PVGTR2005-2c (PVGTRtest-wipf)

5. BRAKING TESTS AND THE REQUIRED PERFORMANCE OF BRAKING SYSTEMS.

5.1. GENERAL REQUIREMENTS

5.1.1. The performance of a braking system shall be determined by measuring the stopping distance in relation to the initial speed of the vehicle or by measuring the mean fully developed deceleration during the test and whilst the braking system shall comply with both these parameters, only in marginal [± 5%] cases will it be necessary to measure both.

5.1.2. The stopping distance shall be the distance covered by the vehicle from the moment when the driver begins to activate the control of the braking system until the moment when the vehicle stops; the initial speed shall be the speed at the moment when the driver begins to activate the control of the braking system; the initial speed shall not be less than **98%** of the prescribed speed for the test in question.

The mean fully developed deceleration (d_m) shall be calculated as the deceleration averaged with respect to distance over the interval v_b to v_e , according to the following formula:

$$MFDD \quad d_m = \frac{v_b^2 - v_e^2}{25.92\ (S_e - S_b)} \quad m/s^2$$

where:
- v_o = initial vehicle speed in km/h,
- v_b = vehicle speed at 0.8 v_o in km/h,
- v_e = vehicle speed at 0.1 v_o in km/h,
- S_b = distance travelled between v_o and v_b in metres,
- S_e = distance travelled between v_o and v_e in metres.

The speed and distance shall be determined using instrumentation having an accuracy of ± **1**% at the prescribed speed for the test. The d_m may be determined by other methods than the measurement of speed and distance; in this case, the accuracy of the d_m shall be within ± **3**%.

5.1.3. **General Test Conditions**:
For the approval or assessment of any vehicle, the braking performance shall be measured during road tests conducted following these rules**:**

5.1.3.1. the vehicle's condition as regards mass must be as prescribed for each type of test and be specified in the test report;

5.1.3.2. the test must be carried out at the speeds prescribed for each type of test.
If the maximum design speed of a vehicle is lower than the speed prescribed for a test, the test shall be performed at a speed that is set at a multiple of 5 km/h that is 4 to 8 km/h less the vehicle's maximum speed. The stopping distance achieved shall be no greater than specified by the formula given for the particular requirement.

5.1.3.3. during the tests, the force applied to the brake control in order to obtain the prescribed performance must not exceed the maximum force laid down;

5.1.3.4. Unless specified otherwise in the relevant stages of the test sequence, the road must be **dry** and have a surface affording an adhesion coefficient (PFC) of 0.9. PFC values below this figure are acceptable provided that the vehicle fulfills the performance requirements.

5.1.3.5. the tests must be performed when there is no wind liable to affect the results;

5.1.3.6. **Temperatures** at the start of the tests.

Ambient. The ambient temperature shall be lie between 0 and 45°C.

Tyres. These must be cold and at the pressure prescribed for the load actually borne by the wheels when the vehicle is stationary

Brakes. The average **initial brake temperature** (IBT) of the wheel brakes on the hottest axle must be between 65 and 100°C. Temperatures may be measured as outlined in ISO PAS 12158.

5.1.3.7. The prescribed performance must be obtained **without locking** of the wheels at speeds exceeding **15 km/h,** without deviation of the vehicle, from a **3.5 m wide lane**, without exceeding a yaw angle of **15°,** and without abnormal vibrations;

5.1.3.8. For vehicles powered completely or partially by an **electric motor** (or motors), **permanently connected to the wheels**, all tests must be carried out with these motor(s) connected.

5.1.3.9. for vehicles as described in paragraph **5.1.3.8.**, fitted with an electric regenerative braking system of **category A,** behaviour tests defined in paragraph **1.4.3.** of this Annex shall be carried out on a track with **low adhesion,** peak friction coefficient (PFC) of 0.3 or less ;

5.1.3.9.1. moreover, for vehicles fitted with an electric regenerative braking system of category **A**, transient conditions such as gear changes or accelerator control release, must not affect the behaviour of the vehicle in these low adhesion conditions.

5.1.3.10. in tests required by paragraphs **5.1.3.9.** and **5.2.6.4.** wheel locking is **not** allowed. However **steering correction** is permitted if the angular rotation of the steering control is within **120°** during the **initial 2 seconds** and not more than **240° in all**.
In other tests, only smaller levels of <90° in all, will be allowed.

5.1.3.11. For a vehicle with **electrically actuated service brakes** powered from traction batteries (or an auxiliary battery) which receive(s) energy only from an independent external charging system, these batteries shall, during braking performance testing, be at an average of not more than **5%** above that (*low*) state of charge at which the brake failure warning prescribed in paragraph **4.3.12.1.**is required to be given.

If this warning is given, the batteries may receive **some recharge** during the tests, to keep them in the required state-of-charge range.

5.1.4. Behaviour of the vehicle during braking

5.1.4.1. In braking tests, and in particular in those at high speed, minor steering correction is allowed but the general behaviour of the vehicle during braking must be recorded.

5.1.4.2. Behaviour of the vehicle when braking on a road on with **reduced adhesion** must meet the relevant Braking Distribution or ABS requirements.

5.1.4.3. In the case of a Regenerative Braking System of **Category B**, where the braking for a particular axle (or axles) is comprised of more than one source of braking torque, and any individual source can be varied with respect to the other(s), the vehicle shall satisfy the Braking Distribution or ABS requirements under all relationships permitted by its control strategy and this may be tested.

5.2. ROAD TEST PROCEDURES.

These shall follow the sequence of tests as specified in Table 1 below

Table 1.--**Road Test Sequence**

Testing order	Section/Paragraph No.
Vehicle laden (to GVWR):	
1 Burnish	5.2.1.
2 Wheel lock sequence	5.2.4.
Vehicle unladen (at LLVW):	
3 Wheel lock sequence	5.2.4.
4 ABS performance	5.2.6.
5 Torque wheel	5.2.5.
Vehicle laden (to GVWR):	
6 Torque wheel	5.2.5.
7 Cold effectiveness	5.2.7.
8 High speed effectiveness	5.2.8.
9 ABS performance	5.2.6.
10 Stops with engine off	5.2.9.
Vehicle unladen (at LLVW):	
11 Cold effectiveness	5.2.7.
12 High speed effectiveness	5.2.9.
13 Failed ABS	5.2.10.
14 Failed proportioning valve	5.2.11.
15 Hydraulic circuit failure	5.2.12.
Vehicle laden (to GVWR):	
16 Hydraulic circuit failure	5.2.12.
17 Failed ABS	5.2.10.
18 Failed proportioning valve	5.2.11.
19 Power brake unit failure	5.2.13.
20 Parking brake	5.2.14.
21 Type 1 test - Heating Snubs	5.2.15.1.
22 Hot Performance	5.2.15.2.
23 Brake cooling	5.2.15.3.
24 Recovery Performance	5.2.15.4.
25 Recovery performance for vehicles with RBS_B	5.2.15.4.4.
26 Hot performance comparison for vehicles with RBS_B	5.2.15.5.

5.2.1. **Preparation of Brake Linings.**

If tests are to be made on a new production vehicle, the **burnish** sequence below shall be undertaken before brake performance tests are commenced.

If testing a manufacturer submitted vehicle which, by bedding and conditioning the linings in a similar manner to the procedure explained below, has been made ready for brake performance testing, the following procedure may be omitted.

General information.

The **burnish procedure** is a series of stops which also provides the opportunity for vehicle familiarization and final adjustment and checking of the instrumentation.

There is no end requirement to this initialization procedure other than brake readiness.

5.2.1.1. **Vehicle conditions.**

a) Vehicle laden.
b) In the normal gear for the test speed.
c) Conducted on a normal dry asphalt road surface or equivalent.

5.2.1.2. **Test conditions and procedure.**

a) IBT: No greater than 100°C at the commencement of each stop.
b) Test speed 80 km/h.
c) Braking rate: Maintain a constant 3.0 m/s^2 during each stop.
d) Pedal force: Adjust as necessary to maintain the 3 m/s^2 braking rate.
e) Make 200 stops as above allowing a time interval between the commencement of each such as to allow brake temperatures to cool to 100°C or the distance interval of 2 km, whichever occurs first.
f) Accelerate, after each stop back to 80 km/h and maintain that speed until making the next stop.
g) After completing the burnish procedure, allow the brakes to cool and then adjust all the brakes in accordance with the manufacturers specification.

5.2.2. **Distribution of braking among the axles of vehicles**

General.

