

Railway applications — Braking — Wheel slide protection

ICS 45.060.01

National foreword

This British Standard is the UK implementation of EN 15595:2009+A1:2011. It supersedes BS EN 15595:2009, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by A1 A1.

The UK participation in its preparation was entrusted by Technical Committee RAE/4, Braking.

The UK Committee would like to emphasize that the requirements contained in this standard are not necessarily representative of all the performance requirements, or the suitability of Wheel Slide Protection systems for all low adhesion service conditions likely to be encountered in the UK. In particular:

- (i) The brake mode designations referenced in this standard (see Subclause 3.3) for passenger and freight train operation are derived from continental European practices and are not used on the UK network.
- (ii) The type test programme for coaches, wagons and trainsets set out in Tables 3, 4 and 5 of this standard assume that the vehicles will be equipped with a level of braking performance that are higher than is needed to operate over the UK network.
- (iii) The testing of the WSP as set out in this standard assumes levels of adhesion will generally be in the range 0.06 to 0.08 (see Subclause 5.3.3). UK experience has shown actual adhesion levels can be significantly lower than this range.

The mandatory testing methodology included in this standard is based on the use of artificially generated low adhesion conditions (e.g. detergent solutions or equivalent). Previous UK experience has shown that WSP systems, tested using such artificially generated low adhesion conditions, have required additional optimization of their performance to satisfy the lower adhesion levels typically encountered on the UK infrastructure. Further optimization of WSP systems can be conducted by using simulators as set out in Annexes A and B of this standard. This approach has proved to be very effective in achieving the required level of WSP system performance on UK infrastructure, in respect of optimized low adhesion braking performance and minimized wheel and rail damage.

In order to minimize the risk of avoidable damage to the UK railway infrastructure, WSP systems fitted to rolling stock intended for operation over the UK railway network should be optimized for the lower levels of adhesion typically encountered on the UK infrastructure.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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Foreword

This document (EN 15595:2009+A1:2011) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2011, and conflicting national standards shall be withdrawn at the latest by November 2011.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document includes Amendment 1, approved by CEN on 2011-04-03.

This document supersedes EN 15595:2009.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**.

A1 This document has been prepared under a mandate given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 2008/57/EC.

For relationship with EU Directive 2008/57/EC, see informative Annex ZA, which is an integral part of this document. **A1**

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

The objectives of fitting WSP systems to trains are to assist in achieving the following:

- 1) minimum extension in stopping distance compared to stopping on clean dry rails (i.e. good adhesion conditions);
- 2) minimum level of wheelset damage due to wheel slide or wheel 'lock-up';
- 3) minimum level of track damage;
- 4) for pneumatic brake systems, minimum increase in air consumption compared to a "non WSP" stop.

The particular priority of these above objectives may vary for different classes of applications or even for a particular application.

Trains fitted with WSP systems may consist of single vehicles, locomotive and trailing vehicles or may be high speed trains, multiple units, commuter trains, wagons, etc.

Such trains will be equipped with a friction brake and may also be equipped with dynamic brakes, magnetic track brakes and/or eddy current brakes and may also be fitted with adhesion improving systems e.g. sanding.

This standard covers both the system acceptance requirements as well as the application specific requirements for WSP Systems.

Each manufacturer is responsible for taking every necessary step to make sure that the quality of workmanship and construction is such as to ensure accordance with good engineering practice.

1 Scope

This European Standard specifies the minimum criteria for system acceptance/type approval of a new wheel slide protection system and implementation of accepted WSP to specific vehicle applications and route requirements, as well as requirements for wheel rotation monitoring (WRM).. This includes the design, testing and quality assessment of the WSP system and its components.

This European Standard is applicable to wheel slide protection systems for pneumatic braking systems without taking the type of vehicles and track-gauge into consideration. The general principles of this standard can also apply as a reference for other types of braking systems and other kinds of railway vehicles. The system is designed to control the sliding of wheels of railway vehicles during braking under degraded adhesion conditions to prevent wheel damage and to minimize the extension of the stopping distance under degraded adhesion conditions by optimizing the available adhesion between wheel and rail.

This European Standard does not apply to the following categories of vehicles:

- 1) tramways;
- 2) light railways;
- 3) metros on steel wheels;
- 4) metros on rubber tyred wheels.

