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Truck and bus tyres — Method for measuring relative wet grip performance — Loaded new tyres

Pneumatiques pour camions et autobus — Méthode de mesure de l'adhérence relative sur revêtement mouillé — Pneumatiques neufs en charge

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Foreword

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

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

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

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

ISO 15222 was prepared by Technical Committee ISO/TC 31, *Tyres, rims and valves*, Subcommittee SC 4, *Truck and bus tyres and rims*.

Truck and bus tyres — Method for measuring relative wet grip performance — Loaded new tyres

1 Scope

This International Standard specifies the method for measuring relative wet grip braking performance index to a reference under loaded conditions for new tyres for use on commercial vehicles on a wet-paved surface.

The methods developed in this International Standard are meant to reduce the variability. The use of a reference tyre is necessary to limit the variability of the testing method procedures.

This International Standard applies to all truck and bus tyres (commercial vehicle tyres).

2 Normative references

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

ISO 4209-1, *Truck and bus tyres and rims (metric series) — Part 1: Tyres*

EN 13036-1:2010, *Road and airfield surface characteristics — Test methods — Part 1: Measurement of pavement surface macrotexture depth using a volumetric patch technique*

ASTM E303:2008, *Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester*

ASTM E501, *Standard Specification for Standard Rib Tire for Pavement Skid-Resistance Tests*

ASTM E965, *Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique*

ASTM E1136, *Standard Specification for P195/75R14 Radial Standard Reference Test Tire*

ASTM F2870, *Standard Specification for 315/70R22.5 154/150L Radial Truck Standard Reference Test Tire*

ASTM F2871, *Standard Specification for 245/70R19.5 136/134M Radial Truck Standard Reference Test Tire*

ASTM F2872, *Standard Specification for 225/75R16C 116/114S M+S Radial Light Truck Standard Reference Test Tire*

3 Terms and definitions

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

3.1 General terms and definitions

3.1.1
test run
single pass of a loaded tyre over a given test surface

3.1.2
candidate tyre "T" (set)
test tyre (or a test tyre set) that is part of an evaluation programme

3.1.3
reference tyre "R" (set)
standard reference test tyre
special test tyre (or a test tyre set) that is used as a benchmark in an evaluation programme

NOTE These tyres usually have carefully controlled design features to minimize variation.

3.2 Terms and definitions for the vehicle testing method described in Clause 6

3.2.1
control tyre "C" (set)
tyre (set) that is part of an evaluation programme

NOTE It is an intermediate set of tyres which is used when the candidate tyre and the reference tyre cannot be directly compared on the same vehicle.

3.3 Terms and definitions for the trailer or tyre test vehicle testing method described in Clause 7

3.3.1
braking force of a tyre
longitudinal force, expressed in newtons, resulting from braking torque application

3.3.2
braking force coefficient of a tyre
BFC
ratio of braking force to vertical load

3.3.3
peak braking force coefficient of a tyre
μ_{peak}
maximum value of tyre braking force coefficient that occurs prior to wheel lockup as the braking torque is progressively increased

3.3.4
lockup of a wheel
condition of a wheel in which its rotational velocity about the wheel spin axis is zero and it is prevented from rotating in the presence of applied wheel torque

3.3.5
vertical load
normal (Z-direction) reaction of the tyre on the road

3.3.6
trailer or tyre test vehicle
special purpose tyre evaluation vehicle which has instruments to measure the longitudinal force on one tyre during braking

3.3.7
coupling (hitch) height
height when measured perpendicularly from the centre of the articulation point of the trailer towing coupling or hitch to the ground, when the towing vehicle and trailer are coupled together

NOTE The vehicle and trailer shall be standing on level pavement surface in its test mode complete with the appropriate tyre(s) to be used in the particular test.

4 Methods for measuring wet grip

Relative wet grip braking performance for loaded commercial vehicle new tyres travelling straight ahead on a wet, paved surface can be measured by one of the following methods:

— a vehicle method consisting of testing a set of tyres mounted on a standard vehicle;

— a test method using a trailer or a tyre test vehicle equipped with one or several test tyre(s).

