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Road vehicles — Air and air/hydraulic braking systems of motor vehicles, including those with electronic control functions — Test procedures

Véhicules routiers — Systèmes de freinage à air comprimé ou hydropneumatiques pour les véhicules à moteur, y compris les systèmes à fonctions de commande électroniques — Méthodes d'essai

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 7635 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 2, *Braking systems and equipment*.

This third edition cancels and replaces the second edition (ISO 7635:2003), which has been technically revised.

Road vehicles — Air and air/hydraulic braking systems of motor vehicles, including those with electronic control functions — Test procedures

1 Scope

This International Standard specifies the method of testing the air or air over hydraulic braking systems of vehicles of categories M and N (excluding M1 and N1) as defined in Annex 7 to the UN-ECE Consolidated Resolution on the Construction of Vehicles (R.E.3.) which are built to comply with UN-ECE Regulation 13/09 including supplements 1-6. Test methods covering lock actuators or the electrical regenerative braking systems of electric and hybrid vehicles are not included in this edition.

NOTE Requirements of UN-ECE Regulation 13 related purely to the design of braking systems and braking system components are not part of this International Standard.

The values in square brackets [ ] and the values in tables are taken from UN-ECE Regulation No. 13.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 611:2003, *Road vehicles — Braking of automotive vehicles and their trailers — Vocabulary*

ISO 1176:1990, *Road vehicles — Masses — Vocabulary and codes*

ISO 3833:1977, *Road vehicles — Types — Terms and definitions*

ISO 7638-1, *Road vehicles — Connectors for the electrical connection of towing and towed vehicles — Part 1: Connectors for braking systems and running gear of vehicles with 24 V nominal supply voltage*

ISO 7638-2, *Road vehicles — Connectors for the electrical connection of towing and towed vehicles — Part 2: Connectors for braking systems and running gear of vehicles with 12 V nominal supply voltage*

ISO 11992 (all parts), *Road vehicles — Interchange of digital information on electrical connections between towing and towed vehicles*

ISO 12161, *Road vehicles — Endurance braking systems of motor vehicles and towed vehicles — Test procedures*

ISO 21069-1:2004, *Road vehicles — Test of braking systems on vehicles with a maximum authorized total mass of over 3,5 t using a roller brake tester — Part 1: Pneumatic braking systems*

ISO 21069-2 [1)], *Road vehicles — Test of braking systems on vehicles with a maximum authorized total mass of over 3,5 t using a roller brake tester — Part 2: Air over hydraulic braking systems*

UN-ECE Regulation N° 13, *Uniform provisions concerning the approval of vehicles with regard to braking*

NOTE UN-ECE Regulation 13 is periodically updated through amendments and supplements, with this International Standard having been prepared in accordance with the 09 series of amendments including supplements 1 to 6. When using this International Standard, care should be taken to ensure that changes have not subsequently occurred that affect the test methods or values given.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 611, ISO 1176, and ISO 3833 and the following apply.

3.1
braking systems

3.1.1
air-over hydraulic braking system
braking system having stored pneumatic energy, hydraulically actuated brakes and transmission means incorporating a pneumatic to hydraulic converter

NOTE For a typical system diagram, see Figure A.1.

3.1.2
pneumatic (full air) braking system
braking system in which the control and energy are transmitted from the point of application to the brakes by pneumatic transmission devices

NOTE For a typical system diagram, see Figure A 2.

3.1.3
electronic braking system
EBS
braking system in which control is generated and processed as an electrical signal in the control transmission

NOTE Electrical output signals control devices, which produce actuation forces from stored pneumatic energy.

3.1.4
antilock braking systems

ABS
3.1.4.1
categories of ABS

— Category 1: ABS which meets all the requirements of ECE R 13 Annex 13;

— Category 2: ABS which meets the requirements of ECE R 13 Annex 13, except paragraph 5.3.5 of ECE R 13 Annex 13 (no braking rate on split-adhesion surfaces is prescribed);

— Category 3: ABS which meets the requirements of ECE R 13 Annex 13, except paragraphs 5.3.4 and 5.3.5 of ECE R 13 Annex 13 (all split adhesion tests are omitted).

1) To be published.

3.1.4.2
wheel control

3.1.4.2.1
directly controlled wheel
wheel whose braking force is modulated according to data provided at least by its own sensor

3.1.4.2.2
indirectly controlled wheel
wheel whose braking force is modulated according to data provided by sensor(s) of other wheel(s)

NOTE ABS with select-high control are deemed to include both directly and indirectly controlled wheels. In systems with select-low control, all sensed wheels are deemed to be directly controlled wheels.

3.1.4.3
full cycling ABS
ABS which is repeatedly modulating the brake force to prevent the directly controlled wheels from locking

NOTE Brake applications where modulation only occurs once during the stop shall not be considered to meet this definition.

3.2
vehicle loading

3.2.1
laden vehicle
vehicle laden so as to reach its maximum mass

3.2.1.1
laden motor vehicle other than semi-trailer tractor
vehicle laden to technically feasible maximum design total mass specified by the vehicle manufacturer and acknowledged by the Technical Services

NOTE This mass may exceed the “maximum authorized total mass” permitted by national regulations. Mass distribution on the axles is stated by the vehicle manufacturer. In the event of several load distribution patterns being planned, the distribution of the maximum design total mass among the axles is such that the load on each axle is proportional to the maximum load for each axle defined by the manufacturer.

3.2.1.2
laden semi-trailer tractor
vehicle laden as in 3.2.1.1, except that the load defined by the manufacturer may be repositioned halfway between the fifth wheel coupling pin position and the centre-line of the rear axle(s), so as to compensate for the dynamic load transfer from the semi-trailer

NOTE This additional load, representing the semi-trailer loading may be carried in a specially designed load frame.

3.2.2
unladen vehicle

3.2.2.1
unladen motor vehicle other than semi-trailer tractor
vehicle laden to complete vehicle kerb mass without load or occupant but with the fuel tank filled to at least 90 % of the capacity specified by the vehicle manufacturer at the start of test and complete with cooling fluid and lubricants, and tools and spare wheel, if provided

NOTE During the tests, the fuel quantity in the fuel tank is maintained at least to 50 % of its capacity. An increase up to 200 kg mass over this mass is allowed. This corresponds, for instance, to the driver, one observer and instrumentation. If necessary, the appropriate vehicle mass may be removed. For a vehicle without body, the manufacturer declares the minimum axle loads for a bodied vehicle.

3.2.2.2
unladen semi-trailer tractor
vehicle laden as in 3.2.2.1 including the fifth wheel coupling or an equivalent load (in value and in position)

3.3
Air system pressures

3.3.1
pressure indicated by manufacturer
reservoir pressure specified by the manufacturer from which it is possible to achieve the required efficiency for service braking and which is the basis for the tests prescribed in 15.7.

3.3.2
maximum pressure
pressure available for normal operation:

— cut-out pressure, in the case of an installation with a pressure regulating device; and

— [90] % of the asymptotic pressure, in the case of an installation with a pressure-limited compressor.

3.3.3
minimum pressure
pressure available for normal operation:

— cut-in pressure, in the case of an installation with a pressure regulating device; and

— [90] % of the pressure indicated by the manufacturer, in the case of an installation with a pressure-limited compressor.

3.4
vehicle types
vehicles subject to the European Agreement Concerning the International Carriage of Dangerous Goods, e.g. ADR vehicles

4 Symbols

For the purposes of this International Standard the symbols given in Table 1 apply.

Table 1 — Symbols

Symbol	Meaning	Unit
a_{m}	mean deceleration	m/s^2
d_{m}	mean fully developed deceleration	m/s^2
E	wheelbase	m
ε	the adhesion utilised by the vehicle: quotient of the maximum braking rate with the ABS operative (z_{AL}) and the coefficient of adhesion (k)	
ε_{i}	the ε value measured on axle i (in case of a power-driven vehicle with a category 3 ABS)	
ε_{H}	the ε value on the high adhesion surface	
ε_{L}	the ε value on the low adhesion surface	
F	actuating force	N
F_{dyn}	Normal reaction of road surface under dynamic conditions with the ABS operative	N
F_{idyn}	F_{dyn} on axle i	N
F_{i}	normal reaction of road surface on axle i under static conditions	N
F_{M}	total normal static reaction of road surface on all wheels of power-driven (towing vehicles)	N

Table 1 (*continued*)

Symbol	Meaning	Unit
F_{Mnd} [a]	total normal static reaction of road surface on the unbraked and non-driven axles of the power-driven vehicle	N
F_{Md} [a]	total normal static reaction of road surface on the unbraked and driven axles of the power-driven vehicle	N
F_{Wm} [a]	0,01 F_{Mnd} + 0,015 F_{Md} (rolling resistance)	N
g	acceleration due to gravity (9,81 m/s^2)	m/s^2
h	height of centre of gravity specified by the manufacturer and agreed by the Technical Service conducting the approval test	m
h_k	height of fifth wheel coupling (king pin)	m
k	coefficient of adhesion between tyre and road	
k_f	k -factor of one front axle	
k_H	k -value determined on the high adhesion surface	
k_i	k -value determined on axle i for a vehicle with a category 3 ABS	
k_L	k -value determined on the low adhesion surface	
k_{lock}	value of adhesion for 100 % slip	
k_M	k -factor of the power driven vehicle	
k_{peak}	maximum value of the curve “adhesion versus slip”	
k_r	k -factor of one rear axle	
n	number of brake applications	
p_{max}	maximum pressure supplied by the towing vehicle in the supply circuit for the trailer	bar
p_1	65 % of p_2	bar
p_2	pressure level specified by the manufacturer enabling the prescribed performance of the service braking system to be achieved	bar
P_M	mass of motor vehicle	kg
P_T	maximum permissible mass of the trailer allowed to be towed by the power-driven vehicle	t
R	ratio of k_{peak} to k_{lock}	
S	stopping distance	m
t, t_i, Δt	time interval	s
t_1, t_2, t_3	pump up times (ref. 9.2.1)	min
t_m	mean value of t	s
t_{min}	minimum value of t	s
v	vehicle speed	km/h
v_{max}	maximum speed of the vehicle	km/h
v_u	lower speed limit for the antilock energy consumption test	km/h
V	reservoir volume	l
z	braking rate	
z_{AL}	braking rate of the vehicle with the ABS operative	
z_m	mean braking rate	
z_{max}	maximum value of z	
z_{mf}	mean braking rate of front axle	
z_{mr}	mean braking rate of rear axle	
z_{MALS}	z_{AL} of the power-driven vehicle on a “split-surface”	

[a] F_{Mnd} and F_{Md}: In case of two-axle power-driven vehicles these symbols may be simplified to corresponding F_i symbol.

5 Test site conditions

5.1 Test site

The test site should be of sufficient size, without obstacles, to provide a safe testing environment.

The test site shall have a road of sufficient length prior to the test area to enable the test speeds to be attained. The test area should be of;

a) sufficient length to allow for poor braking performance; and

b) sufficient width to allow for poor directional stability under braking.

5.2 Road surface condition

5.2.1 Surface

5.2.1.1 The test area shall be a dry, smooth, hard-surface free of loose material providing a peak coefficient of adhesion of about [0,8].

5.2.1.2 Additionally, for the testing of vehicle(s) equipped with an ABS a surface providing a peak coefficient of adhesion k_{peak} of [0,3] or less is needed. It shall be preceded and followed by a surface according to 5.2.1.1 of sufficient length on the approach side to enable the test speeds to be attained.

The ratio $R = k_{peak}/k_{lock}$ and the adhesion vs. slip curve have to be available for this surface in line with ECE R 13, Annex 13, Appendix 4.

Until such test surfaces become generally available, tyres at the limit of wear, and higher values up to [0,4] may be used. The actual value obtained and the type of tyres and surface shall be recorded.

For testing vehicles fitted with ABS of category 1 or 2, it is also necessary for a low adhesion surface (k_L) to have a high adhesion surface (k_H) on at least one side to enable the split-adhesion tests to be performed. Both surfaces shall be sufficiently wide to be able to determine, using the vehicle under test, the peak coefficients of adhesion separately.

