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TYRES

Regulation No. 117
(**UNIFORM PROVISIONS CONCERNING THE APPROVAL OF TYRES WITH REGARD TO ROLLING SOUND EMISSIONS AND TO ADHESION ON WET SURFACES
AND TO ROLLING RESISTANCE**)

Proposal for draft amendments to Regulation No. 117- Rev. 1

Submitted by the expert from France

The text reproduced below was prepared by the expert from France in order to include the Rolling Resistance in Regulation No. 117. The modifications to the existing text of the Regulation are underlined or strikethrough and are based on the text of the proposals made by ETRTO at the 2nd STD meeting (Document STD-02-02) and concerns only annex 6, 8 and 9.

Regulation No. 117

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF TYRES WITH REGARD TO ROLLING SOUND EMISSIONS, TO ADHESION ON WET SURFACES AND TO ROLLING RESISTANCE

CONTENTS

CONTENTS (continued)

1. SCOPE

1.1. This Regulation applies to new pneumatic tyres of Class C1, C2 and C3 with regard to their sound emissions, rolling resistance and to new pneumatic tyres of Class C1 with regard to adhesion performance on wet surfaces (wet adhesion). It does not, however, apply to:

1.1.1. Tyres designed as "Temporary use spare tyres" and marked "Temporary use only";

1.1.2. Tyres having a nominal rim diameter code ≤ 10 (or ≤ 254 mm) or ≥ 25 (or ≥ 635 mm);

1.1.3. Tyres designed for competitions;

1.1.4. Tyres intended to be fitted to road vehicles of categories other than M, N and O 1/;

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

1.1.6. Tyres with a speed rating less than 80 km/h (speed symbol F).

1.1.7 Tyres designed only to be fitted to vehicles registered for the first time before 1st October 1990.

1.1.8 Professional Off Road tyres for the requirements on rolling resistance and rolling noise

1.2. Contracting Parties shall issue or accept approvals to rolling sound and/or wet adhesion and/or rolling resistance. Each Contracting Parties shall notify to the Secretary-General of the United Nations their option for the mandatory performance(s) required. Such notification shall have effect in accordance with the time scales laid down in Article 1, paragraphs 6. and 7. of the 1958 Agreement (E/ECE/TRANS/505/Rev.2).

2. DEFINITIONS

Amends following definitions:

2.18 Rolling resistance measurement – specific definitions

2.18. 1 Rolling Resistance
F_r
loss of energy (or energy consumed) per unit of distance traveled. 1/

2.18.2. Rolling resistance coefficient

C_r
ratio of the rolling resistance to the load on the tyre. 2/

2.18.3 New test tyre
[Tyre which has not been previously used in a rolling deflected test that raises its temperature above that generated in rolling resistance tests, and which has not previously been exposed to a temperature above 40°C. ~~3/~~ 4/]

~~2.18.4 Measurement Result Correlation~~
~~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. 5/~~

~~2.18.5 Reference Machine~~
~~machine considered as a reference for an alignment.~~

~~2.18.6 Alignment Tyres~~
~~set of two predetermined tyres measured by both the candidate and reference machines to perform machine alignment. 6/~~

2.18.~~7~~ 4 Laboratory Control Tyre
Tyre used by an individual laboratory to control machine behaviour as a function of time. 7/

2.18.~~8~~ 5 Capped inflation
Process of inflating the tyre and allowing the inflation pressure to build up, as the tyre is warmed up while running.

2.18.~~9~~ 6 Parasitic loss
Loss of energy (or energy consumed) per unit distance excluding internal tyre losses, attributable to aerodynamic loss of the different rotating elements of the test equipment, bearing friction and other sources of systematic loss which may be inherent in the measurement.

2.18.~~10~~ 7 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.

2.18.~~11~~8 Inertia or Moment of Inertia.
Ratio of the torque applied to a rotating body to the rotational acceleration of this body. 8/

2.18.~~12~~ 9 Measurement reproducibility.

σ_m

capability of a machine to measure rolling resistance 9/

~~2.18.13 Deviation of Alignment Tyre~~

~~Difference in terms of time compared with the mean rolling resistance coefficient measurement results for a given alignment tyre with the appropriate number of repetitions 10/~~

1/ The International System of Units (SI) unit conventionally used for the rolling resistance is the newton-metre per metre, which is equivalent to a drag force in newtons.

2/ The rolling resistance is expressed in newtons and the load is expressed in kilonewtons. The rolling resistance coefficient is dimensionless.

~~3/ [Note to be added to explain the reason]~~

4/ It is permissible to repeat an accepted test procedure.

