

UIC CODE

5 4 1 - 0 5

2nd edition, November 2005

Translation

OR

Brakes - Specifications for the construction of various brake parts - Wheel Slide Protection device (WSP)

*Frein - Prescriptions concernant la construction des différents organes de frein - l'anti-enrayeur
Bremse - Vorschriften für den Bau der verschiedenen Bremsteile - Gleitschutzanlage*



UNION INTERNATIONALE DES CHEMINS DE FER
INTERNATIONALER EISENBAHNVERBAND
INTERNATIONAL UNION OF RAILWAYS

Leaflet to be classified in Volume:

V - Rolling Stock

Application:

With effect from 1 August 2005

All members of the International Union of Railways

With effect from 1 January 1985 for new wheel slide protection equipment (WSP) to be accepted in international traffic, except:

point 2.4: 1.1.1986

points 3.7 and 4: 1.1.1987

The use of WSPs is governed by point 3 of this Leaflet for all members of the International Union of Railways.

As an exception to point 3.2.1, SNCF is authorised to use 340 luggage vans fitted with composite brake shoes without WSP equipment in international traffic.

DB is exempted from applying point 3.2 to some 450 vehicles (ex. DR) built after 1.1.1974 and fitted with WSP equipment of the Knorr-M type.

Record of updates

1st edition, January 1985	First issue with 8 Amendments
2nd edition, November 2005	Overhaul of the leaflet Adaptation to the editor's guide M1

The person responsible for this leaflet is named in the UIC Code

Contents

Summary	1
1 - Required characteristics for WSP systems	2
1.1 - Functional characteristics	2
1.2 - Power supply	3
1.3 - Safety, reliability and maintainability characteristics	4
1.4 - Special features of WSP systems for high speeds ($v > 200$ km/h)	6
1.5 - Special features of WSPs for dynamic and mixed braking systems	7
1.6 - Precision of reference speed	7
2 - WSP approval tests	8
2.1 - General	8
2.2 - Approval tests to be carried out on coaches and wagons	10
2.3 - Supplementary approval tests involving tractive units and trainsets	12
2.4 - Supplementary approval tests for high speeds (speed > 200 km/h)	13
2.5 - Supplementary approval tests for low adhesion	14
2.6 - Supplementary approval tests for WSP acting in vehicles with brakes that are independent of adhesion	14
2.7 - Simulator rig tests	14
3 - Utilisation of the WSP system	16
3.1 - General	16
3.2 - Conditions for utilisations with coaches and wagons	17
3.3 - Conditions for utilisation with tractive units	18
3.4 - Conditions for using WSP for high speeds ($v > 200$ km/h)	18
4 - Type approval of WSP equipment for internal use	19
4.1 - Approval procedure	19
4.2 - Application for approval	19
4.3 - Approvals tests	19
4.4 - Type approval	19
4.5 - Validity of approval following modifications	20

Appendix A - Diagram of electronic wheel slide protection device (WSP)	21
Appendix B - Method of evaluation of the results of slip brake tests in reduced adhesion conditions at initial speeds of 120 and 160 km/h.....	22
B.1 - Test evaluation criteria.....	22
B.2 - Assessment of the test	24
Appendix C - Calculation of relative air consumption	25
Appendix D - Test programme for coaches	26
Appendix E - Test programme for wagons	27
E.1 - Test programme for WSPs to be used on wagons	27
E.2 - Test programme for wagons in addition to Appendix E.1	28
Appendix F - Test programme for tractive units and trainsets	29
Appendix G - Brake test measurement records	30
Appendix H - Simulator test rigs - Design requirements	31
Appendix I - Programme of rig tests	33
Appendix J - Test programme for simulator rig test.....	34
Appendix K - WSPs accepted in international traffic for vehicles built between 1.1.1974 and 31.12.1986	35
Appendix L - WSPs accepted in international traffic for vehicles built after 1.1.1987	36
Appendix M - WSPs also accepted in international traffic for vehicles built after 1.1.2004	37
List of abbreviations	38
Bibliography	41

Summary

This leaflet sets out the basic provisions and minimum requirements to be fulfilled by wheel slide protection equipment. It contains advice on integration into vehicles and defines the extent of the tests to be carried out for approval in international railway traffic.

1 - Required characteristics for WSP systems

The Wheel Slide Protection device (WSP) fitted to a vehicle has the role of reducing excessive wheel slide resulting from brake applications in situations where wheel/rail adhesion is temporarily impaired (inclement weather conditions, fouling of the rail), and of preventing wheels from locking.

A WSP device is activated by a temporary reduction in braking force. The WSP exploits available wheel/rail adhesion to a maximum and improves it by providing controlled wheel slide so that any increase in braking or stopping distance is kept to a minimum.

The WSP shall not alter the functional characteristics of the brakes. The vehicle's air supply equipment shall be dimensioned such that the air consumption of the WSP does not impair the performance of the pneumatic brake.

The WSP shall not have a detrimental effect on the constituent parts of the vehicle (braking gear, wheel tread, axle boxes etc.).

Vehicles that run at speeds above 200 km/h shall be provided with monitoring equipment in addition to the WSP (a rotation monitor), which detects locked axles and indicates this in the driver's cab.

Appendix A - page 21 gives a schematic view of electronic WSP systems.

o 1.1 - Functional characteristics

The WSP shall retain full functionality, regardless of the braking force requested, up to a speed 20% greater than the maximum running speed of the vehicle for which it is designed (if $v_{\max} \leq 200$ km/h) and 10% greater (if $v_{\max} > 200$ km/h).

The WSP shall function reliably:

1. during acceleration: from speeds of 6 km/h (or lower) upwards,
2. during deceleration: down to a speed of 5 km/h, or lower.

At vehicle speeds ≤ 3 km/h the WSP shall not alter the braking force, other than during testing.

1.1.1 - The WSP shall remain fully functional even if additional brakes are used that are not dependent on wheel/rail adhesion. Even if adhesion drops suddenly during braking, the WSP shall retain its efficacy and shall prevent irremediable locking of the wheelsets at vehicle speeds above the initiation threshold for the WSP.

1.1.2 - The WSP shall so vary the braking force as to make maximum use of available adhesion and improve it by providing controlled wheelslide.

1.1.2.1 - Sliding of the wheel on the rail shall be restricted in order to avoid damage.

This wheel slide shall not cause the axles to lock.

1.1.2.2 - 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 or restore braking power, either totally or partially.

Centrally determined train speeds may not be used to regulate the pressure in the brake cylinders as long as the safety and the reliability of that speed information is not guaranteed.

1.1.3 - The consumption of compressed air as a result of WSP actuation shall be reduced to a minimum.

1.1.4 - At no time shall the actuation of the WSP lead to a greater braking force being applied than initiated by the braking command.

1.1.5 - If the existing adhesion level is not reduced, the WSP shall not alter the braking force from that required by the command.

1.1.6 - The system shall take permitted wheel diameter differences on a given vehicle into account when evaluating speed.

1.1.7 - An independent monitoring or "watchdog" device shall support the automatic control system. The device shall prevent triggering of the actuator if venting continues uninterrupted for more than 10 s. A similar monitoring system shall prevent an incorrect force step being sustained unduly as a result of a command fault. The watchdog device shall remain active during WSP tests, in order to restore the braking force required by the command if sustained venting of the brake cylinders occurs during the tests, or if undesired venting continues on completion thereof. Actuation of this device other than during a test shall be indicated and recorded as a fault. If the watchdog device is activated, it shall revert automatically to its stand-by position when the WSP resumes normal functioning.

1.1.8 - WSP systems for tractive units and driving trailers shall be capable of transmitting an indication of poor adhesion to the "sanding" function.

1.1.9 - The WSP of tractive units shall not respond as a result of decreasing wheel slip. Particular attention shall be given to this in cases of sudden transitions from traction to braking.

1.1.10 - At low adhesion (adhesion coefficient $\tau < 0,03$) the WSP shall not allow the wheels to lock. This could occur as a result of:

- incorrect operation of the watchdog device or
- as a result of an error in estimation of train speed.

o **1.2 - Power supply**

1.2.1 - The power supply to the WSP shall be so designed as to guarantee that the WSP powers up. At the latest, power shall be available when the vehicle is set in motion.

1.2.2 - WSP systems require an electrical power supply to function. This can be provided by the vehicles or by the WSP itself.

1.2.3 - If the electronic WSP does not supply its own power, fluctuations in power within the limits of point **1.2.4** supply voltage shall not affect its functioning.

1.2.4 - The WSP shall continue functioning without failure under fluctuations in nominal voltage of up to at least ± 30 %. If the nominal voltage fluctuations exceed the limits where it does not work properly, the WSP shall shut down without disturbing the braking system. As soon as the supply voltage reverts to the permitted range, the WSP shall automatically return to normal functioning.

1.2.5 - The WSP installation shall have its own protected circuit. Fuses or circuit breakers for the WSP shall be so separated from others on the vehicle that they cannot be confused with these or operated in the same manner. In particular, the WSP shall be so connected to the power system that it is not switched off automatically by the vehicle to save the battery (e.g. when battery voltage is low).

NB : For tractive units point 1.2.5 is a recommendation only.

1.2.6 - In all other respects, the WSP shall meet the specifications of *EN 50155*, *EN 50121-3-1* and *EN 50121-3-2* (see Bibliography - page 41).

o **1.3 - Safety, reliability and maintainability characteristics**

1.3.1 - General

The WSP shall conform to the provisions of *EN 50126* (RAMS).

EN 50128 is to be respected for WSP software.

The WSP for coaches shall conform to the specifications of *UIC Leaflet 557* (see Bibliography - page 41).

1.3.1.1 - The WSP shall be capable of initiating tests or checks by means of which a number of malfunctions, or faults can be detected.

Independent of these continuous internal tests, which are inherent to the electronic or micro-processing system, availability tests and the monitoring of proper functioning shall be adapted to the technology employed and defined on the basis of fault analyses specific to the architecture of each WSP and its environment.

