on the maximum gradient of the line and for at least two hours for trains carrying passengers, at least 30 min for other types of trains.

NOTE 3 It is permitted to substitute the immobilization brake function by the parking brake, if this can achieve the required performance.

4.3.2.5.4 Parking

The parking function shall be able to hold a rail vehicle/unit/train stationary under specified load conditions for an indefinite period of time until intentionally released and on a defined gradient without replenishment of the brake system energy.

Additional external devices, e.g. scotches, can be used to supplement the parking brake, in case the defined conditions (e.g. gradient, load) are exceeded.

NOTE 1 The parking function can be used for the immobilizing function.

NOTE 2 Additional external devices can be stored on board or made available at dedicated locations on the network (e.g. freight yard).

4.3.2.6 Checking the brake functionality

As a minimum, the following functions and features of the brake system shall be capable of being checked:

— the continuity of the trainwide emergency brake control line(s) along the whole train;

— the availability of the braking energy supply along the train;

— the status of the parking brake (applied, released and optionally isolated);

— the initiation of the trainwide emergency brake control signal by each emergency brake demand device;

— the application of the brake units initiated by an emergency brake demand;

— the status of the emergency brake units (applied, released or isolated);

— the initiation of the trainwide service brake control signal by each service brake demand device;

— the application of the brake units initiated by a service brake demand;

— the full release of the brake units when commanded;

— the status (on/off) of the wheel slide protection system (WSP), if fitted.

4.3.2.7 Brake status monitoring when running

When running, the brake system shall provide the following information for brake status monitoring:

— the level of the trainwide service brake control line(s) and the status of the trainwide emergency brake control line;

— the status, applied or released, of at least one service brake unit and one emergency brake unit (e.g. a part which is installed on the rail vehicle fitted with an active cab). The monitored brake unit can be used for both emergency brake and service brake application;

— the level (e.g. voltage, pressure) of the trainwide energy supply line to the distributed energy storage for braking force generation;

— the availability and status, applied or released, of other brake systems if they can be used independently of the main brake system (e.g. dynamic brake).

NOTE The brake status is generally presented to the driver at the normal driving position in the active cab and/or to an automatic train control system.

It is recommended that the parking brake units are equipped with means to detect when a parking brake is not released and to provide a message to the driver.

4.3.3 Additional requirements at the vehicle level

4.3.3.1 Emergency brake demand device

When the vehicle is equipped with one or more driving cab(s), each driving cab shall include at least two independent emergency brake demand devices accessible by the driver when in the normal driving position.

If operation takes place with a second staff member in the cab, it is acceptable for one of the emergency brake demand devices to instead be accessible by the second staff member in their normal position.

NOTE 1 One of the emergency brake demand devices is usually incorporated in the driver's brake demand device.

NOTE 2 One of the emergency brake demand devices is usually activated by a red push button (mushroom button).

NOTE 3 For the purpose of this subclause a safety brake demand device can be considered to be an emergency brake demand device.

4.3.3.2 Braking capability

The brake system of each rail vehicle or unit shall be designed so that it is capable of braking the mass of the vehicle or unit with the required performance in all load conditions. However, if it is intended to operate trains incorporating partially braked or unbraked rail vehicles without speed restriction, the other rail vehicles shall be designed to accept a higher braking duty (thermal capacity) so that the train as a whole can be braked with the required performance in all load conditions.

Each rail vehicle of the train shall be capable of dissipating the braking energy so that, when operated in accordance with the vehicle instructions, no damage occurs to the components generating the braking forces (e.g. overheating of friction surfaces) or to the surrounding parts of the vehicle or the infrastructure.

Thermal capacity requirements are set out in 5.5.

NOTE 1 The design of the surrounding parts of the rail vehicle and the infrastructure is outside the scope of this document but either

a) needs to take into account the operating characteristics of the brake system, or

b) any limitations the design of the rail vehicle and infrastructure imposes need to be defined prior to the design of the brake system.

NOTE 2 Defining the actual performance is not in the scope of this document.

