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Tyre sound emission test — Methods of drum

Essai d'émissions acoustiques de pneumatique — Méthode avec un tambour

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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).

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

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

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

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.

Introduction

The external sound emission of a tyre is one out of a multitude of requirements that need to be considered by manufacturers during design and development of tyres. For health and environmental protection reasons, the sound emission should be reduced under all relevant driving conditions. To meet all these demands, an efficient test site is needed that can be operated the whole year round independent of weather conditions or other outside factors. In many countries, the meteorological conditions are so adverse that outdoor testing on a classical proving ground is only possible in a very limited timeframe. Furthermore, performing sound emission tests on various test tracks highly increases the uncertainty and multiplies the workload for a manufacturer.

This document gives specifications for an indoor noise test bench and a test procedure that delivers precise results for indoor testing, comparable to a certified type approval test track. The results are intended to be within the run-to-run variation of the actual valid exterior noise test described in ISO 13325, which is the test standard used for type approval of tyres. An indoor test bench requires tight specifications for the equipment and set up, such as the acoustical treatment of the walls and the ceiling, the microphone array, the roller bench, the adjustment of the tyre load on the roller bench. Special treatment needs to ensure that all rolling sound components of the tyre are comparable to the rolling sound on a road surface as specified in ISO 10844 and as applied in type approvals. This document provides all necessary specifications and procedures to ensure comparability between todays common and well accepted testing on outdoor test tracks with future indoor facilities. It incorporates all relevant International Standards for equipment, measurement uncertainty and test procedures.

The current outdoor method (described in ISO 13325) requests the vehicle to move at various speeds in between two microphones. This imposes to the tyre a high rotation speed which is at the source of sound emission, by creating tyre parts movements, slip and shocks against the track surface. As a vehicle, movement is not possible in a semi-anechoic room, the rotation of a drum is used to create tyre rotation similar to the one observed on track. In order to create excitation similar to the one created on the track, the drum is coated with a surface similar to the one of the tracks. Finally, the vehicle trajectory between the microphones is simulated by a line of microphones, signals of each microphone being used to estimate the noise level of the car moving between microphones.

The results are intended to be within the run-to-run variation of the actual valid exterior noise test described in ISO 13325.

Tyre sound emission test — Methods of drum

1 Scope

This document specifies methods for measuring tyre-to-road sound emissions from tyres fitted on rig that applies the tyre on a rotating drum under coast-by conditions (i.e. when the tyre is in free-rolling, non-powered operation).

The specifications are intended to achieve a correlation between results of testing the exterior noise of tyres in a semi anechoic chamber and outdoor testing as described in ISO 13325.

This document is applicable to passenger cars and light commercial vehicles tyres as defined in 3.1. It is not intended to be used to determine the sound contribution of tyres applying a torque, nor for the determination of traffic sound nuisance at a given location.

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/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO 3745:2012/Amd 1:2017, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for anechoic rooms and hemi-anechoic rooms*

ISO 4000-1, *Passenger car tyres and rims — Part 1: Tyres (metric series)*

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

ISO 4223-1:2017, *Definitions of some terms used in the tyre industry — Part 1: Pneumatic tyres*

ISO 10844, *Acoustics — Specification of test tracks for measuring sound emitted by road vehicles and their tyres*

ISO 13325:2019, *Tyres — Coast-by methods for measurement of tyre-to-road sound emission*

ISO 26101-1, *Acoustics — Test methods for the qualification of the acoustic environment — Part 1: Qualification of free-field environments*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

IEC 61672-3, *Electroacoustics — Sound level meters — Part 3: Periodic tests*

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

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

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

3.1
class of tyre
type of tyres intended to be used on similar vehicles

Note 1 to entry: The various types of class of tyre are named and defined as follows:

— passenger car tyre: tyres conforming to ISO 4000-1;

— light commercial vehicle tyre: tyres conforming to ISO 4209-1 and identified by a load index in single configuration lower or equal to 121 and speed symbol higher or equal to "N".

3.2
tyre category
group of tyres intended to be used for similar purpose

Note 1 to entry: The various types of tyre category are named and defined as follows:

— normal tyre, as defined by ISO 4223-1, 3.1.1;

— snow tyre, as defined by ISO 4223-1, 3.1.3;

— severe snow use tyre, as defined by ISO 4223-1, 3.1.5;

— traction tyre, as defined by ISO 4223-1, 3.1.8;

— special use, as defined by ISO 4223-1, 3.1.2.

3.3
load index
LI
numerical code associated with the maximum load a tyre can carry at the speed indicated by its speed symbol under the service conditions specified by the tyre manufacturer

Note 1 to entry: In cases where the LI consists of two numbers, reference shall be made to the first number. For tyres where the load index is not available, reference shall be made to the maximum load marked on the tyre sidewall.

3.4
rig
device applying a load to tyre and measuring it during the test

4 Symbols and abbreviated terms

All symbols used in this document and that are used in the test report are described in Table 1.

Table 1 — Symbols used and corresponding clauses

Symbol	Unit	Sub-clause	Description
a		9.2.5	Slope of the regression line L_i versus v_{*i}
α_{array}^+ , α_{array}^-		6.2.3	Angles spanned by the circular array in the xy-plane in positive and negative x-directions, respectively
α_{array}^-		6.2.3	Angles spanned by the circular array in the xy-plane in positive and negative x-directions, respectively
$\alpha_{array\,min}$		6.2.3	Minimal acceptable value of α_{array}^+ and α_{array}^-
α_m		6.2.3	Signed angle between projection of the microphone number m of the circular array onto the xy-plane and the y-axis
C_t		9.2.4	Coefficient for tyre impact on sound propagation

Table 1 *(continued)*

Symbol	Unit	Sub-clause	Description
C_v		9.2.4	Coefficient for vehicle impact on sound propagation
D	m	6.3	Largest expected size of acoustic source on the tyre
Dd	mm	7.2.1	Diameter of drum including the surface
$\Delta L(x_m)$		6.5	Relative sound pressure level decay at microphone number m with respect to the central microphone
Δx	m	6.2.2	Spacing of linear array microphones in x-direction NOTE It is the reference distance for definition of coordinates of circular array microphones.
$\Delta x_{\max}$	m	6.2.2	Maximum allowed value of Δx
Hd	mm	7.2.3	Height of the drum top point above the floor
$\bar{L}$	dB(A)	9.2.5	Mean value of representative SPLs
l_{array}^{+}	m	6.2.2	Lengths of linear microphone array in positive x-directions
l_{array}^{-}	m	6.2.2	Lengths of linear microphone array in negative x-directions
$l_{\mathrm{array\ min}}$	m	6.2.2	Minimal acceptable value of l_{array}^{+} and l_{array}^{-}
L_{CBY}	m	6.2.2	Reference distance for definition of $l_{\mathrm{array\ min}}$ and $\alpha_{\mathrm{array\ min}}$
L_f	dB(A)	9.2.5	Final test result
L_i	dB(A)	9.2.4	Representative SPL (test result) at speed v_i
L_R	dB(A)	9.2.5	Interpolated value of SPL at the speed v_{ref}
$L_{R\ \mathrm{aligned}}$	dB(A)	9.2.6	Interpolated value corrected for lab alignment with outdoor
L_{SP}		6.5	Sound pressure level
L_v		9.2.5	Interpolated value of SPL at a speed v
$\lambda_{\min}$	m	6.3	Wavelength of sound wave in the air at the highest frequency of concern
m	m	6.2.1	Number of a microphone
M		6.2.1	Total number of the microphones in the array
M_{s}		11.3	Slope of the regression line $L_{R\ \mathrm{track}\ i}$ versus $L_{R\ \mathrm{drum}\ i}$
M_{negative}		6.2.1	Number of array microphones in negative x-directions
M_{positive}		6.2.1	Number of array microphones in positive x-directions
n		9.1.4	Number of test speeds
$P_A(x_m)$	Pa^2	9.2.1	Mean square value of $p_{mA}(t)$
$P_A^{corr}(X_m)$	Pa^2	9.2.2	Distance corrected mean-square pressure of the microphone m
$P_{FA}^{corr}(X_m)$	Pa^2	9.2.3	Distance-corrected mean-square pressure of the microphone m with emulation of fast time weighting through exponential weighting in X
$p_m(T)$	Pa	9.2.1	Time-signal of the m-th microphone
$p_{mA}(T)$	Pa	9.2.1	A-filtered time signal of the m-th microphone
P_0	Pa	9.2.4	Reference acoustic pressure for dB scale
P_{r}	kPa	9.1.2	Reference pressure
P_{t}	kPa	9.1.2	Test inflation pressure
Q		11.3	Shift at origin of the regression line $L_{R\ \mathrm{track}\ i}$ versus $L_{R\ \mathrm{drum}\ i}$
Q_{r}	N	9.1.1	Reference load, corresponding to max load associated with tyre load index
Q_{t}	N	9.1.1	Test load for the tyre

Table 1 *(continued)*

Symbol	Unit	Sub-clause	Description
r_0		6.5	Distance from the acoustic source to the central microphone of the array
R^2		11.3	Correlation coefficient of the regression line $L_{R\,\text{track}\,i}$ versus $L_{R\,\text{drum}\,i}$
r_{array}	m	6.2.3	Radius of the base circle of the circular microphone array
r_m		6.5	Distance from the acoustic source to the m-th microphone of the array
T	s	9.2.1	Averaging time for mean square calculation
$\bar{v}_*$		9.2.5	Mean value of v_{*i}
v_{*i}		9.2.5	Decimal logarithm of the test speed v_i
v_i	km/h	9.1.4	Value of the i-th test speed
v_{ref}	km/h	9.2.6	Reference speed for test results interpolation
x, y, z	m	6.2.1	Axis of Cartesian coordinate system
X_m	m	9.2.2	Distance-corrected x-coordinate of the microphone ⬚
x_m, y_m, z_m	m	6.2.1	Coordinates of the microphone number m
y_{array}	m	6.2.2	Distance from linear microphone array to the vertical tyre mid-plane
Y_{CBY}	m	6.2.2	Distance from microphone to track centre (as defined in ISO 13325) NOTE It is the reference distance for sound pressure level correction in this document.
z_{array}	m	6.2.2	Height of linear microphone array above the tyre contact patch centre (drum top)
Z_{CBY}	m	6.2.2	Height of microphones above the ground (as defined in ISO 13325) NOTE It is the reference height for definition of array microphones height in this document.