Testing and monitoring during running shall not impair the braking functions. On no account shall testing or monitoring jeopardise the securing of the train when it is stationary.

1.3.1.2 - Any faults detected shall be displayed as a fault code and stored in a fault memory.

In the event of a power supply failure, the WSP shall ensure that the fault codes remain stored in the memory.

The fault codes shall be defined on the basis of a failure analysis and designed such that the smallest exchangeable unit can be identified.

1.3.1.3 - Separate information on the availability status of the WSP shall be provided for Operations, in addition to the codes for "Fault" and "OK" indications required for Maintenance.

1.3.1.4 - If the speed information from the WSP is used for other functions, initialisation and testing shall not generate incorrect information for these functions.

1.3.2 - Permanent checks when the system is functioning.

The following checks shall control:

1. The availability of speed sensors and electrical actuators. In particular, open-circuit and short-circuit conditions shall be detected.
2. The reception by the appropriate actuator of every command sent by the computer.

1.3.3 - Automatic tests

When it is started up (system start), the WSP initiates a self-check aimed at controlling the availability of different sub-assemblies (electronic control units).

1.3.4 - Manual tests at a standstill

1. A device accessible from inside the vehicle shall enable manual initiation of the tests.
2. It shall be possible to read off all faults detected during the run.
3. The manual tests include the availability check of the different sub-assemblies.
4. The tests shall allow a search for faults that subsist when stationary. This sequence also comprises:
 - a. Testing the fail-safe devices;
 - b. The complete venting of the brake cylinders by actuating the release valves one by one.
5. Deletion of the fault display shall be confirmed by a test and by an indication of proper functioning.

1.3.5 - Functioning safety

1. Safety

The WSP approvals documentation shall contain a safety analysis for the following undesirable events:

- ER 1: Unintended venting or constant pressure on one control channel for a duration in excess of that specified in point 1.1.7 - page 3.
- ER 2: Loss of any safety critical speed output (speed-dependent brake force application, magnetic brakes).
- ER 3: Loss of the function indicating a locked wheelset for equipment approved for $v > 200$ km/h.

NB: ER = événement redouté = undesirable event.

The hourly probability of these anticipated events occurring shall be:

- ◆ $ER\ 1 \leq 10^{-6}/h$
- ◆ $ER\ 2 \leq 10^{-5}/h$ for $v < 200$ km/h
- ◆ $ER\ 2 \leq 10^{-6}/h$ for $v > 200$ km/h
- ◆ $ER\ 3 \leq 10^{-5}/h$

These events shall be quantified using the databases for expected reliability or operating reliability valid at the time of approval.

2. Reliability

The approvals documentation for the WSP shall also contain a reliability study. Quantification shall be carried out using the databases of expected or operating reliability valid at the time of approval.

3. Maintainability

The WSP shall be built to a modular design:

- Modules with the same functions shall be interchangeable;
- The physical construction of the modules shall be such that those which are *not* functionally interchangeable are *not* plug-compatible.

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

○ 1.4.1 - General

1.4.1.1 - All characteristics specified above are mandatory for WSP equipment designed for high speeds.

1.4.1.2 - For high speeds, each WSP device shall be supplemented by a rotation monitor to continuously monitor wheelset rotation and to indicate any rotation anomaly in the driver's cab.

1.4.1.3 - Failures of the WSP and of rotation monitoring devices have to be indicated in the driver's cab.

1.4.2 - Functional characteristics

○ 1.4.2.1 - The electrical and electronic circuitry for the WSP and the rotation monitor shall function independently of one another.

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

○ 1.4.2.3 - The WSP devices and the rotation monitor shall function independently of each other on each vehicle.

○ 1.4.2.4 - If, when the train starts up, a wheelset locks, the rotation monitor shall send a signal to the driver's cab no later than 10 s after a speed of 50 km/h has been attained.

○ 1.4.2.5 - If, during a run, and for a period longer than 10 s, the rotation monitor detects an abnormal difference in the speeds of rotation of the wheelsets, that device shall send a signal to the driver's cab.

A difference is considered abnormal if it is ≥ 50 km/h + 0,3 v (v = running speed in km/h).

R 1.4.2.6 - It is recommended that the rotation monitor be so supplemented that:

1. it vents the brake cylinders for the wheelset concerned if abnormal differences in the speed of rotation are observed (see point 1.4.2.5); in such a case, the brake cylinder shall not be vented for a period longer than 10 consecutive seconds;
2. it takes over the principal functions of the WSP if this is defective.

○ 1.4.3 - Monitoring

The functioning of the WSP and the rotation monitor, together with the flow of current to the speed sensors and the WSP valves, shall be monitored automatically while the vehicle is running.

1.5 - Special features of WSPs for dynamic and mixed braking systems

- 1.5.1 - The specifications in this leaflet also apply to the WSPs of dynamic brakes except in cases where this is technically impossible.
- 1.5.2 - Wheel slide shall be kept within the permitted tolerance range in the case of tractive units for which the dynamic brake can be used independently of the automatic brake (particularly for holding brake applications on steep gradients) in order to spare the wheel tread and to minimise any influence on speedometer variations.
- 1.5.3 - If, in case of failure of the dynamic brake or with mixed braking systems, the force of the pneumatic brake takes over, the respective WSP shall become active without delay.

If separate WSPs are used for pneumatic and dynamic brakes, care shall be taken to ensure that the regulating processes of mixed braking systems do not create a mutual hindrance such that the braking force to be transmitted is unacceptably reduced.

- R 1.5.4 - For high-speed trains it is recommended that the wheelset rotation monitoring device totally suppress the force of the dynamic brake if the threshold indicated under point 1.4.2.5 - page 6 is exceeded, independently of the WSP.

○ 1.6 - Precision of reference speed

During brake applications to a standstill in conditions of reduced adhesion, the maximum permissible reference speed deviation shall be as follows:

- if the reference speed is greater than the real speed: 5 km/h,
- if the reference speed is less than the real speed:
 - 10 km/h where the real speed is less than 200 km/h,
 - 15 km/h where the real speed is more than 200 km/h.

2 - WSP approval tests

o 2.1 - General

2.1.1 - Principles of approval

Approval of a new WSP will only be granted once its functioning has been demonstrated by submission of results (recordings and measurements) of tests carried out as specified below.

The test range is dependent on vehicle category and brake characteristics and must comprise the following tests at least:

(See points indicated for special features and alternative or additional tests)

<u>Vehicle category</u>	<u>Tests required as set out in:</u>	
	Appendix	and additional points
Wagons	C + E.1	1 + 2.2 + 2.5 ^a
Coaches	C + D or C + E.1 + E.2	1 + 2.2 + 2.5 ^a + 2.6 ^b
Locomotives, trainsets	C + D or C + F	1 + 2.2 + 2.3 + 2.5 ^a + 2.6 ^b
High speed trains	C + D	1 + 2.2 + 2.3 + 2.4 + 2.5 + 2.6 ^b

a. test rig simulation possible;

b. for adhesion-independent brakes.

2.1.2 - General test conditions

2.1.2.1 - If the vehicles are equipped with brakes that are independent of wheel/rail adhesion (e.g. magnetic brakes), these shall be switched off, except in the conditions defined under point **2.6 - page 14**.

2.1.2.2 - The WSP tests shall be conducted in average weather conditions, at moderate ambient temperatures (between 5°C and 25°C), and shall not be undertaken in snow. The temperature on the rail surface shall be recorded after every test and shall lie between 5°C and 35°C.

2.1.2.3 - For the tests, the capacity of the auxiliary air reservoir(s) shall be sufficient to ensure that there is maximum pressure in the brake cylinders in Brake Positions R and RR under dry conditions.

2.1.2.4 - The fluid used to reduce adhesion shall be an aqueous solution of a detergent with a fatty acid or tenside base (sum of active constituents) in a concentration between 10% and 15% and without mineral fillers. The detergent shall be biodegradable, mix readily with water and be safe to dispose of in the track.

Dilution of the agent shall enable the simulation of a required rate of adhesion τ_a between 0,05 and 0,08 during the initial braking period, not taking into account a possible first peak of the adhesion coefficient. The nominal composition of the mixture shall include 1% active constituents. It is permitted to vary the concentration as a function of available adhesion without, however, exceeding the bottom limit of 0,1% active constituents. The solution shall be released in front of each wheel of the first wheelset under a pressure of 0,1 bar to 0,2 bar through 8 mm dia. nozzles located along the longitudinal axis of the rail, a few centimetres from both the rail and the wheel.

The evaluation of the level of adhesion tested is contained in the method of evaluation of the slip tests described in Appendix B - page 22.

2.1.2.5 - VSP performance shall be evaluated in a series of braking tests on tangent track with a maximum gradient of ± 2 ‰.

2.1.2.6 - Prior to each test series (maximum 10 tests in succession), the wheels of the test vehicle must have been regenerated over a section of at least 20 km.

The different series of tests shall be carried out on different sections of line as far as possible. If tests are carried out on the same section, interruptions shall be scheduled, so that normal adhesion conditions can be restored in the interim as a result of train movements on the section.

2.1.3 - Parameter to be recorded

Various parameters shall be recorded and/or measured during the tests to allow the functions of the WSP to be verified and its capacities to be evaluated.

2.1.3.1 - The following variables shall be recorded simultaneously on a test vehicle equipped with the WSP under investigation, and shall be represented graphically as a function of time:

- vehicle speed v_f ,
- reference speed v_{ref} for the WSP, if this is utilised for regulation,
- circumferential speed of all wheelsets,
- pressure in the brake cylinders behind each WSP valve,
- vehicle deceleration,
- pressure in the main brake pipe,
- pressure in the auxiliary air reservoir R,
- initiation of braking,
- command signals for all WSP valves,
- additional command signals (magnetic brakes, doors, sanding, etc.).

