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Road vehicles — Hydraulic braking systems, including those with electronic control functions, for motor vehicles — Test procedures

Véhicules routiers — Systèmes de freinage hydraulique, y compris ceux à fonction de commande électronique, pour véhicules à moteur — Modes opératoires d'essai

Reference number
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Foreword

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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.

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ISO 6597 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 2, *Braking systems and equipment*.

This fourth edition cancels and replaces the third edition (ISO 6597:2002), which has been technically revised.

This fourth edition incorporates the relevant portions of the International Standard ISO 11835: “Road Vehicles-Motor vehicles. Measurement of braking performance under ABS operation” for testing vehicles which are fitted with anti lock function.

Road vehicles — Hydraulic braking systems, including those with electronic control functions, for motor vehicles — Test procedures

1 Scope

This International Standard specifies the method of testing the hydraulic braking systems of vehicles of categories M and N which are built to comply with ECE-R 13/09, including supplements 1 to 7. The values in square brackets [ ] are taken from ECE Regulation No. 13 for information.

Hydraulic braking systems include vacuum-assisted and power hydraulic-assisted braking systems as well as full power hydraulic braking systems.

NOTE Test methods covering the Electrical Regenerative Braking Systems of Electrical and Hybrid Vehicles are not included in this edition. This omission may be corrected by a further annex once these vehicles are in more common use and suitable practical test methods have been developed.

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.

ECE Regulation No. 13, *Uniform provisions concerning the approval of vehicles with regard to braking, incorporating the 09 series of amendments including supplements 1 to 7*

ECE R.E.3, *Consolidated Resolution on the Construction of Vehicles*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
vehicle categories as defined in ECE R.E.3

3.1.1
category M
power-driven vehicles having at least four wheels and used for the carriage of passengers

3.1.2
category N
power-driven vehicles having at least four wheels and used for carriage of goods

3.2
categories of anti-lock braking function (ABS) as defined in ECE Regulation No. 13, Annex 13

3.2.1
category 1
that which meets all the requirements of ECE R 13, Annex 13

3.2.2
category 2
that which meets all the requirements of ECE R 13, Annex 13 except paragraph 5.3.5.

NOTE No braking rate on split-adhesion surfaces is prescribed.

3.2.3
category 3
that which meets all the requirements of ECE R 13, Annex 13 except paragraphs 5.3.4 and 5.3.5

NOTE All split-adhesion tests are omitted.

3.3
vehicle loading

3.3.1
laden vehicle
vehicle laden to its maximum technically permissible mass M_{max} as 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 to be stated by the vehicle manufacturer. In the event of several load distribution patterns being planned, the distribution of the maximum mass among the axles is such that the load on each axle is proportional to that maximum technically permissible load for that axle.

3.3.2
unladen vehicle
vehicle at its kerb mass [without load or occupant but with the fuel tank filled at the start of the test to at least 90 % of the capacity stated by the vehicle manufacturer and complete with cooling fluid and lubricants, and tools and spare wheel(s)]

NOTE During the tests, the fuel quantity is maintained at least at 50 % of the tank capacity, with an allowed increase of up to 200 kg over the unladen vehicle level. This comprises, for instance, the driver, one observer and instrumentation. If necessary, some vehicle mass may have to be removed. For a vehicle without a body, the manufacturer declares the minimum mass which has to be reached on each axle, to represent the vehicle with a body and spare wheel(s) if these provisions are foreseen.

3.4
hydraulic pressures (Booster and Full Power Systems)

3.4.1
cut-in pressure
system operational pressure in an energy storage device at which the energy source is reconnected

3.4.2
cut-out pressure
system operational pressure in an energy storage device at which the energy source is disconnected

3.5
cold brakes
brakes, the hottest of which has an initial temperature, when measured on the disc or on the outside of the drum or on the brake linings, lower than 100 °C before each stop

NOTE With the exception of the hot braking performance test, all other tests are carried out with the brakes in this cold condition.

3.6
wheel control in anti-lock braking (ABS) functions

3.6.1
directly controlled wheel
wheel whose braking force is modulated according to data provided at least by its own sensor

3.6.2
indirectly controlled wheel
wheel whose braking force is modulated according to data provided by the sensor(s) of another wheel or other wheels

NOTE Anti-lock braking functions with select-high control are deemed to include both directly and indirectly controlled wheels. In functions with select-low control, all sensed wheels are deemed to be directly controlled wheels.

3.7
full cycling
that state of the anti-lock system in which the brake force is repeatedly modulated to prevent the directly controlled wheels from locking

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

3.8
Electronic braking system (EBS)
braking system in which control is generated and processed as an electrical signal in the control transmission

4 Symbols

Table 1 — Symbols

Symbols	Meaning	Unit
E	Wheelbase	m
F	Force	N
F_{dyn}	Normal reaction of road surface under dynamic conditions with the anti-lock system operative	N
F_i	Normal reaction of road surface on axle i (f or r) under static conditions	N
F_{idyn}	F_{dyn} on axle i (f or r) in case of power-driven vehicles	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
k	Coefficient of adhesion between tyre and road	1
k_f	k-factor of the front axle	1
k_H	k-value determined on high-adhesion surface	1
k_L	k-value determined on the low-adhesion surface	1
k_{lock}	Value of adhesion for 100 % slip	1
k_m	Mean k-factor of the vehicle (dynamically weighted)	1
k_{peak}	Maximum value of the curve “adhesion versus slip”	1
k_r	k-factor of the rear axle	1
M	Mass of individual vehicle	kg
M_{max}	Permissible maximum mass	kg
p	Pressure	bar
s	Stopping distance	m
t	Time interval	s
t_m	Mean value of several measurements of t	s
t_{min}	Minimum value of t	s
v	Vehicle speed	km/h
v_{max}	Maximum speed of vehicle (declared by the manufacturer)	km/h
z	Braking rate	1
z_{AL}	Braking rate z of the vehicle with the antilock system operative	1
z_m	Mean braking rate	1
z_{MALS}	z_{AL} of the power-driven vehicle on a “split surface”	1
ε ε_L, ε_H	The adhesion utilized by the vehicle: quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k) values for high and low-adhesion surfaces respectively	1

5 Test site conditions

5.1 Road conditions

5.1.1 Surface

Except for ABS tests (see 5.2), the road surface shall be a smooth, hard-surfaced roadway of asphalt, concrete, or other surface with an equivalent coefficient of adhesion.

The road surface shall be free from loose material and dry for those tests requiring high adhesion.

5.1.2 Gradient

The road surface shall be substantially level; a tolerance of ± 1 % average gradient, measured over a minimum distance of 50 m, is allowed.

The type II test or the braking system hill-holding test may be conducted on a specified gradient or on a level road using a towing vehicle.

5.1.3 Camber

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

5.2 Test area for vehicles with an anti-lock braking function (ABS)

5.2.1 An area for tests on vehicles with ABS shall be provided consisting of a surface providing a peak coefficient of adhesion ($k_{peak} \leqslant 0{,}4$) and of a size sufficient to enable the tests to be performed in safety. Furthermore this area shall be preceded and followed by a surface which provides a peak coefficient of adhesion of about 0,8, which is of sufficient length on the approach side to enable the test speeds to be attained.

For testing vehicles fitted with ABS of categories 1 or 2, a low-adhesion surface shall have a high-adhesion surface on at least one side so as to enable the split-adhesion tests to be performed. Each surface shall be sufficiently wide to allow the separate determination of its peak coefficient of adhesion.

5.2.2 The surfaces used for the split adhesion tests shall be such that:

$$k_H \geqslant [0{,}5] \text{ and } k_H/k_L \geqslant [2]$$

If any doubt arises that this requirement is met, the peak coefficient of adhesion shall be ascertained by using the procedure detailed in D.3. It is always necessary to measure the peak coefficient of adhesion when testing a vehicle fitted with ABS of categories 1 or 2.

5.2.3 For tests of the ABS, the track used shall be regularly characterized by preparation (for the low-adhesion surface) of a curve showing the actual coefficient of adhesion versus slip from 0 to 100 % slip at a speed of approximately 40 km/h.

NOTE Plotting this graph may require a special ABS capable of operating at any preset level of slip.

The peak value k_{peak} and the value at 100 % slip k_{lock} shall be measured and the ratio k_{peak}/k_{lock} calculated and rounded to 1 decimal place.

For the surface to qualify, this ratio shall be:

$$1 \leqslant k_{peak}/k_{lock} \leqslant 2$$

Information on the method of measurement of adhesion levels shall be made available.

5.3 Ambient conditions

The wind speed shall not exceed an average of 5 m/s.

The air temperature shall not exceed 35 °C. In exceptional circumstances, up to 45 °C may be accepted.

This shall be recorded in the test report.

6 General information

6.1 Deceleration measurements used in this procedure refer to the "mean fully developed deceleration" (MFDD). When reference is made to "prescribed effectiveness", this is the MFDD and stopping distance performance required in ECE Regulation No. 13 for the relevant test.

6.2 The use of either pedal-application machines or of robots does not reflect real-life vehicle braking and should be discouraged.

6.3 The determination of the optimum vehicle braking performance shall be entrusted to skilled test drivers. This shall be achieved without wheel-locking except immediately before stopping and without significant deviation being caused by braking. A period of familiarization with the vehicle braking, steering and suspension systems should be allowed.

7 Preliminary comments on test procedures and requirements

7.1 The tests should be carried out in the recommended sequence described in Table 2, but it is recognized that practical circumstances may require variations from this sequence. However, because of thermal influence on friction material behaviour, it is most strongly recommended that:

— the fade test is performed at the end of the sequence; and

— adhesion utilization tests be performed before the corresponding k factor determination.

Any variation in the recommended sequence shall be noted.

7.2 To reduce load changes, all unladen tests are grouped together and followed by the laden tests.

7.3 The parking braking system tests and the response time measurements may be carried out at any time selected by the vehicle manufacturer and agreed with the Technical Services during the testing sequence.

7.4 A preliminary series of five braking system applications may be carried out for vehicle familiarization. Because the total number of stops can significantly change the thermal and mechanical properties of the friction materials (and thus possibly the vehicle braking performance), it is recommended that each test condition be run no more than four times.

7.5 Re-testing in the course of the full procedure shall be avoided, although one or two extra stops are unlikely to prejudice subsequent road test results.

7.6 Full or partial re-tests, after a failed test or to approve alternative braking system components, shall again follow this procedure and with particular emphasis on the vehicle preparation and bedding procedures.