The above described surfaces shall be such that k_H is equal to or greater than [0,5], and k_H/k_L is equal to or greater than [2]. If any doubt arises that this requirement is met (e.g. the high adhesion surface is wet), the peak coefficients of adhesion shall be ascertained by using the procedure detailed in subclauses 12.2 and 12.4. However, the peak coefficients of adhesion shall always be measured when testing a vehicle fitted with antilock brakes of category 1 to check the braking rate on the split surface (reference 13.1).

5.2.2 Gradient

5.2.2.1 Road surface shall be level with a tolerance of ± 1 % of the average gradient, measured over a minimum distance of 50 m.

5.2.2.2 Type II and type IIA test site conditions

Table 2 — Type II and type IIA test site conditions

	Gradient %	**Length of gradient** km
Type II	6	6
Type IIA	7	6

NOTE In support of the tests specified in 15.8, additional information regarding practical test site conditions can be taken from ISO 12161, including a test procedure using a vehicle dynamometer test bench.

5.2.2.3 The parking braking system hill holding test may be conducted on an appropriate gradient or on a level road as specified in 10.3 and 15.1.

5.2.3 Camber

The camber or transverse gradient across the road surface shall not exceed 2 %.

5.3 Ambient conditions

5.3.1 Wind speed

The tests must be performed when there is no wind liable to affect the results. The wind speed shall not exceed an average of 5 m/s.

5.3.2 Air temperature

The air temperature shall be recorded in the test report.

6 General requirements

6.1 General test conditions to be followed during the determination of braking performance

a) vehicle speed (reference 6.11);

b) without exceeding the maximum permissible control force;

c) engine disconnected or connected (as prescribed);

d) without wheel-locking, except immediately before stopping unless specifically allowed;

e) without deviation of the vehicle from its course (steering corrections of less than 90° allowed, if not otherwise specified);

f) loading condition: unless otherwise specified, all tests should be carried out with the vehicle laden and unladen.

6.2 During all phases of the following test procedures, any unusual braking performance characteristics and/or vehicle behaviour e.g. course deviation or abnormal vibration, shall be observed and reported.

6.3 During the tests with the engine connected on vehicles with a manual gearbox, the clutch may be disengaged just before the vehicle stops to avoid the engine stalling.

6.4 Deceleration measurements used in the following test procedures, unless otherwise stated, refer to the "mean fully developed deceleration" as defined in UN-ECE Regulation 13 Annex 4 paragraph 1.1.2.

6.5 Tests may be carried out under adverse conditions to avoid delays, but with due consideration for safety. Such adverse conditions shall be reported. Any failed tests under such conditions shall be repeated under the correct conditions, but not all tests need necessarily be repeated.

6.6 The recommended sequence of the tests is listed in Clause 7.

6.7 Full or partial re-tests, after a failed test or to test alternative braking system components, shall again follow the recommended order (Clause 7), and with particular emphasis on the vehicle preparation and bedding in procedures.

6.8 Control forces shall be applied rapidly, but without significant overshoot, and then be maintained constant during the stop (if not otherwise specified). The use of an adjustable pressure regulating device is recommended.

6.9 Skilled test drivers shall determine the optimum vehicle braking performance without wheel-locking except immediately before stopping and without course deviation [see 6.1. item e) for allowable steering correction] after appropriately familiarizing themselves with the vehicle braking, steering and suspension systems.

6.10 All tests start with cold brakes except the hot performance tests. A brake is deemed to be cold when the temperature measured on the disc or on the outside of the drum or on the brake linings is lower than [100] °C.

6.11 The speed of the vehicle before actuating the braking system control shall be stabilized at a level not less than [98] % of the prescribed speed for the test in question unless there is any other overriding requirement.

6.12 Where a vehicle is so constructed that its maximum speed is lower than that prescribed for any test, the test shall be performed at the maximum speed of the vehicle.

6.13 Tests with the engine connected shall be carried out in the appropriate gear, defined as the highest gear normally used at the specified speed without exceeding the manufacturer's recommended maximum engine speed.

6.14 Each specific failure mode appropriate to the vehicle braking equipment shall be considered and the braking system shall be checked for the worst-case failure modes (for EBS see ECE R 13 Annex 18 reference in 8.1.4 of this International Standard).

6.15 Where fault conditions are imposed on the braking system, they should be removed after the appropriate test has been conducted and the correct operation of the braking system should then be verified.

7 Recommended sequence of the tests

7.1 Preparation and static checks and tests

Table 3 — Preparation and static checks and tests

No.	Test	Engine status	Reference to this International Standard	Reference to ECE R 13/09
1	Preparation (documents, instrumentation, bedding etc.)		8	§ 1-2
2	Static braking force		9.1.1	5.1.4.4
3	Control force vs. line pressure		9.1.2	A4 § 2.1.1
4	Pressures at the coupling heads		9.1.3	A10 § 3.1.3
5	Capacity of energy sources	running	9.2	A7 § 2
6	Response time		9.3	A4 § 4
7	Automatic braking		9.4	5.2.1.18.4
8	Brake failure and defect warning signals		9.5	5.2.1.29 5.2.1.13 5.2.1.25.2.5 A13 § 4.1, 4.2, 4.5.2
9	Spring braking system		9.6	A8
10	Test of EBS operation with ignition off		9.7	5.2.1.27.1

7.2 Basic performance tests — Unladen

Table 4 — Basic performance tests — Unladen

No.	Test	Engine status	Reference to this International Standard	Reference to ECE R 13/09
1	Type 0 test	disconnected	10.1	A4 § 1.4.2, 2.1.1
2	Type 0 test	connected	10.2	A4 § 1.4.3
3	Dynamic test of the parking braking system (if applicable)	disconnected	10.4	A4 § 2.2
4	Parking braking system (hill holding)	disconnected	10.3	not prescribed
5	Wheel locking sequence test	disconnected	10.5	A10 § 3.1.4.2

7.3 Failure tests – Unladen

Table 5 — Failure tests – Unladen

No.	Test	Engine status	Reference to this International Standard	Reference to ECE R 13/09
1	Service braking system failure, type 0 test	disconnected	11.1	A4 § 2.2 or 2.4
2	Failed load sensing device	disconnected	11.2	A10 § 6
3	Failed energy source on vehicles equipped with EBS		11.3	5.2.1.27.5-8

7.4 ABS tests — Unladen

Table 6 — ABS tests — Unladen

No.	Test	Engine status	Reference to this International Standard	Reference to ECE R 13/09
1	ABS failure	disconnected	12.1	A13 § 4.5, A4 § 2.4.1
2	Adhesion utilisation on high adhesion	disconnected	12.3	A13 § 5.2
3	Determination of k_{Hpeak}	disconnected	12.2	A13 § app. 2
4	Adhesion utilisation on low adhesion	disconnected	12.4	A13 § 5.2
5	Determination of k_{Lpeak}	disconnected	12.4	A13 § app. 2
6	Wheel behaviour tests	disconnected	12.5.2.1	A13 § 5.3.1
7	Transition from high to low adhesion	disconnected	12.5.2.2	A13 § 5.3.2
8	Transition from low to high adhesion	disconnected	12.5.2.3	A13 § 5.3.3
9	Split adhesion test	disconnected	12.5.3	A13 § 5.3.4 ABS cat. 1 or 2

7.5 ABS tests — Laden

Table 7 — ABS tests — Laden

No.	Test	Engine status	Reference to this International Standard	Reference to ECE R 13/09
1	ABS failure	disconnected	13	A13 § 4.5, A4 § 2.4.1
2	Adhesion utilisation on high adhesion	disconnected	13	A13 § 5.2
3	Determination of k_{Hpeak}	disconnected	13	A13 § app. 2
4	Adhesion utilisation on low adhesion	disconnected	13	A13 § 5.2
5	Determination of k_{Lpeak}	disconnected	13	A13 § app. 2
6	Wheel behaviour tests	disconnected	13	A13 § 5.3.1
7	Transition from high to low adhesion	disconnected	13	A13 § 5.3.2
8	Transition from low to high adhesion	disconnected	13	A13 § 5.3.3
9	Split adhesion test	disconnected	13, 13.1	A13 § 5.3.4 ABS cat. 1 or 2 A13 § 5.3.5 ABS cat. 1
10	Energy consumption	disconnected	13.2	A13 § 5.1

7.6 Failure tests — Laden

Table 8 — Failure tests — Laden

No.	Test	Engine status	Reference to this International Standard	Reference to ECE R 13/09
1	Service braking system failure, type 0 test	disconnected	14.1	A4 § 2.2 or 2.4
2	Failed load sensing device	disconnected	14.2	A10 § 6
3	Energy source failure	disconnected	14.3	5.2.1.14

7.7 Basic performance tests — Laden

Table 9 — Basic performance tests — Laden

No.	Test	Engine status	Reference to this International Standard	Reference to ECE R 13/09
1	Parking braking system (hill holding)	disconnected	15.1	A4 § 2.3.1-5
2	Electrical parking brake		15.1.3	5.2.1.26
3	Dynamic test of the parking braking system	disconnected	15.2	A4 § 2.3.6 or 2.2
4	Wheel locking sequence test	disconnected	15.3	A10 § 3.1.4.2
5	Type 0 test (plot deceleration vs. pressure)	disconnected	15.4	A4 § 1.4.2, 2.1.1
6	Type 0 test	connected	15.5	A4 § 1.4.3
7	Warning device tests	disconnected	15.6	5.2.1.29 5.2.1.13
8	Capacity of energy storage devices	disconnected	15.7	A7
9	Type II or II/A test	connected	15.8	A4 § 1.6, 1.8, A5
10	Type 0 hot performance test (if the service braking system was used for type II test)	disconnected	15.8.2.2.2 15.8.2.3.2	A4 § 1.6.3
11	Type I test	connected	15.9	A4 § 1.5.1
12	Type 0 hot performance (fade) test	disconnected	15.9.5	A4 § 1.5.3.1

8 Vehicle preparation

8.1 Documents and basic data

NOTE The control of the data in the definitions in 3.2 and 3.3 are an integral part of the vehicle preparation.

The vehicle shall be verified based upon the documentation as follows:

8.1.1 Main technical data according to Annex 2 of ECE R 13.

8.1.2 Piping diagram, layout and list of the elements of the braking system.

8.1.3 Braking system data and performance calculation.

8.1.4 Documentation according to Annex 18 of ECE R 13, if the vehicle is equipped with EBS. This documentation includes an explanation of design provisions guaranteeing compliance with all relevant parts of ECE R 13 (paragraphs 5.2.1.8, 5.2.1.27 and 5.2.1.28) which deal with the special requirements for brake force compensation, EBS and coupling force control. This documentation may also indicate the worst-case failures for EBS.

8.1.5 Report/approval of EMC (if vehicle is equipped with an ABS or EBS) in accordance with ECE R 10/02.

8.1.6 Report (if vehicle is equipped with an electric control line) that the vehicle has been satisfactorily tested to the method described in Annex 17 of ECE R 13.

8.2 Braking system condition and bedding

8.2.1 The braking system components shall be new, or capable of functioning as if new, and within the vehicle manufacturer's specifications.

8.2.2 The brake linings shall be bedded. Until a uniform procedure is established, the bedding of the service and parking brake linings should be carried out according to the manufacturer's recommendations.

The brake linings may be regarded as bedded if at least 80% of their surface contacts with the brake drums or discs. Neither glazed, nor burned or damaged surfaces are acceptable.

8.3 Adjustment of braking equipment

Brake adjustment devices, including those in automatically adjusted brakes, shall be set according to the vehicle manufacturer's recommendations. Re-adjustment of the brakes may be made prior to each specific test. The automatic adjustment of brakes is tested in 15.9.3, which takes place before the type I test.

8.4 Tyre conditions

8.4.1 The tyres shall be inflated to the vehicle manufacturer's recommended pressure levels.

8.4.2 It is recommended that the tyre tread wear not exceed 50 % of the new condition, and that totally new tyres not be used.