2.1.3.2 - The following variables shall be measured:

- brake entry speed,
- stopping distance,
- stopping time,
- rail temperature and ambient temperature,
- pressure in the auxiliary air reservoir at the beginning and at the end of the brake application (in the case of slip tests).

2.1.3.3 - The weather conditions for each test shall be indicated in the report.

2.1.3.4 - If the WSP supplies additional switching signals for auxiliary functions, these shall be monitored during tests with and without spraying.

2.1.3.5 - An odometric signal shall be recorded such that the distances covered can be determined.

A diagram showing the various stages of such a braking test can be found in Appendix G - page 30.

o **2.2 - Approval tests to be carried out on coaches and wagons**

2.2.1 - Slip tests

2.2.1.1 - General conditions for slip tests

The general conditions described in the following paragraphs are supplementary to those listed in point 2.1 - page 8.

Braking performance on dry rail shall be determined in accordance with the requirements of *UIC Leaflet 544-1* (see Bibliography - page 41). Required braking performance in the different brake positions is indicated in the tables in Appendices D - page 26 and E - page 27.

The relative air consumption of the WSP shall be calculated for each test in accordance with Appendix C - page 25 and recorded in the test report.

Care shall be taken when evaluating air consumption not to include consumption by other items of equipment (e.g. secondary suspension).

A supplementary reservoir shall be provided in order to prevent the pressure in the auxiliary air reservoir from dropping below the value corresponding to maximum cylinder pressure in the respective brake position during tests with replenishment.

During the slip tests, the rails shall be sprayed abundantly approx. 300 m (100 m for the tests at 50 km/h) before the point at which the brakes are applied and over the entire length of the braking distance, using a fluid conforming to point 2.1.2.4 - page 9, to reduce adhesion.

Proof of the test at a speed of 50 km/h may be furnished by the slip test method or by using a coupled, but unbraked locomotive.

A further test shall be carried out on dry rail, with a λ of approx. 150% and from a speed of 120 km/h, with approx. 1 kg soap previously distributed regularly over each rail 200 m behind the brake application point over a length of at least 20 m. The wheelsets must not lock during this process.

2.2.1.2 - Number of slip tests

The tests to be undertaken are described in Appendices [D - page 26](#) and [E - page 27](#).

The WSPs for coaches shall be tested according to Appendix [D](#), the WSPs for wagons according to Appendix [E.1](#). WSPs for use on both coaches and wagons shall be tested according to Appendices [D](#) and [E.1](#), on both types of vehicle, or in accordance with Appendix [E](#) on a wagon.

2.2.1.3 - Evaluation of slip tests

None of the wheelsets shall lock during the tests at speeds above 30 km/h. Wheel locks below that speed shall not last longer than 0,4 s.

The instantaneous slide value for the wheelsets shall not exceed the following values for more than 3 seconds:

- 25% of the instantaneous speed if this is between 160 km/h and 120 km/h,
- 30 km/h at an instantaneous speed \leq 120 km/h.

The relative air consumption of the WSP (see Appendix [C - page 25](#) – without replenishment) may not exceed the following values:

Speed	Relative air consumption (C_r)
120 km/h	3,5
160 km/h	7

No undesired venting is permitted.

(Undesired venting: Reduction in braking force not justified by the behaviour of the wheelsets).

In tests conducted at initial speeds of 120 and 160 km/h on sprayed rail, the stopping distance shall not exceed the values given in Appendices [D](#), [E](#) and [F - page 29](#). These tests shall be evaluated according to the method described in Appendix [B - page 22](#).

The reference speed shall conform to the requirements of point [1.6 - page 7](#).

2.2.2 - Drag braking test

The general conditions for these tests are the same as those for the slip tests.

2.2.2.1 - Number of drag tests

A test with a hauled vehicle shall be conducted at a stable speed of around 100 km/h in order to simulate a holding brake application initiated on a line with a gradient, and in order in particular to verify the WSP's inherent regulating qualities.

A full brake application in Brake Position R shall be maintained for a period of 30 s, with adhesion reduced to such an extent that all wheelsets are in slide.

2.2.2.2 - Evaluation of drag brake test

None of the wheelsets shall lock.

The instantaneous values of wheelset slide may not exceed 30 km/h for more than 3 seconds.

No undesired venting is permitted.

2.2.3 - Supplementary tests for speeds up to 200 km/h

The suitability of the WSP for 200 km/h can be demonstrated in slip 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 rig using WSP speed sensors coupled to motors. Where a rig does not use WSP speed sensors, the compatibility of the latter with the electronic systems at 200 km/h shall be demonstrated using alternative tests.

Between 160 and 200 km/h the wheelset slide must not exceed 40 km/h for more than 3 seconds.

All criteria set out under point [2.2.1 - page 10](#) must be fulfilled and the results obtained must be contained in the documents submitted with the request for approval.

o 2.3 - Supplementary approval tests involving tractive units and trainsets

In order to be approved for tractive units and trainsets, the WSP must be approved for coaches and must have proved its aptitude to function as a WSP on a tractive unit with a dynamic brake in combination with a pneumatic brake.

For cases in which it is not possible to approve a WSP for coaches (special case of WSP integrated into other functions, such as engine control, brake control, etc.), Appendix [F - page 29](#) gives the tests to be performed in the most effective braking position.

2.3.1 - General conditions

The conditions in points [2.1.2 - page 8](#) and [2.2.1.1 - page 10](#) shall apply. A variable that is proportional to the dynamic braking force (e.g. engine power) shall be recorded during the tests.

2.3.2 - Braking to a standstill

Emergency braking to a standstill and/or full brake applications shall be performed in the following conditions from the maximum speed of the tractive unit with spraying (according to point [2.1.2.4 - page 9](#)):

1. Dynamic and pneumatic brakes combined.
2. Pneumatic brake only.
3. Failure of dynamic brake after complete build-up of braking power.
4. Dynamic and pneumatic brakes combined; emergency braking applied following a full brake application.

The criteria from point [2.2.1.3 - page 11](#) shall apply to the evaluation of results. The test is considered valid if the initial adhesion criterion (see Appendix [B - page 22](#)) is satisfied.

2.3.3 - Drag tests

The general conditions indicated under point 2.3.1 - page 12 shall apply.

The scope of the tests shall be as indicated under point 2.2.2.1 - page 11, at the maximum braking power of the tractive unit.

The same criteria as those listed in point 2.2.2.2 - page 12 shall apply to the assessment of the tests.

o 2.4 - Supplementary approval tests for high speeds (speed > 200 km/h)

These tests are undertaken with a trainset.

2.4.1 - The proper functioning of the WSP, already tested according to point 2.2 - page 10, shall be checked by undertaking emergency brake applications at the train's maximum speed. The requirements mentioned in *UIC Leaflet 660* (see Bibliography - page 41) must be respected.

2.4.1.1 - 400 m before brake application, the rails shall be sprayed with a solution required in point 2.1.2.4 - page 9, initially of 1% and then, in a second series of tests, of 4%.

At speeds between the maximum speed and 160 km/h the quantity of fluid indicated shall be doubled by adding a second nozzle before each wheel of the leading wheelset. At 160 km/h that second nozzle has to be shut off.

2.4.1.2 - As a minimum, the following parameters shall be recorded during the tests: the speed of rotation of the first four driving wheelsets and the first four carrying wheelsets, the values required under point 2.1.3 - page 9, and the forces from the dynamic brake.

2.4.1.3 - The proper functioning of the WSP devices shall be verified by analysing the test recordings. Wheelset slide shall not exceed 40 km/h for more than 5 seconds at speeds of > 200 km/h.

2.4.2 - The rotation monitoring function described in point 1.4.2.4 - page 6 shall be verified with the vehicle stationary. Three increasing wheelset speeds shall be simulated at the input to the monitoring device. The speed of the fourth wheelset shall be maintained at $v = 0$.

The rotation monitoring device shall transmit a signal to the driver's cab no later than 10 seconds after a speed of 50 km/h has been reached.

2.4.3 - The rotation monitoring function described in point 1.4.2.5 - page 6 shall be verified with the vehicle stationary. The maximum wheelset speeds shall be simulated at the input to the monitoring device. The speed of one wheelset shall then be reduced in accordance with the formula $\Delta v = 50 \text{ km/h} + 0,3v$. A signal shall be sent to the cab after 10 seconds.

The test shall be repeated at 50% of the maximum speed.

2.4.4 - If the rotation monitoring system is designed as per point 1.4.2.6 - page 6, the pressure in the brake cylinders of the wheelset for which the speed was reduced must be restored in the course of Test 2.4.3 no later than 10 seconds after venting.

o 2.5 - Supplementary approval tests for low adhesion

A braking test shall be conducted at 100 km/h on a section of track of at least 500 m with adhesion < 3%. This test can be conducted by spraying oil or soap, or the conditions can be simulated on a test rig, except in the case of a WSP intended for high speed operation, for which a track test is obligatory. During that test the specifications of point 1.1.10 - page 3 shall be applied.

o 2.6 - Supplementary approval tests for WSP acting in vehicles with brakes that are independent of adhesion

Rapid application of the brakes in Brake Position R + adhesion-independent braking from an initial speed of 160 km/h shall furnish proof that:

- The WSP installation takes the greater deceleration of the vehicle into account and does not alter the set braking force, particularly in dry rail conditions without wheelset slide.
- The WSP installation functions correctly in accordance with the characteristics listed under point 1.1 - page 2 when the rails are sprayed using the fluid concentration specified in point 2.1.2.4 - page 9.

In addition to the variables listed in point 2.1.3.1 - page 9, the effect of the adhesion-independent brake shall be recorded during these tests in the form of a signal or as an energy component (e.g. excitation current).

R 2.7 - Simulator rig tests

Simulator rig tests should, where technically possible, both be used as part of the acceptance process and also to validate WSP changes as described in point 4.5.3 - page 20. Simulator rig tests are intended to reduce the number of track tests required and are particularly valuable for the following requirements:

- initial optimisation of the WSP equipment prior to any track testing;
- as a replacement for track tests which present operational difficulties, for example, high speed tests;
- 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;
- to modify the WSP parameters when the WSP is used on a different type of vehicle than that for which it was originally approved.