5 General test conditions

5.1 Track characteristics

5.1.1 General

The surface shall be a dense asphalt surface with a uniform gradient of not more than 2 % and shall not deviate more than 6 mm when tested with a 3 m straight edge.

The test surface shall have a pavement of uniform age, composition, and wear. The test surface shall be free of loose material or foreign deposits.

The maximum chipping size shall be from 8 mm to 13 mm.

The sand depth measured as specified in EN 13036-1:2010 and ASTM E965, shall be (0,7 ± 0,3) mm.

In order to verify the wetted frictional properties of the surface, one of the methods in 5.1.2 or 5.1.3 shall be used.

5.1.2 British Pendulum Number (BPN) method

The averaged BPN British Pendulum Tester method as specified in ASTM E303 using the Pad as specified in ASTM E501 shall be (50 ± 10) BPN after temperature correction.

BPN shall be corrected by the wetted road surface temperature. Unless temperature correction recommendations are indicated by the British pendulum manufacturer, Equation (1) can be used:

$$\text{Temperature correction} = \left(-0{,}001\,8\ T^2\right) + 0{,}34T - 6{,}1 \qquad (1)$$

where “T” is the wetted road surface temperature in degrees Celsius.

Effects of slider pad wear: the pad should be removed for maximum wear when the wear on the striking edge of the slider reaches 3,2 mm in the plane of the slider or 1,6 mm vertical to it in accordance with ASTM E303:2008, 5.2.2 and Figure 3.

Check the test track testing surface BPN consistency for the measurement of wet grip on a standard vehicle. To decrease the dispersion of test results, the BPN values of the track should not vary over the entire stopping distance. The operation shall be repeated five times at each point of the BPN measurement. Measurements for BPN shall be taken every 10 m on the braking lane and the coefficient of variation of the BPN averages shall not exceed 10 %.

5.1.3 Standard Reference Test Tyre (SRTT) method

The average peak braking coefficient ($\mu_{peak,ave}$) of the ASTM E1136 reference tyre (see Clause 7) shall be (0,7 ± 0,1) at 65 km/h.

For the trailer method, testing is run in such a way that braking occurs within 10 m of where the surface was examined.

The average peak braking coefficient ($\mu_{peak,ave}$) of the ASTM E1136 reference tyre shall be corrected by the wetted road surface temperature according to Equation (2):

$$\text{Temperature correction} = 0{,}003\,5 \times (T - 20) \qquad (2)$$

where "T" is the wetted road surface temperature in degrees Celsius.

5.2 Wetting conditions

The surface may be wetted from the track-side or by a wetting system incorporated into the test vehicle or the trailer.

If "external watering" is used, water the test surface at least half an hour prior to testing in order to equalize the surface temperature and water temperature. External watering should be supplied continuously throughout testing.

For the whole testing area, the water depth shall be between 0,5 mm and 2 mm.

5.3 Atmospheric conditions

The wind conditions shall not interfere with wetting of the surface (wind-shields are allowed).

The ambient and the wetted surface temperatures shall be between 5 °C and 35 °C and shall not vary during the test by more than 10 °C.

5.4 Reference tyres

In order to cover the range of the tyre sizes fitting the commercial vehicles, three SRTT sizes shall be used to measure the relative wet index:

— SRTT 315/70R22.5 LI=154/150, ASTM F2870

— SRTT 245/70R19.5 LI=136/134, ASTM F2871

— SRTT 225/75R16C LI=116/114, ASTM F2872

The three SRTT sizes shall be used to measure the relative wet index as shown in Table 1.

Table 1 — Measurement of the relative wet index

SRTT for rim codes > 17 ➔ 2 Families	
FAMILY Rim Code > 17 NARROW $S_{Nominal}$ < 285 mm	**FAMILY Rim Code > 17 WIDE** $S_{Nominal} \geq$ 285 mm
SRTT 245/70R19.5 LI=136/134	**SRTT 315/70R22.5** LI=154/150

SRTT for Rim Codes $\leq$ 17 ➔ Unique Family
SRTT 225/75 R 16 C LI=116/114

$S_{Nominal}$ = *tyre nominal section width*

6 Measurement of tyre wet grip on a standard vehicle

6.1 Principle

The test method covers a procedure for measuring the deceleration performance of commercial vehicle tyres during braking, using a commercial vehicle having an Antilock Braking System (ABS).