7.7 In order to avoid delays, tests may be carried out under adverse conditions but with due consideration for safety; such adverse conditions shall be reported. Any failed test under such conditions may be repeated under the correct conditions, but it is not necessary that all tests be repeated.

7.8 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 stalling the engine.

7.9 Tests with the engine connected should be carried out in the appropriate gear, defined as the lowest gear which would normally be used to reach the speed without exceeding the manufacturer's recommended maximum engine speed.

7.10 Control forces should be applied rapidly, but without significant overshoot, and then be maintained constant during the stop to allow meaningful measurements to be made. Any departure from this International Standard shall be mentioned in the appropriate test procedure paragraph.

7.11 All tests start with cold brakes, except the hot performance tests.

7.12 During all phases of this procedure, any unusual braking performance characteristics, such as deviation or vibration, shall be reported.

7.13 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 modes (for EBS see Annex 18 reference in A.1 d)).

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

8 Recommended test order

Table 2 — Recommended test order

Test required		Engine status		ECE Reg. 13 Paragraph/Comments
		Connected or in gear	Disconnected or neutral	
A — Pre-Test Phase				
1	Documents required			A1, A18
2	Preparation (instrumentation, bedding, etc.)			
3	Line pressure vs. control force, at engine idling after boost is established			Common practice (not an R 13 requirement)
4	Characteristic of pressure reduction valve			
5	Line pressure vs. time curve (vehicle stationary)			A3 § 4
6	ABS warning lamp and mode change check			A13, § 4.1, 4.1.1, 4.1.2
7	Additional tests on vehicles equipped with EBS			§ 5.2.1.27.1
B — Basic Performance Tests — unladen				
1	Type 0 performance		X	A4 § 1.4.2, 2.1.1 plot deceleration vs. line pressure
2	Type 0 performance	X		A4 § 1.4.3
3	Wheel locking sequence			A10 § 3.1.4.2-4
C — Failure Tests — unladen				
1	Partial system failure Type 0 performance		X	A4 § 2.2
2	Failed load sensing-proportioning valve control		X	A10 § 6
3	Sensor fault memory test			A13 § 4.1.1
4	Failure of the energy source on vehicles equipped with EBS			§ 5.2.1.27.5, 5.2.1.27.6, 5.2.1.27.7, 5.2.1.27.8
D — ABS Tests — unladen				
1	ABS – failed case		X	A13 § 4.3, A 4 § 2.4, 2.2
2	ABS – adhesion, utilisation on high adhesion		X	A13 § 5.2.2
3	ABS – determination of k_H		X	A13 - App.2
4	ABS – adhesion, utilisation on low adhesion		X	A13 § 5.2.2
5	ABS – determination of k_L		X	A13 - App.2
6	ABS – wheel behaviour test on homogeneous surfaces		X	A13 § 5.3
7	ABS – transition from high to low adhesion		X	A13 § 5.3.2
8	ABS – transition from low to high adhesion		X	A13 § 5.3.3
9	ABS – split adhesion test		X	A13 App.3 for ABS cat. 1 or 2

Table 2 (*continued*)

Test required		Engine status		ECE Reg. 13 Paragraph/Comments
		Connected or in gear	Disconnected or neutral	
E — ABS Tests — laden				
1	ABS – failed case			as D1
2	ABS – adhesion utilisation on high adhesion		X	as D2
3	ABS – determination of k_H		X	as D3
4	ABS – adhesion utilisation on low adhesion		X	as D4
5	ABS – determination of k_L		X	as D5
6	ABS – wheel behaviour tests on homogeneous surfaces		X	as D6
7	ABS – transition from high to low adhesion		X	as D7
8	ABS – transition from low to high adhesion		X	as D8
9	ABS – split adhesion test		X	as D9
10	ABS – energy consumption		X	A13 § 5.1
F — Failure Tests — laden				
1	Partial system failure Type 0 performance		X	A4 § 2.2
2	Failed load sensing /proportioning valve		X	A10 § 6
3	Failed booster test		X	§ 5.2.1.2.7 & A4 § 1.4.2, 2.2
G — Basic Performance Tests — laden				
1	Type 0 performance		X	as B1
2	Type 0 performance	X		as B2
3	Wheel locking sequence test			A10 § 3.1.4.2 to 3.1.4.4
4	Response time		X	A4 § 4.1.1
5	Type II (engine braking, only M3 urban buses)	X		A4 § 1.6 & 1.8.2 if applicable
6	Parking braking system dynamic test		X	A4 § 2.3.6
7	Parking braking system static test		X	A4 § 2.3.1 to 2.3.5
8	Additional tests on vehicles equipped with electrical parking brake			§ 5.2.1.26 to § 5.2.1.26.4
9	Type I fade test	X		A4 § 1.5.1
10	Type 0 hot performance		X	A4 § 1.5.3.1/2, 1.5.4
H — Special test Whilst not directly required by ECE Regulation No. 13, this test is called for in Directive 71/320 & 98/12 EEC				
1	Temporary use spare wheels, laden		X	EEC Directive, Annex XIII
I — Special tests — Vacuum/hydr. assisted or power hydraulic actuation				
1	General information			
2	Vacuum booster system tests			A7B § 1.2, 2.2
3	Hydraulic booster system tests			A7C § 1.2, 2.1.2/3
4	Hydraulic full power system tests		X	5.2.1.5 & A7C § 1.2, 2.1.2/3
5	Low pressure warning			
X Indicates the status of the engine (connected or disconnected)				

Annex A
(normative)

Pre-test phase and static tests

A.1 Documents and basic data

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

a) Main technical data according to Annex 2 of ECE Regulation No. 13.

b) Layout and list of the elements of the braking system.

c) Braking system performance calculation (optional if vehicle is equipped with ABS).

d) Documentation according to Annex 18 of ECE Regulation No. 13, if the vehicle is equipped with EBS. This documentation includes an explanation of design provisions guaranteeing compliance with all relevant parts of ECE Regulation No. 13 paragraphs 5.1.4.7, 5.2.1.8 and 5.2.1.27 which deal with the special requirements for the verification of the correct operational status, brake force compensation and for EBS. This documentation may also indicate the worst-case failures for EBS.

e) Report/approval of EMC Tests (if vehicle is equipped with ABS or EBS) in accordance with ECE Regulation No. 10.02.

A.2 Vehicle preparation

A.2.1 Vehicle loading

See 3.3.

A.2.2 Basic instrumentation needed for vehicle tests

The vehicle shall be prepared for testing by the addition of the following instruments and/or calibration of existing standard instruments, as required. Other instruments may be useful in providing accurate data, but care needs to be exercised to ensure that instruments added to the standard vehicle braking equipment do not significantly affect the braking system performance.

All the following appropriate data acquisition system instruments shall be checked to ensure that they are functioning correctly and, with the vehicle stationary on a level test surface and without any brake application, all the instruments shall be set to zero:

a) control force gauge for the service braking systems;

b) control force gauge for the parking braking system;

c) control force gauge for the secondary braking system, if this system is not part of either the service or the parking braking system;

d) decelerometer;

e) speed-measuring device or calibrated speedometer;

f) stopping-distance-measuring means;

g) time-measuring means;

h) brake temperature indicating system;

i) line pressure gauges/transducers. Regulations call for pressure measurements to be made at the least favourable brake actuator and in other parts of the system;

j) optional instruments may include wheel lock indicators, control device travel gauges.

A.2.3 Additional instrumentation needed for test on vehicles with ABS

a) vehicle speed and, optionally, stopping distance and/or deceleration-measuring equipment shall be capable of producing a permanent record of these variables during braking. The acquisition system shall also produce a time base;

b) optional equipment to ascertain when and for what period the wheels directly controlled by an ABS actually lock during the test;

c) for ABS/EBS which depend on stored energy assistance rather than an electrically powered energy source, a device shall be provided to isolate the energy source;

d) it is standard practice to use adjustable pressure-limiting valves in the line to each wheel brake that will be used during the determination of k_f or k_r;

e) optional equipment to show the point of transition of the vehicle from the low to the high-adhesion surface on the permanent record;

f) optional means of measuring steering wheel angles (only for vehicles which are fitted with a category 1 ABS).

A.2.4 Provisions for failure simulation

The vehicle shall be equipped with the necessary added devices, piping and wiring according to the manufacturer's recommendations and agreed with the Technical Services, to provide the required failure simulations. Such added devices, piping and wiring shall not significantly affect the intact and/or failed braking system performance.

When a leakage is simulated, the brake fluid shall be returned to the reservoir.

In the electric part of the braking system, a failure generally corresponds 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.

A.2.5 Tyre conditions

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

It is recommended that the tyre tread wear should not exceed 50 % of the new condition.

A.2.6 Braking system condition

The braking system components shall be new, or capable of functioning as if new, and within the vehicle manufacturer's specifications. The service and parking brake linings shall be bedded according to the vehicle manufacturer's recommendations.

A.2.7 Adjustment of braking equipment

Adjustable brake components shall be set according to the vehicle manufacturer's recommendations. Manual re-adjustment of the brakes, even including those with automatic adjusters, may be made in accordance with the vehicle manufacturer's recommendations, prior to each test listed in Table 2, apart from the G10 Hot test and subsequent test for free running of wheels.

Where a secondary braking system effectiveness test is carried out on one axle only, automatic adjustment devices may be disconnected, if requested by the manufacturer.

A.3 Line pressure versus control force

A graph shall be produced by applying the service brake control, fitted with a force gauge and recording the corresponding readings of the pressure gauge in the line. The pedal force should be slowly increased from 0 to the maximum permitted force which is prescribed as [500] N for M1, [700] N for all other classes and the results recorded. A minimum of two curves shall be plotted to show the normal and zero boost conditions as set out below:

a) with engine idling after previously having been operated above 2 500 rpm (41,667s^{-1}) four or five times (for petrol engines only);

b) without any assistance force (booster disconnected from the vacuum/energy source and stored energy depleted).

A.4 Characteristic of the pressure reduction (proportioning) valve

With pressure gauges fitted in both the input and output lines, the pressure transfer characteristic shall be recorded as the pedal force is slowly increased from zero to the maximum as listed in A.2 above. This shall be done for both unladen and laden conditions.

The ambient conditions and any relevant vehicle or component information shall be noted and the method (measurement or calculation) by which the characteristic was obtained shall appear in the report.

A.5 Line pressure versus time curve (vehicle stationary)

NOTE This curve will be used to determine the static response time (see G.4).

A.5.1 Simulate the laden vehicle

This is done by setting the load-sensing device in the position corresponding to a laden vehicle.