5   Instrumentation

5.1   Instruments for acoustical measurement

The sound pressure level meter or equivalent measuring system (including microphone and acquisition system), shall meet the minimum requirements of a Class 1 instrument in accordance with IEC 61672-1. Alternatively, IEC 60651 may be used.

The measurements shall be made using the "A" frequency weighting.

The calibration of the sound pressure level meter shall be checked and adjusted in accordance with the manufacturer's instructions or with a standard sound source (e.g. pistonphone) at the beginning of the measurements and rechecked and recorded at the end of them. The calibration device shall meet the requirements of Class 1 in accordance with IEC 60942.

If the sound pressure level meter indications obtained from these calibrations differ by more than 0,5 dB during a series of measurements, the test shall be considered invalid. Any deviations shall be recorded in the test report.

NOTE   The tests of IEC 61672-3 cover only a limited subset of the specifications in IEC 61672-1 for which the scope is large (temperature range, frequency requirements up to 20 kHz, etc.). It is economically not feasible to verify the whole IEC 61672-1 requirements on each item of a computerized data acquisition systems model.

5.2   Microphones

The microphones setup is described in 6.2. In the vicinity of the microphones, there shall be no obstacles that could influence the acoustical field.

5.3 Temperature measurement

5.3.1 General

For air temperature measurement, the measuring instrument shall have an overall accuracy of at least ±1 °C. Meters utilizing the infrared technique shall not be used for air temperature measurements.

Continuous registration through an analog output may be employed. If such an option is not available, single values shall be measured.

Measurements of air temperature are mandatory and shall be made in accordance with the instrument manufacturer's instructions.

Temperature measurements shall correspond reasonably over time with sound measurements. Alternatively, the average of the temperature at the beginning and the end of the set of tests may be used.

5.3.2 Room temperature

One should position the temperature sensor in an unobstructed location close to the microphone array. The sensor should not be positioned higher than the height of the microphone array (see 6.2).

5.3.3 Calibration

At the beginning and at the end of every measurement session (typically one day of measurement), the entire sound measurement system shall be checked by means of a sound calibrator as described in 5.1. Without any further adjustment, the difference between the readings shall not exceed 0,5 dB. If this value is exceeded, the results of the measurements obtained after the previous satisfactory check shall be discarded.

5.4 Conformity with requirements

At intervals of not more than two years, the sound pressure level meter shall be verified with the requirements of IEC 61672-1. Alternatively, IEC 60651 may be used. At intervals of not more than one year, the calibration device shall be verified with the requirements of IEC 60942.

When no general statement or conclusion can be made about conformance of the sound level meter model to the full specifications of IEC 61672-1, the apparatus used for measuring the sound pressure level shall be a sound level meter or equivalent measurement system meeting the compliance requirements of Class 1 instruments as described in IEC 61672-3.

All conformity testing shall be conducted by a laboratory which meets the requirements of ISO/IEC 17025.

6 Test room requirements

6.1 General

One of the principal criteria of ISO 13325 for tyre sound emission measurement is testing in an acoustic free field.

To reproduce this acoustic criterion in a laboratory, the room design shall be able to provide the same effective propagation characteristics as an open space over a reflecting surface (see specifications in 6.5).

One solution is a semi-anechoic chamber with absorptive materials. Several techniques are available for this purpose. An example of a test room is shown in Figure 1.
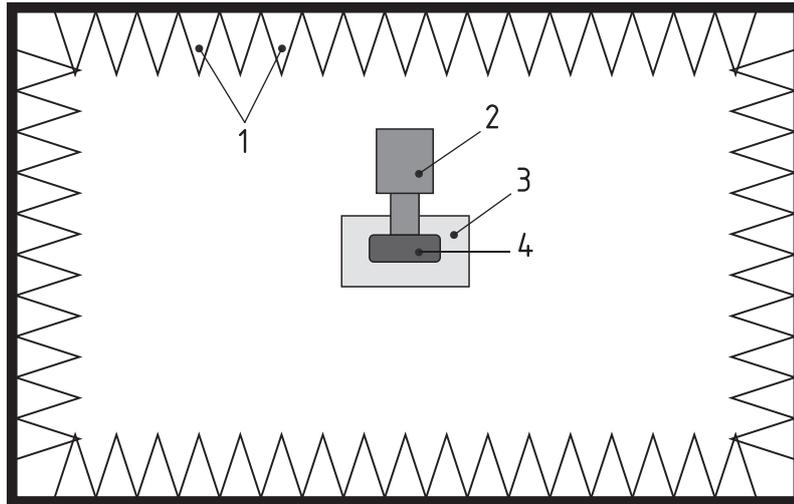
Key

1   absorbing elements
2   rig
3   drum
4   tyre

Figure 1 — Room example

6.2   Microphone array setup

6.2.1   General

There are two possible microphone array setups described in 6.2.2 and 6.2.3.

In both setups:

— Position of each microphone is proportionally simulating a relative position of the tyre contact patch and the microphone position used in ISO 13325.

— All microphones of the array shall be located in the far field zone of the tyre noise acoustic field (see Figure 2).

— Microphones of the array shall be placed at a distance from the walls of the room at least equal to quarter-wavelength of the sound wave in the air at the lowest frequency of concern.

Origin of the coordinate system used to define microphone coordinates in both setups is the projection of tyre centre onto the drum. Axes of the coordinate system are directed as follows:

— x-axis is directed opposite to the tyre rotation direction;

— y-axis is directed along the tyre rotation axis towards the microphone array;

— z-axis is directed vertically upwards.

The microphones of the array are numbered as follows. The microphone with $x = 0$ has number $m = 0$. The microphones in the positive x-direction have numbers $m = 1, 2 \ldots 9_+$ and the microphones in the negative x-direction have numbers $m = -1, -2, \ldots, -9_-$. The total number of microphones is 19 and M is equal to 0 in all clauses.

Microphone coordinates shall be accurate to ±1 cm.

6.2.2   Linear array

A linear array of microphones will be set on a straight line perpendicular to the tyre rotation axle at a distance y_{array} (see Figure 2). The distance y_{array} should be chosen so that all microphones are in the far field zone of the tyre noise acoustic field (see 6.3). Microphone array facing the tyre as shown in Figure 2 shall then respect the following constraints:

Key
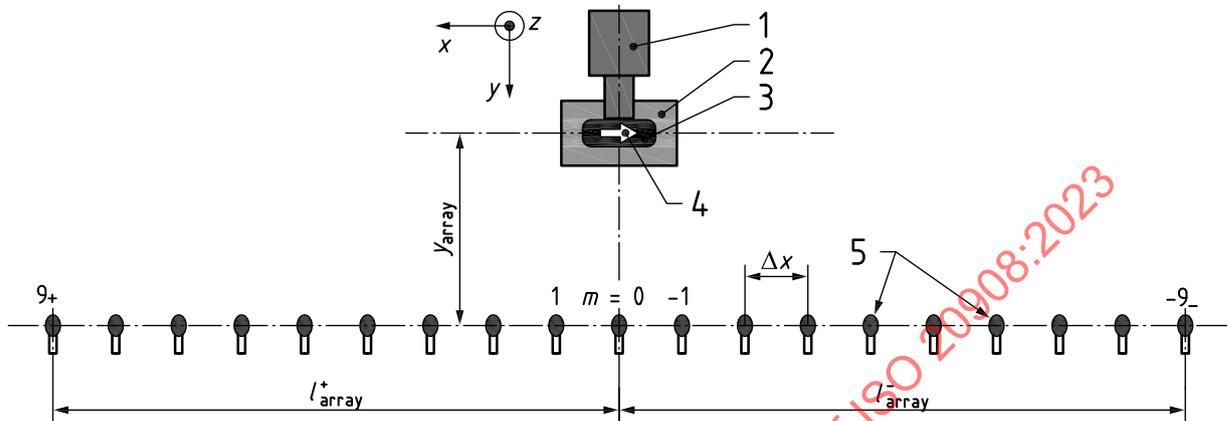
1   rig
2   drum
3   tyre
4   rotation direction
5   microphones

Figure 2 — Linear microphone array setup

All microphones of the array shall have the same y-coordinate:

$$y_m = y_{array,} \quad m = -M_- ... M_+ \tag{1}$$

All microphones of the array shall have the same height with respect to the tyre centre (drum top) which is scaled by the distance as

$$z_m = z_{array} = Z_{CBY} \times \frac{y_{array}}{Y_{CBY}}, \quad m = -M_- ... M_+ \tag{2}$$

With $Z_{CBY} = 1,2$ m, as in ISO 13325 and $Y_{CBY} = 7,5$ m is the reference distance defined in 9.2.2.