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 14478:2005, *Railway Applications — Braking — Generic Vocabulary*

EN 50121-3-1, *Railway applications — Electromagnetic compatibility — Part 3-1: Rolling stock — Train and complete vehicle*

EN 50121-3-2, *Railway applications — Electromagnetic compatibility — Part 3-2: Rolling stock — Apparatus*

EN 50125-1, *Railway applications — Environmental conditions for equipment — Part 1: Equipment on board rolling stock*

EN 50126-1, *Railway applications — The specification and demonstration of reliability, availability, maintainability and safety (RAMS) — Part 1: Basic requirements and generic process*

EN 50128, *Railway applications — Communications, Signalling and Processing Systems — Software for Railway Control and Protection Systems*

EN 50155:2007, *Railway applications — Electronic equipment used on rolling stock*

EN 60529:1991, *Degrees of protection provided by enclosures (IP code) (IEC 60529:1989)*

EN 61373, *Railway applications — Rolling stock equipment — Shock and vibration tests (IEC 61373:1999)*

EN ISO 228-2, *Pipe threads where pressure-tight joints are not made on the threads — Part 2: Verification by means of limit gauges (ISO 228-2:1987)*

EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories* (ISO/IEC 17025:2005)

ISO 8573-1, *Compressed air — Part 1: Contaminants and purity classes*

3 Terms and definitions, symbols, and abbreviations

3.1 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 14478:2005 and the following more specific definitions apply.

3.1.1 Wheel slide protection (WSP) terms

3.1.1.1

adhesion profile

predefined set of data representing the adhesion characteristics of a section of running line

3.1.1.2

relative air consumption

ratio of the total volume of air consumed during a braking stop with WSP activity against that which would be consumed during a stop with no WSP activity

3.1.1.3

auxiliary reservoir

protected and dedicated source of pressure energy for local brake actuation and also known as a Brake Supply Reservoir

3.1.1.4

supplementary reservoir

pressure reservoir used for determination of relative air consumption

3.1.1.5

crush laden

vehicle load condition in excess of the normal fully laden condition that may arise during exceptional operating circumstances

3.1.1.6

low adhesion

conditions where the wheel/rail adhesion is insufficient to sustain the required braking rate

3.1.1.7

true train speed

v_t

actual current train speed, also commonly referred to as “ground speed”

3.1.1.8

wheel lock

extreme example of wheel slide where the wheel set ceases to rotate during braking, whilst the vehicle is in motion

3.1.1.9

wheel slide

condition where a wheel set rotational speed is lower than that corresponding to the true train speed

3.1.1.10

circumferential speed

rotational speed of wheel set times radius of wheel

NOTE For vehicles with independent wheels all requirements described for wheelsets apply to the individual wheels.

3.1.1.11
reference speed

v_{ref}
signal generated and generally used by the WSP or WRM (wheel rotation monitoring system) to determine an approximation to the true train speed

3.1.1.12
duty cycle

percentage of time which the WSP and brake control element is active compared with the total operational time

3.1.1.13
nominal train speed

v
specified speed at start of braking during brake tests

NOTE Real speed may slightly differ.

3.1.1.14
uncoupled test

slip test
method of brake testing where the vehicle under test is uncoupled from the rear of the test train and brakes separately

3.1.1.15
absolute wheel slide
difference between true train speed and circumferential speed

3.1.1.16
relative wheel slide
absolute wheel slide divided by true train speed

3.1.1.17
undesired venting
reduction in braking force not justified by behaviour of wheelsets

3.1.1.18
drag braking test
test with auxiliary tractive unit performed as a braking with constant brake application and constant speed

3.1.1.19
dynamic brake blending curve
curve describing the characteristics of blending of dynamic brake as function of speed

3.1.2 Components

3.1.2.1
WSP rack/controller
device having the power supply interface with the vehicle control supply and the electronic hardware and software to receive the signals from the speed sensors and provide the outputs to the WSP brake control elements, for example dump valves enabling the modulation of the brake cylinder pressure

3.1.2.2
WSP dump valve
device used to control the amount of air within the brake cylinder in relation to the adhesion level perceived by the WSP controller

3.1.2.3

speed sensor

device used to generate an individual wheelset or wheel speed signal to a WSP controller

3.1.2.4

service interface

access point for diagnostic information and maintenance test

3.2 Symbols

v	nominal train speed (km/h)
v_{ref}	WSP vehicle reference speed (km/h)
v_t	true train speed (km/h)
λ	braked weight percentage (%)
τ	adhesion coefficient
σ	coefficient of inertia of rotating masses

