INTERNATIONAL STANDARD

ISO 15222

Second edition
2021-11

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

Reference number
ISO 15222:2021(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 31, *Tyres, rims and valves*.

This second edition cancels and replaces the first edition ISO 15222:2011 been technically revised.

The main changes compared to the previous edition are as follows:

— the SRTT for tracks validation has been changed (from SRTT 14" to SRTT 16" due to SRTT 14" discontinuation);

— the SRTT selection rules (wide SRTT or narrow SRTT) have been revised;

— test results' calculations and validation have been clarified and simplified;

— the wording and designations have been aligned with ISO 23671 for better consistency.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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

1 Scope

This document 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 document are meant to reduce the variability. The use of a reference tyre is necessary to limit the variability of the testing method procedures.

This document applies to all commercial vehicle, truck and bus tyres.

This document does not apply to:

— tyres fitted with additional devices to improve traction properties (e.g. studded tyres);

— professional off-road tyres.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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*

ISO 4223-1, *Definitions of some terms used in the tyre industry — Part 1: Pneumatic tyres*

ISO 23671, *Passenger car tyres — Method for measuring relative wet grip performance — Loaded new tyres*

ASTM E965-15, *Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4223-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
test run
single pass of a loaded tyre over a given test surface

3.2
candidate tyre
T
test tyre that is part of an evaluation programme

3.3
reference tyre
R
standard reference test tyre (3.17) that is used as a benchmark in an evaluation programme

Note 1 to entry: These tyres usually have carefully controlled design features to minimize variation.

3.4
control tyre
C
intermediate tyre that is used when the *candidate tyre* (3.2) and the *reference tyre* (3.3) cannot be directly compared on the same vehicle

3.5
braking force
longitudinal force between a tyre and the road resulting from braking torque application

Note 1 to entry: It is expressed in newtons.

3.6
braking force coefficient
BFC
<vehicle method> ratio between the average deceleration in a *test run* (3.1) and the acceleration gravity (9,81 $m \cdot s^{-2}$)

3.7
dynamic tyre braking force coefficient
$\mu(t)$
<trailer (or tyre test vehicle) method> ratio between the *braking force* (3.5) and the *vertical load* (3.10) acquired in real time

3.8
peak braking force coefficient
μ_{peak}
<trailer or tyre test vehicle method> maximum value of the *dynamic tyre braking force coefficient* (3.7) that occurs prior to the *lockup of a wheel* (3.9) as the braking torque is progressively increased

3.9
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

3.10
vertical load
normal force (Z-direction) of a tyre exerted on the road resulting from the mass supported by the tyre

Note 1 to entry: It is expressed in newtons.

3.11
tyre test vehicle
trailer vehicle
special purpose tyre evaluation vehicle which has instruments to measure the vertical and longitudinal forces on one tyre during braking

3.12
hitch height
coupling 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 1 to entry: The vehicle and trailer shall be standing on level pavement surface in their test mode complete with the appropriate tyre(s) to be used in the particular test.

3.13
braking test
series of a specified number of *test runs* (3.1) of the same tyre repeated within a short time frame

3.14
braking test cycle
series of *braking tests* (3.13) that consist of an initial braking test of the *reference tyre* (3.3) set, of up to three braking tests of either *candidate tyre* (3.2) sets or *control tyre* (3.4) sets, or both, and a final braking test of the same reference *tyre set* (3.16)

3.15
tyre set
<vehicle method> four or six tyres depending on the test vehicle

3.16
tyre set
<trailer or a tyre test vehicle method> one or two tyres

3.17
standard reference test tyre
SRTT
tyre that is produced, controlled and stored under specific conditions, in order to be used as reference tyre for testing

Note 1 to entry: These tyres usually have carefully controlled design features to minimize variation. The requirements for SRTTs are given in ASTM international standards.

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 tyre set mounted on a standard vehicle;

— a test method using a trailer or a tyre test vehicle equipped with a test tyre set.

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 macro texture depth MTD of the area of the track to be used for the wet grip test shall be measured as specified in ASTM E965-15, and shall be (0,7 ± 0,3) mm.