Vehicles which are not equipped with an ABS function as defined in paragraph **3.22.1.** of this Regulation shall meet all the requirements of this section. If a special device is used, this must operate automatically.

5.2.2.1. **Requirements.**

For all states of load of the vehicle, the adhesion utilization curve (see definition 3.16.) of the front axle shall be situated above that for the rear axle - for all braking rates between **0.15 and 0.8** :

5.2.2.2. The manufacturer, who has obtained the adhesion utilization curves for the front and rear axles may refer to these where they have been calculated by the formulae which use the following symbols.

Demonstration, from these curves, of satisfactory distribution of braking in accordance with paragraph **5.2.2.1,** may be accepted as an alternative to completing the 'wheel locking order' and 'torque wheel tests'.

Distribution Symbols.

i	=	axle index (i = 1 , front axle ; i = 2 , rear axle)
P_i	=	normal reaction of road surface on axle i under static conditions
N_i	=	normal reaction of road surface on axle i under braking
T_i	=	force exerted by the brakes on axle i under normal braking conditions on the road
f_i	=	T_i / N_i , adhesion utilized by axle$_i$
J	=	deceleration of the vehicle
g	=	acceleration due to gravity : g = 10 m/s^2
z	=	braking rate of vehicle = J/g
P	=	mass of vehicle
h	=	height of centre of gravity specified by the manufacturer and agreed by the Technical Services conducting the approval test
E	=	wheelbase
k	=	theoretical coefficient of adhesion between tyre and road

Adhesion utilised: (front):

$$f_1 = \frac{T_1}{N_1} = \frac{T_1}{P_1 + z.\frac{h}{E}.P.g}$$

(rear):

$$f_2 = \frac{T_2}{N_2} = \frac{T_2}{P_2 - z.\frac{h}{E}.P.g}$$

The curves shall be plotted for both the following load conditions:

5.2.2.2.1. unladen, in running order with the driver on board ie. lightly laden;

5.2.2.2.2. laden; Should there be provision for several possibilities of load distribution, the one whereby the front axle is the most heavily laden shall be the one considered ;

5.2.2.2.3. For vehicles fitted with an electric regenerative braking system of **category B**, where the electric regenerative braking capacity is influenced by the electric state of charge, the curves shall be plotted by taking account of the regenerative braking component under the minimum and maximum conditions of delivered braking force. This requirement is not applicable if the vehicle is equipped with ABS which controls the wheels subjected to the regenerative braking, since the ABS requirements of this Regulation shall apply.

5.2.3. Requirements to be met in case of failure of the braking distribution system.

When these braking distribution requirements are fulfilled by means of a special device (e.g. controlled mechanically by the suspension of the vehicle), it shall be possible, in the event of a simulated failure of its control, (e.g. by disconnecting the control linkage), to stop the vehicle under the conditions of the Type-0 test with the engine disconnected as in Section **5.2.11**. to give a stopping distance not exceeding 0.1v + 0.0100 v^2 (m) and a mean fully developed deceleration not less than **3.86 m/s^2**.

5.2.4. Vehicle Testing.

Braking distribution, where submitted adhesion utilisation curves cannot be accepted, shall be verified for conformity with the requirements of paragraphs **5.2.2.1.** by carrying out the following tests:

5.2.4.1. <u>Wheel Lock-up Sequence.</u>

General information.

(a) This test is for vehicles without ABS and is to ensure that lock-up of both front wheels occurs either simultaneously with or at a lower braking rate than lock-up of both rear wheels.

(b) Axle lock-up is defined as the point in time when the second wheel on that axle locks up. A simultaneous lock-up of the front and rear wheels refers to the condition when the time interval between the lock-up of the second wheel on the rear axle and the second wheel on the front axle is **< 0.1 seconds** for vehicle speeds **> 30 km/h.**

(c) Tests are made on 2 surfaces having adhesion levels such that, on the lower adhesion surface, wheel locking on the first axle occurs at braking rates between 0.15 and 0.45 and then, on the higher adhesion surface between 0.55 and 0.8.
The wheel lock-up sequence tests are to be used as a screening procedure to determine whether the Torque Wheel tests need to be conducted.

5.2.4.1.1. Vehicle conditions.

(a) Vehicle unladen (lightly laden with driver and instrumentation) and then laden .
(b) Engine disconnected (in neutral).

5.2.4.1.2. Test conditions and procedures.

(a) Initial brake temperature: Between **65° C and 100° C** average on the hottest axle.

(b) Test speed: **65 km/h** for a braking rate **≤ 0.50** ;
100 km/h for a braking rate **> 0.50** .

(c) **Pedal force**:

(1) Pedal force is applied and controlled by a skilled driver or by a mechanical brake pedal actuator.

(2) Pedal force is increased at a linear rate such that the first axle lock-up occurs no less than **0.5 seconds** and no more than **1.5 seconds** after the initial application of the pedal.

(3) The pedal is released when the second axle locks, or when the pedal force reaches **1 kN**, or **0.1 seconds** after the first lock-up, whichever occurs first.

(d) Wheel lock-up: Only wheel lock-ups **above** a vehicle speed of **15 km/h** are considered.

(e) Test surface: This test is conducted on road test surfaces on which wheel lockup occurs at braking rates between **0.15 and 0.3 and between 0.5 and 0.8**.

(f) Data recorded: The following information from the test must be automatically recorded in-phase and continuously throughout each test run such that values of the variables can be cross referenced in real time:
(1) Vehicle speed.
(2) Instantaneous vehicle braking rate (e.g. by differentiation of vehicle speed).
(3) Brake pedal force (or hydraulic line pressure).
(4) Angular velocity at each wheel.

(g) Each test run shall be repeated once to confirm the wheel lock-up sequence: if one of these two results indicates a failure to comply, then a third test, run under the same conditions, will be decisive.

5.2.4.1.3. Performance Requirements.

(a) **Both** rear wheels shall **not** reach a locked condition prior to **both** front wheels being locked --- at vehicle braking rates between **0.15** and **0.8** .

(b) If, when tested to the procedure specified above, and at vehicle braking rates between **0.15** and **0.8** the vehicle meets one of the following criteria, then it passes this wheel lockup sequence requirement:

(1) **No** wheels lock.

(2) **Both** wheels on the front axle and **one or no** wheels on the rear axle lock.

(3) **Both** axles **simultaneously** lock.

(c) If wheel lockup commences at a braking rate less than **0.15** and more than **0.8** then the test is invalid and should be repeated on a different road surface.

(d) If, either laden or unladen, at a braking rate between **0.15** and **0.8** both wheels on the rear axle and one or no wheels on the front axle lock, then the wheel lock-up sequence test **has failed**.

In this latter case, the vehicle must be submitted to the 'torque wheel test procedure' to determine the objective brake factors for calculation of the adhesion utilization curves.

5.2.5. Torque Wheel Test.

General Information.

The purpose of this test is to measure the brake factors and thus determine the adhesion utilization of the front and rear axles over a range of braking rates between **0.15** and **0.8** .

5.2.5.1. Vehicle conditions.

(a) Vehicle load: Unladen and then laden
(b) Transmission position: Engine disconnected **(**in neutral**)**

5.2.5. 2. Test conditions and procedures.

(a) Initial brake temperature: Between **65° C and 100° C** average on the hottest axle.
(b) Test speeds: **100 km/h** and **50 km/h**
(c) **Pedal force**: Pedal force is increased at a linear rate of between **100** and **150 N/sec** for the **100 km/h** test speed, or between **100** and **200 N/sec** for the **50 km/h** test speed, until the first axle locks or until a pedal force of **1000 N** is reached, whichever occurs first.
(d) **Brake cooling**: Between brake applications, the vehicle is driven at speeds up to **100 km/h** until the initial brake temperature specified in paragraph **3.(a)** above is reached.
(e) **Number of runs**: With the vehicle **unladen**, run **5 stops** from a speed of **100 km/h** and **5 stops** from a speed of **50 km/h**, while alternating between the two test speeds after each stop.

With the vehicle **laden**, repeat the **5 stops** at each test speed while alternating between the two test speeds.

(f) **Test surface**: This test is conducted on a dry road surface with PFC of 0.9.

(g) **Data to be recorded**: The following information must be automatically recorded in phase continuously throughout each test run such that values of the variables can be cross referenced in real time:

(1) Vehicle speed.