3.3 Abbreviations

AR	auxiliary reservoir
BP	brake pipe
BSR	brake supply reservoir; for an air brake system with distributor valve, referred to as auxiliary reservoir
DNRA	detection of non-rotating axle (same as WRM)
EB	emergency brake
ER	anticipated event – used in safety analysis
FS	full service brake
G	brake mode G: brake mode used for freight trains with specified brake application time and brake release time.
MRP	main reservoir pipe
NI	normal litre
P	brake mode: brake mode for passenger and freight trains with specified brake application time and brake release time and specified brake mass percentage
P(SS)	brake mode P(SS): brake mode for passenger and freight trains with specified brake application time and brake release time and specified brake mass percentage equipped with a self adjusting load-proportional brake system
R	brake mode R: brake mode for passenger trains and fast freight trains with specified brake application time and brake release time as for braking mode P and specified minimum brake mass percentage
RAMS	reliability, availability, maintainability and safety
WRM	wheel rotation monitoring system (sometimes called DNRA)
WSP	wheel slide protection

4 Requirements

4.1 General

4.1.1 General requirements

A WSP system is designed to make the best use and improve available adhesion for all operating conditions by a controlled reduction and restoration of the brake force to prevent wheel sets from locking and uncontrolled sliding due to low adhesion. Thus the stopping distance is optimized and the extension of stopping distance and the occurrence of wheelset damage minimized. The WSP device shall not alter the functional characteristics and performance of the brakes.

The design of the WSP system, its components and vehicle shall be such that the WSP system and its operation (in all modes) shall not have a detrimental effect on the constituent parts of the vehicle, bogie, train or track.

An additional WRM system shall detect locked wheels, which shall be indicated to the driver, where fitted.

4.1.2 Service life

This standard gives no rigid specification for service life performance.

4.2 WSP controller

4.2.1 Principle of operation

The speed of rotation of the wheelsets is calculated on the basis of information provided by sensors, and monitored by regulators or automatic control systems. These transmit commands to the WSP actuators to reduce, hold or restore braking force (where applicable), either totally or partially.

The WSP shall be available for operation on braking forces as soon as reference speed is greater than a threshold which is not higher than 6 km/h.

The WSP shall not alter the demanded braking force at reference speed less than a predefined threshold and if the brake force has been reduced by the WSP system then the brake force shall be raised to the demanded value.

This reference speed threshold shall not be higher than 3 km/h.

The WSP shall not be capable of applying a greater brake force than that demanded.

The WSP shall not alter the demanded braking force at standstill except during test.

WSP-actuators (e.g. WSP dump valves) are able to reduce braking force.

4.2.2 WSP watchdog (safety timer)

The independent monitoring or watchdog function shall be provided for all systems. The watchdog function shall remain permanently active including WSP tests, in order to restore the braking force required by the command if sustained release of the brake occurs. Actuation of this function other than during a test shall be indicated and recorded as a fault. If the watchdog function is activated, it shall be able to revert automatically to its stand-by position when the WSP resumes normal functioning.

The reliability of the watchdog device shall conform to ER1 in 4.2.3.4.

An independent monitoring or watchdog function, independent from the control algorithm and processor, shall support the automatic control system. The function shall prevent triggering of the actuator if total release of the brake, friction or dynamic brake (or a combination of them during blending), continues uninterrupted for a set

period which shall not be more than 10 s. Also after 10 s the monitoring system shall prevent an incorrect brake force step being sustained as a result of a command fault. The watchdog function shall remain active during WSP tests, in order to restore the braking force required by the command if sustained release of the brake occurs during the tests, or if undesired venting continues on completion thereof.

4.2.3 Reliability, availability, maintainability and safety (RAMS)

4.2.3.1 General

The WSP shall be capable of initiating tests to detect a number of malfunctions, or faults. When the system is functioning the availability of speed sensors and the electrical circuits of the actuators (dump valves), particularly the open-circuit and short-circuit conditions, shall be detected. The reception of every command sent by the control system to the appropriate actuator (dump valve) shall also be monitored. The WSP shall initiate an automatic self-check when it starts up to ensure at least the electrical operational availability of the electronic control unit and the peripherals.

Independent from the above testing, continuous internal tests inherent to the electronic system technology employed shall be performed to monitor the proper functioning and availability of the WSP. This shall be adapted to and defined on the basis of the specific architecture of each WSP. The testing and monitoring during the running of the vehicle shall not impair the braking functions. This testing and/or monitoring shall not jeopardise securing the train when it is stationary.

