INTERNATIONAL STANDARD

ISO 362-3

Second edition
2022-09

Acoustics — Measurement of noise emitted by accelerating road vehicles — Engineering method —

Part 3:
Indoor testing M and N categories

Acoustique — Mesurage du bruit émis par les véhicules routiers en accélération — Méthode d'expertise —

Partie 3: Essais en intérieur pour les catégories M et N

Reference number
ISO 362-3:2022(E)

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Published in Switzerland

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Foreword

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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

This document was prepared by Technical Committee ISO/TC 43, Acoustics, Subcommittee SC 1, Noise.

This second edition cancels and replaces the first edition (ISO 362-3:2016), which has been technically revised.

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

— Improvement of the wording for a better understanding

— Definition of a data exchange format for the tyre-/road noise coefficients

— Introduction of an energetic model of the tyre torque influence (Annex C)

— Revision of 9.7, Annex B and Annex E.

A list of all parts in the ISO 362 series can be found on the ISO website.

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 vehicle is one out of a multitude of requirements that needs to be considered by manufacturers during design and development of vehicles. For health and environmental protection reasons, the sound emission should be reduced under all relevant driving conditions. However, there is a growing awareness that vehicles should not be too quiet either to ensure that they are still acoustically perceivable by pedestrians and don't endanger them as they might be missed.

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. While this was acceptable in the past, the increasing workload in the future will make it nearly impossible to do the complete development of a vehicle on a single test track at one particular place. However, 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 362-1, which is the test standard used for type approval of vehicles.

An indoor test bench requires tight specifications for the equipment and set up, such as the acoustical treatment, the microphone arrays, the roller bench, the adjustment for the dynamic behaviour of the vehicle on the roller test bench, the preconditioning of the vehicle, as well as the thermal conditions for testing. Special treatment needs to ensure that all rolling sound components of the tire are comparable to the rolling sound on a road surface as specified in ISO 10844 and as applied in type approvals.

It is conceivable that in the future, certain sound emissions of vehicles (like e.g. minimum sound emission of electric vehicles) can be verified on an indoor test bench, as the natural background noise might prohibit testing on a classical outdoor test track. The specifications set forth in this document could be transferred to a future minimum noise test procedure.

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.

Acoustics — Measurement of noise emitted by accelerating road vehicles — Engineering method —

Part 3: Indoor testing M and N categories

1 Scope

This document specifies an engineering method for measuring the noise emitted by road vehicles of categories M and N by using a semi anechoic chamber with a dynamometer installed.

The specifications are intended to achieve an acoustical correlation between testing the exterior noise of road vehicles in a semi anechoic chamber and outdoor testing as described in ISO 362-1.

This document provides all necessary specifications and procedures for indoor testing to obtain results which are comparable to typical run-to-run variations of measurements in today's type approval tests.

This document provides a method designed to meet the requirements of simplicity as far as they are consistent with the reproducibility of results under the operating conditions of the vehicle.

NOTE 1 The results obtained by this method give an objective measure of the noise emitted under the specified conditions of test. It is necessary to consider the fact that the subjective appraisal of the noise annoyance of different classes of motor vehicles is not simply related to the indications of a sound measuring system. As annoyance is strongly related to personal human perception, physiological human conditions, culture, and environmental conditions, there is a large variation and annoyance is therefore not useful as a parameter to describe a specific vehicle condition.

NOTE 2 If measurements are carried out in rooms which do not fulfil the requirements stated in this document, the results obtained can deviate from the results using the specified conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 362-1, *Measurement of noise emitted by accelerating road vehicles — Engineering method — Part 1: M and N categories*

ISO 1176, *Road vehicles — Masses — Vocabulary and codes*

ISO 2416, *Passenger cars — Mass distribution*

ISO 3745, *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 10844, *Acoustics — Specification of test tracks for measuring sound emitted by road vehicles and their tyres*

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

ISO 26101, *Acoustics — Test methods for the 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 Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 362-1, ISO 1176 and ISO 2416 and the following apply.

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

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

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

3.1
virtual vehicle speed
virtual speed of the test vehicle calculated from the circumference and the revolutions of the roller

Note 1 to entry: See Formula 1.

3.2
virtual line AA'
virtual position for the definition of the *virtual vehicle speed* (3.1), $v_{AA'}$

3.3
virtual line PP'
virtual position for the definition of the *virtual vehicle speed* (3.1), $v_{PP'}$

3.4
virtual line BB'
virtual position for the definition of the *virtual vehicle speed* (3.1), $v_{BB'}$

4 Symbols and abbreviated terms

Table 1 lists the symbols used in this document and the clause number where they are used for the first time.

Table 1 — Symbols used and corresponding clauses

Symbol	Unit	Clause	Designation
a, a_{PTN}	m/s^2	B.3.3	vehicle acceleration (at power train noise measurement)
AA'	—	3.1	line perpendicular to vehicle travel which indicates beginning of zone in which to record sound pressure level during test
BB'	—	3.1	line perpendicular to vehicle travel which indicates end of zone in which is 10,00 m behind line PP'
d_{absorb}	m	7.2	thickness of absorbing elements
d_{roller}	m	5.1.1	diameter of dynamometer roller
F	N	B.4.1	propulsion force of the vehicle
F_{Cor}	dB	D.4	correction for tyre/road noise in variant B
F_{PTN}	N	B.4.4	propulsion force of the vehicle to be tested indoor
F_{TRN}	N	B.4.3	propulsion force of the tyre test vehicle
K	dB/°C	B.2.4	temperature correction coefficient

Table 1 *(continued)*

Symbol	Unit	Clause	Designation
k_P	—	5.5	partial power factor
l_{AB}	m	3.2	virtual length of test section for calculation of acceleration from AA' to BB'
$l_{min,room}$	m	7.2	minimum length of the test room
l_{PB}	m	3.2	virtual length of test section for calculation of acceleration from PP' to BB'
l_{veh}	m	7.2	length of vehicle
$L_{acc\ rep}$	dB	E.2.1	reported vehicle sound pressure level at wide-open throttle
$L_{crs\ rep}$	dB	E.2.1	reported vehicle sound pressure level at constant speed
L_{FRN}	dB	B.4.1	free rolling noise sound pressure level
L_{PTN}	dB	10.2.4	power train noise sound pressure level
L_{PTNi}	dB	D.3	power train noise sound pressure level indoor
L_{TI}	dB	C.2	torque influence sound pressure level
L_{TRN}	dB	10.2.4	tyre/road noise sound pressure level
L_{TRNi}	dB	D.3	tyre/road noise sound pressure level indoor
$L_{TRN\ indoor}$	dB	B.6	calculated tyre/road noise sound pressure level indoor
L_{TRNo}	dB	D.4	tyre/road noise sound pressure level outdoor
L_{TVN}	dB	10.2.4	total vehicle noise sound pressure level
L_{TVNi}	dB	B.6	total vehicle noise sound pressure level indoor
L_{TVNo}	dB	D.5	total vehicle noise sound pressure level outdoor
L_{urban}	dB	9.7	reported vehicle sound pressure level representing urban operation
$m_{ac\ ra\ max}$	kg	9.4.2.2.3	maximum rear axle capacity
m_d	kg	9.4.2.2.3	mass of driver
$m_{fa\ load\ unladen}$	kg	9.4.2.2.3	unladen front axle load
m_{kerb}	kg	9.4.2.2.3	kerb mass of the vehicle
$m_{ra\ load\ unladen}$	kg	9.4.2.2.3	unladen rear axle load
m_{ref}	kg	9.4.2.2.3	kerb mass + 75 kg for the driver
m_{ro}	kg	9.4.2.2.3	mass in running order
$m_{ro\ indoor\ test}$	kg	B.6	mass in running order of the vehicle to be tested indoor
$m_{tyre\ test}$	kg	B.4.3	test mass of the tyre test vehicle (including driver and test equipment)
m_t	kg	9.4.2.2.3	virtual or actual physical test mass of the vehicle, that is used as an input for simulating the vehicle transient behaviour by the dynamometer control system
m_{target}	kg	9.4.2.2.3	target mass of the vehicle
$m_{unladen}$	kg	9.4.2.2.3	unladen vehicle mass
m_{xload}	kg	9.4.2.2.3	extra loading
$n_{BB'}$	r/min	10.3	engine speed when the reference point passes BB'
$n_{PP'}$	r/min	10.3	engine speed when the reference point passes PP'
$n_{roller\ AA'\ test\ i}$	r/min	5.1.1	rotational speed of the dynamometer roller for the test run *i*
P_{ref}	hPa	B.2.3	Tyre inflation pressure recommended by the vehicle manufacturer
P_{test}	hPa	B.2.3	Tyre test inflation pressure
PP'	—	3.2	line perpendicular to vehicle travel which indicates location of microphones
Q_{ref}	kg	B.2.3	weight of the vehicle to be tested indoor
Q_{test}	kg	B.2.3	weight of the tyre test vehicle

Table 1 *(continued)*

Symbol	Unit	Clause	Designation
r_0	m	7.3.2.4	reference path length of the centre measurement position
r_x	m	7.3.2.4	path length to the microphone at distance x
$u_{L,\text{urban},i}$	dB	E.2.2	is the standard deviation of the sound pressure level under urban conditions for the quantity i
v	km/h	B.4.2	vehicle speed
$v_{\text{AA'}}$	km/h	5.1.1	vehicle speed when reference point passes line AA'
$v_{\text{AA' test } i}$	km/h	5.1.1	vehicle speed when reference point passes line AA' for the test run i (see 5.1 for definition of reference point)
$v_{\text{BB'}}$	km/h	5.1.1	vehicle speed when reference point or rear of vehicle passes line BB' (see 5.1 for definition of reference point)
$v_{\text{PP'}}$	km/h	5.1.1	vehicle speed when reference point passes line PP' (see 5.1 for definition of reference point)
v_{PTN}	km/h	B.5	vehicle speed at the power train noise measurement indoor
v_{test}	km/h	9.5.1.2	target vehicle test speed
v_{TRN}	km/h	B.4.3	vehicle speed at the tyre/road noise measurement outdoor
w_{room}	m	7.2	width of the room
$w_{\text{single,room}}$	m	7.2	width of the room for a single-sided facility
$w_{\text{dual,room}}$	m	7.2	width of the room for a dual-sided facility
w_{veh}	m	7.2	width of the vehicle
x	m	B.3.3	vehicle position on the (virtual) test track
x_{micro}	m	7.3.2.4	position of the microphone in the arrays in driving direction
α	dB	B.4.2	coefficients of free rolling noise
β	dB	B.4.2	coefficients of free rolling noise
γ	—	B.4.3	coefficient of the exact torque influence
δ	—	B.4.3	coefficient of the exact torque influence
$\Delta L_{\text{acc, max dev},i}$	dB	E.2.1	the maximum deviation of the quantity i of the sound pressure level from acceleration tests
$\Delta L_{\text{crs, max dev},i}$	dB	E.2.1	the maximum deviation of the quantity i of the sound pressure level from cruise tests
ΔL_{TI}	dB	B.3.3	torque influence of the sound pressure level
$\Delta L_{\text{urban, max dev},i}$	dB	E.2.1	the estimated maximum deviation (peak-to-peak) of the sound pressure level under urban conditions for the quantity i
ΔL_x	dB(A)	7.3.2.4	relative sound pressure level decay at position x
Δn	r/min	D.2	maximum parameter variability in the test situation for the engine speed
Δs	m	D.2	maximum parameter variability in the test situation for the acceleration position
ζ	—	B.3.3	coefficient of standard torque influence
ϑ_{REF}	°C	B.5	reference air temperature at the power train noise measurements indoor
ϑ_{FRN}	°C	B.5	averaged air temperature from all runs of the free rolling noise measurement
$\lambda_{\text{cut off}}$	m	7.2	wavelength at the cut-off frequency

5 Acceleration for vehicles of categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg, and of category N1

5.1 Applicability and conditions

All accelerations are calculated using different vehicle speeds during the test. All virtual vehicle speeds are calculated from the number of revolutions of the roller as given in Formula (1) (as example for AA'):

$$v_{\text{AA'test}\,i} = \frac{3{,}6}{60} \cdot \pi \cdot d_{\text{roller}} \cdot n_{\text{roller AA'test}\,i} \quad (1)$$

where

$v_{\text{AA' test}\,i}$	is the vehicle speed when the reference point passes virtual line AA' for the test run *i*;
d_{roller}	is the diameter of the dynamometer roller;
$n_{\text{roller AA' test}\,i}$	are the revolutions per minute of the dynamometer roller for the test run *i*.

The virtual line AA' indicates the beginning of the test track, PP' indicates the virtual position of the two pass-by microphones, and BB' indicates the end of the test track, as defined in ISO 362-1:2022, 7.1.