8.5 Devices and instruments needed for the testing

Care should be taken to ensure that instruments and devices added to the vehicle braking equipment do not significantly affect braking system performance.

8.5.1 Additional devices for carrying out the testing of the braking systems

These consist of the following:

- Pressure regulating/shut-off devices;
- Air reservoir of 0,5 litre for trailer control line;
- Air reservoir for simulation of trailer compressed air system capacity (9.2.2);
- Signalling device (e.g. control lamp) to show functioning of the retarder and in case of integrated retarder control, a means of disabling the retarder;
- Towing vehicle for optional drag test(s).

8.5.2 Instrumentation

The test vehicle (and the towing vehicle if appropriate) shall be prepared for testing by the installation of additional instruments and/or calibration of the existing standard vehicle instruments, as required.

All the instruments shall be checked to ensure correct function and, with the vehicle stationary on the test surface, all the instruments shall be set.

It is recommended that the instrumentation include the following:

- Control force gauges for the service braking system, for the parking braking system and for the secondary braking system (if this system is not combined with either the service or the parking braking system);
- Decelerometer;
- Vehicle speed measuring and recording system;
- Stopping distance measuring means;
- Time measuring means;
- Brake temperature indicating system;
- Application and response time measuring equipment;
- Line pressure gauges/transducers;
- Towing force measuring system;
- Wheel speed measuring and recording system;
- Steering wheel angle indicator;
- Optional instruments, which may include:
  a) control travel gauges;
  b) low to high adhesion surface transition indicator;
  c) high capacity bi-directional ammeter (for EBS electrical tests, see 11.3.3.2).

8.5.3 Provision for failure simulation

The vehicle shall be equipped with the necessary added devices, piping and wiring as agreed with the vehicle manufacturer to provide the required failure simulations.

8.5.3.1 In the pneumatic part of the braking system, a failure should correspond to an uncoupled pipe.

8.5.3.2 In the hydraulic part of the braking system, a leakage should be simulated with the brake fluid being returned to its reservoir.

8.5.3.3 In the electric part of the braking system, a failure should generally correspond to a disconnection, but a short circuit or a ground connection may be specified by the manufacturer in certain instances. This may be done by using prepared components or sections of wiring.

9 Static tests and checks

9.1 Static braking force and control force vs. line pressure

9.1.1 Static braking forces

Determine maximum braking forces under static conditions on a rolling road or roller brake tester according to ISO 21069-1 and ISO 21069-2.

9.1.2 Control force vs. control line pressure

Produce statically a graph of line pressure against increasing control force up to the maximum force/pressure allowed for the service, secondary and parking braking functions. If the graphs are to be constructed from a series of individual readings, then at least five readings should be taken, including the threshold value. Care should also be taken to accurately depict any changes in the force-pressure relationship by taking additional readings if necessary.

9.1.3 Pressures at the coupling heads

In the case of a power-driven vehicle authorized to tow trailers of category O3 or O4, fully apply the service brake control with the system at cut-in and cut-out pressures and the energy source isolated. Check that the pressures of both the pneumatic control and supply lines are between 0,65 MPa (= 6,5 bar) and 0,85 MPa (= 8,5 bar) with a 0,5 litre volume connected to the control line, irrespective of the load condition of the vehicle. With the reservoir at cut-in pressure, check that the supply line is at least at 0,7 MPa (= 7 bar) without the application of the service brake.

When an electric control line is provided, the digital demand value according to ISO 11992 shall be fulfilled.

NOTE ISO 11992 defines the digital demand value such that 1 bit corresponds to 5/256 kPa, i.e. 33280d corresponds to 0,65 MPa (6,5 bar).

9.2 Capacity of energy sources

9.2.1 Definitions

t_1 is the time required for the pressure to rise from zero to p_1, measured in the braking energy reservoir which shows the slowest pressure rise;

t_2 is the time required for the pressure to rise from zero to p_2, measured in the braking energy reservoir which shows the slowest pressure rise, where the vehicle is equipped with no pneumatic reservoir for auxiliary equipment or with one or more pneumatic reservoirs for the same purpose, with a total capacity not exceeding [20] % of the total capacity of the braking system pneumatic reservoirs;

t_3 is the time required for the pressure to rise from zero to p_2, measured in the braking energy reservoir which shows the slowest pressure rise, where the vehicle is equipped with one or more pneumatic reservoirs for auxiliary equipment with a total capacity exceeding [20] % of the total reservoir capacity of the braking system.

9.2.2 Measurement conditions

The speed of the compressor shall be that corresponding to the maximum power of the engine or to that allowed by the engine governor. The auxiliary equipment reservoirs shall be isolated during the tests for determination of t_1, and t_2.

On motor vehicles with the capability to tow air braked trailers, the trailer shall be simulated by a reservoir attached to the supply line and whose volume V, expressed in litres, is given from the formula:

$$p_{max} \times V = [20] \, P_T$$

9.2.3 Basic test (all vehicles)

NOTE Vehicles with the capability to tow air braked trailers are tested in this case without the trailer simulation reservoir.

9.2.3.1 The pump-up time t_1 should not be greater than [3] minutes.

9.2.3.2 The pump-up time t_2 should not be greater than [6] minutes.

9.2.4 Basic test (vehicles with the capability to tow air braked trailers)

9.2.4.1 The pump-up time t_1 should not be greater than [6] minutes.

9.2.4.2 The pump-up time t_2 should not be greater than [9] minutes.

9.2.5 Additional tests

The following tests should be carried out if the auxiliary equipment reservoirs capacity is more than [20] % of the total capacity of the braking system reservoirs.

Independently of t_3, the pressure in the auxiliary equipment reservoirs should reach the pressure(s) specified by the vehicle manufacturer.

9.2.5.1 The pump-up time t_3 for all vehicles should not be greater than [8] minutes.

NOTE Vehicles with the capability to tow air-braked trailers are tested in this case without the trailer simulation volume.

9.2.5.2 The pump-up time t_3 for vehicles with the capability to tow air braked trailers should not be greater than [11] minutes.

9.3 Service braking system — Response time measurement

9.3.1 Test conditions

9.3.1.1 The response time of the service braking system shall be measured at the input port to that pneumatic actuator which is in the least favourable position.

9.3.1.2 In the case of towing vehicles having a pneumatic control line, the response time shall also be measured at the end of a pipe [2,5] m long with an internal diameter of [13] mm. This pipe shall be connected to the coupling head of the control line of the service braking system. A volume of [(385 ± 5)] cm^3 shall be connected to the coupling head of the supply line.

In the case of towing vehicles having an electric control line, the response time of the digital demand value according to ISO 11992 shall also be measured.

NOTE ISO 11992 defines the digital demand value such that 1 bit corresponds to 5/256 kPa, i.e. 33280d corresponds to 0,65 MPa (= 6,5 bar).

9.3.1.3 At the beginning of each test, the pressure in all reservoirs shall be equal to the minimum pressure defined in 3.3.3.

9.3.1.4 Load-sensing device(s), if fitted, shall be set in the position corresponding to the laden vehicle.

9.3.2 Test procedure

9.3.2.1 Determine the response times to reach [10] % and/or [75] % of the asymptotic pressures, by a succession of full brake actuations beginning with the fastest possible control application time and slowing to an application time of about [0,4] s.

9.3.2.2 Plot the measured response times on a graph. If the figure representing the 100th is five or more, round the value up to the next higher tenth.

9.3.2.3 The response time to be taken into consideration for the purpose of the test is that corresponding to an application time of [0,2] s. This response time can be obtained from the graph by linear interpolation rounded to the nearest tenth of a second.

9.3.2.4 In the case of a semi-trailer tractor, record the length and internal diameter of the coiled flexible pipes prior to the coupling heads.

9.3.2.5 The time elapsing from the initiation of brake pedal actuation to the moment:

- when the pressure measured at the pneumatic actuator which is in the least favourable position, and
- when the pressure demand at the coupling head of the pneumatic control line where such is present and/or the digital demand value according to ISO 11992 where an electric control line is present reaches x % of its asymptotic final value shall not exceed the times shown below:

Location	Percentage (x) %	Time s
A	75	0,6
B	10	0,2
B	75	0,4

9.3.3 Correspondence of pneumatic and electric control line signals

Apply the service brake control so as to generate an electrical control line signal equivalent to 0,11 MPa (1,1 bar) and check that within 1 second a detectable pneumatic signal is present at the pneumatic control line

9.4 Automatic braking

The following test shall be carried out from the maximum supply line pressure to check the automatic braking function in the case of a trailer control line failure.

Simulate a break in the trailer control line at the coupling head. Apply the service braking system control device fully and check that the pressure at the end of the [2,5] m long, [13] mm internal diameter pipe now connected to the supply line coupling head falls to [1,5] bar within [2] s from initiation of movement of the control device.

Check that, when the brake control is released, the supply line is re-pressurized.

9.5 Brake failure and defect warning signals

9.5.1 Verify that the prescribed optical warning devices as shown below for the indication of the specified failures are fitted on the vehicle.

Failure warning for an electrical parking brake shall be checked as detailed in 15.1.3.2.

Table 10 — Brake failure and defect warning signals

Vehicle exhibiting the failure	Colour	Displayed failures	Remark
Motor vehicle	Red	Any failure precluding the achievement of the prescribed service brake performance or the function of one of two independent service brake circuits	Shall be used also for the low stored energy level warning signal (see 15.6.2) if an optical signal is being used for this function. May also be used for the low pressure warning in the spring brake feed line (see 9.6.2.6).
Motor vehicle	Yellow	Electrically detected defect within the braking system not indicated by the red light (above)	May be used also for the indication of non-specified failures of the braking system and of running gear in a flashing mode with the vehicle stationary (to be terminated when the vehicle moves off < 10 km/h).
Trailer	Yellow	Defect within the trailer ABS or the electric control transmission of the trailer braking equipment	If authorized to tow a trailer with ABS or electric control transmission.
Trailer	Red	Any failure precluding the achievement of the prescribed service brake performance of the trailer when using an electric control line	The same function can be achieved with the simultaneous lighting up of the motor vehicle red and the trailer yellow warning lights.

9.5.2 Check that the warning lights are visible even in daylight and easy for the driver to verify that they are in working order. The warning signal must be constant (if not specified otherwise). Check that the warning devices light up when the electrical equipment of the vehicle (and the braking system) is energized and that they are extinguished after a verification phase only if none of the specified failures are present. Specified failures, which are not detected under static conditions, will be stored and displayed at start up.

It is generally allowed that a specified failure is signalled to the driver not later than on actuation of the relevant braking control and shall remain displayed as long as the failure persists and the ignition switch is in the “on” position.

9.5.3 Verify that any electrically detected defect in the braking system not resulting in lighting up the red warning light will light up the yellow warning signal of the motor vehicle braking system.

Especially verify that the yellow warning signal informs the driver about any electrical failure or sensor anomaly that affects the ABS.

NOTE With no defect present, the warning signal may light up again, provided that it is extinguished before the vehicle reaches a speed of 10 km/h.

9.5.4 For vehicles authorized to tow a trailer equipped with an ABS, verify that a yellow warning signal for the trailer can be activated via pin 5 of the special connector for ABS/EBS (5-pin or 7-pin application as appropriate), according to ISO 7638-1 and ISO 7638-2. Check that this warning device does not light up automatically when a trailer without an ABS is coupled or when no trailer is coupled.

9.5.5 If there is an antilock mode change system as allowed by ECE R 13 Annex 13 4.5, check that an optical warning signal (the yellow brake warning signal for the motor vehicle may be used for this purpose) informs the driver that the ABS has been disconnected or the control mode changed. The warning signal may be constant or flashing.

Check that the ABS is automatically reconnected/returned to normal mode when the ignition (start) device is again set to the “on” position.

9.6 Tests on vehicles equipped with spring brake actuators

9.6.1 Initial test conditions

The initial pressure in the reservoir(s) shall be equal to the maximum pressure defined in 3.3.2.

The engine shall be switched off.