Any faults detected shall be displayed as a fault code and stored in a fault memory. The WSP shall ensure that the fault codes remain stored in the memory in the event of a power supply failure. The fault codes shall be defined on the basis of a failure analysis and designed such that the smallest exchangeable unit can be identified.

Separate information on the availability status of the WSP shall be provided for the operational state, in addition to the codes for "Fault" and "OK" indications for maintenance.

Initialization and testing shall not generate incorrect information for those other functions which use the speed information provided by the WSP. The design of the WSP shall ensure that other functions than braking functions do not alter the proper function of the WSP.

It shall be possible to manually initiate a WSP self test with the vehicle at standstill. The test shall include those on the sensors, actuators and the operational availability of the electronic control unit, plus faults that exist when stationary. The test sequence also comprises tests of the watchdog plus the complete venting of the brake cylinders by actuating the release valves/actuators. It shall be possible to read off all faults detected during the test run. Deletion of the memorized fault shall be confirmed by a test and by an indication of the correct functioning of the WSP equipment. The manual test sequence shall be cancelled if the vehicle is above 3 km/h. The testing and monitoring shall not release more than 50 % of the brakes within a vehicle at the same time.

In addition, the above test may be initiated automatically when the vehicle is at standstill.

The WSP shall be equipped with a service interface.

If the reference speed signal is used by other functions, external to the WSP equipment, these other functions shall not affect the integrity of the reference signal or the WSP equipment.

4.2.3.2 Reliability

A reliability study shall be carried out on the WSP system in accordance with EN 50126-1.

4.2.3.3 Maintainability

The WSP shall be built to a modular design and modules with the same functions shall be interchangeable. Modules which are not functionally interchangeable shall not be able to be physically plugged into the incorrect location.

4.2.3.4 Safety

The WSP shall have a safety analysis performed for the following anticipated events (ER):

- ER1: Unintended reduction or retention of a brake force on one control channel for a duration in excess of that specified in 4.5.
- ER2: Failure of any speed output used by a safety critical function (speed-dependent brake force application, electromagnetic track brake).
- ER3: Loss of the function indicating a locked wheelset for equipment approved for $v > 200$ km/h.

The hourly probability of these anticipated events occurring shall be calculated by adequate numerical means, e.g. fault tree analysis.

4.2.3.5 Ambient temperature

The WSP system shall be able to operate within the temperature classes as specified by EN 50125-1 inside vehicles and inside cubicles.

NOTE EN 50155 applies for electronics.

4.2.3.6 Environmental specification and external appearance

The externally mounted WSP components shall withstand corrosion due to normal atmospheric pollutants and operate without restrictions under conditions as specified in EN 50125-1. The WSP control unit shall operate within the requirements of EN 50121-3-1 and EN 50121-3-2.

NOTE Further to EN 50121-3-2 for the WSP system, EN 50121-3-1 applies for the complete vehicle.

The design and installation of the dump valve shall be such as to protect the venting ports against snow and ice. When required by the purchaser the WSP components shall show conformity with this requirement by testing or by design documentation. Components that are mounted at the outside of the vehicle shall be to IP65.

The components of the WSP system shall be installed in a way so that the risk for persons who are working in the vehicle is minimized (for example injury caused by sharp edges).

4.2.4 Functional characteristics

4.2.4.1 Wheel diameter differences

The system shall tolerate permitted differences of the wheel diameter differences on a given vehicle when evaluating speed.

4.2.4.2 Special features of WSPs for dynamic and mixed braking systems

The characteristics according to 4.1.1 to 4.2.3 are also mandatory for WSP of dynamic brakes if applicable (except 4.2.2).

Wheel slide shall be kept within the tolerance range as specified for friction brake in Clause 6.4.3.2 in the case of tractive units where the dynamic brake can be used independently of the friction brake (particularly for drag

brake applications on steep gradients) to prevent damage to the wheel tread and to minimize the influence on speedometer variations.

The respective WSP shall become active immediately where the pneumatic brake force takes over in cases of failure of the dynamic brake or with mixed braking systems. Where separate WSPs are used for pneumatic and dynamic brakes, a strategy shall be used to ensure that the braking force to be transmitted is not unacceptably reduced (or increased) due to the regulating processes of mixed braking systems and there shall be a strategy to avoid conflicting actions, for example automatic inhibition of the dynamic brake.

It is recommended that for high-speed trains the wheelset rotation monitoring device totally suppresses the force of the dynamic brake if the threshold indicated in 4.2.4.3.2 is exceeded, independently from the WSP.

