



BSI Standards Publication

Railway applications — Braking — Wheel slide protection

National foreword

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European foreword

This document (EN 15595:2018+A1:2023) 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of an identical text or by endorsement, at the latest by April 2024, and conflicting national standards shall be withdrawn at the latest by April 2024.

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

This document supersedes A1 EN 15595:2018 and EN 15595:2018/AC:2021 A1.

This document includes the corrigendum EN 15595:2018/AC:2021 which corrects the wording of the 1st sentence of 8.3.3.3.1, the 2nd sentence of 8.3.3.3.2 and the 2nd sentence of 8.3.3.3.3.

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A1 *deleted text* A1

The rationale behind the changes between Revision 1 and this Revision of this standard is given in Annex H.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

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Introduction

A Wheel Slide Protection (WSP) system is designed to make the best use of available adhesion and to improve adhesion 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 braking performance is optimized and the occurrence of wheelset damage is minimized.

The Wheel Rotation Monitoring (WRM) system is designed to detect locked wheels and to give immediate information in this case.

Trains fitted with WSP systems may consist of single vehicles, locomotive and trailing vehicles or may be high speed trains, multiple units, commuter trains, Light Rail Vehicles (LRV) and Tram Trains of any track gauge, etc.

Such trains will be equipped with friction brakes and may also be equipped with additional braking systems, e.g. dynamic brakes, wheel/rail adhesion independent brakes, and may also be fitted with adhesion improving systems, e.g. sanding.

This European Standard is not intended to be used to determine the stopping performance of a WSP equipped train under all environmental conditions.

1 Scope

This document specifies the criteria for system acceptance and type approval of a wheel slide protection (WSP) system. It also specifies criteria for the implementation of WSP to specific vehicle applications and specific operating conditions, as well as requirements for wheel rotation monitoring (WRM). This includes the design, testing and quality assessment of the WSP and WRM systems and their components.

This European Standard does not apply to vehicles on rubber tyred wheels or vehicles equipped with hydraulic brakes.

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.

EN 14478:2017, *Railway applications — Braking — Generic vocabulary*

EN 15663, *Railway applications — Vehicle reference masses*

EN 16834:2019, *Railway applications — Braking — Brake performance*

EN 45545 (all parts), *Railway applications — Fire protection on railway vehicles*

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: Rolling stock and on-board equipment*

EN 50126-1, *Railway Applications — The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) — Part 1: Generic RAMS Process*

EN 50128, *Railway applications — Communication, signalling and processing systems — Software for railway control and protection systems*

EN 50129, *Railway applications — Communication, signalling and processing systems — Safety related electronic systems for signalling*

EN 50155, *Railway applications — Rolling stock — Electronic equipment*

EN 60529, *Degrees of protection provided by enclosures (IP Code) (IEC 60529)*

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

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)*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14478:2017 and the following apply.

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

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

adhesion profile

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

3.2

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

3.3

supplementary reservoir

pressure reservoir used for determination of relative air consumption during WSP testing

3.4

crush laden

vehicle load condition based on the design mass under exceptional payload in accordance with EN 15663

3.5

dry rail

conditions where 100 % of the brake force of the vehicle can be applied with no axle sliding more than 2 %

3.6

dry rail stopping distance

actual measured stopping distance in dry rail conditions

3.7

low adhesion

conditions where the wheel/rail adhesion is in the range 0,08 to 0,05

3.8

very low adhesion

conditions where the wheel/rail adhesion is in the range 0,05 to 0,03

3.9

extremely low adhesion

conditions where the wheel/rail adhesion is below 0,03

3.10

reference speed

signal generated and generally used by the WSP or WRM to determine an approximation to the true train speed

3.11

nominal initial train speed

specified speed at start of braking during brake tests

Note 1 to entry: True train speed can slightly differ.

Note 2 to entry: This may be known as target speed.

3.12

uncoupled test

method of brake testing where the vehicle (or single unit) under test is uncoupled from the rear of the test train and brakes separately, also referred to as a slip test

3.13

brake to stop test

brake test starting from a nominal initial speed going to a stop, performed with either an individual vehicle (locomotive, coach) or a train set as the tested unit

3.14

absolute wheel slide

difference between true train speed and circumferential speed

3.15

relative wheel slide

absolute wheel slide divided by true train speed

3.16

undesired brake force reduction

reduction in brake force not justified by behaviour of wheelsets

3.17

brake blending curve

curve describing the characteristics of blending of dynamic and pneumatic brakes as function of speed

3.18

WSP controller

device having 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 force

3.19

WSP actuator

device used by the WSP controller to control the brake force

3.20

WSP dump valve

WSP actuator to control the brake cylinder pressure

3.21

speed sensor

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

3.22**service interface**

access point for diagnostic information and maintenance test

3.23**validation**

process of analysis followed by a judgment based on evidence to determine whether an item (e.g. process, documentation, software or application) fits the user needs, in particular with respect to safety and quality and with emphasis on the suitability of its operation in accordance to its purpose in its intended environment

3.24**verification**

process of examination followed by a judgment based on evidence that output items (process, documentation, software or application) of a specific development phase fulfils the requirements of that phase with respect to completeness, correctness and consistency

Note 1 to entry: Verification is mostly based on document reviews (design, implementation, test documents, etc.).