The simulated vehicle speed at AA', $v_{\text{AA'}}$, or PP', $v_{\text{PP'}}$, is defined by the roller speed when the reference point of the vehicle (as defined in ISO 362-1:2022, 3.5) passes the virtual line AA' or PP', respectively. The simulated vehicle speed at BB', $v_{\text{BB'}}$, is defined when the rear of the vehicle passes the virtual line BB'.

The method used for the determination of the acceleration shall be indicated in the test report.

Due to the large variety of technologies, it is necessary to consider different modes of calculation. New technologies (such as continuously variable transmission) as well as dated technologies (e.g. automatic transmissions without electronic control units) require a more specific treatment for a proper determination of the acceleration. Any alternatives for calculation of the acceleration shall cover these needs.

5.2 Calculation of acceleration

5.2.1 Calculation procedure for vehicles with manual transmission, automatic transmission, adaptive transmission, and continuously variable transmission (CVT) tested with locked gear ratios

As defined in ISO 362-1:2022, 5.2.1.

5.2.2 Calculation procedure for vehicles with automatic transmission, adaptive transmission, and CVT tested with non-locked gear ratios

As defined in ISO 362-1:2022, 5.2.2.

5.3 Calculation of the target acceleration

As defined in ISO 362-1:2022, 5.3.

5.4 Calculation of the reference acceleration

As defined in ISO 362-1:2022, 5.4.

5.5 Partial power factor, k_P

As defined in ISO 362-1:2022, 5.5.

6 Instrumentation

6.1 Instruments for acoustical measurement

6.1.1 General

The apparatus used for measuring the sound pressure level shall be a sound level meter or equivalent measurement system meeting the requirements of Class 1 instruments (including a recommended windscreen, if used). These requirements are specified in IEC 61672-1.

The entire measurement system shall be checked by means of a sound calibrator that fulfils the requirements of Class 1 sound calibrators in accordance with IEC 60942.

Measurements shall be carried out using time weighting “F” and frequency weighting “A” as specified in IEC 61672-1. When using a system that includes periodic monitoring of the A-weighted sound pressure level, a data extract should be made at a time interval not greater than 30 ms.

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 conformity requirements of Class 1 instruments as described in IEC 61672-3.

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. Apparently, until today, no computerized data acquisition system available complies with the full specifications of IEC 61672-1. It is beyond the possibilities of the users of these systems to prove conformity of the instrumentation required by the test code.

When no general statement or conclusion can be made about conformity of the sound level meter by conformity of each channel of the array (this applies, e.g., if the signal of each individual microphone is used to recompose one overall time progression of the signal for the complete pass-by test, to which subsequently the A-weighted assessment is applied), a simulated pass-by run shall be performed at a constant roller speed of 50 km/h without a vehicle on the dynamometer while a constant tone signal is supplied to all channels of the array, e.g. by using a signal generator. The simulated A-weighted sound level is processed and the deviation from a reference tone signal shall be determined in accordance with IEC 61672-3.

Simulation algorithms using noise source localization detection should deactivate that feature for these tests.

A qualified calibration method (i.e. electrical calibration) is recommended to be provided by the hardware supplier and, in that case, shall be implemented in the measurement software used.

The instruments shall be maintained and calibrated in accordance with the instructions of the instrument manufacturer.

6.1.2 Calibration

At the beginning and at the end of every measurement session, the entire sound measurement system shall be checked by means of a sound calibrator as described in 6.1.1. 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.

As an alternative, at the beginning and at the end of every measurement session, the entire sound measurement system shall be checked by means of a calibration system (i.e. electrical calibration), provided by the hardware supplier and implemented in the measurement software used as a simulated pass-by run as described in 6.1.1.

For this alternative, at least every six months, the entire sound measurement system shall be checked by means of a sound calibrator as described in 6.1.1.

6.2 Conformity with requirements

Conformity of the sound calibrator with the requirements of IEC 60942 shall be verified once a year. Conformity of the instrumentation system with the requirements of IEC 61672-3 shall be verified at least every 2 years or at each modification of the system (software, microphone, etc.). All conformity testing shall be conducted by a laboratory which meets the requirements of ISO/IEC 17025.

6.3 Instrumentation for speed measurement

The rotational speed of the engine shall be measured using an instrument with an uncertainty of not more than ±2 % at the engine speeds required for the measurements being performed.

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

The minimum update rate for the continuous speed device shall be 20 Hz.

6.4 Meteorological instrumentation

The meteorological instrumentation used to monitor the environmental conditions during the test shall have an uncertainty of not more than the following:

— ±1 °C for a temperature measuring device;

— ±5 hPa for a barometric pressure measuring device;

— ±5 % for a relative-humidity measuring device.

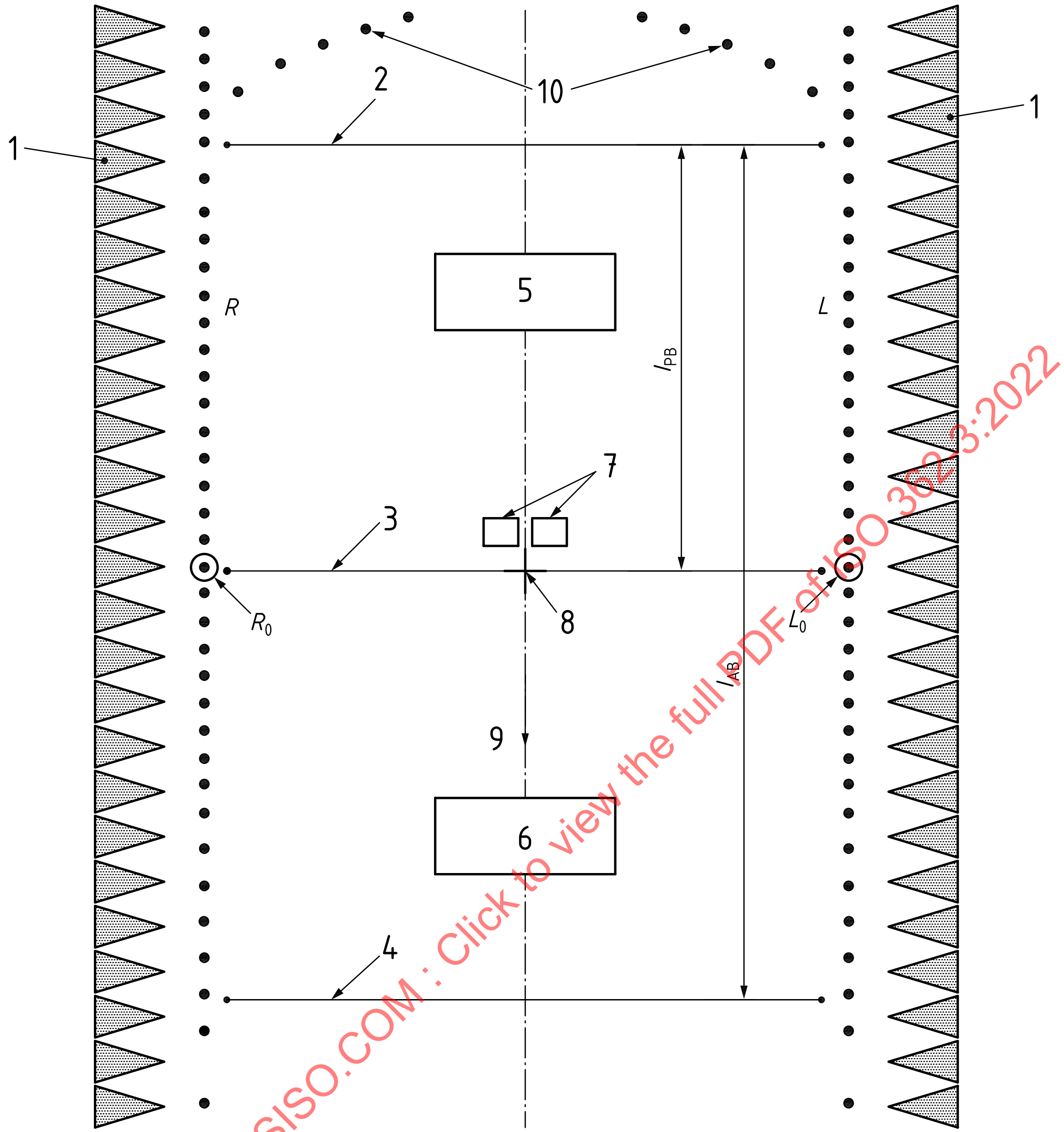
7 Test room requirements

7.1 General

One of the principal criteria of ISO 362-1 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 7.3).

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



Key

L	left-hand side microphone array	4	virtual line AA'
L_0	microphone array centre point	5	rear ventilation
R	right-hand side microphone array	6	front ventilation
R_0	microphone array centre point	7	rollers
1	absorbing elements	8	centre of room
2	virtual line BB'	9	driving direction
3	virtual line PP'	10	additional microphones for test track extension

Figure 1 — Example of a test room; configuration for rear wheel drive vehicles

7.2 Test room dimensions

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

The length of the room depends on several factors including the following:

— the length of the longest vehicle to be tested;

— the location where the relevant sound pressure levels are expected;

— the lowest frequency of concern (see 7.3).

To cover all possible cases, the minimum room length, $l_{min,\,room}$ (base size), is recommended as given in Formula (2):

$$l_{min,room} = 20\,\mathrm{m} + l_{veh} + 2 \cdot d_{absorb} + 2 \cdot \frac{1}{4} \cdot \lambda_{cut\,off} \quad (2)$$

where

20 m	is the original length of test track;
l_{veh}	is the length of longest vehicle to be tested for vehicles of categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg, and category N1; is 5 m for vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg, and categories M3, N_2 and N3;
d_{absorb}	is the thickness of absorbing elements;
1/4 $\lambda_{cut\,off}$	is 1/4 of the wavelength at the cut-off frequency (2 times 1/4 wavelength from the outer microphones to the absorbing walls).

If this is not possible, see Annex F for further information on minimum room length. The width, w_{room}, of the room is dependent on whether it is a single-sided facility or a dual-sided facility. In any case, the distance from the centreline to the microphone line shall be 7,5 m. A shorter distance with a correction of the sound pressure level is not permissible.

When measurements shall be performed for distances longer than the length of the test track plus the length of the vehicle, additional microphones, additional signal processing algorithms, or a combination of both are required. (see Figure 1).

The width, $w_{single,room}$, of single-sided facilities is as given in Formula (3):

$$w_{single,room} = 7{,}5\,\mathrm{m} + 2 \cdot d_{absorb} + 2 \cdot \frac{1}{4} \cdot \lambda_{cut\,off} + \frac{1}{2} \cdot w_{veh} \quad (3)$$

where

7,5 m	is the original distance from the centreline to the microphone line;
d_{absorb}	is the thickness of absorbing elements;
1/4 $\lambda_{cut\,off}$	is 1/4 of the wavelength at the cut-off frequency (1 time 1/4 of the wavelength from the microphones to the absorbing elements + one time 1/4 of the wavelength from the vehicle to the absorbing elements);
w_{veh}	is the width of vehicle.

The width, $w_{dual,room}$, of dual-sided facilities is as given in Formula (4):

$$w_{dual,room} = 2 \cdot 7{,}5\,\mathrm{m} + 2 \cdot d_{absorb} + 2 \cdot \frac{1}{4} \cdot \lambda_{cut\,off} \quad (4)$$

where

7,5 m	is the original distance from the centreline to the microphone line;
d_{absorb}	is the thickness of absorbing elements;
$1/4\ \lambda_{cut\ off}$	is 1/4 of the wavelength at the cut-off frequency (two times 1/4 of the wavelength from the microphones to the absorbing elements).

It is recommended to ensure a distance of 1/4 of the wavelength from the microphones to the absorbing elements for single-sided and dual-sided facilities. If this is not fulfilled, the free-field condition at the microphone array shall be checked as described in 7.3.

The minimum height of the room is dependent on the vehicle height and the location of noise sources (exhaust outlet). See 7.3. To minimize the influences, the distance from the relevant source to the absorbing elements shall be at least 1/2 of the wavelength at the cut-off frequency.

7.2.1 Test room dimensions for measurements where the length of the test track is greater than 20m

To account for test track dimensions longer than 20 m, additional microphones may be placed at the end of the test chamber (see Figure 2; Key No. 6). When such microphones are used, corrections (e.g. inverse square distance law) shall be determined to account for the physical location of the microphones in the room as compared to the virtual location of the microphones (see Figure 2; Key No. 8) of an extended microphone array. This setup ensures a correct consideration of the sound propagation characteristic of the object to be tested and is able to interpolate samples between the virtual microphone locations.