~~5/ The results of these measurements are used to compute "alignment" corrective coefficients and permits calculation of aligned rolling resistance measurement, $Cr_{aligned}$. See Annex 6 part7.~~

~~6/ see clause 7~~

7/ An example of machine behaviour is drift.

8/ The rotating body can be, for example, a tyre assembly or machine drum.

9/ σ_m can be estimated by measuring n times (where $n \geq 3$) the whole procedure described in clause 4 for ~~the~~ [two] ~~alignment~~ tyres, assuming that the variances of the [two] ~~alignment~~ tyres are homogeneous, as follows:

$$\sigma_m = \sqrt{\frac{1}{2} \cdot \sum_{i}^{2} \sigma_{m,i}^2}$$

$$\sigma_{m,i} = \sqrt{\frac{1}{n-1} \cdot \sum_{j=1}^{n} \left(Cr_{i,j} - \frac{1}{n} \cdot \sum_{j=1}^{n} Cr_{i,j} \right)^2}$$

where

i = either 1 or [2] corresponding to each of the ~~alignment~~ tyres

j = is the counter from 1 to n for the number of repetitions of each measurement for a given tyre

n = repetitions of tyre measurements

~~10/ see Annex 6 paragraph 7.2.~~

……..

Annex 6

TEST PROCEDURE FOR MEASURING ROLLING RESISTANCE

1. TEST METHODS

The alternative measurement methods listed below are given in this Regulation 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) in the force method: the reaction force measured or converted at the tyre spindle

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.

b) in the torque method: the torque input measured at the test drum.
c) in the deceleration method: the measurement of deceleration of the test drum and tyre assembly
d) in the power method: The measurement of the power input to the test drum

~~NOTE~~ Note 2 The measured value in the torque, deceleration and power methods also includes the bearing and aerodynamic losses of the wheel, the tyre, and the drum which are also to be considered for further data interpretation.

2 TEST EQUIPMENT

2.1 Drum specifications

2.1.1 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 drum diameter different than 2.0 m is used, a correlation adjustment must be made following the method in 6.3.

2.1.2 Surface
The surface of the drum shall be smooth steel. Alternatively, in order to improve skim test reading accuracy, a textured surface may also be used, which should be kept clean.
The F_r and C_r values shall be expressed relative to the "smooth" drum surface. If a textured drum surface is used, see Appendix 1, paragraph 7.

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

2.2 Measuring rim
The tyre shall be mounted on a steel or light alloy measuring rim, as follows:
- for passenger car tyres, the width of the rim shall be as defined in ISO 4000-1:[2009]
- for truck and bus tyres, the width of the rim shall be as defined in ISO 4209-1:2001
No other rim width shall be allowed. See Appendix 2.

2.3 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 Appendix 1.

2.4 Thermal environment

2.4.1 Reference conditions

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

2.4.2 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 6.2.

2.4.3 Drum surface temperature.
Care should be taken to ensure that the temperature of the test drum surface is the same as the ambient temperature at the beginning of the test.

3. TEST CONDITIONS

General
The test consists of a measurement of rolling resistance in which the tyre is inflated and the inflation pressure allowed to build up, i.e., "capped air".

3.1 Test speeds
The value shall be obtained at the appropriate drum speed specified in Table 1.

Table 1 — Test Speeds (in km/h)

Tyre Type	Passenger Car	Truck and Bus		
Load Index	All	~~LI~~ LI=121 and below	~~LI~~ LI=122 and above	
Speed Symbol	All	All	J [100 km/h] and lower or tyres not marked with speed symbol	K [110 km/h] and higher
Speed	80	80	60	80

3.2 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 appendix 1.

3.3 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 Appendix 1 paragraph.4.

Table 2 — Test Loads and Inflation Pressures

Tyre Type	Passenger Car [a]		Truck and Bus
	Standard Load	Reinforced or Extra Load	
Load- % of maximum load capacity	80	80	85[b] (% of single load)
Inflation Pressure kPa	210	250	Corresponding to maximum load capacity for single application[c]
NOTE 1 The inflation pressure shall be capped with the accuracy specified in Appendix 1 paragraph 4.			

[a]	For those passenger car tyres belonging to categories which are not shown in ISO 4000-1:[2009], 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]	As a percentage of single load, or 85% of maximum load capacity for single application specified in applicable tyre standards manuals if not marked on tyre.
[c]	Inflation pressure marked on sidewall, or if not marked on sidewall, as specified in applicable tyre standards manuals corresponding to maximum load capacity for single application.

3.4 Duration and speed

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

a) For duration, Δt, 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.

