INTERNATIONAL STANDARD

**ISO 28580**

Second edition
2018-07

# Passenger car, truck and bus tyre rolling resistance measurement method — Single point test and correlation of measurement results

*Méthode de mesure de la résistance au roulement des pneumatiques pour voitures particulières, camions et autobus — Essai à condition de mesure unique et corrélation des résultats de mesure*

Reference number
ISO 28580:2018(E)

# Contents

Page

# Foreword

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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).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

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

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.

This second edition cancels and replaces the first edition (ISO 28580:2009), which has been technically revised. The main changes compared to the previous edition are as follows:

— Incorporation of clarifications and additional detail, for example those identified in ISO/TR 16377;

— Expansion of the concept of reference machine to include two possible types, a physical reference or a virtual reference;

— Allowance for alignment to be carried out based on a set of two or more alignment tyres as defined by the authorizing body;

— Ability to reduce the warm-up duration of larger truck and bus tyres under certain conditions;

— Alignment improvement through the use of four measures of each alignment tyre, using only the last three measures for computations;

— Additional information concerning machine drift evaluation.

# Passenger car, truck and bus tyre rolling resistance measurement method — Single point test and correlation of measurement results

## 1 Scope

This document specifies methods for measuring rolling resistance, under controlled laboratory conditions, for new pneumatic tyres designed primarily for use on passenger cars, trucks and buses. This document is not applicable to tyres intended for temporary use only. It includes a method for correlating measurement results to allow inter-laboratory comparisons. It is designed to facilitate international cooperation and, possibly, regulation building.

Measurement of tyres using this method enables comparisons to be made between the rolling resistance of new test tyres when they are free-rolling straight ahead, in a position perpendicular to the drum outer surface, and in steady-state conditions.

## 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 4000-1:2015, *Passenger car tyres and rims — Part 1: Tyres*

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 8855, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ISO 17025, *General requirements for the competence of testing and calibration laboratories*

## 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 terminological databases for use in standardization at the following addresses:

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

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

**3.1**
**rolling resistance**
$F_r$
loss of energy (or energy consumed) per unit of distance travelled

Note 1 to entry: The SI unit conventionally used for the rolling resistance is the newton metre per metre (N m/m). This is equivalent to a drag force in newtons (N).

**3.2**
**rolling resistance coefficient**
$C_r$
ratio of the rolling resistance to the load on the tyre

Note 1 to entry: Rolling resistance is measured in newtons (N).

Note 2 to entry: Load on the tyre is measured in kilonewtons (kN).

Note 3 to entry: Although this quantity is dimensionless, it is conventionally expressed in N/kN.

**3.3**
**capped inflation**
process of inflating the tyre to the required cold pressure and allowing the inflation pressure to build up as the tyre is warmed up while running

**3.4**
**parasitic loss**
loss of energy (or energy consumed) per unit distance excluding internal tyre losses, and attributable to aerodynamic loss of the different rotating elements of the test equipment, bearing friction and other sources of systematic loss which can be inherent in the measurement

Note 1 to entry: This document describes which of them are to be excluded from the result of the measurement.

**3.5**
**skim test reading**
type of parasitic loss measurement, in which the tyre is kept rolling, without slippage, while reducing the tyre load to a level at which energy loss within the tyre itself is virtually zero

**3.6**
**moment of inertia**
inertia
ratio of the torque applied to a rotating body, such as a tyre assembly or machine drum, to the rotational acceleration of this body

Note 1 to entry: See Annex B.

**3.7**
**new test tyre**
tyre which has not been previously used in a rolling deflected test which elevates the tyre's temperature to higher than that generated in rolling resistance tests or has not been exposed to a temperature higher than 40 °C

Note 1 to entry: Repetition of allowed test procedures is permitted.

Note 2 to entry: See examples in this document, ISO 18164, SAE J1269, SAE J2452.

**3.8**
**correlation of measurement results**
computations on a set of rolling resistance measurements to be carried out on a regular time basis by separate laboratories in order to allow direct comparisons between their rolling resistance results

Note 1 to entry: The results of these measurements are used to compute "alignment" corrective coefficients and permit calculation of aligned rolling resistance measurement, $C_{r\ aligned}$ (see Clause 10).

**3.9**
**reference machine**
any machine considered as a reference for an alignment

Note 1 to entry: Every tyre testing spindle in one specific measurement method is considered a machine for the purposes of this standard. For example, two spindles acting on the same drum shall not be considered as one machine. One spindle able to measure tyre rolling resistance through different methods shall not be considered as one machine.

**3.9.1**
**physical reference machine**
machine (and its corresponding laboratory quality systems) used to set alignment values

**3.9.2**
**virtual reference machine**
several machines (and their corresponding laboratory quality systems) used to set alignment values

**3.10**
**candidate machine**
machine intended to measure new test tyres, with alignment to a reference machine, according to this document

**3.11**
**alignment tyres**
set of tyres measured by both the candidate and reference machines to perform machine alignment

**3.12**
**laboratory control tyre**
tyre used by an individual laboratory to control machine behaviour, e.g. machine drift, as a function of time

**3.13**
**measurement repeatability**
$\sigma_{\mathrm{m}}$
dispersion of the results obtained on one machine for different measurements performed on the same tyre(s) over a short period of time under the same testing conditions

Note 1 to entry: Measurement repeatability is estimated by measuring $n$ + 1 times the whole process described in Clause 7 ($n \geq 3$) for $p$ alignment tyres, assuming that the variances of the alignment tyres are homogeneous:

$$\sigma_{\mathrm{m}} = \sqrt{\frac{1}{p} \cdot \Sigma_{i=1}^{p} \sigma_{\mathrm{m},i}^{2}} \quad \text{with } \sigma_{\mathrm{m},i} = \sqrt{\frac{1}{(n-1)} \cdot \sum_{j=2}^{n+1} \left( C_{\mathrm{r}i,j} - \frac{1}{n} \sum_{j=2}^{n+1} C_{\mathrm{r}i,j} \right)^{2}}$$

where

| | |
|---|---|
| $p$ | is the number of alignment tyres; |
| $i$ | is the counter from 1 to $p$ for the alignment tyres; |
| $j$ | is the counter from 2 to $n$ + 1 for the $n$ last repetitions of each measurement of a given alignment tyre; |
| $n$ + 1 | is the number of repetitions of tyre measurements ($n$ + 1=4 for reference laboratories and $n + 1 \geq 4$ for candidate laboratories). The last $n$ measurement results are used for the computation. |

**3.14**
**machine drift**
change in the measured value over time which can be attributed to systematic (or progressive) sources of variation

**3.15**
**passenger car tyre**
tyre of a group intended for application on 4-wheeled vehicles designed primarily for carrying fewer than 10 persons

Note 1 to entry: See Annex D for a list of standards which identify this tyre type.

**3.16**
**truck and bus tyre**
tyre of a group intended for application on vehicles designed primarily for the transportation of property or for carrying more than 10 persons

Note 1 to entry: Such tyres are normally primarily designed for use on light trucks, trucks, buses and their trailers and include those tyres marked with “LT”, “C”, “ST”, “CP”.