The design requirements for simulation rigs are set out in Appendix H - page 31.

2.7.1 - Validation of the simulation

The braking performance of the vehicle used in the simulation test should first be validated by comparing the results of track tests on dry rail (or the design braking performance for a new vehicle type) with the results of equivalent tests produced on the simulation rig. The braking distances should agree within ± 5 %. The vehicle parameters used in the simulation should be submitted as part of any approval submission together with a statement authenticating the accuracy of the values used.

These tests are used as a reference to assess further developments as described in point 4.5.3.

2.7.2 - Programme of rig tests

The range of rig tests, the criteria for acceptance and any additional results required are set out in Appendix I - page 33.

2.7.3 - Further rig tests

It is recommended that the simulation facility also be used to explore and optimise the WSP performance over a much wider range of adhesion and vehicle conditions than may be utilised during track testing. In particular, the following tests may be considered:

- the effect of variations in vehicle loading, from tare to crush laden;
- the effect of variations in wheelset inertia due to diameter changes, e.g. new wheels versus wheels at minimum (i.e. scrapping) diameter;
- the effect of variations in the required level of braking, i.e. λ values between 65% and 200%;
- the effect of variations in brake demand level;
- the effect of variations in adhesion and step changes in adhesion;
- the ability of the WSP to maintain accurate wheel speed control at lower constant levels of adhesion than those utilised in the standard UIC track test. Constant adhesion levels of 0,02 to 0,06 may be used.

2.7.4 - Approvals Documentation

If simulation tests form part of the approval tests, the approvals documentation shall include:

- a description of the test rig based on the requirements set out in Appendix H - page 31;
- validation of the simulation model;
- the simulation results in accordance with Appendix I.

3 - Utilisation of the WSP system

3.1 - General

- **3.1.1** - Vehicles used for international services shall only be equipped with WSP approved in accordance with point 4 - page 19 and listed in Appendices K - page 35, L - page 36 or M - page 37.
- **3.1.2** - The WSP used shall protect all braked wheelsets of the vehicle.
- **3.1.3** - The following specifications are mandatory.
 - 3.1.3.1** - A control channel (logic + actuator) shall not act on:
 - more than half the wheels,
 - wheels in different trailer bogies,
 - wheels with different levels of adhesion demands.
 - 3.1.3.2** - On vehicles which have braking performance adapted to load, a single control channel shall not act on wheels that have different load control equipment.
 - 3.1.3.3** - A single control channel (logic + actuator) should not act on wheelsets that are different in nature (carrying or driving).
- R **3.1.4** - To optimise a braking performance it is recommended that running gear that may differ from the others in sliding speed should always be equipped with its own control channel ("wheelset/wheelset" or "single wheel/single wheel").
- **3.1.5** - If a WSP is fitted to a vehicle that is also equipped with a brake that is not dependent on adhesion and/or the inertia, vertical load or adhesion utilised are essentially different to the wheelset on the coach used for verification, the control system for the WSP must be suitably adapted and its key criteria must be checked again as part of the vehicle approval process.

o 3.2 - Conditions for utilisations with coaches and wagons

3.2.1 - The mandatory or recommended nature of the use of WSP for coaches and wagons built after 1 July 2002 is shown in the following table:

Speed range	Braking configurations	Range of required adhesion τ and associated λ		
		$\tau \leq 0,11$ and $\lambda \leq 125\%$	$0,11 < \tau \leq 0,12$ and $125 < \lambda \leq 135\%$	$\tau > 0,12$ and $\lambda > 135\%$
$160 < v \leq 200$	all kinds	WSP recommended	WSP MANDATORY	WSP MANDATORY
$v \leq 160$	discs only	WSP recommended	WSP MANDATORY	
	discs and shoes (all types)	no specification	WSP recommended	
	K shoes only			
	cast-iron or sintered shoes only			

The required utilisation of adhesion τ is the maximum rate corresponding to the highest holding force step. This is the maximum value in the overall range of possible axle-loads for a vehicle. This table applies to vehicles with wheels having a diameter ≥ 840 mm.

For vehicles with wheel diameters < 840 mm and a $\lambda > 125\%$ and a $\tau > 0,11$ the use of WSP is mandatory.

3.2.2 - Use of electronic WSP is mandatory for all coaches and wagons built after 1 January 1980 and designed for speeds above 160 km/h.

3.2.3 - Wagons and coaches for international traffic built between 1 January 1974 and 31 December 1986 shall be fitted with WSP equipment of one of the types listed in Appendix K - page 35.

WSPs approved for international traffic from 01.01.1987 are listed in Appendix L - page 36.

WSPs approved for international traffic from 01.01.2004 are listed in Appendix M - page 37.

o 3.3 - Conditions for utilisation with tractive units

The specifications that apply to coaches and wagons are also applicable to tractive units. Dynamic brake function shall be taken into account when determining utilisation of adhesion.

3.3.1 - In the case of tractive units (power cars, locomotives, track cars, railcars) that are capable of running alone, there must be a means of ensuring that a fault in the WSP (e.g., reference speed higher than vehicle speed) does not result in more than 50% of the braking force being released.

Use of two WSP devices is permissible here, or of an independent braking system that cannot be influenced by the WSP (e.g. automatic brake).

3.3.2 - The use of an electronic WSP is mandatory for all new tractive units (locomotives and power cars) designed for speeds above 160 km/h.

o 3.4 - Conditions for using WSP for high speeds ($v > 200$ km/h)

The recommendation set out in point **3.1.4 - page 16** is mandatory for trailer bogies.

The use of an electronic WSP in conjunction with a rotation monitoring device is mandatory for all vehicles built after 1 January 1997 and designed for speeds above 200 km/h.

4 - Type approval of WSP equipment for internal use

WSP equipment requires the approval of the UIC Braking Sub-Commission.

o 4.1 - Approval procedure

The procedure described in *UIC Leaflet 541-00* (draft version) shall be applied (see Bibliography - page 41).

o 4.2 - Application for approval

The following documents shall be submitted:

- functional description,
- list of hardware components and software version,
- standards applied,
- reports on the approval tests carried out,
- service test report,
- reliability, availability, maintainability and safety documentation.

4.3 - Approvals tests

o 4.3.1 - The type and content of these tests is set out in point 2.1.1 - page 8.

R 4.3.2 - Simulator rig tests as set out in point 2.7 - page 14; if part of the approval.

o 4.3.3 - Service tests

Service testing shall be carried out on at least 5 vehicles over a period of one year and shall be documented in a report.

o 4.4 - Type approval

The UIC Braking Sub-Commission shall issue type approval for the use of the WSP equipment in international traffic on the basis of the test report described in point 4.2 and the additional UIC requirements.

The Braking Sub-Commission shall determine whether preliminary tests are necessary and the appropriate test programme.

The UIC shall maintain a list of approved WSP equipment as stipulated in Appendices K - page 35 to M - page 37.

o 4.5 - Validity of approval following modifications

4.5.1 - The manufacturer is responsible for the constituent components of the WSP assembly being identical to those approved by the UIC.

The manufacturer is liable for any modifications to the approved device fitted to a given type of vehicle.

These modifications (as set out in point 4.5.4, paragraphs 1 to 3 and 5 to 6) shall be examined during type testing and approved (by the issue of a declaration of compliance) by the managing railway.

4.5.2 - If a WSP approved for international traffic is subjected to design modifications as described in point 4.5.4, paragraphs 4 or 7 which are likely to have an influence on the control system or that involves the use of new components, the approval shall lapse.

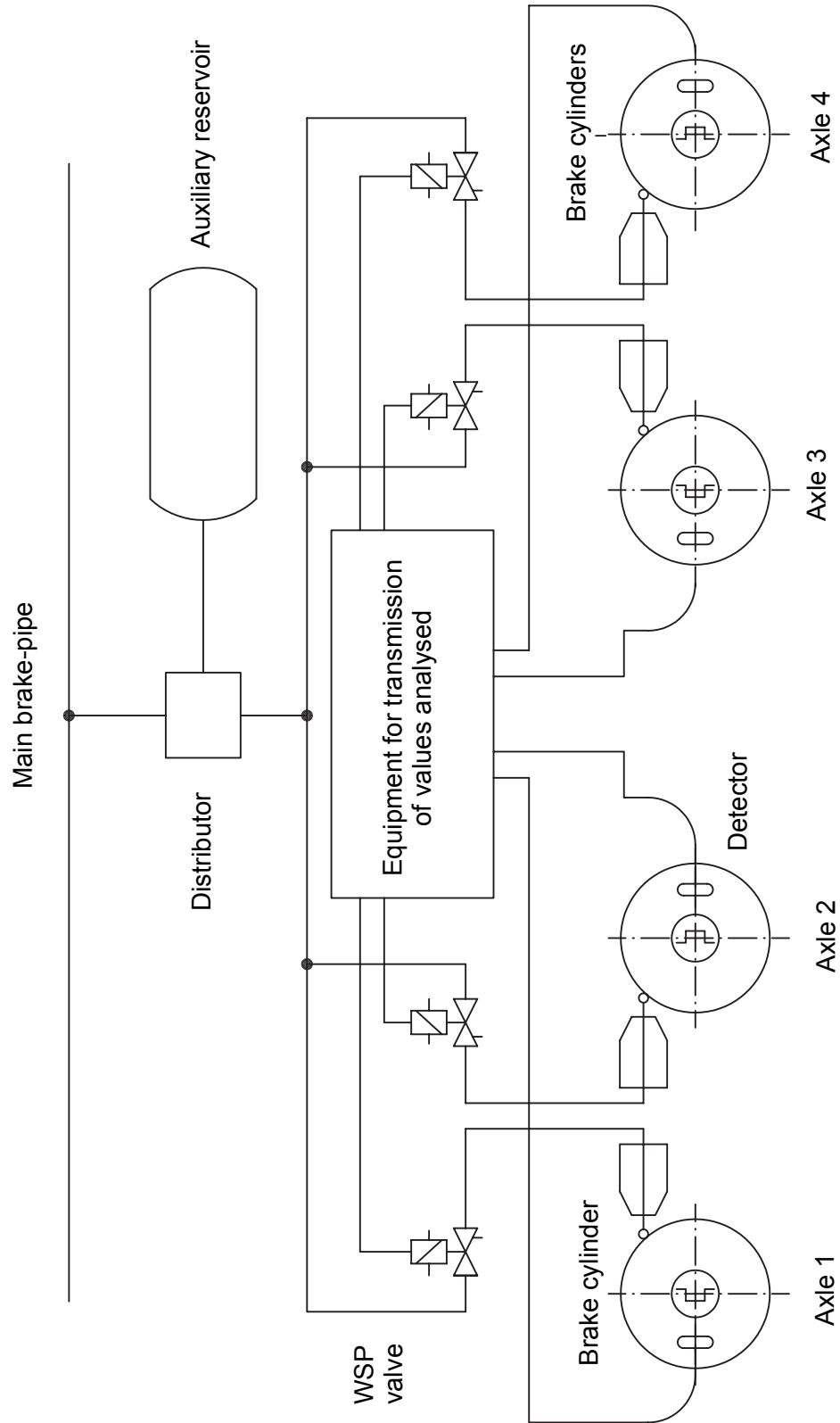
4.5.3 - In the event of design modifications as described in point 4.5.2, a report shall be submitted to the Sub-Commission demonstrating that the functional characteristics have been maintained. The Sub-Commission shall decide on the subsequent approval conditions.