4.3.3.3 Application of manual effort

The manual effort required to activate mechanical interfaces, such as handles, levers, etc., shall be subject to an ergonomic assessment.

Any manual parking brake shall be designed so it can be fully applied with an application force at the mechanical interface (hand brake wheel, lever, etc.) not exceeding 500 N. It is recommended to use a lower target value when designing parking brake arrangements.

NOTE 1 In Europe, the recommended maximum application force is 250 N.

NOTE 2 In Japan, the recommended maximum application force is 294 N by one hand or 441 N by both hands according to technical regulatory standards on Japanese railways, article 69 and the approved model specifications (see Reference [22]).

4.4 Brake management / brake blending

Brake blending can take place at either the local level (e.g. bogie level) or the train level, or both.

Brake blending can be realized with more than one brake system acting simultaneously, or by replacing the braking force of a brake unit by the braking force of another brake unit.

The following blending modes may be considered:

— substitution: replacing a brake unit's braking force by another one, typically the friction brake when the dynamic brake is active;

— fixed blending: adding constant braking force typically braking force of the friction brake to the braking force of the dynamic brake;

— programmed blending: adjusting typically the braking force of the friction brake to the expected braking force of the dynamic brake in accordance with an agreed characteristic (feedback from dynamic brake only on/off);

— continuous blending: adjusting typically the braking force of the friction brake to the achieved braking force of the dynamic brake.

From the economical/environmental point of view, a service brake demand, for example, the movement of the driver's brake interface or an automatic service brake application by one of the train protection systems, should initiate the dynamic brake units prior to others, if the dynamic brake units are capable of ensuring the required braking performance. If not, it can be substituted by or blended with other brake units of the main brake system.

If the dynamic brake system satisfies the necessary safety requirements, the dynamic brake may also be used in the blending strategy during emergency brake applications.

Brake blending shall respect the maximum adhesion demand set out in 5.6.

4.5 Additional brake systems

4.5.1 General

Subclause 4.5 describes some types of additional brake systems. This document does not specify whether or not it is required to install any additional brake systems on any vehicle, unit or train.

4.5.2 Independent dynamic braking

Independent dynamic braking is an additional brake system which can be applied independently from other brake systems or in combination with them. For example, when operating on either significant or long gradients, or both, the dynamic braking should be capable of being applied independently from the friction brakes of the train.

Dynamic braking is permitted to be demanded by one or more of the following:

— a dedicated dynamic brake demand device;

— a dynamic braking demand device combined with traction demand device;

— an automatic train control system (e.g. cruise control); if permitted by the brake architecture.

It shall be possible to vary independent dynamic braking force with a minimum of seven levels including “OFF” and “MAXIMUM”.

Independent dynamic braking which has been applied separately by the dedicated dynamic brake demand device may be substituted automatically by the local friction brake at low speed only (e.g. maximum shunting speed).

4.5.3 Independent direct brake for locomotives and traction units

4.5.3.1 General requirements

The independent direct brake is an additional brake system which can be applied separately from other brake systems or in combination with them and is not intended for use as a main brake system on a train level. It is used as

— an adjustable and fast-acting brake for shunting movements of locomotives or when traction units are running alone,

— an additional brake system for rail vehicles that can be operated individually where the failure of a control unit (e.g. distributor valve) would lead to a loss of braking force of more than 50 % and where no other brake system is available as a backup, and

— a holding brake described in 4.3.2.5.2.

Locomotives and traction units that can be operated individually shall be equipped with an independent direct brake in addition to the main brake system if no trainwide direct brake as main brake system is implemented. It is permitted to equip driving trailers with an independent direct brake to provide a holding brake.

NOTE 1 The independent direct brake can be used as a holding brake in order to keep the train stationary when carrying out a brake test on the main brake system of the train.

NOTE 2 The independent direct brake can be used as a holding brake that is initiated automatically by train control systems (such as the door release command).