(2) Brake pedal force.
(3) Angular velocity of each wheel.
(4) Brake torque at each wheel.
(5) Hydraulic line pressure in each brake circuit, including transducers on at least one front wheel and one rear wheel downstream of any operative proportioning / pressure limiting valve(s).
(6) Vehicle deceleration.

(h) **Sample rate**: All data acquisition and recording equipment shall support a minimum sample rate of **40 H**z on all channels.

(i) **Determination of front versus rear brake pressure**: Determine the front vs. rear brake pressure relationship over the entire range of line pressures. Unless the vehicle has a variable brake proportioning system, this determination is made by static tests. If the vehicle has a variable brake proportioning system, dynamic tests are run with the vehicle both laden and unladen**. 15 snubs** from **50 km/h** are made for each of the two load conditions, using the same initial conditions specified in this Appendix.

5.2.5.3. Data reduction.

(a) The data from each brake application prescribed in paragraph **3.(e)** above is filtered using a five-point, on-centre moving average for each data channel.

(b) For each brake application prescribed in paragraph **3.(e)** above, determine the slope (brake factor) and pressure axis intercept (brake hold-off pressure) of the **linear** least squares equation best describing the measured torque output at each braked wheel as a function of measured line pressure applied at the same wheel.

Only torque output values obtained from data collected when the vehicle deceleration is within the range of **1.5** to **8.0 m/s²** are used in the regression analysis.

(c) Average the results of paragraph **(b)** above to calculate the average brake factor and brake hold-off pressure for all brake applications for the **front** axle.

(d) Average the results of paragraph **(b)** above to calculate the average brake factor and brake hold-off pressure for all brake applications for the **rear** axle.

(e) Using the relationship between front and rear brake line pressure determined in paragraph **3.(i)** above and the dynamic tyre rolling radius, calculate the braking force at each axle as a function of front brake line pressure.

(f) Calculate the braking rate of the vehicle as a function of the front brake line pressure using the following equation:

$$z = (T_1 + T_2)/P.g$$

where z = braking rate at a given front brake line pressure
T_1, T_2 = braking forces at the front and rear axles respectively, corresponding to the same front brake line pressure
P = vehicle mass.

(g) Calculate the adhesion utilized at each axle as a function of braking rate using the following formulae:

(front):

$$f_1 = \frac{T_1}{P_1 + z \cdot \frac{h}{E} \cdot P \cdot g}$$

(rear):

$$f_2 = \frac{T_2}{P_2 - z \cdot \frac{h}{E} \cdot P \cdot g}$$

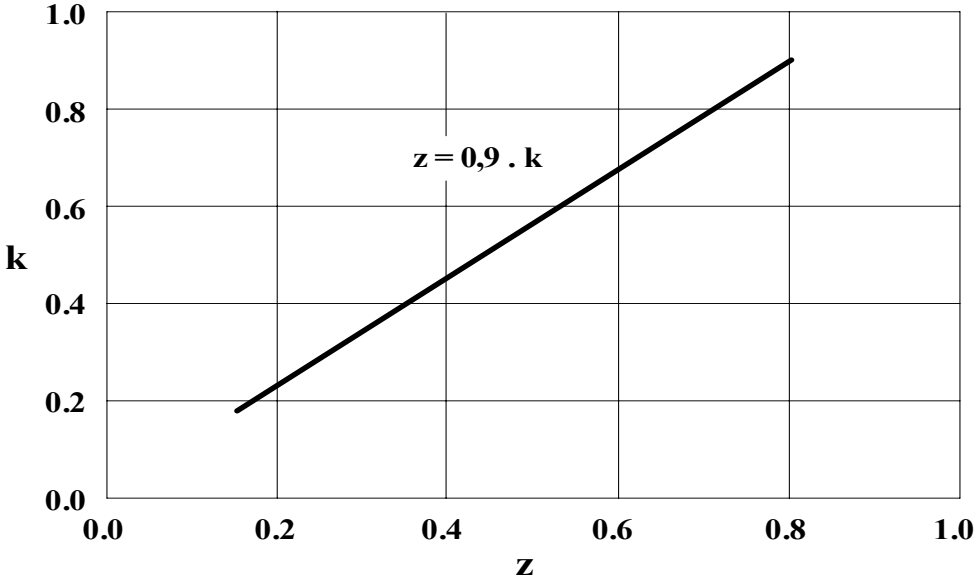
The symbols are defined in paragraph **2.3.2.** above**.**

(h) Plot f_1 and f_2 as a function of z , for both laden and unladen load conditions.

5.2.5.4. Requirements.

5.2.5.4.1. For all states of load of the vehicle and for all braking rates between **0.15 and 0.8**, the adhesion utilization curve of the front axle shall be situated above that for the rear axle and the rear axle curve must lie below the line **z = 0.9 k**

DIAGRAM



5.2.6. Performance requirements for vehicles equipped for Anti-lock Braking (ABS).

5.2.6.1. Performance and wheel behaviour test on homogeneous surfaces:

The stopping distance under ABS operation is measured on the high and low adhesion surfaces with sufficient force being applied to the brake control so as to provoke skidding. No wheel shall lock when the full pedal force is suddenly applied but brief periods [<0.5s on the low μ surface] of wheel-locking shall be allowed. Furthermore, wheel-locking is permitted at low vehicle speeds but stability and steerability must be maintained.

5.2.6.1.1. Vehicle conditions

(a) Vehicle unladen (at LLVW) and then laden
(b) Transmission in Neutral

5.2.6.1.2. Test conditions and procedures

(a) IBT between 65°C and 100°C at the hottest brake.
(b) Test speed v: 100 km/h on the high adhesion surface and 55 km/h on the low adhesion.
(c) Pedal force between 450 and 500 N applied quickly.
(d) Test surface High adhesion – PFC 0.9 and then low adhesion – PFC <0.3
(e) With the vehicle unladen, 1 stop is made on each surface from the test speed and then repeated later on the high adhesion surface only, with the vehicle laden.
(f) On both surfaces, the stopping distance / MFDD is measured as the vehicle is brought to a standstill with small steering corrections being made if necessary

5.2.6.1.3. Performance required.

No wheels of the vehicle must lock other than as a short initial transient (<0.1s on the high adhesion surface) but wheel locking at vehicle speeds below **15 km/h** is permitted although steering must be maintained and the vehicle must not exceed a yaw angle of **15°** or deviate from a **3.5 m** wide lane**.**

(a) The achieved service braking performance on the **high adhesion surface** must not be less than the prescribed performance according to the Type-0 Cold effectiveness test with the engine disconnected. This means achieving a stopping distance of: $\leq 0.01v + 0.0060v^2$ m (70m from 100 km/h) and a mean fully developed deceleration of $\geq$ **6.43 m/s^2.**

(b) The performance on the **low adhesion** surface is optional for compliance with the provisions of this GTR and will be applied at a National or Regional level by the appropriate administrative authority.
Where applied, the braking performance shall generate an efficiency of adhesion utilisation >0.75.
The means for measuring this factor are laid out in **Appendix 1** to this Regulation and require the surface adhesion (PFC) to be measured by means of a k-test which should be completed after the [unladen] performance stop has been made.

5.2.6.2. Transition from high to low adhesion surfaces:

When an axle passes from a **high-adhesion** surface (k_H) **to a low-adhesion** surface (k_L) with the full force applied to the brake control, no wheel shall lock.

5.2.6.2.1. Vehicle conditions

(c) Vehicle unladen (at LLVW) and then laden.
(d) Transmission in Neutral

5.2.6.2.2. Test conditions and procedures

(e) IBT between 65°C and 100°C at the hottest brake.

(f) Test surface High adhesion (PFC >0.7 due to surface wetting) with a transition to low adhesion (PFC <0.3)

(g) The running speed and the instant of applying the brakes shall be so calculated that, with the ABS fully cycling on the high adhesion surface, the passage from one surface to the other is made at approximately 40 km/h. - Then, repeat the test from approximately 0.8 v_{max} but < 120 km/h with the transition occurring at a proportionally higher speed.

(h) Pedal force between 450 and 500 N applied quickly.

(e) make 1 stop from each speed and then repeat later with the vehicle laden.

5.2.6.2.3. Performance required.

No wheels of the vehicle must lock other than as a short initial transient (<0.5s), but wheel locking is permitted at vehicle speeds below **15 km/h**. The vehicle must remain stable during the tests, steerability must be maintained and the vehicle must not exceed a yaw angle of **15°** or deviate from a **3.5 m** wide lane.