4.2.4.3 Special features of WSP systems for high speeds ($v > 200$ km/h)

4.2.4.3.1 General

These characteristics are additional to those in 4.1.1 to 4.2.3 for WSP equipment designed for high speeds.

Each WSP device shall be supplemented by a WRM to continuously monitor wheelset rotation and to indicate any rotation anomaly. The WSP device and WRM shall have outputs to provide indication of failure of these devices.

4.2.4.3.2 Functional characteristics

The electrical/electronic circuits for the WSP and the rotation monitor shall function independently of each other and of these devices on other vehicles. The functioning of the WSP and the rotation monitor, together with the continuity of the circuits of the speed sensors and the WSP dump valves, shall be automatically monitored while the vehicle is running.

The rotation monitor shall compare the speed of rotation of at least four wheelsets at all speeds.

The rotation monitor shall output a signal no later than 10 s after a speed of $50 \text{ km/h} + 0,3 v_{\text{ref}}$ has been attained if a wheelset locks when the train starts up. Should the rotation monitor detect an abnormal difference in the speeds of rotation of the wheelsets during a run for a period longer than 10 s, that device shall output a signal. A difference is considered abnormal if it is $\geq X \text{ km/h} + Y \times v$, X and Y parameters being defined case by case, but not exceeding $50 \text{ km/h} + 0,3 v$.

4.2.4.3.3 Recommended features

It is recommended that the rotation monitor also has the functionality to remove the brake force for the wheelset concerned if abnormal differences in the speed of rotation are observed, but in such a case the brake force shall not be removed for a longer period than 10 consecutive seconds.

It is also recommended that the rotation monitor takes over the principal functions of the WSP if this is defective.

4.3 Axle speed sensors

4.3.1 Integration

The WSP sensors shall be an integral part of the WSP system.

4.3.2 Electrical connection

The sensor shall be easy to disconnect for bogie or axle maintenance. The sensor should connect into a junction box or should be fitted with a plug.

4.3.3 Mechanical strength of assembly

The WSP dump valve and its connector(s) shall withstand the environment of body or bogie mounting. It shall withstand, as minimum proof loads, the inertia forces associated with the following accelerations: EN 61373 Category 1 (class A or class B) or category 2 (depending on the mounting place). As a recommendation the vibration level should be raised by a factor of 3 for vertical, factor of 4 for longitudinal and lateral proof loads for axle mounted sensors compared with those in EN 61373.

It shall have a fatigue life of not less than 10^7 cycles with a probability of failure of not more than 2,5 %, under the inertia forces associated with the accelerations defined by the location of the mounting.

Compliance may be demonstrated by design and test documentation.

4.4 Dump valves or other device with a similar function

4.4.1 Specific requirements – friction brake

The control of the braking force is by the use of either WSP dump valves or other pneumatic control devices.

The dump valve shall vent, hold and fill the brake cylinder under the control of the WSP control unit.

4.4.2 Hardware requirements

4.4.2.1 Pneumatic interface

The pneumatic interface with the vehicle piping shall be via a manifold to enable the dump valve to be removed without disturbing the pipe work. The pipe connections shall be in conformity with a pipe thread to EN ISO 228-2. Chokes should be mounted in the bracket of the dump valves.

The diameter of the pipes has to be attuned to the nominal width of the dump valves.

4.4.2.2 Electrical connection

The connector for the dump valve shall be at least to IP67 in accordance with EN 60529:1991.

4.4.2.3 Mechanical strength of assembly

The WSP dump valve and connector shall withstand the environment of body or bogie mounting. It shall withstand, as proof loads, the inertia forces associated with the following accelerations: EN 61373 Category 1 and 2, and EN 50155.

It shall have a fatigue life of not less than 10^7 cycles with a probability of failure of not more than 2,5 %, under the inertia forces associated with the following accelerations.

Compliance may be demonstrated by design and test documentation.

4.4.2.4 Leakage

The WSP dump valve shall prevent any unacceptable loss of brake cylinder air to atmosphere. Between – 25 °C and + 70 °C the WSP dump valve shall not leak at a rate greater than 0,01 NI/min when tested at a pressure of 7 bar. This requirement shall be tested in accordance with subclause 5.5.5.1.

Between – 40 °C and – 25 °C a WSP dump valve shall have a leakage rate of not greater than 0,1 NI/min when tested at a pressure of 4 bar in accordance with subclause 5.5.5.2.