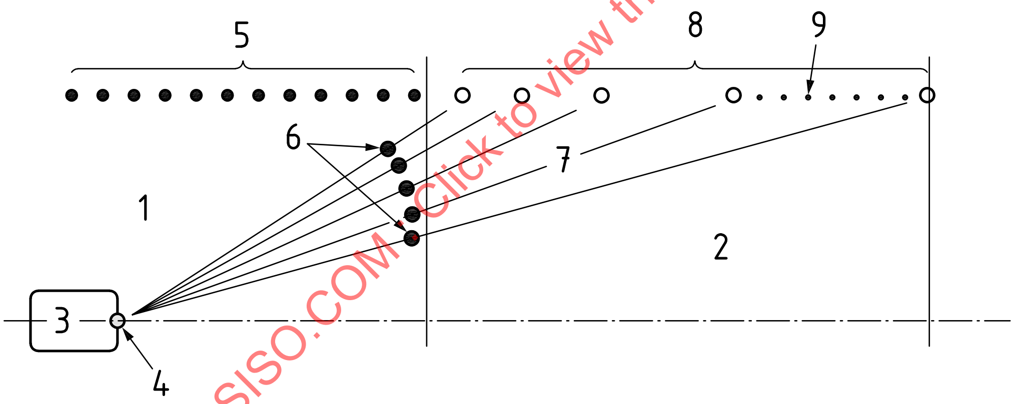


Figure 2 — Test setup for indoor test track extension

Key

1 test room
2 test track extension
3 vehicle
4 acoustical centre
5 physical microphone array
6 additional microphones
7 corrections
8 virtual microphone locations
9 interpolated samples

If no additional microphones in the end of the test chamber are available at least one microphone on each side of the microphone array shall be used for the extrapolation of the sound pressure level in the extended area. The location of this reference microphone shall be at least at x = 10 m or more.

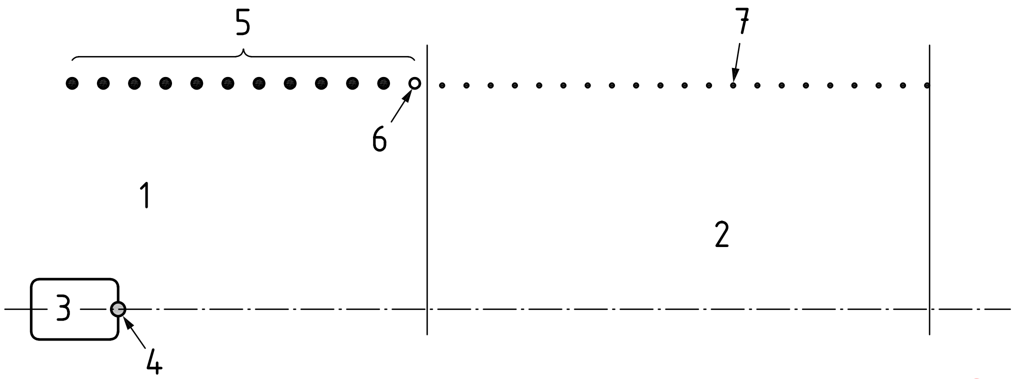


Figure 3 — simplified test setup for test track extension

Key

1 test room
2 test track extension
3 vehicle
4 acoustical centre
5 physical microphone array
6 reference microphone
7 extrapolated samples based on reference microphone

7.3 Acoustical qualification of the room

7.3.1 General

The free field of the room shall meet the requirements of ISO 3745 or alternatively ISO 26101.

To consider special use of the room, additional validation shall be done for indoor microphone arrays. The microphone array validation shall also meet requirements given in Table 2 at a minimum of 98 % of all microphone locations and one-third octave frequency bands of interest.

The 98 % requirement shall be applied against the product of the number of microphone locations used for testing and the one-third octave bands of interest.

No individual band/microphone shall have more than 2 dB exceedance.

NOTE As an example, if a microphone array has 40 microphones, and one-third octave bands from 50 Hz to 10,000 Hz are used, this results in a total of 40 × 24 = 960 microphone/band validation points.

7.3.2 Validation of free-field conditions of the microphone array

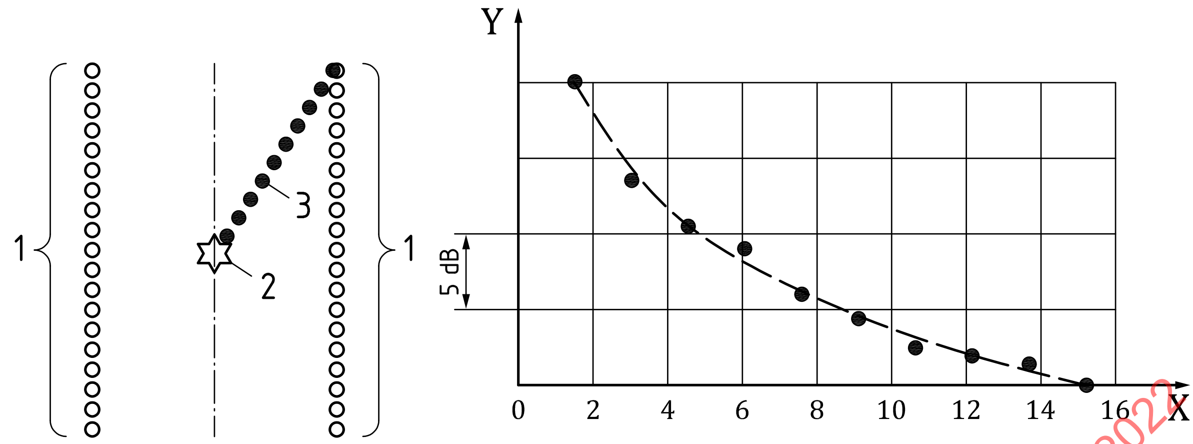
7.3.2.1 General

Three options of evaluation are possible to validate the free field conditions of the microphone array; see 7.3.2.2 to 7.3.2.4.

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

The source is placed on the floor on the virtual line PP' in the centre between the microphone arrays (see Figure 4). Lines to be evaluated are plotted from the source to each microphone of the indoor microphone arrays. 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 4) and processed according to ISO 3745 or, alternatively, ISO 26101.



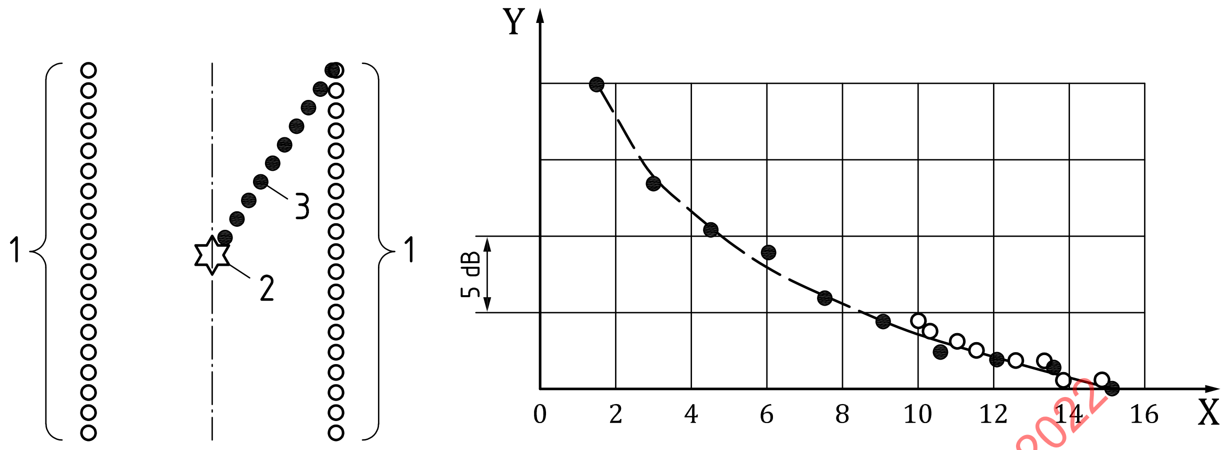
Key

X	distance from the sound source, m
Y	sound pressure level, dB
1	measuring line
2	sound source
3	measuring points
— —	inverse square law
●	measured points on the line

Figure 4 — Example of validation according to 7.3.2.2

7.3.2.3 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 floor on the virtual line PP' in the centre between the microphone arrays (see Figure 5). 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 5). Processing for all these measurement points shall be done according to ISO 3745, or alternatively, ISO 26101.



Key

X	distance from the sound source, m
Y	sound pressure level, dB
1	measuring line
2	sound source
3	measuring points
— —	inverse square law
●	measured points on the line
○	measured points on the microphone array

Figure 5 — Example of validation according to 7.3.2.3

7.3.2.4 Validation of the inverse square law along the complete microphone arrays

The source is placed on the floor on the virtual line PP' in the centre between the microphone arrays (see Figure 6). The free-field conditions are verified along both microphone array lines left (L) and right (R) in driving direction, each at a distance of 7,5 m from the centre line of the room (see Figure 6). The tests are performed for the complete length of the microphone array lines (usually 20 m, original length of outdoor test track) at measurement positions in 1,2 m height at each microphone position of the microphone arrays. The tests can be made symmetrically to both sides of the lines L and R when choosing the centre points R_0 and L_0 (intersection of the virtual line PP' with the microphone array at the height of the microphones) as starting points.

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_n, that are given from the source position to the respective measurement position on lines L and R and the reference path length, r_0, of the centre measurement position.

With the source on the floor and the reference microphone at the centre measurement position, the reference path length, r_0, in metres, is given by Formula (5):

$$r_0 = \sqrt{(7{,}5)^2 + (1{,}2)^2} = 7{,}595 \quad (5)$$

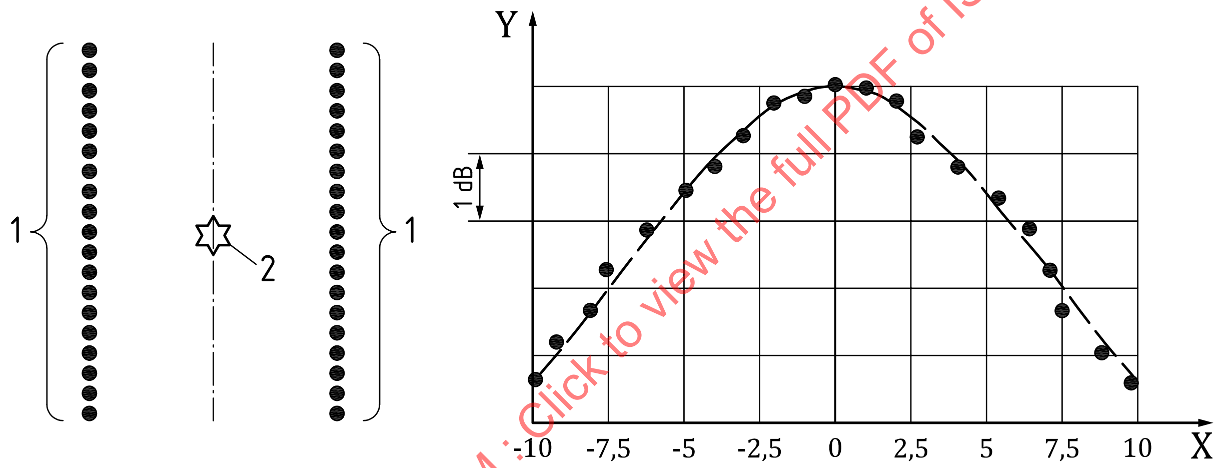
Subsequently, the path lengths, r_x, to the microphone at distance x to the reference microphone position along the lines R and L are given by Formula (6):

$$r_x = \sqrt{{r_0}^2 + {x_{micro}}^2} \quad (6)$$

where x_{micro} is the position of the microphone in the arrays in driving direction, given as distance to the reference microphone position

The relative sound pressure level decay, ΔL_x, in dB, is then computed according to Formula (7):

$$\Delta L_x = 20 \cdot \lg\left(\frac{r_x}{r_0}\right) \quad (7)$$



Key

X microphone position, m

Y sound pressure level, dB

1 measuring line

2 sound source

— — inverse square law

● measured points on the line

Figure 6 — Example of validation according to 7.3.2.4

These predicted relative sound pressure level decays are used for the comparison with the measured sound pressure levels at the same measurement positions (see Figure 6). The centre positions R_0 and L_0 on microphone lines R and L serve as 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 7.3.3.

7.3.3 Qualification procedure

The lowest frequency which meets the requirements given in Table 2 defines the cut-off frequency of the room. The cut-off frequency of the room shall be less than the lowest frequency of concern. The highest 1/3 octave frequency used for qualification shall be no lower than 10 000 Hz but may be higher.

Frequency of concern refers to a single frequency or band which influences the overall level by more than 0,4 dB.