A.5.2 Initial energy level

The initial energy level in reservoirs or accumulators is important where assistance is given to the driver at each brake application. This level shall be set at 90 % of the value specified by the vehicle manufacturer.

Systems such as vacuum boosters, which have no external reservoir, shall be conditioned as indicated in A.2 before each performance test or recording.

A.5.3 Determination of the “line pressure versus time” curve

This curve is most easily measured with the vehicle stationary, by recording the pressure rise at the least favourably placed axle/wheel in response to a sudden brake application.

The force on the service brake control, up to a maximum value of [500] N for vehicles of category M1 and [700] N for vehicles of other categories, shall be applied as quickly as possible but without significant overshoot, as soon as the recorder is started.

The beginning of the movement of the service brake control shall also be recorded as this will provide the start point for the response time assessment.

A.6 ABS/EBS function — Warning lamp check and mode change check

A.6.1 Static warning lamp check

Verify that a specific optical warning device is fitted, which will signal to the driver any electrical break in the supply of electricity to the ABS/EBS or in the external wiring to the controller(s) and any system disconnection or ABS mode change. Check that this warning device lights up when the ABS/EBS is energized and that it is extinguished after a brief verification phase, only if none of the above-mentioned faults are present. This will require the simulation of such faults in order to check the detection capability of the electronic controller.

Check that the warning signal is visible in daylight and that the switch-on warning flash shows it to be in working order.

NOTE 1 With no defect present, the warning signal may light up again, but it shall be extinguished before the vehicle speed reaches 15 km/h, by which point in the speed range all the wheel speed sensors shall be generating reliable signals.

NOTE 2 To check the function of sensor fault memory see C.3.

A.6.2 Mode change check

Check if the subject vehicle specification shows it to be an off-road power driven vehicle of category N2 as defined in Annex 7 of the UN Consolidated Resolution on the Construction of Vehicles/RE3. If this is the case and it is equipped with means to manually disconnect or change the control mode of the ABS function, check that the manufacturer's calculations show that, with this function disabled or in the changed mode, the vehicle conforms to Annex 10 of ECE Regulation No. 13 in that front wheels lock before rear wheels. (Simultaneous locking is accepted for 4WD vehicles.)

NOTE This check is not necessary if, in this changed control mode, all the requirements of the normal system are fulfilled.

Check that an optical warning signal informs the driver of the system disconnection or mode change. The ABS optical warning device may be used for this purpose.

Check that the ABS function is automatically reset to the operational condition in the normal mode when the vehicle ignition switch is again set to the ON condition.

Check that the user handbook, provided by the manufacturer, explains the consequences of such manual disconnection or mode change on the operation of the ABS function.

A.7 Additional tests on vehicles equipped with EBS

A.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 when the ignition key cannot be removed unless the parking brake is applied and where subsequent release is prevented.

The vehicle shall be left stationary with the parking brake released, the ignition in the “off” position and the key removed for 5 to 10 m.

Fully apply the service brake control within 1 s.

The test shall show that the required static total braking force is produced within 2 s after the control is fully applied. Force build-up shall start no later than 300 ms after the initial application of the control.

The static total 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.

Annex B
(normative)

Basic performance test — Unladen

B.1 Service braking system cold effectiveness (type 0) test with engine disconnected

B.1.1 Test procedure and requirement

ECE Regulation No. 13 requires results from a single type 0 test, but in practice it is recommended to undertake, from the speed set out in Table B.1, a series of stops, using reasonably spaced increments of line pressure/control force. This is used to build up a picture of the service braking capability. From this speed, it is good practice to make at least three stops to condition the linings, before actually measuring the performance. These stops can be used to ascertain the maximum pedal force which can be applied without the onset of wheel locking.

Check that the brake temperatures are all below 100 °C and if energy assistance, such as vacuum boost, is provided, that this is at the initial level recommended by the manufacturer. Drive the vehicle at 5 km/h above the test speed on the selected flat, level, high-adhesion surface and disengage the gear being employed whilst starting the recorder at the same time. When the speed drops to the test speed, apply the service brake as quickly as possible, to the planned level. (Line pressure limiters as used in ABS testing can help in this series of tests.)

During this series of tests, record the control pedal force, the deceleration achieved and the resulting stopping distance. From the resulting Mean Fully Developed Deceleration (MFDD) figures and stopping distances, a graph shall be produced showing the braking rate and stopping distance against control force and line pressure, up to the point where the tendency to wheel lock would occur.

This graph will provide figures to demonstrate that both the required deceleration level and stopping distance targets, as specified in Table B.1, have been obtained without exceeding the force limit on the control pedal.

Table B.1 — Service braking with engine disconnected

	Vehicle category	**M1**	**M2**	**M3**	**N1**	**N2**
Type 0 test with engine disconnected	v (km/h)	80	60	60	80	60
	$s <=$ (m)	$0{,}1v + \left(v^2/150\right)$	$0{,}15v + \left(v^2/130\right)$			
	$dm >=$ (m/s^2)	5,80	5,00			
Control force limit	$F <=$ (N)	500	700			

B.2 Service braking system — Cold effectiveness (type 0) test with engine connected

B.2.1 Test procedure and requirements

Following a similar procedure to that used in B.1.1, but without disengaging the gear used for building up speed, make stops from speeds of 30 %, 55 % and 80 % of v_{max} (not exceeding the limits of Table B.2). Carry out single brake applications with a level of control force such as to achieve and record the maximum practical vehicle braking performance.

The vehicle shall show no abnormality such as skidding, pulling off line or requiring serious steering correction to hold on line. The maximum MFDD and the stopping distances shall be noted for the record.

Further tests shall be carried out from the appropriate speed of Table B.2, with control pedal forces which will just allow the deceleration and stopping distances to exceed the required levels of Table B.2, and the control force needed shall be noted.

Table B.2 — Service braking with engine connected

	Vehicle category	M1	M2	M3	N1	N2
Type 0 test with engine connected	80 % v_m but not exceeding (km/h)	160	100	90	120	100
	$s <=$ (m)	$0{,}1v + \left(v^2 / 130\right)$	$0{,}15v + \left(v^2 / 103{,}5\right)$			
	$dm >=$ (m/s²)	5,00	4,00			
Control force limit	$F <= (N)$	500	700			

B.3 Wheel locking sequence test

This test is required only for vehicles with permanent 4 wheel drive in which it is not possible to calculate the adhesion utilization curves for the vehicle due to the torque balancing effects of the 4WD linkages.

The wheel locking sequence shall be checked by making wheel speed recordings as the braking pressures are increased up to the point where all wheels show the development of a lock-up condition. These recordings shall then be analysed to verify the order in which lock-up occurred.

The tests, which may call for some practice in braking application rates, are required to be made on both high and low-adhesion surfaces with adhesion coefficient levels of about 0,8 (normal dry road) and not greater than 0,3 as used for ABS testing.

Commence with the test on the high-adhesion surface and brake from 80 km/h or the maximum speed possible if 80 km/h cannot be achieved. The brake control force shall be built up steadily so that the second wheel reaches lock-up between 0,5 s and 1,0 s after the commencement of braking and the build-up shall be continued until all wheels approach or reach the lock-up condition. It may be necessary to exceed the brake control force limit in order to produce this condition.

The test shall then be repeated and the resulting recordings examined to verify that, in both tests, both rear wheels did not lock up before both front wheels. If the results show that this condition was met on only one test, a third test may be made which shall meet the requirement for the vehicle to be acceptable.

NOTE Simultaneous (within 0,1 s) locking of front and rear wheels is acceptable.

These tests shall be repeated on the low-adhesion surface from a speed of 60 km/h or 80 % v_{max} whichever is the lower, and similar results shall be obtained.

Annex C
(normative)

Failure test — Unladen

C.1 Secondary braking system — Service braking system partial failure (type 0) test

C.1.1 General

C.1.1.1 Secondary braking system

Two types of secondary braking system are considered, depending on the basic design of the braking system in use on the vehicle:

a) one which is part of the service braking system;

b) one which is independent of the service braking system; e.g. this may require the secondary braking performance to be achieved by the parking brake system.

C.1.1.2 Secondary braking performance

This is considered to be the minimum performance required of the secondary braking system, whichever secondary provision, a) or b) above, is made.

C.1.1.3 Residual braking performance of the service braking system

This is considered to be the minimum performance required of the service braking system in case of a transmission circuit failure, even though the secondary braking system is not part of the service braking system.

NOTE Residual braking has no meaning in case C.1.1.1 a).

C.1.2 Test procedure and requirements

C.1.2.1 The secondary and/or residual braking performance (see C.1.1.2 or C.1.1.3) shall be checked for the worst-case failure modes appropriate to the vehicle braking system where all circuits shall be considered.

C.1.2.2 The conditions of the test shall be as follows:

a) vehicle speed (see Table C.1);

b) with the engine disconnected;

c) without wheel-locking, except immediately before stopping;

d) with steering-wheel corrections, if necessary, to keep the vehicle on course;

e) unladen as defined in 3.3.2 (the laden test appears in Annex F);

f) a single stop suffices for each test; additional stops may be run, if necessary;

g) each test shall be made with cold brakes as defined in 3.5;

h) if the secondary braking system is independent of the service braking system as in C.1.1.1 b), both the service braking system with a partial failure and the secondary braking system need to be tested.

C.1.2.3 Procedure for applying the failure condition

C.1.2.3.1 The failure of one service braking system circuit shall be simulated as follows by either:

a) a valve controlled by-pass which is opened to connect one circuit to the reservoir, or

b) a shut-off valve in one circuit which is closed to isolate that section of the master-cylinder from the brakes. This closure shall be made only when the service brake control has been released for at least 1 s.

Either method ensures that the circuit line pressure remains at zero during the entire test phase, but the pedal feel will be affected differently in a) and b).

C.1.2.4 Required performance

C.1.2.4.1 Secondary braking system which is part of service braking system

For a secondary braking system which is part of the service braking system, as in C.1.1.1 a), the test shall produce mean fully developed deceleration and stopping distance figures which, at least, conform to values listed in Table C.1.

Table C.1 — Secondary braking with engine disconnected

	Vehicle category	M1	M2	M3	N1	N2
Type 0 test with engine disconnected	v (km/h)	80	60	60	70	50
	$s <=$ (m)	$0{,}1v + \left(2v^2/150\right)$	$0{,}15v + \left(2v^2/130\right)$		$0{,}15v + \left(2v^2/115\right)$	
	$dm >=$ (ms^{-2})	2,9	2,5		2,2	
Pedal control force limit	$F <= (N)$	500	700			
Hand control force limit	$F <= (N)$	400	600			

C.1.2.4.2 Independent secondary braking system

For a vehicle with an independent secondary braking system as in C.1.1.1 b), the test shall produce the following.