The wheels shall be chocked to ensure that the vehicle does not roll when the spring brakes are released.

The spring brakes shall be released.

For vehicles authorized to tow trailers with air braking systems:

— the supply line shall be closed off at the coupling head;

— a volume of [0,5] litre shall be connected to the control line coupling head.

9.6.2 Test procedure

9.6.2.1 Apply the service braking system control device fully and check that the spring brake actuators remain fully pressurized.

9.6.2.2 Check that the spring brake actuators are fed from at least two reservoirs, if there is not a specific spring brake reservoir.

Where auxiliary equipment draws its energy from the feed line to the spring brake actuators, check that its operation in the event of an energy source failure does not prevent at least one release of the spring brake actuators being possible.

If the trailer supply is taken from the feed line for the spring brake actuators, check that a failure of the trailer supply will not cause automatic operation of the towing vehicle spring brakes when their control device is set in the release position.

9.6.2.3 With all reservoirs at zero pressure, the spring brakes applied and the spring brake control device in the brake release position, charge the system and note the pressure in the service braking system at which the spring brakes release. This pressure in the service braking system should not be less than that required to ensure at least the prescribed secondary braking performance of the laden vehicle.

NOTE The secondary braking system performance requirement can be verified either by using the deceleration against brake line pressure graph (reference 15.4.2) or by conducting a specific cold brake engine disconnected stop from the appropriate initial speed, as detailed in Table 12.

9.6.2.4 With the spring brakes applied via their control device, reduce the pressure in the service braking system until the pressure in the service braking system is at a level with the service braking control device applied, at which it is possible to achieve the prescribed residual braking performance of the laden vehicle. This pressure level can be determined by using the deceleration against brake line pressure graph (see 15.4.2). At this pressure, it must not be possible to release the spring brakes.

9.6.2.5 With the spring brakes released, recharge the system to the maximum pressure as defined in 3.3.2. Without further recharging, apply and release the spring brakes three times by fully operating the control device and allowing 20 s to 30 s between each application and release to charge and exhaust the spring brake actuators fully each time.

After the third release of the spring brakes, check that no spring brakes are even partially applied by verifying that the wheels rotate freely.

9.6.2.6 Recharge the system to the maximum pressure as defined in 3.3.2 and slowly deplete the pressure in the spring brake actuators by loosening a pipe connection.

Record the two pressures in the spring brake actuators at which the optical (see Table 10, item 1) or audible warning device begins to operate and at which the spring brake actuators begin to move.

Verify that the warning device operates at or above the pressure when the spring brake actuators begin to move.

Check that the pressure, when the spring brake actuators begin to move, is not greater than [80] % of the minimum pressure defined in 3.3.3.

9.6.2.7 For vehicles with the capability to tow air braked trailers, recharge the system to the minimum pressure defined in 3.3.3.

With the spring braking system control device in the released position, loosen the pipe connection at the spring brake actuator to cause loss of air and automatic operation of the brake.

Check that during this operation there is either a reduction of pressure in the trailer supply line sufficient to cause an automatic braking of the trailer (i.e. reduction to a pressure value below 2 bar), or an adequate increase in pressure in the trailer control line for applying the trailer brakes.

9.6.2.8 With the pipe connection still loosened, check that all the brakes can be released by auxiliary (pneumatic, mechanical, etc.) means.

If a tool is required for this purpose, check that it is carried on the vehicle.

9.7 Additional tests on vehicles equipped with EBS

9.7.1 Test for system operation with ignition off

This test is not necessary if documentary evidence is provided which shows that the electric control transmission is fully operational within 2 s after the brake pedal is fully applied. This is also the case where the ignition key cannot be removed unless the parking brake is applied and where subsequent release without the ignition on is prevented.

The vehicle must be left stationary with the parking brake released, the ignition in the off position and the key removed for five to ten min.

Then fully apply the brake pedal rapidly (< 1 s).

The test shall show that the required static total braking force is produced within 2 sec after the pedal is fully applied. Force buildup must start no later than 300 ms after the initial application of the pedal.

The total static braking force shall be at least equivalent to that required in the Type 0 test. Testing may be done on a roller bench tester for each axle.

For vehicles authorized to tow trailers of category O3 or O4, check that a full control signal is supplied on the electric control line and/or the pneumatic control line.

10 Basic performance tests — Unladen

10.1 Type 0 test (service braking system cold brake effectiveness, engine disconnected)

A mean fully developed deceleration (d_m) and stopping distance (S) as prescribed for the vehicle category under test shall be attained from the specified speed with the engine disconnected, with cold brakes and a control force (F) not greater than that specified. The applicable values are given in Table 11.

Table 11 — Type 0 test (service braking system cold brake effectiveness, engine disconnected)

Vehicle category	M2	M3	N2	N3
v	60 km/h		60 km/h	
$S \leqslant$	0,15 v + (v^2/130)			
$d_m \geqslant$	5,0 m/s^2			
$F \leqslant$	700 N			

10.2 Type 0 test (service braking system cold brake, engine connected)

At vehicle speeds of [30 %], 55 % and [80 %] of v_{max}, conduct a stop using a control force not greater than that specified in Table 12, with the engine connected and cold brakes.

For ECE R 13, semi-trailer tractors shall not be tested above [80 km/h].

The behaviour of the vehicle shall be recorded together with the mean fully developed deceleration (d_m) and stopping distance (S).

Table 12 — Type 0 test (service braking system cold brake effectiveness, engine connected)

Vehicle category	M2	M3	N2	N3
v = 80 % of v_{max}, but not exceeding	100 km/h	90 km/h	100 km/h	90 km/h
$S \leqslant$	0,15 v + (v^2/103,5)			
$d_m \geqslant$	4,0 m/s^2			
$F \leqslant$	700 N			

At the speed specified in Table 12 for the vehicle category under test, the prescribed mean fully developed deceleration (d_m) and stopping distance (S) given in Table 12 shall be attained.

10.3 Parking braking system — Hill holding test

Although ECE R 13 does not require any testing of the parking braking system in the unladen state of the vehicle, it is strongly recommended to check the performance of the parking braking system either by carrying out the gradient test as in 15.1.1 (in the appropriate load condition) or by calculation of the necessary adhesion (see also 15.1.2).

10.4 Secondary braking system test

Where the parking braking system is also the secondary braking system, a mean fully developed deceleration (d_m) and stopping distance (S) value as prescribed for the vehicle category under test shall be attained from the specified speed with the engine disconnected, with cold brakes and a control force not greater than that specified. The applicable values are given in Table 13.

Table 13 — Secondary braking system test

Vehicle category	M2	M3	N2	N3
v	60 km/h		50 km/h	40 km/h
$S \leqslant$	0,15 v + (2 v^2/130)		0,15 v + (2 v^2/115)	
$d_m \geqslant$	2,5 m/s^2		2,2 m/s^2	
Hand control effort $\leqslant$	600 N			
Foot control effort $\leqslant$	700 N			

Using the braking system diagram, check for common components in the transmissions of the service and parking braking systems, and note that these might be electrical. If there are common components, impose the worst-case fault on these components and check that secondary braking performance can still be achieved using the parking brake control.

10.5 Wheel locking sequence

The wheel locking sequence shall only be demonstrated for vehicles without ABS or where the ABS can be disconnected manually. This is normally demonstrated by calculation. In the event that this cannot be demonstrated by calculation (e.g. permanent all wheel drive vehicles), then a test shall be carried out as follows.

Disable the ABS and make two stops from [60] km/h on a surface (reference 5.2.1.2) having adhesion less than [0,3] and record the wheel speed signals. Compare the recordings and note that the rear axle wheels do not both lock before the front wheels when the brakes are suddenly and firmly applied, such that the second wheel to lock does so in [0,5-1,0] s after the initiation of braking.

Repeat this test on a dry high adhesion surface from [80] km/h, and similar wheel locking sequence is required.

If on one stop the result is not satisfactory, the test may be repeated on a third stop and this should be successful.

11 Failure tests — Unladen

11.1 Service braking system partial failure test (type 0 test, cold brake effectiveness, engine disconnected)

Each specific failure mode appropriate to the vehicle braking equipment shall be considered and the service braking system shall be checked for the worst-case failure mode(s) (reference 6.14 and 8.5.3).

Make a stop to check that, with cold brakes, a mean fully developed deceleration (d_m) and stopping distance (S) as prescribed for the vehicle category under test is attained from the specified speed with the engine disconnected, at a control force (F) not greater than that specified.

11.1.1 If the secondary braking system is combined with the service braking system, the applicable values are given in Table 13.

11.1.2 If the secondary braking system is independent of the service braking system (e.g. combined with the parking braking system — reference subclause 10.4), then the service braking system shall meet the residual braking performance requirements. In this case, the applicable values are to be found in Table 14.

Table 14 — Service braking system partial failure test (residual braking performance)

Vehicle category	v (km/h)	S laden (m) ⩽	d_m laden (m/s²) ⩾	S unladen (m) ⩽	d_m unladen (m/s²) ⩾	F (N) ⩽
M2	80	$0{,}15v + \frac{100}{30} \times \frac{v^2}{130}$	1,5	$0{,}15v + \frac{100}{25} \times \frac{v^2}{130}$	1,3	700
M3	60	$0{,}15v + \frac{100}{30} \times \frac{v^2}{130}$	1,5	$0{,}15v + \frac{100}{30} \times \frac{v^2}{130}$	1,5	700
N2	50	$0{,}15v + \frac{100}{30} \times \frac{v^2}{115}$	1,3	$0{,}15v + \frac{100}{25} \times \frac{v^2}{115}$	1,1	700
N3	40	$0{,}15v + \frac{100}{30} \times \frac{v^2}{115}$	1,3	$0{,}15v + \frac{100}{30} \times \frac{v^2}{115}$	1,3	700

11.2 Failed load sensing device test/function test

This test simulates the failure of the control of the load-sensing device/function, if fitted, by disconnecting the control means (e.g. mechanical linkage or pneumatic control pipe, having made provision for holding air pressure in the suspension) or disabling the function.

11.2.1 Check that, without wheel locking occurring (except immediately before stopping), a mean fully developed deceleration (d_m) and stopping distance (S) as prescribed for the service braking system of the vehicle category under test can be attained from the specified speed with the engine disconnected, with cold brakes and a control force (F) not greater than that specified. The applicable values (for secondary performance) are given in Table 13.

For vehicles with electronic load sensing function, check that the failure produces a red driver warning unless it is possible to achieve the prescribed service braking performance (reference 9.5).

NOTE The test may be omitted and calculations made on braking distribution to show that secondary braking performance can be achieved without wheel locking.

11.2.2 Despite the above-mentioned control failure, the resulting trailer control line pressure shall still be between [6,5] bar and [8,5] bar.

11.3 Failure of the energy source on vehicles equipped with EBS

11.3.1 Where the electrical supply of the braking system is also used by other electrical equipment, disable the generator at nominal battery voltage level so that the battery is no longer charged, and demonstrate that it is still possible to actuate all brakes of the service braking system and to supply the essential vehicle electrical loads such as lighting and wipers.

11.3.2 As a second test without the additional (non-braking) load, disable the generator at a nominal battery voltage level. Demonstrate after 20 consecutive full stroke actuations of the service braking control that the full control range of the service braking system is available. On each actuation, the braking control shall be fully applied for 20 s and released for 5 s. Ensure that during the above-described test, sufficient energy is available in the energy transmission for full actuation of the service braking system.

NOTE If two independently driven generators supply battery charge, the two tests above do not have to be made.

11.3.3 Battery charge/discharge measurement — For these tests, the battery shall be discharged, e.g. using the full vehicle electrical load with the engine at rest. Check for automatic reversion to the back-up system at a voltage which is approximately that declared by the manufacturer. This switching voltage should be available in the Vehicle Technical Specification or in the Annex 18 Safety Concept information along with designed back-up performance level.

Alternatively, for the low-voltage detection test, the vehicle battery may be replaced by an external high power electrical supply in which the voltage can be adjusted.