Microphones of the array shall be placed with constant interval Δx in x-direction so x-coordinate of the m-th microphone is given by

$$x_m = m\Delta x, \quad -M_- \ldots M_+ \tag{3}$$

The interval Δx shall be at most equal to $\Delta x_{\max}$:

$$\Delta x \leq \Delta x_{\max} = y_{\text{array}} / 6 \tag{4}$$

The lengths of the array l_{array}^+ and l_{array}^- in positive and negative x-directions, respectively, shall be at least equal to $l_{\text{array min}}$:

$$l_{\text{array}}^+ \geq l_{\text{array min}} = L_{\text{CBY}} \times \frac{y_{\text{array}}}{Y_{\text{CBY}}} \tag{5}$$

with L_{CBY} = 10 m as half-length of the measurement area in ISO 13325.

Symmetric placement of the microphone array with respect to tyre rotation axis $\left(l_{\text{array}}^+ = l_{\text{array}}^- \right)$ is recommended. For non-symmetric placements, when there is a choice, one should make longer the half of the array in the negative x-direction.

6.2.3 Circular array

A circular array of microphones will be set on a circular arc centred at the tyre centre (drum top) of radius r_{array} (see Figure 3). The radius r_{array} should be chosen so that all microphones are in the far field zone of the tyre noise acoustic field (see 6.3). Microphone array facing the tyre as shown in Figure 3 shall then respect the following constraints:

Key
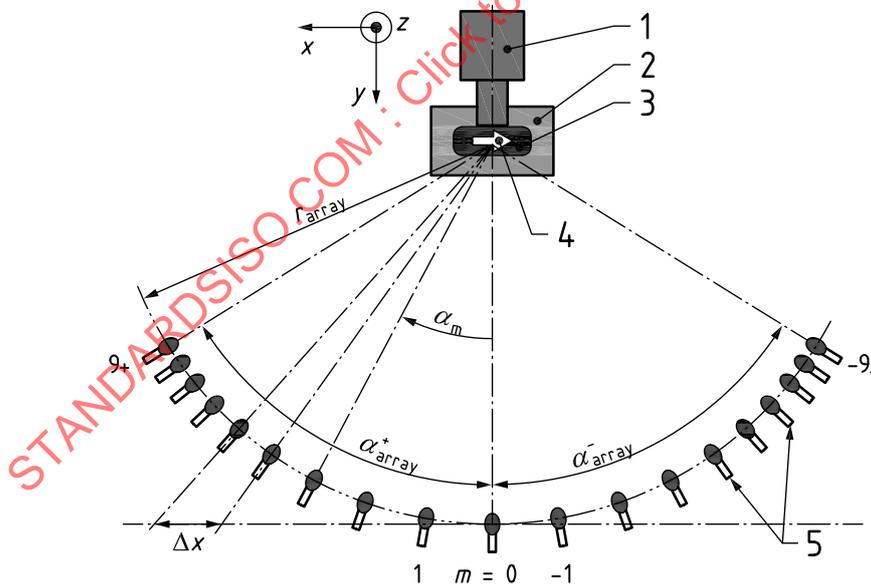
1 rig
2 drum
3 tyre
4 rotation direction
5 microphones

Figure 3 — Circular microphone array setup

Positions of the microphones in the *xy*-plane shall be such that their projections on the line $y = r_{array}$ have constant interval Δx in *x*-direction. This is achieved by setting for the microphone *m*:

$$\alpha_m = \operatorname{atan}\frac{m\Delta x}{r_{array}}, \quad x_m = r_{array}\sin\alpha_m, \quad y_m = r_{array}\cos\alpha_m, \quad m = -M_- \ldots M_+ \tag{6}$$

The interval Δx shall be at most equal to Δx_{max}:

$$\Delta x \le \Delta x_{max} = r_{array} / 6 \tag{7}$$

Height of the microphone *m* with respect to the tyre contact patch centre (drum top) is scaled by the distance as

$$z_m = Z_{CBY} \times \frac{y_m}{Y_{CBY}}, \quad m = -M_- \ldots M_+ \tag{8}$$

with Z_{CBY} = 1,2 m, as in ISO 13325 and Y_{CBY} = 7,5 m is the reference distance defined in 9.2.2.

The angles α_{array}^+ and α_{array}^- spanned by the array in the *xy*-plane in positive and negative *x*-directions, respectively, shall be at least equal to $\alpha_{array\,min}$:

$$\alpha_{array}^+ \ge \alpha_{array\,min} = \operatorname{atan}\left(L_{CBY} \times \frac{r_{array}}{Y_{CBY}} \right) \tag{9}$$

with L_{CBY} = 10 m as half-length of the measurement area in ISO 13325.

Symmetric placement of the microphone array with respect to tyre rotation axis $\left(\alpha_{array}^+ = \alpha_{array}^-\right)$ is recommended. For non-symmetric placements, when there is a choice, one should make longer the half of the array in the negative *x*-direction.

6.2.4 One microphone measurement set up

After tyre warm-up procedure, tyre sound emission can be considered as stationary and measurement can be alternatively performed by moving a single mic, step by step, through all the positions of mics in the array configuration both circular and linear. Steady state condition shall be monitored by a reference mic lodged in far field position: measurement is valid only in case reference mic shows a sound pressure level variation lower than 0,1 dB. See Figure 4.

Key
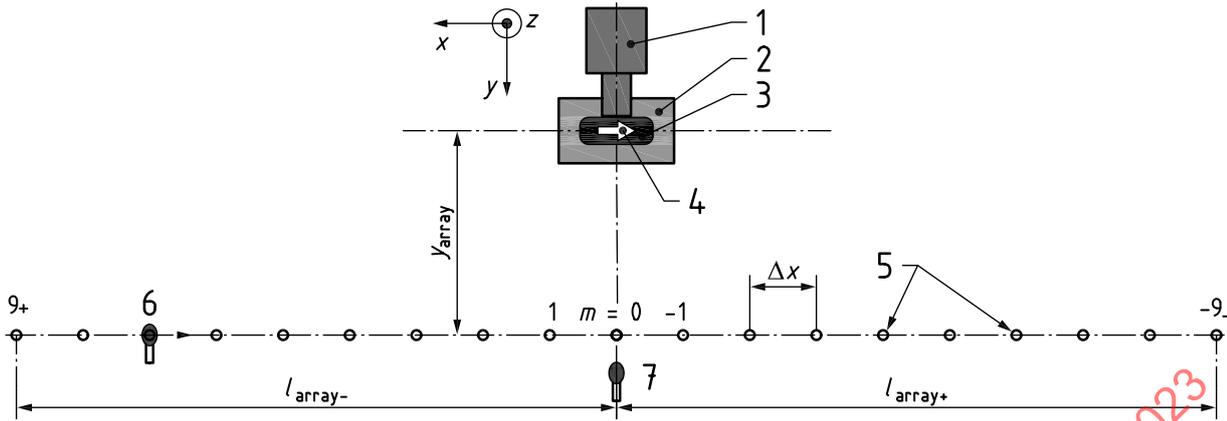
1   rig
2   drum
3   tyre
4   rotation direction
5   observation points
6   moving mic
7   reference mic

Figure 4 — One microphone measurement set up

6.3   Far field conditions

Typically microphone array will be closer to tyre than microphones in the on-vehicle test of ISO 13325. In order to make the results of the indoor tyre noise measurement comparable to results of the on-vehicle test, one should compensate for this difference. Such compensation is possible if two conditions are fulfilled.

—   Noise absorbing treatment of the walls and the ceiling and the design of the spindle should be such that acoustic free field conditions are fulfilled (see 6.5).

—   All microphones of the array are in the far field zone of the tyre noise acoustic field.

Definition of far field zone can be done as follows:

$$y_{\text{array}} \geq \frac{D^2}{\lambda_{\min}}, \text{ for the linear array and} \tag{10}$$

$$r_{\text{array}} \geq \frac{D^2}{\lambda_{\min}}, \text{ for the circular array} \tag{11}$$

with D being the largest expected size of acoustic source on the tyre (contact patch size), and $\lambda_{\min}$ is the wavelength of sound wave in the air at the highest frequency of concern.

Calculation using a contact patch size of 350 mm shows that y_{array} and r_{array} shall be equal or greater than 1,75 m with a frequency of 5 kHz and 0,07 m as wavelength.

6.4   Test room dimensions

Room dimensions shall conform to the requirements of ISO 3745:2012/Amd 1:2017.

All room dimensions shall be adjusted to meet the specific application for the products being tested.

6.5 Acoustical qualification of the room

6.5.1 General

The free field shall meet the requirements of ISO 3745:2012/Amd 1:2017 or, alternatively, ISO 26101-1. To consider special use of the room, the validation shall be done for indoor microphone arrays.

Three options of evaluation are possible to validate the free field conditions; see 6.5.2 to 6.5.4.

There are two main sources of deviations from the free field conditions: reflections by the walls and the ceiling and reflections by the rig and the drum. One shall validate the free field conditions with drum and rig configuration as close as possible to the one of the actual tyre testing.