C.1.2.4.2.1 Secondary braking performance

In the unladen case, the vehicle shall achieve at least the value obtained from the appropriate section of Table C.1 with the corresponding limit on the hand control force (if the parking brake or other hand control applies the secondary brake).

C.1.2.4.2.2 Residual braking performance

Using the normal service brake control, the partial service braking system performance shall achieve at least the value taken from the appropriate section of Table C.2.

This procedure shall be repeated with the vehicle in the laden condition with the test that appears in Annex F.

Table C.2 — Residual braking with engine disconnected

Vehicle category	v km/h	s (laden) m	d_m m/s²	s (unladen) m	d_m m/s²
M1	80	$\leqslant 0{,}1\ v+\left(\frac{100}{30}\right)\left(\frac{v^2}{150}\right)$	$\geqslant 1{,}7$	$\leqslant 0{,}1\ v+\left(\frac{100}{25}\right)\left(\frac{v^2}{150}\right)$	$\geqslant 1{,}5$
M2	60	$\leqslant 0{,}15\ v+\left(\frac{100}{30}\right)\left(\frac{v^2}{130}\right)$	$\geqslant 1{,}5$	$\leqslant 0{,}15\ v+\left(\frac{100}{25}\right)\left(\frac{v^2}{130}\right)$	$\geqslant 1{,}3$
M3	60	$\leqslant 0{,}15\ v+\left(\frac{100}{30}\right)\left(\frac{v^2}{130}\right)$	$\geqslant 1{,}5$	$\leqslant 0{,}15\ v+\left(\frac{100}{30}\right)\left(\frac{v^2}{130}\right)$	$\geqslant 1{,}5$
N1	70	$\leqslant 0{,}15\ v+\left(\frac{100}{30}\right)\left(\frac{v^2}{115}\right)$	$\geqslant 1{,}3$	$\leqslant 0{,}15\ v+\left(\frac{100}{25}\right)\left(\frac{v^2}{115}\right)$	$\geqslant 1{,}1$
N2	50	$\leqslant 0{,}15\ v+\left(\frac{100}{30}\right)\left(\frac{v^2}{115}\right)$	$\geqslant 1{,}3$	$\leqslant 0{,}15\ v+\left(\frac{100}{25}\right)\left(\frac{v^2}{115}\right)$	$\geqslant 1{,}1$

C.2 Failed load sensing-proportioning valve control

This control is a mechanical linkage, which under failure can be assumed to adopt either extreme condition. Therefore, in the unladen state, it shall be assumed that the valve takes up a laden position.

A test shall be made with the valve control adjusted to put the valve into the laden position and with the engine disconnected, and from the speed specified in Table C.1. Make a stop using only sufficient pedal force to achieve the secondary deceleration selected, as appropriate from that table.

Check the vehicle behaviour to verify that this deceleration level can be achieved without loss of vehicle stability.

For vehicles having Electronic Braking Distribution (EBD), the system failure is likely to result in loss of the modulation of braking pressure resulting in the application of full braking pressures when the system is shut down. For EBD-equipped vehicles, check that the failure produces a red driver warning but only the C.2 test is required and the F.2 test may be omitted.

NOTE This test may be omitted and calculations made on braking distribution to show that secondary braking performance in the unladen case can be achieved with a margin of stability retained.

C.3 Sensor fault memory test

It is necessary to check the function of the ABS sensor fault memory and 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 to be held away from the sensor wheel. In this way, the setting of the original sensor remains undisturbed and the substitute sensor shall 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 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 m. Switch on the ignition and verify that 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, switch off the ignition, remove the key and then re-instate 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.

C.4 Failure of the electrical energy source on vehicles equipped with EBS

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 or batteries are no longer charged. 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.

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

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

C.4.1 Battery charge/discharge measurement

For these tests, it is necessary to discharge the EBS supply battery or batteries, e.g. using the full vehicle electrical load (or an external load) with the engine at rest and to check for automatic reversion to the back-up system at a voltage which is approximately that declared by the manufacturer. This voltage is expected to be available in the Vehicle Technical Specification or in the of ECE Regulation No. 13 Annex 18 Safety Concept information along with designed back-up performance level.

Alternatively for the low voltage detection test the vehicle battery/EBS supply battery may be replaced by a high power supply in which the voltage can be adjusted.

C.4.2 Low voltage detection

Start with the nominal voltage and then gradually reduce the voltage until it is 10 % above the value declared by the manufacturer, at which point 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 value and check at this level that braking pressures corresponding to residual/secondary braking performance can be achieved.

It will also 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.

NOTE 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:

a) Use of a precision very low value power resistor inserted into the battery connection across which the small voltage drop is accurately measured.

b) A Hall Effect sensor which is clipped round all the battery cables.

C.4.3 Battery discharge 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 switch-over 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.

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

C.4.4 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.

Annex D
(normative)

ABS function tests with the vehicle unladen

D.1 Dynamic test with ABS in the failed case

D.1.1 Disable the ABS function and check that on a high-adhesion surface, it is still possible to achieve at least the secondary braking performance via the service brake control.

This requirement does not replace the need for secondary braking system performance in the event of a service braking system failure. Thus, on most vehicles, the performance with the ABS disabled shall be at least equal to the secondary level but many vehicles are capable of meeting the prescribed service braking performance.

D.1.2 If, in the event of an electrical fault or loss of sensor signal, it is possible to achieve a partial ABS system shut-down, the braking performance shall be checked with the ABS operational but with, in turn, each part of the braking system-split in the shut-down condition. The braking system shall also be tested with the total ABS shut-down.

D.1.3 Record the deceleration achieved in this ABS failed case.

D.2 Determination of the adhesion utilized on a high-adhesion surface

D.2.1 From an initial vehicle speed of 55 km/h, ascertain the braking rate which the vehicle with the ABS can achieve on that selected surface on which the coefficient of adhesion will be measured as the next action of this procedure. Perform this test with sufficient pedal force/line pressure to ensure that full cycling of the ABS function is invoked, up to a maximum of 1 000 N if necessary. If full cycling can still not be produced, wet the surface to reduce the adhesion coefficient, keeping in mind the requirement of D.3.

The result shall be calculated from the time t, in seconds, taken for the speed to reduce from 45 km/h to 15 km/h, using the following formula:

$$z = \frac{0,849}{t}$$

D.2.2 Repeat this test twice more on the same part of the surface, and calculate the average t_m of the three t values obtained to find the z_{AL} figure to be used in the adhesion utilization calculation, using the following formula:

$$z_{AL} = \frac{0,849}{t_m}$$

D.2.3 This value z_{AL} will then provide the adhesion utilization result, once the adhesion coefficient for the surface k_m has been measured in D.3.5 below, from:

$$\varepsilon_H = \frac{z_{AL}}{k_m}$$

D.3 Determination of the peak coefficient of adhesion of the high-adhesion surface

D.3.1 This test shall be carried out immediately following the adhesion utilization measurement of section D.2 above and it is important that, if the surface was damp for that test, the same level of moisture is employed for this measurement.

D.3.2 Disable the ABS function and the rear axle service braking system.

NOTE In some cases, it is permitted to allow the ABS function to be operational, provided that no cycling takes place between 40 km/h and 20 km/h and that brake pressure has reached the demanded level.

Determine the peak coefficient of adhesion for the front axle as in the following procedure. The result is then used in the calculation of the mean surface adhesion value, which is required for the adhesion utilization assessment.

D.3.3 Check that the test instrumentation is fully operational and carry out a number of brake applications from an initial vehicle speed of 50 km/h, on the test surface. During each application, the line pressure shall be held constant but increased for each subsequent run until the optimum vehicle deceleration is achieved (probably where slight skidding occurs).

To ensure that the highest deceleration result is included, the series of increments shall be extended to the point where the wheels actually lock during the stop. The braking rate z is calculated by reference to the time t, in seconds, taken for the speed to reduce from 40 km/h to 20 km/h, i.e.:

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

During this procedure, care shall be taken and cooling periods allowed to prevent serious rise in brake temperature, as this may distort the results.

From the minimum recorded value of t, (t_{min}), select three values of t which lie within t_{min} and 1,05 t_{min}, and calculate the arithmetical mean value t_{m}, and then the optimum braking rate:

$$z_{\mathrm{mf}} = \frac{0{,}566}{t_{\mathrm{m}}}$$

If it is demonstrated that practical reasons prevent the three values defined above from being obtained, the minimum time t_{min} may be used in place of t_{m}.

NOTE This procedure is most accurately performed using an adjustable control line pressure regulator.

In order to obtain a valid result, both wheels on the axle being measured shall reach the lock point simultaneously. The use of individual line pressure regulators for each wheel may be necessary to make the individual pressure adjustments which will achieve this.

D.3.4 Calculate the value of k_{f} for a two-axle, rear-wheel drive vehicle with the front axle only being braked, using the following formula:

$$k_{\mathrm{f}} = \frac{z_{\mathrm{mf}} \times g \times M - 0{,}015 F_{\mathrm{r}}}{F_{\mathrm{f}} + \frac{h}{E} \times z_{\mathrm{mf}} \times g \times M}$$

For front wheel driven vehicles the term (0,015F_{r}) shall be replaced by (0,01F_{r}).

D.3.5 Repeat the procedure of paragraph D.3.3 using rear axle braking only whilst maintaining the ABS function disabled. A second mean deceleration z_{mr} figure for the rear axle is obtained and used in the following formula to give k_r:

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

For front wheel driven vehicles, the term ($0{,}01F_f$) shall be replaced by ($0{,}015F_f$).

(k_f and k_r values shall be rounded to three decimal places).

Vehicles of categories N2 with a wheelbase < 3,8 m and with $h/E > 0{,}25$ do not need a k_m value but can take $k_m = k_f$

D.3.6 The two coefficients obtained are then combined into a single value k for the vehicle on the test surface by allowing for the dynamic axle loading under ABS performance as follows:

$$k_m = \frac{k_f \times F_{fdyn} + k_r \times F_{rdyn}}{g \times M}$$

where:

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

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

This value for the surface coefficient of adhesion k_m shall be calculated and used to form the adhesion utilization ε_H from:

$$\varepsilon_H = \frac{z_{AL}}{k_m}$$ rounded to two decimal places.