5.2.6.3. Transition from low to high adhesion surfaces:

When a vehicle passes from a **low-adhesion** surface (k_L) **to a high-adhesion** surface (k_H) with the full force applied to the brake control, the deceleration of the vehicle must rise to the appropriate high value within a reasonable time and the vehicle must not deviate from its initial course.

5.2.6.3.1. Vehicle conditions

(a) Vehicle unladen (at LLVW) and then laden.

(b) Transmission in Neutral.

5.2.6.3.2. Test conditions and procedures

(c) IBT between 65°C and 100°C at the hottest brake.

(d) Test surface Low adhesion – [PFC <0.3] with a sudden transition to high adhesion – [PFC >0.6 since surface wetting will occur]

(e) Pedal force between 450 and 500 N applied quickly.

(f) The running speed and the instant of applying the brakes shall be so calculated that, with the ABS fully cycling on the low adhesion surface, the passage from one surface to the other is made at approximately **50 km/h**.

(g) 1 stop made from the test speed and then repeated later with the vehicle laden.

5.2.6.3.3. Performance required.

The deceleration of the vehicle shall rise from the initial low adhesion value to the appropriate high value within [1 second].

5.2.6.4. ABS Performance on split adhesion surfaces:

When the right and left wheels of the vehicle are being braked on surfaces with differing coefficients of adhesion (k_H and k_L)*/, no wheel shall lock when the full force is suddenly applied to the brake control.

5.2.6.4.1. Vehicle conditions

(a) Vehicle unladen (at LLVW) and then laden.

(b) Transmission in Neutral

5.2.6.4.2. Test conditions and procedures

(c) IBT between 65°C and 100°C at the hottest brake.

(d) Test surface Low adhesion **k_L** (PFC <0.3) on one side of the axles and high adhesion **k_H** (PFC >0.6 due to surface wetting) on the other side so that **$k_H \geq 0.5$ and $k_H / k_L \geq 2$**,

(e) Pedal force between 450 and 500 N applied quickly.

(f) Test speed : 50 km/h.

(g) Steering correction is permitted, provided that the angular rotation of the steering control is within 120° during the **initial 2 seconds,** and not more than **240° in all.**

(h) 1 stop made in each direction and then repeated later with the vehicle laden.

5.2.6.4.3. Performance required.

Other than for a brief initial transient period, no wheel locking shall occur when the brakes are applied. Wheel-locking is however, permitted when the vehicle speed is less than **15 km/h** but stability and steerability must be maintained and the vehicle must neither exceed a yaw angle of **15°** nor deviate from a **3.5 m** wide lane. Furthermore, at the beginning of these tests the longitudinal median plane of the vehicle must pass over the boundary between the high- and low-adhesion surfaces and, during these tests, no part of the tyres must cross this boundary

NOTE : */ k_H and k_L are respectively, the high-adhesion and low-adhesion coefficients of surface adhesion, and **Appendix 1** gives an example of how to measure the coefficient of adhesion.

5.2.7. Type 0 tests to determine cold braking effectiveness.

5.2.7.1. General information.

The vehicle must be laden with axle load distribution as stated by the manufacturer. Every test must be repeated on the vehicle lightly laden by carrying driver, possible observer and instrumentation.

5.2.7.2.Requirements of the test.

5.2.7.2.1. In the case of a vehicle equipped with an electric regenerative braking system, the requirements depend on the Category of this system:

Category A.

Any separate electric regenerative braking control which is provided, shall not be used during the Type-0 tests.

Category B.

The contribution of the electric regenerative braking system to the braking force generated shall not exceed that minimum level which is guaranteed by the system design.

This condition is deemed to be satisfied if the state of charge of the batteries is in one of the following conditions:

(a) at the **maximum** charge **level** recommended by the manufacturer, as listed in the vehicle specification,

(b) at a level not less than **95%** of the full charge level, where the manufacturer has made no specific recommendation,

c) at a maximum level resulting from **automatic charge control** on the vehicle.

5.2.7.2.2. The limits prescribed for minimum performance, both for tests with the vehicle lightly laden and for tests with the vehicle laden, shall be those laid down in this section and the vehicle must satisfy both the prescribed stopping distance **and** the prescribed mean fully developed deceleration. See the note to paragraph 5.1.1.

5.2.7.2.3. The road must be dry and level and, unless otherwise specified, each test may comprise **up to 6 stops** including any needed for familiarization.

5.2.7.2.4. The test shall be carried out at the speed prescribed and, using the highest gear which is appropriate, the vehicle should be accelerated to 5 km/h above the test speed and braking applied as the vehicle speed falls to the test speed.
At least, the minimum prescribed performance for the test must be attained.

5.2.7.3. Service braking Cold Performance test with the engine disconnected (ie in neutral).

5.2.7.3.1. Vehicle conditions.

(a) Vehicle laden and then unladen (at LLVW)
(b) Transmission in Neutral

5.2.7.3.2. Test conditions and procedures

(a) IBT between 65°C and 100°C at the hottest brake.
(b) Test speed v: 100 km/h
(c) Pedal force between 65 and 500 N for non ABS equipped vehicles but not so high as to cause locking of the wheels for periods longer than 0.1 second at speeds >15 km/h
(d) For ABS equipped vehicles, the pedal force should be 500 N and ABS cycling is allowed.
(e) Test surface High Adhesion [PFC: 0.9] in accordance with paragraph **5.1.3.4.**

(f) For non-ABS equipped vehicles, up to 6 stops (only one to count) including those for familiarization are allowed for. IBT applies on each stop.
At the selected test stop bring the vehicle from the test speed to a stop in the shortest possible distance under the conditions specified
(g) For ABS equipped vehicles, only one stop at the 500 N brake force input is allowed..

For vehicles with electrically actuated service brakes as described in paragraph **5.1.3.11,** this test is performed by the same procedure but making 10 stops as above, starting with the state of charge of the batteries at not more than **5%** above that level at which the brake failure warning has to be given.

5.2.7.3.3. Performance required.

Stopping distance $\leq 0.01v+0.0060v^2$ (70m from 100km/h) and a MFDD of $\geq$ **6.43 m/s²** shall be achieved. For **vehicles with electrically actuated service brakes** as described in paragraph **5.1.3.11,** this shall be achieved on the last of the 10 stops.

The results obtained are to be used for comparison in the subsequent Hot Performance test of section **5.2.15.2.**

5.2.7.4. In the case of a motor vehicle authorized to tow an **unbraked trailer**, the minimum Type-0 performance of the combination shall be not less than 5.4 m/s² in the laden condition. Where the certification process can accommodate the procedure, the combination performance shall be verified by calculations, which should be made in all cases by the manufacturer, referring to the maximum braking performance actually achieved by the motor vehicle alone (laden) during the Cold Performance test using the following formula. No practical tests with a coupled unbraked trailer are required:

$$d_{M+R} = d_M \cdot \frac{P_M}{P_M + P_R}$$

where:

d_{M+R} = calculated mean fully developed deceleration of the motor vehicle when coupled to an unbraked trailer, in m/s^2

d_M = maximum mean fully developed deceleration in m/s^2 of the motor vehicle alone achieved during the Cold Performance Reference test with engine disconnected,

P_M = mass of the motor vehicle (laden)

P_R = maximum mass of an unbraked trailer which may be coupled, as declared by the motor vehicle manufacturer up to a limit of 750 kg..

5.2.8. Service braking **Type-0 High speed effectiveness test** with engine **connected.**

This test shall be carried out in gear from the speed prescribed and the minimum performance prescribed shall be attained.
This test is not run if the **maximum** speed of the vehicle does not exceed **125 km/h.**

5,2.8.1. The **maximum practical performance** figures shall be measured, and the behaviour of the vehicle shall be in accordance with the braking distribution requirements of paragraphs **5.2.2.1**. However, if the maximum speed of the vehicle is greater than **200 km/h**, the test speed shall be **160 km/h**.

5.2.8.2. Vehicle conditions.

(a) Vehicle laden and then unladen (at LLVW)
(b) Transmission in the normal gear for the start speed.

5.2.8.3. Test conditions and procedure

(a) IBT between 65°C and 100°C at the hottest brake.
(b) Test speed v: 80% of vehicle maximum speed but not exceeding 160 km/h.
(c) Pedal force between 65 and 500 N but less than that force which gives wheel lock.
(d) Test surface High Adhesion – [PFC of 0.9] in accordance with paragraph **5.1.3.4.**
(e) No wheel locking allowed for longer than 0.1 seconds at speeds >15 km/h.
(f) 6 stops including those for familiarization. IBT applies on each stop.
(g) At each stop, bring the vehicle from the test speed to a stop in the shortest distance under the conditions specified.