4.5.3.2 Application of the independent direct brake by the driver

The independent direct brake demand devices shall be separate from the brake demand devices for the main brake system.

If it is intended for locomotives to operate in multiple traction then it is permitted for the independent direct brake on both locomotives to be controlled by the independent direct brake demand device(s) of the leading locomotive. This can be achieved by transferring electrical/electronic signals or by a dedicated pneumatic inter-vehicle connection.

It shall be possible to vary the independent direct braking force with a minimum of seven levels including “RELEASED” and “FULLY APPLIED”.

NOTE Levels can be achieved, for example, through notch positions on the brake demand device or the capability for application demands by the driver on a time dependent brake demand device to result in different braking forces.

4.5.3.3 Functional requirements

An independent direct brake, where fitted, shall be able to operate in parallel with the main brake system.

For systems where the independent direct brake and the main brake system are acting on the same wheelset, when brake demands are sent simultaneously from the independent direct brake and the main brake system, the one with the highest braking force shall take effect.

The energy supply of the independent direct brake shall be designed so that no single point failure in the local energy supply of the main brake system will lead to a complete loss of the independent direct brake, to ensure at least one independent direct brake application.

No failure in the independent direct brake system shall lead to a complete loss of the main brake, see 4.2.

The design of the independent direct brake shall not assume a maximum adhesion wheel/rail level greater than 0,25, if used as a static holding brake. For other uses, the assumed maximum adhesion level shall comply with 5.6.

NOTE 1 The maximum braking force of the direct brake can be different from the braking forces of the rail vehicle's main brake system.

An error message shall be displayed in the active driver's desk if a release demand is issued from the active driver's desk and the direct brake remains applied anywhere in the train formation.

In the case of electro-pneumatically and electronically controlled direct brakes, the following requirements apply:

— the brake signal shall be based on the “energize to release” principle;

— an error message shall be displayed in the active driver's desk if an application demand is issued from the active driver's desk and the speed of 60 km/h has been exceeded;

— either no single point failure of the direct brake control valves shall result in an unintended brake application or, in the event of a failure of the direct brake control valves, this shall be brought to the driver’s attention.

In the case of faults and for maintenance and rescue purposes, it shall be possible to isolate and release the direct brake by an intentional action.

For a rail vehicle/unit/train in normal operation mode, the availability of the brake systems shall be indicated on the driver's desk (e.g. display message, pressure gauge display).

The independent direct brake shall be integrated into the vehicle diagnostic system, if available.

The build-up time for the full direct brake application shall be measured and recorded.

NOTE 2 In Europe, a common value for the build-up time for the full direct brake application is (3 ± 1) s measured between 5 % and 95 % of the maximum brake cylinder pressure of the direct brake.

NOTE 3 In China, a common value for the build-up time for the full direct brake application is (2 to 4) s measured between 0 % and 95 % of the maximum brake cylinder pressure of the direct brake.

The release time shall be measured and recorded.

NOTE 4 In Europe, a common value for release time is (4 ± 1) s measured starting from the reduction in maximum brake cylinder pressure until the pressure falls below 0,4 bar[2].

NOTE 5 In China, a common value for release time is (3 to 5) s measured starting from the reduction in maximum brake cylinder pressure until the pressure falls below 0,4 bar.

4.5.3.4 Interaction with the wheel slide protection system

A single failure in the wheel slide protection system shall not lead to a reduction of the independent direct braking force of more than 50 %.

It is permissible to deactivate the WSP in defined independent direct brake applications or brake steps, in which case the WSP shall be immediately reactivated on deselection of the defined brake applications or steps.

4.5.3.5 Interaction with other systems

The independent direct brake shall not be adversely affected by any brake management system which is used in accordance with 4.4.

The independent direct brake shall be functionally independent of the dynamic brake. It is permitted to automatically substitute the dynamic brake by the independent direct brake.

When the independent direct brake is actuated at the same time as the dynamic brake, the adhesion demand shall be in accordance with 5.6. The requirement shall be met by an adequate reduction of the braking force of the dynamic brake.