Note 2 to entry: See Annex D for a list of standards which identify this tyre type.

**3.16.1**
**smaller truck and bus tyre**
truck and bus tyre with a load index of 121 and smaller or, where the load index is not marked, a maximum load of 1 450 kg and lower

**3.16.2**
**larger truck and bus tyre**
truck and bus tyre with a load index greater than 121 or, where the load index is not marked, a maximum load of more than 1 450 kg

# 4 Test methods

The following are alternative measurement methods. The choice of an individual method is left to the tester. For each method, the test measurements shall be converted to a force acting at the tyre/drum interface. The measured parameters are:

a) Force method: the reaction force measured or converted at the tyre spindle (see NOTE 1);

b) Torque method: the torque input measured at the test drum (see NOTE 2);

c) Deceleration method: the measurement of deceleration of the test drum and tyre assembly (see NOTE 2);

d) Power method: the measurement of the power input to the test drum (see NOTE 2).

NOTE 1 This measured value also includes the bearing and aerodynamic losses of the wheel and tyre which are also to be considered for further data interpretation.

NOTE 2 This measured value also includes the bearing and aerodynamic losses of the wheel, the tyre, and the drum losses which are also to be considered for further data interpretation.

# 5 Test equipment

## 5.1 General

In measuring tyre rolling resistance, it is necessary to measure small forces in the presence of much larger forces. It is, therefore, essential that equipment and instrumentation of appropriate accuracy be used.

## 5.2 Drum specifications

### 5.2.1 Diameter

The test dynamometer shall have a cylindrical flywheel (drum) with a diameter of at least 1,7 m.

The $F_r$ and $C_r$ values shall be expressed relative to a drum diameter of 2,0 m. If a drum diameter other than 2,0 m is used, a correlation adjustment shall be made following the method in 9.3.

### 5.2.2 Surface

The surface of the drum shall be smooth steel. Optionally, a textured surface may also be used in order to improve skim test reading accuracy. It shall be kept clean.

The $F_r$ and $C_r$ values shall be expressed relative to the “smooth” drum surface. If textured drum surface is used, reference A.6.

### 5.2.3 Width

The width of the drum test surface shall exceed the width of the test tyre contact patch.

## 5.3 Measuring rim

The tyre shall be mounted on a steel or light alloy measuring rim, with the width as defined in ISO 4000-1 for passenger car tyre rims and as defined in ISO 4209-1 for truck and bus tyre rims. If a size is not included in ISO 4000-1 or ISO 4209-1, refer to the relevant calculation section. Mounting tyres on other rim widths shall be done with the agreement of the requestor and the tester and such deviation shall be noted on the test report. Rim runout guidelines are listed in Annex C.

## 5.4 Load, alignment, control and instrumentation accuracies

Measurement of these parameters shall be sufficiently accurate and precise to provide the required test data. The specific and respective values are shown in Annex A.

## 5.5 Thermal environment

### 5.5.1 Reference conditions

The reference ambient temperature, as measured at a distance from the tyre sidewall of not less than 0,15 m and not more than 1 m, shall be 25 °C.

### 5.5.2 Alternative conditions

If the test ambient temperature is different from the reference ambient temperature, the rolling resistance measurement shall be corrected to the reference ambient temperature in accordance with 9.2.

# 6 Test conditions

## 6.1 General

The test consists of a measurement of rolling resistance in which the tyre is inflated to the required cold pressure and the inflation pressure allowed to build up (i.e. “capped inflation”).

Any measurement other than what is prescribed within this document shall be done under the requestor’s responsibility and should be noted on the test report (e.g. retread tyres, buffed tyres, different rim width, pressures, loads, etc.). Studded tyres are not allowed due to potential drum damage.

## 6.2 Test speeds

The rolling resistance coefficient value shall be obtained at a drum speed as shown in Table 1.

**Table 1 — Test speeds**

Speeds in km/h

| Tyre type | Passenger car | Smaller truck and bus | Larger truck and bus | |
|---|---|---|---|---|
| Speed symbol[a] | All | All | J (100 km/h) and lower | K (110 km/h) and higher |
| Speed | 80 | 80 | 60 | 80 |

[a] If the tyre is not marked with a speed symbol, consult the manufacturer databook for the maximum rated speed and select a test speed of 60 km/h for maximum rated speed of 100 km/h or lower; otherwise, test speed is 80 km/h.

## 6.3 Test load

The standard test load shall be computed from the values shown in Table 2 and shall be kept within the tolerance specified in Annex A.

## 6.4 Test inflation pressure

The inflation pressure shall be in accordance with that shown in Table 2 and shall be capped with the accuracy specified in A.4.

**Table 2 — Test loads and inflation pressures**

| Tyre type | Passenger car[a] | | Truck and bus[b] |
|---|---|---|---|
| | Standard load or light load | Reinforced or extra load | |
| Load — % of maximum load capacity | 80 | 80 | 85[c]<br>(% of single load) |
| Inflation pressure[d]<br>kPa | 210 | 250 | Corresponding to maximum single tyre load carrying capacity[e] |

[a] For those passenger car tyres belonging to categories which are not shown in ISO 4000-1:2015, Annex B, the inflation pressure shall be the inflation pressure recommended by the tyre manufacturer, corresponding to the maximum tyre load capacity, reduced by 30 kPa.

[b] If there are multiple values given, the highest load and corresponding pressure should be selected, disregarding any additional service description, which, if present, is located in a circle close to the primary service description.

[c] 85 % of maximum load capacity for single application specified in applicable tyre standards manuals.

[d] The inflation pressure shall be capped with the accuracy specified in A.4.

[e] Inflation pressure as specified in applicable tyre standards manuals corresponding to maximum single tyre load carrying capacity.

## 6.5 Duration and speed

When the deceleration method is selected, the following requirements apply:

a) For duration $\Delta t$, the time increments shall not exceed 0,5 s;

b) Any variation of the test drum speed shall not exceed 1 km/h within one time increment.

# 7 Test procedure

## 7.1 General

The test procedure steps described below are to be followed in the sequence given.

## 7.2 Thermal conditioning

Place the inflated tyre in the thermal environment of the test location for a minimum of 3 h for passenger car tyres and a minimum of 6 h for truck and bus tyres.

## 7.3 Pressure adjustment

After thermal conditioning, the inflation pressure shall be adjusted to the test pressure and verified 10 min after the adjustment is made.

## 7.4 Warm-up

Warm-up duration is given in Table 3.

**Table 3 — Warm-up duration**

| Tyre type | Passenger car | Smaller truck and bus | Larger truck and bus[a] | |
|---|---|---|---|---|
| Nominal rim diameter code | All | All | <22,5 | ≥22,5 |
| Warm-up duration | 30 min | 50 min | 150 min | 180 min |

[a] For the torque and force methods, larger truck and bus warm-up duration can be decreased from the specified values if the following requirements can be met:

1) Real time machine monitoring is available for input torque or spindle force with data averages every minute, and

2) It can be demonstrated that a tyre has reached a stabilized steady-state value of rolling resistance when the absolute difference between data samples over a 10 min period is ≤0,1 N.