4 TEST PROCEDURE

General:

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

4.1 Thermal conditioning

The inflated tyre shall be placed in the thermal environment of the test location for a minimum of:

- 3 h for Passenger Car tyres
- 6 h for Truck and Bus tyres.

4.2 Pressure adjustment

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

4.3 Warm-up

~~Yhe~~The warm-up durations shall be as specified in Table 3.

Table 3 — Warm Up Durations

Tyre Type	Passenger Car	Truck and Bus Tyres LI ≤ 121 ~~LI~~ LI=121 and below	Truck and Bus Tyres LI > 121 ~~LI~~ LI=122 and above	
Nominal Rim Diameter	All	All	< 22.5	≥ 22.5
Warm up duration	30 min	50 min	150 min	180 min

4.4 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) ~~the~~ The initial test inflation pressure as defined in 3.3.

d) The Coefficient of Rolling Resistance measured, Cr, and its corrected value, Crc, at 25°C and for a drum diameter of 2m.

e) ~~the~~ The distance from the tyre axis to the drum outer surface under steady state $r_{L,}$ expressed in metres.

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

g) Test drum radius, R.

h) Test method chosen.

i) Test rim (size and material).

j) Tyre size, manufacturer, type, identity number (if one exists), ~~speedb symbol~~speed symbol, load index, DOT number (Department of Transportation).

All the mechanical quantities (forces, torques) will be orientated in accordance with the axis systems specified in ISO 8855:1991.

The directional tyres shall be run in their specified rotation sense.

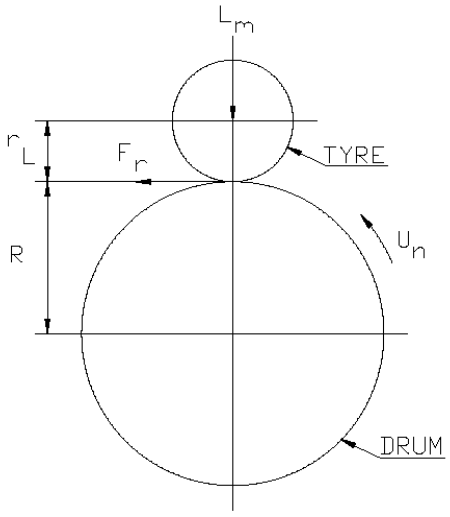

FIGURE 1

4.5 Measurement of parasitic losses

~~general:~~

The parasitic losses must be determined by one of the following procedure given in 4.5.1 or 4.5.2

4.5.1 Skim test reading

Skim test reading follows the procedure below:

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.

- truck and bus tyres (LI $\leq$ 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

- 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 (see section 7).~~

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~~ Note 1 With the exception of the Force method, the measured value includes the bearing and aerodynamic losses of the wheel, the tyre, and the drum losses which also need to be considered.

Note 2 It is known that the spindle and drum bearings friction depend on the applied load; consequently, it is different for the loaded system measurement and the Skim test reading. However, for practical reasons, this difference can be disregarded.

4.5.2 Deceleration method

The deceleration method follows the procedure below:

a) Remove the tyre from the test surface.

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

NOTE 1: The measured value includes the bearing and aerodynamic losses of the wheel, the tyre, and the drum losses which also need to be considered.

Note 2 It is known that the spindle and drum bearings friction depend on the applied load; consequently, it is different for the loaded system measurement and the Skim test reading. However, for practical reasons, this difference can be disregarded.

4.6 Allowance for machines exceeding $\sigma_{m,i}$ criterion

The steps described in 4.3 to 4.5 shall be carried out one time if the measurement standard deviation, determined in accordance with section ~~7.3.3~~6.5, is:

- not greater than 0.075 N/kN for Passenger Car and smaller Truck and Bus tyres (LI ≤ 121)
- not greater than 0.06 N/kN for larger Truck and Bus tyres (LI ≥ 122).

If the measurement standard deviation exceeds this criterion, the measurement process will be repeated n times as described in section ~~7.3.3~~6.5. The rolling resistance value reported shall be the average of the n measurements.

5 DATA INTERPRETATION

5.1 Determination of parasitic losses

5.1.1 General

The laboratory shall perform the measurements described in 4.5.1 for the Force, Torque and Power methods or those described in 4.5.2 for the Deceleration method, in order to determine precisely in the test conditions (load, speed, temperature) the tyre spindle friction, the tyre and wheel aerodynamic losses, the drum (and as appropriate, engine and/or clutch) bearing friction, and the drum aerodynamic losses.

The parasitic losses related to the tyre/drum interface, F_p expressed in newtons, shall be calculated from the force F_t, torque, power or the deceleration, as shown in 5.1.2 to 5.1.5 below.