The independent direct brake shall be controllable in any case, even if a traction force is active.

4.6 Wheel slide protection

If the WSP system is active in emergency braking, the train management system shall be informed for any WSP failures.

Rail vehicles with wheels having a nominal new diameter equal to or greater than 840 mm shall be equipped with a wheel slide protection system active in both emergency braking and service braking as set out in Table 1 and Table 2.

NOTE 1 Regional conditions which do not result in low values of wheel/rail adhesion can justify alternative limits in Table 1 and Table 2.

2) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2.

Table 1 — Application of WSP for locomotives and passenger vehicles

Range of speed v km/h	Wheelset brake equipment	Maximum demanded wheel/rail adhesion τ		
		$\tau \leq 0,11$	$0,11 < \tau \leq 0,12$	$\tau > 0,12$
$v > 150$	All wheel/rail adhesion dependent brake units	WSP mandatory	WSP mandatory	WSP mandatory
$v \leq 150$	Disc brake units	WSP recommended	WSP mandatory	
	Wheel/rail adhesion dependent dynamic brake	WSP recommended	WSP mandatory	
	Disc brake unit(s) plus tread brake unit(s)	WSP optional	WSP recommended	
	Tread brake units			

Table 2 — Application of WSP for freight vehicles

Range of speed v km/h	Wheelset brake equipment	Maximum demanded wheel/rail adhesion τ		
		$\tau \leq 0,11$	$0,11 < \tau \leq 0,12$	$\tau > 0,12$
$v > 120$	All wheel/rail adhesion dependent brakes acting on the wheel	WSP recommended	WSP mandatory	WSP mandatory
$v \leq 120$	Disc brakes units	WSP optional	WSP mandatory	
	Tread brake units with composite blocks	WSP optional	WSP mandatory	
	Discs brake unit(s) plus tread brake unit(s) with composite blocks	WSP optional	WSP mandatory	
	Discs brake unit(s) plus tread brake unit(s) with all types of blocks except composite blocks	WSP optional	WSP optional	
	Tread brake units with all types of blocks except composite blocks			

The use of adhesion τ shall be determined in accordance with 5.6.

Independent dynamic braking force shall be taken into account when determining demanded wheel/rail adhesion.

In the case of rail vehicles that are capable of running alone, there shall be a means of ensuring that a fault in the WSP (e.g. reference speed higher than true train speed) does not result in a continuous release of the brakes on the entire vehicle. There is no need for two independent WSP systems on a single vehicle on which there is a brake system that cannot be influenced by the WSP.

NOTE 2 In Europe, additional requirements are defined in EN 15595.

NOTE 3 In Japan, additional requirements are defined in JRIS R 1607.

NOTE 4 In China, additional requirements are defined in TB/T 3009.

NOTE 5 In the United Kingdom, additional guidance is given in GM/GN2695.

NOTE 6 In Europe, for all rail vehicle/unit/train with wheels having a nominal new diameter less than 840 mm and $\tau > 0,11$, EN 14198 applies.

4.7 Enhancement of wheel/rail adhesion

Vehicles/units can be fitted with a means to compensate for insufficient wheel/rail adhesion during braking. Any system for enhancement of wheel/rail adhesion shall be based upon the application of a suitable substance, for example, sand, to the wheel/rail interface when the level of adhesion available at this interface is less than the level of adhesion demanded by the brake and it shall be available at all times during braking.

This system may also be used as an aid to reduce wheel slip in traction mode – however, its use in traction mode shall be limited in such a way that its availability for use during emergency braking is ensured at all times.

It shall be possible to deposit the substance used in an effective, reliable and repeatable manner in all train operating conditions during service and emergency braking. Equipment heating and ventilating devices, etc., may be incorporated into the low adhesion compensation system, if required.

The following shall be considered when selecting the substance to be used to compensate for insufficient wheel/rail adhesion and the equipment used to deposit the substance at the wheel/rail interface:

— the effect on wheel wear;

— the effect on rail wear;

— possible detrimental effects on train detection systems;

— the effect on adhesion.