In order to verify the wetted frictional properties of the surface, the following method in 5.1.2 shall be used.

5.1.2 Standard reference test tyre method

This method uses P225/60R16 97S, defined in ASTM F2493-20, SRTT (SRTT16).

Perform at least six valid measurements of the peak braking force coefficients (μ_{peak}) with SRTT16 using a trailer or special purpose tyre evaluation vehicle test procedure as specified in Clause 7 or in ISO 23671 at 65 km/h and 180 kPa.

The average of the measured peak braking force coefficients ($\mu_{peak,ave}$) shall be corrected for the effects of temperature as follows:

$$\mu_{peak,corr} = \mu_{peak,ave} + a \cdot (\vartheta - \vartheta_0)$$

where

$\mu_{peak,corr}$ is the temperature corrected average peak braking force coefficient;

a is equal to 0,002 °C^{-1};

ϑ is the wetted surface temperature in degree Celsius;

ϑ_0 is equal to 20 °C.

$\mu_{peak,corr}$ shall be not less than 0,65 and not greater than 0,90.

The test shall be conducted using the lanes and length of the track to be used for the wet grip test.

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

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 both external watering and self-watering systems, the water depth shall be not less than 0,5 mm and not greater than 2,0 mm measured from the peaks of the pavement for the braking lanes used.

5.3 Atmospheric conditions

The wind conditions shall not interfere with wetting of the surface (windshields 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 tyre

In order to cover the range of tyre sizes fitting the commercial vehicles the three standard reference test tyres SRTT16C, SRTT19.5 and SRTT22.5 shall be used to measure the relative wet grip index according to Table 1.

Table 1 — Measurement of the relative wet grip index — Reference tyre

Tyres with one of the following combinations of load index (LI) in single formation and speed category: load index single ≤121 and speed category ≤130 km/h (speed symbol M); or load index single ≥122 and any speed category; 2 specific families defined:	
NARROW family $S_{Nominal}$ **<285 mm**	**WIDE family** $S_{Nominal}$ **≥285 mm**
SRTT19.5 (245/70R19.5 136/134M)	SRTT22.5 (315/70R22.5 154/150L)

Tyres with a load index in single formation load index single ≤121 and a speed category ≥140 km/h (speed symbol N) → Unique family
SRTT16C (225/75 R 16 C 116/114S)

$S_{Nominal}$ **is the tyre nominal section width.**

NOTE 1 The reference tyre SRTT16C (225/75R16C 116/114S) is defined in ASTM F2872.

NOTE 2 The reference tyre SRTT19.5 (245/70R19.5 136/134M) is defined in ASTM F2871.

NOTE 3 The reference tyre SRTT22.5 (315/70R22.5 154/150L) is defined in ASTM F2870.

6 Measurement of tyre wet grip on a standard vehicle

6.1 Principles

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 braking force coefficient (BFC) is calculated between the initial speed of 60 km/h and the final speed 20 km/h.

6.2 Equipment

6.2.1 Vehicle

The standard equipment is a two-axle standard-model commercial vehicle equipped with four-disc brakes and an ABS. In case tyre fitting is not possible, for example, 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, for example, radar, GPS) 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 10 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 speed

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 fitted with 2 tyres or 4 tyres.

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

For the candidate tyre testing, three 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 2 h 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 is greater than rear axle load.

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

— Conf.3: Rear axle load is greater than front axle load multiplied by 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 Formula (1):

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

where

p_r is the reference inflation pressure corresponding to the indication of the inflation pressure marked on the sidewall;

Q_t is the static test load of the tyre;

Q_r is the reference load 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 Formula (2):

$$p_t = p_r \times (0,75)^{1,25} = 0,7 \times p_r \quad (2)$$

where p_r is the reference inflation pressure corresponding to the indication of the 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 Procedures

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 press the brake pedal down 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 press the brake pedal down sharply, holding it down as long as necessary to perform the measurement.

Automatic activation of the brakes may 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) are not met when a measurement is made (e.g. speed tolerance, braking time), the measurement shall be discarded and a new measurement shall be made.