NOTE 1 For evaluation below 100 Hz, ISO 3745 indicates that difficulties can occur due to effects of the increasing nearfield of the source.

NOTE 2 No additional content in the signal expected in frequencies above 10 000 Hz.

The deviations of measured sound pressure levels from those estimated using the inverse square law shall not exceed the values given in Table 2 for 98 % or more of all combinations of microphone locations and 1/3 octave frequency bands.

NOTE 3 The requirement of 98 % of all combinations of frequency band and array microphone location is to recognize that there can be a situation where a very small number of frequency band/microphone combinations may not meet the requirements of Table 2. As the room itself meets the requirements of 7.3.1, it is rated acceptable if a very small number of frequency band/array microphone combinations do not meet Table 2.

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
≤630	±3,5
800 to 5 000	±3,0
≥6 300	±4
NOTE An additional tolerance of 1 dB has been added on the ISO 3745 requirement considering that indoor pass-by is an engineering and not a laboratory method.	

7.4 Condition of the floor

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

7.5 Cooling, ventilation, air temperature, exhaust gas management

The room temperature shall be within the limits as defined in ISO 362-1:2022, 7.2, i.e. 5 °C to 40 °C.

During the measurements, the exhaust system of the vehicle shall be acoustically fully exposed to the acoustic space. Exhaust gas extraction systems present inside the room are not recommended.

When using dedicated exhaust gas extraction systems, these should be at least 0,5 m away from the tailpipe outlet and the devices shall not block the line of sight from the outlet to any microphone in the microphone arrays.

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 cover a wide range of room temperatures, it is recommended to install an air conditioning system. This allows creating conditions comparable to temperature conditions on an outdoor track.

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

7.6 Background noise

In accordance with ISO 362-1:2022, 7.2, the indoor test facility shall be designed for an A-weighted sound pressure level of the background noise (including the noise caused by air handling, vehicle cooling, etc.) at least 10 dB below the maximum A-weighted sound pressure level produced by the vehicle under test as measured in the test room. If the level difference is between 10 dB and 15 dB, the measured sound pressure level shall be corrected according to Table 3.

Table 3 — Correction for background noise

Background sound pressure level difference to measured sound pressure level dB	Correction dB
10	0,5
11	0,4
12	0,3
13	0,2
14	0,1
≥ 15	0,0

8 Dynamometer requirements

8.1 Type of texture of the rollers

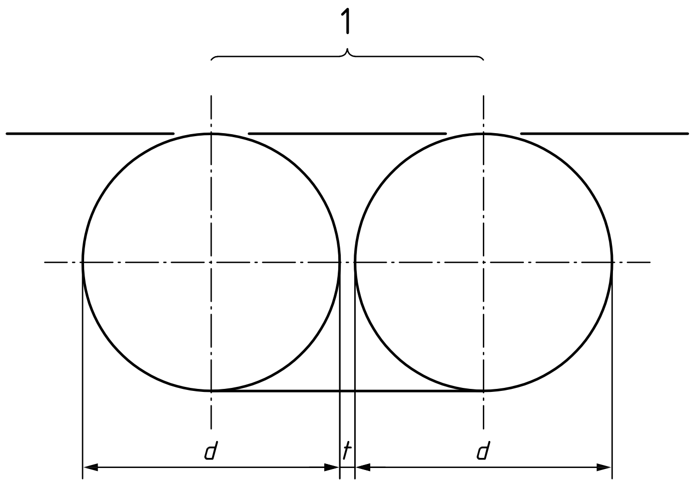
The texture of the rollers shall be rough enough to transfer the torque of the tested vehicle under the required conditions.

NOTE A texture comparable to an abrasive paper P80 or P100 (as defined in ISO 6344–1) is a good compromise between grip and emitted noise.

8.2 Diameter of the rollers

The diameter of the rollers of a four-wheel dynamometer is limited by the shortest wheelbase of the vehicle to be tested (see Figure 7). On the other hand, the diameter shall be as big as possible to minimize the acoustical effects in comparison to a flat track.

NOTE For example, a diameter of 1,91 m (6 m circumference) is applicable for vehicles with a wheelbase down to 2,2 m (with consideration of some tolerance between the rollers).



Key

1 wheelbase

d roller diameter

t tolerance

Figure 7 — Dynamometer dimensions

8.3 Reproducibility of the pass-by dynamics

The response of the dynamometer should be able to follow the rapid transient of the vehicle acceleration cycle. Therefore, the response time of the dynamometer shall not be greater than the response time of the vehicle under testing conditions.

The vehicle on the roller bench shall be able to reproduce the outdoor dynamics (averaged engine speed and averaged vehicle speed from at least four outdoor measurements in comparison to the average of four indoor measurements) under the same initial conditions within a maximum deviation of ±2 % between the lines PP' and BB' for M1, M2 not exceeding 3 500 kg and N1 vehicles. Because of the higher spread in the run-to-run variation, the corresponding maximum deviation for M2 exceeding 3 500 kg, M3, N_2, and N3 is ±4 %.

8.4 Single-axle or multi-axle operation

When using variant A (see 10.1), which measures the tyre/road noise independently on an outdoor test track and then combines the results (power train noise from indoor testing), it is recommended to use the least possible number of driven axles (to minimize the tyre/road noise on the dynamometer).

When using variant B (see 10.1), which measures the overall vehicle noise directly on the dynamometer, it is recommended to use the operation of all axles of the vehicle under test.

8.5 Noise emission limit under operating conditions produced by the dynamometer rollers

The noise emitted by the roller bench under operating conditions (without vehicle on the rollers) shall be low enough not to influence the expected sound levels of interest.

Normally, this is fulfilled if the difference between the measurements with and without vehicle is greater than 15 dB (measured with the microphones at the 7,5 m line).

NOTE Typical measurements 1,2 m above rotating dynamometer show A-weighted sound pressure levels, independent of drum speed, up to approximately 70 km/h with less than 45 dB. Air-handling sound pressure levels dominate the roller bench sound pressure level. Sound pressure levels below 45 dB for air-handling noise and dynamometer noise are achievable.

9 Test procedures

9.1 General

Acoustic data from each of the measuring microphones are acquired and stored to computer memory as time histories. At the same time, data are acquired to quantify the vehicle speed and engine speed during the test. These various sources of information are combined, based on a trigger signal relating to line AA' of the test track when the accelerator is applied. The time data from each of the microphones are sequenced over time, based on the speed of the vehicle and its simulated position along the test track. Through the process of combining these signals, a virtual sweep is made of the microphone array to represent the movement of the vehicle past a single microphone. The digital signal processing system provides a single plot of the overall sound pressure level of the vehicle as a function of its position along the “course”.

NOTE In addition, typical commercially available systems generally have the capability to provide additional time-based analysis of each of the individual microphones. This enhances the capability of defining specific noise sources, such as the level from the microphone directly in line with the exhaust outlet or at the centreline of the vehicle front axle. Most data processing systems offer an array analysis tool that provides a detailed mapping of the vehicle noise information.

9.2 Microphone array — Hardware and software

It shall be ensured that the calculating method of the overall sound pressure level is able to deliver values within certain accuracy every 0,5 m along the test track (the minimum requirement is 30 readings per second). Therefore, the density of the microphones shall be coordinated with the algorithm of the calculation method. In case of calculation after BB’ line, measured sound level at the end of microphone array may be used to calculate projected microphone positions. The acoustic centre for calculation shall be at rear of the vehicle on the CC’ line.

NOTE This does not require to have microphones every 0,5 m, but that the A-weighted sound pressure level can be interpolated to some accuracy to estimate dB values every 0,5 m along the simulated path of travel.

The software shall be able to emulate the position equivalent to an outdoor measurement and shall match the position of the microphones to the vehicle for the indoor test.

This is deemed to be fulfilled if the software meets the requirements formulated in Annex A.

9.3 Vehicle fixing system

The fastening system should be small enough to avoid disturbance of the sound field.

NOTE There is a non-negligible disturbance of the sound field if the fixing system is too big and located beside the wheels. If using a fixing system in the front or the rear of the vehicle (rods or chains), no significant disturbance of the sound field is expected. In this case, however, mechanical noise needs to be avoided.

For avoiding slip, the fixing system may include arrangement(s) for adding a downwards-directed force. This force may be applied as an additional mass on the driving axle(s) or as a downwards pulling strap between the centre of the axle(s) and the foundation of the dynamometer rollers.

9.4 Conditions of the vehicle

9.4.1 General conditions

As defined in ISO 362-1:2022, 8.2.1.

9.4.2 Test mass of the vehicle

9.4.2.1 General

The control system of the dynamometer rollers shall simulate the vehicle acceleration in accordance with Clause 8, based on the test mass, m_t, as specified in Table 4.

Table 4 — Virtual or actual physical test mass

Vehicle category	Vehicle test mass
M1	$m_t = m_{ref} = m_{kerb} + 75$ kg. The 75 kg added mass accounts for the mass of the driver according to ISO 2416. The test mass m_t shall be achieved with a tolerance of ±5 %.
M2, M3	$m_t = m_{ro}$. The mass in running order, m_{ro}, shall be achieved with a tolerance of ±5 %.
N1[a,b]	$m_t = m_{ref} = m_{kerb} + 75$ kg. The 75 kg added mass accounts for the mass of the driver according to ISO 2416. The test mass, m_t, shall be achieved with a tolerance of ±5 %.
N2, N3	$m_{target} = 50$ [kg/kW] × Pn [kW]. Extra loading m_{xload} to reach the target mass, m_{target}, of the vehicle shall be placed above the rear axle. The sum of the extra loading and the unladen rear axle load, $m_{ra\ load\ unladen}$, is limited to 75 % of the maximum axle capacity, $m_{ac\ ra\ max}$, allowed for the rear axle. The target mass, m_{target}, shall be achieved with a tolerance of ±5 %. If the centre of gravity of the extra loading cannot be aligned with the centre of the rear axle, the test mass, m_t, of the vehicle shall not exceed the sum of the unladen front axle load, $m_{fa\ load\ unladen}$, and the unladen rear axle load plus the extra loading and the mass of driver, m_d. The test mass for vehicles with more than two axles shall be the same as for a two-axle vehicle. If the unladen vehicle mass, $m_{unladen}$, of a vehicle with more than two axles is greater than the test mass for the two-axle vehicle, then this vehicle shall be tested without extra loading.

[a] N1 category vehicles may be loaded, at the decision of the vehicle manufacturer, for practical reasons during the test. This practice is acceptable; however, it can lead to a higher level of vehicle noise (typically 1 dB).

[b] If load is added to these vehicles during the test, the added payload shall be noted in the test report.

9.4.2.2 Calculation procedure to determine virtual or actual physical test mass, m_t, of N2 and N3 vehicles only

9.4.2.2.1 Calculation of extra loading

As defined in ISO 362-1:2022, 8.2.2.2.1.

9.4.2.2.2 Loading considerations if load cannot be aligned with the centre of rear axle

As defined in ISO 362-1:2022, 8.2.2.2.2.

9.4.2.2.3 Test mass for vehicles with more than two axles

As defined in ISO 362-1:2022, 8.2.2.2.3.

9.4.2.2.4 Calculation of the test mass of a virtual vehicle with two axles

As defined in ISO 362-1:2022, 8.2.2.2.4.

9.4.3 Tyre selection and tyre condition

If using variant A (see 10.1), which measures the tyre/road noise independently on the test track, it is necessary to have a very low tyre noise on the rollers. For example, smooth tread tyres (slicks) are able to provide this. But also, other systems (noise barriers) are applicable if the propagation of sound from other sources is not obstructed.

For the corresponding tyre/road noise measurements as described in Annex B the tyres shall be appropriate for the vehicle and shall be inflated to the pressure recommended by the vehicle manufacturer for the test mass of the vehicle.

If using variant B (see 10.1), the tyres shall be appropriate for the vehicle and shall be inflated to the pressure recommended by the vehicle manufacturer for the test mass of the vehicle.

Snow tyres, traction tyres, and special-use tyres are not recommended due to their own specification (reproducibility and spread of results), e.g. due to temperature behaviour and tread pattern influence. For this reason, such tyres shall not be used.

For certification and related purposes, additional requirements for the tyres, defined by regulation, are to be complied with. The tyres for such a test shall be selected by the vehicle manufacturer and shall correspond to one of the tyre sizes and types designated for the vehicle by the vehicle manufacturer. The tyre shall be commercially available on the market at the same time as the vehicle. The tread depth shall be according to ISO 362-1:2022, 8.2.3.

NOTE The tread depth can have a significant influence on the acoustic test result.

The exact knowledge of the tyre noise is crucial to obtain reliable results. For this reason, the condition of the tyres as described above and B.2.3 shall be closely adhered to.

9.4.4 Calculation of total engine power

As defined in ISO 362-1:2022, 8.2.4.