This shall have a value ⩾ [0,75].

D.4 Determination of the adhesion utilized on the low-adhesion surface

Using the test surface with a low peak coefficient of adhesion (less than 0,3) with the ABS operating, repeat the procedure in section D.2 to obtain z_{AL}, which will be used with the result of the adhesion coefficient measurement in D.5 to determine the low-adhesion surface utilization figure ε_L, (z_{AL}/k_m) which again shall be ⩾ [0,75].

D.5 Determination of the peak coefficient of adhesion on the low-adhesion surface

Repeat the procedure of D.3 with the ABS disabled in order to measure k_m for the low-adhesion surface and then use this figure to determine the result in D.4.

D.6 Wheel behaviour test on homogeneous surfaces

With all brakes operating and the ABS function enabled, carry out a series of stops to confirm that the directly controlled wheels do not lock (other than momentarily) when brakes are suddenly and fully applied. These tests are to be performed on both the low and high-adhesion surfaces used earlier, from two initial speeds: 45 km/h and a higher speed of 80 % of the vehicle's maximum speed, v_{max} but not exceeding 120 km/h.

M2, M3 and N2 vehicles are restricted to [80] km/h on low-adhesion surfaces.

This restriction also applies to N2 vehicles on high-adhesion surfaces.

NOTE 1 In the tests in D.6 to D.9, momentary locking (typically $\leqslant$ 0,5 s) of directly controlled wheels is permitted. 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 shall not be noticeably affected.

NOTE 2 The definition of “fully applied” in relation to the service brake control normally means the maximum permitted control force for the vehicle category. A higher control force, however, may be used if it is necessary to cause the ABS function to come into operation, with the vehicle on high-adhesion surfaces and during the transition test from high to low-adhesion surfaces.

D.7 Transition test: from high to low-adhesion surfaces

Check that when an axle passes from the high-adhesion surface to the low-adhesion surface, with the brake control fully applied and the ABS fully cycling, the directly controlled wheels do not lock (other than momentarily as in D.6 Note 1).

The initial vehicle speed and the timing of the full brake application shall be such that ABS operation commences on the high-adhesion surface and the transition from high to low adhesion occurs at the two vehicle speeds specified in D.6.

D.8 Transition test: from low to high-adhesion surfaces

When an axle passes from the low-adhesion surface to the high-adhesion surface, with the brake control fully applied and the ABS fully cycling on the low-adhesion surface, check that the vehicle deceleration rises to a value appropriate to the high-adhesion surface within a reasonable time (typically $<$ 2 s), without the vehicle deviating from its initial course. For this test, the vehicle initial speed shall be such that ABS operation gives full cycling on the low-adhesion surface and the transition of the front wheel, from the low to high adhesion occurs at approximately 50 km/h.

NOTE It is useful to install some device which will show the point of surface transition on the instrumentation record.

D.9 Split adhesion test

D.9.1 For vehicles fitted with an ABS of category 1 or 2, check that the directly controlled wheels do not lock other than momentarily (as in D.6 Note 1), when, with the right and left wheels on surfaces having quite different coefficients of adhesion k_H and k_L, the brakes are suddenly and fully applied at a vehicle speed of 50 km/h. The vehicle shall be positioned centrally over the division between the two surfaces used for the test. During the course of this test, no part of the vehicle's tyres shall cross the division but steering correction is allowed as specified in the Note below.

The surfaces shall be chosen so that $k_H \geqslant$ [0,5] and $k_H/k_L \geqslant$ [2].

NOTE Steering control correction is permitted in order to hold a straight course during the split-adhesion tests described in D.9 provided that the angular rotation of the steering wheel, within the first 2 s of the brake application, is no greater than 120° and is less than 240° in total during the remainder of the test.

D.9.2 For vehicles fitted with an ABS of category 1, check that when the split adhesion test D.9.1 is performed, the vehicle meets the prescribed braking rate z_{MALS} as follows:

$z_{MALS} \geqslant [0,75\ (4\ k_L + k_H)/5]$ (subscripts $_L$ and $_H$ mean low and high)

$z_{MALS} > k_L$

NOTE It may be necessary to measure k_H again if, as is usual for split adhesion testing, the high-adhesion surface is wet but was dry for the previous k_H measurement.

Annex E
(normative)

ABS function tests — with the vehicle laden

E.1 General

The remainder of the ABS tests and the following braking performance tests require the vehicle to be in this fully laden state.

E.2 Dynamic test with ABS in the failed case

Repeat the test described in D.1.1 with the vehicle fully laden. At least the residual service braking performance shall be obtained, but if the secondary braking system corresponds to C.1.1.1 a), the secondary performance of 2,9 m/s^2 shall be achieved. (2,5 m/s^2 for M2 and M3 and 2,2 m/s^2 for N category vehicles.)

E.3 Determination of the adhesion utilised on the high-adhesion surface

Repeat the procedure described in D.2 with the vehicle fully laden. If the maximum prescribed force on the control pedal of 500 N cannot achieve full cycling of the ABS, this test and the following adhesion measurement may be omitted.

In full power braking systems, the stored energy level may not be increased for this test. If cycling is achieved, the test will generate an ABS braking rate (z_{AL}) to be used with the result of the following adhesion coefficient measurement.

E.4 Determination of the peak coefficient of adhesion on the high-adhesion surface

Repeat the procedure of section D.3 with the vehicle fully laden to determine the high-adhesion surface coefficient k_m.

Use this figure to calculate the adhesion utilization using the following formula:

$$k_H = k_m$$

$$\varepsilon_H = \frac{z_{AL}}{k_H} \text{ which shall be } \geqslant [0,75]$$

E.5 Determination of the adhesion utilized on a low-adhesion surface

Repeat the procedure described in D.2 with the vehicle fully laden, to obtain z_{AL} on the low-adhesion surface, which will be used with the result of the following adhesion coefficient measurement.

E.6 Determination of the peak coefficient of adhesion on the low-adhesion surface

Repeat the procedure described in D.3 with the vehicle fully laden to produce a figure for k_m on this surface and use this figure to calculate the adhesion utilization using the following formula:

$$k_L = k_m$$

$$\varepsilon_L = \frac{z_{AL}}{k_L} \text{ which shall be } \geqslant [0,75]$$

E.7 Wheel behaviour test on homogeneous surfaces

Repeat the tests described in D.6 with the vehicle fully laden and the same results as required in D.6 shall be obtained.

NOTE The same speed restrictions apply.

E.8 Transition test from high- to low-adhesion surfaces

Repeat the test described in D.7 and the corresponding results shall be obtained laden.

E.9 Transition test from low- to high-adhesion surfaces

Repeat the test described in D.8 and the corresponding results shall be obtained laden.

E.10 Split adhesion test

Repeat the test described in D.9 and the corresponding results shall be obtained laden.

NOTE It may be necessary to measure k_H again if, as is usual for split adhesion testing, the high-adhesion surface is wet but was dry for the previous k_H measurement.

E.11 Energy consumption of the ABS on the low-adhesion surface (k = 0,3 or less)

E.11.1 It is only necessary to carry out this test on vehicles fitted with an ABS which uses stored energy and in which the necessary energy source has only a limited capacity.

E.11.2 Check that application of the service brake control causes all brakes to function normally. Ensure that if any auxiliary accumulator is fitted which is fed from the braking power source but does not contribute to braking, that this is isolated from the service braking system during these tests.

E.11.3 The manufacturer may closely adjust the brakes prior to this energy consumption test.

E.11.4 This test checks the capacity of the energy storage accumulators in relation to the supply and consumption of energy whilst the ABS is operating. The test comprises a braking run with the engine idling in neutral, in which the ABS shall operate in order to control brake pressures for a period of time set as follows:

Braking time t in seconds = v_{max} /7 but $>$ [15] s

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

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

E.11.5 The pressure level in the accumulator(s) shall be that specified by the manufacturer. This level shall be at least that which ensures the laden vehicle will meet the prescribed service braking performance but may be the cut-in pressure of the energy supply device.

E.11.6 Practical considerations mean that artificial test surfaces are often too short to allow the braking time to be achieved in a single stop unless the vehicle has a very low maximum speed. This leads to the permitted (but more complicated) alternative of performing the test in several phases, up to a maximum of four times.

In such cases, it is necessary to determine the number of phases and the initial vehicle speed on each phase, (which shall exceed 50 km/h), so as to meet the required overall total braking time, taking into account the following factors:

a) surface adhesion level and thus the expected deceleration under ABS control;

b) cut-off speed below which the ABS operation may cease and at which each brake application should be released;

c) length of the low-adhesion test surface available.

As an example, consider a vehicle with the following values:

Max speed v_{max}	160 km/h
Lower cut-off speed	15 km/h
Surface coefficient of adhesion	0,25
Expected braking rate z_{AL}	0,2 g (7 km/h/s) assumed constant
Braking time 160/7	22,86 s

Check 1: try two stops 11,43 s each
Start speed = cut-off speed + (duration × deceleration) 15 + (11,43 × 7) = 95 km/h
Now estimate the stopping distance:
Mean speed during the stop = 15 + (95-15)/2 = 55 km/h (15,27 m/s)
Stop time = 11,43 s
Distance = 15,27 × 11,43 = 175 m
This may be too long for most test tracks.

Check 2: try three stops. 7,62 s each
Start speed = 15 + (7,62 × 7) = 68,34 km/h
To estimate the stopping distance:
Mean speed during the stop = 15 + (68,34-15)/2 = 41,67 km/h (11,575 m/s)
Distance = 7,62 × 11,575 = 88,2 m

Therefore, three phases are a practical test requiring some 90 m of test surface.

For each stop, the engine shall be disconnected, the ABS shall be fully cycling down to the brake release (cut-off) speed of 15 km/h. The brake control shall be released at this point and the vehicle turned round for the next phase without use of the brake so as not to affect the stored energy level.

The energy storage accumulators are allowed to be charged only during each braking phase in which ABS is in operation.

It is thus recommended to install an electrical valve which, when energized, disconnects the energy source to prevent recharge of the accumulator.

This device would be energized normally during this particular test and released only during the braking phases when charging is permitted.

At the end of the total braking time, no further charging of the energy accumulator(s) is permitted so the disconnection device shall be energized for the remainder of the test, even though the brake control is required to be operated as in E.11.9 below.

E.11.7 If a single phase test is possible, at the end of the braking time, bring the vehicle to rest without further operation of the ABS and without further recharging of the energy accumulator. If the service braking system has been used to bring the vehicle to rest, increase the brake pedal force up to a full application and release.