3.25**designed deceleration**

maximum deceleration which is provided by the brake system of the vehicle, in a normal manner on level track and which is defined by calculation

3.26**slide test**

test performed under degraded adhesion conditions

3.27**dry rail test**

test performed where the adhesion conditions will support the maximum brake force

3.28**drag test**

test to simulate braking on a falling gradient, performed with an auxiliary tractive unit to achieve a constant speed with a constant brake application

3.29**brake test**

test where the brakes are applied to achieve a deceleration

3.30**tare laden**

vehicle load condition based on the design mass in working order in accordance with EN 15663

Note 1 to entry: This can have to include additional test equipment and personnel.

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

g	acceleration due to gravity, in m/s^2
v_{nom}	nominal initial train speed, in km/h
v_{ref}	WSP vehicle reference speed, in km/h
v_t	true train speed, in km/h
μ	adhesion coefficient
ρ	coefficient of inertia of rotating masses
τ	initial adhesion coefficient
AR	auxiliary reservoir
BP	brake pipe
BSR	brake supply reservoir; may also be referred to as an auxiliary reservoir
EB	emergency brake
ER	(fr: événement redouté) anticipated event – used in safety analysis
MMI	Man Machine Interface
MTB	magnetic track brake
Nl	normal litre
RAMS	reliability, availability, maintainability and safety
VIT	Vehicle Implementation Test
WRM	wheel rotation monitoring system (sometimes called DNRA, detection of non-rotating axle)
WSP	wheel slide protection

5 Requirements

5.1 Functional requirements

5.1.1 Objectives of wheel slide protection

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

- minimum extension in stopping distance compared to stopping on clean dry rails (i.e. good adhesion conditions);
- minimum level of wheelset damage due to wheel slide or wheel lock;
- minimum level of track damage;
- for pneumatic brake systems, minimum increase in air consumption compared to a dry rail stop with no WSP activity.

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

The objectives are deemed to be fulfilled, if the requirements of this standard are met.

5.1.2 General functional requirements

One independent WSP/WRM system shall control no more than eight axles.

In the case of tractive units that are capable of running alone, any single fault of the WSP system shall not result in a loss of brake force on more than 50 % of the braked axles. This may be achieved by multiple WSP systems or an independent braking system that cannot be influenced by WSP.

The circumferential speed of the wheelsets is calculated on the basis of information provided by sensors, and monitored by regulators or automatic control systems (WSP controller).

The WSP controller may use additional information (e.g. signals from pressure sensors) about the status of the train for WSP control.

The WSP controller transmits commands to the WSP actuators (e.g. WSP dump valves) to reduce, hold or restore brake force, either totally or partially.

The WSP shall not reduce the brake force below a low speed threshold. This threshold shall not be higher than 5 km/h and not lower than 0,5 km/h. If the brake force is already reduced when the train speed falls below this threshold, the WSP system shall restore the brake force to the demanded value.

When starting the train the WSP shall be available for operation before the speed achieves 6 km/h. For freight applications where power supply is not provided at low speed, this threshold may be increased up to 15 km/h.

The WSP system shall remain operative whilst there is brake force present (i.e. until the brakes are fully released).

The WSP shall not be capable of increasing the brake force above that demanded by the braking system.

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

All speed thresholds defined in this standard shall be related to nominal mean wheel diameter if the true wheel diameter is not known.

5.1.3 Control of the brake force

5.1.3.1 Requirements for pneumatic actuation of the friction brake

WSP-actuators (e.g. WSP dump valves or other pneumatic control devices - integrated brake valve) are used to modify brake force.

The WSP-system shall not allow a direct connection between supply and exhaust.

5.1.3.2 Dynamic brake

Dynamic brakes shall have either WSP control in accordance with this standard or means to switch them off in the event of sliding.

If the dynamic brake is used for emergency brake applications a WSP control of the dynamic brake shall be provided.

If the dynamic brake is commanded by an independent control command, separate from the regular train wide control command, the maximum slide criteria, as defined in 5.4.3.1, shall at least be met.

The dynamic brake may be equipped with its own WSP. As long as the friction brake is not activated the slide can be controlled by the WSP of the dynamic brake alone.

A WSP strategy shall be adopted for the two systems if dynamic brake and friction brake are coordinated by a blending function or operated independently to fulfil the requirements of this standard.

5.1.4 Wheel slide protection watchdog (safety timer)

For safety reasons, a monitoring function is provided to avoid an excessive reduction of braking effort.

This WSP watchdog function shall be provided for WSP systems capable of acting during emergency braking, and shall be independent from the WSP control algorithm and processor.

A continuous brake effort release demanded by the WSP shall not exceed 10 s. After this time, the WSP watchdog shall inhibit WSP intervention.

The WSP watchdog shall inhibit WSP intervention in the case where the brake effort is maintained constant or continuously reduced below the demanded level with no rise in brake effort for a period which shall not exceed 15 s. The watchdog function shall remain permanently active including during WSP tests, in order to restore the demanded brake force if sustained release or reduction of this brake force occurs because of WSP operation. Activation of this function other than during a test shall be indicated and recorded.

If the watchdog function is activated, it shall be reset only after the WSP controller stops demanding a reduction in brake force.

5.1.5 Air supply

As an option, the WSP should have the capability of being inhibited if the BSR pressure falls below a defined value.

For single-pipe systems, the WSP system shall ensure that WSP activity is inhibited if the auxiliary reservoir pressure is less than 300 mbar above the highest brake application pressure.

WSP shall be automatically re-enabled when the inhibit signal is removed.

5.1.6 Wheel diameter differences

When evaluating speeds on a given vehicle, the WSP and WRM system shall tolerate permitted differences of the wheel diameters, within the range from new to worn wheels, so as not to cause WSP or WRM activity because of these differences.