5.1.2 Force method at tyre spindle

Calculate: $F_{pl} = F_t(1 + r_L/R)$

where

F_t is the tyre spindle force in newtons (see 4.5.1);

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.

5.1.3 Torque method at drum axis

Calculate: $F_{pl} = T_t/R$

where

T_t is the input torque in newton metres as determined in 4.5.1

R is the test drum radius, in metres.

5.1.4 Power method at drum axis

Calculate: $F_{pl} = \frac{3{,}6V \times A}{U_n}$

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.

5.1.5 Deceleration method

Calculate the parasitic losses, Fpl, in newtons.

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

where

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

R is the test drum surface radius, in metres;

ω_{Do} is the test drum angular speed, without tyre, in radians per second;

Δt_o 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 is the tyre rolling radius, in metres;

ω_{To} is the tyre angular speed, unloaded tyre, in radians per second.

5.2 Rolling resistance calculation

5.2.1 General

The rolling resistance, Fr, expressed in newtons, is calculated using the values obtained by testing the tyre to the conditions specified in this International Standard and by subtracting the appropriate parasitic losses, Fpl, obtained according to 5.1.

5.2.2 Force method at tyre spindle

The rolling resistance, Fr, in newtons, is calculated using the equation

$F_r = F_t[1 + (r_L/R)] - F_{pl}$

where

F_t is the tyre spindle force in newtons;

F_{pl} represents the parasitic losses as calculated in 5.1.2;

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.

5.2.3 Torque method at drum axis

The rolling resistance, Fr, in newtons, is calculated with the equation

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

where

T_t is the input torque, in newton metres;

F_{pl} represents the parasitic losses as calculated in 5.1.3;

R is the test drum radius, in metres.

5.2.4 Power method at drum axis

The rolling resistance, Fr, in newtons, is calculated with the equation:

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

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 .5.1.4.

5.2.5 Deceleration method

The rolling resistance, F_r, in newtons, is calculated using the equation:

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

where

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

R is the test drum surface radius, in metres;

F_{pl} represents the parasitic losses as calculated in 5.1.5;

Δt_v is the time increment chosen for measurement, in seconds;

$\Delta\omega_v$ is the test drum angular speed increment, without tyre, in radians per second;

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_r is the rolling resistance, in newtons.

6. DATA ANALYSIS

6.1 Rolling resistance coefficient

The rolling resistance coefficient C_r is calculated by dividing the rolling resistance by the load on the tyre:

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

Where:

F_r is the rolling resistance, in newtons;

L_m is the test load, in knewtons.

6.2 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 the following equation, where F_{r25} is the rolling resistance at 25°C, in newtons:

$$F_{r25} = F_r\left[1 + K\left(t_{amb} - 25\right)\right]$$

where

F_r is the rolling resistance, in newtons;

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

K is equal to

0,008 for passenger tyres
0,01 for truck and bus tyres with load index 121 and lower
0,006 for truck and bus tyres with load index 122 and above

6.3 Drum diameter correction

Test results obtained from different drum diameters may be compared by using the following theoretical formula:

$$F_{r02} \cong KF_{r01}$$

with

$$K = \sqrt{\frac{\left(R_1/R_2\right)\left(R_2 + r_T\right)}{\left(R_1 + r_T\right)}}$$

where:

R_1 is the radius of drum 1, in meters;

R_2 is the radius of drum 2, in meters;

r_T is one-half of the nominal design tyre diameter, in meters;

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

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

6.4 Measurement Result

Where n measurements are greater than 1, if required by section 4.6, the

measurement result shall be the average of the Cr values obtained for the n measurements, after the corrections described in 6.2 and 6.3 have been made.

Add new § 6.5 and 6.7

6.5 The laboratory shall ensure that, based on a minimum of three measurements, the machine maintains the following values of σ_m, as measured on a single tyre:

$\sigma_{m,i} \leq$ [**0.075**] N/kN for Passenger Car and small Truck and Bus tyres (LI ≤ 121)
$\sigma_{m,i} \leq$[**0.06**] N/kN for larger Truck and Bus tyres (LI ≥ 122).