4.5.4 - Retention / modification of approval conditions

Type of development		Condition for retention of approval
1 Hardware	Replacement of one or more component parts (electronic components, connectors)	Agreement of the user railway Documentation of rig or track tests
2 Hardware	Modification of the electronics not related to control of the WSP (adding input or output data, etc.)	Agreement of the user railway Documentation of rig or track tests
3 Hardware	Modification to the layout of the electronics	Agreement of the user railway Documentation of rig or track tests
4 Hardware	Modification of the electronics related to control of the WSP; replacement of one or several components which have an influence on the control cycle (e.g. WSP valves, speed sensors)	Agreement of the Sub-Commission for Braking Obligatory change of name
5 Software	Change in the value of a parameter (wheel diameter, rotating mass inertia, control threshold, braking force, filter constant, etc.)	Agreement of the user railway Documentation of rig or track tests
6 Software	Modification of the software unrelated to control of the WSP (adding a door control or electromagnetic rail brake function, etc.)	Agreement of the user railway Documentation of rig or track tests
7 Software	Change in the software related to control of the WSP (principle of calculating the speed or corrections, etc.)	Agreement of the Sub-Commission for Braking Obligatory change of name

Appendix A - Diagram of electronic wheel slide protection device (WSP)

Application example



Appendix B - Method of evaluation of the results of slip brake tests in reduced adhesion conditions at initial speeds of 120 and 160 km/h

This method is applied to slip brake tests carried out at initial speeds of 120 and 160 km/h.

With this method conformity checks have to be performed for adhesion conditions as specified in point 2.1.2.4 - page 9.

This method takes the following three criteria into account:

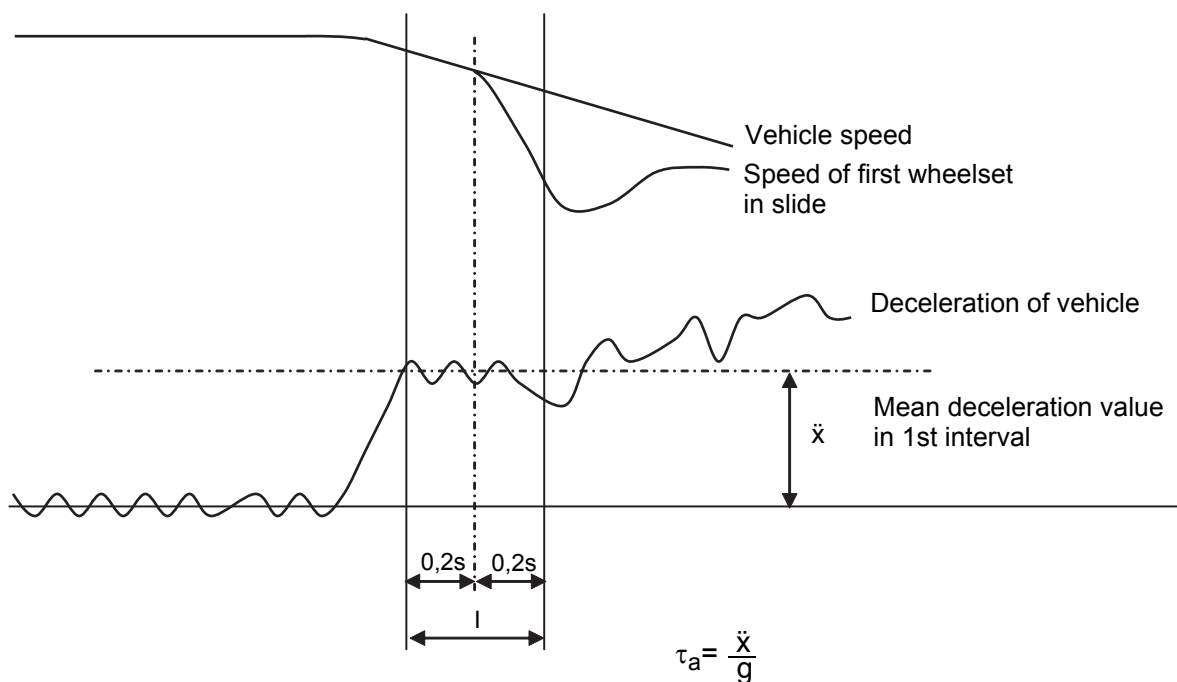
1. initial adhesion,
2. minimum slide of the wheelsets,
3. specified stopping distance.

B.1 - Test evaluation criteria

The following procedure should be adopted for any slip test performed at a nominal initial speed of 120 or 160 km/h:

B.1.1 - Determination of initial adhesion

The initial adhesion is assessed using the method below.



The initial adhesion criterion is observed if, in the first phase of braking, τ_a is less than 0,08.

B.1.2 - Minimum slide of the wheelsets of a vehicle (GM)

The following relationship should be calculated for each wheelset of a vehicle:

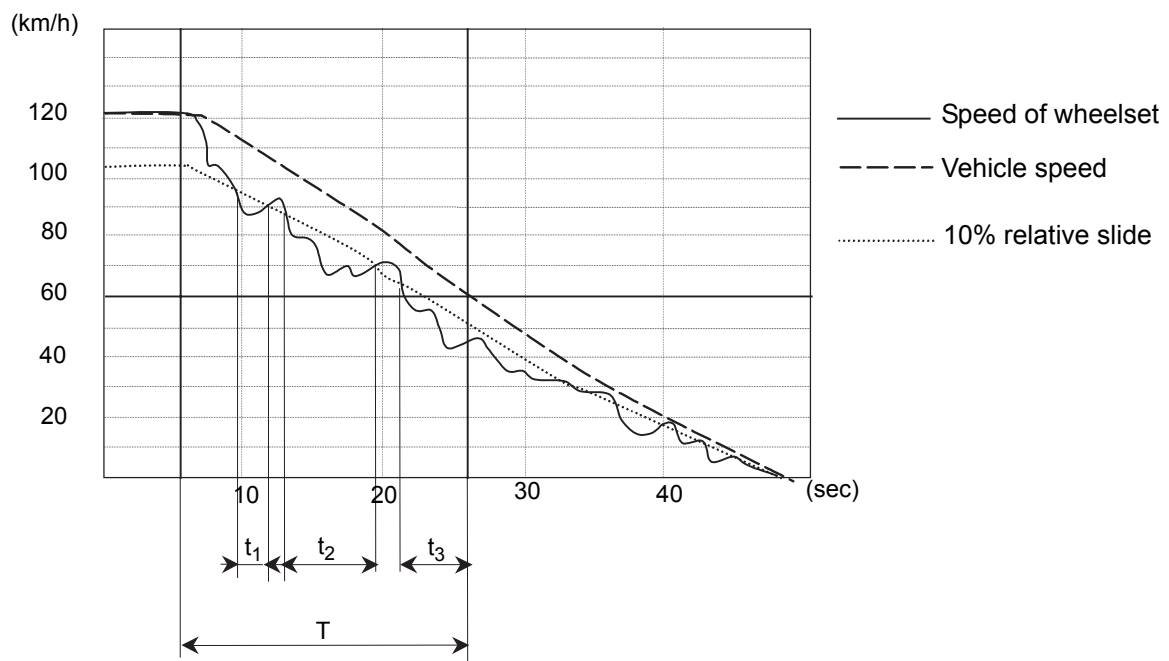
$$GM(n) = 100 \times \frac{\sum_{i=1}^m t_i}{T}$$

where: n = axle number
 m = number of intervals
 t_i = partial intervals

T = Time between the start of braking and the point at which the vehicle reaches a speed of 60 km/h.

$\sum_{i=1}^m t_i$ = Total time within interval T, during which the wheelset is in more than 10% relative slide.

An example in which the calculation is applied to a wheelset is given below:



t₁ + t₂ + t₃ = Total time within the interval from the start of braking to the point at which a vehicle speed of 60 km/h (T) is reached, during which the wheelset is in more than 10% relative slide.

The criterion of "minimum slide" is observed when for at least half the wheelsets of a vehicle, the value GM(n) is greater than:

- 35% for tests at a speed of 120 km/h;
- 20% for tests at a speed of 160 km/h.

B.1.3 - Specified stopping distance

The specified stopping distance for any braking position is given in Appendices D - page 26, E - page 27 and F - page 29 angegeben.