For some rig designs, it is possibly beneficial to apply noise absorbing treatment to the spindle whereas for other designs it can be detrimental. One should assess the effects of such treatment and apply it if it can improve free field conditions of the setup.

6.5.2 Validation of the inverse square law on lines from the centre of the room to microphone position

The source (relatively omnidirectional and covering at least the frequency of interest [200 Hz to 5 000 Hz]) is placed on the drum at the centre of the centre of the tyre (see Figure 5 and Figure 6). Lines to be evaluated are plotted from the source to each microphone of the microphone array. It is possible to reduce the number of lines by considering representative microphone positions and symmetry of the room.

For each line, at least 10 equidistant points shall be measured (see Figure 5 and Figure 6) and processed according to ISO 3745 or, alternatively, ISO 26101-1.
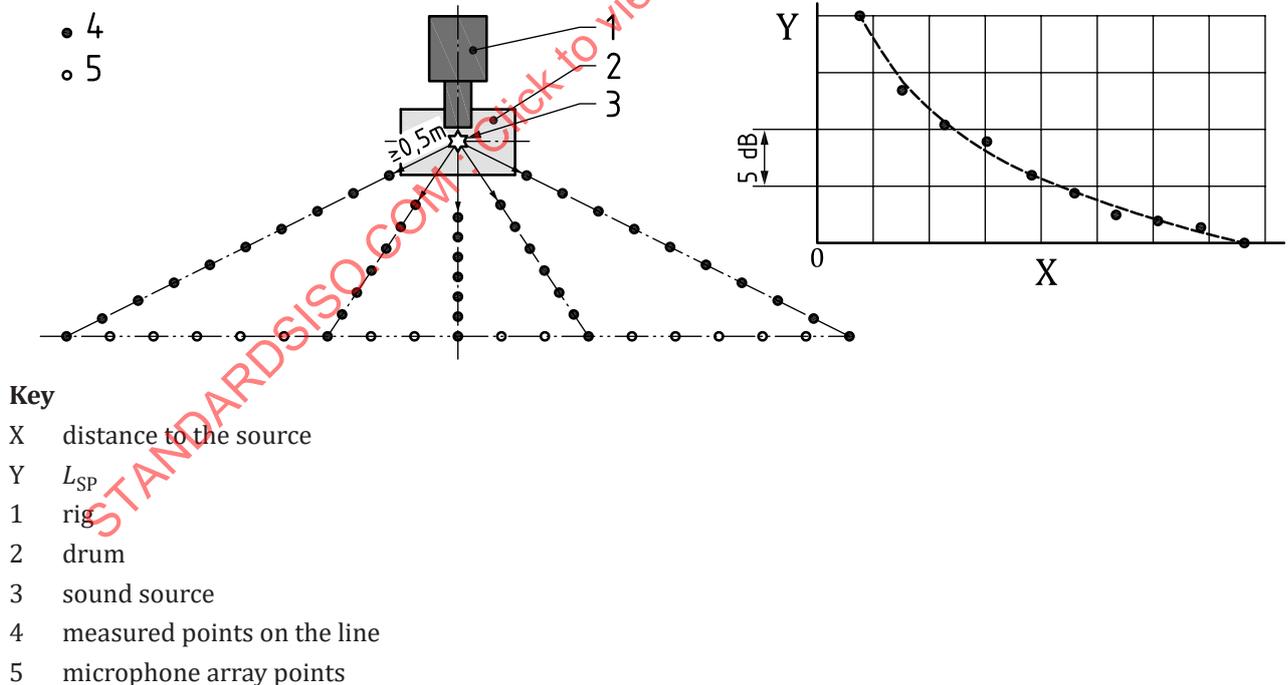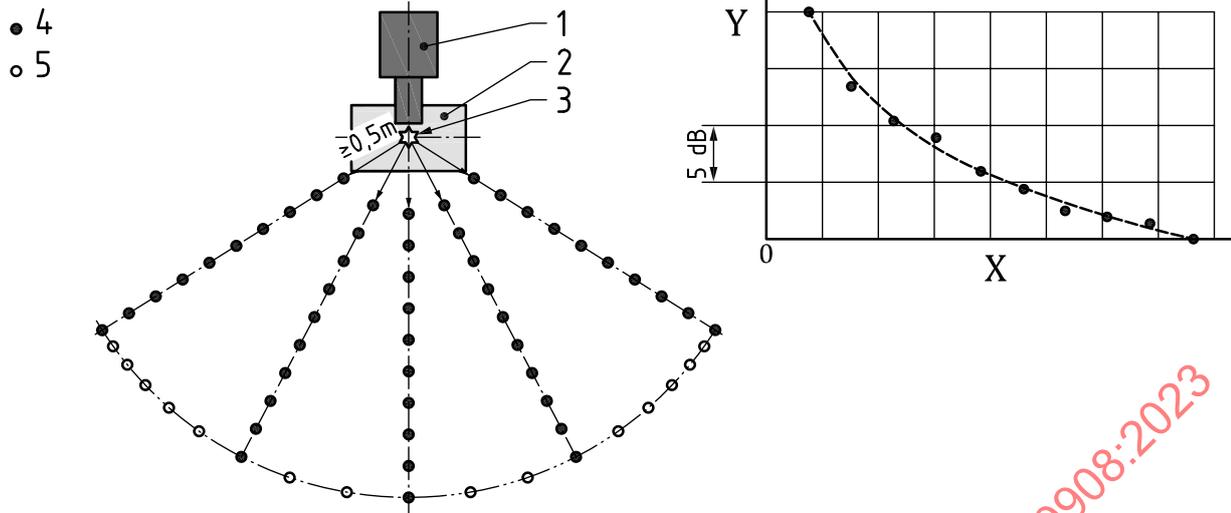

Key
X   distance to the source
Y L_{SP}
1   rig
2   drum
3   sound source
4   measured points on the line
5   microphone array points

Figure 5 — Example of validation according to 6.5.2 for linear array setup

Key

X   distance to the source

Y L_{SP}

1   rig

2   drum

3   sound source

4   measured points on the line

5   microphone array points

Figure 6 — Example of validation according to 6.5.2 for circular array setup

6.5.3   Validation of the inverse square law with at least one line from the centre of the room to a microphone position and the points of concern of the microphone arrays

The source is placed on the drum at the centre of the contact patch of the tyre (see Figure 7 and Figure 8). A line to be evaluated is plotted from the source to each microphone at the corners. At least 10 equidistant points shall be measured. In addition, points of concern of the indoor microphone arrays are measured (see Figure 7 and Figure 8). Processing for all these measurement points shall be done according to ISO 3745, or alternatively, ISO 26101-1.
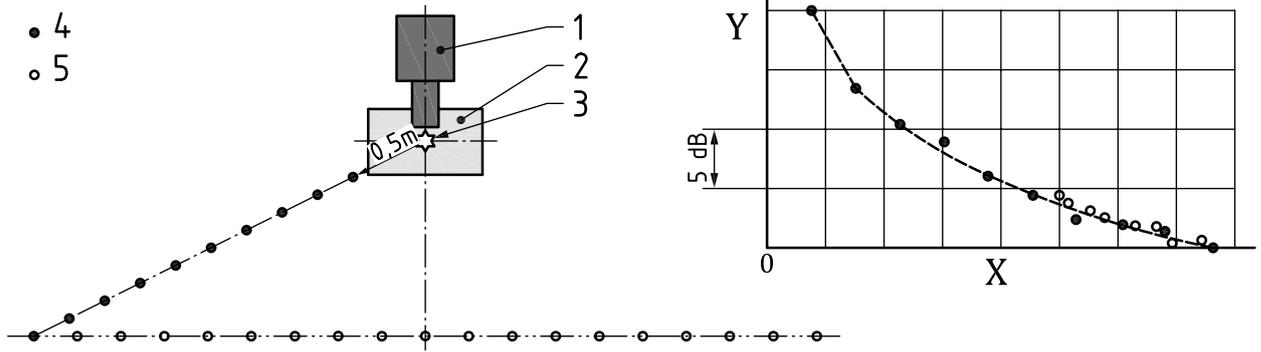
Key

X distance to the source

Y L_{SP}

1 rig

2 drum

3 sound source

4 measured points on the line

5 microphone array points

Figure 7 — Example of validation according to 6.5.3 for linear array setup
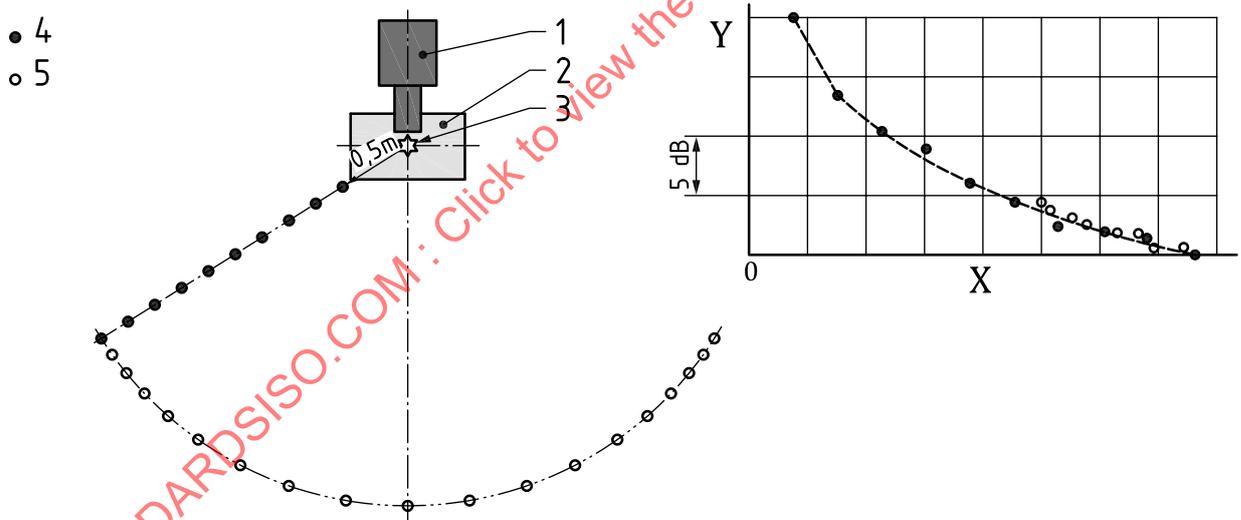
Key

X distance to the source

Y L_{SP}

1 rig

2 drum

3 sound source

4 measured points on the line

5 microphone array points

Figure 8 — Example of validation according to 6.5.3 for circular array setup

6.5.4 Validation of the inverse square law along the complete microphone array

The source is placed on the drum at the centre of the contact patch of the tyre (see Figure 9 and Figure 10). The free-field conditions are verified along the microphone array line. The tests are performed for the complete length of the microphone array line at each microphone position.