An example is provided in Annex E. The warm-up duration shall be indicated on the test report if different from that shown in the table.

## 7.5 Measurement and recording

The following shall be measured and recorded (see Figure 1):

a) Test speed, $U_n$;

b) Load on the tyre normal to the drum surface, $L_m$;

c) Test inflation pressure: initial, as defined in 6.4;

d) Rolling resistance coefficient measured, $C_r$, and its corrected value, $C_{rc}$, at 25 °C and for a drum diameter of 2 m;

e) Distance from the tyre axis to the drum outer surface under steady state conditions, in metres, $r_L$;

f) Ambient temperature, $t_{amb}$;

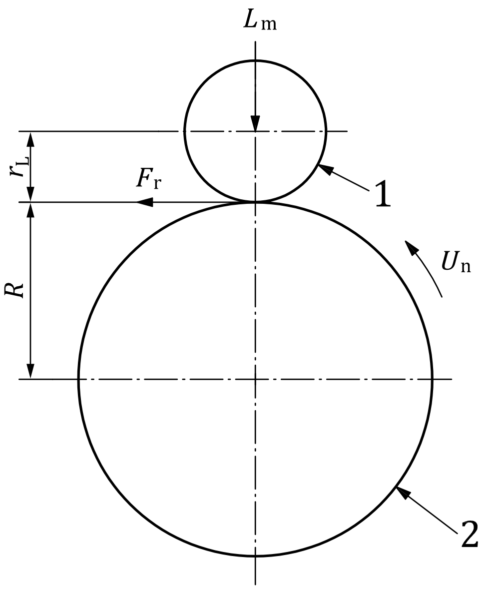
g) Test drum radius, $R$;

h) Test method chosen;

i) Test rim (size and material). If not the prescribed measuring rim, the deviation shall be highlighted;

j) Tyre identification such as: size, manufacturer, type, and, if it exists, SS, LI, Load Range, DOT Tire Identification number and/or serial number.

All the mechanical quantities (forces, torques) shall be orientated according to the ISO 8855 referential. The directional tyres shall be run in their specified rotation sense.




**Key**

1 tyre

2 drum

**Figure 1 — Measurement orientation**

## 7.6 Measurement of parasitic losses

### 7.6.1 General

The parasitic losses shall be determined by one of the procedures given in 7.6.2 or 7.6.3.

### 7.6.2 Skim test reading

a) Reduce the load to maintain the tyre at the test speed without slippage. The load values should be as follows:

Passenger car tyres: recommended value of 100 N; not to exceed 200 N.

Smaller truck and bus tyres (LI ≤ 121): recommended value of 150 N; not to exceed 200 N for machines designed for passenger car tyre measurement or 500 N for machine designed for truck and bus tyres.

Larger truck and bus tyres (LI > 121): recommended value of 400 N; not to exceed 500 N.

Skim values shall be the same for both standard testing and alignment (Clause 10).

b) Record the spindle force, $F_t$, input torque, $T_t$, or the power, whichever applies.

c) Record the load on the tyre normal to the drum surface, $L_m$.

NOTE 1 Except for the force method, the measured value includes the bearing and aerodynamic losses of the wheel, the tyre, and the drum losses. For the force method, the measured value includes the bearing and aerodynamic losses of the wheel and the tyre.

NOTE 2 It is known that the spindle and drum bearings friction depends on the applied load and, in consequence, is different for the loaded system measurement and the skim test reading. But for practical reasons, this difference could be disregarded.

### 7.6.3 Deceleration method

a) Remove the tyre from the test surface while running at a speed greater than test speed.

b) Record the deceleration of the test drum, $\Delta\omega_{Do}/\Delta t_0$, and that of the unloaded tyre, $\Delta\omega_{To}/\Delta t_0$.

The speed range for measurement includes the test speed and does not exceed 10 km/h above and 10 km/h below the test speed.

The measured value includes the bearing and aerodynamic losses of the wheel, the tyre, and the drum losses which are also to be considered.

NOTE It is known that the spindle and drum bearings friction depends on the applied load and, in consequence, is different for the loaded system measurement and the free deceleration. But for practical reasons, this difference can be disregarded.

The speed range of the rolling resistance measurement with loaded tyre shall respect the same condition as for the parasitic losses measurement as described above.

## 7.7 Allowance for machines exceeding $\sigma_m$ criterion

The steps described in 7.4 to 7.6 shall be carried out one time if the measurement standard deviation, determined as described in 10.3.3, is not greater than 0,075 N/kN for passenger car and smaller truck and bus tyres and not greater than 0,06 N/kN for larger truck and bus tyres. If the measurement standard deviation exceeds this criterion, the measurement process shall be repeated $n$ times as described in 10.3.3. The rolling resistance value reported shall be the average of the $n$ measurements.

# 8 Data interpretation

## 8.1 Determination of parasitic losses

### 8.1.1 General

The laboratory shall perform the measurements described in 7.6.2 for force, torque and power methods or 7.6.3 for deceleration, in order to precisely determine the tyre spindle friction, the tyre + wheel aerodynamic losses, the drum (+ eventually engine and/or clutch) bearings friction and the drum aerodynamic losses, in the test conditions (load, speed, temperature). The parasitic losses, $F_{pl}$, related to the tyre/drum interface, expressed in newtons, shall be calculated from the force $F_t$, torque, power or the deceleration, as shown below.

### 8.1.2 Force method at tyre spindle

Calculate $F_{pl}$ using Formula (1):

$$F_{pl} = F_{tp}\left(1 + \frac{r_{Lp}}{R}\right) \tag{1}$$

where

$F_{tp}$ is the tyre spindle force in newtons (see 7.6.2);

$r_{Lp}$ is the distance from the tyre axis to the drum outer surface under steady state conditions, in metres;

$R$ is the test drum radius, in metres.

### 8.1.3 Torque method at drum axis

Calculate $F_{pl}$ using Formula (2):

$$F_{pl} = \frac{T_{tp}}{R} \tag{2}$$

where

$T_{tp}$ is the input torque in newton metres as determined in 7.6.2;

$R$ is the test drum radius, in metres.

### 8.1.4 Power method at drum axis

Calculate $F_{pl}$ using Formula (3):

$$F_{pl} = \frac{3{,}6 V_p \times A_p}{U_n} \tag{3}$$

where

$V_p$ is the electrical potential applied to the machine drive, in volts;

$A_p$ is the electric current drawn by the machine drive, in amperes;

$U_n$ is the test drum speed, in kilometres per hour.