B.2 - Assessment of the test

If the initial adhesion criteria are observed, the evaluation of the test continues with the combination of minimum slide criteria and stopping distance, otherwise the test is not valid.

A combined evaluation of the two criteria minimum slide and stopping distance leads to one of the following four solutions:

A. Valid test, unsatisfactory WSP

- ◆ "Minimum slide" criterion not observed;
- ◆ Stopping distance > specified limit (as defined in Appendix D - page 26 or E - page 27).

B. Invalid test

(Repeat test with greater concentration of soap in the solution)

- ◆ "Minimum slide" criterion not observed;
- ◆ Stopping distance \leq specified limit.

C. Invalid test

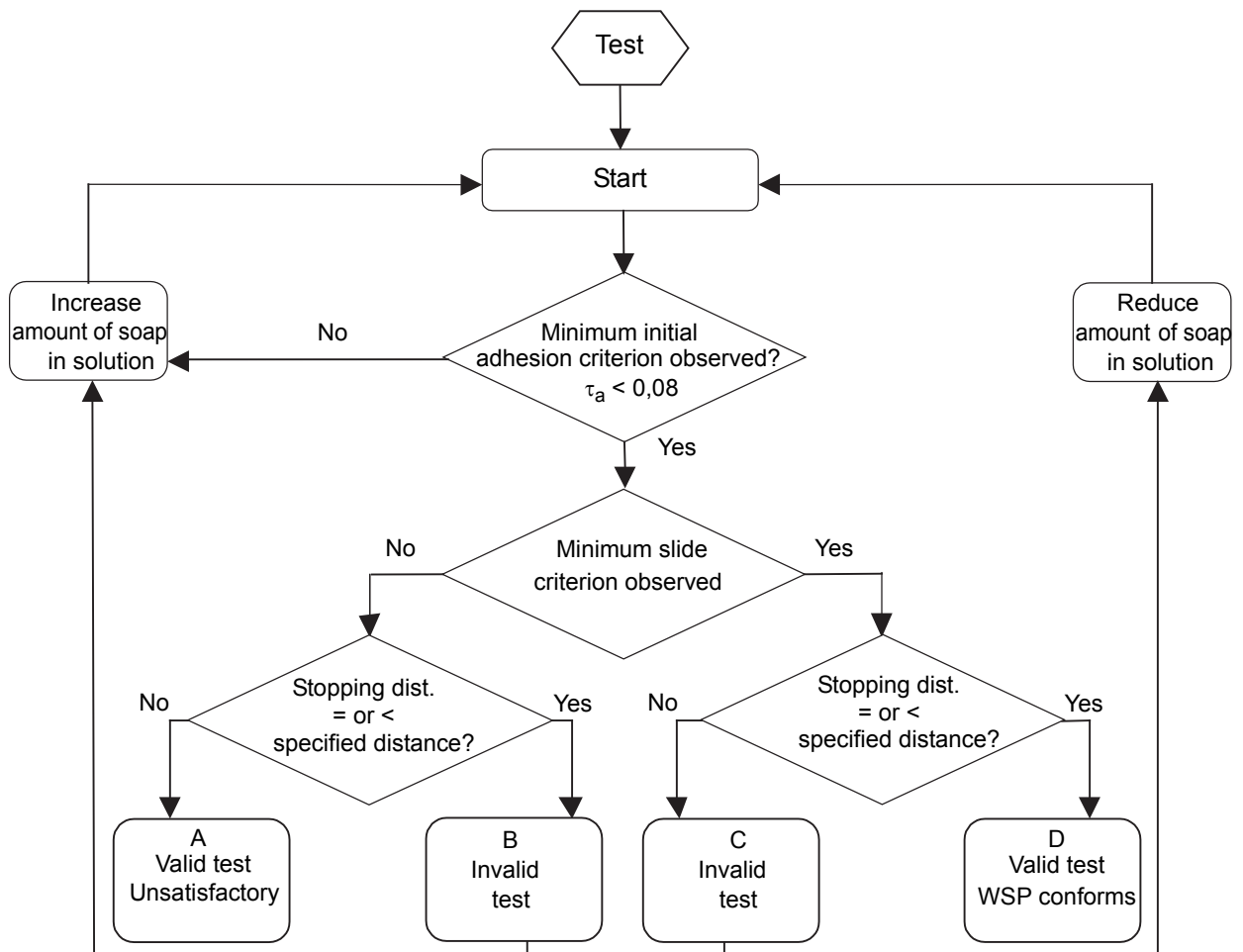
(Repeat test with lower concentration of soap in the solution)

- ◆ "Minimum slide" criterion not observed;
- ◆ Stopping distance > specified limit.

D. Valid test

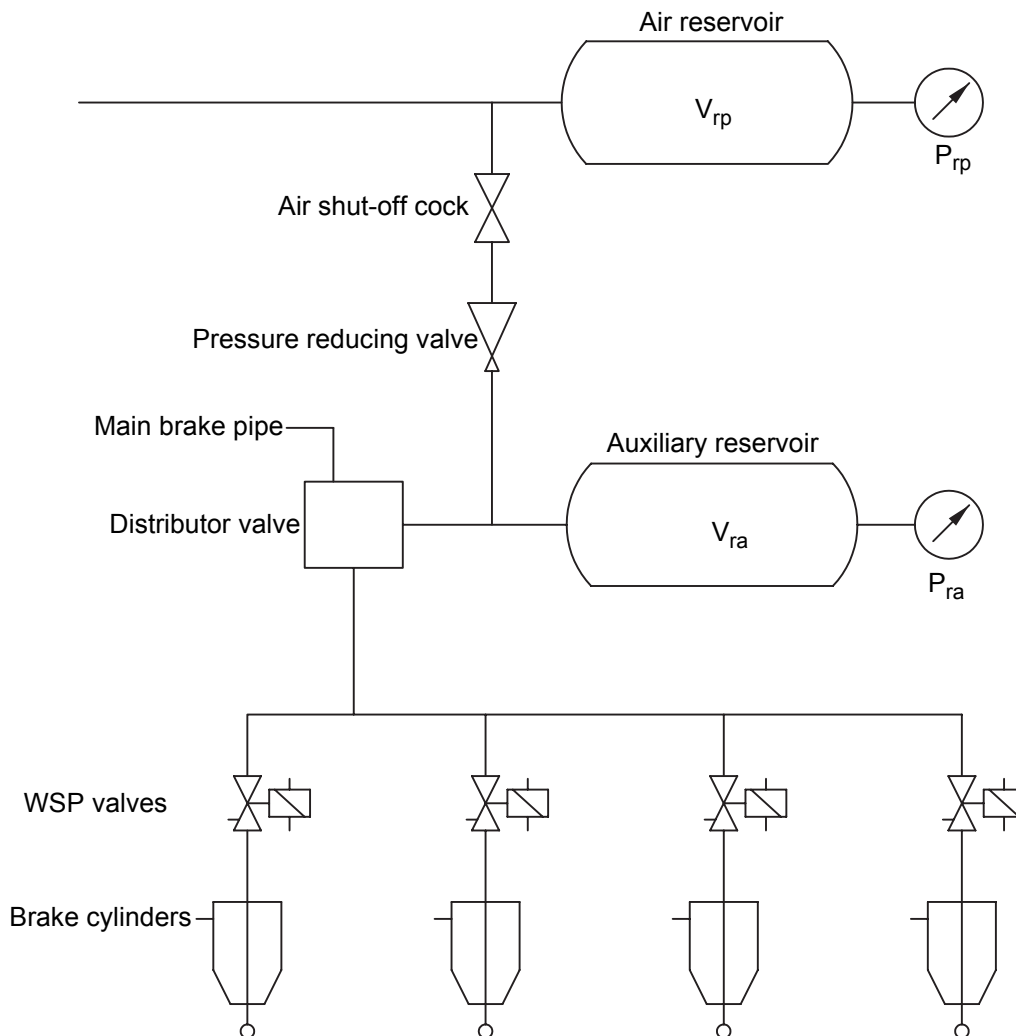
- ◆ "Minimum slide" criterion observed;
- ◆ Stopping distance \leq specified limit.

The described method is shown in the diagram below:



Appendix C - Calculation of relative air consumption

C.1 - Schematic diagram



C.2 - Relative air consumption without replenishment

$$c_r = (p_{ra1} - p_{ra2}) / (p_{ra1} - p_{ra3})$$

- ◆ Air shut-off cock closed
- ◆ p_{ra1} : Initial pressure before braking
- ◆ p_{ra2} : Residual pressure at a standstill with reduced adhesion
- ◆ p_{ra3} : Residual pressure at a standstill in dry conditions

C.3 - Relative air consumption without replenishment

$$c_r = (p_{rp1} - p_{rp2}) / (p_{rp1} - p_{rp3})$$

- ◆ Air shut-off cock open
- ◆ p_{rp1} : Initial pressure before braking
- ◆ p_{rp2} : Residual pressure at a standstill with reduced adhesion
- ◆ p_{rp3} : Residual pressure at a standstill in dry conditions
- ◆ Verify that $p_{ra1} = p_{ra2} = p_{ra3}$

Appendix D - Test programme for coaches

Test No.	Brake position	Initial test speed	Loading condition	Supply to auxiliary reservoir	Spraying of rail Adhesion	Stopping distance criterion	Special conditions
1	R	120	10 to 12 t axle load	without	dry rail	$440 < s < 490$ m	number of tests according to <i>UIC Leaflet 544-1 Tare</i>
2	P	120	"	without	dry rail	$580 < s < 620$ m	"
3	R	160	"	with	dry rail	Reference for extensions of braking distance at 160	"
4	RR	160	"	with	dry rail	$720 < s < 770$ m	"
5	R	120	"	without	sprayed rail	$s < 700$ m	minimum number of tests: 4
6	P	120	"	without	sprayed rail	$s < 730$ m	minimum number of tests: 4
7	R	160	"	with	sprayed rail	maximum 50% extension compared to dry braking distance	"
8	RR	160	"	with	sprayed rail	maximum 50% extension compared to dry braking distance	"
9	R	120	"	with	1 kg soap, distributed over 20 m, 200 m after brake initiation; otherwise dry rail		1 test
10	R	100 constant speed	"	with	sprayed rail		full application, all wheelsets shall slide
11	R	50	"	with	sprayed rail		

NB : Position RR is used for acceptance of WSP and corresponds approximately to a λ value of 190-205%.