Starting with a defined initial speed, the brakes are applied hard enough on the two axles at the same time to activate the ABS. The average deceleration (AD) is calculated between two defined speeds, with an initial speed of 60 km/h and a final speed of 20 km/h. When the braking system is not operating automatically, a minimum of 600 N pedal effort is required.

6.2 Equipment

6.2.1 Vehicle

The standard equipment is a two axle standard-model commercial vehicle equipped with 4 disc brakes and an ABS. In case tyre fitting is not possible, e.g. multi-purpose tyres (MPT) or free rolling tyres (FRT), a vehicle model with drum-brakes and ABS is allowed.

The permitted modifications are:

— those allowing the number of tyre sizes that can be mounted on the vehicle to be increased;

— those permitting automatic activation of the braking device to be installed.

Any other modification of the braking system is prohibited.

6.2.2 Measuring equipment

Measuring device(s) suitable for measuring speed on wet surface and distance covered between two speeds shall be used.

To measure vehicle speed, a fifth wheel or non-contact precision (including radar, GPS, etc.) speed-measuring system shall be used.

The following tolerances shall be respected:

— for speed measurements: ± 1 % km/h or ± 0,5 km/h, whichever is greater,

— for distance: $\pm 1 \times 10^{-1}$ m.

The measured speed or the difference between the measured speed and the reference speed for the test should be displayed inside the vehicle, so that the driver can adjust the speed of the vehicle.

A data acquisition system can be used for storing the measurements.

6.3 Conditioning of the test track

Condition the pavement by conducting at least ten test runs with tyres not involved in the test programme at an initial speed higher or equal to 65 km/h (which is higher than the initial test speed to guarantee that a sufficient length of track is conditioned).

6.4 Measurement requirements for test speeds

The speed at the start of braking shall be (65 ± 2) km/h.

The average deceleration shall be calculated between 60 km/h and 20 km/h.

6.5 Tyres and rims

6.5.1 Vehicle equipment

The rear axle may be indifferently fitted with 2 or 4 tyres.

For the reference tyre testing, both axles are fitted with reference tyres (a total of 4 or 6 reference tyres depending on the choice mentioned above).

For the candidate tyre testing, 3 fitting configurations are possible:

— configuration “Conf.1”: candidate tyres on front and rear axles (standard configuration that should be used whenever possible);

— configuration “Conf.2”: candidate tyres on front axle and reference tyre or control tyre on rear axle (allowed where fitting the candidate tyre on the rear position is not possible);

— configuration “Conf.3”: candidate tyres on rear axle and reference tyre or control tyre on front axle (permitted where fitting the candidate tyre on the front position is not possible).

6.5.2 Tyre preparation and break-in

Fit the test tyres on rims in accordance with ISO 4209-1 using conventional mounting methods. Ensure proper bead seating by the use of a suitable lubricant. Excessive use of lubricant should be avoided to prevent slipping of the tyre on the wheel rim.

Place the fitted test tyres in a location for a minimum of two hours.

Place the fitted test tyres in a location such that they all have the same ambient temperature prior to testing, and shield them from the sun to avoid excessive heating by solar radiation.

For tyre break-in, perform two braking runs.

6.5.3 Tyre load

The static load on each axle tyre shall lie between 60 % and 100 % of the tested tyre load capacity. Tyre loads on the same axle should not differ by more than 10 %.

The use of fitting as per Conf.2 and Conf.3 shall fulfil the following additional requirements:

— Conf. 2: Front axle load > Rear axle load;

  — The rear axle shall be indifferently fitted with 2 or 4 tyres.

— Conf.3: Rear axle load > Front axle load × 1,8.