5.1.7 Wheel rotation monitoring (WRM)

5.1.7.1 General

These characteristics are additional to those in 5.1.1 to 5.1.6 for WSP equipment designed for high speeds. Where fitted, WRM supplements the WSP device with a “rotation monitor function” to continuously monitor wheelset rotation and to indicate rotation anomalies.

5.1.7.2 Functional characteristics

If a wheelset locks when the train starts up a “rotation monitor function” shall output a locked axle indication no later than 10 s after a train speed of 50 km/h has been attained.

During a run the “rotation monitor function” shall output a signal on detecting an abnormal difference in the speeds of the wheelsets for a period longer than 10 s. A difference is considered abnormal if it is at least $X \text{ km/h} + Y \cdot v_{\text{ref}}$. X and Y parameters being defined case by case, but not exceeding $50 \text{ km/h} + 0,3 \cdot v_{\text{ref}}$.

5.1.7.3 System requirements

The “rotation monitor function” is implemented in the WRM and may additionally be implemented in the WSP controller.

Where trains are required to be equipped with independent rotation monitoring systems they may both (WSP and WRM) provide locked axle information to the train system.

For each monitored wheelset the WRM shall include at least one speed sensor circuit that is electrically independent from the WSP. WSP and WRM may exchange data for diagnostic purposes.

The electrical/electronic circuits for the WSP and the WRM including power supply from the battery and protecting circuits shall function independently of each other. Electrical interfaces shall be such that a failure of one system does not impair the other e.g. galvanic isolation.

WSP may act as the WRM system for axles other than those for which it provides the WSP-control.

5.1.7.4 Recommended features

It is recommended that the WRM also has the functionality to remove the brake force for the wheelset concerned (including dynamic brake of motor axles) if abnormal differences in the circumferential speed are observed. If the WRM also has WSP exhaust functionality then the WSP requirements on safety timer, dump valves and diagnostics for the reduction of brake force shall also apply to the WRM.

WRM may also take over the principal functions of the WSP if this is defective. In this case it shall comply with WSP requirements.

5.1.8 Diagnostics

5.1.8.1 Permanent self-diagnostic

When the WSP or WRM system is operating the availability and correct functioning of speed sensors shall be checked.

Open-circuit and short-circuit conditions of speed sensors shall be detected.

If sensors for additional signals are used in the WSP system a diagnosis of these sensors shall be implemented.

The availability of the electrical circuits of the WSP actuators (dump valves), the open-circuit and short-circuit conditions, shall be detected when commands are sent by the controller to the appropriate WSP actuator (dump valve).

Additional permanent diagnostic functions, inherent to the electronic system technology employed, shall be performed to monitor the correct operation and availability of the WSP. These are adapted to and defined on the basis of the specific architecture of each WSP.

The diagnostic monitoring shall not impair the braking functions during the running of the vehicle.

Information shall be provided to the train system to enable detection of simultaneous failure of WSP and WRM on any single axle.

5.1.8.2 Manually initiated test

It shall be possible to manually initiate a WSP test with the vehicle at standstill. Automatic or remote initiation of this test may also be allowed, provided that all the requirements for manual initiation are met.

The manually initiated WSP test shall be aborted when the WSP detects vehicle movement which shall be before the vehicle reaches 3 km/h.

The manually initiated WSP test includes tests for dormant faults that can be detected when the vehicle is stationary.

The manually initiated WSP test shall include tests of the WSP watchdog function.

The manually initiated WSP test shall include the test of each WSP actuator. In the case of more than one WSP actuator per WSP system the test should be done sequentially on these WSP actuators.

All states of the WSP actuator shall be tested including complete release of the brake force. The WSP actuators function can be checked by audibility of venting air, visibility or other means.

If possible the manually initiated WSP test shall sequence the release of WSP actuators in order not to jeopardize securing the train when it is stationary.

The manually initiated WSP test shall provide fault codes and availability information that can be accessed via the WSP system's service interface.

The manually initiated WSP test shall not have a detrimental effect on other functions which use output signals provided by the WSP.

5.1.8.3 Automatically initiated test

The WSP shall initiate an automatic self-test when it starts up to ensure at least the electrical operational availability of the electronic control unit and the peripherals.

In addition, part or all of this test sequence may be initiated automatically at other times e.g. when the vehicle stops.

The automatically initiated test shall not impair the braking functions.

5.1.8.4 Fault management

Any faults detected shall be displayed at the service interface as a fault code and stored in the fault memory of the WSP system and/or the vehicle diagnostic system.

Technology for fault storage shall be chosen to ensure that fault information remains stored in the memory for at least 3 months even without power supply.

The fault codes and maintenance procedure should be designed such that the smallest exchangeable failed unit can be identified.

5.1.8.5 Service interface

The service interface shall be a local MMI and/or a connection to a diagnostic computer or diagnostic system.

The service interface should provide, as a minimum, information on the availability status of the WSP, in the form of "Fault" and "OK" indications.

The service interface shall provide access to fault codes and internally stored diagnostic information.

The service interface shall provide a means by which manually initiated tests in accordance with 5.1.8.2 can be run.

5.2 Design requirements

5.2.1 Environmental specification

WSP/WRM System shall withstand environmental conditions as specified in EN 50125-1, depending on the location of the components on the vehicle and on operating conditions.

Regarding the electronics ambient temperature requirements of EN 50155 also apply.

The WSP control unit shall operate within the requirements of EN 50121-3-2.

Components that are directly exposed to external environment shall be to IP65 in accordance with EN 60529.

5.2.2 Fire behaviour

Compliance to the EN 45545 series shall be the minimum requirement for the WSP/WRM system.