4.4.3 Functional characteristics

4.4.3.1 General requirements

Dump valves shall not retain more than 0,1 bar in the brake cylinders when de-energized in the running condition and the brakes released. The WSP-system shall not allow the vent and fill passages to be open simultaneously.

4.4.3.2 Integration

The dump valves shall be an integral part of the WSP system.

4.5 Power supply

Where the design of the vehicle requires the WSP to have a standby option, the power supply to the WSP shall be designed to ensure that the WSP powers up and that power is available when the vehicle is set in motion. WSP systems require a power supply to function and this can be provided by the vehicles or by the WSP itself.

WSP systems shall be designed to function correctly allowing for fluctuations in voltage as permitted in EN 50155, Clause 3.1.2. If the voltage fluctuation exceeds this limit, the WSP shall either operate normally or shut down without disturbing all connected systems (such as brake system, door control). The WSP shall automatically return to normal functioning if it shuts down during the voltage fluctuation as soon as the supply voltage reverts to the permitted range. If the WSP does not supply its own power, fluctuations in voltage as permitted in EN 50155, Clause 3.1.2 shall not affect its functioning.

The WSP installation for friction brake shall have its own protected electrical circuit except if it is an integrated part of the brake control.

Power supply for WRM shall be protected by its own circuit breaker in order to make it independent.

A WSP installation on a trailing (non-powered) vehicle, which is not part of a fixed formation multiple unit, shall have its own protected circuit. Fuses or circuit breakers for the WSP shall be separated from others on the vehicle so that they cannot be confused with or operated in the same manner. The WSP shall be supplied whenever there is power available. Automatic cut-off of the supply is only permissible in the case of sleep-mode (no vehicle movement) or battery protection for battery safety reasons (degraded battery situation or low voltage caused by long-term lack of supply).

4.6 Air supply

4.6.1 Air consumption

The WSP shall be designed to minimize the additional air consumption due to its operation. The vehicle's air equipment shall be dimensioned such that the air consumption of the WSP does not impair the performance of the pneumatic brake. In particular, operation of the WSP shall not give rise to BSR pressures below the demanded brake application pressure. As an option, the WSP shall be inhibited if the BSR pressure falls below a fixed pressure. For vehicles with limited air supply, for example single brake pipe freight wagons the WSP shall be disabled when the Brake supply reservoir (AR) pressure drops to the minimum emergency brake pressure.

4.6.2 Air quality

It shall be possible to operate the WSP dump valve or control device without restrictions with compressed air quality according to the following classes defined by ISO 8573-1 or better:

Class 4 – for the maximum particle size and the maximum concentration of solid contaminants;

Class 4– for the water dewpoint;

Class 4 – for the maximum total oil concentration (droplets, aerosols and vapours).

Where the WSP components are designed only for use in a “dry” system, it is permissible for the compressed air quality to be changed to ISO 8573-1, Classes 2-2-2.

4.6.3 Fire behaviour

Any specific fire requirements for the WSP system for particular lines or train services shall be observed. The fire requirements shall be tested in accordance with that specification.

5 Type test

5.1 General

5.1.1 Type testing and vehicle implementation testing - general

The WSP system shall be type tested by a combination of track tests on a vehicle and on a validated test facility (simulator testing), which faithfully represents the track gradient, adhesion conditions, vehicle parameters, etc. and is validated against practical test results. The test laboratory where the test facility is located shall be accredited in accordance with EN ISO/IEC 17025 and has to fulfil requirements as described in Annex A.

The simulator testing (type test) may be replaced partially by track test on a vehicle.

A track test, as part of the vehicle implementation test, shall be performed except where there is previous evidence of track testing.

The requirement for re-testing (type-test) if hardware or software is modified, is derived from EN 50128.

5.1.2 Conditions of test

Testing shall include vehicle types as coaches, wagons and tractive units, depending on the intended applications for the equipment. Slip tests shall be performed in accordance with Tables 3, 4 and 5 dependent upon the vehicle type and speed. The simulator facility shall be capable of testing a range of vehicle types and conditions.

The general design requirements for the simulator facility are identified in Annex A.

5.1.3 Ambient temperature for track testing

The vehicle WSP tests shall be performed at moderate ambient temperatures (between 5 °C and 25 °C), and shall not be performed in snow. The temperature on the rail surface shall be recorded after every test and shall lie between 5 °C and 35 °C.

5.1.4 Air supply

For the tests, measures shall be taken to ensure that the auxiliary reservoir provides sufficient air so that there is maximum pressure in the brake cylinders in all brake positions under dry conditions.