6.5.4 Tyre inflation pressure

For a vertical load higher or equal to 75 % of the load capacity of the tyre, the test inflation pressure p_t shall be calculated using Equation (3):

$$p_t = p_r \times \left(\frac{Q_t}{Q_r}\right)^{1,25} \quad (3)$$

where

p_r is inflation pressure marked on the sidewall. If p_r is not marked on the sidewall, refer to the specified pressure in applicable tyre standards manuals corresponding to maximum load capacity for single applications;

Q_t is the static test load of the tyre;

Q_r is the maximum mass associated with the load capacity index of the tyre.

For a vertical load lower than 75 % of the load capacity of the tyre, the test inflation pressure, p_t shall be calculated using Equation (4):

$$p_t = p_r \times (0,75)^{1,25} = (0,7) \times p_r \quad (4)$$

where p_r is inflation pressure marked on the sidewall.

NOTE If p_r is not marked on the sidewall, refer to the specified pressure in applicable tyre standards manuals corresponding to maximum load capacity for single applications.

Check the tyre pressure just prior to testing at ambient temperature.

6.6 Procedure

First, mount the set of reference tyres on the vehicle. Accelerate the vehicle in the starting zone up to (65 ± 2) km/h.

The brakes shall always be activated at the same place on the track, with a longitudinal tolerance of 5 m and transverse tolerance of 0,5 m.

According to the type of transmission, two cases are possible.

a) manual transmission: As soon as the driver is in the measuring zone and has reached (65 ± 2) km/h, release the clutch and depress the brake pedal sharply, holding it down as long as necessary to perform the measurement;

b) automatic transmission: As soon as the driver is in the measuring zone and has reached (65 ± 2) km/h, select neutral gear and then depress the brake pedal sharply, holding it down as long as necessary to perform the measurement.

Automatic activation of the brakes can also be performed by means of a detection system made of two parts, one indexed to the track and one on board the vehicle. In this case, braking is more precise on the same portion of the track.

If any of the conditions in a) or b) is not met when a measurement is made (speed tolerance, braking time, etc.), the measurement is discarded and a new measurement is made.

For each test and for new tyres, the first two braking measurements are discarded.

After at least three valid measurements have been made, in the same direction, the reference tyres are replaced by a set of the candidate tyres (one of the three configurations presented in 6.5.1) and at least six valid measurements shall be performed.

A maximum of three sets of candidate tyres can be tested before the reference tyre is re-tested.

EXAMPLES

The run order for a test of three sets of candidate tyres (T_1 to T_3) plus a reference tyre R would be:

$R – T_1 – T_2 – T_3 – R$

The run order for a test of five sets of tyres (T_1 to T_5) plus a reference tyre R would be:

$R – T_1 – T_2 – T_3 – R –T_4 – T_5 – R$

6.7 Processing of measurement results

6.7.1 Calculation of the average deceleration, AD

Each time the measurement is repeated, the average deceleration AD (m/s^2) is calculated by Equation (5):

$$\mathrm{AD} = \left| \frac{v_\mathrm{f}^2 - v_\mathrm{i}^2}{2D} \right| \qquad (5)$$

where

D is the distance covered (m) between v_i and v_f;

v_f is the final speed (m/s);

v_i is the initial speed (m/s).

6.7.2 Validation of results

6.7.2.1 For the reference tyre:

If the “coefficient of variation” of AD of any two consecutive groups of three runs of the reference tyre is higher than 3 %, discard all data and repeat the test for all tyres (the candidate tyres and the reference tyre).

The coefficient of variation is calculated using Equation (6):

$$\frac{\text{standard deviation}}{\text{average}} \times 100 \qquad (6)$$

6.7.2.2 For the candidate tyres:

The coefficients of variation [see Equation (6)] are calculated for all the candidate tyres. If one coefficient of variation is greater than 3 %, discard the data for this candidate tyre and repeat the test.

6.7.3 Calculation of average AD

If R_1 is the average of the AD values in the first test of the reference tyre and R_2 is the average of the AD values in the second test of the reference tyre, the following operations are performed, according to Table 2.