5.2.3 RAMS

5.2.3.1 Reliability

A reliability study shall be carried out on the WSP/WRM system in accordance with EN 50126-1 (during design phase test).

5.2.3.2 Safety

The WSP/WRM 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 period in excess of that specified in 5.1.4;
- ER2: failure of any speed output used by a safety critical function (speed-dependent brake force application, magnetic track brake).
- ER3: loss of the “rotation monitor function” when applicable.

The hourly probability of these anticipated events occurring shall meet the values below.

- ER1 $\leq 10^{-6}/h$
- ER2 $\leq 10^{-5}/h$ for $v_{nom} \leq 200$ km/h
 $\leq 10^{-6}/h$ for equipment approved for $v_{nom} > 200$ km/h
- ER3 $\leq 10^{-5}/h$

5.2.3.3 Maintainability

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

5.2.3.4 Degraded mode conditions

A detected single axle sensor failure shall not have detrimental effect on the control of the other axles.

In this case another speed signal which is related to this WSP could be used to control the axle. This signal could be from WRM, from traction control, from the adjacent axle on the same bogie or from the closest other axle, etc., dependant on vehicle configuration.

5.2.4 Mechanical construction

System components and their connector(s) shall withstand the environment defined in EN 61373 depending on their mounting place.

Compliance may be demonstrated by design and test documentation.

5.2.5 Power management

The WSP/WRM system shall be designed to function correctly allowing for fluctuations in voltage as permitted in EN 50155 except where the WSP system generates its own power.

If the voltage fluctuation exceeds this limit, the WSP/WRM shall either operate normally or shut down to a state where predetermined signals are given to all connected systems (such as brake system, door control, etc.).

WSP equipment may have a standby option included. If the WSP has a standby option, the power supply to the WSP/WRM shall be designed to ensure that the WSP powers up at the latest when its function is needed. It is permissible to use the brake release demand to leave standby without directly detecting vehicle motion.

5.2.6 Software

Software used in the WSP/WRM shall be developed in accordance with EN 50128.

5.2.7 Electronic control unit Input/Output (I/O)

Where there are requirements for the WSP or WRM system to interface to other vehicle functions (doors, magnetic track brake, etc.), these interfaces shall be designed in accordance with EN 50129.

I/O signals provided in the interface to another vehicle function shall comply with the safety integrity levels required by the function for those signals.

The interfaces between the WSP or WRM and other vehicle functions shall ensure that no malfunctioning of the WSP or WRM can occur as a result of faults or short-circuits in those interface signals.

5.2.8 Sensor - axle speed acquisition

The speed sensors shall be treated as an integral part of the WSP or WRM system.

The sensor should be easy to disconnect for bogie or axle maintenance.

5.2.9 Actuator - modification of brake force

5.2.9.1 General requirements

The WSP actuators used to modify the brake force shall be treated as an integral part of the WSP system and WRM if the option of modifying brake force is included within the WRM system.

5.2.9.2 Pneumatic systems

5.2.9.2.1 Air retention

Dump valves or other control devices shall not retain more than 0,1 bar in the brake cylinders when de-energized in the running condition and the brakes released.

5.2.9.2.2 Air quality

The manufacturer shall specify the air quality requirements of the WSP system in accordance with ISO 8573-1.

5.2.9.2.3 Pneumatic interface

The pneumatic interface with the vehicle piping should 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 manifold of the dump valves.

5.2.9.2.4 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 Nl/min when tested at normal working pressures.

Between – 40 °C and – 25 °C a WSP dump valve shall have a leakage rate of not greater than 0,1 Nl/min when tested at normal working pressures.

This leakage is tested in accordance with 6.2.3.2.2.

5.2.9.3 Electrical connection

The electrical connection shall be designed to prevent dust and water ingress.

This shall be demonstrated if the connection for the WSP actuator is rated to IPXX in accordance with EN 60529. If the connection is rated for IP67, it shall be for a versatile application and be IP65/IP67 in accordance with EN 60529.

5.3 Installation recommendations

5.3.1 General installation requirements

The design and integration of the WSP/WRM ensures that other systems or vehicle functions do not alter the correct operation of the WSP/WRM.

Manufacturers' installation requirements shall be provided when necessary to ensure that the installed system continues to comply with the Type Tested design requirements.

The requirements for the implementation of the WSP/WRM system and its components on the vehicle are such that the WSP/WRM system and its operation (in all modes) do not have a detrimental effect on the constituent parts of the vehicle, bogie, train or track.

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

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

Speed sensors should connect into a junction box or should be fitted with a plug.

5.3.2 Air system

5.3.2.1 Air supply

The vehicle's air equipment (in particular the size of the BSR) should be dimensioned such that the air consumption of the WSP does not impair the performance of the pneumatic brake.

5.3.2.2 Piping and layout

The following statements are recommendations for the installation of the vehicle pipework:

- where practicable pipe volumes should have equal dimensions and should be similar for each axle;
- the diameter of the pipes should be tuned to the nominal port diameter of the dump valves;
- where practicable the WSP dump valve should be mounted close to the brake cylinder;
- Installation of the dump valve should be arranged to protect the venting ports against snow and ice.

5.3.3 Power supply and electrical system

5.3.3.1 Protection

Power supply for WRM should be protected by its own circuit breaker in order to make it independent from the WSP monitoring the same axles.

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

A WSP installation on a trailing (non-powered) vehicle, which is not part of a fixed formation multiple unit, should have its own protected circuit.

Fuses or circuit breakers for the WSP/WRM should be clearly identified so that they cannot be confused with, or operated, in the same manner.

5.3.3.2 Control

The WSP/WRM should always be supplied with power whenever there is power available.