11.3.3.1 Low voltage detection — Start with the nominal voltage and then gradually reduce the voltage until it is 10 % above the switching value declared by the manufacturer, when change-over to back-up shall occur. Check at this level that braking pressures corresponding to full service braking performance can be achieved. Then further reduce the voltage until it is 10 % below the declared switching value and check at this level that braking pressures corresponding to residual/secondary braking performance can be achieved.

Further, it will be necessary to verify that in between these two test levels, the change-over to back-up is accompanied by the yellow warning signal if full braking performance is available, or the red warning if only secondary performance can be provided.

11.3.3.2 Battery charging capacity test procedure — This test need not be conducted where the braking system is designed such that in the non-electrical back-up mode the prescribed service braking performance is ensured.

It should be noted that, on some vehicles, the electrical supply will be organized such that as the voltage falls, selected electrical loads are switched off to reduce drain. This will be evidenced by the removal of certain non-vital electrical functions as the voltage reduction, specified above, takes effect.

After the verification of the switchover to back-up, remove some of the remaining electrical loads and charge the battery until the voltage increases to a point where upon reconnection of these electrical loads, change-over to back-up does not immediately reoccur.

Then, with the vehicle engine running at 80 % of the speed at which maximum power is developed, check that the battery is not being discharged.

For vehicles equipped to tow trailers, the electrical trailer load which should be allowed is 400 W. This can be simulated by connecting across the (24 V) battery, a high-power resistance of 1,8 ohms.

Measurement of the battery current requires the use of a high capacity bi-directional ammeter.

Two possible examples of means for providing this are suggested:

— use of a precision very low value power resistor inserted into the battery connection across which the small voltage drop is accurately measured;

— alternatively, a Hall effect sensor, which is clipped round all the battery cables.

11.3.3.2.1 Calculation alternative — It is permitted to supply a calculation of the maximum discharge current from a knowledge of the essential vehicle electrical loads and compare this with the rated alternator current output at the 80 % of the maximum power speed with the battery at the nominal voltage.

12 ABS tests — Unladen

12.1 ABS failure

12.1.1 Disconnect, one at a time, the electrical connections to the controller(s) (including the electrical supply) and the modulator(s). In each case, test that the service braking system performance is at least that residual level listed in Table 14.

12.1.2 In the case of ADR vehicles, check that when an electrical failure of the ABS is simulated, any integrated or combined endurance braking systems are automatically switched off.

12.1.1 ABS sensor fault memory check

The function of the ABS sensor fault memory shall be checked. This may be performed in the following manner:

With the vehicle stationary, the ignition switched off and the key removed, simulate an operational sensor failure which can only be detected when the wheel is rotating.

For sensors having an electrical connector nearby, unplug the sensor and plug in a loose identical sensor, which is then held away from the sensor wheel. In this way, the setting of the original sensor remains undisturbed and the substitute sensor should be taped to a suitable hub or suspension component, so that it will not be damaged when the vehicle is driven.

For sensors which are permanently wired, demount one sensor from its normal location, saving any components which will be required to set the sensor back in place after completion of this part of the test. Tape this sensor in a position away from the sensor wheel.

Gently accelerate the vehicle to a speed of 15 km/h, taking care to avoid any wheel spin, and verify that the yellow (or red) warning signal is produced by the time that the vehicle speed reaches 15 km/h.

NOTE Vehicles which rely on the ABS for control of braking distribution, indicate ABS failure by the red warning signal.

Bring the vehicle to a halt, switch off the ignition, remove the key and wait for a period of at least 10 min. Switch on the ignition and verify that the normally transient start-up warning signal remains on and is maintained when the vehicle is driven above 15 km/h.

With the vehicle at rest again, switch off the ignition, remove the key and then re-install the original sensor. Avoiding any wheel spin, accelerate the vehicle to a speed of 15 km/h and verify that the warning signal is now extinguished.

NOTE Some manufacturers may have chosen to implement a more complicated procedure by which the sensor fault memory is reset and the warning signal may not be cancelled at 15 km/h. If this is the case, refer to the manufacturer's instructions for the memory reset requirements.

12.2 Determination of the peak coefficient of adhesion on the high adhesion surface

This series of tests should be carried out AFTER the adhesion utilisation test detailed in 12.3 and as close as possible to that test in order to minimize surface adhesion changes.

The following procedure, defined in the 12.2 and 12.3, may be omitted for the high adhesion surface if the prescribed force on the control device does not achieve a full cycling of the ABS.

Vehicles of categories N2 and N3 with a wheelbase less than 3,8 m and h/E ratio $\geqslant$ 0,25 do not require a separate value for the rear axle coefficient of adhesion.

For vehicles equipped with three axles, only the axle not associated with a close coupled bogie will be used to establish a k value for the vehicle.

12.2.1 Disable the antilock function and the rear service brake operation. The following test sequence is to determine the peak coefficient of adhesion of the surface k_f, first for the front axle and after that k_r, for the rear axle(s) by a repeat process with the front axle brakes disabled and the rear circuit brakes enabled. The results are used in the calculations of 12.3.

12.2.2 After ensuring that all the necessary test equipment is operational, carry out a number of brake applications on the test surface with a low peak coefficient of adhesion. The line pressure shall be set in increasing steps for each run until optimum performance is established (this will normally be when slight locking occurs, wheel lock may occur below 20 km/h). To ensure that the highest possible result has been included, the series of increments is extended to the point where the wheels lock above 20 km/h. The tests shall be performed from an initial vehicle speed of [50] km/h and the braking rate is calculated by reference to the time t, in seconds, taken for the speed to reduce from [40] km/h to [20] km/h, using the following formula:

$$z = \frac{[0{,}566]}{t}$$

Starting from the minimum measured value of t, called t_{min}, select three values of t comprised within t_{min} and 1,05 t_{min} and calculate their arithmetical mean value t_m then calculate

$$z_m = \frac{[0{,}566]}{t_m}$$

If it is demonstrated that for practical reasons the three values defined above cannot be obtained, then the minimum time t_{min} may be utilised.

NOTE 1 This procedure may be most accurately carried out when some form of adjustable line pressure regulator is fitted.

NOTE 2 In order to obtain a valid result, both wheels of the axle must reach the lock point simultaneously. For the purposes of establishing the k value, it may be necessary to make special adjustments to individual line pressures to achieve this.

12.2.3 Calculate the value of k_f and k_r using the following formula where z_{mf} and z_{mr} are the mean decelerations found in 12.2.2. This takes into account the rolling resistance of the unbraked axle and the dynamic load transfer.

12.2.3.1 In case of a two-axle rear-wheel drive vehicle with the front axle being braked, the coefficient of adhesion k_f is given by:

$$k_f = \frac{z_{mf} \times P_M \times g - 0{,}015 \times F_r}{F_f + \frac{h}{E} \times z_{mf} \times P_M \times g}$$

Round the value to the third decimal place.

12.2.3.2 In case of a two-axle rear-wheel drive vehicle with the rear axle being braked, the coefficient of adhesion k_r is given by:

$$k_r = \frac{z_{mr} \times P_M \times g - 0{,}01 \times F_f}{F_r - \frac{h}{E} \times z_{mr} \times P_M \times g}$$

Round the value to the third decimal place.

Vehicles of categories N2 and N3 with a wheelbase less than 3,8 m and h/E ratio $\geqslant$ 0,25 do not require a separate value for the rear axle coefficient of adhesion.

For vehicles equipped with three axles, only the axle not associated with a close coupled bogie will be used to establish a k value for the vehicle.

12.3 Determination of adhesion utilization on high adhesion surface

12.3.1 Vehicles fitted with an ABS of category 1 or 2

12.3.1.1 With the ABS operational.

12.3.1.2 From an initial vehicle speed of [55] km/h, using the same test surface on which the peak coefficient of adhesion will be determined (reference to 12.2), ascertain the braking rate, which the ABS can achieve. Perform the test with sufficient line pressure or pedal effort to ensure that full cycling of the ABS occurs. The time t, in seconds, taken for the speed to reduce from [45] km/h to [15] km/h, shall be determined.

12.3.1.3 Repeat the test in 12.3.1.2 twice more and calculate the average of the three t values, i.e. t_{m}, which then gives the z_{AL} value to be used in the adhesion utilization calculation from the following formula:

$$z_{\text{AL}} = \frac{0{,}849}{t_{\text{m}}}$$

12.3.1.4 The coefficient of adhesion k_{m} shall be determined by weighting with the dynamic axle loads, using the following formula:

$$k_{\text{m}} = \frac{k_{\text{f}} \times F_{\text{fdyn}} + k_{\text{r}} \times F_{\text{rdyn}}}{P_{\text{M}} \times g}$$

where

$$F_{\text{fdyn}} = F_{\text{f}} + \frac{h}{E} \times z_{\text{AL}} \times P_{\text{M}} \times g$$

$$F_{\text{rdyn}} = F_{\text{r}} - \frac{h}{E} \times z_{\text{AL}} \times P_{\text{M}} \times g$$

The value should be rounded to two decimal places.

12.3.1.5 Once the tests of 12.2 are complete, calculate the adhesion utilization, using the following formula:

$$\varepsilon = \frac{z_{\text{AL}}}{k_{\text{m}}}$$

According to ECE R 13, ε shall be greater than or equal to 0,75.

12.3.2 Vehicles fitted with an ABS of category 3

Some multiaxle vehicles in this category have only a partial installation of antilock control on the braking system, so that the adhesion utilization has to be obtained separately for each controlled axle.

12.3.2.1 With the ABS operational, ensure that when the service braking system control device is applied, only the brakes on one axle, which has at least one directly controlled wheel, will function normally and that the service braking system on the other axles is non-operational.

12.3.2.2 Carry out the steps detailed in 12.3.1.2 and 12.3.1.3.

12.3.2.3 Once the tests of 12.2 are complete, calculate the adhesion utilization, taking into account the rolling resistance of the unbraked axle(s) and load transfer using the following formulae:

In case of a two-axle rear wheel drive vehicle, ε is given:

a) If this is a front axle, z_{AL} measured $= z_{\text{F}}$

$$\varepsilon_1 = \frac{z_{\text{f}} \times P_{\text{M}} \times g - 0{,}015 \times F_{\text{r}}}{k_{\text{f}} (F_{\text{f}} + \frac{h}{E} \times P_{\text{M}} \times z_{\text{f}} \times g)}$$

b) If this is a rear axle, z_{AL} measured $= z_R$

$$\varepsilon_2 = \frac{z_r \times P_M \times g - 0{,}01 \times F_f}{k_r (F_r - \frac{h}{E} \times z_r \times P_M \times g)}$$

If $\varepsilon > 1$, the measurements of coefficients of adhesion shall be repeated. A tolerance of 10 % is acceptable.

According to ECE R 13, ε shall be greater than or equal to 0,75.

12.3.2.4 If the vehicle has more than one axle having at least one directly controlled wheel, repeat the tests in 12.3.2.1 to 12.3.2.3 for the other axle(s) as necessary by braking one axle at a time.

12.3.2.5 If the vehicle has an axle (or bogie) which does not include at least one directly controlled wheel, then check by calculation that the adhesion utilization and wheel lock sequence requirements of Annex 10 of ECE R 13 are satisfied by that axle (or bogie). It is not necessary to check that axles with at least one directly controlled wheel meet requirements of ECE R 13 Annex 10.

12.3.2.6 If in 12.3.2.5 it is found that the relative position on the adhesion utilization curves does not meet the prescribed requirements, carry out additional dynamic tests to verify that the wheels on at least one of the rear axles do not lock before those of the front axle(s). This is checked by performing a number of stops (with the ABS in operation) from an initial vehicle speed of [50] km/h on both the high and low adhesion surfaces (reference 5.2.1), using increasing increments of line pressure until wheel lock occurs. The vehicle mass distribution shall be as used for the adhesion utilisation calculations.

12.4 Determination of adhesion utilization on low adhesion surface

Using a test surface with a low peak coefficient of adhesion (5.2.1.2), repeat the tests in 12.3 and 12.2 as applicable.