5.2 Overview of required test programmes

The function of the WSP shall be tested as in Table 1 below:

Table 1 — Testing of the function of the WSP system

Vehicle category	Tests required as set out in	
	Table	Additional subclauses
Wagons	4	4.1; 6.4; 6.4.2; 6.4.3; 6.4.3.2; 6.4.3.3; 6.4.4.4
Coaches	3	4.1; 6.4; 6.4.2; 6.4.3; 6.4.3.2; 6.4.3.3; 6.4.3.4 ^a ; 6.4.3.6 ^b ; 6.4.4.4
Locomotives	5	4.1; 6.4; 6.4.2; 6.4.3; 6.4.3.2; 6.4.3.3; 6.4.3.4 ^a ; 6.4.3.7; 6.4.4.4
High speed trains	5	4.1; 6.4; 6.4.2; 6.4.3; 6.4.3.2; 6.4.3.3; 6.4.3.4; 6.4.3.5; 6.4.3.6 ^b ; 6.4.3.7; 6.4.4.4
Multiple units (e.g. commuter, regional railway trains)	5	4.1; 6.4; 6.4.2; 6.4.3; 6.4.3.2; 6.4.3.3; 6.4.3.4 ^a ; 6.4.3.6 ^b ; 6.4.3.7; 6.4.4.4
^a Test facility simulation possible ^b For adhesion-independent brakes		

5.3 Tests on simulation rig

5.3.1 General

Simulator facility tests should, where technically possible, be used both as part of the verification process and also to validate WSP changes. Simulator facility tests are intended to reduce the number of track tests required and are particularly valuable for the following requirements:

- 1) initial optimization of the WSP equipment prior to any track testing;
- 2) as a replacement for track tests which present operational difficulties, for example, high speed tests, or operational track access limitations;
- 3) to modify the WSP parameters when changes are required to suit a variation in the vehicle design, for example when there are significant variations in wheelset inertia between a trailer vehicle and a motored vehicle of the same basic unit type;
- 4) to modify the WSP parameters when the WSP is used on a different type of vehicle than that for which it was originally approved;
- 5) to evaluate the implication of sanding or other system that could impact upon the WSP performance;
- 6) as part of a post incident investigation.

The design requirements for simulation facilities are set out Annex A.

This subclause details the simulation testing of WSP systems. The performance criteria that are to be met by the WSP system under evaluation are outlined in 6.3.1 and 6.3.2.

5.3.2 Simulation Validity Test

Prior to the commencement of the testing programme, the accuracy of the vehicle model simulation shall be validated by comparing the braking performance predicted by the computer model to actual track test data for

that particular type of rolling stock. This validation shall include the ability of the simulation to detect behaviour that has the potential to occur if WSP units in a train communicate to each other, such functions have to be tested in the vehicle implementation test unless the simulator is able to simulate the whole part of the train which is relevant for WSP control.

The simulation validity test shall be performed on an adhesion profile representing a level of adhesion consistently greater than that which will sustain the vehicle's maximum braking rate (i.e. equivalent to good, dry conditions). If track test figures are unavailable (e.g. for new rolling stock), predicted/calculated dry rail stopping distances provided by the train braking designer/supplier may be used for the validation process.

The adhesion profile shall be described in terms of the coefficient of railhead friction against distance along the running line. This will vary with the level of wheel slide.

The test(s) shall be performed for at least one vehicle condition (tare/laden) for each vehicle type, from a braking speed based upon track test measurements or calculation data. This shall be the train's maximum operating speed. The vehicle model simulation shall be deemed acceptable provided the predicted stopping distance(s) concur to within $\pm 5\%$ of the dry rail stopping distances achieved by the track tests or by the braking equipment suppliers' calculations.

5.3.3 Simulator Tests

For simulation testing it is highly desirable to be able to recreate the characteristics of:

- 1) track based detergent (6.3);
- 2) leaf film (6.3.3.1);
- 3) presence of water (moisture, mist, drizzle; etc).

As the wheels of the vehicle on test slip, they modify the adhesion level between wheel and rail so it will be necessary to re-create this conditioning effect.

Values of adhesion shall be from 0,06 to 0,08.

5.4 Test of WSP-controller

If the test vehicle is equipped with any brakes not dependent on wheel/rail adhesion, these brakes shall be isolated. For specific tests these brakes have to be enabled and the WSP shall work properly. The test vehicle or validated test facility shall have a brake system representative of the system for which the WSP has been designed (for disc and/or block and/or dynamic).