### 8.1.5 Deceleration method

Calculate the parasitic losses, $F_{pl}$, in newtons, using Formula (4):

$$F_{pl} = \frac{I_D}{R}\left(\frac{\Delta\omega_{D0}}{\Delta t_0}\right) + \frac{I_T}{R_r}\left(\frac{\Delta\omega_{T0}}{\Delta t_0}\right) \tag{4}$$

where

$I_D$ is the test drum inertia in rotation, in kilogram metres squared;

$R$ is the test drum surface radius, in metres;

$\Delta\omega_{D0}$ is the test drum angular speed increment, drum without tyre, in radians per second;

$\Delta t_0$ is the time increment chosen for the measurement of the parasitic losses without tyre, in seconds;

$I_T$ is the spindle, tyre and wheel inertia in rotation, in kilogram metres squared;

$R_r$ is the tyre rolling radius, in metres;

$\Delta\omega_{T0}$ is the tyre angular speed increment, unloaded tyre, in radians per second.

## 8.2 Rolling resistance calculation

### 8.2.1 General

Calculate the rolling resistance using the values obtained by testing the tyre to the conditions specified in this document and by subtracting the appropriate parasitic losses, $F_{pl}$, obtained according to 8.1.

### 8.2.2 Force method at tyre spindle

The rolling resistance, $F_r$, in newtons, is calculated using Formula (5):

$$F_r = F_t\left(1+\frac{r_L}{R}\right) - F_{pl} \tag{5}$$

where

$F_t$ is the tyre spindle force, in newtons;

$F_{pl}$ represents the parasitic losses as calculated in 8.1.2;

$r_L$ is the distance from the tyre axis to the drum outer surface under steady-state conditions, in metres;

$R$ is the test drum radius, in metres.

### 8.2.3 Torque method at drum axis

The rolling resistance, $F_r$, in newtons, is calculated using Formula (6):

$$F_r = \frac{T_t}{R} - F_{pl} \tag{6}$$

where

$T_t$ is the input torque, in newton metres;

$F_{pl}$ represents the parasitic losses as calculated in 8.1.3;

$R$ is the test drum radius, in metres.

### 8.2.4 Power method at drum axis

The rolling resistance, $F_r$, in newtons, is calculated using Formula (7):

$$F_r = \frac{3{,}6V \times A}{U_n} - F_{pl} \tag{7}$$

where

$V$ is the electrical potential applied to the machine drive, in volts;

$A$ is the electric current drawn by the machine drive, in amperes;

$U_n$ is the test drum speed, in kilometres per hour;

$F_{pl}$ represents the parasitic losses as calculated in 8.1.4.

### 8.2.5 Deceleration method

The rolling resistance, $F_r$, in newtons, is calculated using Formula (8):

$$F_r = \frac{I_D}{R}\left(\frac{\Delta\omega_v}{\Delta t_v}\right) + \frac{R I_T}{{R_r}^2}\left(\frac{\Delta\omega_v}{\Delta t_v}\right) - F_{pl} \tag{8}$$

where

$I_D$ is the test drum inertia in rotation, in kilogram metres squared;

$R$ is the test drum surface radius, in metres;

$\Delta\omega_v$ is the test drum angular speed increment, loaded tyre, in radians per second;

$\Delta t_v$ is the time increment chosen for measurement, in seconds;

$I_T$ is the spindle, tyre and wheel inertia in rotation, in kilogram metres squared;

$R_r$ is the tyre rolling radius, in metres;

$F_{pl}$ represents the parasitic losses as calculated in 8.1.5.

NOTE Annex B gives guidelines and practical examples to measure the moments of inertia for the deceleration method.

## 9 Data analysis

### 9.1 Rolling resistance coefficient

The rolling resistance coefficient $C_r$ is calculated by dividing the rolling resistance by the load on the tyre using Formula (9):

$$C_r = \frac{F_r}{L_m} \tag{9}$$

where

$F_r$ is the rolling resistance, in newtons;

$L_m$ is the test load, in kilonewtons.

### 9.2 Temperature correction

If measurements at temperatures other than 25 °C are unavoidable (only temperatures not less than 20 °C nor more than 30 °C are acceptable), then a correction for temperature shall be made using Formula (10):

$$F_{r25} = F_r\,[1 + K_t\,(t_{amb} - 25)] \tag{10}$$

where

$F_{r25}$ is the rolling resistance at 25 °C, in newtons

$F_r$ is the rolling resistance, in newtons;

$K_t$ is equal to

0,008 for passenger car tyres;

0,010 for smaller truck and bus tyres;

0,006 for larger truck and bus tyres;

$t_{amb}$ is the ambient temperature, in degrees Celsius.

## 9.3 Drum diameter correction

Test results obtained from different drum diameters may be compared by using Formula (11) (theoretical):

$$F_{r02} \cong K_R F_{r01} \tag{11}$$

with

$$K_R = \sqrt{\frac{\left(\frac{R_1}{R_2}\right)(R_2 + r_T)}{(R_1 + r_T)}} \tag{12}$$

where

$F_{r02}$ is the rolling resistance value measured on drum 2, in newtons;

$F_{r01}$ is the rolling resistance value measured on drum 1, in newtons;

$R_1$ is the radius of drum 1, in metres;

$R_2$ is the radius of drum 2, in metres;

$r_T$ is one-half of the nominal design tyre diameter, in metres.

## 9.4 Measurement result

Where $n$ measurements are greater than 1, if required by 10.3.3, the measurement result shall be the average of the $C_r$ values obtained for the $n$ measurements, after the corrections described in 9.2 and 9.3.

Following this method, final $C_r$ results shall be expressed in N/kN and rounded to the first decimal place as follows:

rounding range: 0,1

| given number | rounded number |
|---|---|
| 12,25 | 12,3 |
| 12,35 | 12,4 |

[SOURCE: ISO 80000-1:2009, B.3, rule B (Example 1)]

# 10 Measurement machines alignment and monitoring requirements

## 10.1 General

This part describes the procedure to be used to align measurement results and allow direct inter-laboratory comparisons. This process shall be applied to each measurement machine the results of which are declared conforming to this document and where inter-comparability is required.

This procedure may be used both for alignment to a physical reference machine or for alignment to a virtual reference, according to the body (public authority or other party) decision. This machine alignment procedure requires alignment tyres provided by the candidate laboratory operating the machine. The number of alignment tyres is defined by the body requesting the machine alignment. These tyres are used to align candidate machine(s) by comparing the measured $C_r$ results to the ones obtained on a reference machine. An alignment formula is then built and has to be used to translate the results obtained on the candidate machine into aligned results.

In the case of a physical reference machine, its actual measured values are used to build the alignment formula. In the case of a virtual reference machine, the way of alignment of a candidate machine is defined by the body requesting the machine alignment.

## 10.2 Conditions for reference machine

**10.2.1** The laboratory(ies) operating the reference machine(s) shall comply with ISO/IEC 17025.

**10.2.2** The reference machine laboratory control tyre monitoring shall occur at a maximum interval of one month. Monitoring shall include a minimum of three separate measurements sometime during this one month period. The average of the three measurements made during a one month interval shall be evaluated for machine drift from one monthly evaluation to another. See Annex F.