12.5 Additional checks

12.5.1 Test conditions

12.5.1.1 In the tests detailed in 12.5.2, momentary locking of directly controlled wheels, e.g. when passing from a high adhesion surface to a low adhesion surface, or when using a retarder, is permitted when the vehicle speed is more than [15] km/h. In addition, it is permitted for directly controlled wheels to lock when the vehicle speed is less than [15] km/h. Indirectly controlled wheels may lock at any speed, but stability and steerability should not be affected.

12.5.1.2 Steering control correction is permitted during the tests described in 12.5.3.1 and 13.1, provided that the angular rotation of the steering wheel is within [120°] during the initial [2] s of the braking system application and within [240°] during the remainder of the test.

12.5.1.3 The definition of “fully applied” or a “full application of the service braking system control device” means maximum line pressure in the case of an air braking system or maximum permitted pedal effort for the vehicle category for other braking systems. A higher service braking system control force may be used if necessary to cause the ABS to come into operation.

12.5.1.4 In the case of ADR vehicles with any type of endurance braking system, and non-ADR vehicles with an integrated endurance braking system, check that the requirements of 12.5.2 and 12.5.3 are also met when the endurance braking system is in operation, either alone or combined with the service braking system.

12.5.2 Procedure for transition tests

12.5.2.1 Wheel behaviour test: With all brakes operational and the ABS connected, carry out a series of tests to ascertain that the directly controlled wheels do not lock when the brakes are suddenly fully applied. These tests shall be performed on both the low and the high adhesion surfaces used for the tests in 12.3 and 12.4, from an initial vehicle speed of [40] km/h and from another initial speed according to Table 15.

Table 15 — ABS — Wheel behaviour test

	Vehicle Category	Maximum Test Speed
High adhesion surface	All categories except N2, N3 laden	0,8 v_{max}, but ⩽ 120 km/h
	N2, N3 laden	0,8 v_{max}, but ⩽ 80 km/h
Low adhesion surface	M2, M3, N2 except semi-trailer tractors	0,8 v_{max}, but ⩽ 80 km/h
	N3 and N2 tractors for semi-trailers	0,8 v_{max}, but ⩽ 70 km/h

12.5.2.2 Transition from high to low adhesion: Check that when an axle passes from a high adhesion surface to a low adhesion surface, with the brakes fully applied, the directly controlled wheels do not lock. The vehicle speed and the timing of the full brake application shall be such that the ABS cycles fully on the high adhesion surface and the transition from high to low adhesion surfaces occurs at the two vehicle speeds specified in 12.5.2.1.

12.5.2.3 Transition from low to high adhesion: Check that when the vehicle passes from a low adhesion surface to a high adhesion surface, with the brakes fully applied, the vehicle braking rate rises to an appropriate value for the high adhesion surface within a reasonable time (typically 1 to 2 s), and without the vehicle deviating from its initial course. For this test, the vehicle speed shall be such that the ABS cycles fully on the low adhesion surface and the transition from low to high adhesion surfaces occurs at approximately [50] km/h.

NOTE It may be necessary to install additional equipment (see 8.5.2.12, item b) to show the point of transition of the surfaces on the record.

12.5.3 Procedure for split adhesion tests

12.5.3.1 For vehicles fitted with an ABS of category 1 or 2, check that the directly controlled wheels do not lock when the right and left hand wheels are on surfaces with different peak coefficients of adhesion (k_H and k_L) and the brakes are suddenly fully applied at a vehicle speed of [50] km/h. The vehicle shall be positioned centrally over the division between the two surfaces at the start of the test. During the test, no part of the tyres shall cross the division (outer tyres in the case of twin wheels).

13 ABS tests — Laden

With the laden vehicle, repeat the tests as defined in Clause 12. Additionally, carry out the following tests.

13.1 Additional split adhesion test

For vehicles fitted with an ABS of category 1, check that when the test in 12.5.3.1 is performed, the vehicle meets the prescribed braking rate z_{MALS} as follows:

$$z_{MALS} \geqslant \frac{0{,}75\left(4k_L + k_H\right)}{5}$$

$$z_{MALS} \geqslant k_L$$

13.2 Energy consumption on low adhesion surface

It is only necessary to carry out this test on vehicles fitted with an ABS, which use stored energy or whose energy source has a limited capacity.

13.2.1 Check that when the service braking system control device is applied, all brakes function normally. Ensure that any auxiliary storage device (if fitted) is isolated from the service braking system.

NOTE Indirectly and non-controlled wheels may lock during this test.

13.2.2 Calculate the braking time t, in seconds, to be used in the energy consumption test using the following formula:

$$t = \frac{v_{\text{max}}}{7}$$

where

v_{max} is the maximum design speed of the vehicle, in km/h, with an upper limit of [160] km/h.

The braking time calculated shall be equal to or greater than [15] s.

13.2.3 Taking into consideration the time t obtained in 13.2.2 and the length of the low adhesion surface available, the minimum initial speed for performing the energy consumption test may be calculated. When making this calculation, the braking rate likely to be achieved shall be based on the coefficient of adhesion found in 12.2. If the ABS becomes ineffective below about [15] km/h ([4,2] m/s), then the time of application shall only be the time taken to reduce the vehicle speed to this lower speed. It is permissible to complete the time, t, in phases, up to a maximum of four, so as to reduce initial speed and the distance required. The initial speed shall, however, be at least [50] km/h.

EXAMPLE Take the following values:

$v_{\text{max}} = 129$ km/h

$v_{\text{u}} = 15$ km/h $= 4,2$ m/s

$g = 9,81$ m/s^2

$k = 0,3$

$$t = \frac{129}{7} = 18,4 \text{ s}$$

The speed is given by the formula:

$$v = v_{\text{u}} + k \times g \times t$$

Assume four phases:

$$v = v_{\text{u}} + k \times g \times \frac{t}{4} =$$

$$= 4,2 + \frac{0,3 \times 9,81 \times 18,4}{4} =$$

$$= 17,7 \text{ m/s} = 63,9 \text{ km/h}$$

Assume three phases:

$$v = v_{\text{u}} + k \times g \times \frac{t}{3} =$$

$$= 4,2 + \frac{0,3 \times 9,81 \times 18,4}{3}$$

$$= 22,3 \text{ m/s} = 80,1 \text{ km/h}$$

The braking distance is given by the formula:

$$S = \frac{v^2 - v_\mathrm{u}{}^2}{2 \times k \times g}$$

If four phases:

$$S = \frac{(17{,}7)^2 - (4{,}2)^2}{2 \times 0{,}3 \times 9{,}81} = 50{,}2\ \mathrm{m}$$

If three phases:

$$S = \frac{(22{,}3)^2 - (4{,}2)^2}{2 \times 0{,}3 \times 9{,}81} = 81{,}5\ \mathrm{m}$$

If this calculation method is used, ensure that the pressure in the reservoirs or accumulators is that specified by the manufacturer, and then carry out a number of test runs with the engine disconnected and idling to ensure that the calculations are realistic, and that when the consumption test is carried out, the vehicle speed at the end of the total application time is as low as possible, but not lower than [15] km/h.

Also ensure that it will be possible to bring the vehicle to rest at the end of time t without the use of any stored energy of the service braking system. If track space permits, the vehicle can be allowed to roll to rest.

Alternatively, at the end of time t, bring the vehicle to rest by applying the service braking system control device without the ABS functioning and without releasing the brakes at rest. With the vehicle stationary, increase the brake application up to a full application and release subsequently. This is considered to be the first static application.

13.2.4 Check that the pressure in the service braking system reservoirs or accumulators is as specified by the manufacturer, is at least sufficient to achieve prescribed service braking system performance, and that provision is made to stop the supply of energy to them at the end of the application time on each run, preferably by a solenoid valve switched by the service braking system control device movement.

13.2.5 If the vehicle is capable of towing an air braked trailer, ensure that the supply line for the trailer is shut off and that a 0,5 litre reservoir (reference 8.5.1.2) is attached to the control line coupling head.

13.2.6 From the initial speed, which shall not be less than [50] km/h, and using the low adhesion test surface determined as in 12.2, apply the service braking system control device fully, with the engine disconnected and idling, until time t is completed, noting the time taken. Ensure that during the time t, the ABS cycles continuously. Release the service braking system control device and simultaneously cut off the supply of energy to the service braking system reservoirs or accumulators.

13.2.7 Repeat 13.2.6, if necessary, up to a maximum of four times in all, until the total time t has been achieved, ensuring that the energy supply is reconnected at the instant the control device is applied and cut off at the instant the control device is released.

From the second phase, the energy consumption corresponding to the initial brake application may be taken into account, by subtracting one full brake application from the full four applications.

13.2.8 Bring the vehicle to rest without reducing the level of the stored energy of the service braking system. After ensuring that all brakes are released, fully apply and release the service braking system control device [four] times.

During the tests, additional energy shall not be supplied to the service braking system reservoirs or accumulators.

13.2.9 Check that, when the brakes are applied for the [fifth] time, it is possible to achieve the prescribed secondary braking performance (Table 13).

NOTE Verification can be either by using the deceleration against brake line pressure graph (reference 15.4.2), or by conducting a specific engine disconnected stop at the [fifth] application pressure from the appropriate initial speed as detailed in Table 13.

During the tests, additional energy shall not be supplied to the service braking system reservoirs or accumulators.

It may be necessary to off-load some vehicles partially in order to ensure that the ABS still operates as the pressure reduces. This is acceptable, but the requirement for secondary performance remains related to the maximum mass of the laden vehicle.

13.2.10 In addition, if the vehicle is capable to tow an air braked trailer, check that, when the brakes are supplied for the [fifth] time, the pressure supplied to the control line is at least [half] that supplied on the first full application of the service braking system with the initial pressure level specified by the manufacturer.

During the tests, additional energy shall not be supplied to the service braking system reservoirs or accumulators.

14 Failure tests — Laden

14.1 Service braking system partial failure test (type 0 test, cold brake effectiveness, engine disconnected)

The test is carried out as detailed in 11.1.

14.2 Failed load sensing device test

The test is carried out as detailed in 11.2.

14.3 Energy source failure test

Commencing with the pressure indicated by the vehicle manufacturer (reference 3.3.1) in the air reservoirs and with the engine not running (or with the drive of the energy source disconnected), a mean fully developed deceleration (d_m) and stopping distance (S) as prescribed for the vehicle category under test shall be attained from the specified speed with the engine disconnected, with cold brakes and a control force (F) not greater than that specified. The appropriate values are given in Table 11.

15 Basic performance tests — Laden

15.1 Parking braking system — Hill holding test

The parking braking system efficiency of a towing vehicle shall be checked both for the individual vehicle and for the towing vehicle/trailer combination at the maximum authorized mass of the vehicle combination.

15.1.1 Gradient test

This is a static, cold brake test conducted with the vehicle facing upwards and downwards on a minimum gradient as prescribed in Table 16. The vehicle shall remain stationary on the specified minimum gradient with the control effort to apply the brakes not exceeding the value given in Table 16. The time period allowed for evaluating the capability of the parking braking system to hold the vehicle stationary shall not be less than 1 minute.

Towing vehicle/trailer combinations shall remain stationary on the gradient specified in Table 16, using only the towing vehicle parking braking system. As part of the test, check that the trailer control line is not pressurized.

NOTE Some parking brake control devices include a “park” position in which the trailer control line is pressurized and a “test” position in which the trailer control line is not pressurized.

Table 16 — Parking braking system — Hill holding test

Vehicle category	M2	M3	N2	N3
Individual vehicle up and down gradient	18 %			
Towing vehicle/trailer combination up and down gradient	12 %			
Hand control effort ⩽	600 N			
Foot control effort ⩽	700 N			

15.1.2 Drag test

Where a surface of the prescribed minimum gradient is not available, the parking brake efficiency may be verified by attempting to drag the vehicle under test forwards and backwards on a level surface with the parking brake applied.