Table 2

If the number of sets of candidate tyres between two successive runs of the reference tyre is:	and the set of candidate tyres to be qualified is:	then R_a is calculated by applying the following:
1 R – T_1 – R	T_1	$R_a = 1/2(R_1 + R_2)$
2 R – T_1 – T_2 – R	T_1	$R_a = 2/3R_1 + 1/3R_2$
	T_2	$R_a = 1/3R_1 + 2/3R_2$
3 R – T_1 – T_2 – T_3 – R	T_1	$R_a = 3/4R_1 + 1/4\ R_2$
	T_2	$R_a = 1/2(R_1 + R_2)$
	T_3	$R_a = 1/4R_1 + 3/4R_2$

T_a (a = 1, 2, etc.) is the average of the AD values for a test of a candidate tyre.

6.7.4 Calculation of braking force coefficient, BFC

BFC(T) and BFC(R) are calculated according to Table 3.

Table 3 — Calculation of braking force coefficient

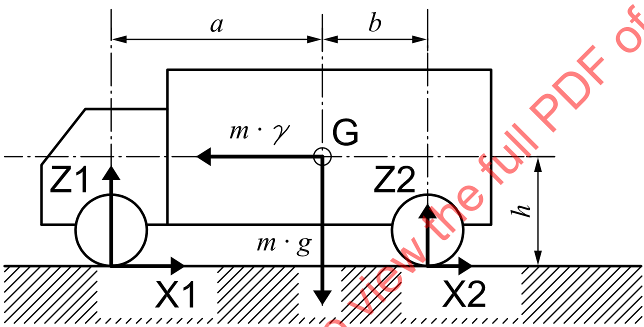
Tyre type	Braking force coefficient
Reference tyre	$\text{BFC(R)} = \frac{R_a}{g}$
Candidate tyre	$\text{BFC(T)} = \frac{T_a}{g}$
R_a and T_a are expressed in m/s^2. g is gravity acceleration (rounded to 9.81 m/s^2).	

6.7.5 Calculation of the relative wet grip index of the tyre

The wet grip index represents the relative performance of the candidate tyre compared to the reference tyre. The way to obtain it depends on the test configuration as defined in 6.5.1, by applying the formulas contained in Table 4 (see Figure 1 for nomenclature explanation).

Table 4 — Calculation of the relative wet grip index of the tyre

Configuration C1: candidate tyres on both axles	Wet grip index = $\frac{\text{BFC(T)}}{\text{BFC(R)}} \times 100$
Configuration C2: candidate tyres on front axle and reference tyres on rear axle	Wet grip index = $\frac{\text{BFC(T)}\left[a+b+h\times\text{BFC(R)}\right]-a\times\text{BFC(R)}}{\text{BFC(R)}\left[b+h\times\text{BFC(T)}\right]}\times 100$
Configuration C3: candidate tyres on rear axle and reference tyres on front axle	Wet grip index = $\frac{\text{BFC(T)}\left[-a-b+h\times\text{BFC(R)}\right]+b\times\text{BFC(R)}}{\text{BFC(R)}\left[-a+h\times\text{BFC(T)}\right]}\times 100$
a is the horizontal distance between front axle and centre of gravity of the loaded vehicle (m).	
b is the horizontal distance between rear axle and centre of gravity of the loaded vehicle (m).	
h is the vertical distance between ground level and centre of gravity of the loaded vehicle (m). When h is not precisely known, these worst case values shall apply: 1,2 for configuration C2, and 1,5 for configuration C3.	



Key

G centre of gravity of the loaded vehicle

a horizontal distance between front axle and centre of gravity of the loaded vehicle

b horizontal distance between rear axle and centre of gravity of the loaded vehicle

h vertical distance between ground level and centre of gravity of the loaded vehicle

m mass (in kilograms) of the loaded vehicle

γ loaded vehicle acceleration (m/s^2)

g acceleration due to the gravity (m/s^2)

X1 longitudinal (X-direction) reaction of the front tyre on the road

X2 longitudinal (X-direction) reaction of the rear tyre on the road

Z1 normal (Z-direction) reaction of the front tyre on the road

Z2 normal (Z-direction) reaction of the rear tyre on the road

Figure 1 — Nomenclature explanation related to grip index of the tyre

6.8 Wet grip performance comparison between a candidate tyre and a reference tyre using a control tyre

6.8.1 General

When the candidate tyre size is significantly different from that of the reference tyre, a direct comparison on the same vehicle may not be possible. This approach uses an intermediate tyre, hereinafter called the control tyre.