5.2.8.4. Performance required.

Stopping distance $\leq 0.01v+0.0067v^2$ and a MFDD of $\geq$ **5.76 m/s²** must be achieved.

5.2.8.5. Response time measurement.

5.2.8.5.1. Examination of the instrumentation records produced during the procedure **5.2.8.3.** paragraph (f) allows a measurement of the Braking Response time.
Comparing the time taken between the initial pedal force/movement against the deceleration build up to the highest required level of **6.43m/s²**, gives the Response Time.

5.2.8.5.2.. Performance required.
The response time shall not exceed **0.6** seconds.

5.2.9. Engine off - Service braking performance with sudden energy source failure.

General information.
This test is for laden vehicles equipped with Power Assisted or Full Power braking systems as specified in Paragraphs **4.3.1.6.** or **4.3.1.7.** of this Regulation.
This failure test examines the capability, should the energy source fail, of the stored energy in the system to maintain full service braking for a **single** stop.

5.2.9.1. This test may alternatively be made statically if, prior to the laden Type 0 test, a plot is made of the laden deceleration achieved against brake line pressure. It is then only necessary to stop the engine or otherwise disable the energy source after ensuring that the pressure in the reservoir(s) is at the level specified by the manufacturer but not exceeding the cut-in pressure p_0, and then apply the service brake with 500 N pedal force checking that the brake line pressure is sufficient to produce a deceleration of **6.43 m/s²**.

5.2.9.2. Vehicle conditions.

(a) Vehicle laden (only)
(b) Transmission in neutral.
(c) Vehicle engine shall be turned off or the energy source isolated from the power circuit once the accumulator(s) have, by repeated short brake pedal applications, been brought to p_0 and the test speed has been reached.

5.2.9.3. Test conditions and procedure.

(a) IBT between 65°C and 100°C at the hottest brake.
(b) Test speed: 100 km/h or from the vehicle maximum speed if this is less than 100 km/h.
(c) Pedal force 500 N applied quickly for ABS equipped vehicles or to a level just not sufficient to produce skidding on non-ABS equipped vehicles.
(d) Test surface: High adhesion – [PFC of 0.9] in accordance with paragraph **5.1.3.4.**
(e) No wheel locking allowed for longer than 0.1 seconds at speeds >15 km/h.
(f) Number of runs: 1 stop, after pedal effort to achieve condition (c) has been determined.
(g) any auxiliary hydraulic equipment must not be isolated.
(h) Select neutral, stop the engine or otherwise disable the energy source after ensuring that the pressure in the accumulator(s) is at the level specified by the manufacturer but not exceeding the cut-in pressure p_0**.**
(i) if the vehicle is equipped with RBS of Category B this shall not be disabled.
(j) make the stop from the Test speed.

5.2.9.4. Performance requirements.

(a) Full service braking performance: MFDD ≥ **6.43 m/s²**, S ≤ 70m from 100 km/h
(b) From reduced speed v: MFDD ≥ **6.43 m/s²**, $S \leq 0.1v + 0.006v^2$.
where: S = Stopping distance**.**

5.2.10. <u>Service braking performance with failure of the ABS function.</u>

Failure of the ABS function will cause full or partial shutdown of this function accompanied by a driver warning which shall be checked: Yellow if only ABS is affected but Red if the braking distribution function is also disrupted.
Irrespective of the level of shutdown, the test of braking performance is as follows:

5.2.10.1. Vehicle conditions.

(a) Vehicle unladen (at LLVW) and then laden.
(b) Transmission in Neutral

5.2.10.2. Test conditions and procedures

(a) IBT between 65°C and 100°C at the hottest brake.
(b) Test speed v: 100 km/h
(c) Test surface High Adhesion – [PFC of 0.9] in accordance with paragraph **5.1.3.4.**
(d) Pedal force between 65 and 500 N applied quickly to a level which will achieve the required deceleration without causing any wheel locking at speeds above 15 km/h
(e) Make 6 stops including those for familiarization. IBT applies on each stop.
(f) At each stop, the vehicle shall be brought from the test speed to a stop in the shortest distance under the conditions specified in (d).
(g) Functional failure simulation.
Refer to the recommendation of the manufacturer as to how to electrically create an ABS functional failure and after following this operation, check that the driver warning

signal is given.
(h) Make the test runs and then restore the system back to normal.

5.2.10.3. Performance requirement.
The service braking system shall, in the failed condition, warn the driver as in paragraph **5.2.10.** above and continue to operate with some possible reduction in performance but shall stop the vehicle as follows:

(a) Service braking performance: MFDD ≥ **5.144 m/s²**, S ≤ 85m from 100 km/h
(b) From reduced speed v: MFDD ≥ **5.144 m/s²**, $S \leq 0.1v + 0.0075v^2$.

5.2.11. Service braking performance with a functional failure of the brake proportioning.

The braking proportioning means will be either a mechanical device or an electronic function possibly associated with the ABS.

5.2.11.1. Vehicle conditions.
(a) Vehicle unladen (at LLVW).
(b) Transmission in neutral.

5.2.11. 2. Test conditions and procedure.
(a) IBT between 65°C and 100°C at the hottest brake.
(b) Test speed v: 100 km/h
(c) Test surface High Adhesion – [PFC of 0.9] in accordance with paragraph **5.1.3.4.**
(d) Pedal force between 65 and 500 N applied quickly to a level which will achieve the required deceleration without causing any wheel locking at speeds exceeding 15 km/h
(e) Make 6 stops including those for familiarization. IBT applies on each stop.
(f) At each stop, bring the vehicle from the test speed to a stop in the shortest distance under the conditions specified in (d).
(g) Functional failure simulation:
(1) Render the variable brake proportioning means inoperative.
Eg. Disconnect the control linkage to a mechanical device or,

(2) If the proportioning means is an electronic function, follow the recommendation of manufacturer as to how this should be disabled.
Unless the mechanical device always fails into a known condition as declared by the manufacturer, with the vehicle unladen, the mechanical device control input shall be set into the laden position and with the vehicle laden it should be set into the unladen position.
With an **electronic function**, the single failed-to-laden state applies under both load cases.

(h) If more than one brake proportioning sub-system is provided, repeat the test for each sub-system failure in turn.
(i) Make the test runs and restore the system back to normal.

5.2.11.3. Performance requirements.
In this test, with a single failure, the service braking performance shall be as follows and at the levels of deceleration required, the vehicle stability must be maintained:
(a) service braking performance: MFDD ≥ **3.858 m/s²**, S ≤ 110m from 100 km/h
(b) From reduced speed v: MFDD ≥ **3.858 m/s²**, $S \leq 0.1v + 0.0100v^2$.

5.2.12. Secondary braking performance.

Secondary braking can result from a loss of part of the braking system whether purely hydro-mechanical or electro-hydraulic.

Alternatively, the condition may result from a loss of braking power assistance as tested in section **5.2.13.** below.

5.2.12.1. Braking circuit failure.

This cold effectiveness test assumes vehicles are manufactured with split service braking systems and applies also to those with Electric Control transmissions.

It examines the performance of the braking circuit remaining after the failure.

5.2.12.1.1 Vehicle conditions.

(a) Vehicle unladen (at LLVW) and then laden.
(b) Transmission in Neutral

5.2.12.1.2. Test conditions and procedures

(a) IBT between 65°C and 100°C at the hottest brake.
(b) Test speed v: 100 km/h
(c) Pedal force between 65 and 500 N applied quickly
(d) Test surface - High Adhesion [PFC of 0.9] in accordance with paragraph **5.1.3.4.**
(e) No wheel locking allowed for longer than 0.1 second at speeds >15 km/h.

(f) Modify the service brake system to produce a single failure.
For a **hydraulic** circuit, this may be any **single rupture or leakage** type failure, other than a structural failure of a housing that is common to two or more subsystems.
For a vehicle with **electrical transmission** of the brake signal between the service brake control and some or all of the friction brakes, regardless of the means by which they are actuated, this may be any **single failure in any circuit** that electrically transmits the braking command signal.
(g) Determine the maximum pedal effort which can be applied without causing skidding of the wheels still being braked
(h) If the driver brake warning is generated by low fluid level detection, remove fluid to the point at which this warning is given.
(i) Make 4stops by a continuous application of the service brake control at the pedal effort determined in (g), checking that the warning is present, and measure the stopping distance/MFDD on the last stop.
(j) Restore the service brake system to normal at the completion of this test.
(k) Repeat the entire sequence for the other subsystem.