Automatic cut-off of the supply should only be permitted in the case of standby or battery protection for battery safety reasons (degraded battery situation or low voltage caused by long-term lack of supply).

Following a shutdown due to voltage fluctuations, the WSP/WRM should automatically return to normal operation once the supply voltage stabilizes within the specified voltage range.

5.4 Performance requirements for WSP

5.4.1 Performance

The performance of the WSP system is measured in terms of its ability to achieve the objectives in 5.1.1 when a vehicle is braked in degraded adhesion conditions.

For Type and Vehicle Implementation Testing the performance of the WSP system shall be validated by track-tests or on a simulation rig. The minimum requirements for a simulation rig are specified in Annex B.

Any assessment of the performance of a WSP system in terms of its ability to achieve these objectives in any given test shall consider the following criteria:

- the level of adhesion (low, very low, extremely low);
- the vehicle braking rates in dry conditions;
- the nature of the rail contaminant;
- the vehicle speed when braking commences;
- the train consist in which the vehicle is tested;
- the configuration, mechanical and pneumatic, of the vehicle's brakes;
- the air supply or air storage system of the vehicle.

The general performance criteria are given assuming a WSP fitted on a vehicle with per axle WSP control and an air supply that is normally continuously replenished. Where this is not the case, the reduction of performance is indicated in appropriate sections or described in Annex G.

The stated performance requirements shall be taken for the WSP system alone when it is not influenced by other systems like traction and dynamic brake.

Where vehicles have more than one WSP system and/or more than one braking system in operation there shall be an agreed interface on the interaction between them to provide the required performance in all operating modes on the vehicle.

WSP shall work from the maximum vehicle speed as brake application speed, however it shall work properly at any lower initial speed.

The pass/fail status of a WSP system with regard to any of the performance requirements shall be ultimately determined with reference to the particular test procedures adopted, the test conditions and on analysis of the test results.

5.4.2 Stopping distance and adhesion improvement

5.4.2.1 Low adhesion

Under low adhesion conditions it is usually possible to improve the available adhesion such that the stopping distance performance is improved over what would be expected without WSP equipment.

This is achieved by controlling the wheel slide in a way that the contaminated rail is conditioned and thus the adhesion raised. The WSP shall be considered to fulfil the first objective from 5.1.1 if tested in accordance with this standard. However, the extension of stopping distances is not predictable for all contaminants or environmental conditions.

5.4.2.2 Very low adhesion

In very low adhesion conditions, improvement of the adhesion value might not be achieved by slide control.

Under very low adhesion the WSP shall continue to operate in a normal manner, but the low adhesion stopping distance criteria may not be achievable, dependent on the contaminant causing the very low adhesion.

Alternative strategies of controlling slide under these conditions may be adopted if the adhesion remains at this very low level.

5.4.2.3 Extremely low adhesion

In extremely low adhesion conditions, improvement of the adhesion value normally cannot be achieved by slide control.

Under extremely low adhesion the WSP shall continue to operate in a normal manner, but stopping distance cannot be defined.

Under these conditions, if the adhesion remains at an extremely low level, alternative strategies of WSP control may be adopted. For example controlling the axles at different levels of slide or allowing the wheelsets to lock.

5.4.3 Wheelset slide limits

5.4.3.1 Low adhesion wheelset slide limits

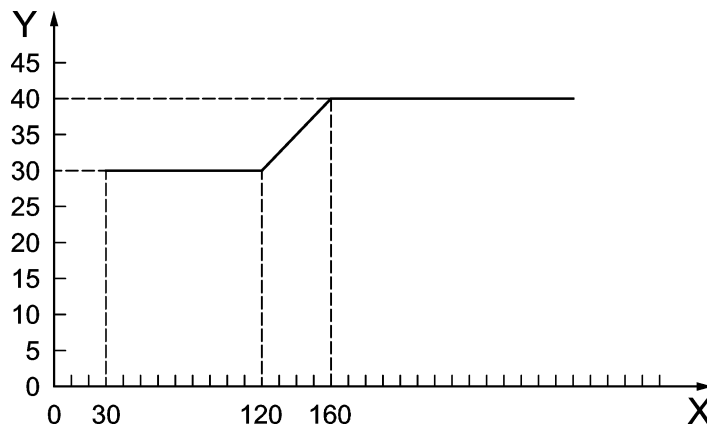
In any 3 s period, there shall not be an absolute slide of more than 30 km/h at speeds between 30 km/h and 120 km/h, 25 % of the vehicle speed between 120 km/h to 160 km/h and 40 km/h at speeds greater than 160 km/h.

At speeds > 200 km/h, there shall not be an absolute slide of more than 40 km/h in any 5 s period.

If the period of high absolute slide starts at speeds > 200 km/h the 5 s period shall apply even if the speed drops below 200 km/h during the slide.

During the tests, none of the wheelsets shall lock when the true train speed is above 30 km/h.

Wheel locks below 30 km/h true train speed and above 5 km/h shall not last longer than 0,4 s.

**Key**

X vehicle speed, in km/h

Y wheel slide, in km/h

Figure 1 — Absolute slide limit**5.4.3.2 Very low and extremely low adhesion wheelset slide limits**

The absolute slide under these adhesion conditions may be greater than for low adhesion, but there shall be evidence of WSP activity to attempt to restore one or more wheelset(s) to vehicle speed during periods of large differential speeds.

Wheel locking should only be for durations given by Formula (1).

$$t = \frac{W}{v \cdot \mu \cdot \frac{m}{2} \cdot g} \quad (1)$$

where

μ is the adhesion experienced;

W = 26 kJ, which is the energy per contact point;

m the axle load;

v vehicle speed.