The driver can be provided with a manual control for use at the driver's discretion.

A means shall be provided for testing the correct function of the wheel/rail adhesion compensation system during train maintenance, including a means for checking that the rate and consistency of deposition of the substance used is within acceptable limits and that speed and other vehicle system interlocks (e.g. WSP) are active.

It shall be possible to check the quantity of the substance used for compensating low levels of wheel/rail adhesion both locally at all storage positions on the train and remotely from the active driver's cab as an option. This option should also provide an audible or visual warning to the driver in the event that the quantity falls below the minimum level prescribed for normal train operation.

If the substance used for compensating low levels of wheel/rail adhesion is sand, the use of sanders and the amount of sand shall be in line with the requirements of the infrastructure.

Automatic sanding during emergency brake application is permitted for a speed higher than or equal to 15 km/h when WSP activity is detected.

4.8 Compatibility for rescue purposes

It shall be possible, following a failure during operation, for a train to be able to be rescued when it has no energy available on board by a recovery locomotive or multiple unit.

It is permitted to rely on low voltage provided by a battery to supply control circuits on the rescued train. The battery shall be able to supply the brake system and the interface device of the rescued unit. When available on the rescuing unit, the rescued train should be able to use the power supply of the rescuing unit.

The rescued train shall be capable of responding to a trainwide emergency brake command.

When the intended rescuing speed is above a defined speed, the rescued train shall also be capable of responding to a trainwide service brake command with at least five levels of increasing service brake application (including brakes released and full service brake application).

NOTE The defined speed will depend on the local operational rules and a suggested value is 25 km/h which is a typical maximum permitted shunting speed.

5 Calculation requirements

5.1 General aspects

The required braking performance of a rail vehicle/unit/train depends on the intended service. The braking performance can be specified in terms of decelerations, distances, braking ratio and braked weight percentage (λ) values.

NOTE 1 In Europe, EN 16834 or EN 13452 is used to assess the nominal braking performance.

NOTE 2 For Japan, see Annex C.

The braking performance required with wheel/rail adhesion dependent brakes shall be designed not to exceed the nominal wheel/rail adhesion limits (see also 5.6).

If adhesion independent brakes are used, the effort generated by these brakes shall be in addition to the effort generated by the adhesion dependent brakes. The maximum overall average retardation shall not exceed the limitation based on the longitudinal resistance of the track.

NOTE 3 In Europe, the general limitation value is 2,5 m/s^2. Higher retardation values between 2,8 m/s^2 and 5 m/s^2 are permitted in the EN 13452 series for urban rail trains.

In normal mode and for the same operating conditions when starting at the same initial speed, the stopping distance for an emergency brake application at train level shall not be longer than that related to the full service brake.

NOTE 4 This is not valid in degraded modes.

5.2 Performance calculation

5.2.1 General

The emergency braking performance of each rail vehicle/unit/train shall be calculated in accordance with ISO 20138 series.

The calculation of the deceleration when applying the full service brake shall be performed in accordance with ISO 20138 series with at least the following conditions:

— brake system in normal mode;

— nominal value of the friction coefficients used by friction brake equipment;

— load condition “design mass under normal payload” or “operational mass under normal payload” in accordance with ISO 10516;

— design maximum speed.

5.2.2 Calculations for degraded mode

The calculation of the braking performance for the degraded mode shall be done considering the single failure leading to the greatest loss of train braking force (see 4.2).

5.3 Relevant load conditions

The design of the brake system shall enable the rail vehicle/unit/train to meet the braking performance requirements throughout the full range of expected load conditions in operation.

For the definitions of load conditions, refer to ISO 10516.

NOTE In Europe, the load conditions are defined in EN 15663.

The payload for standing areas in passenger vehicles shall be expressed in kg/m^2. For trains which do not permit standing passengers, for braking purposes a payload of 0 kg/m^2 in the standing area shall be used.