5.2.12.1.3. In the event of any failure in a single subsystem, as specified in paragraph **5.2.12.1.2.(f)** above, and after activation of the braking system failure warning **indicator** as specified in paragraph **5.2.12.1.2.(g)**, the remaining portions of the service brake system shall continue to operate with **Secondary** Braking performance.

5.2.12.1.4. Secondary Braking performance

(a) Stopping distance **S,** from **100 km/h** test speed: **≤168 m**.
(b) For reduced test speed v: $S \leq 0.10v + 0.0158v^2$ and **MFDD ≥ 2.44 m/s²**.

5.2.13. Brake (full) power unit or brake power assist unit inoperative (Energy depleted).

General information.

This test is for vehicles equipped with one or more brake power units or a brake power assist unit, where Service Braking performance cannot be achieved without this energy input.
Two tests are required, selected as appropriate from those listed below.

5.2.13.1. Vehicle conditions.

(a) Vehicle laden only.
(b) Transmission position: In neutral.

5.2.13.2. General Test conditions

(a) IBT: between 65°C and 100°C at the hottest axle.
(b) Test speed: 100 km/h .
(c) Pedal Force: between 65 and 500 N applied quickly to a level needed to exceed slightly, the required deceleration.
(d) Test surface: High adhesion – [PFC of 0.9.] in accordance with paragraph **5.1.3.4.**
(e) Wheel lockup: No lockup of any wheel for longer than **0.1** seconds allowed at speeds greater than 15 km/h.

5.2.13.2.1. Test 1 Procedure.

(a) Disconnect or disable the energy source(s) for the brake power assist unit and deplete the energy reserve(s).
For brake full power unit(s) disable the energy source and commence the test at the cut-in pressure p_0.
(b) Under these conditions make 4 static full brake applications.
(c) Then make a single full brake application from the test speed.

5.2.13.2.1.1. Performance requirement.

On the final braking application of the test the secondary performance must be achieved:
(a) Stopping distance **S,** from **100 km/h** test speed: **≤168 m**.
(b) For reduced test speed v: $S \leq 0.10v + 0.0158v^2$ and **MFDD ≥ 2.44 m/s²**

5.2.13.2.2. Test 2A Procedure for brake full power systems.

For vehicles which meet the requirements of paragraph **4.3.3.1.**

(a) Apply a transmission failure to one of the brake power unit subsystems given that two or more subsystems are required to be provided, which discharges the energy reserve of that subsystem and holds its pressure at zero.
(b) If the brake power unit operates in conjunction with a backup system, which is automatically activated in the event of a primary power service failure, the backup system is allowed to be operative during this test.
(d) Make **5** full force stops, each by a continuous application of the service brake control These may, except for the last application, be made statically but the 5th stop must be made from the test speed.
(e) For vehicles equipped with more than one brake power unit or brake power assist unit, conduct tests for each such unit in turn.
(f) For vehicles with **electrically-actuated** service brakes (brake power unit), this test is conducted with any **single electrical failure** in the electrically-actuated service brakes but with all other systems intact.
(g) Restore the system to normal at completion of this test.

5.2.13.2.2.1. Performance requirements.

The service brakes on a vehicle equipped with one or more brake power assist units or brake power units, with one such unit inoperative and depleted of all reserve, shall stop the vehicle with Secondary Braking performance.
(a) Stopping distance from 100 km/h test speed**:** ≤168 m
(b) From reduced test speed v: $S \leq 0.10v + 0.0158v^2$ and MFDD = **2.44 m/s²**.

5.2.13.2.3. Test 2B Procedure. (Alternative to Test 2A)

This test is for vehicles which only meet the requirement of paragraph **4.3.3.3.**

(a) Apply a transmission failure to one of the brake power unit or brake power assist unit subsystems which discharges the energy reserve of that sub-system, holds its pressure at zero and prevents further charging of the reserve of the other sub-system.
(b) Using the reserve of this remaining sub-system, make **9** full force stops, each by a continuous application of the service brake control. These may, except for the last

application, be made statically but the 9th stop must be made from the test speed.

5.2.13.2.3.1. Performance requirements.

The 9th application shall stop the vehicle with at least the Secondary Braking performance.

(a) Stopping distance from 100 km/h test speed**:** ≤168 m

(b) From reduced test speed v: S ≤0.10v + 0.0158v^2 and MFDD = **2.44 m/s^2**.

(c) The driver warning given shall be optical and acoustic.

5.2.13.2.4. Test 3 procedure for vehicles with electrically actuated service brakes as specified in paragraph **5.1.3.11.**

(a) This test, made with the laden vehicle, and it is practical to perform this following the Type 0 test of paragraph 5.2.7.3 for this type of vehicle and shall follow on from the 10 stops made starting with the state of charge of the batteries at a level 5% above that at which the low voltage warning is given.

(b) Further discharge the batteries until the low voltage warning is produced.

(c) Make a further 8 static full brake applications and then make 1 test run from 100 km/h or from the maximum speed which the vehicle can achieve if this is lower, and measure the braking performance.

5.2.13.2.4.1. Performance requirement.

The 9th application shall stop the vehicle with at least the Secondary Braking performance specified in paragraph **5.2.13.2.3.1.** above**.**

5.2.14. Parking brake.

5.2.14.1. Vehicle conditions.

(a) Vehicle load: laden only.

(b) Transmission position: In gear or for automatic transmissions, in PARK.

(c) Parking brake burnish:

(1) For vehicles with parking brake systems not utilizing the service friction elements, the friction linings of such a system are burnished prior to the parking brake test according to the published recommendations furnished to the purchaser by the manufacturer.

(2) If no recommendations are furnished, the vehicle's parking brake system is tested in an unburnished condition.

(d) **Parking brake applications**: **1** application and **up to 2** re-applications, if necessary.

(e) [Parking with a trailer: Vehicles to which the coupling of a trailer is authorised, shall be tested to the above procedure, as a combined vehicle with the trailer at the maximum mass specified by the manufacturer, but on an **uphill** gradient of **12%.** Vehicles equipped with automatic transmission may perform this test with the assistance of the transmission set in the 'Park' position whilst those with manual transmission, may engage a low gear for this test.]

5.2.14.2. Test conditions and procedures.

(a) **IBT**: (1) Parking brake systems utilizing service brake friction materials shall be tested with the IBT between **65** and **100°C** (212 deg.F) and shall have no additional burnishing or artificial heating prior to the start of the parking brake test.

(2) Parking brake systems utilizing **non-service** brake friction materials shall be tested with the friction materials at ambient temperature at the start of the test.

(b) Parking brake control force: Hand control **≤400 N** ; foot control **≤500 N**.

(c) Hand force measurement locations: The force required for actuation of a hand-operated brake system is measured at the centre of the hand grip area or at a distance of **40 mm**

from the end of the actuation lever. (See Appendix 3 for other alternatives.)

(d) Parking brake applications: **1** application and **up to 2** re-applications, if necessary.

(e) Test surface gradient: **20%** grade for the vehicle alone and **12%** for vehicle + trailer.

(f) Drive the vehicle onto the grade with the longitudinal axis of the vehicle in the direction of the slope of the grade.

(g) Stop the vehicle and hold it stationary by applying the service brake control and, except for the test with a trailer, place the transmission in neutral.

(h) With the service brake applied sufficiently to just keep the vehicle from rolling, apply the parking brake.

(i) For a vehicle equipped with **mechanically-applied parking brakes**, make a single application of the parking brake control with a force not exceeding the limits specified in **(b)** above**.**
For a vehicle using a parking brake with **electrical control transmission/actuation**, apply the parking brake by operating the parking brake control (switch).

(j) Following the application of the parking brakes, release all force on the service brake control and, if the vehicle remains stationary, start the measurement of time.

(k) Verify the operation of the 'parking brake applied' indicator.

(l) If the vehicle does not remain stationary, reapplication of a force to the parking brake control at the level specified in **(b)** above, as appropriate for the vehicle being tested (without release of the ratchet or other holding mechanism of the parking brake) is allowed up to two times, to attain a stationary holding position.