9.4.5 Battery state of charge

As defined in ISO 362-1:2022, 8.2.5.

9.4.6 Additional sound emitting devices

As defined in ISO 362-1:2022, 8.2.6.

9.4.7 Vehicle cooling fans or cooling systems

As defined in ISO 362-1:2022, 8.2.7.

9.5 Operating conditions

9.5.1 Vehicles of categories M1, M2 having a maximum authorized mass not exceeding 3 500 kg, and N1

9.5.1.1 General conditions

The vehicle shall be fixed on the rollers in a way that the centreline of the vehicle is within a tolerance of ±0,05 m to each microphone array throughout the entire test.

Any trailer that is not readily separable from the towing vehicle shall be ignored when considering the crossing of the line BB'. If a vehicle is fitted with more than two-wheel drive, test it in the drive selection that is intended for normal road use. If the vehicle is fitted with an auxiliary manual transmission or a multi-gear axle, the position used for normal urban driving shall be used. In all cases, the gear ratios for slow movements, parking, or braking shall be excluded.

9.5.1.2 Test speed

The test speed v_{test} shall be (50 ± 1) km/h. The test speed shall be reached when the reference point according to ISO 362-1:2022, 3.5, is at the virtual line PP'. If the test speed is modified according to 9.5.1.3.2, the modified test speed shall be used for both the acceleration and constant-speed tests.

To detect excessive slip, it is recommended to control the ratio of engine rotational speed and vehicle speed between the acceleration phase and the constant-speed status. To avoid slip, it is possible to increase the axle load. If this measure does not succeed check the tyres and the roller texture.

9.5.1.3 Gear ratio selection

9.5.1.3.1 General

As defined in ISO 362-1:2022, 8.3.1.3.1.

9.5.1.3.2 Manual transmission, automatic transmission, adaptive transmission, or transmission with continuously variable gear ratio (CVT) tested with locked gear ratio

As defined in ISO 362-1:2022, 8.3.1.3.2.

9.5.1.3.3 Automatic transmission, adaptive transmission, and transmission with variable gear ratio tested with non-locked gear ratio

As defined in ISO 362-1:2022, 8.3.1.3.3.

9.5.1.3.4 Vehicles with one gear ratio

As defined in ISO 362-1:2022, 8.3.1.3.4.

9.5.1.4 Acceleration test

As defined in ISO 362-1:2022, 8.3.1.4.

9.5.1.5 Constant-speed test

As defined in ISO 362-1:2022, 8.3.1.5.

9.5.2 Vehicles of categories M2 having a maximum authorized mass exceeding 3 500 kg, M3, N2 and N3

9.5.2.1 General conditions

As defined in ISO 362-1:2022, 8.3.2.1.

9.5.2.2 Target conditions

9.5.2.2.1 General

As defined in ISO 362-1:2022, 8.3.2.2.

9.5.2.2.2 Vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg, and category N2

As defined in ISO 362-1:2022, 8.3.2.2.1.

9.5.2.2.3 Vehicles of categories M3 and N3

As defined in ISO 362-1:2022, 8.3.2.2.2.

9.5.2.3 Gear selection

9.5.2.3.1 General

As defined in ISO 362-1:2022, 8.3.2.3.1.

9.5.2.3.2 Manual transmission, automatic transmission, adaptive transmission, or transmission with continuously variable gear ratio (CVT) tested with locked gear ratio

As defined in ISO 362-1:2022, 8.3.2.3.2.

9.5.2.3.3 Automatic transmission, adaptive transmission, and transmission with variable gear ratio tested with non-locked gear ratio

As defined in ISO 362-1:2022, 8.3.2.3.3.

9.5.2.3.4 Power trains with no rotational engine speed available

As defined in ISO 362-1:2022, 8.3.2.3.4.

9.5.2.4 Acceleration test

As defined in ISO 362-1:2022, 8.3.2.4.

9.6 Measurement readings and reported values

9.6.1 General

At least four measurements for all test conditions shall be made on each side of the vehicle and for each gear ratio.

The maximum A-weighted sound pressure level indicated during each run of the vehicle between the virtual lines AA' and BB' shall be noted to the first significant digit after the decimal place. If a sound peak obviously out of character with the general sound pressure level is observed, that measurement shall be discarded.

The first four valid consecutive measurement results for any test condition, within 2,0 dB allowing for the deletion of non-valid results, shall be used for the calculation of the appropriate intermediate or final result.

The speed measurements at lines AA', BB', and PP' shall be noted and used in the calculations to one digit after the decimal place.

9.6.1.1 Measurement conditions and acceptance

As defined in ISO 362-1:2022, 8.4.1.1

9.6.1.2 Vehicles of categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg, and category N1

As defined in ISO 362-1:2022, 8.4.1.2

9.6.1.3 Vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg and categories M3, N2, and N3

As defined in ISO 362-1:2022, 8.4.1.3

9.6.2 Data compilation

As defined in ISO 362-1:2022, 8.4.2.

9.6.3 Vehicles of categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg, and of category N1

9.6.3.1 Acceleration

As defined in ISO 362-1:2022, 8.4.3.1.

9.6.3.2 Reported value and final results

As defined in ISO 362-1:2022, 8.4.3.2.

9.6.4 Vehicles of categories M2 having a maximum authorized mass exceeding 3 500 kg, M3, N2, and N3

As defined in ISO 362-1:2022, 8.4.4.

9.7 Measurement uncertainty

The measurement procedure described in 9.6 is affected by several parameters (e.g. surface texture variation, environmental conditions, measurement system uncertainty, etc.) that lead to variation in the resulting sound level observed for the same vehicle. The source and nature of these perturbations are not completely known and sometimes affect the end result in a non-predictable way. The uncertainty of results obtained from measurements according to this document can be evaluated by the procedure given in ISO/IEC Guide 98-3, or by interlaboratory comparisons in accordance with ISO 5725 (all parts). Since extensive inter- and intra-laboratory data are not available, the procedure given in ISO/IEC Guide 98-3 is followed to estimate the uncertainty associated with the measurement procedure of this document. The uncertainties given in Table 5 are based on existing statistical data, analysis of tolerances stated in this document, 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 road surface conditions (for tyre/road noise measurements outdoors) also are different (site-to-site).

d) vehicle-to-vehicle variation: variability for L_{urban} due to production variances of noise relevant components and different equipment.

NOTE 1 Part d) factors include but are not exclusive to: Tyres, battery state of charge, engine power output variation, part manufacturing tolerances, or variations in the vehicle mass.

If reported, the expanded measurement uncertainty together with the corresponding coverage factor for the stated coverage probability of 95 % as defined in ISO/IEC Guide 98-3 shall be given. Information on the determination of the expanded uncertainty is given in Annex E.

NOTE 2 Annex E 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 this document.

These data are given in Table 5 for two different vehicle categories. The variability is given for a coverage probability of 95 %. The data from a, b, and c express the variability of results for a certain measurement object and do not cover product variation. The measurement uncertainties in Table 5 applies for Variant A in 10.2.

The total variation comprises uncertainty sources from a), b), c) and d). The estimate for total variation is provided for reference only. Variation between different units of a production process is not within the scope of this standard.

Table 5 — Variability of measurement results for a coverage probability of 95 %

Vehicle category	Run-to-run dB	Day-to-day dB	Site-to-site dB	Product variation at different sites
M1, M2 having a maximum authorized mass not exceeding 3 500 kg and N1	0,5	0,9	2,6	2,8
M2 having a maximum authorized mass exceeding 3 500 kg and N2, M3, N3	0,6	1,1	1,5	2,0

10 Test methods and test report

10.1 General

There are two possibilities of doing an indoor pass-by test.

a) **Variant A**: Measurement of power train noise on the dynamometer analogously to ISO 362-1 and energetical addition of the tyre/road noise (measured separately on an outdoor test track) (see 10.2).

b) **Variant B**: Direct measurement of the overall vehicle noise on the dynamometer (with or without road shells) analogously to ISO 362-1 and correction of the obtained noise values to come to an outdoor prediction. This variant is still under development; an overview is given in Annex D.

10.2 Variant A

10.2.1 General

This method is a combination of indoor testing (power train noise) and outdoor testing (tyre/road noise).

It is not necessary to do the measurement of the tyre/road noise every time a vehicle is tested. The data of several tyres can be stored in a database and a matching data set from the database can then be used for the test.

10.2.2 Power train noise

It shall be ensured that there is no remaining tyre/road noise affecting the measurements.

NOTE For example, this can be accomplished by using smooth tread tyres (slicks).

In any case it shall be ensured that the remaining tyre/road noise shall be at least 10 dB below the maximum A-weighted sound pressure level produced by the vehicle under test. If this condition cannot be fulfilled, a correction shall be carried out. This correction procedure is described in B.7.

The vehicle shall be measured according to the operating condition specified in 9.5.

10.2.3 Tyre/road noise

The measurements of the tyre/road noise shall be performed on a test track as described in ISO 10844.

The evaluation of tyre noise consists of two procedures, namely:

a) evaluation of free rolling noise;

b) evaluation of torque influence which can be derived from a) by the method described in Annex B, B.4.3.

All conditions for evaluation of tyre/road noise, free rolling noise, and torque influence are described in Annex B.

10.2.4 Calculation of the total vehicle noise using variant A

The total vehicle noise L_{TVN} is the energetically sum of tyre/road noise L_{TRN} and power train noise L_{PTN}. This calculation shall be carried out for each single run as given in Formula (8):

$$L_{TVN} = 10 \cdot \lg\left(10^{\frac{L_{PTN}}{10}} + 10^{\frac{L_{TRN}}{10}}\right) \text{dB} \qquad (8)$$

The calculation of the tyre/road noise L_{TRN} is described in B.6.

10.3 Test report

The test report shall include the following information:

a) a reference to this document, i.e. ISO 362-3:2022;

b) the details of the test site and ambient conditions including air temperature, barometric pressure, and relative humidity;

c) the type of measuring equipment;

d) the maximum A-weighted sound pressure level typical of the background noise;

e) the identification of the vehicle, its engine, power, its transmission system including available transmission ratios, size and type of tyres, tyre pressure, tyre production type, test mass, power-to-mass ratio, vehicle length, and location of the reference point;

f) the transmission gears or gear ratios used during the test;

g) the vehicle speed and engine rotational speed at the beginning of the period of acceleration, and the location of the beginning of the acceleration phase;

h) the vehicle speed ($v_{PP'}$, $v_{BB'}$) and engine rotational speed ($n_{BB'}$, $n_{PP'}$) at line PP' and at end of the acceleration phase;

i) the method used for calculation of the acceleration;

j) the variant (A or B) used for calculation of tyre/road noise;

k) the auxiliary equipment of the vehicle, where appropriate, and its operating conditions;

l) all valid A-weighted sound pressure levels measured for each test, listed according to the side of the vehicle and the direction of the vehicle movement on the test site.

Annex A
(normative)

Validation of method

A.1 General

This annex defines a procedure which shall be used to ensure that the used method delivers results within a defined accuracy.

To make the accuracy of the method used transparent, it is necessary to make a comparison between a real outdoor measurement and an indoor measurement. The deviation of the results shall be within an acceptable range.

In order to check whether the method used is delivering stable results, this validation shall be repeated after any relevant software release.

A.2 Process of validation

A.2.1 General

The validation process is shown in Figure A.1.

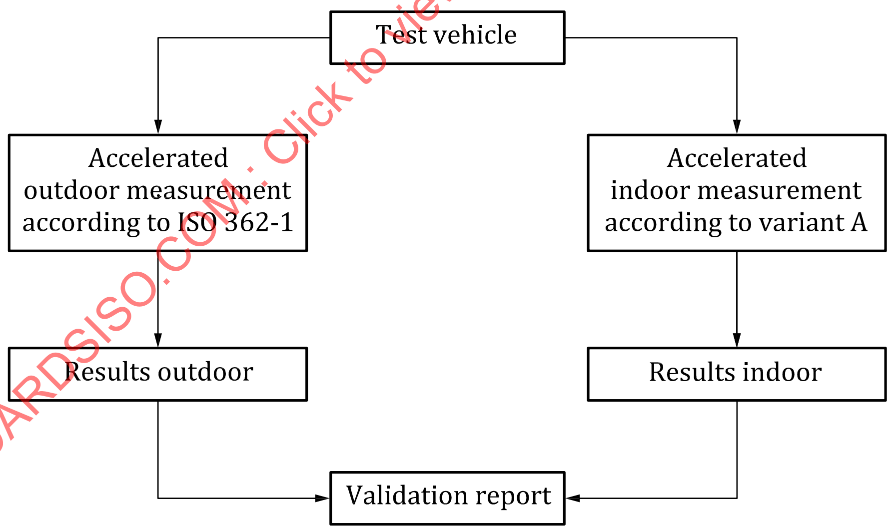


Figure A.1 — Chart for the process of validation

Additional validations with changed boundary conditions shall deliver results with a comparable precision.