For comparison of measured sound pressure levels with the inverse square law, the theoretical level decay at the microphone test positions shall be calculated from the individual path lengths, r_m, that are given from the source position to the respective measurement positions on the microphone array line and the reference path length, r_0, of the central measurement position.

These predicted relative sound pressure level decays are used for the comparison with the measured sound pressure levels at the same measurement positions. The central position serves as the reference for the computed relative sound pressure level decay from measurement. The difference between the measured and predicted relative decays is compared with the permissible deviations given in 6.5.5.

6.5.4.1 Linear array

With the source on the floor and the reference microphone at the central measurement position, the reference path length, r_0, is given by
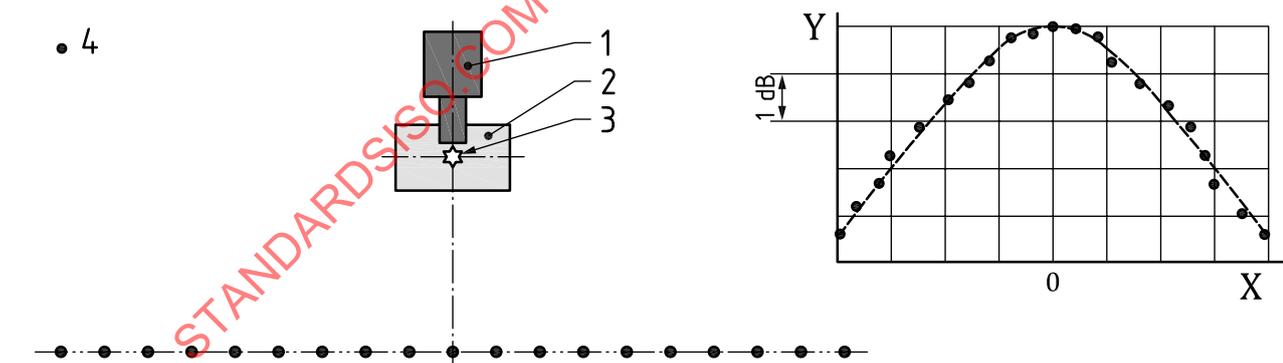
$$r_0 = \sqrt{y_{\text{array}}^2 + z_{\text{array}}^2} \tag{12}$$

Subsequently, the path lengths, r_m, to the microphone at a distance X_m to the reference microphone position along the linear microphone array line are given by

$$r_m = \sqrt{r_0^2 + x_m^2} \tag{13}$$

The relative sound pressure level decay, $\Delta L(x_m)$, is then computed for linear array line according to

$$\Delta L(x_m) = 20 \log_{10} \frac{r_m}{r_0} \tag{14}$$

Key

X   microphone *x*-coordinate

Y L_{SP}

1   rig

2   drum

3   sound source

4   measured array points

Figure 9 — Example of validation according to 6.5.4 for linear array

6.5.4.2 Circular array

For the circular array setup, maximal theoretical relative sound pressure level decay with respect to the central measurement position is less than 0,1 dB and can be rounded to 0.
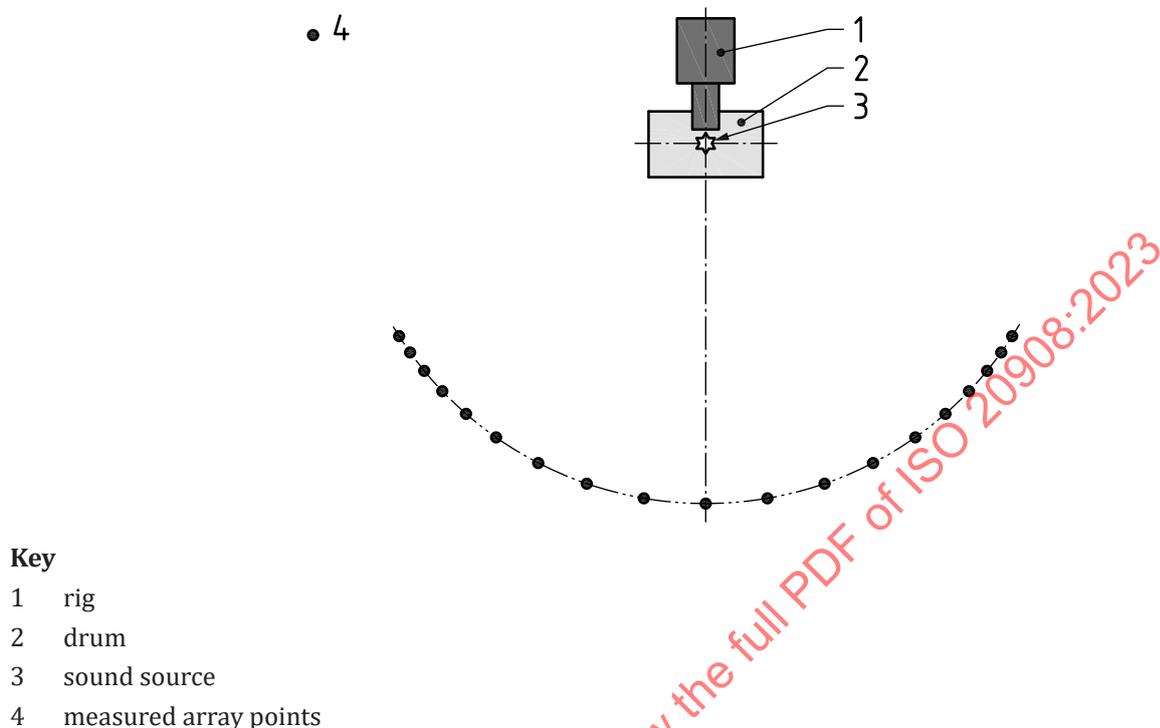
Key

1 rig
2 drum
3 sound source
4 measured array points

Figure 10 — Example of validation according to 6.5.4 for circular array

6.5.5 Qualification procedure

Room shall be validated in one third octave bands between 200 Hz and 5 kHz, with tolerances given in Table 2.

The deviations of measured sound pressure levels from those estimated using the inverse square law shall not exceed the values given in Table 2 at least in 95 % of the cases. The permissible deviation can be extended till 5 dB in the other 5 % of the cases.

Table 2 — Maximum permissible deviation of measured sound pressure levels from theoretical levels using the inverse square law

One-third-octave-band mid frequency Hz	Permissible deviation dB(A)
≤ 630	±3,5
800 to 5 000	±3,0
NOTE An additional tolerance of 1 dB has been added to the ISO 3745 requirement considering that indoor coast-by is an engineering and not a laboratory method.	

6.6 Condition of the floor

The absorption coefficient of the floor shall not exceed the coefficient defined in ISO 10844 for propagation area.

6.7 Cooling, ventilation, room temperature

The room temperature shall be within the limits 23 °C ± 3 °C.

The volume flow of the room ventilation system is dependent on the room dimensions, the geometry and orientation of the test object and the type of test run.

In order to be able to maintain the requested temperature, it is recommended to install an air conditioning system.

All safety regulations for indoor testing facilities concerning harmful substances shall be fulfilled.

6.8 Background noise

The background sound pressure level at each microphone (including the noise caused by air conditioning, drum rotation at maximal speed rotation, and other components, with a tyre fitted on the rig but not touching the drum) shall be at least 10 dB(A) overall less than the measured tyre-road sound emission at the lowest speed, in the range 200 Hz and 5 kHz. It should be measured for each measurement session (typically one day of measurement).

7 Drum, drum surface and loading device requirements

7.1 Tyre loading device

The tyre loading device shall apply a constant load to the tyre during the measurement readings:

— Admitted deviation from the nominal value of average load during the measurement at each speed is +/− 150 N or +/− 3 % whichever is greater.

7.2 Drum characteristics

7.2.1 Drum diameter

Test drum nominal diameter Dd is at least 1 700 mm. The drum diameter should be as large as possible to minimize the acoustical effects in comparison to a flat track.

7.2.2 Drum width

Drum measuring surface width shall be greater than the width of the running surface of the tested tyre.