(m) Following observation of the vehicle in a stationary condition for 5 minutes in one direction, **repeat** the same test procedure with the vehicle being held in the opposite direction on the same grade.

5.2.14.3. Performance requirement.

The parking brake system shall hold the vehicle stationary on the **20% grade** for **5 minutes** pointing in both upward and downward directions and with a trailer attached on a **12%** grade.

5.2.14.4. Test of an Electric Parking brake (EPB) in the failed case.

This test is made on an **8%** grade with the assistance of the Automatic Transmission in Park or the engagement of a low gear but otherwise under the same conditions of **5.2.14.2.** **A**pply a single electrical failure to the EPB electrical transmission between the control and the ECU and check that a driver warning is produced. Actuate the parking brake control and check that this warning is given by the Red signal and is flashing and this is continued for at least 10 seconds after the ignition switch is turned off.
If the vehicle will not hold the test is failed.

5.2.14.4.1. Performance requirement.

The vehicle shall be held in both directions on the 8% grade.

5.2.15. **Type-I test** (fade and recovery test)

General information.

This is a 4-part laden vehicle test designed to expose service braking performance when the brakes are hot through excessive use. There is a heating phase achieved by snub applications and followed by a hot test to assess the fall in braking efficiency.
Part 3 is a sequence of 4 brake cooling stops which, because of the distance travelled between stops, allows cooling and some normalization of service braking effectiveness.

This is followed by 2 stops to show the recovery in service braking performance.

5.2.15.1. <u>Heating procedure</u> - braking snubs.

The service brakes of all vehicles must be heated by successively applying and releasing the brakes **15** times, in the following conditions:

5.2.15.1.1. Vehicle conditions

(a) Vehicle laden only

(b) Transmission: in gear – using the gearbox so as to accelerate back to the start speed v_1 in the shortest possible time and holding the highest gear (excluding overdrive) during the braking phases.

5.2.15.1.2. Test conditions and procedures.

(a) Establish an IBT before the first brake application which is between 55 and 65°C and the following snubs take place at the temperature which has been reached.

(b) Number of snubs: 15:

(c) The initial speed v_1 for each snub is 80% of the maximum speed of the vehicle v_{max} but not exceeding 120 km/h. Each snub is terminated at ½ the initial speed.

(d) Deceleration rate:
Attain the specified deceleration rate of 3.0 m/s^2 on each snub and adjust the pedal force to maintain this rate constant for the remainder of each snub.

(e) Time interval:
Maintain a time cycle Δt which gives an interval of 45 seconds between the start of each snub application yet allows a 10 second period in the cycle for stabilizing the speed at v_1.

(f) Immediately after completion of the 15th snub accelerate to 100 km/h and commence the Hot Performance test.

5.2.15.1.3. Special practical considerations.

(a) If the characteristics of the vehicle make it impossible to abide by the duration prescribed for Δt, this duration may be increased; in any event, in addition to the time necessary for braking and accelerating the vehicle, it is still necessary to allow a period of **10 seconds** in each cycle for stabilizing the speed v_1 .

(b) For vehicles **not having sufficient power** to carry out the cycles of heating of the brakes, the tests shall be carried out by achieving the **prescribed speed** before the **first** braking application and thereafter by using the maximum acceleration available to regain speed and then braking successively at the speed reached at the end of each **45 second cycle** duration.

(c) For vehicles equipped with an **electric regenerative braking** system of **category B**, the condition of the vehicle batteries at the start of the test, shall be such that the braking force contribution provided by the electric regenerative braking system does **not exceed the minimum** guaranteed by the system design. This requirement is deemed to be satisfied if the batteries are at one of the state of charge conditions as listed in **paragraph 5.2.7.2.1.** above.

5.2.15.2. <u>Hot performance</u>

At the end of the Type-I test the hot performance of the service braking system must be measured in the same conditions (and in particular at a mean control force no greater than the mean force actually used) for the Type-0 reference test with the engine disconnected (the temperature conditions should be quite different).

5.2.15.2.1. Vehicle conditions.

(a) Vehicle laden.
(b) Transmission in neutral

5.2.15.2.2. Test conditions and procedure.

(a) IBT: The hot temperature attained by the heating process just completed.
(b) Number of stops: 2. (a second stop may be omitted if both requirements are met on the first stop.
(c) Pedal force on the 1st stop: at a mean control force no greater than the mean force actually used for the Type-0 cold performance test or, for vehicles equipped with ABS, no greater than 500 N.
The second stop for non-ABS equipped vehicles shall be made with a greater pedal force but not exceeding 500 N.
(d) The test is made on the high adhesion surface used for the test in section **5.2.7.3.&4.** and no wheel locking for periods longer than 0.1 seconds is allowed at speeds greater than 15 km/h.
(e) Accelerate to 100 km/h and make the first stop.
If the vehicle is incapable of attaining 100 km/h, it is tested at the same speed as was used in the laden Type 0 cold effectiveness test.
(f) In the case of vehicles equipped with an electric regenerative braking system of **category B**, having carried out the heating cycles according to **paragraph 5.2.15.1.2.** or **5.2.15.1.3.** of this Annex as appropriate, the hot performance test shall be carried out at the maximum speed which can be reached by the vehicle at the end of the brake heating cycles, but not exceeding **100 km/h.**

(g) Immediately after the completion of the first hot performance stop, accelerate rapidly back to the start speed used in (e) and conduct the second hot performance stop unless the required performance is completely satisfied by the performance of the first stop.

(h) Immediately after the completion of the second hot performance stop, or the first if there was only one was necessary, drive 1.5 km at 50 km/h so as to be ready to make the first cooling stop.

5.2.15.2.3. Performance requirements.

(a) The hot performance of the first stop shall not be less than **60%** of the MFDD **recorded** in the laden Type-0 test with the engine disconnected.
(b) The hot performance of the second stop shall not be less than **75%** of that **prescribed** for the Type 0 cold effectiveness - MFDD of **4.83 m/s²** or stopping distance $S \leq 0.1v + 0.0079v^2$ (where v is the test speed used)
Both performance criteria may be achieved on the first stop but the second stop shall not be used to meet requirement (a).

5.2.15.3. <u>Brake cooling stops.</u>

5.2.15.3.1. Vehicle conditions,

(a) Vehicle laden only.
(b) Transmission: In gear.

5.2.15.3.2. Test conditions and procedures.

(a) IBT: Temperature achieved at the end of the hot performance test
(b) Test speed: 50km/h.
(c) Pedal force: Adjusted as necessary to maintain a constant 3.0 m/s^2 deceleration.
(d) No locking of any wheel for longer than 0.1 seconds is allowed at speeds greater than 15 km/h.

(e) Number of runs; 4 stops.
(f) Immediately after the hot performance stops, drive 1.5 km at 50 km/h before making the first stop in this sequence.

(g) For the 1st, 2nd and 3rd stops, immediately accelerate at the maximum rate, back to 50 km/h and maintain this speed until beginning the next stop at a distance of 1.5 km beyond the beginning of the previous stop.
(h) Make the 4th stop in the sequence and accelerate at the maximum rate to a speed of 100 km/h or the maximum speed attainable in 1.5 km.
(i) After 1.5 km at the set or achieved speed. the Recovery performance can be assessed.
(j) Vehicles equipped with an electrical regenerative braking system of category B may, unless they are charged by an on-board electricity generator, have their **batteries re-charged or replaced** by a charged set, in order to complete the recovery procedure.

5.2.15.4. Recovery performance test.

Except in the case of (j) above, the recovery performance is conducted immediately after the brake cooling stops.

5.2.15.4.1. Vehicle conditions.
(a) Vehicle laden.
(b) Transmission in neutral

5.2.15.4.2. Test conditions and procedure.
(a) IBT: Temperature resulting after completion of the cooling stops.
(b) Test speed: 100 km/h.
(c) Pedal force: made at a mean control force no greater than the mean force actually used for the Type-0 cold performance test.
(d) The test is made on the high adhesion surface used for tests in section **5.2.7.3.&4.** and no wheel locking for periods longer than 0.1 seconds is allowed at speeds greater than 15 km/h.
(e) Number of runs: 2 stops.
(f) After accelerating to speed and travelling for 1.5 km as in paragraph **5.2.15.3.2.(** i **),** make the first recovery stop from the attained speed noting the deceleration (MFDD) achieved.
(g) Accelerate again up to the previous start speed and repeat the test at the same pedal effort, noting again, the deceleration (MFDD) achieved.