If the above requirement for $\sigma_{m,I}$ is not met, the following formula must be applied to determine the minimum number of measurements n (rounded to the immediate superior integer value) that are required by the machine to qualify for conformance with this Regulation.
$n = (\sigma_{m,I} / x)^2$

where
x = [**0.075**] N/kN for Passenger Car and small Truck and Bus tyres (LI ≤ 121)
x = [**0.06**] N/kN for larger Truck and Bus tyres (LI ≥ 122)

If a tyre needs to be measured several times, the tyre/wheel assembly shall be removed from the machine between the successive measurements.
If the removal/refitting operation duration is less than 10 minutes, the warm-up durations indicated in section 4.3 may be reduced to:
a) 10 minutes for Passenger Car tyres
b) 20 minutes for Truck and Bus tyres (LI ≤121)
c) 30 minutes for the larger Truck and Bus tyres (LI > 121)

6.6 Monitoring of the laboratory control tyre shall be carried out at intervals no greater than [one] month. Monitoring shall include a minimum of 3 separate measurements taken during this [one] month period. The average of the 3 measurements taken during a given [one]-month period shall be evaluated for drift from [one] monthly evaluation to another.

Delete all §7

~~7 MEASUREMENT MACHINES ALIGNMENT AND MONITORING REQUIREMENTS.~~

~~7.1 General~~
~~This clause describes the procedure to be followed to align measurement results and allow direct inter-laboratory comparisons. This process shall be applied to each measurement machine for whose results conformance is~~

~~claimed with this International Standard.~~

~~The machine alignment procedure requires two predetermined alignment tyres used by the candidate laboratory operating the machine. These tyres are used to align candidate machine(s) by comparing the measured Cr results to the ones obtained on a reference machine. An alignment formula is then established and shall be used to translate the results obtained on the candidate machine into aligned results.~~

~~7.2 Conditions for reference machine:~~

~~7.2.1 The laboratory operating the reference machine shall comply with either ISO/TS 16949:2002 or ISO/IEC 17025:2005.~~

~~7.2.2 Monitoring of the reference machine laboratory control tyre shall be carried out at intervals no greater than one month. Monitoring shall include a minimum of 3 separate measurements taken during this one month period. The average of the 3 measurements taken during a given one month period shall be evaluated for drift from one monthly evaluation to another.~~

~~7.2.3 The laboratory shall ensure that, based on a minimum of three measurements, the reference machine maintains a value of $\sigma_m \leq 0.05$ N/kN. This may be done using the laboratory control tyres (as specified in 7.2.2).~~

~~7.3 Conditions for candidate machine~~

~~7.3.1 The laboratory operating the candidate machine shall comply with either ISO/TS 16949:2002 or ISO/IEC 17025:2005.~~

~~7.3.2 Monitoring of the candidate machine laboratory control tyre shall be carried out at intervals no greater than one month. Monitoring shall include a minimum of 3 separate measurements taken during this one month period. The average of the 3 measurements taken during a given one month period shall be evaluated for drift from one monthly evaluation to another.~~

~~7.3.3 The laboratory shall ensure that, based on a minimum of three measurements, the candidate machine maintains the following values of σ_m, as measured on a single tyre:~~

~~$\sigma_{m,i} \leq 0.075$ for Passenger Car and small Truck and Bus tyres (LI ≤ 121)~~
~~$\sigma_{m,i} \leq 0.06$ for larger Truck and Bus tyres (LI ≥ 122).~~

~~If the above requirement for $\sigma_{m,i}$ is not met, the following formula must be applied to determine the minimum number of measurements n (rounded to the immediate superior integer value) that are required by the candidate machine to qualify for conformance with this International Standard.~~
~~$n = (\sigma_{m,i} / x)^2$~~

~~where~~
~~x = 0.075 for Passenger Car and small Truck and Bus tyres (LI ≤ 121)~~
~~x = 0.06 for larger Truck and Bus tyres (LI ≥ 122)~~

~~If a tyre needs to be measured several times, the tyre/wheel assembly shall be removed from the machine between the successive measurements.~~
~~If the removal/refitting operation duration is less than 10 minutes, the warm-up durations indicated in section 4.3 may be reduced to:~~
~~a) 10 minutes for Passenger Car tyres~~
~~b) 20 minutes for Truck and Bus tyres (LI ≤121)~~
~~c) 30 minutes for the larger Truck and Bus tyres (LI > 121)~~

~~7.4 Alignment Tire Requirements~~

~~7.4.1 The predetermined alignment tyres used to conduct the alignment procedure shall be identified to cover the needed usage range in terms of load index, Cr and Fr as follows:~~

~~a) Cr values shall have a minimum range of:~~
~~- 3 N/kN for Passenger Car and smaller Truck and Bus tyres~~
~~- 2 N/kN for larger Truck and Bus tyres.~~

~~b) The alignment tyre section width should be:~~
~~- ≤245 mm for Passenger Car and smaller Truck and Bus machines~~
~~- ≤345 mm for larger Truck and Bus tyre machines.~~

~~c) The alignment tyre outer diameter should be~~
~~- between 510 to 800 mm for passenger car and smaller truck and bus machines~~
~~- between 771 to 1143 mm for larger truck and bus tyre machines~~

~~d) load index values shall adequately cover the range for the tyres to be tested, ensuring that the Fr values also cover the range for the tyres to be tested.~~

~~e) the number of alignment tyres shall be equal to two, i.e. there shall be:~~
~~- two alignment tyres for passenger car and smaller Truck and Bus tyres, and~~

- two alignment tyres for larger Truck and Bus tyres.