7.2.3 Height of the drum top point above the floor

The height of the drum top point (including the drum surface) Hd should be above the ground. The drum top point (including the drum surface) shall not be greater than 60 mm. The drum top point shall not be lower than 10 mm under the floor level.

7.2.4 Drum speed

The drum speed shall be measured using instruments with an uncertainty of not more than ±0,5 km/h. The speed of the tyre is calculated by using the drum speed.

Deviation of average speed during the measurement from the prescribed value (see 9.1.4) shall be within +/− 0,5 km/h.

7.3 Tyre condition

Slip and camber angle set to 0 ± 0,12 degree (0 rad ± 0,002 rad) in loaded condition.

7.4 Drum surface

The test surface, including voids, shall be dry and clean for all measurements.

The drum surface shall be obtained by copying a track conforming to ISO 10844 geometrical requirements for the mean profile depth (MPD), in an area chosen in one of the tyre running lanes after the track has been used for tyre measurement.

The drum surface shall be built with rigid and not deformable material.

The copy of the surface can be obtained by:

a) Molding the ISO 10844 test surface in the centre of one of the driving lane, then using this mold to create plates which will be then formed to shape and radius of the drum, then fixed on the drum.

b) Scanning the ISO 10844 test surface in the centre of one of the driving lanes, and then reproducing by machining or 3D printing plates to be fixed on the drum or the complete continuous drum surface.

c) In case the copy or scan process is not used, drum test surface can be obtained by reproducing the track surface layer, conforming to the specifications of ISO 10844 surface excluding the absorption value, regardless the used materials are exactly the same or not, directly on the drum or reproducing the track surface layer on the other material and fixing it onto the drum.

In any case, the correlation of the drum surface with a track in accordance with ISO 10844 shall be established, when a new surface is installed, or renewed.

The drum surface shall respect MPD value tolerances as described in ISO 10844.

The drum shall be built with plain metal without any void under the zone of the replica in order to get no absorption from the drum.

7.5 Tyre pressure measurement device

The device shall have an accuracy +/− 5 kPa.

8 Preparation and adjustments with respect to tyres

Test tyres shall be mounted on any rim approved by the tyre manufacturer. The rim width shall be recorded. Tyres with special fitment requirements, such as asymmetric or directional design, shall also be mounted in accordance with these requirements: direction of rotation shall be respected, and the side of the tyre intended to face vehicle outside should face the microphone array.

Test tyres shall be warmed-up immediately prior to testing for 30 min at a speed of 90 km/h, loaded following the prescription of 9.1.1 with tyre pressure following the prescription of 9.1.2.

Tyres with special fitment requirements shall be warmed up in accordance with these requirements. The tyres fitted to the test rig shall rotate in the same direction of rotation as when they were warmed up.

For asymmetrical tyres, measurement should be done in both rotation directions and the final result shall be the average of both measurements.

Apart from the tread wear caused by the warmup procedure, the tyres shall have full tread depth.

A maximum of two repetitions with the same tyre is allowed in a 24 h period.

If needed, the load shall be adjusted to the prescription given in 9.1.1 after the warm-up, before starting the measurement readings. If the tyre is stopped for less than 5 min for load adjustments, a 5 min additional warm-up shall be performed. Above 5 min of interruption, the full warmup shall be performed again.

9 Test method and report

9.1 General

9.1.1 Tyre load

— The load Q_t on the tyre to measure shall be 75 % of its LI load Q_r, where: Q_r is the reference load, corresponding to the maximum mass associated with the LI of the tyre;

— Q_t is the test load for the tyre.

9.1.2 Tyre pressure

The tyre shall be inflated to the cold inflation pressure using Formula (15):

$$P_t = P_r \left(\frac{Q_t}{Q_r} \right)^{1,25}$$

(15)

where

P_t is the test inflation pressure, and P_r is the reference pressure, in kilopascals.

For a standard C1 tyre, P_r = 250 kPa.

For a reinforced C1 tyre, P_r = 290 kPa.

For C2 tyres, P_r is the pressure marked on the tyre sidewall.

The pressure shall be adjusted after the thermal conditioning.

9.1.3 Thermal conditioning

The inflated tyre shall be placed in the same thermal environment 23 °C ± 3 °C of the test location for a minimum of 3 h.

After thermal conditioning, the inflation pressure shall be adjusted to the test pressure and verified before starting the measurement.

9.1.4 Speed range

Tyre noise shall be measured for n = 9 speeds in the range from 70 km/h to 90 km/h with 2,5 km/h step for C1 and C2 tyres.

$$v_i = 70 + 2,5 \times (i-1) [\text{km/h}], i = 1...9$$

(16)

For each test speed v_i, acoustic pressure data should be treated according to 9.2.1 to 9.2.4.

For reference speeds, see 9.2.6.

9.2 Data processing

9.2.1 Data pre-treatment

For each test speed v_i defined in 9.1.4, the following treatment is applied to the acoustic pressure data:

— Filter the data keeping only frequency between 200 Hz and 5 000 Hz.

— A-filter is applied to time-signal $p_m(t)$ of each microphone m giving the signal $p_{mA}(t)$.

— Mean square A-weighted pressure at each microphone m is computed with averaging time T ≥ 5 s:

$$P_A(x_m) = \frac{1}{T}\int_0^T p_{mA}^2(t)\,dt \tag{17}$$

sA value of $P_A(x_m)$ shall be invalid if an abnormal discrepancy between the values is recorded and it is not repeatable.

NOTE   Some tyres can give peaks ("resonances") at certain speeds.

9.2.2   Normalization with respect to distance

In order to normalize sound pressure level with respect to distance, a reference distance Y_{CBY} = 7,5 m shall be used.

Distance correction is applied to the mean square data and x-coordinates of the microphones:

$$P_A^{corr}(X_m) = P_A(x_m)\times\left(\frac{y_m}{Y_{CBY}}\right)^2, \quad X_m = x_m\frac{y_m}{Y_{CBY}} \tag{18}$$

with X_m and y_m defined in 6.2.

9.2.3   Emulation of fast time weighting

Moving exponential window in space is applied to the mean-square data. Ideally, for a test at a speed v, the following integral should be computed.

$$P_{FA}^{corr}(X) = \frac{1}{v\tau}\int_{-\infty}^X P_A^{corr}(X)e^{-\frac{X-\eta}{v\tau}}\,d\eta \tag{19}$$

As P_A^{corr} only known at discrete set of points $X_m \in \left[X_{-M_-}, X_{M_+}\right]$ the lower integration limit is replaced by X_{-M_-} and the integral is computed by the trapezoidal method:

$$P_{FA}^{corr}(X_m) = \frac{1}{v\tau}\int_{X_1}^{X_m} P_A^{corr}(\eta)e^{\frac{\eta-X_m}{v\tau}}\,d\eta \approx \frac{1}{v\tau}\sum_{k=-M_-}^{m-1}(X_{k+1}-X_k)\frac{P_A^{corr}(X_k)e^{\frac{X_k-X_m}{v\tau}}+P_A^{corr}(X_{k+1})e^{\frac{X_{k+1}-X_m}{v\tau}}}{2}$$
(20)

Such two-step treatment gives results similar to the application of fast time weighting to the signal measured on track since the fast time-weighting time τ = 0,125 s is much longer than the characteristic period of the tyre noise (0,01 – 0,001 s).

Maximal value of $P_A^{corr}(X_m)$ is taken for calculation of sound pressure level at each speed v_i according to 9.2.4.

9.2.4   Normalization with respect to number of tyres, tyre masking effect and vehicle impact

In order to normalize the sound pressure level with respect to number of tyres, a reference number of four tyres shall be used.

In order to normalize the sound pressure level with respect to the masking and diffraction effect of the tyre which is the closest to the microphone, a coefficient C_t = 0,8 shall be used. This value has been estimated after experimental measurements of tyre masking and diffraction effect (see Annex B).

In order to normalize the sound pressure level with respect to the vehicle impact on sound propagation, which depends on the vehicle geometry, an average coefficient C_v of 0,8 shall be used. This value has

been estimated after experimental measurements of vehicle masking and diffraction effect, as well as calculation of the acoustic propagation depending on the vehicle geometry (see Annex B).

To obtain L_i, the representative sound pressure level value corresponding to the measurement made on a vehicle, following the ISO 13325 reference method, the maximal value of $P_A^{corr}(X_m)$ at the test speed v_i as defined in 9.2.3, shall be multiplied by the reference number of tyres, 4, the coefficient C_t representing the average tyre effect and the coefficient C_v representing the average vehicle effect, and then converted to decibel value:

$$L_i = 10\log_{10}\left(C_v C_t \, 4 \, \frac{\max\limits_{m} P_{FA}^{corr}(X_m)}{p_0^2} \right) \tag{21}$$

with $p_0 = 20\,\mu\text{Pa}$ being the reference acoustic pressure defined in IEC 61672-1.

NOTE   Term $\max\limits_{m} P_{FA}^{corr}(X_m)$ dimension is Pa², as pressure has been squared in Formula (17).

9.2.5   Normalization with respect to speed

In order to normalize sound with respect to speed, a reference speed, v_{ref} = 80 km/h for C1 and C2 tyres shall be used.