**10.2.3** The laboratory(ies) shall ensure that, based on a minimum of three measurements, the reference machine(s) maintain(s) a value of $\sigma_m \leq 0{,}05$ N/kN. This may be done using the laboratory control tyre(s) (as specified in 10.2.2).

## 10.3 Conditions for candidate machine

**10.3.1** The laboratory which operates the candidate machine shall comply with ISO/IEC 17025.

**10.3.2** The candidate machine laboratory control tyre monitoring shall occur at a maximum interval of one month. Monitoring shall include a minimum of three separate measurements sometime during this one month period. The average of the three measurements made during a one month interval shall be evaluated for machine drift from one monthly evaluation to another. See Annex F.

**10.3.3** The laboratory shall ensure that, based on a minimum of three measurements, the candidate machine maintains the following values of $\sigma_m$ as measured on a single tyre.

— $\sigma_m \leq 0{,}075$ N/kN for passenger car and smaller truck and bus tyres;

— $\sigma_m \leq 0{,}06$ N/kN for larger truck and bus tyres.

If the above requirement for $\sigma_m$ is not met, Formula (13) shall be applied to determine the minimum number of measurements, $n$ (rounded to the immediate superior integer value), required by this machine to qualify for use according to this document.

$$n = \left( \frac{\sigma_m}{x} \right)^2 \tag{13}$$

where

$x$ = 0,075 for passenger car and smaller truck and bus tyres;

$x$ = 0,06 for larger truck and bus tyres.

If a tyre needs to be measured several times, the tyre/wheel assembly shall be removed from the machine between the successive measurements.

### 10.4 Alignment tyre requirements

**10.4.1** The alignment tyres used to conduct the alignment procedure shall be identified to cover the needed usage range in terms of load index, $C_r$ and $F_r$ as follows:

— $C_r$ values having a minimum range of 3 N/kN for passenger car and smaller truck and bus tyres and 2 N/kN for larger truck and bus tyres.

— In the case where more than two alignment tyres are used, the declared $C_r$ values of each alignment tyre of the set shall be distributed uniformly.

— Load index values shall adequately cover the range for the tyres to be tested, ensuring that the $F_r$ values also cover the range for the tyres to be tested. The ratio of rolling resistance force ($F_r$) between the highest $F_r$ and the lowest $F_r$ of the tyre set shall be, before alignment, at least equal to 2, for passenger car, smaller and larger truck and bus tyres.

— In the case of an alignment with a physical reference, both reference and candidate machines shall use the same physical alignment tyres.

— In the case of an alignment with a virtual reference, both reference machine (from the network) and candidate machine shall use the same physical alignment tyres.

**10.4.2** Each alignment tyre shall be checked prior to use and replaced when either of the following occurs:

a. it shows a condition which makes it unusable for further tests;

b. there are deviations of $C_r$ for alignment tyre measurement greater than 1,5 % relative to earlier measurements after correction for any machine drift.

### 10.5 Alignment procedure

**10.5.1** Each time an alignment tyre is measured, the tyre/wheel assembly shall be removed from the machine and the entire test procedure specified in Clause 7 shall be followed again. This requirement applies to both the reference laboratory(ies) and the candidate laboratory.

**10.5.2** The laboratory(ies) operating the reference machine shall measure each alignment tyre four times in accordance with Clause 7 applying the conditions in Clause 6, and provide the mean value and standard deviation established from the three last measurements, for each tyre.

**10.5.3** The candidate machine shall measure each alignment tyre four times, the last three measurements being used for the computations in accordance with Clause 7 applying the conditions in Clause 6, with a measurement standard deviation for each tyre of

— not greater than 0,075 N/kN for passenger car and smaller truck and bus tyres, and

— not greater than 0,06 N/kN for larger truck and bus tyres.

If this measurement standard deviation exceeds this criterion with four measurements, where the last three measurements are used for the computations, then the number $n$ + 1 of measurement repetitions shall be increased as per Formula (14):

$$n+1=\left(\frac{\sigma_{\mathrm{m}}}{\gamma}\right)^2+1 \tag{14}$$

where

$\gamma$ = 0,043 for passenger car and smaller truck and bus tyres;

$\gamma$ = 0,035 for larger truck and bus tyres.

**10.5.4** In the case of a physical reference machine, the alignment shall be performed by the candidate laboratory unless otherwise specified by the body requesting the alignment, and shall be a linear regression technique with the alignment results, A and B, given as per Formula (15):

$$C_{\mathrm{r\ aligned}} = (A \times C_{\mathrm{r}}) + B \tag{15}$$

where $C_{\mathrm{r}}$ is the rolling resistance coefficient measured by the candidate machine.

The measurement standard deviation estimate, $\sigma_{\mathrm{m}}$, shall also be given.

In the case of a virtual reference machine, the alignment of a candidate machine is defined by the body requesting the machine alignment.

In all cases, the data format and rounding to be used for the alignment computations shall be defined by the body requesting the machine alignment.

**10.5.5** The alignment process of candidate machines shall be repeated at least every second year and always after any significant machine change or any machine drift in control tyre monitoring data.

**10.5.6** If the linear regression coefficient of determination $R^2$ is lower than 0,97 the candidate laboratory shall not be aligned.

# Annex A
(normative)

# Test equipment tolerances

## A.1 Purpose

The limits specified in this annex are necessary in order to achieve suitable levels of repeatable test results, which can also be correlated among various test laboratories.

## A.2 Alignment

### A.2.1 General

Angle deviations are critical to the test results.

### A.2.2 Load application

The direction of tyre loading application shall be kept normal to the test surface and shall pass through the wheel centre within

— 1 mrad for the force method;

— 5 mrad for the torque, deceleration and power methods.

### A.2.3 Tyre alignment

#### A.2.3.1 Camber angle

The plane of the wheel shall be normal to the test surface within 2 mrad for all methods.

#### A.2.3.2 Slip angle

The plane of the tyre shall be parallel to the direction of the test surface motion within 1 mrad for all methods.

## A.3 Control accuracy

Exclusive of perturbations induced by the tyre and rim non-uniformity, test conditions shall be maintained at their specified values such that the overall variability of the rolling resistance measurement is minimized. To meet this requirement, the average value of measurements taken during the rolling resistance data collection period shall be within the accuracies stated as follows:

— tyre loading:

Greater of ±20 N or ±0,5 % for passenger car and smaller truck and bus tyres;

Greater of ±45 N or ±0,5 % for larger truck and bus tyres;

— inflation pressure: ±3 kPa;

— surface speed:

±0,2 km/h for the power, torque and deceleration methods;

±0,5 km/h for the force method;

— time:

(i) ±0,02 s for the time increments specified in 6.5 a) for the data acquisition in the deceleration method;

(ii) ±5 % for the other time durations specified in the method.