This is considered to be the first static brake application of E.11.8.

E.11.8 After the energy consumption run(s) of E.11.6 or E.11.7, it is required to make four additional full brake applications without any further charging of the energy accumulator(s). Then on the fifth such application, it shall be possible to achieve the secondary braking performance with the laden vehicle.

This may be verified by performing a vehicle test on the high-adhesion surface or by statically checking that the line pressure achieved is sufficient to provide the secondary performance, based on calibration tests made earlier.

E.11.9 In the 3-phase example cited, the brake applications of runs two and three are considered to take the place of two of the four specified static applications. Thus, only two further full brake applications need to be made before the fifth test application, which shall then achieve at least the secondary braking performance.

E.11.10 The ABS cycling shall continue to function during the whole of the consumption test time t and it may be necessary to partially off-load some vehicles to ensure that this cycling continues as the pressure falls due to energy usage. This is acceptable, but note that the fifth application requirement for secondary performance still relates to the vehicle in the fully laden state.

Annex F
(normative)

Failure test — Laden

F.1 General

The procedure described in C.1.2 shall be repeated with the vehicle laden and the performances shall at least achieve the values listed in Table C.1.

F.2 Failed load sensing-proportioning valve control

The test procedure described in C.2 shall be repeated except that, in the laden state, the control linkage shall be adjusted so that the valve takes up the extreme unladen condition. Then make a stop from the speed stated in Table C.1 for the appropriate vehicle category. Use a control force not exceeding the corresponding 500 N or 700 N limit of Table C.1 and the secondary performance shall be at least equal to the appropriate level taken from that table.

NOTE This test may be omitted and calculations made on braking distribution to show that secondary braking performance in the laden case can be achieved.

For vehicles having Electronic Braking Distribution, this test does not have to be made but check that, in the failed case, a red warning is given to the driver.

F.3 Failed booster test

F.3.1 Failure of energy assistance source

A failure of the booster has the same effect in removing the assistance as does a failure of the energy reserve. Thus, only a failure in the energy reserve will be considered, as this is easily simulated.

This simulation is made by depleting all the stored energy in the assistance device(s). If more than one energy-assistance device is fitted in the service braking system, the test shall be carried out for each such device in turn. Once depletion is complete, the energy source shall be disconnected from the booster whilst the test is made.

The test shall be made from the test speed for secondary braking set out in Table C.1 with the engine disconnected.

Measured performance shall be at least equal to secondary braking level, also in Table C.1.

F.3.2 Engine stopped or sudden failure of the boost force

This failure can most easily be simulated by charging the energy-assistance device(s) to the normal operating level and then stopping the engine (or disconnecting the supply of energy from the engine). The test shall be made as soon as this has been done.

The test shall be made in neutral (engine disconnected), from the test speed for secondary braking as in F.3.1 but the measured performance, for one stop only, shall be at least equal to the service braking effectiveness as in the appropriate section of Table B.1.

F.3.3 Single energy reserve with driver push through

For vehicles with full power braking systems in which the braking energy is stored in a single reservoir (such as some Electronic Braking Systems for example), the automatic change-over to hydrostatic back-up shall be tested as follows.

F.3.3.1 Disable the power system source by opening the pump bypass, for example, and depleting the energy reserve by repeated operation of the service brake control until the stored pressure falls below the critical level.

At this point, verify that the red warning signal is given and check that the braking system has reverted to push-through back-up operation on one or both axles as laid down in the vehicle specification or the Annex 18 documentation from the manufacturer. This shall be done by monitoring the braking pressures in response to a full force brake application.

F.3.3.2 Under these conditions, with the vehicle laden and the engine disconnected, make a stop to check that the secondary braking performance can be achieved using only the driver's muscular energy, with control force not exceeding 500 N for M_1 vehicles or 700 N for N_1 vehicles.

Table C.1 lists, for the appropriate vehicle category, the starting speed, the control force limit and the necessary stopping distance and MFDD performance which shall be achieved for acceptance.

F.3.3.3 Restore the pump feed (or remove any other disabling provision) and run the system.

The red warning signal shall be extinguished at the latest when the service brake control is operated and brake pressure established. This may be checked at low speed to ensure that normal braking is provided and the driver shall not leave the vehicle until this is ensured.

Annex G
(normative)

Basic performance test — Laden

G.1 Service braking system — Cold effectiveness (type 0) test with engine disconnected

G.1.1 Test procedure and requirements

A series of tests shall be made to display the performance of the braking system in terms of the MFDD and stopping distance achieved for a range of increasing service brake control force inputs, still less than the limit imposed by Table B.1, up to the point at which wheel locking is about to occur.

The procedure and requirements for these tests are the same as for the series of tests described earlier in B.1.1, the only difference being that the vehicle is now fully laden with the consequence that the tests are more stringent.

In this and subsequent tests, the vehicle axle weights, the ambient conditions and any wheel locking or deviation from the intended course shall be noted for the record.

The additional test which causes just the appropriate MFDD level required in Table B.1 to be achieved, shall also be repeated and the level of service brake control force especially noted, since this is the value that will be allowed in the later hot test described in G.8, when the hot/cold deceleration figures obtained will be compared.

G.2 Service braking system — Cold effectiveness (type 0) test with engine connected

G.2.1 Test procedure and requirements

Repeat the tests described in B.2 to show the maximum braking performance of the vehicle in the laden state. The MFDD and the stopping distances shall again be recorded for the result documentation.

The additional tests which cause just the appropriate MFDD level required in Table B.2 to be achieved, shall also be repeated and the value of the necessary service brake control force again noted.

G.3 Wheel locking sequence test

This test is required only for vehicles with permanent 4 wheel drive in which it is not possible to calculate the adhesion utilization curves for the vehicle due to the torque balancing effects of the 4 wheel drive linkages.

The test is a repeat, with the vehicle laden, of that defined in B.3, and similar results shall be obtained.

G.4 Response time measurement

G.4.1 Definition

The response time is defined as the time interval between the beginning of the movement of the service brake control and the moment when the line pressure at the least favourably placed axle/wheel reaches the level corresponding to that at which the prescribed vehicle performance is achieved.

G.4.2 Test procedure

One of the two following methods, G.4.2.1 or G.4.2.2, may be used.

G.4.2.1 By reference to graphs already plotted

From the curve established in G.1, note the line pressure which produces the prescribed laden vehicle deceleration (as set out in Table B.1) and put this into the pressure versus time graph plotted in A.4 of Table 2.

The A.4 result plots the build-up of line pressure against time and also indicates the point at which the brake control movement commenced. From this diagram, read the time taken to reach the noted line pressure. This is the response time.

G.4.2.2 By direct measurement

Measure and record the control force/movement and corresponding line pressure build-up along with the deceleration response during a dynamic test under the conditions described in G.1. The response time shall then be read from these recorded results by referring to the prescribed deceleration value (as set out in Table B.1).

Using this method, the control force on the service brake control shall be applied as quickly as possible and without significant overshoot, up to a maximum permissible value of 500 N for vehicles of category M1 and 700 N for vehicles of other categories.

G.4.2.3 Performance required

In all vehicles, the response time for the laden vehicle shall be no greater than 0,6 s.

G.5 Type II downhill test (engine braking, for M3 vehicles only)

G.5.1 General

This test applies to all sections of category M3 vehicles which are equipped with a hydraulic (not air over hydraulic) braking system. If vehicles are equipped with an additional endurance braking system (retarder), this may be used in this test.

It is assumed that hydraulically braked vehicles do not have exhaust brakes.

G.5.2 Test conditions

Conditions shall be the same as in 5.1.2. For practical reasons, the test site gradient may be modified slightly in a sense which adversely affects the performance. If these modified conditions exist, any test which is failed can be repeated under more normal conditions.

Tests are carried out with the vehicle laden, in an appropriate gear for 30 km/h running, using one of the methods described in G.5.3.1 or G.5.3.2 below.

G.5.3 Test methods

G.5.3.1 Test on the gradient

The vehicle speed shall be maintained at an average speed of 30 km/h (± 5 km/h) using only engine braking on a 6 % downhill gradient, for a distance of 6 km. The gear engaged shall be such that the maximum engine speed specified by the manufacturer is not exceeded.

G.5.3.2 Towed test to simulate the gradient

The vehicle under test is towed by a tractive vehicle equipped with a strain-gauged and calibrated towing link or coupling, at an average speed of 30 km/h (± 5 km/h) with the test vehicle using engine only braking, against the pull of the towing vehicle, for a distance of 6 km.

The level of engine braking and the tractive power of the towing vehicle shall be jointly adjusted to simultaneously maintain a constant 30 km/h and the towing link force equivalent to 6 % of the test vehicle weight. In order to maintain test validity, this force shall never fall below 4 % of the weight. Vehicle speed and coupling force shall be recorded as the test takes place.

NOTE This test requires the close cooperation of both drivers with the towing vehicle driver maintaining speed and the test vehicle driver giving constant attention to the tow bar load by adjusting the braking effort particularly where the additional use of a retarder or some service braking assistance is required.

G.5.4 Additional provisions

G.5.4.1 Type II test which can be met with the assistance of a retarder

Some retarders are, to an extent, affected by the distance travelled under endurance braking, so the test distance on the 6 % gradient, or under gradient simulation, shall be maintained at 6 km. It may be necessary to step up the retarder setting to maintain the towing link tension.

G.5.4.2 Type II test which requires assistance from the service braking system

This may be needed if the engine braking cannot alone generate the necessary braking force. This will be noticed by an inability to maintain the speed at 30 km/h downhill or to develop the towing link force when being towed. The speed or force shall in this case be regulated by a light application of the service brake to assist the engine braking.

Under these circumstances, the test shall be considered as a heating procedure for the service brakes, which then shall be subjected to an efficiency test which shall take place within 60 s of completing the downhill/towing test.

G.5.4.3 Efficiency test of hot brakes

This test is carried out under the conditions specified for the type 0 test with the vehicle laden and the engine disconnected (see G.9).

The performance demonstrated by M3 vehicles shall be such as to at least generate a mean fully developed deceleration of 3,75 m/s^2, without exceeding the control force limit of 700 N.

G.5.5 Presentation of results

During the type II test, the following information and measurements shall be recorded:

a) Description of the type of test conducted, stabilized speed maintained and the gradient and variations encountered (downhill test), or towing force and the gradient noted if not zero (towing test).

b) If engine braking and the service brake were used together, the service brake line pressure and the gradient. This recognizes that the most likely combination will be the engine braking plus service brake and that engine braking output value will not be determined, so only the service brake level can be recorded.

c) In the case b) above, the result of the hot brake efficiency test.