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

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

A maximum of three candidate tyre sets may be tested within the same braking test cycle.

EXAMPLE 1 The run order for a braking test cycle with three candidate tyre sets (T_1 to T_3) would be the following:

$R_i - T_1 - T_2 - T_3 - R_f$

EXAMPLE 2 The run order for a series of braking test cycles with a total of five candidate tyre sets (T_1 to T_5) would be the following:

$R_i - T_1 - T_2 - T_3 - R_f/R_i - T_4 - T_5 - R_f$,

where the final braking test of the reference tyre set (R_f) of the first braking test cycle serves as initial braking test (R_i) of the second braking test cycle.

6.7 Processing of measurement results

6.7.1 Calculation of the braking force coefficient

Each time the measurement is repeated, the braking force coefficient is calculated using Formula (3):

$$BFC = \frac{v_i^2 - v_f^2}{2 \times d \times g} = \frac{12{,}585\ \text{m}}{d} \tag{3}$$

where

d is the distance covered between v_i and v_f, in m;

v_f is the final speed, in $m \cdot s^{-1}$; v_f = 5,556 $m \cdot s^{-1}$;

v_i is the initial speed, in $m \cdot s^{-1}$; v_i = 16,667 $m \cdot s^{-1}$;

g is the acceleration due to gravity (rounded to 9,81 $m \cdot s^{-2}$).

6.7.2 Validation of results

6.7.2.1 General

The coefficient of variation, $CV(BFC)$, is calculated using Formula (4):

$$CV(BFC) = \frac{\sigma_{BFC}}{BFC_{\text{ave}}} \times 100\ \% \tag{4}$$

where

$$\sigma_{BFC} = \sqrt{\frac{1}{N-1} \times \sum_{i=1}^{N} (BFC_i - BFC_{\text{ave}})^2}$$

where

σ_{BFC} is the corrected sample standard deviation;

BFC_{ave} is the arithmetic mean of the braking force coefficients BFC_i of N test runs.

6.7.2.2 For the reference tyre

If the coefficient of variation *CV(BFC)* of the initial and the final braking test of the reference tyre within one braking test cycle is greater than 3 % discard all data and repeat the test for all tyres (the candidate tyres and the reference tyre).

6.7.2.3 For the candidate tyre

The coefficients of variation [see Formula (4)] are calculated for each candidate tyre. If the coefficient of variation *CV(BFC)* for one candidate tyre is greater than 3 %, discard the data for this candidate tyre and repeat the test.

6.7.3 Calculation of the adjusted braking force coefficients of the reference tyre

For the calculation of the wet grip index $G(T_n)$, the braking force coefficient *BFC* of the reference tyre set is adjusted according to the positioning of each candidate tyre set (T_n) within a given braking test cycle.

This adjusted braking force coefficient $BFC_{adj}(R)$ of the reference tyre is calculated in accordance with Table 2, where $BFC_{ave}(R_i)$ and $BFC_{ave}(R_f)$ are respectively the arithmetic means of the braking force coefficients in the initial and in the final braking test of the reference tyre within a braking test cycle.

Table 2 — Calculation of the adjusted braking force coefficients $BFC_{adj}(R)$ of the reference tyre