5.4.4 Track damage

Minimization of track damage is assumed if the wheelset slide control criteria are satisfied.

5.4.5 Maximum deceleration

WSP shall be able to cope with decelerations higher than the designed deceleration, which are caused by external influences.

Up to a margin of 0,3 m/s² (higher than designed deceleration) no undesired brake force reduction shall occur.

For a margin higher than 0,3 m/s² no full release of the brake force of the vehicle for a time longer than 2 s shall occur.

5.4.6 Air consumption

The WSP should be designed to minimize the additional air consumption due to its operation.

The relative air consumption of the WSP as calculated in [A1](#) 8.3.4 [A1](#) shall not exceed the following values (see Table 1).

Table 1 — Speed and relative air consumption

Speed km/h	Relative air consumption
120	< 3,5
160	< 7,0
NOTE 1 This is not a specification for sizing of air reservoir. NOTE 2 The air consumption at varying adhesion conditions can be much higher. NOTE 3 The air ratio values may not be achievable in very low and extremely low adhesion conditions.	

The additional air consumed by WSP operation should not prevent the train stopping within the specified distance under low adhesion conditions.

No requirements apply for the air consumption under very low and extremely low adhesion conditions.

However, the options in 5.1.5 for WSP inhibit should be considered.

5.4.7 Output based on speed information provided by WSP

The reference speed calculated by the WSP may deviate from the true train speed due to variations in the wheel diameters between the new to worn wheel states and additionally as a result of wheels sliding in low adhesion conditions.

If the WSP system provides signals based on its reference speed to other functions, the deviations due to wheels sliding in low adhesion conditions shall not exceed those shown in Table 2.

Table 2 — Speed output tolerances

Speed	Tolerance
$0 \leq v_t \leq 100 \text{ km/h}$	+ 5 km/h - 10 km/h
$v_t > 100 \text{ km/h}$	+ 5 km/h - 10 %

Speed measurements shall be based on mean wheel diameters where no true diameters are available as stated in 5.1.2.

If output signals are digital outputs the required accuracy shall be fulfilled in the range of switching thresholds.

Short duration excursions of speed information outside the speed information limits may be tolerated if the duration of any such excursion does not exceed 5 s.

6 Range of tests

6.1 General

6.1.1 Test classifications

The object of testing is to ascertain the behaviour and performance of the WSP or WRM system against the Test Specification and appropriate standards, with particular respect to safety.

A1 The tests shall be performed by a competent authority.

NOTE As an example, a test institute in accordance with EN ISO/IEC 17025. **A1**

The testing of requirements is divided into Type Test and Vehicle Implementation Test (VIT). All requirements are summarized in a table in Annex A. This table shows which tests shall be carried out for a Type Test or for a VIT.

A Type Test of the core functional, design and performance requirements shall be required for the approval of a WSP or WRM system.

A VIT shall be required to prove the functionality and performance of the WSP or WRM System as installed for a specific vehicle configuration.

Tests are not necessary if conformity can be shown to a function that has already been tested.

Tests shall be repeatable and, if practicable, be performed by automatic means.

6.1.2 Assessor

An Assessor shall be appointed by the supplier, the customer or the Safety Authority for the Type Test and for VIT where there are additional safety related WSP functions that cannot be tested during the Type Test as defined by the EU Legal Framework.

An Assessment is not required for a part of the system if an Assessment Report from another Assessor already exists for that part. The Assessor shall check that the former assessment applies to its use within the intended environment and conforms to the requirements of the appropriate European Standards.

6.2 Type Test

6.2.1 General

The Type Test is a generic test to ensure that a system satisfies the basic requirements. It can be carried out on a test bench or on a test vehicle or a combination of both.

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).

6.2.2 Test requirements

The list of tested requirements can be found in Annex A.

The specific tests, including Supplementary tests, required for Type Testing are identified in the tables in 6.4. The tests marked with "T" in the tables are the Type Tests.

6.2.3 Individual component Type Test

6.2.3.1 Wheel slide protection controller

The Type Test of a WSP controller shall show conformity with the requirements in 5.1 and 5.2 as set out in Annex A. The equipment shall be tested in accordance with the relevant requirements of EN 50125-1, EN 50155 and EN 50121-3-2.

6.2.3.2 Peripheral component tests

6.2.3.2.1 General

Peripheral components required for the WSP function such as speed sensor and dump valves may be subject to individual Type Tests as set out in Annex A.

6.2.3.2.2 Leakage tests

The WSP dump valve shall be tested for leakage to atmosphere as a design requirement with a 4,0 bar feed. It shall be tested in three states, 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.

The tests shall be performed at $(70 \pm 5) ^\circ\text{C}$, $(- 25 \pm 1) ^\circ\text{C}$ and at $(- 40 \pm 1) ^\circ\text{C}$.

Pass/fail criteria: No leakage to atmosphere greater than in Table 3.

Table 3 — Leakage rates

Temperature °C	Output pressure bar	Valve state	Maximum tolerated leakage Nl/min
+ 70 (±5)	4,0	valve de-energized	0,01
	3,0	valve in hold position	
	0,5		
- 25 (±1)	4,0	valve de-energized	
	3,0	valve in hold position	
	0,5		
- 40 (±1)	4,0	valve de-energized	0,1
	3,0	valve in hold position	
	0,5		

6.3 Vehicle Implementation Test

6.3.1 General

The Vehicle Implementation Test shall demonstrate that the tested system includes correct specific vehicle parameters and satisfies the requirements under real or artificial conditions. This test shall be focused on the requirements that have not been tested in the Type Test, or which could give different behaviour on the vehicle.