G.6 Parking braking system — Dynamic test

This requires that a brake application is made on the laden vehicle, with the engine disconnected, from a speed of 30 km/h.

The speed and deceleration shall be recorded from the point of applying the brakes until the vehicle comes to a standstill.

The deceleration which builds up as the brake is applied and also as measured just before the vehicle comes to a stop shall not be less than 1,5 m/s^2.

The force on the hand control shall not exceed the specified limit appropriate to the category of vehicle, as set out in G.7.2.

G.7 Parking braking system — Static test

G.7.1 General

This test can be performed on a hill having an 18 % gradient or under an attempted towing test using a towing vehicle equipped with a towing link in which the tension force is measured.

G.7.2 Gradient test

Drive the vehicle on to an 18 % gradient, first facing downhill.

Hold the vehicle stationary by applying the service brake and then apply and set the parking brake, measuring the application force. This measurement needs to be carefully done so as to just engage a tooth on the ratchet and the force shall not exceed:

— 400 N on M1 vehicles with normal hand control;

— 600 N for other categories with hand control.

If a foot control is installed, the force may be 100 N greater, i.e. 500 N or 700 N is permitted.

Release the service brake and note the ability of the parking brake to hold the vehicle.

Repeat the test, reducing the application force and setting on a lower ratchet tooth. Note the application force and record whether this also holds the vehicle.

Repeat until the vehicle does not hold.

Reposition the vehicle so as to face uphill and repeat the above sequence noting the new results.

G.7.3 Towing test

G.7.3.1 General

In the absence of a suitable gradient, this towing test can be applied provided that the towing vehicle is instrumented to measure and record the tension force in the towing link and the vehicle under test has been fitted with the means of connecting this link to both front and rear.

This is virtually a static test and the towing force to be resisted shall be calculated from 18 % of the total permissible maximum mass M_{max} of the vehicle.

G.7.3.2 Test procedure and requirements

Connect up the towing vehicle, having previously calibrated the towing link instrumentation, and apply the parking brake fully. Be careful not to exceed the maximum control force for the vehicle category as specified in G.7.2 and keep in mind that this force shall be applied steadily with gradual increase so as to just engage the next step of the ratchet. If the control force limit is exceeded, release the brake and start again.

NOTE 1 It may be necessary to settle for the next lower step of the ratchet.

Then gradually apply the towing effort, recording the developed tension force and any movement which eventually occurs. Verify that the force required for movement to be detected was greater than the target figure calculated.

NOTE 2 The vehicle only has to withstand a towing force greater than this target without moving, in order to be acceptable.

Repeat this test by trying to tow the vehicle backwards and verify that the target tension can be achieved without moving.

G.8 Additional tests on vehicles equipped with electrical parking braking system

G.8.1 Performance test in fault 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 described in G.7 on an 8 % up-and-down gradient. It shall be possible to apply the parking brake from the driver's seat by using the control of the parking braking system 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 brake 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 %. These are:

a) a check that the parking brake remains applied when the ignition switch is turned off;

b) a check that the parking brake is automatically released as soon as the vehicle is set in motion again.

If in the test above, the vehicle was not held stationary on the 8 % gradient, for vehicles of categories M1 and N1, repeat the test with additionally a suitable gear or the parking position of the automatic transmission engaged. If the vehicle is now held stationary the parking braking system performance in the failed case is acceptable.

There shall also be means to release the parking brake in the failed-when-applied case. Follow the manufacturer's guidelines in the handbook and check that any necessary tool(s) are provided on-board and verify that release is possible without going underneath the vehicle (but access by wheel removal is acceptable).

G.8.2 Failure warning

Simulate a break in one wire of the electrical control transmission and check that the yellow warning signal is immediately activated. 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 a further 10 s.

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

G.8.3 Energy management test

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

G.8.4 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 m. 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 built up shall 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.

G.9 Service braking system — Type I fade test

G.9.1 General

This is a laden test of M and N category vehicles which is performed by repeatedly applying and releasing braking on a preset time cycle. Each cycle consists of a braking phase from a prescribed start speed v_1 down to an end speed v_2, which is half the start speed.

The vehicle shall be accelerated back to just above the start speed as quickly as possible and held, in top gear, at this speed until it is time to start the next cycle.

Clearly, this shall be organized so as to suit the test track available and if the vehicle needs to be turned around, this shall be done just after the brakes are released.

G.9.2 Procedure and requirements

G.9.2.1 Using Table G.1, determine the start speed appropriate to the vehicle category and note the number and duration of the braking cycles. Make a number of brake applications, in top gear from an initial speed of v_1, keeping the brake temperatures below 100 °C (at the start of each application), in order to establish the control force which gives a deceleration of 3,0 m/s^2. This is the control force which shall be applied for all the subsequent applications in this test.

Check that the vehicle can accelerate back to v_1 in: [the cycle time - (the braking time + 10 s)].

If this cannot be achieved 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 the start speed. Alternatively, If a problem is caused by test track size limitations, then strict adherence to individual cycle times may be relaxed but the objective shall be to complete 5 cycles in the sum of 5 specified cycle times.

Table G.1 — Service braking system — Type I fade test

Vehicle Category	Conditions of Test			
	Start Speed v_1 (km/h)	End Speed v_2 (km/h)	Cycle Time (s)	No of Cycles
M1	80 % $v_{max} \leqslant 120$	1/2 v_1	45	15
M2	80 % $v_{max} \leqslant 100$	1/2 v_1	55	15
N1	80 % $v_{max} \leqslant 120$	1/2 v_1	55	15
N2, M3	80 % $v_{max} \leqslant 60$	1/2 v_1	60	20

G.9.2.2 Starting with cold brakes (<100 °C), make the first brake application from a speed of v_1 at the control force previously determined, and note that the deceleration achieved remains at 3 m/s^2.

Note that the clutch need not be disengaged as the speed only reduces to 1/2 v_1.

Complete the cycle and accelerate back to the start speed, using the appropriate gears to regain a speed just in excess of v_1 as quickly as the engine power will allow.

G.9.2.3 Repeat the procedure so as to complete the number of cycles specified in the appropriate section of Table G.1, recording the temperature rise of the brakes and the deceleration figures achieved on each cycle. The hot performance test described in G.8 shall be made as soon as the final cycle has been completed.

G.10 Hot performance test

G.10.1 Test procedure

This is a single type 0 test with the engine disconnected from the normal start speed as set out in Table B.1, but using the same control force as the original laden type 0 test with the engine disconnected. The brake temperature condition is different from that of type 0.

It is to be expected that the achieved deceleration will be somewhat less than that recorded with cold brakes under the same conditions, so the requirement is consequently reduced.

G.10.2 Performance required

In this hot condition, the mean fully developed deceleration shall:

a) not be less than 80 % of the prescribed level for the category;

b) not be less than 60 % of the actual achieved level recorded in the original type 0 test made in the laden condition with the engine disconnected.

If a vehicle meets the 60 % requirement but at the original control force used in G.8.1 cannot achieve 80 % of the prescribed deceleration, then this hot performance test may quickly be repeated using a higher control force but not exceeding the limit set out in Table B.1 (500 N/700 N). In this case, the results of both tests shall be included in the report.

If the special test of Annex H is required because the vehicle is equipped with a temporary-use spare wheel, it would be good practice to carry out this test before the fade test in G.9. If the manufacturer is totally confident in the recovery of the brake lining performance to such a level as would allow a before and after comparison, this test may be done in this position.

G.10.3 Free running test

After cooling from the hot test described in G.10.1, jack up the vehicle wheels and verify that all wheels can be turned by hand. If any wheel is subject to brake drag such that turning 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 increase in the brake temperatures over a distance between 1 km and 2 km. The free running condition is acceptable if none of the brake temperatures rise by more than 80 °C.

Annex H
(normative)

Special test

H.1 Braking test for category M1 vehicles with temporary use spare wheels/tyres

The test shall be conducted with the temporary use spare wheel/tyre fitted in place of one front wheel and then in place of one rear wheel.

NOTE If this temporary use wheel is restricted to a specific axle, then the test need only be made with the wheel in that position.

A Type 0 test (cold) shall be made on a high-adhesion surface using the service braking system from an initial speed of 80 km/h with the engine disconnected.

The braking performance shall be such as to give a stopping distance of less than 50,7 m and MFDD not less than 5,8 m/s^2 at a control force not exceeding the limits set out in Table B.1.

NOTE This is the normal requirement of a Type 0 test for M1 vehicles (the only category likely to use these wheels). Stopping distance is given by: $s < 0{,}1v + v^2/150$.

The deceleration of 5,8 m/s^2 shall be achieved without any of the following problems:

— wheel locking;

— deviation of the vehicle from the intended course;

— abnormal vibration;

— excessive steering correction being needed in order to stay on a straight course.

Annex I
(normative)

Braking systems with energy assistance — Tests for vehicles with vacuum or hydraulic boosters or full power braking systems

I.1 General

I.1.1 Energy assisted systems have the following special requirements where the energy in the reservoir(s) is necessary to meet the requirements of secondary performance. However, many lighter vehicles, which have some form of assistance, can meet the secondary performance by the use of the driver's muscular energy alone. These vehicles do not have to pass these special tests.

I.1.2 Vehicles which are subject to this special test shall be equipped with vacuum or pressure gauges and these shall be installed as near to the reservoirs/accumulators as possible. Time-measuring instruments or recorders with a suitable timebase shall also be required.

I.1.3 Determine the type of assisted/powered braking system on the vehicle and, from the manufacturer's specification, ascertain whether the assistance or power is needed to achieve the prescribed secondary braking performance. If this is the case, select the appropriate part of the following procedure to be adopted for the test.

I.1.4 The following tests shall be made with the parking brake released and with the brakes adjusted as closely as possible consistent with being able to turn the wheel by hand.

I.2 Vacuum booster systems

I.2.1 Capacity of the energy source

I.2.1.1 Test conditions

If the energy source is the vacuum developed by the engine, the test shall be made at the engine idling speed specified by the manufacturer, with the vehicle stationary and with the engine disconnected.

If the source of vacuum is, however, a pump driven by the engine, the test shall be conducted at an engine speed of 65 % of that which generates maximum power or at 65 % of the governor limited speed if the engine is so equipped.