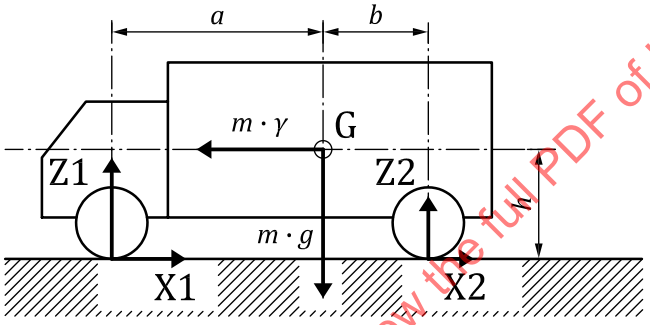
If the number and the sequence of candidate tyre sets within one braking test cycle is:	and the candidate tyre set to be qualified is:	the corresponding adjusted braking force coefficient $BFC_{adj}(R)$ of the reference tyre is calculated as follows:
$1\mid R_i - T_1 - R_f$	T_1	$BFC_{adj}(R) = \frac{1}{2} \times [BFC_{ave}(R_i) + BFC_{ave}(R_f)]$
$2\mid R_i - T_1 - T_2 - R_f$	T_1	$BFC_{adj}(R) = \frac{2}{3} \times BFC_{ave}(R_i) + \frac{1}{3} \times BFC_{ave}(R_f)$
	T_2	$BFC_{adj}(R) = \frac{1}{3} \times BFC_{ave}(R_i) + \frac{2}{3} \times BFC_{ave}(R_f)$
$3\mid R_i - T_1 - T_2 - T_3 - R_f$	T_1	$BFC_{adj}(R) = \frac{3}{4} \times BFC_{ave}(R_i) + \frac{1}{4} \times BFC_{ave}(R_f)$
	T_2	$BFC_{adj}(R) = \frac{1}{2} \times [BFC_{ave}(R_i) + BFC_{ave}(R_f)]$
	T_3	$BFC_{adj}(R) = \frac{1}{4} \times BFC_{ave}(R_i) + \frac{3}{4} \times BFC_{ave}(R_f)$

6.7.4 Calculation of the relative wet grip index of the tyre

The wet grip index $G(T_n)$ represents the relative performance of the candidate tyre T_n (n = 1, 2, ...) compared to the reference tyre. The way to obtain it depends on the test configuration as defined in 6.5.1, by applying the formulae contained in Table 3 (see Figure 1 for nomenclature explanation).

Table 3 — Calculation of the relative wet grip index of the tyre

Configuration 1: Candidate tyres on both axles	$G(\mathrm{T}_n)=\dfrac{BFC_{\mathrm{ave}}(\mathrm{T}_n)}{BFC_{\mathrm{adj}}(\mathrm{R})}$
Configuration 2: Candidate tyres on front axle and reference tyres on rear axle	$G(\mathrm{T}_n)=\dfrac{BFC_{\mathrm{ave}}(\mathrm{T}_n)\times\left[a+b+h\times BFC_{\mathrm{adj}}(\mathrm{R})\right]-a\times BFC_{\mathrm{adj}}(\mathrm{R})}{BFC_{\mathrm{adj}}(\mathrm{R})\times[\boldsymbol{b}+h\times BFC_{\mathrm{ave}}(\mathrm{T}_n)]}$
Configuration 3: Candidate tyres on rear axle and reference tyres on front axle	$G(T_n)=\dfrac{BFC_{\mathrm{ave}}(T_n)\times\left[-a-b+h\times BFC_{\mathrm{adj}}(R)\right]+b\times BFC_{\mathrm{adj}}(\mathrm{R})}{BFC_{\mathrm{adj}}(\mathrm{R})\times[-a+h\times BFC_{\mathrm{ave}}(\mathrm{T}_n)]}$
where a is the horizontal distance (m) between front axle and centre of gravity of the loaded vehicle; b is the horizontal distance (m) between rear axle and centre of gravity of the loaded vehicle; h is the vertical distance (m) between ground level and centre of gravity of the loaded vehicle; when h is not precisely known, these worst-case values shall apply: 1,2 m for configuration 2 and 1,5 m for configuration 3.	



Key

X1 longitudinal (X-direction) force of the front tyre on the road
X2 longitudinal (X-direction) force of the rear tyre on the road
Z1 normal (Z-direction) force of the front tyre on the road
Z2 normal (Z-direction) force of the rear tyre on the road
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 ($\mathrm{m{\cdot}s^{-2}}$)
g acceleration due to the gravity ($\mathrm{m{\cdot}s^{-2}}$)

Figure 1 — Nomenclature explanation related to wet 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, where 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 shall be in conformity with 6.2 to 6.5.

The control tyre set (4 tyres or 6 tyres) shall be physically the same set used for the first and second assessments described hereafter.

The first assessment is a comparison between the control tyre C and the reference tyre. The result [wet grip index G_1(C)] is the relative efficiency of the control tyre compared to the reference tyre.