NOTE Changed boundary conditions can include different vehicles, different environmental conditions, like temperature or different tyres.

A.2.2 Master measurement for validation (outdoor measurement according to ISO 362-1)

A complete accelerated (and if applicable, constant speed) test as described in ISO 362-1:2022, 8.3.1.4 and 8.3.2.4, shall be carried out.

The environmental conditions (especially the air temperature) shall be within a range which can be simulated in the test room.

The following should be reported:

— surface temperature of the catalyst or the diesel particulate filter;

— surface temperature of the rear muffler;

— intake air temperature.

The measured temperatures of the exhaust system should be within a range of 30 °C during four valid measurements. Intake air temperatures should be within a range of 10 °C during 4 valid measurements.

Additional tyre rolling noise measurements as described in Annex B shall be carried out. If no tyre test vehicle is available a normal vehicle can be used for the measurements. In that case the principles as described in B.4.4 shall be applied.

A.2.3 Validation measurement (indoor measurement according variant A)

A complete accelerated test as described in this document (variant A) shall be carried out, using the same vehicle as used during the master measurement (see A.2.2).

The following parameters shall be controlled:

— intake air temperature compared to the intake air temperature of the master measurement (average of four valid measurements);

— surface temperature of the exhaust system compared to the master measurement (average of four valid measurements);

— engine speed curves shall be within a range of ±2 % compared to the master measurement for vehicles of category M1, M2 not exceeding 3 500 kg, and N1;

— engine speed curves shall be within a range of ±4 % compared to the master measurement for vehicles of category M2 exceeding 3 500 kg, M3, N2, and N3;

— vehicle speed curves shall be within a range of ±1 km/h compared to the master measurement.

A.2.4 Evaluation of the results

A.2.4.1 Deviation of L_{acc}

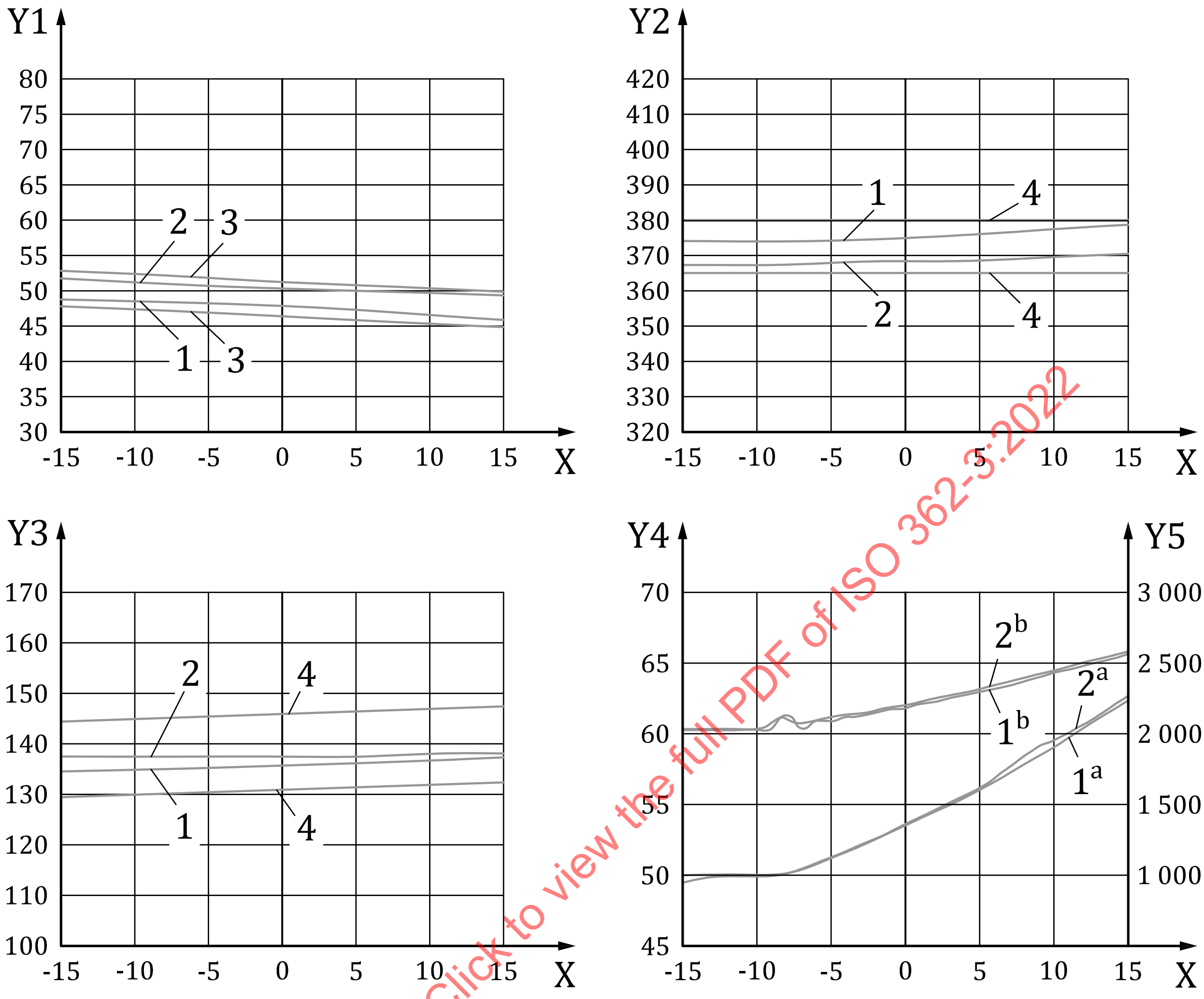
The deviation of L_{acc} between the both measurements (indoor and outdoor) shall not exceed 1 dB.

A.2.4.2 Deviation of L_{crs}

The deviation of L_{crs} between the both measurements (indoor and outdoor) shall not exceed 1 dB.

A.3 Example for a validation (variant A)

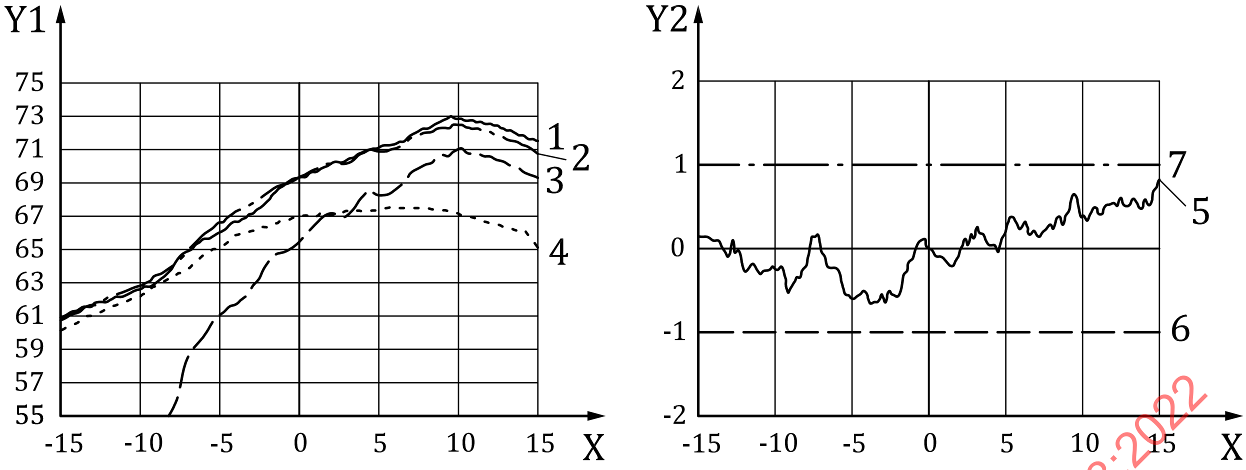
Basis of an exact validation are comparable relevant parameters (within the above-mentioned tolerances). Examples for a validation (variant A) are shown in Figures A.2 and A.3.



Key

X	*x*-position, m		1	indoor
Y1	intake air temperature, °C		2	outdoor
Y2	catalyst temperature, °C		3	limits of 5 °C temperature range
Y3	rear muffler temperature, °C		4	limits of 15 °C temperature range
Y4	speed, km/h		[a]	Deviation of speed is ±1 km/h.
Y5	engine rotational speed, r/min		[b]	Deviation of engine rotational speed is ±2 %.

Figure A.2 — Examples for the most relevant parameters



Key

X *x*-position, m

Y1 sound pressure level, dB(A)

Y2 deviation, dB

1 total vehicle noise outdoor

2 total vehicle noise indoor

3 power train noise indoor

4 tyre/road noise calculated

5 actual deviation

6 lower limit of permissible maximum deviation

7 upper limit of permissible maximum deviation

Figure A.3 — Example of an indoor/outdoor validation with indication of the permissible maximum deviation

Annex B
(normative)

Procedure for measurement, evaluation, and calculation of tyre/road noise when using variant A

B.1 General

This annex describes the method of measuring and evaluation of the tyre/road noise when using variant A (see 10.2). The idea of the method is the decomposition of tyre/road noise in its main components, i.e. in the free rolling noise and the torque influence, and their description by certain regression models. The result of the analysis is a data set of regression coefficients for each test track position. These coefficients are only related to the test track used for the measurement.

B.2 General conditions

B.2.1 Tyre test vehicle

The vehicle used shall be representative of vehicles to be tested indoors.

The tyre test vehicle shall have the same number of axles as the vehicle tested indoors or two axles, with two test tyres on each axle by default.

The weight on each tyre of the tyre test vehicle shall be similar or higher than vehicles to be tested indoors. The tyre inflation pressure may be adapted according B.2.3.1.

The vehicle's track width and wheelbase fitted with test tyres shall be equal to vehicles to be tested indoors ±25 %.

To ensure that tyre noise is not significantly affected by the test vehicle design, the following requirements shall be fulfilled:

— spray suppression flaps or other extra devices to suppress spray shall not be fitted;

— addition or retention of elements in the immediate vicinity of the rims and tyres which might screen the emitted sound is not permitted;

— wheel alignment (toe in, camber, and caster) shall be checked on the unloaded vehicle and found to be in full accordance with the vehicle manufacturer’s recommendations;

— additional sound absorbing material shall not be mounted in the wheel housings or under the underbody;

— the windows and sliding roof of the vehicle shall be closed during testing.

B.2.2 Power train conditions for the tyre measurements

To ensure that there is no power train noise affecting the measurements, the use of a silent propulsion vehicle is recommended (tyre test vehicle). If such a vehicle is not available, using a normal vehicle to measure the free rolling noise is possible. A “simplified procedure” may then be used for the torque influence evaluation.

When a normal vehicle is used (not a tyre test vehicle), the following conditions apply:

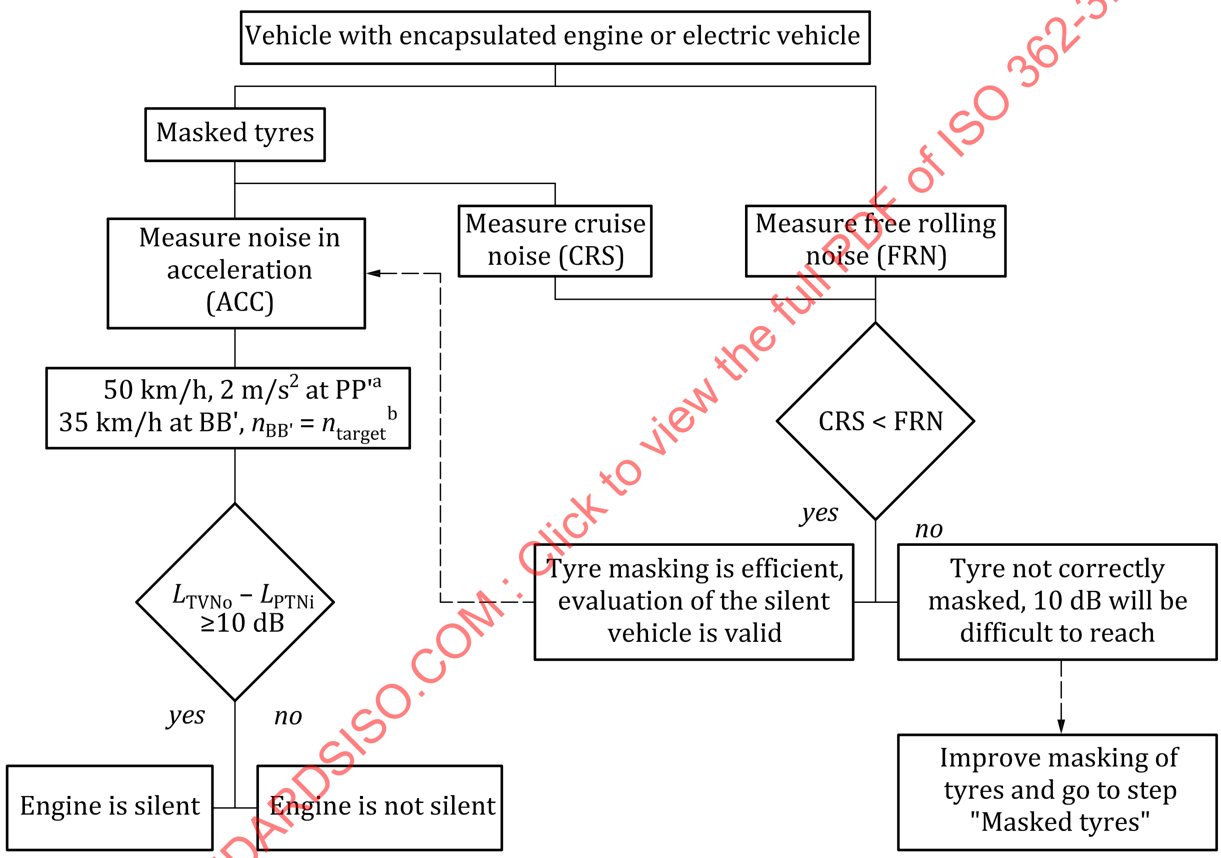
— the transmission is in neutral position;

— the engine is switched off or at idle. In this case vehicle noise shall be evaluated at idle to ensure that it does not affect the free rolling noise.