Appendix E - Test programme for wagons

E.1 - Test programme for WSPs to be used on wagons

Test No.	Brake position	Initial test speed	Loading condition	Supply to auxiliary reservoir	Spraying of rail. Adhesion	Stopping distance criterion	Special conditions
1	P (SS)	120	tare	without	dry rail	560 < s < 600 m	number of tests according to <i>UIC Leaflet 544-1</i>
2	P (SS)	120	18 t axle load	"	"	700 < s < 730 m	"
3	R	120	tare	"	"	440 < s < 490 m	"
4	R	120	18 t axle load	"	"	520 < s < 540 m	"
5	R	160	18 t axle load	"	"	Reference for extensions of braking distance at 160	"
6	P (SS)	120	tare	without	sprayed rail	s < 730 m	minimum number of tests: 4
7	P (SS)	120	18 t axle load	"	"	s < 800 m	"
8	R	120	tare	"	"	s < 700 m	"
9	R	120	18 t axle load	"	"	s < 700 m	"
10	R	160	18 t axle load	without	"	maximum 50% extension compared to dry braking distance	"
11	R	120	18 t axle load	with	1 kg soap distributed over 20 m, 200 m after brake initiation, otherwise dry rail		1 test
12	R	100 constant speed	"	with	sprayed rail		drag test full application, all wheelsets shall slide
13	R	50	18 t axle load	with	sprayed rail		1 test

E.2 - Test programme for wagons in addition to Appendix E.1

To be applied when tests have been carried out on a wagon in accordance with Appendix E.1 - page 27 but the WSP is also to be approved for coaches.

Test No.	Brake position	Initial test speed	Loading condition	Supply to auxiliary reservoir	Spraying of rail Adhesion	Stopping distance criterion	Special conditions
1	RR	120	10 to 12 t axle load	with	dry rail	reference for extension of stopping distance at 120	number of tests according to <i>UIC Leaflet 544-1</i>
2	RR	160	"	"	"	720 < s < 770 m	"
3	RR	120	"	"	sprayed rail	s < 700 m	minimum number of tests: 4
4	RR	160	"	"	"	s < 1 000 m	"

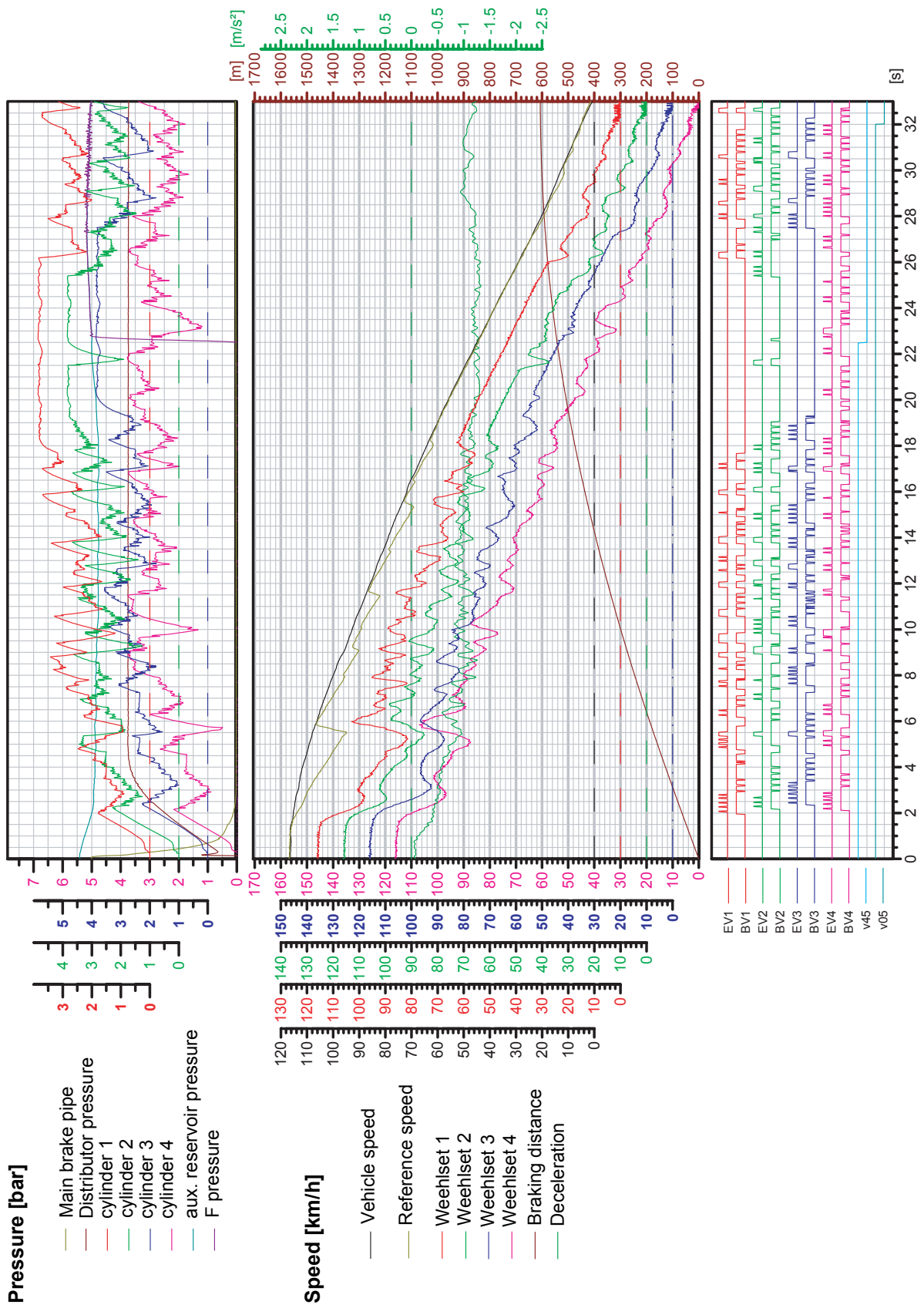
Appendix F - Test programme for tractive units and trainsets

Test No.	Initial test speed	Spraying of rail Adhesion	Stopping distance criterion	Special conditions
1	120	dry rail	reference for extension of stopping distance at 120	number of tests according to <i>UIC Leaflet 544-1</i>
2	maximum speed ^a	dry rail	reference for extension of stopping distance at 120	number of tests according to <i>UIC Leaflet 544-1</i>
3	120	sprayed rail	maximum extension 25% in relation to dry stopping distance	minimum number of tests: 4
4	maximum speed ^a	sprayed rail	maximum extension 25% in relation to dry stopping distance	minimum number of tests: 4
5	120	1 kg soap distributed over 20 m, 200 m after brake initiation, otherwise dry rail		
6	75 stabilised	sprayed rail		drag test with dynamic brake for 5 min, all wheelsets shall slide
7	100 stabilised	sprayed rail		drag test with dynamic brake for 5 min, all wheelsets shall slide
8	50	sprayed rail		full application

a. Where maximum speeds exceed 160 km/h, it is possible to replace maximum speed tests with tests at 160 km/h together with supplementary tests according to point 2.1.3.

This table applies to all tractive units with a braking power range corresponding to Position P through Position R.

Appendix G - Brake test measurement records



Appendix H - Simulator test rigs - Design requirements

H.1 - A simulation rig should comprise, as a minimum, the following elements:

- the WSP electronics under test;
- the WSP exhaust valves;
- a system for generation of the axle speeds. This may consist of the axle end speed sensors coupled to motors driven at axle speed from the computer simulation of the test vehicle. Alternatively, the computerised vehicle model may be used to generate a simulation of the axle speed sensor output;
- a computer simulation of the test vehicle;
- a computer simulation of the railhead adhesion conditions, including the modification of those conditions by controlled slippage of the test vehicle wheelsets, to allow the instantaneous available adhesion at the wheel to rail interface to be calculated for each axle;
- a hardware model of the vehicle braking system, coupled to the WSP exhaust valves, with the correct brake pressures and vehicle and exhaust valve pneumatic responses;
- a means of measuring the brake pressure from each wheelset. This pressure shall be used by the computer simulation of the test vehicle to calculate the applied brake force at the wheel to rail interface.

H.2 - The rig should be capable of simulating the following adhesion and test conditions:

- levels of adhesion between 2% and dry;
- variations in adhesion according to the level of wheel slip;
- variations in adhesion consistent with the natural variations that occur along the track;
- sudden changes of adhesion, such as that which may occur if sand is applied to the wheel to rail interface to improve the available adhesion;
- modification of the adhesion conditions by the dynamic variation of adhesion with vehicle speed and by the WSP controlled slippage of the test vehicle wheelsets;
- a maximum positive or negative gradient of 50 ‰;
- constant speed drag brake testing.

H.3 - The rig must be capable of simulating a range of vehicle characteristics as described below:

- a vehicle operating speed of up to 240 km/h,
- variations in vehicle parameters such as wheelset diameter and inertia, vehicle and bogie mass and centres of gravity, passenger or freight loading, and the brake friction interface characteristics;
- different braking modes, with λ values of between 25% and 200% for braking systems which are totally adhesion dependent;
- adhesion independent systems operating in addition to the normal friction brake system, for example electro-magnetic track brakes.

H.4 - It is recommended that the rig should be capable of simulating dynamic braking in addition to the normal friction brake systems.