The second assessment is a comparison between the candidate tyre T_n and the control tyre C. The result [wet grip index $G_2(T_n)$] is the relative efficiency of the candidate tyre compared to the control tyre.

The second assessment shall be 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 wet grip index $G(T_n)$ of the candidate tyre T_n compared to the reference tyre is deduced by multiplying the relative efficiencies calculated above:

$$G(T_n) = G_1(C) \times G_2(T_n)$$

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, for example, radar, GPS) speed-measuring system shall be used. Output may be directly displayed to the driver and may 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 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 10 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 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 temperature prior to testing, and shield them from the sun to avoid excessive heating by solar radiation.

7.4.3 Check the test tyres for the specified inflation pressure at ambient temperature (cold), just prior to testing. For the purpose of this document, the testing tyre cold inflation pressure p_t shall be calculated using Formula (1) again:

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

where

p_r is the reference test inflation pressure corresponding to the indication of the inflation pressure marked on the sidewall;

Q_t is the static test load of the tyre (see 7.6);

Q_r is the reference load associated with the load index.

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.

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

7.4.5 One tyre set shall consist of the standard reference test tyre required for the evaluation of the test tyres (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 10 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 associated with 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 the application of the brake (for a self-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 7.7.1 to 7.7.5 at least six times, making runs in the same direction.

7.7.7 Test consecutive sets of tyres by repeating 7.7.1 to 7.7.6, 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 candidate tyre sets may be tested within the same braking test cycle.

EXAMPLE

The run order for a braking test cycle with three candidate tyre sets (T_1 to T_3) would be the following:

$R_i - T_1 - T_2 - T_3 - R_f$

The run order for a series of braking test cycles with a total of five candidate tyre sets (T_1 to T_5) would be the following:

$R_i - T_1 - T_2 - T_3 - R_f/R_i - T_4 - T_5 - R_f$

where the final braking test of the reference tyre set of the first braking test cycle serves as initial braking test of the second braking test cycle.

7.8 Processing of measurement results

7.8.1 General

7.8.1.1 Calculate the dynamic tyre braking force coefficient, $\mu(t)$, for each test using Formula (5):

$$\mu(t) = \left| \frac{f_{h\,(t)}}{f_{v\,(t)}} \right| \tag{5}$$

where

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

$f_h(t)$ is the dynamic braking force in real time, in newtons;

$f_v(t)$ is the dynamic vertical load in real time, in newtons.

7.8.1.2 Using Formula (5) 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. Analogue 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 $\mu_{peak,ave}$ of peak braking force coefficients, by averaging six or more repeated runs for each set of test and reference tyres for each test condition.

7.8.2 Validation of results

For each braking test, the coefficient of variation of the μ_{peak}, $CV(\mu_{peak})$, is calculated as follows:

$$\mathrm{CV}\,(\mu_{peak}) = 100 \times \frac{\sigma_\mu}{\mu_{peak,ave}}$$

where

$$\sigma_\mu = \sqrt{\frac{1}{N-1} \times \sum_{i=1}^{N} \left(\mu_{peak,i} - \mu_{peak,ave}\right)^2}$$

$\mu_{peak,ave}$ is the arithmetic mean of the peak braking force coefficients ($\mu_{peak,i}$) of N test runs.

The standard deviation and average refer to the measured μ_{peak} values of all runs of that braking test.

7.8.2.1 For the reference tyre

If the coefficient of variation $CV(\mu_{peak})$ of the initial or the final braking test of the reference tyre within one braking test cycle is greater than 5 %, discard all data and repeat the test for all tyres (the candidate tyres and the reference tyres).

7.8.2.2 For the candidate tyres

The coefficients of variation are calculated for each candidate tyre. If the coefficient of variation $CV(\mu_{peak})$ for one candidate tyre is greater than 5 %, discard the data for this candidate tyre and repeat the test.

7.8.3 Calculation of the relative wet grip index of the tyre

For the calculation of the wet grip index $G(T_n)$, the peak braking force coefficient of the reference tyre set is adjusted according to the positioning of each candidate tyre set (T_n) within a given braking test cycle.