## A.4 Instrumentation accuracy

The instrumentation used for readout and recording of test data shall be accurate within the tolerances stated in Table A.1:

**Table A.1 — Instrumentation accuracy**

| Parameter | Passenger car and smaller truck and bus tyres | Larger truck and bus tyres |
|---|---|---|
| tyre load | Greater of ±10 N or ±0,5 % | Greater of ±30 N or ±0,5 % |
| inflation pressure | ±1 kPa | ±1,5 kPa |
| spindle force | Greater of ±0,5 N or ±0,5 % | Greater of ±1,0 N or ±0,5 % |
| torque input | Greater of ±0,5 N · m or ±0,5 % | Greater of ±1,0 N · m or ±0,5 % |
| distance | ±1 mm | ±1 mm |
| electrical power | ±10 W | ±20 W |
| temperature | ±0,2 °C | |
| surface speed | ±0,1 km/h | |
| time | ±0,01 s for the time increments specified in paragraph 6.5 a) for the data acquisition in the deceleration method; ±10 s for the other time durations specified in the method. | |
| angular velocity | ±0,1 % | |

## A.5 Compensation for load/spindle force interaction and load misalignment for force method only

Compensation of both load/spindle force interaction ("cross talk") and load misalignment may be accomplished either by recording the spindle force for both forward and reverse tyre rotation or by dynamic machine calibration. If spindle force is recorded for forward and reverse directions (at each test condition), compensation is achieved by subtracting the "reverse" value from the "forward" value and dividing the result by two. If dynamic machine calibration is intended, the compensation terms may be easily incorporated in the data reduction.

In cases where reverse tyre rotation immediately follows the completion of the forward tyre rotation, a warm-up time for reverse tyre rotation shall be at least 10 min for passenger car tyres and 30 min for all other tyre types.

## A.6 Test surface roughness

The roughness, measured laterally, of the new smooth steel drum surface shall have a maximum centreline average height value of 6,3 µm. This value should be reconfirmed in case visible damage should occur (e.g. in case tyres are measured which are out of scope of this document.)

In cases where a textured drum surface is used instead of a smooth steel surface, this fact shall be noted in the test report. The surface texture shall then be 180 µm deep [(nominally) 80 grit] and the laboratory is responsible for maintaining the surface roughness characteristics. No specific correction factor is recommended for cases where a textured drum surface is used because the correlation applied in Clause 10 will already account for this test condition difference. Additionally, the surface roughness evolves with time and a correction factor specifically to address surface roughness would only be precise at the point it is established.

# Annex B
(informative)

# Measurement methods of moment of inertia for drum and tyre assembly — Deceleration method

## B.1 Limitation

The methods presented here should be considered only as guidelines or practical examples of methods used to measure moments of inertia for the deceleration method to achieve reliable test results.

## B.2 Test drum inertia

### B.2.1 Measurement method

#### B.2.1.1 Equipment needed

The arrangement shown in Figure B.1 requires, in addition to the drum and its angular encoder:

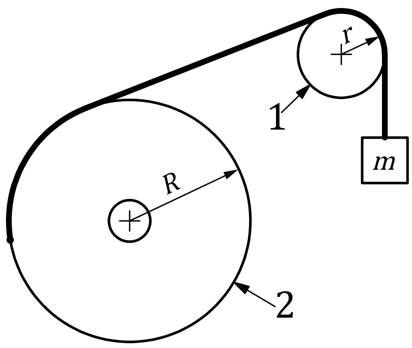
— a lightweight pulley mounted on low-friction bearings;

— a weight of known mass, *m*, in the range 50 kg to 100 kg;

— suitable wire rope and attachments.

#### B.2.1.2 Test arrangement

See Figure B.1.




**Key**

1 pulley
2 drum
*m* mass
*r* pulley radius
*R* drum radius

**Figure B.1 — Test arrangement**

### B.2.1.3 Theory

Application of laws of mechanics to the system shown in Figure B.1 leads to Formula (16):

$$I_D = \frac{mgR - C}{\Delta\omega_D / \Delta t} - mR^2 - I_p \frac{R^2}{r^2} \quad (16)$$

where

| | |
|---|---|
| $I_D$ | is the drum inertia, in kilogram metres squared; |
| $m$ | is the mass, in kilograms; |
| $g$ | is the earth's gravity, equal to 9,81 m/s$^2$; |
| $R$ | is the drum radius, in metres; |
| $C$ | is the friction torque of drum bearings, in Newton metres; |
| $\Delta\omega_D/\Delta t$ | is the angular acceleration or deceleration; |
| $I_p$ | is the pulley inertia, in kilogram metres squared; |
| $r$ | is the pulley radius, in metres. |

NOTE The friction torque of pulley bearings, $C$, can be neglected.

### B.2.1.4 Method

When the mass, $m$, is released, the angular acceleration is measured through the angular encoder fitted to the drum axle (and otherwise used to measure drum decelerations). The friction torque, $C$, of drum bearings can also be measured provided that the rope can be separated from the drum once mass, $m$, has given sufficient momentum to the drum; the subsequent drum deceleration is directly related to $C$ according to Formula (17):

$$C = I_D \left( \frac{\Delta\omega_D}{\Delta t} \right) \quad (17)$$

where the values are as defined under B.2.1.3.

## B.2.2 Determination method

The drum inertia is estimated by calculation.

The drum inertia, $I_D$, in kilogram metres squared, is determined by the summation of the inertia of each drum part (flange, disc, reinforced rib):

$$I_D = I_f + I_d + I_r \quad (18)$$

where

| | |
|---|---|
| $I_f$ | is the drum flange inertia; |
| $I_d$ | is the drum disc inertia; |
| $I_r$ | is the reinforced rib inertia. |

All values are expressed in kilogram metres squared.

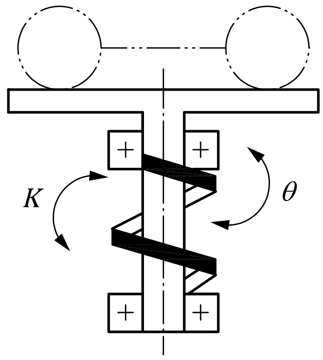
 

## B.3 Tyre assembly inertia

### B.3.1 Spring method

#### B.3.1.1 Equipment needed

Torsion pendulum of inertia $I_0$ and spring constant $K$ (see Figure B.2).




**Key**

$K$ spring constant

$\theta$ oscillation angle

**Figure B.2 — Spring method**

#### B.3.1.2 Theory

Free movement of pendulum, if $\theta$ is the angle from equilibrium, is given by Formula (19):

$$I_0 \frac{d^2\theta}{dt^2} + K\theta = 0 \tag{19}$$

Natural oscillation period, $T_0$ is given by Formula (20):

$$T_0 = 2\pi\sqrt{\frac{I_0}{K}} \tag{20}$$

where

$I_0$ is the torsion pendulum inertia, in kilogram metres squared;

$\theta$ is the angle of oscillation, in radians;

$t$ is the period of time, in seconds;

$K$ is the spring constant.