A towing force is applied by a suitable means to the vehicle under test with the parking brake applied. A force up to a value corresponding to the vehicle’s maximum mass multiplied by the prescribed hill gradient (%) should be used. The time period allowed for evaluating the capability of the parking braking system to hold the vehicle stationary shall not be less than 1 minute.

When using the drag test method, it is also necessary to determine if an adhesion of maximum 0,8 will be sufficient when the vehicle is actually parked on a hill of the prescribed gradient. For example, for a two-axle vehicle with the parking brake on the rear axle, the following condition shall be fulfilled (checking for sufficient adhesion on the more critical downward gradient).

$$\frac{P_{\mathrm{M}} \times g \times 0{,}18 - F_{\mathrm{Wm}}}{F_2 - P_{\mathrm{M}} \times g \times 0{,}18 \times \dfrac{h}{E}} \leqslant 0{,}8$$

15.1.3 Additional tests on vehicles equipped with electrical parking brake

15.1.3.1 Performance test in failure condition

Simulate a break in one wire of the electrical control transmission or a single failure in the control (which excludes multiple wire disconnections such as would occur from an uncoupled multi-pin connector). Simulation may be achieved by a prepared control or wiring harness. In the fault condition, repeat the test of 15.1.1 on an 8 % up and down gradient or the equivalent for the drag test of 15.1.2. It shall be possible to apply the parking braking system from the driver’s seat by using the control of the parking brake or an auxiliary control, if such is provided, and thereby be capable of holding the laden vehicle stationary. As an alternative to the application by the driver, the parking braking system may be automatically applied each time the vehicle becomes stationary. If this is the case, two further factors shall be checked by making stop and go operations on a gradient, which is at least 8 %:

a) the park brake shall remain applied when the ignition switch is turned off; and

b) the park brake is automatically released as soon as the vehicle is set in motion again.

There shall also be means to release the parking braking system in failure mode. Follow the manufacturer’s guidelines in the handbook and check that any necessary tool(s) are provided on-board.

15.1.3.2 Failure warning

Simulate a break in one wire of the electrical control transmission and check that the yellow warning signal is activated immediately. Apply the parking brake and check that the red warning signal begins to flash and continues to do so as long as the control of the parking braking system is in the on (activated) position. Turn the ignition off, remove the key, and check that the flashing of the red warning signal continues for at least 10 seconds more.

Where a separate red warning signal indicating actuation of the parking brake is provided, check that this is the one that flashes.

15.1.3.3 Energy management test

Check that, with the ignition on but with the engine not running, it is possible to apply the parking braking system with headlights, wipers and rear window heating on.

15.1.3.4 Test with ignition off and key removed

Turn the ignition off and remove the key. If the parking brake is not applied automatically, apply the control of the parking braking system after 5 to 10 min. Check that the system is able to produce the force necessary to hold the laden vehicle on an 18 % up or down gradient within 2 s. Force buildup must start no later than 300 ms after application of the control. Release the control of the parking braking system and check that the parking brake does not release under the ignition-off condition.

15.2 Parking braking system — Dynamic test

15.2.1 If the service braking system and the secondary braking system have the same control, and there is no auxiliary control for applying the service braking system, the parking braking system shall achieve a mean fully developed deceleration and a deceleration immediately before the vehicle stops of not less than [1,5 m/s^2] from a speed of [30 km/h] with the engine disconnected and cold brakes. The force applied to the parking brake control shall not be greater than that prescribed for the hill holding test (Table 16).

15.2.2 Where the parking braking system is also the secondary braking system, this becomes a test of secondary braking capability, and is to be carried out as detailed in 10.4, which has the same requirements.

15.3 Wheel locking sequence

The test shall be carried out as detailed in 10.5.

15.4 Type 0 test (service braking system cold brake effectiveness, engine disconnected)

15.4.1 A test shall be carried out as detailed in 10.1.

15.4.2 It is recommended to undertake a series of stops from the specified speed with reasonably spaced increments of control force/brake control line pressure for all service braking circuits, and to construct a graph of deceleration against control force and brake line pressure for each service circuit up to a point where there is a tendency for wheel locking to occur.

NOTE 1 The control force or brake line pressure used to attain the prescribed mean fully developed deceleration is required later for the hot brake performance test within the type I test (15.9.4).

NOTE 2 The graph of deceleration against brake line pressure can be used to determine braking performance as part of the warning device test (15.6) and the energy storage capacity test (15.7).

15.5 Type 0 test (service braking system cold brake, engine connected)

Tests shall be carried out as detailed in 10.2.

15.6 Warning device test

15.6.1 Basic failure conditions for illumination of red warning signal

Check that each specific failure mode appropriate to the vehicle braking equipment which causes the prescribed service brake performance not to be achieved, and/or one of two independent brake circuits not to function, will result in the lighting up of the red warning signal of the motor vehicle.

15.6.2 Checking of the low stored energy warning device

Without the energy storage devices (air reservoirs) being re-supplied, operate the service brake control with the parking brake control in the brakes released position, until the low stored energy warning device just operates. Record the pressure in the air reservoirs when it occurs.

For giving the warning signal, check that the red warning lamp of the motor vehicle braking system (9.5.1) and/or an acoustic signal is being used.

Operate and release the service brake control a further [four] times, ensuring that the control is held fully applied until the pressures stabilize and that on each release there is a 20 to 30 second pause before re-applying. Verify that on the [fifth] application, the prescribed secondary braking performance for the vehicle category under test can be achieved, as detailed in Table 13.

NOTE Verification can be either by using the deceleration against brake line pressure graph (reference 15.4.2) or by conducting a specific cold brake engine disconnected stop at the [fifth] application pressure from the appropriate initial speed as detailed in Table 13.

15.7 Energy storage capacity test

15.7.1 Charge the air storage reservoirs to the pressure indicated by the manufacturer (reference 3.3.1) with the parking brake control in the released position and auxiliary equipment reservoirs isolated. Then disable any further charging of the reservoirs and fully apply and release the service brakes [eight] times, ensuring that on each application, the control is held fully applied until the pressures stabilize and allow 20 s to 30 s delay after each release before re-applying. Fully apply the service brakes a ninth time, and check that the laden vehicle can still achieve the secondary braking performance set out in Table 13.

NOTE The secondary braking system performance requirement can be verified either by using the deceleration against brake line pressure graph (15.4.2) or by conducting a specific cold brake engine disconnected stop at the 9th application pressure from the appropriate initial speed, as detailed in Table 13.

15.7.2 Note that towing vehicles shall have the supply line to the trailer closed at the coupling head and a [0,5 l] reservoir connected directly to the control line coupling head. On the ninth application (as detailed in 15.7.1) of the service brake control, the pressure in the control line reservoir shall not be less than half the value obtained on the first application.

Verify that after each release of the service brake control, the pressure in the control line additional reservoir is also completely released.

15.8 Type II or type IIA tests (downhill, endurance braking test)

15.8.1 These tests, which are only applicable to certain categories of vehicles, evaluate the braking efficiency of the fully laden vehicle with regard to the independent or combined use of:

— the braking action of the engine (including exhaust brake etc.);

— an endurance braking system (retarder);

— wheel (foundation) brakes (type II test only), if necessary to achieve the required performance.

15.8.2 Type II test

15.8.2.1 This test is applicable to M3 (except inter-urban and long distance touring coaches — see 15.8.3) and N3 vehicles (except those with the capability to tow 04 trailers and ADR vehicles over 16 t GVW — see 15.8.3), and may be conducted using one of the following methods.

NOTE During the test, the lowest gear can be selected, provided that the engine speed does not exceed the maximum value prescribed by the vehicle manufacturer.

15.8.2.2 Gradient test

Make a downhill test in which the vehicle is held at an appropriate speed (i.e. an average speed of 30 km/h) for a period of 12 min on a gradient of 6 % as specified in 5.2.2.2.

If the braking efficiency is not affected by the distance travelled, the test period may be reduced from 12 min, but not to less than 1 min.

15.8.2.2.1 When using only the braking action of the engine, a tolerance of [± 5 km/h] is permitted on the average vehicle speed, with the appropriate gear being engaged to stabilize the speed of the vehicle as close as possible to [30 km/h].

15.8.2.2.2 If it is necessary to use the wheel (foundation) brakes during the descent to maintain the appropriate speed, a service braking system hot performance test shall be carried out with the engine disconnected.

On completing the 12-min test period, this is performed by accelerating the vehicle as quickly as possible to the 60 km/h and carrying out a stop on a level surface within 60 s and noting that the performance listed in Table 17 is obtained.

Table 17 — Type II test (hot performance)

Vehicle category	M2	M3	N2	N3
v		60 km/h		60 km/h
$S \leqslant$		$0{,}15v + \frac{1{,}33v^2}{130}$		$0{,}15v + \frac{1{,}33v^2}{115}$
$d_m \geqslant$		3,75 m/s^2		3,3 m/s^2
$F \leqslant$		700 N		700 N

15.8.2.3 Gradient simulation (towing) test

15.8.2.3.1 The vehicle under test may alternatively be towed such that the energy absorbed is equivalent to that dissipated in maintaining a constant speed on a 6 % down gradient for a distance of 6 km. The average speed shall be 30 km/h and the average towing force shall be equivalent to 6 % of the laden vehicle mass. This is only achieved with care and requires close cooperation of both drivers with the towing vehicle driver maintaining speed and the test vehicle driver giving constant attention to regulating the tow bar load by adjusting the braking effort.

If the braking efficiency is not affected by the distance travelled, the test period may be reduced from 12 min but not to less than 1 min.

15.8.2.3.2 If it is necessary to use the wheel (foundation) brakes of the vehicle under test to maintain the speed/towing force relationship, a service braking system hot performance test shall be carried out as prescribed for the gradient test (15.8.2.2.2).

15.8.2.4 Engine deceleration test

Where the type II test requirement is to be met using the braking action of the engine, it is accepted that this does not need to be tested over the 6 km distance. It is therefore possible to make a short stop on a level surface, in which the achieved engine braking deceleration is recorded in a suitable gear. To be acceptable, the main deceleration produced needs to be at least [0,5 m/s^2].

The mean deceleration (a_m) can be determined by measuring the time taken for a 5 km/h (1,39 m/s) reduction in vehicle speed between speed values in the range 35-25 km/h, using the lowest possible gear without the engine speed exceeding the maximum value prescribed by the vehicle manufacturer, when the accelerator is released.

The average time (t_0) for two test runs in opposite directions shall be used in the following formula to calculate the achieved deceleration:

$$a_m = \frac{1{,}39}{t_0}$$

If the deceleration of [0,5 m/s^2] cannot be achieved, then the downhill or towing test (as in 15.8.2.2 or 15.8.2.3) should be made and some level of foundation braking is allowed to be additionally applied.

15.8.3 Type IIA test

15.8.3.1 This test is applicable to M3 inter-urban and long distance touring coaches, N3 vehicles with the capability to tow O4 trailers and ADR motor vehicles having GVW exceeding 16 t or authorized to tow an O4 trailer, and may be conducted using one of the following methods.

The test is conducted at the maximum mass of the motor vehicle or in the case of ADR vehicles at the maximum mass of the motor vehicle-trailer combination. If for N3 non-ADR vehicles the maximum laden mass exceeds 26 t the test mass is limited to 26 t, or if the unladen mass exceeds 26 t, the vehicle is tested at its unladen mass but the gradient/towing force/deceleration requirements are reduced by the factor 26/actual unladen mass.

In the case of ADR vehicles, if the maximum laden mass of the towing vehicle and its authorized maximum laden towed mass exceeds 44 t, the test shall be conducted at 44 t.

The use of the wheel (foundation) brakes is not permitted during this test, whichever method is used. This may be verified, for the case of an integrated retarder, by checking that the brakes remain cold, as defined in 6.10.

15.8.3.2 Gradient test

Make a downhill test in which the vehicle is held at an appropriate speed (i.e. an average speed of 30 km/h) for a period of 12 min on a 7 % gradient as specified in 5.2.2.2.

If the braking efficiency is not affected by the distance travelled, the test period may be reduced from 12 min but not to less than 1 min.