5.4 Service braking

The minimum possible service brake application shall provide the driver a clear difference between coasting (released brake status) and the deceleration from the smallest possible brake demand, excluding effects of running resistance. Further increases in brake demand shall increase the retardation in proportion to the increasing demand.

Service braking shall not generate unacceptable longitudinal forces or wear or damage in the wheel/rail contact.

During the transition from a full service brake application to an emergency brake application on level track, a maximum reduction of deceleration and its maximum duration shall be defined.

NOTE 1 In Europe, the maximum reduction of deceleration of 0,2 m/s^2 for a maximum duration of one second is permitted.

NOTE 2 In Europe for Locomotives: During the transition from a full service brake application and additional brake force demanded by an independent control command, separate from the regular train wide control command to an emergency brake application a maximum reduction of deceleration of 0,2 m/s^2 is permanently permitted.

NOTE 3 In US, the maximum reduction of deceleration of 0,2 m/s^2 for a maximum duration of one second is applied for locomotives in passenger service.

5.5 Thermal capacity

5.5.1 General

The thermal capacity of the brake system shall be evaluated taking into account the following properties:

— structural integrity of the brake components;

— stopping distance extension;

— service life/durability.

5.5.2 Conditions

The thermal brake capacity shall permit both:

— two consecutive emergency brake applications from maximum speed at maximum braking load on level track with fully functional brake installation (normal mode), and

— a most challenging duty cycle (see 5.5.5) at maximum braking load (normal and degraded mode).

If the rail vehicle is equipped with additional brake system(s) and/or dynamic brakes incorporated in the emergency braking performance, either:

— the brake system shall be designed to also withstand a single emergency brake application without both the additional brake unit(s) and the dynamic brake at maximum braking mass on level track or

— the additional and/or dynamic brake unit(s) shall have the same safety integrity as the friction brake.

NOTE 1 More than one normal mode is possible.

NOTE 2 The equivalent rotating mass is considered in addition to the maximum braking load when assessing the thermal capacity of the brake system.

A duty cycle can be, for example:

— operating with defined speeds on a representative route profile, or

— operating on a representative gradient by maintaining a defined speed.

Maintaining the speed on a gradient can be achieved by use of service brake application or the independent dynamic braking only, if fitted (see 4.5.2).

The assumptions and results shall be declared.

NOTE 3 In Europe, a representative gradient for vehicles operating at 250 km/h or greater is defined in Commission Regulation (EU) No 1302/2014, 4.2.4.5.4, (5)[20]. Further suggested representative gradient are described in Commission Regulation (EU) No 1302/2014, 4.2.4.5.4, (4) and Commission Regulation (EU) No 321/2013, 4.2.4.3.3[21].

NOTE 4 For Japan, see Annex C.

5.5.3 Structural integrity of the brake components

The brake components shall be sized to withstand the occurring temperatures and mechanical stresses without endangering their structural integrity.

5.5.4 Stopping distance extension

The extension of the stopping distances resulting from the second emergency brake application shall be stated to evaluate the fading behaviour of the brake pads or brake blocks. The extension may be stated as, for example, an absolute value or a percentage value.

If the total stopping distance, or the extension of the stopping distance, is more than permitted by the infrastructure, adapted operational conditions in terms of speeds or times shall be defined.

The time interval between the two emergency brake applications shall take into account the unit's own traction performance without additional waiting time. The maximum acceleration is given by the specification. For not self-propelled vehicles, the acceleration shall be 0,5 m/s^2.

Verification of the stopping distance extension shall be performed. It can be done for example by an on-track or a dynamometer test or simulation.

5.5.5 Duty cycle

The evaluation of the most challenging duty cycle shall be done either by using a simulation or an on-track test.

The duty cycle is the most challenging route profile taking into account

— the normal mode,

— the maximum track-specific speed,

— the maximum speed of the vehicle,

— gradients and waiting times,

— the distance of stopping and passing points,

— project-specific maximum acceleration,

— the deceleration with a fully established brake, and

— the maximum ambient temperature.