7.4.2 Each alignment tyre must be checked prior to use and replaced when:
- it shows a condition which makes it unusable for further tests
- there are deviations of Cr for alignment tyre measurement greater than 1.5% relative to earlier measurements after correction for any machine drift.

7.5 Alignment Procedure

7.5.1 Each time an alignment tyre is measured, the tyre/wheel assembly shall be removed from the machine and the entire test procedure specified in section 4 shall be followed again. This requirement applies to both the reference laboratory and the candidate laboratory.

7.5.2 The laboratory operating the reference machine shall measure each alignment tyre three times in accordance with section 4 and applying the conditions in section 3, and provide the mean value and standard deviation established from the 3 measurements for each tyre.

7.5.3 The candidate machine shall measure each alignment tyre three times in accordance with section 4 and applying the conditions in section 3, with a measurement standard deviation for each tyre of
- not greater than 0.075 N/kN Passenger Car and smaller Truck and Bus tyres (LI ≤ 121) and
- not greater than 0.06 N/kN for larger Truck and Bus tyres (LI ≥ 122).

If this measurement standard deviation exceeds this criterion with 3 measurements, then the number of measurement repetitions shall be increased to meet the criterion:

$$n = (\sigma_m/\gamma)^2$$

where
γ = 0.043 for Passenger Car and small Truck and Bus tyres (LI ≤ 121)
γ = 0.035 for larger Truck and Bus tyres (LI > 121).

7.5.4 The correlation shall be performed by the candidate laboratory and shall be a linear regression technique with the alignment results, A and B, given in the equation::
Cr aligned = A x Cr,corrected + B.
where Cr,corrected is the Cr of the candidate machine.

The measurement standard deviation estimate, σm, will also be given.

~~7.5.5. The alignment process must be repeated at least every second year and always after any significant machine change or any drift in candidate machine control tyre monitoring data.~~

Annex 6 Appendix 1

Test equipment tolerances

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. These tolerances are not meant to represent a complete set of engineering specifications for test equipment; rather, they should serve as guidelines for achieving reliable test results.

2 Test rims

2.1 Width

For passenger car tyre rims, the test rim width shall be the same as the measuring rim determined in ISO 4000-1:[2009] clause 6.2.2

For truck and bus tyres, the rim width shall be the same as the measuring rim determined ISO 4209-1:2001 clause 5.1.3

See Appendix 2.

2.2 Run-out

Run-out shall meet the following criteria:

- maximum radial run-out: 0,5 mm
- maximum lateral run-out: 0,5 mm

3 Alignment

General:

Angle deviations are critical to the test results.

3.1 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 and deceleration methods;
- 5 mrad for the torque and power methods.

3.2 Tyre alignment

3.2.1 Camber angle

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

3.2.2 Slip angle

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

4 Control accuracy

Test conditions shall be maintained at their specified values, independent of perturbations induced by the tyre and rim non-uniformity, such that the overall variability of the rolling resistance measurement is minimized. In order 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:
- for LI ≤ 121) +/- 20 N or +/- 0,5%, whichever is greater
- for LI > 121) +/- 45 N or +/- 0,5% whichever is greater
- 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: + 0,02 s

5 Instrumentation accuracy

The instrumentation used for readout and recording of test data shall be accurate within the tolerances stated below:

Parameter	Load Index ≤ 121	Load Index > 121
tyre load	+/- 10 N or +/- 0,5% (a)	+/- 30 N or +/- 0,5% (a)
inflation pressure	+/- 1 kPa	+/- 1,5 kPa
spindle force	+/- 0,5 N or + 0,5% (a)	+/- 1,0 N or + 0,5% (a)
torque input	+/- 0,5 N.m or + 0,5% (a)	+/- 1,0 N.m or + 0,5% (a)
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
angular velocity	+ /-0,1 %

(a): whichever is greater

6 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 achieved 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 must be at least 10 min for passenger car tyres and 30 min for all other tyre types.

7 Test surface roughness

The roughness, measured laterally, of the smooth steel drum surface shall have a maximum centreline average height value of 6,3 μ-m.