15.8.3.2.1 When using only the braking action of the engine, a tolerance of [± 5 km/h] is permitted on the average vehicle speed, with the appropriate gear being engaged to stabilize the speed of the vehicle as close as possible to [30 km/h].

15.8.3.3 Gradient simulation test

The vehicle under test may alternatively be towed such that the energy absorbed is equivalent to that dissipated in maintaining a constant speed on a 7 % down gradient for a distance of 6 km. The average speed shall be 30 km/h and the average towing force shall be equivalent to 7 % of the laden vehicle mass.

15.8.3.4 Engine deceleration test

This test is carried out as detailed in 15.8.2.4, with the braking action of the engine maintaining for a short period a mean vehicle deceleration of at least [0,6 m/s^2] measured on a level surface. If the deceleration of [0,6 m/s^2] cannot be achieved, then the full downhill or towing test (as in 15.8.3.2 or 15.8.3.3) should be made, but no foundation braking is allowed to be used.

15.9 Type I test (fade test)

15.9.1 This test evaluates the operation of the automatic brake adjustment device and the fade resistance of the fully laden vehicle service braking system, and consists of 5 parts:

- determination of the control force (or line pressure);
- automatic brake adjustment device test;
- repeated braking (heat generation);
- hot brake performance; and
- brake free running test.

15.9.2 Determination of the control force

It is necessary to determine the control force (or line pressure) required to achieve, with cold brakes, a [3 m/s^2] deceleration for the first brake application in the repeated braking sequence. Subsequent brake applications in the repeated braking sequence are made at this control force (or line pressure) but with increasing temperatures.

It is allowed to experiment to find the control force/line pressure needed to establish, with the engine connected, an initial deceleration of [3 m/s^2] between speeds v_1 and v_2 (Table 18). The temperature of the hottest brake at the start of each exploratory braking attempt must not exceed 100 °C.

Table 18 — Type I test (fade test)

Vehicle category	v_1	v_2	Δt	n
M2	80 % of v_{max}, $\leqslant$ 100 km/h	0,5 v_1	55 s	15
M3, N2, N3	80 % of v_{max} $\leqslant$ 60 km/h	0,5 v_1	60 s	20

v_1 initial speed at start of braking;

v_2 speed at end of braking;

v_{max} maximum speed of vehicle;

Δt duration of braking cycle (elapsed time between the initiation of one brake application and the initiation of the next);

n number of brake applications.

15.9.3 Automatic brake adjustment device test

Vehicles with air-operated brakes have a test of the automatic adjustment function by de-adjusting the device in each brake followed by repeated application of the brakes, which is designed to produce re-adjustment.

For the test, de-adjust each brake to a point where the actuator stroke becomes at least 110 % of the value at which, according to the manufacturer's data, the adjustment action is designed to start.

To achieve automatic readjustment, apply and release the service brakes 50 times up to an actuator pressure which is 30 % of the maximum pressure for normal operation, but never less than 2 bar. Make the final 51st application to a pressure of 6,5 bar. The vehicle is now in the condition to commence the heat generation process.

15.9.4 Repeated braking (heat generation)

Once the control force/line pressure is known, the braking cycles can begin. This same force/pressure shall be used on each braking cycle, from the set speed with the highest gear being used for the braking phase of each braking cycle.

Table 18 shows the number of braking cycles (n), the time of each cycle (Δt) and the vehicle speeds (v_1 and v_2) at which the brakes are to be applied and released.

In between each braking cycle, the vehicle shall, using gears as appropriate, be accelerated rapidly back to the starting speed and 10 s must be allowed in the set cycle time for the speed to stabilize at v_1.

If the vehicle cannot accelerate back to v_1 in Δt – (the braking time + 10 s), because of insufficient acceleration, then the cycle time may be extended to compensate for this lack of power, but 10 s shall be allowed for stabilizing at v_1. If a problem is caused by test track size limitations, then strict adherence to the individual cycle times may be relaxed, but the objective shall be to complete five cycles in the sum of five specified cycle times.

It is recommended that the actual cycle times used be recorded along with the decelerations achieved on each cycle and the overall brake temperature rise.

15.9.5 Hot brake performance

Within 60 s of completing the last brake application in the repeated braking sequence, the vehicle shall be accelerated as quickly as possible to the speed used for the type 0 engine disconnected test as detailed in Table 11.

15.9.5.1 On reaching the prescribed vehicle speed, a service braking system stop shall be carried out with the same value of control force (or brake line pressure) as used in the cold brake type 0 engine disconnected test (15.4) to attain the prescribed mean fully developed deceleration/stopping distance, with the engine disconnected.

15.9.5.1.1 The braking effectiveness shall not be less than:

a) [60 %] of the actual value obtained in the type 0 engine disconnected test (15.4); and

b) [80 %] of the prescribed value for the type 0 engine disconnected test (Table 11).

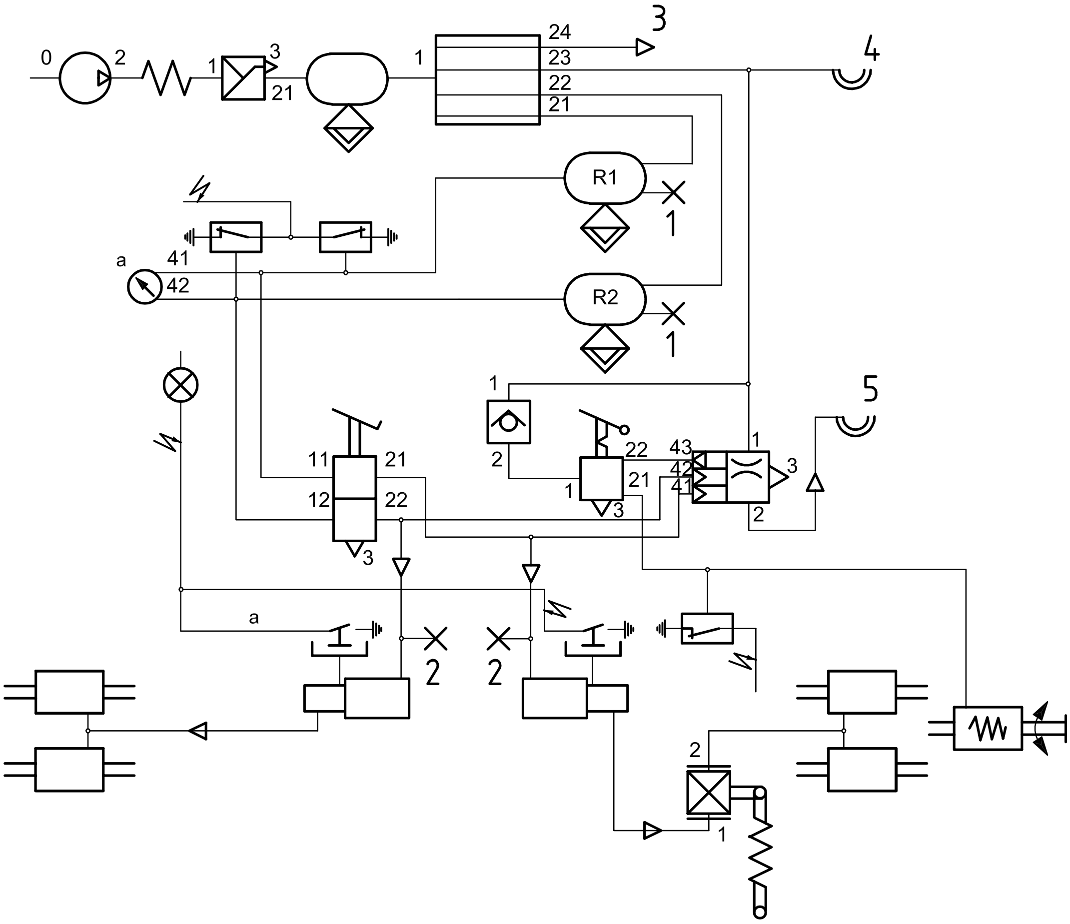
15.9.5.1.2 Should the [60 %] requirement be achieved, but not the [80 %] requirement, the hot brake performance test may be immediately repeated with an increase in the control force up to the maximum value prescribed for the type 0 engine disconnected test as detailed in Table 11. The requirement is now considered to be met provided [80 %] of the prescribed braking effectiveness value is achieved.

15.9.6 Brake-free running test

Allow the brakes to become cold after completion of the hot performance test, jack up the vehicle axles and verify that all wheels can be rotated by hand. If wheels are subject to brake drag such that rotation by hand is largely prevented, an alternative test may be made. To do this, drive the vehicle at a constant speed of 60 km/h and measure the increasing brake temperature over 1-2 km of travel. It is acceptable if none of the brake temperatures rise by more than 80 °C.

Annex A
(normative)

Typical braking equipment



Key

1 connections to be checked for pressure build-up times and depletions

2 connections to be checked for response times and actual braking pressure

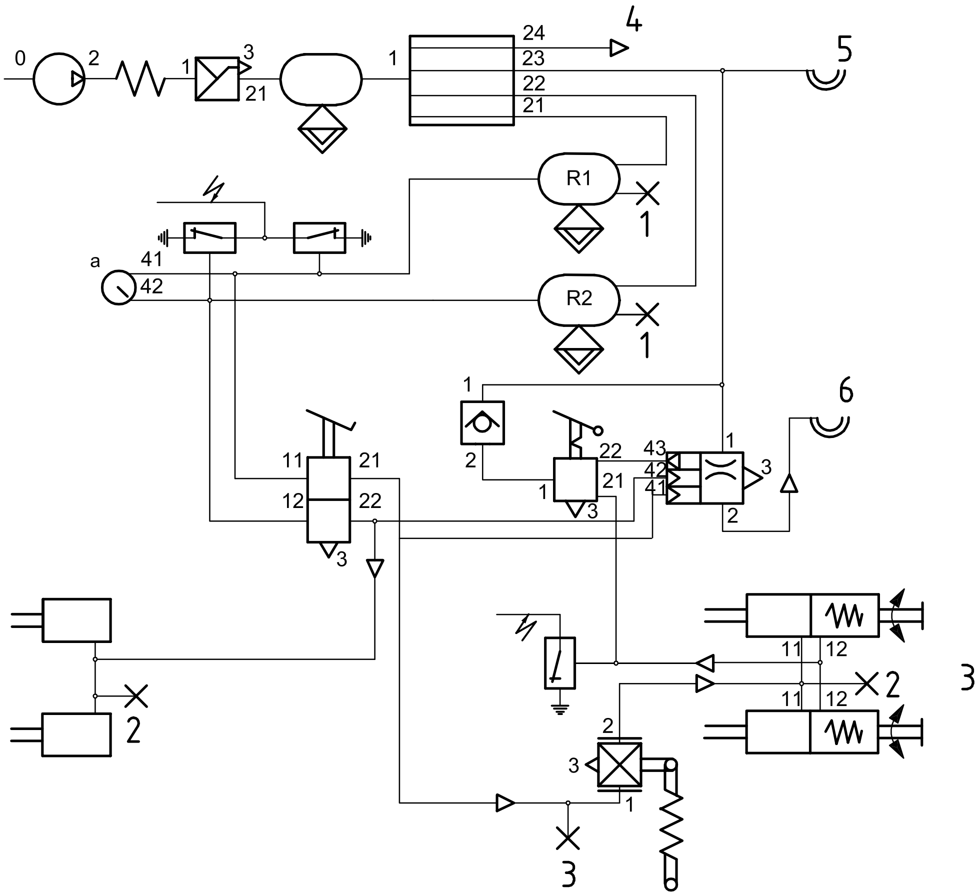
3 auxiliary

4 supply

5 control

a Optional.

Figure A.1 — Typical air over hydraulic braking equipment with pressure test connections



Key

1 connections to be checked for pressure build-up times and depletions

2 connections to be checked for response times and actual braking pressure

3 connections to be checked for adjustment of load sensing value

4 auxiliary

5 supply

6 control

a Optional.

Figure A.2 — Typical pneumatic braking equipment with pressure test connections

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