6.8.2 Principle of the approach

The principle is the use of a control tyre and two different vehicles for the assessment of a candidate tyre set in comparison with a reference tyre set.

One vehicle can be fitted with the reference tyre set and the control tyre set, the other with the control tyre set and the candidate tyre set. All conditions are in conformity with 6.2 to 6.5.

The control tyre set (4 or 6 tyres) is physically the same set as the set used for the first assessment.

The first assessment is a comparison between the control tyre and the reference tyre. The result (wet grip index 1) is the relative efficiency of the control tyre compared to the reference tyre.

The second assessment is a comparison between the candidate tyre and the control tyre. The result (wet grip index 2) is the relative efficiency of the candidate tyre compared to the control tyre.

The second assessment is done on the same track as the first one within one week maximum. The wetted surface temperature shall be within ± 5 °C of the temperature of the first assessment. The control tyre set (four tyres) is the same set as was used for the first assessment.

The wet grip index of the candidate tyre compared to the reference tyre is deduced by multiplying the relative efficiencies calculated above:

$$\text{wet grip index 1} \times \text{wet grip index 2} \times 10^{-2}$$

When the test expert decides to use an SRTT tyre as a control tyre (i.e. in the test procedure two SRTTs are compared directly instead of an SRTT with a control tyre), the result of the comparison between the SRTTs is called the “local shift factor”. The use of a previous SRTT comparison is allowed. The comparison results shall be checked periodically.

6.8.3 Selection of a set of tyres as a control tyre set

A control tyre set is a group of identical tyres made in the same factory during a one-week period.

6.8.4 Storage and preservation of control tyres

Before the first assessment (control tyre/reference tyre), normal storage conditions can be used. It is necessary for all the tyres of a control tyre set to have been stored in the same conditions.

As soon as the control tyre set has been assessed in comparison with the reference tyre, specific storage conditions shall be applied for “control tyre replacements”.

6.8.5 Replacement of control tyres

When irregular wear or damage results from tests, or when wear influences the test results, the use of the tyre shall be discontinued.

7 Test method using a trailer or a tyre test vehicle

7.1 Principle

The measurements are conducted on tyres mounted on a trailer towed by a vehicle or a tyre test vehicle. The brake on the test position is applied firmly until sufficient braking torque is generated to produce the maximum braking force that will occur prior to wheel lockup at a test speed of 50 km/h.

7.2 Apparatus

7.2.1 The test apparatus consists of a tow vehicle and trailer or a tyre test vehicle.

7.2.1.1 The test apparatus shall have the capability of maintaining the specified speed, (50 ± 2) km/h, even under the maximum braking forces.

7.2.1.2 The test apparatus shall be equipped with one test position and the following accessories:

— equipment to actuate brakes on the test position;

— a water tank to store sufficient water to supply the watering system, unless external watering is used;

— recording equipment to record signals from transducers installed at the test position and to monitor water application rate if the self-watering option is used.

7.2.2 The limiting change of toe and camber for the test position shall be within ± 0,5° with maximum vertical load. Suspension arms and bushings shall have sufficient rigidity necessary to minimize free play and ensure compliance under application of maximum braking forces. The suspension system shall provide adequate load-carrying capacity and be of such a design as to isolate suspension resonance.

7.2.3 The test position shall be equipped with a typical or special automotive hydraulic brake system which can apply sufficient braking torque to produce the maximum value of braking test wheel longitudinal force at the conditions specified.

7.2.4 The brake application system shall be able to control the time interval between initial brake application and peak longitudinal force as specified in 7.5.3.2.