The test result for the reported tyre-to-road sound pressure level L_R shall be obtained from the n = 9 values of sound pressure level L_i obtained according to 9.2.1 to 9.2.4 at speeds v_i by a regression analysis using Formula (22):

$$L_R = \bar{L} - a\bar{v} \tag{22}$$

where $\bar{L}$ is the arithmetic mean value of L_i, in decibels, with

$$\bar{L} = \frac{1}{n}\sum_{i=1}^{n} L_i \tag{23}$$

$\bar{v}$ is the arithmetic mean value of the decimal logarithm of speeds, with

$$\bar{v} = \frac{1}{n}\sum_{i=1}^{n} \log_{10}\frac{v_i}{v_{ref}} \tag{24}$$

α is the slope of the regression line, in decibels per speed decade, with

$$\alpha = \frac{\sum_{i=1}^{n}\left(\log_{10}\frac{v_i}{v_{ref}} - \bar{v}\right)\left(L_i - \bar{L}\right)}{\sum_{i=1}^{n}\left(\log_{10}\frac{v_i}{v_{ref}} - \bar{v}\right)^2} \tag{25}$$

The reported tyre-to-road sound pressure level L_R, in decibels, should be expressed to one decimal place.

Optionally, the interpolated level L_v at any other speed v (within the speed range defined in 9.1.4), can be determined as

$$L_v = L_R - a\log_{10}\left(\frac{v}{v_{ref}}\right) \tag{26}$$

For asymmetric tyres, L_v shall be calculated separately for each rotation and direction, the final L_v shall be the arithmetic average of both values.

For directional tyres, only one direction of rotation shall be measured.

For symmetric tyres, one direction of rotation is allowed, but each rotation direction can be tested as well. If both directions have been tested, the final L_v shall be the arithmetic average of both values.

9.2.6 Correlation with outdoor measurement

The alignment coefficients determined in Clause 11 shall be used to correct the value measured on the drum, by applying the following correction determined in 11.3:

$$L_{R\ aligned} = ML_R + Q \tag{27}$$

9.2.7 Adjustment of the reported value

Same as in ISO 13325, in order to take account of any measurement inaccuracies, the value of $L_{R\ aligned}$ according to the above formula shall be reduced by 1 dB(A). The final result L_f, tyre rolling sound level in dB(A), shall be rounded down to the nearest lower whole value.

10 Test report

The test report shall include the following information:

a) reference to this document, i.e. ISO 20908:2023;

b) room temperature after warmup;

c) when and how conformity of the test surface MPD according to the ISO 10844 MPD specification was checked;

d) type (linear or circular) of the microphone array and coordinates of all microphones;

e) drum diameter;

f) test speeds v_i at which the tyres were run.

For each tested tyre, the following information shall be reported:

a) tyre data, including manufacturer, brand name, trade name, size, LI or load capacity, speed symbol, reference pressure, and serial number of the tyre;

b) test rim width;

c) measured tyre load at each speed in newton and targeted tyre load in newton;

d) cold inflation pressure or regulated pressure in kilopascals, mentioning if it is regulated or capped pressure;

e) representative sound pressure level L_i for each test speed v_i;

f) reported sound pressure level L_R, in decibels, normalized to the reference speed and expressed to one decimal place;

g) alignment coefficients, track used for alignment, list of the tyres used for alignments and date of alignment;

h) reported sound pressure $L_{R\ aligned}$ after applying alignment correction coefficients;

i) the final result L_f as described in 9.2.6.

Examples of presentation for the test report information are given in Tables 3 to 7.

Table 3 — Test report

Coast-by testing of tyres with respect to sound emission, in accordance with ISO 20908
Test report no.:
Tyre make (trade name, brand name, manufacturer):
Manufacturer tyre range trade description(s):
Address(es) of tyre manufacturing plant(s):
Size of tyre: _____ Tyre serial number:
Tyre load index (LI) and speed symbol: _____ Ref. pressure:
Class of tyre: ☐ Passenger car (C1)
(mark one box)   ☐ Commercial vehicle (C2)
Category of use:
Enclosures to this report:
Reported A-weighted sound pressure level (L_R): _____ dB(A), at reference speed of: ☐ 80 km/h
Reported A-weighted sound pressure level aligned with outdoor measurement: ($L_{R\,aligned}$): _____ dB(A)
Final result sound pressure level (L_f): _____ dB(A)
Technical service responsible for carrying out the tests:
Name and address of applicant:
Date of test report: _____ Signature:

Table 4 — Background data/information on tyre sound tests

This form belongs to Test report no.: _____ Date of sound testing:
Location of test lab: _____ Date of lab certification:
Lab certification available at:
Location of test track used for alignment: _____ Date of track certification:
Drum diameter in mm: _____ height of the drum top point in mm: _____
Test track certification available at:
Load in % of LI: _____
Tyre inflation in kPa: _____
Test rim width:
Temperature measuring sensor type _____ Air temperature: _____
Background noise measured during the measurement session: _____ dB(A)

Table 5 — Test results

Test no.	Speed	Running direction 1 measure	Running direction 2 measure[a]	Sound pressure level	Air tempera-ture	Comments
	km/h	dB(A)	dB(A)	dB(A)	°C	
1						
2						
3						
4						
5						
6						
7						
8						
[a] To be filled only if necessary.						

Table 6 — Alignment campaign result

Tyre #	Tyre class (C1/C2)	Tyre category Normal Severe snow Special	$L_{R \text{ track}}$ dB(A)	$L_{R \text{ drum } i}$ dB(A)	$L_{R \text{ drum } i1}$ dB(A)	$L_{R \text{ drum } i2}$ dB(A)	$L_{R \text{ drum } i3}$ dB(A)	$L_{R \text{ drum } i4}$ dB(A)
1				72	71	71	71	75
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								

Table 7 — Calculated alignment coefficients

Symbol	Value	Coefficient name	Comment
M		Alignment slope of regression	
Q		Alignment shift at origin	
R^2		Alignment correlation coefficient	

11 Validation method and alignment coefficient to outdoor measurement

11.1 Correlation with outdoor reference measurement using ISO 13325 method

In order to guarantee that:

— the best possible testing practices are used,

— the standard is respected,

— the impact of parameters such as the drum diameter, the horn effect, the semi-anechoic room and rig design is taken into account,

— the results of the measurement in the indoor facility shall be aligned to the results of a measurement following ISO 13325. When calculating the correction coefficients defined in 11.3.1, the L_R on track values are the ones corrected in temperature prior to being reduced by 1 dB(A) and prior to being rounded down to the nearest lower whole value.

The following test session shall then be performed, in order to validate the semi-anechoic room setup and characteristics, and obtain correlation coefficients to align each tyre measurement.

11.2 Alignment process

For this alignment process for passenger car tyres:

— at least 12 passenger car tyres (see 3.2) sets (including 6 normal tyres and 6 severe snow use tyres) and optionally 2 special use tyres (only if special use tyres are to be measured on the indoor facility) shall be selected,

— any size or load index is accepted as long as these products are tyres available on the market,

— the usage of only one vehicle is recommended for alignment process, however a maximum of 2 vehicles models shall be used,

— slick or studded tyres shall be excluded.

For this alignment process for light commercial vehicles tyres:

— at least 5 light commercial vehicles tyres sets (3 normal tyres, 1 severe snow use tyre and 1 tyre of a severe snow tyre and a traction tyre at the same time), and optionally 2 special use (only if special tyres are to be measured on the indoor facility) shall be selected,

— any size or load index is accepted as long as these products are available on the market,

— the usage of only one vehicle is recommended for alignment process, however a maximum of 2 vehicles models shall be used,

— slick or studded tyres shall be excluded.

Selected tyres shall be tested in accordance with ISO 13325, and results shall be recorded for every set. Results shall be distributed between a minimum and a maximum value range of at least 4 dBA. This distribution shall be as uniform as possible (equal amount of data for the high and low noise emitted by the tyres).

After outdoor testing in accordance with ISO 13325, each tyre of the set measured in accordance with ISO 13325 shall be tested in the indoor facility according to this document. However, the pressure, load and rim width used indoor for alignment process shall be the same as those used outdoor, even if they deviate from the boundary conditions of this document. The tyres shall be tested in both directions (clockwise and counter clockwise), excepted for directional tyres.

The laboratory performance is acceptable if the following conditions are met.

— The difference between the track and drum measurement before any correlation for each set of tyres (value L_R of the drum) shall not exceed 5 dB(A). This is performed by comparing the calculated L_R on the track to each actual L_R average value measured on the drum.

— The difference among the 4 tyres of the same set each tyre measured on the drum should be less than 1 dB(A). A tyre set showing a dispersion of more than 1 dB(A) should be discarded and replaced.

— A linear correlation coefficient shall confirm an R^2 value higher than 0,80.

— After applying the correction defined in 11.3, the difference between the track (L_R on track) on drum measurement ($L_{R\ \text{aligned}}$ on drum) shall not exceed 1 dB(A) for each set of tyres.