Simulator testing for the specific vehicle implementation can be conducted in order to limit the amount of track testing and to exercise the system performance in conditions that may be difficult to achieve in real track testing.

To be tested in Vehicle Implementation Test (where applicable):

- a) WSP-functions incl. stopping distance extension;
- b) compatibility with other vehicle-systems;
- c) display, diagnosis and service functions on the system or on a central MMI;
- d) WRM-system;
- e) interaction of the WSP and WRM-systems;
- f) transfer of sensor information;
- g) activation of WSP-valves from WRM-system;
- h) system communication.

6.3.2 Test requirements

The list of tested requirements can be found in Annex A.

The specific tests, including Supplementary tests, required for Vehicle Implementation Testing are identified in the tables in 6.4. The tests marked with "I" in the tables are the Vehicle Implementation Tests.

Vehicle Implementation Tests can be performed in tare load, but if the load to tare ratio is higher than 2:1 the tests shall be performed in tare and tests 2, 6 and 13 from Table 4 shall be performed in crush load. If the performance of the WSP varies significantly from that in the same tests performed in the tare condition then all tests shall be carried out in crush.

For freight wagons all tests (as far as applicable) shall be performed in loaded condition, (18 t axle load). Tests Nos. 1, 2, 3 and 5 in Table 4 shall be performed in tare and loaded conditions.

6.3.3 Conformity of previous vehicle tests

A Vehicle Implementation Test shall be carried out on each vehicle type, except where conformity with another vehicle type having had a Vehicle Implementation Test can be proved.

Where a Vehicle Implementation Test has been carried out on another vehicle type the functions that have been tested on that previous vehicle do not need to be repeated. The only tests required are those to demonstrate that changes in functionality between the vehicles do not affect the performance of the WSP system.

As a minimum the braking distance tests, 2, 4, 5 and 6 in Table 4 shall be carried out.

6.4 List of tests

6.4.1 Standard tests

For combined or mixed WSP and/or braking systems, where more than one WSP controller can influence the brake effort applied to the axles, tests shall be carried out to validate the operation of the entire system with regard to all possible configurations and interactions of those controllers within that system.

If the maximum speed of the vehicle is lower than the v_{nom} given for a test, that test shall be performed using the vehicle's maximum speed as the v_{nom} .

NOTE All Type Tests can be carried out on a simulator.

6.4.2 Drag tests

For friction or blended braking systems, a full service brake application shall be maintained for a period of 30 s with adhesion reduced to such an extent that all braked wheelsets are in slide.

Where dynamic only braking can be commanded by an independent control command, with no train wide control command, a full service dynamic brake application shall be maintained for a period of 120 s with adhesion reduced to such an extent that all braked wheelsets are in slide.

6.4.3 Test methods for speeds from 160 up to 200 km/h

The suitability of the WSP for 200 km/h can be demonstrated in uncoupled tests, in tests with a trainset (the test vehicle with its spraying system being placed at the front of the train) or in tests on an approved simulator facility using WSP speed sensors coupled to motors. Where a facility does not use WSP speed sensors, the compatibility of the latter with the electronic systems at 200 km/h shall be demonstrated using appropriate tests.

6.4.4 Test methods for speeds > 200 km/h

If these tests are performed as track tests, they shall be carried out with a trainset. Locomotives are tested coupled with coaches in line with operational requirements.

The rotation monitoring function described in 5.1.7 shall be tested as described in 6.4.8.

6.4.5 Supplementary higher deceleration tests

If the WSP system is designed to manage higher deceleration levels, supplementary tests shall be carried out. The higher deceleration level can occur due to an external influence (Table 5) or be indicated by a signal (Table 6).

Examples of causes of higher deceleration may be:

- a) on a locomotive with an MTB-braked train;
- b) a missing MTB signal on a coach;
- c) a coach with a load valve problem.

6.4.6 Supplementary approval tests for WSP acting in vehicles with brakes that are independent of adhesion

For brake architectures that include adhesion independent brakes (e.g. magnetic track brake), tests shall be performed to demonstrate that the WSP system operates correctly at the higher decelerations caused by the adhesion independent brakes. In particular that the WSP does not alter the braking force in dry rail conditions where no wheel-slide is occurring and functions correctly in accordance with the requirements in 5.1 when the rails are sprayed using the fluid concentration specified in 7.3.2.1.

The test shall be an emergency application, performed from an initial speed of 160 km/h with adhesion independent brakes active.

6.4.7 Supplementary approval tests involving tractive units and trainsets having dynamic brakes

In order to be approved for tractive units and trainsets, the ability of the WSP system to meet the requirements of the standard when fitted on a tractive unit with a combined dynamic and pneumatic brake, shall be demonstrated.

With adhesion reduced as specified in 7.3.2.1, an emergency or service brake application (i.e. the maximum brake rate where both dynamic and pneumatic brake are active) shall be performed from the maximum speed of the traction unit/trainset to standstill, under the following conditions:

- dynamic and pneumatic brakes combined;
- pneumatic brake only (if not yet fully covered by previous Type Test);
- failure of dynamic brake after complete build-up of brake force;
- emergency braking applied following a full brake application.

The criteria from 7.1 shall apply to the evaluation of results. The test is considered as valid if the initial adhesion criterion from 8.3.3.2 is satisfied.

The general conditions and scope of the tests shall apply at the maximum brake rate of the tractive unit.

The performance criteria from 5.4.3.1, 5.4.6 and 5.4.7 shall apply.