For degraded mode, the same route profile is used considering any necessary speed restrictions.

NOTE 1 Normal mode can consider the dynamic brake.

NOTE 2 For coaches in general operation, the acceleration is usually 0,5 m/s^2.

NOTE 3 The deceleration with an established brake is usually taken to be 75 % of the maximum deceleration related to the characteristic of the full service brake application but not higher than 0,75 m/s^2.

NOTE 4 In Europe, the value for maximum ambient temperature is defined in EN 50215, CEN/TR 16251 and EN 50125-1.

The thermal capacity of the brake system shall permit a single emergency brake application, when applied at any point on the specified route profile with a stopping distance extension less than permitted by the infrastructure.

The thermal capacity of the brake system shall be verified for the most critical point of the route profile.

The identification of the most critical point of the route profile with the relevant starting temperature is the result of the duty cycle taking into account with dynamic brake available.

The duty cycle and route profile will be used to establish the brake temperature before and after the emergency brake application, which shall be compared with the maximum tolerable temperature.

The result will be the starting temperature for the emergency brake and the resulting one which shall be compared with the tolerable maximum temperature. If not all brake systems are in force (failure or degraded mode), operational restrictions shall be derived on the basis of acceptable and tolerable temperatures. Additional evaluations can be required to verify these restrictions.

NOTE 5 Additional requirements can be necessary for operation on routes with significant gradients steeper than 40 ‰.

5.6 Wheel/rail adhesion

The design of the brake system (including any dynamic brake systems) of a rail vehicle/unit shall not assume wheel/rail adhesion that leads to a sliding of the wheelsets or the wheels during a brake application in nominal conditions for all relevant load conditions as defined in 5.3.

The demanded wheel/rail adhesion shall be determined for each wheelset or wheel using the smallest wheel diameter for the relevant load cases permitted in operation.

NOTE 1 For Europe, common values for wheel/rail adhesion are described in Annex B.

NOTE 2 The determination of an appropriate level of assumed wheel/rail adhesion is beyond the scope of this document.

NOTE 3 For calculation of wheel/rail adhesion, see also ISO 20138 series.

5.7 Parking brake

The design calculation shall be in accordance with ISO 20138-1.

Annex A
(informative)

Automatic air brake system

A.1 Automatic air brake system according to UIC principles

One of the most used brake systems in the world is the automatic air brake system according to the UIC principles.

Possible applications are described in the following standards:

— in Europe: EN 14198;

— in China: TB/T2951.1, TB/T2951.2;

— in Japan: JRIS R 1613.

A.2 Principals of pneumatic systems using brake pipe control

The trainwide brake control signal is achieved by varying the pressure in the brake pipe below the normal working pressure.

The trainwide brake control line may also be used as trainwide energy supply line, for example, along freight trains.

A.3 Brake pipe pressure control device

The pneumatic trainwide brake control device is capable of maintaining the normal working pressure by compensating for small system leakages but is not capable of overcoming an automatic brake application (such as triggered by an unattended train separation or by a decentralized device).

NOTE 1 In the release condition, the normal working pressure is set to (5 ± 0,05) bar (Europe) or (4,9 ± 0,1) bar (Japan) or (5 ± 0,1) bar (China) or (6 ± 0,1) bar (China).

The service brake application is controlled by partially venting the brake pipe pressure down to a defined value, which is associated with the full service brake application. A further reduction of the brake pipe pressure does not increase the service brake application.

NOTE 2 Full service brake application command from the active cab is initiated

— for a 5,0 bar system, by a reduction of:

  — $1{,}6_{0}^{+0{,}2}$ bar (Europe);

  — (1,5 ± 0,1) bar (China);

— for a 4,9 bar system, by a reduction of: (2,0 ± 0,2) bar (Japan);

— for a 6 bar system, by a reduction of: 1,7 bar to 1,9 bar (China).

An emergency brake application is initiated by a greater and more rapid reduction of brake pipe pressure than for the service brake application.