7.2.5 The test apparatus shall have provisions for adjustment of vertical load as specified in 7.5.1.

7.2.6 The apparatus may be optionally equipped with a pavement-wetting system, less the storage tank, which, in the case of the trailer, is mounted on the tow vehicle. The water being applied to the pavement ahead of the test tyres shall be supplied by a nozzle suitably designed to ensure that the water layer encountered by the test tyre has a uniform cross-section at the test speed with a minimum splash and over-spray. The nozzle configuration and position shall ensure that the water jets are directed towards the test tyre and pointed towards the pavement at an angle of 15° to 30°.The water shall strike the pavement 0,25 m to 0,5 m ahead of the centre of tyre contact. The nozzle shall be located 100 mm above the pavement or at the minimum height required to clear obstacles which the tester is expected to encounter, but in no case more than 200 mm above the pavement. The water layer shall be at least 25 mm wider than the test tyre tread and applied so the tyre is centrally located between the edges. The volume of water per unit of wetted width shall be directly proportional to the test speed. The quantity of water applied at 50 km/h shall be 14 l/s per metre of the width of the wetted surface. The nominal values of rate of water application shall be maintained within ± 10 %.

7.3 Instrumentation

7.3.1 General

The test wheel position on the trailer or the tyre test vehicle shall be equipped with a wheel rotational velocity measuring system and with transducers to measure the braking force and vertical load at the test wheel.

7.3.2 General requirements for measurement system

7.3.2.1 General

The instrumentation system shall conform to the following overall requirements at ambient temperatures between 0 °C and 45 °C:

— overall system accuracy, force: ± 2,0 % of the full scale of the vertical load or braking force;

— overall system accuracy, speed: ± 1,5 % of speed or ± 1,0 km/h, whichever is greater.

7.3.2.2 Vehicle speed

To measure vehicle speed, a fifth wheel or non-contact precision (including radar, GPS, etc.) speed-measuring system shall be used. Output can be directly visible to the driver and can be simultaneously recorded.

7.3.2.3 Braking forces

The braking force-measuring transducers shall measure longitudinal force generated at the tyre-road interface as a result of brake application within a range from 0 % to at least 125 % of the applied vertical load. The transducer design and location shall minimize inertial effects and vibration-induced mechanical resonance.

7.3.2.4 Vertical load

The vertical load-measuring transducer shall measure the vertical load at the test position during brake application. The transducer shall have the same specifications as described previously.

7.3.2.5 Signal conditioning and recording system

All signal conditioning and recording equipment shall provide linear output with necessary gain and data reading resolution to meet the specified previous requirements. In addition, the following requirements apply.

— The minimum frequency response shall be flat from 0 Hz to 50 Hz (100 Hz) within ± 1 % full scale.

— The minimum sampling frequency of digital signals shall be 100 Hz. Tyre vertical load, braking force, vehicle and wheel speeds and a time base must be recorded in phase (0 Hz to 100 Hz with a maximum phase difference of ± 0,1 rad).

— The signal-to-noise ratio shall be at least 20:1.

— The gain shall be sufficient to permit full-scale display for full-scale input signal level.

— The input impedance shall be at least ten times larger than the output impedance of the signal source.

— The equipment shall be insensitive to vibrations, acceleration, and changes in ambient temperature.

7.4 Selection and preparation of test tyres

7.4.1 Fit the test tyres on rims in accordance with ISO 4209-1 (or as specified by the appropriate tyre and rim standards organizations) using conventional fitting methods. Ensure proper bead seating by the use of a suitable lubricant. Excessive use of lubricant should be avoided to prevent slipping of the tyre on the wheel rim.

7.4.2 For tyre break-in, perform two braking runs.

7.4.3 Place the fitted test tyres for a minimum of 2 h near the test site in such a location that they all have the same ambient termperature prior to testing, and shield them from the sun to avoid excessive heating by solar radiation.