If the dynamic WSP controller works independently from the pneumatic WSP controller and has not been Type Tested over the range of tests in 6.2.2 remaining tests shall be carried out as part of the Vehicle Implementation Test.

6.4.8 Testing of wheel rotation monitoring (WRM)

Testing of the WRM function shall be carried out on a test bench or on a vehicle by simulation of a locked axle by falsifying the WRM speed sensor signal. WRM tests may be performed by a simulator test facility, taking into account that no adhesion profile is needed, e.g. open loop simulation.

The rotation monitoring function described in 5.1.7 may be verified with the vehicle stationary where increasing wheelset speeds are simulated at the input to the monitoring device with the speed of one wheelset maintained at zero. Alternatively, this function can be verified with the vehicle in motion where one sensor produces no speed input. The rotation monitoring device shall meet the WRM criteria (see 5.1.7.2).

The maximum wheelset speeds shall be simulated at the input to the rotation monitoring device. The speed of one wheelset shall then be reduced in accordance with the following formula:

$$\Delta v = X + Y \cdot v \quad (2)$$

where

X and Y refer to 5.1.7.2.

A signal shall meet the WRM criteria (see 5.1.7.2). The test shall be repeated at 50 % of the maximum speed.

If the rotation monitoring system has the recommended features from 5.1.7.4, the pressure in the brake cylinders of the wheelset for which the speed was reduced shall be restored in the course of the previous test no later than 10 s after venting.

Table 4 — Test program for the function “Wheel slide control” of braking system using adhesion

Test No	Adhesion level	Track condition	Deceleration level (brake mode) ^a	Test method	v_{nom} km/h	Purpose of test	WSP pass/fail criteria	Stopping distance criteria	T/I ^b	Number of tests - evaluation
1	Dry rail	Dry rail	Maximum (Emergency)	To stop	120	Verify brake performance	No undesired brake force reduction	Refer to brake calculation ^c	T	4 [A ₁] (8.1 and 8.2) [A ₁]
2	Dry rail	Dry rail	Maximum (Emergency)	To stop	160	Verify brake performance	No undesired brake force reduction	Refer to brake calculation ^c	T, I	4 [A ₁] (8.1 and 8.2) [A ₁]
3	Dry rail	Dry rail	Maximum (Full Service Brake)	To stop	120	Verify brake performance	No undesired brake force reduction	Refer to brake calculation ^c	T	4 [A ₁] (8.1 and 8.2) [A ₁]
4	Dry rail	Dry rail	Each distinct level of brake setting, or categories of decelerations, including maximum. (As per selected setting)	To stop	120	Verify brake performance	No undesired brake force reduction	Refer to brake calculation ^c	I	4 [A ₁] (8.1 and 8.2) [A ₁]
5	Low	Sprayed rail	Maximum (Emergency)	To stop	120	Verify WSP performance	All tests to meet stopping distance criteria, air consumption, 5.4.6 and speed output, 5.4.7	Threshold from 8.3.2	T, I	4 [A ₁] (8.1 and 8.3) [A ₁]
6	Low	Sprayed rail	Maximum (Emergency)	To stop	160	Verify WSP performance	All tests to meet stopping distance criteria, air consumption, 5.4.6 and speed output, 5.4.7	Threshold from 8.3.2	T, I	4 [A ₁] (8.1 and 8.3) [A ₁]
7	Low	Sprayed rail	Maximum (Full Service Brake)	To stop	120	Verify WSP performance	All tests to meet stopping distance criteria, air consumption, 5.4.6 and speed output, 5.4.7	Threshold from 8.3.2	T, I	4 [A ₁] (8.1 and 8.3) [A ₁]

Test No	Adhesion level	Track condition	Deceleration level (brake mode) a)	Test method	v_{nom} km/h	Purpose of test	WSP pass/fail criteria	Stopping distance criteria	T/1 ^b	Number of tests - evaluation
8	Low	Sprayed rail	Each distinct level of brake setting, or categories of decelerations, including maximum. (As per selected setting)	To stop	120	Verify WSP performance	All tests to meet stopping distance criteria, air consumption, 5.4.6 and speed output, 5.4.7	Threshold from 8.3.2	I	4 [A] (8.1 and 8.3) [A]
9d	Low	Sprayed rail	Maximum, dynamic brake shall operate.	To stop	120 ^e	Verify WSP performance with dynamic brake	No undesired loss of braking, air consumption, 5.4.6 and speed output, 5.4.7	N/A	I	1
10	Changing	Interval spraying. With the spraying started and stopped 3 times during the test.	Maximum (Emergency)	To stop	160	Verify WSP performance with changing adhesion	Maximum slide in accordance with 5.4.3.1, air consumption, 5.4.6 and speed output, 5.4.7	N/A	T	2
11	Changing	Interval spraying. Test over 1 km (this distance needs to increase for dynamic brake only) with spraying started and stopped 3 times during the test.	Constant speed (Full Service Brake)	Drag test	100	Verify WSP performance with changing adhesion	Maximum slide in accordance with 5.4.3.1 and speed output, 5.4.7	N/A	T	1
12	Very low	Sprayed rail with increased soap concentration.	Constant speed (Full service Brake)	Drag test	100	Test for slide on all axles in very low adhesion conditions	Maximum slide in accordance with 5.4.3.2	N/A	T	1
13	Very low	Very low adhesion. Spraying with increased soap concentration, start spraying before braking and spray for 10 s after max. brake force build up time.	Maximum (Emergency)	To stop	40	Test of low speed behaviour in very low adhesion conditions	Verify wheel-lock criteria 5.4.3.2	N/A	T, I	1