5.2.15.4.3. Recovery performance required.
The highest MFDD figure shall be not less than 70% nor more than 150% of the figure recorded in the laden Type 0 cold performance test.

5.2.15.4.4. Recovery test for vehicles with electrical regenerative braking.
For vehicles equipped with an **electrical regenerative braking** system of **category B**, the recovery test shall be made by the above procedure and with the above requirement, but with all **regenerative** braking disabled.

5.2.15.4.5. Following the recovery process and test, further reconditioning of the linings shall be permitted before a repeat laden vehicle **Type-0 test** with cold brakes shall be made from the same speed as was used in the recovery performance test of section **5.2.15.4.2.** but made with the regenerative braking system disabled. The comparison of clause **5.2.15.4.3.** is made between the recovery performance and this repeat **Type 0 performance.**

5.2.15.5. Hot performance comparison for vehicles with electric regenerative braking

A second repeat **laden Type-0** cold performance **test** shall be made from the same speed and with a similar electric regenerative braking contribution, as set by an appropriate state of battery charge as was available during the hot performance test of **section 5.2.15.2.2.** above

The Hot performance comparison is made between the deceleration achieved on this second cold performance test and that achieved in the hot test of section **5.2.15.2.2.**, against the criteria set out in **paragraphs 5.2.15.2.3.**

Appendix 1

PROCEDURE FOR MEASURING THE ABS EFFICIENCY OF ADHESION UTILISATION.

	SYMBOLS AND DEFINITIONS
SYMBOL	EXPLANATION
E	Wheelbase.
ε	The adhesion utilized of the vehicle: quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k).
ε_i	The ε - value measured on axle i (in the case of a motor vehicle with a **category 3** anti-lock system).
ε_H	The ε - value on the high-adhesion surface.
ε_L	The ε - value on the low-adhesion surface.
F	Force (N).
F_{dyn}	Normal reaction of road surface under dynamic conditions with the anti-lock system operative.
F_{idyn}	F_{dyn} on axle i (f or r).
F_M	Total normal static reaction of road surface on all wheels of power driven vehicle.
F_f	Normal static reaction of road surface on the front axle of the vehicle
F_r	Normal static reaction of road surface on the rear axle of the vehicle
G	Acceleration due to gravity (9.81 m/s^2).
H	Height of centre of gravity specified by the manufacturer and agreed by the Technical Service conducting the approval test.
K	Coefficient of adhesion between tyre and road.
k_f	k-factor of the front axle.
K_H	k-value determined on the high-adhesion surface.
k_r	k-factor of the rear axle.
K_L	k-value determined on the low-adhesion surface.

Appendix 1 continued

	SYMBOLS AND DEFINITIONS continued
SYMBOL	EXPLANATION
k_{lock}	Value of adhesion for 100 % slip.
k_{peak}	Maximum value of the curve "adhesion versus slip".
P	Mass of the passenger vehicle (kg)
R	Ratio of k_{peak} to k_{lock} .
T	Time interval (s) .
t_m	Mean value of t .
t_{min}	Minimum value of t .
Z	Braking rate.
z_{AL}	Braking rate z of the vehicle with the anti-lock system operative.
z_m	Mean braking rate
z_{max}	Maximum value of z.
z_{MALS}	Z_{AL} of the power driven vehicle on a "split surface".

1. Measurement of ABS PERFORMANCE on the low adhesion surface (from Section **5.1.6.1.2**.)

1.1. From an initial vehicle speed of **55 km/h**, the maximum braking rate (z_{AL}) shall be measured with full cycling of the anti-lock braking system The result shall be based on the average value of **3** tests, as in paragraph **2.1.3.2.** of this Appendix, using the time taken for the speed to reduce from **45 km/h to 15 km/h,** according to the following formula:

$$z_{AL} = \frac{0.849}{t_m}$$

2. Method of measurement of the UTILIZATION OF ADHESION

2.1. Determination of the coefficient of adhesion (k) of the low adhesion surface.

2.1.1. The coefficient of adhesion (k) shall be determined as the quotient of the maximum braking forces without locking the wheels and the corresponding dynamic load on the axle being braked.

2.1.2. The brakes shall be applied on only **one** axle of the vehicle under test, at an initial speed of **50 km/h**. The braking forces shall be balanced between the wheels of the axle to reach maximum performance. The anti-lock system shall be **disconnected, or inoperative**, between **40 km/h and 20 km/h**.

2.1.3. A number of tests at increments of line pressure shall be carried out to determine the maximum braking rate of the vehicle (z_{max}). During each test, a constant brake pedal force shall be maintained and the braking rate will be determined by reference to the time taken (t) for the speed to reduce from **40 km/h to 20 km/h** using the formula:

Appendix 1 continued.

$$z = \frac{0.566}{t}$$

2.1.3.1. Wheel lock may occur below **20 km/h.**

2.1.3.2. Starting from the minimum measured value of t, called t_{min} , then select **3** values of t comprised within t_{min} and 1.05 t_{min} and calculate their arithmetical mean value t_m ,
then calculate:

$$z_m = \frac{0.566}{t_m}$$

z_{max} is the maximum value of z ; t is in seconds.

If it is demonstrated that, for practical reasons, the **3** values defined above cannot be obtained, then the minimum time t_{min} may be utilized. However, the requirements of paragraph **1.3.** shall still apply.

2.1.3.3. The braking forces shall be calculated from the measured braking rate and the rolling resistance of the unbraked axle which is equal to **0.015** and **0.010** of the static axle load for a driven axle and a non-driven axle, respectively.

2.1.3.4. The dynamic load on the axle shall be that given by the formulae in paragraph **2.1.5.** below

For example, in the case of a two-axle rear-wheel drive vehicle, with the front axle being braked, the coefficient of adhesion (k) is given by :

$$k_f = \frac{z_m \cdot P \cdot g - 0.015 \cdot F_r}{F_f + \frac{h}{E} \cdot z_m \cdot P \cdot g}$$

2.1.3.5. The value of k_f shall be rounded to **3** decimal places.

2.1.4. Then the test as defined in paragraphs **2.1.2.** and **2.1.3.** above, will be repeated for the other axle.

2.1.4.1. Coefficients will have been determined for the front axle k_f and for the rear axle k_r .

2.1.5. The coefficient of adhesion k_M shall be determined by weighting with the dynamic axle loads.

$$k_M = \frac{k_f \cdot F_{fdyn} + k_r \cdot F_{rdyn}}{P \cdot g}$$

where:

$$F_{fdyn} = F_f + \frac{h}{E} \cdot z_{AL} \cdot P \cdot g$$

$$F_{rdyn} = F_r - \frac{h}{E} \cdot z_{AL} \cdot P \cdot g$$

2.1.6. The adhesion utilized (ε) is defined as the quotient of the maximum braking rate with the anti-lock system operative (z_{AL}) and the coefficient of adhesion (k_M) i.e.,

$$\varepsilon = \frac{z_{AL}}{k_M}$$

The value of ε shall be rounded to **2** decimal places and if it exceeds **1.00** the process must be repeated. However a tolerance of 10% is accepted.

Appendix 2

PROCEDURE FOR MONITORING THE STATE OF BATTERY CHARGE.

This procedure is applicable to vehicle batteries used for traction and regenerative braking.

The procedure requires the use of a bi-directional DC Watt-hour meter.

1. Procedure.

1.1. If the batteries are new or have been subject to extended storage, they shall be cycled as recommended by the manufacturer. A **minimum 8 hour soak** period at ambient temperature shall be allowed after completion of cycling.
A **full charge** shall be established using the manufacturer's recommended charging procedure.

1.2. When the braking tests of **paragraphs 5.2.7., 5.2.8.,5.2.9., 5.2.15.1., 5.2.15.2., 5.2.15.4.4.** and **5.2.15.5.** are conducted, the watt-hours consumed by the traction motors and supplied by the regenerative braking system shall be recorded as a running total which shall then be used to determine the state of charge existing at the beginning or end of a particular test.

1.3. To replicate a level of state of charge in the batteries for comparative tests, such as those of **paragraph 5.2.15.5,** the batteries shall be either recharged to that level or charged to above that level and discharged into a fixed load at approximately constant power until the required state of charge is reached. Alternatively, for vehicles with battery powered electric traction only, the state of charge may be adjusted by running the vehicle. Tests conducted with a battery partially charged at their start shall be commenced as soon as possible after the desired state of charge has been reached.

Appendix 3

Location for the measurement of Hand Brake Application Force.