The alignment coefficients are valid for a maximum period of 4 years. The alignment tests shall be repeated at least every 4 years on a new set of tyres, or when the track surface and/or the drum surface and/or major feature in the indoor equipment are renewed.
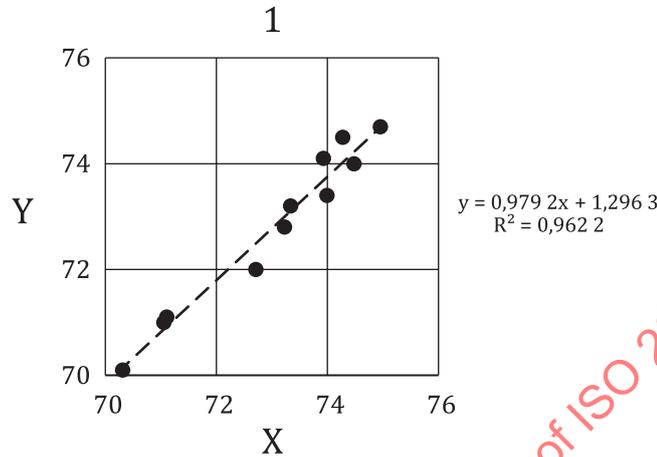
Key

X   drum L_v measurement (four tyres average)

Y   ISO 13325 track reference measurement L_v (dB(A))

1   correlation reference track and average measurement

Figure 11 — Example of indoor-outdoor correlation

11.3 Correction coefficients

11.3.1 Correction coefficients calculation

For each of the 11 tyres sets (see 11.2):

— an $L_{R\ \text{track}\ i}$ value is available;

— 4 $L_{R\ \text{drum}\ ij}$ values are available, and should be arithmetically averaged to one value $L_{R\ \text{drum}\ i}$.

M_s, the slope of the regression line of the track compared to the drum, is given by Formula (28):

$$M_s = \frac{\sum_{i=1}^{11}\left(L_{R\ \text{track}\ i} - \overline{L_{R\ \text{track}\ i}}\right) \times \left(L_{R\ \text{drum}\ i} - \overline{L_{R\ \text{drum}\ i}}\right)}{\sum_{i=1}^{11}\left(-L_{R\ \text{drum}\ i} - L_{R\ \text{track}\ i}\right)^2} \tag{28}$$

Q, shift at origin, is given by Formula (29):

$$Q = \overline{L_{R\ \text{track}\ i}} - M_s \times \overline{L_{R\ \text{drum}\ i}} \tag{29}$$

11.3.2 Correlation coefficient calculation

$$R = \frac{\sum_{i=1}^{11}\left(L_{R\ \text{track}\ i} - \overline{L_{R\ \text{track}\ i}}\right) \times \left(L_{R\ \text{drum}\ i} - \overline{L_{R\ \text{drum}\ i}}\right)}{\sqrt{\sum_{i=1}^{11}\left(L_{R\ \text{track}\ i} - \overline{L_{R\ \text{track}\ i}}\right)^2 \times \sum_{i=1}^{11}\left(L_{R\ \text{drum}\ i} - \overline{L_{R\ \text{drum}\ i}}\right)^2}} \tag{30}$$

11.3.3 Correction coefficients usage

The linear correlation also allows to define the correction coefficients to be applied on the indoor test in order to be aligned with the outdoor test.

d stands for data.

$$d_{\text{indoor aligned to outdoor}} = M_\text{s}\left(d_{\text{indoor}}\right) + Q \tag{31}$$

Once the formula of the linear trend line has been defined, in order to calculate the final result of the report, the same correction shall be applied to the L_f result.

$$L_f^{\text{Aligned}} = M_\text{s}\left(L_f\right) + Q \tag{32}$$

The corrected value L_f^{Aligned} shall be reported in the report, as the final result.

11.4 Measurement stability among time

At least one tyre stored in controlled temperature, humidity and light shall be measured after each alignment process and measured again each month. The L_f between two consecutive months shall not be higher than 0,5 dB(A).

In case of difference between two consecutive months greater than 0,5 dB(A), correction actions on the indoor equipment shall be taken, and measure(s) shall be repeated, or a new alignment process shall be run.

12 Measurement uncertainty

The measurement procedure described in 9.2 is affected by several parameters (e.g. surface texture variation, drum diameter, environmental conditions, measurement system uncertainty) that lead to variation in the resulting sound level observed for the same tyre. The source and nature of these perturbations are not completely known and sometimes affect the end result in a non-predictable way. Since extensive inter- and intra-laboratory data are not available, the procedure given in ISO/IEC Guide 98-3 and shown in Annex A is followed to estimate the uncertainty associated with the measurement procedure of ISO 20908. The uncertainties given in Table 8 are based on existing statistical data, analysis of tolerances stated in ISO 20908 and engineering judgment. The uncertainties so determined are grouped as follows:

a) variations expected within the same indoor test facility and slight variations in ambient conditions found within a single test series (run-to-run);

b) variations expected within the same indoor test facility but with variations in ambient conditions and equipment properties that can normally be expected during the year (day-to-day);

c) variations between indoor test facilities where, apart from ambient conditions, equipment, staff and drum surface conditions also are different (site-to-site).

If reported, the expanded measurement uncertainty together with the corresponding coverage factor for the stated coverage probability of 80 % as defined in ISO/IEC Guide 98-3, shall be given. Information on the determination of the expanded uncertainty is given in Annex A.

NOTE   Annex A gives a framework for analysis in accordance with ISO/IEC Guide 98-3, which can be used to conduct future research on measurement uncertainty for ISO 362-3.

Uncertainty data are given in Table 8 for all tyre classes of this document. The variability is given for a coverage probability of 95 %. The data express the variability of results for a certain tested vehicle and do not cover product variation.

Until more specific knowledge is available, the data for site-to-site variability may be used in test reports to state the expanded measurement uncertainty for a coverage probability of 95 %.

Table 8 — Variability of measurement results for a coverage probability of 95 %

Tyre category	Run-to-run dB(A)	Day-to-day[a] dB(A)	Site-to-site dB(A)
C1 and C2 tyres	0,3	0,5 to 0,9	2
[a] The actual measurement uncertainty for the day-to-day situation is dependent on which kind of test room, e.g. open test room, or which kind of climatic control is used. A lower temperature variation causes a smaller measurement uncertainty.			

Annex A
(informative)

Measurement uncertainty — Framework for analysis according to ISO/IEC Guide 98-3

A.1 General

The measurement procedure is affected by several factors causing disturbance that lead to variations in the resulting level observed for the same tyre set under test. The source and nature of these perturbations are not completely known and sometimes affect the end result in a non-predictable way. The accepted format for expression of uncertainties generally associated with methods of measurement is that given in ISO/IEC Guide 98-3. This format incorporates an uncertainty budget, in which all the various sources of uncertainty are identified and quantified, and from which the combined standard uncertainty can be obtained. Uncertainties are due to the following factors:

— variations in measurement devices, such as sound level meters, calibrators and speed measuring devices;

— semi-anechoic room design influence;

— variations in tyre/drum speed during the pass-by runs;

— variations in local environmental conditions that affect sound propagation at the time of measurement of sound pressure levels;

— variations in local environmental conditions that affect the characteristics of the source;

— effects of environmental conditions (air pressure, air density, humidity, air temperature) that influence the mechanical characteristics of the source;

— effects of environmental conditions that influence the sound production and the rolling noise (tyre and track surface temperature);

— test site properties (test surface texture and absorption, surface gradient).

The uncertainty determined according to Clause 12 represents the uncertainty associated with this document. It does not cover the uncertainties associated with the variation in the production processes of the tyres manufacturer. The variations in the sound pressure level of identical tyres of a production process are outside the scope of this document.

The uncertainty effects for tyre testing can be grouped in three areas composed of the following sources (see Clause 12):

a) run-to-run variations: uncertainty due to changes in the test operation within consecutive runs and measurement system uncertainty; changes in climatic conditions and in background noise levels are practically negligible;

b) day-to-day variations: uncertainty due to changes in the test operation, changes in the measurement system performance over longer periods, not changing drum surface nor room set-up, changing properties of the test facility over time and small changes in climatic conditions throughout the year;

c) site-to-site variations: uncertainty due to different semi-anechoic room design, drum diameter and properties, and set-up, measurement systems, test site locations, and track surface characteristics (tyre/road noise data from different test surfaces).

Annex B
(informative)

Normalization with respect to number of tyres, tyre masking effect, and vehicle impact

## B.1 Normalization with respect to number of tyres

In ISO 13325, the microphones are measuring the sound created by 4 tyres rolling on the track, where in the indoor method, only 1 tyre is used.

In order to normalize the sound pressure level with respect to number of tyres, a reference number of 4 tyres shall be used.

B.1.1 Normalization with respect to tyre masking effect

In order to normalize the sound pressure level with respect to the masking and diffraction effect of the tyre which is the closest to the microphone when the vehicle travels in front of microphones, a coefficient $C_t = 0,8$ has been estimated, after theoretical approach and experimental measurements of tyre masking and diffraction effect.

B.1.2 Theoretical approach
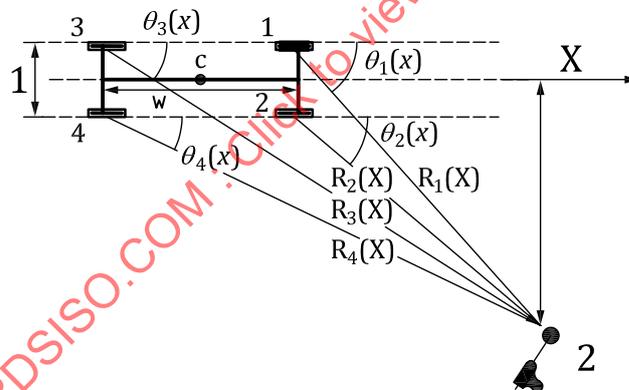
Key
1   track
2   mic

Figure B.1 — Diagram of outdoor test method