I.2.1.2 Procedure

In either case, with the engine stopped, deliberately release any stored vacuum by repeated operation of the brake pedal (until the gauge reads zero vacuum). Then start the engine and run at the appropriate speed as in I.2.1.1 and measure the time taken for the pressure to fall from an initial atmospheric level to the vacuum pressure p_0, designated by the manufacturer, at which he has determined that the prescribed service braking performance can be achieved with the vehicle laden. This time shall be no greater than 3 min.

p_0 shall not exceed 90 % of the maximum vacuum level supplied by the energy source and shall be determined by the manufacturer since special regulated vacuum equipment has to be employed.

I.2.2 Capacity of vacuum storage reservoir(s)

I.2.2.1 Test conditions

The initial energy level in the reservoir(s) should follow the manufacturer's recommendations but shall not exceed 90 % of the maximum vacuum level.

This initial level shall be such as to enable the prescribed service braking performance, laden, to be readily achieved.

Reservoir(s) shall not be fed with further energy from the supply (by having the engine stopped), and if auxiliary reservoir(s) are fitted, then these and the devices fed from them shall be isolated.

I.2.2.2 Test procedure and requirements

I.2.2.2.1 If the energy source is a pump, carry out eight full applications of the service braking system control under static conditions. Then drive the vehicle, with the supply disconnected, at the appropriate speed, as set out in Table C.1 for secondary braking, and check that at least the secondary performance level can be achieved at the ninth brake application without exceeding the control force limit.

Alternatively, a static brake application can be made and the line pressure measured at the control force limit. This figure is noted and compared with the line pressure/deceleration characteristic recorded in the laden test of G.1.1 to derive the equivalent deceleration capability at the final level of vacuum boost. This deceleration shall be at least equal to the secondary performance set out in the appropriate column of Table C.1.

I.2.2.2.2 If the energy source is the engine vacuum, the test is the same but only four full applications of the service braking control are required. The procedure follows that of I.2.2.2.1 to determine the braking performance on the fifth application in this case.

I.2.3 Low vacuum warning tests

Vehicles that have to undergo these tests need vacuum assistance to meet the secondary braking requirements. They also are required to have low vacuum warning devices which need to be tested.

In order to be assured that the warning is given whilst adequate vacuum energy remains in the system, it is then necessary to make the following demanding test.

Examine the vacuum system to verify that it is fitted with a detector giving an optical or acoustic warning signal of significantly reduced vacuum level in addition to any gauge that may be fitted.

To test this warning, deplete the system to the level at which the warning just operates then, without recharging the vacuum reservoir, actuate the service brake control fully four times and on the fifth application it shall still be possible to achieve secondary braking performance. This can of course be checked by noting the vacuum pressure and comparing this with the manufacturer's figure for achieving secondary braking performance if such a figure is available or if this is not the case, a vehicle test shall be made with the vacuum source cut off.

I.3 Hydraulic booster systems

I.3.1 General

These systems are capable of producing, by the use of the driver's muscular energy alone, some reduced level of braking in the case of a failure in energy assistance.

I.3.2 Capacity of the pump

I.3.2.1 Variables used

The hydraulic pump capacity is checked by measuring the time t taken to charge the storage accumulator(s) between two pressure levels p_2 and p_1, so chosen that the accumulator capacity has only a minor influence.

For this test, the two pressures are defined as:

— P_1 is the cut-out pressure where charging is discontinued;

— p_2 is the pressure remaining after four full brake applications, starting from p_1 without any further feed to the accumulator(s);

— t is the charge time, without any operation of the brake control.

I.3.2.2 Measurement conditions

Any accumulator installed for auxiliary devices shall not be isolated except in the case where this action takes place automatically.

The output of the energy source is assessed with the engine running at the speed at which maximum power is developed or at the limit set by the governor if so equipped.

If in any vehicle, the p_2 level is higher than the cut-in pressure, the accumulator pressure needs to be reduced. This is most easily done by repeated operations of the brake pedal without the engine running, and shall be continued until the measured pressure falls below the cut-in point and charging will take place once the engine is run.

I.3.2.3 Requirement

The charging time t, shall not exceed 20 s for vehicles of categories M1, N1 and M2 and 30 s for vehicles of categories N2 and M3.

I.3.3 Capacity of the energy accumulators

I.3.3.1 Test conditions

The initial energy level in the accumulator(s) should be as specified by the manufacturer, but it shall not exceed the cut-in pressure. However, this level shall be sufficient to ensure that the prescribed service braking performance can be achieved in the laden condition.

Accumulator(s) shall not be fed during the test and any auxiliary devices and associated accumulators shall be isolated.

Full-stroke brake applications shall be made at a rate which allows an interval at least of 60 s between each application.

I.3.3.2 Test procedure and requirement

Under static conditions, carry out eight full applications of the service brake control, having regard to the intervals stated above, and then drive the vehicle, with the supply still disconnected, at the appropriate speed for secondary braking as set out in Table C.1.

On the ninth application, it shall be possible to achieve at least the performance prescribed in Table C.1, for secondary braking.

I.3.4 Low pressure warning

Vehicles which are subject to these tests need hydraulic boost in order to meet the secondary braking requirements. They are also required to have low boost pressure warning device(s) which need to be tested.

In order to be assured that the warning is given whilst adequate stored energy remains in the boost system, it is then necessary to make the test as detailed in the following section.

I.4 Full power hydraulic braking systems

I.4.1 General

Vehicles in this category are not able to achieve any service braking performance without stored hydraulic energy. They shall have at least one accumulator on each separate circuit and fall into two types:

a) those which use part of the service braking system to achieve secondary braking performance as C.1.1.1 a.);

b) those with a separate secondary braking system as C.1.1.1 b).

The requirements differ between the two groups.

The service braking system of group a) shall meet the secondary braking performance in the event of one circuit failure, whilst that of group b) shall meet the lower residual braking performance under the same circumstances.

I.4.2 Capacity of the pump

This is checked in the same way as for the hydraulic booster system, set out in I.3.

I.4.3 Capacity of the energy accumulators

This is checked in the procedure set out in I.4.4.2.

I.4.4 Failure of the energy source (pump)

I.4.4.1 Reason for the test

Because of the importance of the energy source in these vehicles, the effect of pump failure shall be checked.

The failure is simulated by disconnecting the pump or by removing the drive from the engine.

Auxiliary devices and associated accumulators shall also be isolated.

I.4.4.2 Test procedure and requirement

From an accumulator pressure specified by the manufacturer, but not exceeding the cut-in pressure, carry out eight full applications of the service braking system, under static conditions. Each application shall be held for 20 s to 30 s and at least 1 m allowed between applications.

The stored pressure shall then be noted and, with the pump still disconnected, the vehicle shall be driven at the speed prescribed in Table C.1 for the secondary braking performance test.

It shall be possible on a ninth application to achieve at least the performance required for secondary braking.

I.4.5 Hydraulic transmission failure

I.4.5.1 General

I.4.5.1.1 If the system has only a single pump feeding the required two accumulators, the following test shall be made.

A double pump system with dual drive provisions forms two completely separate circuits. This provides the condition where a circuit failure leaves a complete second circuit in operation, and thus does not need to satisfy this test.

I.4.5.1.2 The transmission comprises all those elements, including the accumulators, located between the service brake control and the wheel brakes, which link them functionally. The test shall make a first check as to whether a leakage fault in one transmission circuit will prevent the common pump feeding the other circuit.

NOTE This will generally require pressure protection valves. Simple check valves in the charging feed line will not be adequate, as both accumulators will fail to be charged when the whole pump supply is lost in the event of a single fault in one of the circuits.

I.4.5.1.3 If the continuing feed condition cannot be ensured, then the warning device (see I.5) shall have both optical and acoustic elements and the following test of the energy storage capacity shall be made.

I.4.5.2 Test procedure and requirement

I.4.5.2.1 Create a failure in the least favourable part of one hydraulic transmission circuit.

Isolate any auxiliary equipment and associated accumulators and set the braking accumulator pressure to a level specified by the manufacturer, but not exceeding the pump cut-in pressure p_1.

With the pump stationary or operating at engine idling speed, carry out eight full applications of the service brake. On the ninth such application, record the line pressure which can be generated.

I.4.5.2.2 If this is a vehicle which has an independent secondary braking system, the line pressure shall be at least sufficient to produce the appropriate residual braking performance, as set out in Table C.2.

If the vehicle has no such independent secondary system, the line pressure recorded shall be sufficient to produce at least the appropriate secondary braking performance, as set out in Table C.1.

I.4.5.2.3 If there is any doubt about the selection of the least favourable point at which to create a failure, this test shall be repeated with alternative failures present (one at a time).

I.4.5.2.4 If the continuing feed condition of I.4.5.1.2 can be met, the test shall be conducted exactly as described above in I.4.5.2, but it is only necessary to make four full service brake applications.

Then on the fifth such application, the performance shall be as defined in the appropriate part of I.4.5.2.2.

I.5 Low pressure warning

I.5.1 Preliminary precautions

The satisfactory functioning of the warning device shall be verified at some time during the course of the complete test procedure. The circuit failure test, simulated by an open-circuit leakage type failure, which ensures that the circuit line pressure remains at zero, provides a logical opportunity to check this feature.

I.5.2 Warning test

I.5.2.1 General

This test applies to full power hydraulic braking systems or energy-assisted hydraulic braking systems, for which stored energy is required to achieve secondary braking performance.

I.5.2.2 Test procedure

I.5.2.2.1 With the vehicle stationary, the engine off and commencing at a pressure specified by the manufacturer but not exceeding the cut-in pressure p_1, carry out two full applications of the service braking system control device.

At this point, the low pressure warning shall not have been activated.

I.5.2.2.2 Continue to operate the service braking system control device until the accumulator pressure has fallen to the level where the alarm device activation threshold has just been reached.

From this first signal of the alarm device, carry out four full actuations of the service braking system control device.

I.5.2.3 Requirements

When tested according to I.5.2.2.2, ensure that, at the fifth full service brake application, the pressure remaining is sufficient to meet the appropriate requirement of I.4.5.2.2 This shall be checked for the laden vehicle, either by interpolation from a braking efficiency graph or by a test on track under the conditions of a Type 0 test with engine disconnected.

The alarm device shall not operate during normal system running when there is no actual failure but only the normal cyclic variations in accumulator pressure as the system is used.

NOTE This may be conveniently verified during the earlier dynamic tests.

I.5.2.4 Additional alarm device

When the continuing power feed to the second circuit cannot be ensured, the alarm device shall include an acoustic element as well as the optical warning.

The acoustic device shall not operate before the optical one but both may operate simultaneously.

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