When a tyre test vehicle is used, it shall be ensured that the remaining power train noise shall be at least 10 dB below the A-weighted sound pressure level produced by the vehicle under all relevant driving conditions as described for the acceleration test in 9.5.1.4. This shall be checked by carrying out the test on the dynamometer with fitted slicks and additional noise barriers on the tyres for suppression of the tyre/roller noise.

To achieve these requirements a tyre test vehicle could be an internal combustion engine vehicle or an electric vehicle. Power train, exhaust system, admission, transmissions, or significant accessories running during the test may be encapsulated.

Figure B.1 shows an example for a checking procedure of a tyre test vehicle. It is applicable to all vehicle categories of this document.



a For vehicles of category M1, M2 not exceeding 3 500 kg, and N1.

b For vehicles of category M2 exceeding 3 500 kg, M3, N2, and N3.

Figure B.1 — Example for a checking procedure of a tyre test vehicle

B.2.3 Tyre conditions

B.2.3.1 Adjustment of the tyre inflation pressure

Test tyres shall be mounted on any rim approved by the tyre manufacturer. Tyre inflation pressure shall not exceed those recommended for the vehicle to be tested indoor. In case of overweight of the test vehicle compared to the vehicle tested indoor, it is permitted to adapt the inflation pressure, P_{test}, of the tyres during the test to keep an equivalent footprint as given in Formula (B.1):

$$P_{test} = P_{ref} \cdot \left(\frac{m_{tyre\ test}}{m_{ro\ indoor\ test}} \right)^{1,25} \quad (B.1)$$

where

P_{ref} is the inflation pressure recommended by the vehicle manufacturer;

$m_{tyre\ test}$ is the test mass of the tyre test vehicle;

$m_{ro\ indoor\ test}$ is the mass in running order of the vehicle to be tested indoor.

B.2.3.2 Preconditioning of the tyre

Prior to testing, tyres shall be warmed up by running under test conditions for at least 10 min to allow the rubber compound to warm-up.

B.3 Measurement procedure for tyre/road noise evaluation

B.3.1 General conditions

To ensure consistent results the measurements of the tyre/road noise with torque influence and under free rolling conditions shall be carried out in two consecutive test series under very similar conditions. The drift of the air temperature during these test series shall be less than or equal 2 °C. The averaged air temperature ϑ_{FRN} from the free rolling noise measurement runs shall be reported.

NOTE The averaged air temperature ϑ_{FRN} is reported for the purpose of a temperature correction of the free rolling noise component of the tyre road noise.

B.3.2 Vehicle operating conditions for the free rolling noise component

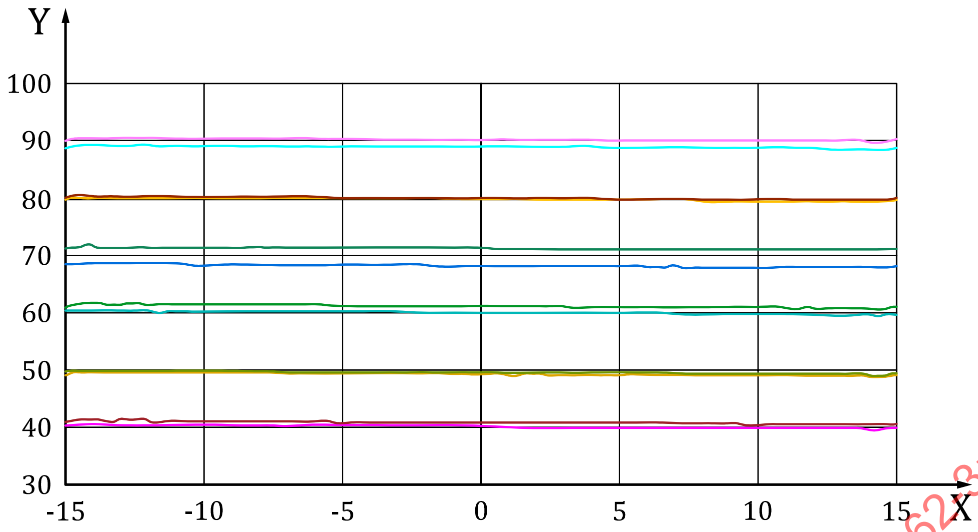
Several pass-by measurements shall be carried out with different constant speeds.

For vehicles of categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg, and category N1, the speed range shall be at least from 40 km/h to 60 km/h in steps of not more than 10 km/h and for vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg, and categories M3, N2, and N3, the speed range shall be at least from 25 km/h to 45 km/h in steps of not more than 10 km/h. At least two measurements per speed step shall be conducted.

The maximum background ambient level shall be 10 dB below any measurement result. If this condition is not fulfilled the speed range shall be extended. The extension of the speed range can be up to a maximum speed of 90 km/h.

When a production vehicle is used, the free rolling noise is measured within a light deceleration: the vehicle enters the measurement area with a speed just above the target speed (that should be reached near line PP'), then, before line AA', either the engine is switched off (recommended, if possible) or the gear lever is put to neutral (engine idling). The deceleration shall be not greater than 0,30 m/s^2. In case of more than 0,30 m/s^2 deceleration the impact of the torque shall be checked.

Figure B.2 shows an example for vehicle speed profiles to determine the free rolling noise component.



Key

X *x*-position, m

Y vehicle speed, km/h

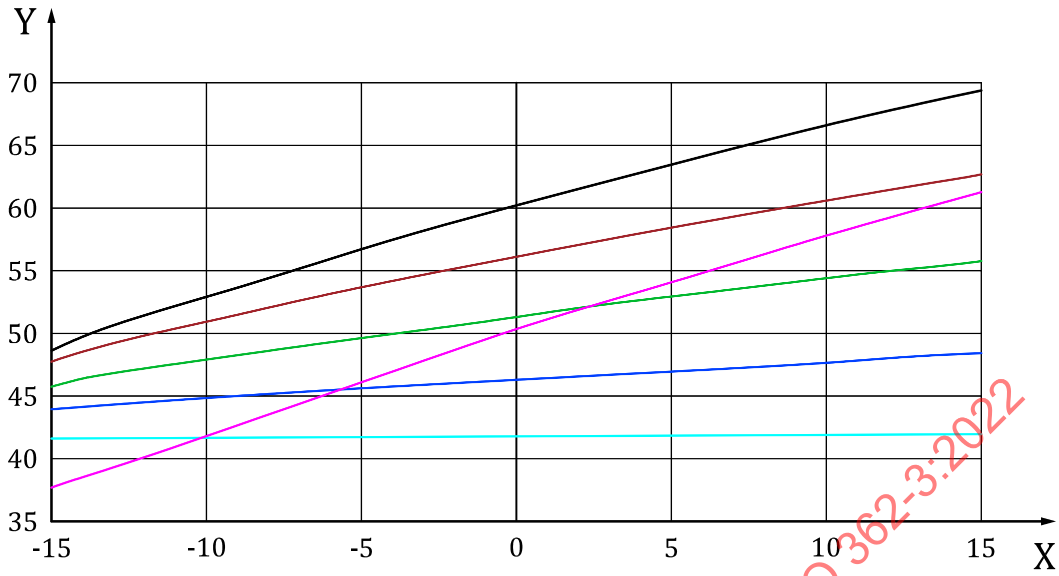
Figure B.2 — Example for vehicle speed profiles to determine the free rolling noise component

B.3.3 Vehicle operating conditions for the torque influence component

This procedure is possible only with a tyre test vehicle. In case of using a normal vehicle, the torque influence is evaluated with the simplified procedure as described in B.4.4.

Several accelerated pass-by measurements shall be carried out with different accelerations. The range of the acceleration shall be from zero up to the maximum available acceleration, but not more than 4 m/s^2 and the step size shall not exceed 1 m/s^2. The speed range shall correspond approximately to the typical testing situation (e.g. for M1 from 40 km/h to 60 km/h at line PP', and for N3 from 25 km/h to 45 km/h at line BB').

Figure B.3 shows an example for vehicle speed profiles for a M1 vehicle to determine the torque influence component.



Key

X x-position, m

Y vehicle speed, km/h

Figure B.3 — Example for vehicle speed profiles for a M1 vehicle to determine the torque influence component

B.4 Calculation of tyre/road noise coefficients

B.4.1 General

The tyre/road noise can be described using a simple model. This divides the tyre/road noise, L_{TRN}, into two main components, the free rolling noise, L_{FRN}, and the torque influence, ΔL_{TI}. The free rolling noise is a function of the vehicle speed, v, and the torque influence is a function of vehicle propulsion force, F. The model is described at each x-position, the usual increment of which is 0,2 m and is given by Formula (B.2):

$$L_{TRN}(F,v,x) = L_{FRN}(v,x) + \Delta L_{TI}(F,x) \quad \text{(B.2)}$$

The tyre model and its coefficients shall cover at least a range of vehicle positions between the expected maximum sound pressure levels of the power train noise measured indoors and of the associated tyre road noise.

NOTE A minimum coverage of test track area from -10 m to 15 m is recommended.

B.4.2 Calculation of free rolling noise coefficients

The coefficients of the free rolling noise sound pressure level, L_{FRN}, can be determined directly from the measurement. The free rolling noise can be described by a logarithmical regression model, as given by Formula (B.3):

$$L_{FRN}(v,x) = \alpha(x) + \beta(x) \cdot \lg\left[\frac{v(x)}{v_{test}}\right] \quad \text{(B.3)}$$

where

α, β are the coefficients of free rolling noise, in decibels (dB);

v is the vehicle speed, in kilometres per hour (km/h);

v_{test} is the vehicle target speed, in kilometres per hour (km/h);

x is the x-position of the vehicle, in metres (m).

The coefficient of determination (R^2) of the regression shall not be less than 0,9 and the determination of the coefficients shall be conducted for the left and right microphone positions separately.

The coefficients a and b should be determined by an appropriate method such as by a linear regression or a total least squares method[15][16].