7.4.4 Check the test tyres for the specified inflation pressure at ambient temperature (cold), just prior to testing. For the purpose of this International Standard, the testing tyre cold inflation pressure p_t shall be calculated using Equation (3) again:

$$p_t = p_r \times \left(\frac{Q_t}{Q_r} \right)^{1,25}$$

where

p_r is inflation pressure marked on the sidewall. If p_r is not marked on the sidewall, refer to the specified pressure in applicable tyre standards manuals corresponding to maximum load capacity for single applications;

Q_t is the static test load of the tyre;

Q_r is the maximum mass associated with the load capacity index of the tyre.

7.4.5 One set of tyres shall be one of the available references (see 5.4).

7.5 Preparation of the apparatus and the test track

7.5.1 Towed trailer

7.5.1.1 Install the test tyre on the measuring device.

7.5.1.2 Load each of the wheels to the specified test load.

7.5.1.3 Adjust the hitch height and transverse position as necessary for a given test.

7.5.1.4 Check the wiring connections between tow vehicle and the trailer for open circuits and short circuits.

7.5.2 Tyre test vehicle

7.5.2.1 Install the test tyre on the measuring device.

7.5.2.2 Load the test tyre to the specified test load.

7.5.3 Instrumentation and equipment

7.5.3.1 Install the fifth wheel, when used, in accordance with the manufacturer's specifications and locate it as near as possible to the mid-track position of the tow trailer or the tyre test vehicle.

7.5.3.2 The rate of braking application shall be such that the time interval between initial application of force and peak longitudinal force is in the range from 0,2 s to 1,0 s.

7.5.4 Conditioning of the track

Condition the track by conducting at least ten test runs at 50 km/h with a tyre not involved in the test programme.

7.6 General test conditions

The test load shall be (75 ± 5) % of the load index.

7.7 Procedure

7.7.1 Approach the test site in a straight line at the specified test speed, (50 ± 2) km/h.

7.7.2 Start the recording system.

7.7.3 Deliver water to the pavement ahead of the test tyre approximately 0,5 s prior to brake application (for internal watering system).

7.7.4 When the test tyres reach the test site, apply the trailer brakes. The test should be run at the same area on the test pad.

7.7.5 Stop the recording system.

7.7.6 For new tyres, the first two braking runs are discarded for tyre break-in. Repeat 7.6.1 to 7.6.5 at least six times, making runs in the same direction.

7.7.7 Test consecutive sets of tyres by repeating 7.6.1 to 7.6.6, provided that the tests are completed within one day.

7.7.8 Test the reference tyre adjacent to each set of test tyres, for example in the sequence R–T_1–T_2–R–T_3–T_4–R, etc., where R = Reference tyre and T_n = test tyre.

A maximum of three sets of candidate tyres may be tested before the reference tyre is re-tested.

EXAMPLE

The run order for a test of 3 sets of candidate tyres (T_1 to T_3) plus a reference tyre R would be:

R – T_1 – T_2 – T_3 – R

The run order for a test of 5 sets of candidate tyres (T_1 to T_5) plus a reference tyre R would be:

R – T_1 – T_2 – T_3 – R – T_4 – T_5 – R

7.8 Processing of measurement results

7.8.1 General

7.8.1.1 Calculate the peak braking force coefficient, μ_{peak}, for each test using Equation (7):

$$\mu(t) = \left| \frac{f_{\text{h}}(t)}{f_{\text{v}}(t)} \right| \quad (7)$$

where:

$\mu(t)$ is the dynamic tyre braking force coefficient in real time;

$f_{\text{h}}(t)$ is the dynamic braking force in real time, N;

$f_{\text{v}}(t)$ is the dynamic vertical load in real time, N.

7.8.1.2 Using Equation (7) for dynamic tyre braking force coefficient, calculate the peak tyre braking force coefficient, μ_{peak}, by determining the highest value of $\mu(t)$ before lockup occurs. Analog signals should be filtered to remove noise. Digitally recorded signals may be filtered using a moving average technique.

7.8.1.3 Calculate the average values $\mu_{\text{peak,ave}}$ of peak braking coefficient, by averaging four or more repeated runs for each set of test and reference tyres for each test condition.