The following shall be measured/recorded as a minimum during all the testing of the WSP system:

- 1) vehicle speed v_t ;
- 2) rotational speed of individual axles;
- 3) brake cylinder pressures/forces measured downstream from the valves of the WSP and brake force of the dynamic brake,
- 4) vehicle deceleration;
- 5) energy storage for braking (for example, for air braking - auxiliary reservoir/BSR pressure);
- 6) time;
- 7) commencement of braking;

- 8) activation of the dump/control valves;
- 9) stopping distance;
- 10) stopping time;
- 11) reference speed v_{ref} if used for WSP regulation or external systems;
- 12) pressure of main air supply;
- 13) gradient;
- 14) adhesion treatment measures;
- 15) brake entry speed;
- 16) rail temperature and ambient temperature;
- 17) circumferential speed of all wheelsets. In trainsets, all wheelsets that can be relevant depending on the WSP design;
- 18) pressure in the auxiliary air reservoir or BSR at the beginning and at the end of the brake application (in the case of slip tests);
- 19) initiation of braking;
- 20) additional command signals (magnetic track brake, doors, sanding, dynamic brake inhibit, etc.);
- 21) input signals (availability of dynamic brake, other vehicle status information, etc.);
- 22) output signals (doors, magnetic track brake, sanding, dynamic brake inhibit, etc.).

The following variables shall be measured:

- 24) rail temperature and ambient temperature, measured after the test.

5.5 Actuator tests

5.5.1 Sampling for type test

Component type testing shall be performed on a single component issued from the serial production. All components of WSP system are subject to the type test.

5.5.2 Test requirements

All the type tests shall be performed at $(20 \pm 5)^\circ\text{C}$ and the air quality of the compressed air class 4-4-4 specified in ISO 8573-1:2001, unless the WSP components are designed only for use in a “dry” system, where the quality can be 2-2-2. Unless otherwise specified, tests marked with a « * » shall be performed additionally at TX specified in the EN 50125-1, with the upper temperature limit of 60°C and at a wider temperature range.

5.5.3 Test procedure

Tests shall be performed in the order shown in Table 2.

Table 2 — Operations to carry out for qualification

Tests	Corresponding standard sub-clause	Tested component number									
		1	2	3	4	5	6	7	8	9	10
Physical and geometrical characteristics	5.5.4	X	X	X	X	X	X	X	X	X	X
Leakage Test *	5.5.5	X*					X			X*	

5.5.4 Check of physical and geometrical characteristics

The requirements of subclauses 4.4.2.1, 4.4.2.2, 4.6.2, 4.3.1 and 4.3.2 shall be checked using appropriate measuring instruments, in accordance with the specification and the manufacturer's drawings. Threaded connections shall be checked by GO/NO-GO gauges.

Pass/fail criteria: The result is satisfactory if all the specified characteristics are met.

5.5.5 Leakage test

5.5.5.1 Leakage test – ambient and - 25 °C

The WSP dump valve is tested for leakage to atmosphere with 4,0 bar feed in when totally de-energized (4,0 bar on the output) and when the valve is in a hold position with 0,5 bar and 3,0 bar on the output.

This test shall be performed at $(20 \pm 5) ^\circ\text{C}$ and $(- 25 \pm 1) ^\circ\text{C}$

Pass/fail criteria: No leakage to atmosphere greater than 0,01 NI/min.

5.5.5.2 Leakage test – - 40 °C

The WSP dump valve is tested for leakage to atmosphere with 4,0 bar feed in when totally de-energized (4,0 bar on the output) and when the valve is in a hold position with 0,5 bar and 3,0 bar on the output.

This test shall be performed at $(- 40 \pm 1) ^\circ\text{C}$.

Pass/fail criteria: No leakage to atmosphere greater than 0,1 NI/min.

5.6 In-service monitoring

Where required by the Railway Undertaking, in-service monitoring of satisfactory system performance shall be performed on at least 5 vehicles over a period of one year.

An in-service monitoring is only applicable as a part of the type test of the equipment and shall not be required if the equipment is already successfully tested in service test with another Railway Undertaking. It applies to any new components as well as systems.

The parameters to be monitored shall include:

- 1) visual inspection;
- 2) open circuit/short circuit dump valves and speed sensors;
- 3) watchdog failures;
- 4) conditions of low air and excessive stopping distances;
- 5) quality of diagnosis.