#### B.3.1.3 Method

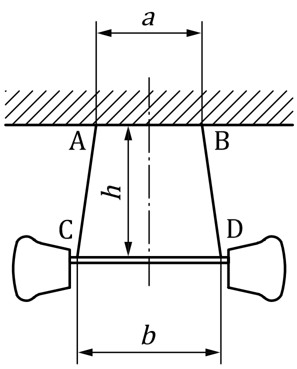
Measurement of oscillation periods, with the tyre assembly, $T_1$, and without, $T_o$, can be used to give the tyre assembly inertia, $I_t$, as given in Formula (21):

$$I_t = \frac{K}{4\pi^2}\left(T_1^2 - T_o^2\right) \tag{21}$$

### B.3.2 Bifilar pendulum (rope) method

#### B.3.2.1 General

Tyre inertia can be obtained by the period time of twisted oscillation of a tyre hanging from two steel ropes of exactly the same length (see Figure B.3).




**Key**

A, B, C, D measurement points

*a* distance between points A and B

*b* distance between points C and D

*h* vertical distance between lines AB and CD

**Figure B.3 — Bifilar pendulum (rope) method**

#### B.3.2.2 Theory

The tyre inertia, $I_t$, in kilogram metres squared, is determined by Formula (22):

$$I_t = \tau^2 \times \frac{Wab}{4\pi^2 h} \tag{22}$$

where

- $\tau$ is the oscillation period, in seconds;
- $W$ is the tyre and wheel weight, in newtons;
- $a$ is the distance between points A and B, in metres;
- $b$ is the distance between points C and D, in metres;
- $h$ is the vertical distance between lines AB and CD, in metres.

#### B.3.2.3 Method

The time period, $\tau$, of the twisted oscillation of a tyre is measured, and tyre inertia can be calculated from the equation given in B.3.2.2.

# Annex C
(informative)

# Test rim runout

Based on the experiences of the experts, the following criteria are recommended:

— for passenger car and smaller truck and bus tyres:

  — Maximum radial runout: 0,5 mm;

  — Maximum lateral runout: 0,5 mm;

— for larger truck and bus tyres:

  — Maximum radial runout: 2 mm;

  — Maximum lateral runout: 2 mm.

# Annex D
(informative)

# Publications of tyre standards organizations

— Yearbook of The Tire and Rim Association, Inc. (TRA)[1)]

— Standards Manual of the The European Tyre and Rim Technical Organisation (ETRTO)[2)]

— JATMA Year Book of The Japan Automobile Tyre Manufacturers' Association (JATMA)[3)]

— Tyre & Rim Association of Australia's Standards Manual of The Tyre and Rim Association of Australia (TRAA)[4)]

— China Tyre Rim & Valve Standards Year Book of the China Association for Standardization (CAS)[5)]

— ALAPA Manual de Normas Técnicas of the Associação Latino Americana de Pneus e Aros (ALAPA)[6)]

— Standards Manual of the Indian Tyre Technical Advisory Committee (ITTAC)[7)]

— ISO 4000-1 and ISO 4209-1[8)]

1) Available from The Tire and Rim Association, Inc., 175 Montrose West Ave., Suite 150, Copley, OH 44321, USA

2) Available from The European Tyre and Rim Technical Organisation, 78/80, rue Defacqz, 1060 Brussels, Belgium.

3) Available from The Japan Automobile Tyre Manufacturers Association, Inc., No. 33 Mori Bldg. 8th Floor, 3-8-21 Toranomon, Minato-ku, Toyko, Japan 105-0001.

4) Available from The Tyre and Rim Association of Australia, Suite 1, Hawthorn House, 795 Glenferrie Road, Hawthorn, Victoria, 3122, Australia.

5) Available from the China Association for Standardization, A19 Fushi Road, 100143 Beijing, China.

6) Available from the Associação Latino Americana de Pneus e Aros, Alameda Santos, 200 - 1° andar – Ed. Victória Plaza, São Paulo – S.P. – Brazil.

7) Available from the Indian Tyre Technical Advisory Committee, c/o Automotive Tyre Manufacturers' Association, PHD House (4th Floor), 4/2 Siri Institutional Area, August Kranti Marg, New Delhi, India.

8) Available from the International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

# Annex E
(informative)

## Example for larger truck bus warm-up duration

An example for larger truck bus warm-up duration is given in Figure E.1.

| Time (min) | Spindle force (N) | 10 min Differences | Steady-state criteria met? ≤ 0,1 N |
|---|---|---|---|
| 1 | 116,856 | | |
| 2 | 113,669 | | |
| 3 | 110,972 | | |
| 4 | 108,760 | | |
| 5 | 106,885 | | |
| 6 | 105,299 | | |
| 7 | 103,807 | | |
| 8 | 102,557 | | |
| 9 | 101,446 | | |
| 10 | 100,406 | | |
| 11 | 99,564 | 17,292 | No |
| 12 | 98,678 | 14,991 | No |
| 13 | 97,868 | 13,104 | No |
| 14 | 97,190 | 11,570 | No |
| 15 | 96,531 | 10,354 | No |
| 16 | 95,911 | 9,387 | No |
| 17 | 95,368 | 8,439 | No |
| 18 | 94,701 | 7,856 | No |
| 19 | 94,215 | 7,231 | No |
| 20 | 93,727 | 6,679 | No |
| 21 | 93,339 | 6,225 | No |
| 22 | 92,958 | 5,720 | No |
| 23 | 92,654 | 5,215 | No |
| 24 | 92,232 | 4,957 | No |
| 25 | 91,931 | 4,600 | No |
| 26 | 91,637 | 4,274 | No |
| 27 | 91,340 | 4,028 | No |
| 28 | 91,081 | 3,620 | No |
| 29 | 90,825 | 3,390 | No |
| 30 | 90,574 | 3,153 | No |
| 31 | 90,289 | 3,049 | No |
| 32 | 90,100 | 2,858 | No |
| 33 | 89,889 | 2,765 | No |
| 34 | 89,639 | 2,593 | No |
| 35 | 89,480 | 2,451 | No |
| 36 | 89,300 | 2,337 | No |
| 37 | 89,144 | 2,196 | No |
| 38 | 89,000 | 2,081 | No |
| 39 | 88,845 | 1,980 | No |
| 40 | 88,657 | 1,916 | No |
| 41 | 88,554 | 1,736 | No |
| 42 | 88,421 | 1,679 | No |
| 43 | 88,285 | 1,604 | No |
| 44 | 88,110 | 1,529 | No |
| 45 | 87,971 | 1,510 | No |
| 46 | 87,906 | 1,394 | No |
| 47 | 87,833 | 1,311 | No |
| 48 | 87,709 | 1,292 | No |
| 49 | 87,631 | 1,214 | No |
| 50 | 87,550 | 1,107 | No |
| 51 | 87,491 | 1,063 | No |
| 52 | 87,445 | 0,977 | No |
| 53 | 87,424 | 0,862 | No |
| 54 | 87,325 | 0,785 | No |
| 55 | 87,260 | 0,710 | No |
| 56 | 87,234 | 0,672 | No |
| 57 | 87,206 | 0,627 | No |
| 58 | 87,143 | 0,565 | No |
| 59 | 87,090 | 0,541 | No |
| 60 | 87,025 | 0,525 | No |
| 61 | 86,965 | 0,526 | No |
| 62 | 86,918 | 0,527 | No |
| 63 | 86,867 | 0,557 | No |
| 64 | 86,813 | 0,512 | No |
| 65 | 86,834 | 0,427 | No |
| 66 | 86,758 | 0,476 | No |
| 67 | 86,694 | 0,512 | No |
| 68 | 86,642 | 0,501 | No |
| 69 | 86,556 | 0,534 | No |
| 70 | 86,547 | 0,478 | No |
| 71 | 86,528 | 0,437 | No |
| 72 | 86,455 | 0,463 | No |
| 73 | 86,422 | 0,445 | No |
| 74 | 86,407 | 0,406 | No |
| 75 | 86,429 | 0,405 | No |
| 76 | 86,382 | 0,377 | No |
| 77 | 86,383 | 0,311 | No |
| 78 | 86,393 | 0,249 | No |
| 79 | 86,356 | 0,200 | No |
| 80 | 86,398 | 0,149 | No |
| 81 | 86,379 | 0,148 | No |
| 82 | 86,368 | 0,087 | **Yes** |