Appendix I - Programme of rig tests

Test	Criteria to be respected	Additional results
Programmes as set out in Appendices D, E and F	<ul style="list-style-type: none"> ◆ maximum slip (1.1.2.1) ◆ no locked axles ◆ no undesired venting ^a 	<ul style="list-style-type: none"> ◆ stopping distance (extension) ◆ air consumption
Tests at maximum speed <ul style="list-style-type: none"> ◆ up to 200 km/h + 20 % ◆ up to 350 km/h + 10 % 	<ul style="list-style-type: none"> ◆ no locked axles ◆ no undesired venting ◆ maximum slip 	<ul style="list-style-type: none"> ◆ stopping distance (extension) ◆ air consumption ◆ verification of reference speed
drag braking tests ($\tau = 0,05$ at $v = 100$ km/h for 30 s)	<ul style="list-style-type: none"> ◆ no activation of watchdog device ◆ no locked axles ◆ no undesired venting 	<ul style="list-style-type: none"> ◆ maximum slip ◆ verification of reference speed ◆ air consumption
low-adhesion tests ($\tau = 0,02$ at $v = 120$ km/h for 120 s)	<ul style="list-style-type: none"> ◆ no activation of watchdog device ◆ no locked axles ◆ no undesired venting 	<ul style="list-style-type: none"> ◆ maximum slip ◆ verification of reference speed ◆ air consumption
dry tests on gradient (5 %)	<ul style="list-style-type: none"> ◆ no undesired venting 	
reduced adhesion tests on gradient (5 %)	<ul style="list-style-type: none"> ◆ no activation of watchdog device ◆ no undesired venting 	<ul style="list-style-type: none"> ◆ verification of reference speed
fault detection (speed sensors and valves open circuit and short-circuited) <ul style="list-style-type: none"> ◆ watchdog device ◆ locked wheelset signal 	<ul style="list-style-type: none"> ◆ conformity with the leaflet ◆ conformity with the manufacturer's technical data 	

a. Undesired venting: reduction in braking force not justified by behaviour of wheelsets.

Appendix J - Test programme for simulator rig test

Reserved

Appendix K - WSPs accepted in international traffic for vehicles built between 1.1.1974 and 31.12.1986

The list of WSPs approved for international traffic is available on the UIC website:
<http://www.uic.asso.fr>.

Appendix L - WSPs accepted in international traffic for vehicles built after 1.1.1987

The list of WSPs approved for international traffic is available on the UIC website: <http://www.uic.asso.fr>.

Appendix M - WSPs also accepted in international traffic for vehicles built after 1.1.2004

The list of WSPs approved for international traffic is available on the UIC website:
<http://www.uic.asso.fr>.

List of abbreviations

ER	événement redouté = undesirable event
g	Standard gravitational acceleration value; $1\text{ g} = 9,80665\text{ m/s}^2$
P	Brake position P as defined in UIC Leaflet 544-1
R	Brake position R as defined in UIC Leaflet 544-1
RR	Brake position RR with a λ value greater than 180%
SS	Wagon brakes which conform to the requirements of SS traffic
WSP	Wheel Slide Protection device

Glossary

Adhesion	Tractive or braking force transferred in relation to the wheel/rail contact force.
Adhesion coefficient	Quantity not measured in units – expressing the relationship between the tractive or braking force transferred by wheel/rail adhesion and the wheel/rail contact forces (also known as friction coefficient) in the case of a small slide.
Automatic application of the brakes	A rapid drop in main brake pipe pressure caused by breakage of coupling or the triggering of a monitoring device.
Control channel	Control system based on one sensor which records the speed of a particular axle, processes it in the WSP calculator and sends control signals to one WSP valve to regulate the braking force on the axle in question (rigidly coupled axles may form a single control channel).
Emergency braking	Rapid discharge of the main brake pipe with the driver's brake valve in the rapid braking position to obtain the maximum braking effect.
Fictitious speed	See reference speed.
Full service braking	Maximum service brake application obtainable with a drop in pressure of 1,5 bar in the main brake pipe.
Initial adhesion coefficient	Instantaneous value of the adhesion coefficient at the moment when the first wheelset enters a larger slide (see Appendix B for calculation method).
Instantaneous slide	Slide at a specific moment.
Main brake pipe	Also known as the main line, a continuous line of compressed air charged at a working pressure of 5 bar, which connects the driver's brake valve to the vehicle braking equipment in the train, controls the application and release functions, and recharges the auxiliary reservoir after braking.
Minimum slide criterion	Calculated parameter used to assess the validity of a WSP test (see Appendix B).
Reference speed	Fictitious speed generated by the WSP based on the speed of the available axles. In braking mode, the highest speed of a single axle constitutes the basis. In the event of all axles sliding and high levels of axle deceleration, the reference speed will be based on a predefined deceleration, which represents the maximum deceleration physically possible for the vehicle.
Relative slide	Percentage value at a given moment of the ratio between wheel slide and vehicle speed.

Rotation monitor	A system, independent of the WSP, that monitors the rotation of the axles, specifically required for high speed trains ($v > 200$ km/h). Locked wheelsets or unusually high levels of slide must trigger an error message in the driver's cab.
Service braking	Based on the operating situation, graduated application and release of the brake with a maximum drop in pressure of $1,5^{+0,1}$ bar in the main brake pipe.
Utilisation of adhesion	Ratio between tractive or braking force created and wheel/rail contact forces.
Wheel/rail adhesion	Process of transmitting force through friction.
Wheel slide	Difference between the wheel circumference speed and the translational speed of the vehicle.
Wheel slip	Transition to greater slide in traction mode.

Bibliography

1. UIC leaflets

International Union of Railways (UIC)

UIC Leaflet 540: Brakes - Air Brakes for freight trains and passenger trains, 4th edition, June 2002

UIC Leaflet 541-00: Brakes - Approval of brake parts, 1st edition under preparation

UIC Leaflet 541-03: Brakes - Regulations concerning manufacture of the different brake parts - Driver's brake valve, 1st edition of 1.1.84

UIC Leaflet 541-5: Brakes - Electropneumatic brake (ep brake) - Electropneumatic emergency brake override (EBO), 3rd edition, May 2003

UIC Leaflet 543: Brakes - Regulations governing the equipment of trailing stock, 12th edition, June 2003

UIC Leaflet 544-1: Brakes - Braking power, 4th edition, October 2004

UIC Leaflet 544-2: Conditions to be observed by the dynamic brake of locomotives and motor coaches so that the extra braking effort produced can be taken into account for the calculation of the braked-weight, 2nd edition of 1.1.83

UIC Leaflet 546: Brakes - High power brakes for passenger trains, 5th edition of 1.1.67 - Reprint dated 1.1.80 incorporating 5 Amendments

UIC Leaflet 547: Brakes - Air brake - Standard programme of tests, 4th edition of 1.7.89

UIC Leaflet 550: Power supply installations for passenger stock, 11th edition, April 2005

UIC Leaflet 556: Information transmission in the train (train bus), 4th edition, August 2005

UIC Leaflet 557: Diagnostics on passenger rolling stock, 2nd edition of 1.1.98

UIC Leaflet 660: Measures to ensure the technical compatibility of high-speed trains, 2nd edition, August 2002

UIC Leaflet 704: Railway Transport Systems - Electromagnetic Compatibility (EMC), Withdrawn on 1.7.05

2. Minutes of meetings

International Union of Railways (UIC)

Traction and Rolling Stock Committee: Question 5/T/FIC - Approval of amendments and additions to UIC Leaflet 541-05 "wheel-slip" prevention equipment and granting of exemption to DR, June 1986

Sub-Committee for Braking: Question 5/T/36 - Conditions for the acceptance of brake equipment - Application from FS for acceptance of the Parizzi WUPAR 83 electronic WSP device for disc-braked wagons, October 1986

Sub-Committee for Braking: Question 5/T/36: Conditions for the acceptance of brake equipment - Application from FS for acceptance of the Westinghouse WABCO WGMC 19/1 electronic WSP device combined with FS-Parizzi WSP valves, September/October 1992

Sub-Committee for Braking: Question 5/T/36 - Conditions for the acceptance of brake equipment - DB request for acceptance of electronic WSP device MRP-GMC 29 for coaches and wagons built by Mannesmann Rexroth Pneumatik GmbH, October 1993

Sub-Committee for Braking: Question 5/T/36 - Conditions for the acceptance of brake equipment - DB request for acceptance of SWKP AS 20 WSP equipment built by SAB-WABCO KP GmbH, October 1997

Sub-Committee for Braking: Question 5/T/36 - Conditions for the acceptance of brake equipment - Application from FS for acceptance of the Parizzi μ WUPAR electronic WSP device built by Alstom, June 2004

3. European standards

European Committee for Standardization (CEN)

EN 50121-3-1:2001 : Railway applications. Electromagnetic compatibility - Part 3-1: Rolling stock - Train and complete vehicle, 2001

EN 50121-3-2:2001 : Railway applications. Electromagnetic compatibility - Part 3-2: Rolling stock - Apparatus, 2001

EN 50126:2000 : Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS), 2000

EN 50128:2001 : Railway applications - Communications, signalling and processing systems. Software for railway control and protection systems, 2001

EN 50155:2004 : Railway applications - Electronic equipment used on rolling stock, 2004

Warning

No part of this publication may be copied, reproduced or distributed by any means whatsoever, including electronic, except for private and individual use, without the express permission of the International Union of Railways (UIC). The same applies for translation, adaptation or transformation, arrangement or reproduction by any method or procedure whatsoever. The sole exceptions - noting the author's name and the source - are "analyses and brief quotations justified by the critical, argumentative, educational, scientific or informative nature of the publication into which they are incorporated".

(Articles L 122-4 and L122-5 of the French Intellectual Property Code).

© International Union of Railways (UIC) - Paris, 2005

Printed by the International Union of Railways (UIC)
16, rue Jean Rey 75015 Paris - France, November 2005
Dépôt Légal November 2005

ISBN 2-7461-0967-0 (French version)
ISBN 2-7461-0968-9 (German version)
ISBN 2-7461-0969-7 (English version)