NOTE In cases where a textured drum surface is used instead of a smooth steel surface, this fact is noted in the test report. The surface texture shall then be 180 μ-m 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 section 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 6 Appendix 2

Measuring rim width

1 Passenger cars tyres.
The measuring rim width, *R*m, is equal to the product of the nominal section width, S_N, and the coefficient, K_2:
$Rm = K_2 \times SN$
rounded to the nearest standardized rim, where K_2 is the rim/section width ratio coefficient. For tyres mounted on 5° drop-centre rims with a nominal diameter expressed by a two-figure code:
- $K_2 = 0,7$ for nominal aspect ratios 95 to 75;
- $K_2 = 0,75$ for nominal aspect ratios 70 to 60;
- $K_2 = 0,8$ for nominal aspect ratios 55 and 50;
- $K_2 = 0,85$ for nominal aspect ratio 45;
- $K_2 = 0,9$ for nominal aspect ratios 40 to 30;
- $K_2 = 0,92$ for nominal aspect ratios 20 and 25.

2 Truck and Bus tyres.
The measuring rim width, Rm, is equal to the product of the nominal section width, SN, and the coefficient, K4:
Rm = K4 X SN, rounded to the nearest standardized rim width.

Table 1
Coefficients for determining Measuring rim width

Tyre Construction Code	Type of Rim	Nominal aspect ratio H/S	Theoretical rim/section ratio K_1	Minimum Dual Spacing K_3	Measuring rim/section ratio K_4
B, D, R	5º tapered	100 to 75	0,70	1,15	0,70
		70 and 65	0,70	1,15	0,75
		60	0,70	1,15	0,75
		55	0,70	1,15	0,80
		50	0,70	1,15	0,80
		45	0.85	1.15	0.85
		40	0.85	1.15	0.90
	15º tapered (drop-centre)	90 to 65	0,75	1,125	0,75
		60	0,80	1,125	0,80
		55	0,80	1,125	0,80
		50	0,80	--	0,80
		45	0,85	--	0,85
		40	0.85	--	0.85
NOTE Other factors may be established for new tyre concepts (constructions).					

Annex 6 – Appendix 3

TEST REPORT (Rolling Resistance)

Part 1 Report

1. Type approval authority or Technical Service: .....
2. Name and address of applicant: .....
3. Test report No.: .....
4. Manufacturer and brand name or trade description: .....
5. Tyre Class (C1, C2 or C3): .....
6. Category of use: .....
7 Rolling Resistance coefficient (temperature and drum diameter corrected~~, then aligned with reference machine~~) : .....
8. Comments (if any): .....
9. Date: .....
10. Signature: .....

Part 2 Test data

1. Date of test: .....
2. Test Machine identification ~~code~~ and drum diameter / surface: .....
.....

~~3. Alignment: .....~~
~~3.1. Reference Laboratory / machine: .....~~
~~3.2. Date of last alignment: .....~~
~~3.3. Measurement standard deviation: .....~~
~~3.4. Number of measurements: .....~~

~~4~~3. Test tyre details: .....
~~4~~3.1. Tyre size designation and service description: .....
~~4~~3.2. Tyre brand and trade description: .....
~~4~~3.3. Reference inflation pressure: kPa .....

4 Test data: .....
4.1 Measurement method: .....
4.2 Test speed km/h: .....
4.3 Load daN: .....
4.4 Test Inflation Pressure, initial: .....
4.5 Distance from the tyre axis to the drum outer surface under steady state conditions, in meters, r_L : : .....
4.6 Test rim width and material: .....

4.7 Ambient temperature °C: .....
4.8 Skim test load (except deceleration method) N: .....
5 Rolling Resistance Coefficient: .....
5.1 Initial value (or average in the case ~~or~~ of more than 1) N/kN: .....
5.2 Temperature corrected N/kN: .....
5.3 Temperature and drum diameter corrected N/kN: .....
~~6.4.Temperature and drum diameter corrected, then aligned with reference machine N/kN: .....~~

Annex 8 (informative)

Procedure for Technical Services interlaboratory comparison

1. General

   This clause describes the procedure to be followed to perform interlaboratory comparison. It can be used for determination of assigned values (see § 3) for a set of reference tyres.

2. The Cr results of each reference tyre measured by each Technical Service participating to the interlaboratory comparison according to ISO 5725 can be used for determining the Cr assigned value for each reference tyre. The procedure requires [at least five] predetermined reference tyres to be used by the Technical Service laboratory operating the machine. Every Technical Service machine participating to the interlaboratory comparison must be in accordance with this regulation.