=116,856-99,564

=IF(ABS(17,292)<=0,1,"Yes","No")

**Criteria met:** 0,087 ≤ 0,1

**Warm-up can be stopped at 82 min**

**Figure E.1 — Steady-state determination of TB warm-up duration (force method)**

# Annex F
(informative)

# Example for machine drift evaluation

## F.1 General

This procedure may be used to evaluate the machine behaviour with regard to its possible measurement drift. Although machine drift evaluation is required by this document, this annex is provided as only one example of a procedure which meets the intention of this document. It is provided for informative guidance for the user and is not mandatory to be applied directly as it is written here. Normally the procedure used by any laboratory would be documented in its quality system documentation and would become mandatory, rather than optional, as it is shown below.

## F.2 Concept of a moving average

A moving average is an arithmetic average of successive groups of observations. For clarity, the following example is provided.

EXAMPLE

In a series of observations: 2; 3; 2; 3; 4; 3; 4 the moving average of 4 measures is of interest

The moving average of 4 measures would be: 2,5; 3; 3; 3,5

**2; 3; 2; 3;** 4; 3; 4

2,5 = (2+3+2+3)/4 = the average of the first 4 observations

2; **3; 2; 3; 4;** 3; 4

3 = (3+2+3+4)/4 = the average of the next group of 4 observations

2; 3; **2; 3; 4; 3;** 4

3 = (2+3+4+3)/4 = the average of the next group of 4 observations

2; 3; 2; **3; 4; 3; 4**

3,5 = (3+4+3+4)/4 = the average of the next group of 4 observations

## F.3 Application of the concept

### F.3.1 General

This procedure can be used to assess the potential of machine drift for either a reference or candidate machine, by distinguishing two cases:

1. Laboratory with two or more machines
2. Laboratory with only one machine or Laboratory being the unique physical Reference machine selected by the body (public authority or other party) to establish the inter-comparability relationship.

### F.3.2 Laboratory with two or more machines

The values from the control tyre used for monitoring (10.2.2 or 10.3.2) may be used. The same control tyre will be measured on more than one machine.

The moving average of the $C_r$ for the control tyre is calculated over the past month and is monitored every week.

If the moving average has the same evolution on multiple machines, it may be attributed to tyre evolution, or a parameter that affects the multiple machines and is not attributed to a singular machine drift.

If the moving average does not have the same evolution on multiple machines, then the issue cannot be attributed to tyre evolution and a machine drift may have occurred on at least one of them.

A moving average maximum value could be established to assess whether machine drift has occurred. If the monitoring indicates that there is machine drift, then the machine should be considered non-compliant and the Laboratory may

— Stop the machine and perform maintenance, then

— Re-measure the control tyre, re-check compliance, and

— Treat the non-conforming measured values according to the internal quality procedures.

NOTE For the quality procedure, additional requirements could be specified.

### F.3.3 Laboratory with only one machine or a single physical reference machine

The laboratory may assess machine drift by following one of the methods described below, according to a control map and timeline established in advance.

1. Measure at least 2 control tyres on a weekly basis, or at least 3 times a month. The moving average is assessed according to established metrics and is monitored every week. Machine drift can be distinguished from tyre evolution or some other parameter by comparing the behaviour on multiple control tyres.

2. Re-measure the alignment tyres which have been properly stored according to the following conditions:

   — Under controlled temperature conditions 25 ± 5 °C;

   — Kept mounted on rim with storage position defined (vertical or piled for passenger car and smaller truck and bus tyres and vertical for larger truck and bus tyres);

   — Inflation pressure of 150 kPa for passenger car and smaller truck and bus tyres, plus recording and adjusting monthly;

   — Inflation pressure of 200 kPa for larger truck and bus tyres, plus recording and adjusting monthly;

   — Protection from light by covering (not wrapping for air circulation);

   — Storage of the tyres not directly on the floor (on rack or pallet, etc.).

   The moving average is assessed using the established metrics and shall be monitored according to the timeline set beforehand. In this case, the alignment tyres supplement the control tyre data, and provide a separate reference to assess machine behaviour.

3. Run a proficiency testing program with another lab (in case of a candidate machine, the reference machine can be considered). The moving average is assessed, using the established metrics set beforehand within a control map and is monitored according to the timeline set beforehand.

A moving average maximum value could be established to assess whether machine drift has occurred. If the monitoring indicates that there is machine drift, then the machine should be considered non-compliant and the Laboratory may:

— Stop the machine and perform maintenance, then

— Re-measure the control tyre, re-check compliance and

— Treat the non-conforming measured values according to the internal quality procedures.

NOTE For the quality procedure, additional requirements could be specified.

# Bibliography


[1] ISO/TR 16377, *Further clarification of ISO 28580*

[2] ISO 18164, *Truck, bus, passenger-car and motorcycle tyres — Methods of measuring rolling resistance*

[3] ISO 80000-1:2009, *Quantities and Units — Part 1: General*

[4] SAE J1269, *Rolling Resistance Measurement Procedure for Passenger Car, Light Truck, and Highway Truck and Bus Tires*

[5] SAE J2452, *Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance*

[6] TRA, Yearbook of The Tire and Rim Association, Inc.

[7] ETRTO, Standards Manual of the The European Tyre and Rim Technical Organisation

[8] JATMA, Year Book of The Japan Automobile Tyre Manufacturers' Association

[9] TRAA, Tyre & Rim Association of Australia’s Standards Manual of The Tyre and Rim Association of Australia

[10] CAS, China Tyre Rim & Valve Standards Year Book of the China Association for Standardization

[11] ALAPA, Manual de Normas Técnicas of the Associação Latino Americana de Pneus e Aros

[12] ITTAC, Standards Manual of the Indian Tyre Technical Advisory Committee

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