3. The assigned value for each reference tyre is the general average of the results obtained by all Technical Service for this reference tyre in this interlaboratory comparison.

Annex 9 (informative)

MEASUREMENT MACHINES ALIGNMENT AND MONITORING REQUIREMENTS.

1. Definitions

   a. Alignment Tyres
   set of [two] predetermined tyres measured by both the candidate and Technical Service machines to perform machine alignment.
   b. Deviation of Alignment Tyre
   Difference in terms of time compared with the mean rolling resistance coefficient measurement results for a given alignment tyre with the appropriate number of repetitions.

2. General
   This annex describes the procedure to be followed if needed to align measurement results on assigned values issued from interlaboratory comparisons.

3. The machine alignment procedure requires [two] predetermined alignment tyres used by the candidate laboratory operating the machine. These tyres are used to align candidate machine(s) by comparing the measured Cr results to the ones obtained by a Technical Service eligible in the interlaboratory comparison. An alignment formula is then established and shall be used to translate the results obtained on the candidate machine into aligned results.

4. Conditions for candidate machine
   The candidate machine must be in accordance with this regulation

5. Alignment Tyre Requirements

   a. The predetermined alignment tyres used to conduct the alignment procedure shall be identified to cover the needed usage range in terms of load index, Cr and Fr as follows:

      - Cr values shall have a minimum range of:
        - [3 N/kN] for Passenger Car and smaller Truck and Bus tyres
        - [2 N/kN] for larger Truck and Bus tyres.

      - The alignment tyre section width should be:
        - ≤245 mm for Passenger Car and smaller Truck and Bus machines
        - ≤345 mm for larger Truck and Bus tyre machines.

- The alignment tyre outer diameter should be
  - between 510 to 800 mm for passenger car and smaller truck and bus machines
  - between 771 to 1143 mm for larger truck and bus tyre machines

- load index values shall adequately cover the range for the tyres to be tested, ensuring that the Fr values also cover the range for the tyres to be tested.

- the number of alignment tyres shall be equal to [two], i.e. there shall be:
  - [two] alignment tyres for passenger car and smaller Truck and Bus tyres, and
  - [two] alignment tyres for larger Truck and Bus tyres.

b. Each alignment tyre must be checked prior to use and replaced when:
   - it shows a condition which makes it unusable for further tests
   - there are deviations of Cr for alignment tyre measurement greater than 1.5% relative to earlier measurements after correction for any machine drift.

6. Alignment Procedure

a. Each time an alignment tyre is measured, the tyre/wheel assembly shall be removed from the machine and the entire test procedure specified in section 4 shall be followed again. This requirement applies to both the Technical Service laboratory and the candidate laboratory.

b. The Technical Service shall measure each alignment tyre three times in accordance with section 4 and applying the conditions in section 3, and provide the mean value and standard deviation established from the 3 measurements for each tyre.

c. The candidate machine shall measure each alignment tyre three times in accordance with section 4 and applying the conditions in section 3, with a measurement standard deviation for each tyre of
   - not greater than [0.05] N/kN Passenger Car and smaller Truck and Bus tyres (LI $\leq$ 121) and
   - not greater than [0.05] N/kN for larger Truck and Bus tyres (LI $\geq$ 122).

   If this measurement standard deviation exceeds this criterion with 3 measurements, then the number of measurement repetitions shall be increased to meet the criterion:

$n = (\sigma_m/\gamma)^2$where
γ = [0.029] N/kN for Passenger Car and small Truck and Bus tyres (LI ≤ 121)
γ = [0.029] N/kN for larger Truck and Bus tyres (LI > 121).

d. The alignment shall be performed by the candidate laboratory and shall be a linear regression technique, A and B, are given in the equation:

$$Cr\_ass\_TS = A1 \times Cr\_TSi + B1$$

$$Cr\_TSi = A2 \times Cr\_CM + B2$$

$$Cr\_ass\_TS = A1 \times (A2 \times Cr\_CM + B2) + B1$$

Where:

- Cr ass TS is the assigned value of the Rolling Resistance coefficient
- Cr Tsi is the measured value of the Rolling Resistance Coefficient by the Technical service including temperature and drum diameter influences.
- Cr CM is the measured value of the Rolling Resistance Coefficient by the Candidate laboratory including temperature and drum diameter influences.
- The aligned Cr value for the Technical Service must take into account coefficients A1 and B1
- The aligned Cr value for the Candidate laboratory must take into account coefficients A1&A2 and B1&B2

The measurement standard deviation estimate, σm, will also be given.

7 [The alignment process must be repeated at least every second year and always after any significant machine change or any drift in candidate machine control tyre monitoring data.]