Using the linear regression, the coefficients α and β are determined using the following Formulae B.4, B.5 and B.6:

$$\alpha(x) = \overline{L_{FRN}(x)} - \beta(x) \cdot \frac{1}{n} \sum_{i=1}^{n} \lg \left[\frac{v_i(x)}{v_{test}} \right] \tag{B.4}$$

where $\beta(x)$ is the slope of the regression line at the position x, in decibels per speed decade, with:

$$\beta(x) = \frac{\sum_{i=1}^{n} \left\{ \lg \left[\frac{v_i(x)}{v_{test}} \right] - \frac{1}{n} \sum_{i=1}^{n} \lg \left[\frac{v_i(x)}{v_{test}} \right] \right\} \cdot \left[L_{FRN,i}(x) - \overline{L_{FRN}(x)} \right]}{\sum_{i=1}^{n} \left\{ \lg \left[\frac{v_i(x)}{v_{test}} \right] - \frac{1}{n} \sum_{i=1}^{n} \lg \left[\frac{v_i(x)}{v_{test}} \right] \right\}^2} \tag{B.5}$$

$\overline{L_{FRN}(x)}$ is the arithmetic mean value of sound pressure levels of the free rolling noise for all runs and speed steps at the position x, in decibels (dB) with:

$$\overline{L_{FRN}(x)} = \frac{1}{n} \sum_{i=1}^{n} L_{FRN,i}(x) \tag{B.6}$$

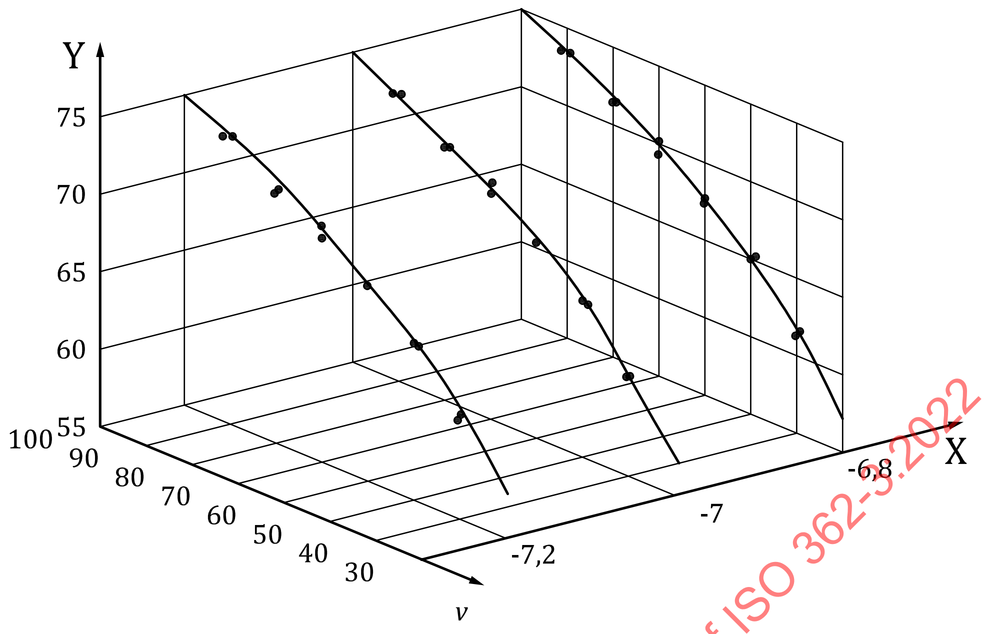
$L_{FRN,i}(x)$ is the sound pressure level of the free rolling noise for the run or speed step i at the position x, in decibels (dB);

$v_i(x)$ is the vehicle speed for the run or speed step *i at the position x*, in kilometres per hour (km/h);

v_{test} is the vehicle target speed, in kilometres per hour (km/h);

x is the x-position of the vehicle, in metres (m).

Figure B.4 shows an example for curve fitting (regression) at certain x-positions and Table B.1 gives an example for a coefficient data set.



Key

X *x*-position, m

Y free rolling noise L_{FRN}, dB(A)

v vehicle speed, km/h

Figure B.4 — Example for curve fitting at the *x*-positions −7,2 m up to −6,8 m

Table B.1 — Example for a coefficient data set

x-position m	*α* dB	*β* dB
−10	30,96	11,81
−9,8	30,86	12,14
−9,6	31,02	11,83
−9,4	31,49	11,19
−9,2	31,94	10,49
−9	32,02	10,46
−8,8	32,04	10,53
−8,6	32,26	10,19
–	–	–
–	–	–
–	–	–

B.4.3 Calculation of torque influence coefficients

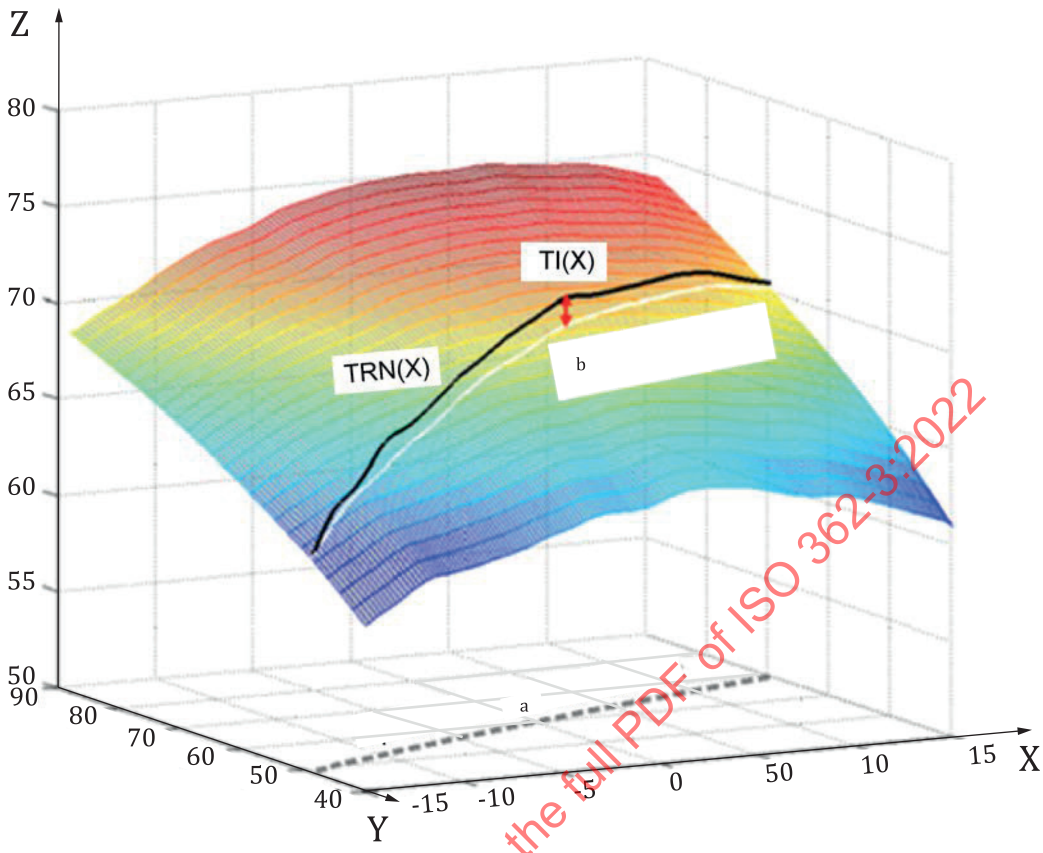
The exact torque influence cannot be determined directly from the measurement. Before the torque influence sound pressure level, ΔL_{TI}, can be described (using a regression model), it has to be determined from the measured tyre/road noise, L_{TRN}, and the corresponding calculated free rolling noise, L_{FRN}, by subtraction. The associated free rolling noise is determined from the coefficients α, β, and the vehicle speed profile of the torque influence measurement given by Formula (B.7):

$$\Delta L_{TI}(F,x) = L_{TRN}(F,v,x) - \left\{ \alpha(x) + \beta(x) \cdot \lg\left[\frac{v_{TRN}(x)}{v_{test}}\right] \right\} \quad \text{(B.7)}$$

where

L_{TRN}	is the tyre/road noise sound pressure level, in decibels (dB);
F	propulsion force per axle, in newton (N);
α, β	are the coefficients of free rolling noise, in decibels (dB);
v_{test}	is the vehicle target speed, in kilometres per hour (km/h);
v_{TRN}	is the vehicle speed at the tyre/road noise measurement outdoors, in kilometres per hour (km/h);
x	is the x-position of the vehicle in metres (m).

Figure B.5 shows an example for tyre/road noise and its corresponding free rolling noise.



Key

X x-position, m

Y sound pressure level, dB(A)

Z vehicle speed, km/h

a Speed of TRN measurement.

b Corresponding calculated FRN(X).

Figure B.5 — Example for tyre/road noise TRN and its corresponding free rolling noise FRN using the torque influence TI

For the description of the torque influence sound pressure level, ΔL_{TI}, an empirical model is used. The model is a function of the propulsion force, $F_{TRN,}$ and is described by a 2nd degree polynomial. At propulsion forces nearly zero, e. g. at constant vehicle speeds or at coast downs, it is assumed that the torque influence sound pressure level, ΔL_{TI}, is neglectable. For this reason, there is no constant in the 2nd degree polynomial Formula B.8.

Note In comparison to the former version of this standard (ISO362-3:2016) the coefficient ε(x) was deleted.

The coefficient of determination (R^2) of the regression shall be greater than 0,7. The 2nd degree polynomial model is given by Formula (B.8):

$$\Delta L_{TI}(F_{TRN}, x) = \gamma(x) \cdot F_{TRN}^{2}(x) + \delta(x) \cdot F_{TRN}(x) \tag{B.8}$$

where F_{TRN} is the propulsion force of the tyre test vehicle with one driven axle in newton (N) with:

$$F_{TRN}(x) = a(x) \cdot m_{\text{tyre test}} \tag{B.9}$$

a is the acceleration of the tyre test vehicle, in metres per square second (m/s^2);

$m_{\text{tyre test}}$ is the test mass of the tyre test vehicle, in kilogram (kg);

x is the x-position of the vehicle in metres (m);

γ, δ are the coefficients of the exact torque influence.

The coefficients γ and δ shall be determined by an appropriate method. Using the total least squares method[15][16] is recommended.

B.4.4 Simplified procedure for the torque influence component

If no tyre test vehicle (electric vehicle or vehicle with internal combustion engine and fully encapsulated drive train) is available, it is possible to calculate the tyre road noise from a free rolling noise measurement with a production vehicle and a standard function for the torque influence. In this case, the following is assumed: The standard function is the same for each x-position and the result is only a function of propulsion force. The torque influence component, ΔL_{TI}, of the sound pressure level is calculated as given in Formula (B.10):

$$\Delta L_{\text{TI}}\left(F_{\text{PTN}}, x\right) = 2 \cdot \zeta \cdot F_{\text{PTN}}^{2}\left(x\right) + \zeta \cdot F_{\text{PTN}}\left(x\right) \tag{B.10}$$

where F_{PTN} is the total propulsion force of the vehicle to be tested indoor in newton (N) with:

$$F_{\text{PTN}}\left(x\right) = a\left(x\right) \cdot m_{\text{ro indoor test}} \tag{B.11}$$

a is the acceleration of the vehicle to be tested indoors, in metres per square second (m/s^2);

$m_{\text{ro indoor test}}$ is the test mass in running order of the vehicle to be tested indoor, in kilogram (kg);

x is the x-position of the vehicle in metres (m);

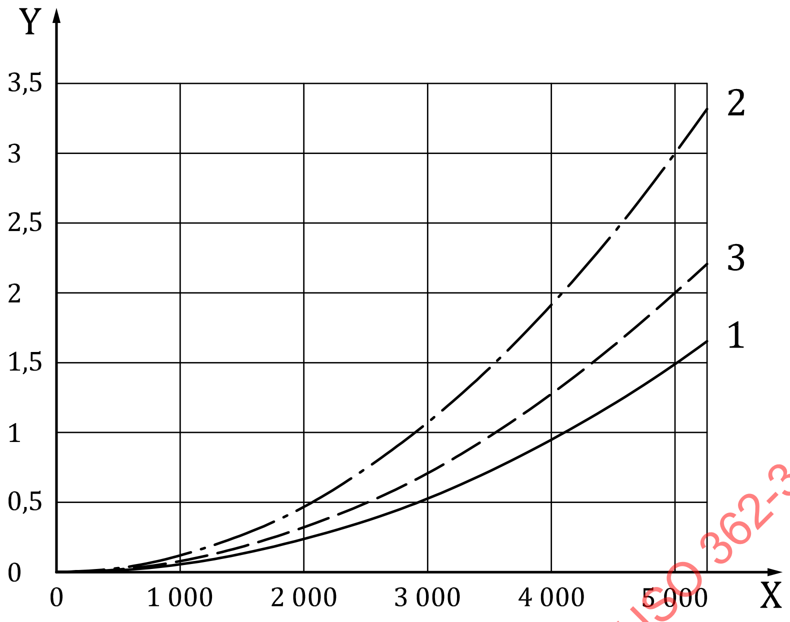
ζ is the coefficient of the standard torque influence.

If this simplified method is used, the mean coefficients of the test track shall be known.

NOTE Experience shows that the coefficient ζ is between 0,000 000 03 (3E-8) for loud test tracks and 0,000 000 06 (6E-8) for quieter test tracks.

Since the free rolling noise measurement with a production vehicle is carried out with engine off, a measurement at a constant speed is not possible. It is important to ensure that the deceleration is not greater than 0,3 m/s^2.

Figure B.6 shows an example for the standard function torque influence.



Key

X force, N

Y torque influence ΔL_{TI}, dB(A)

1 $\Delta L_{TI,\ min}$

2 $\Delta L_{TI,\ max}$

3 $\Delta L_{TI,\ used}$

Figure B.6 — Example for standard function torque influence

Figure B.7 gives, by way of an example, a procedure for checking which method to use.

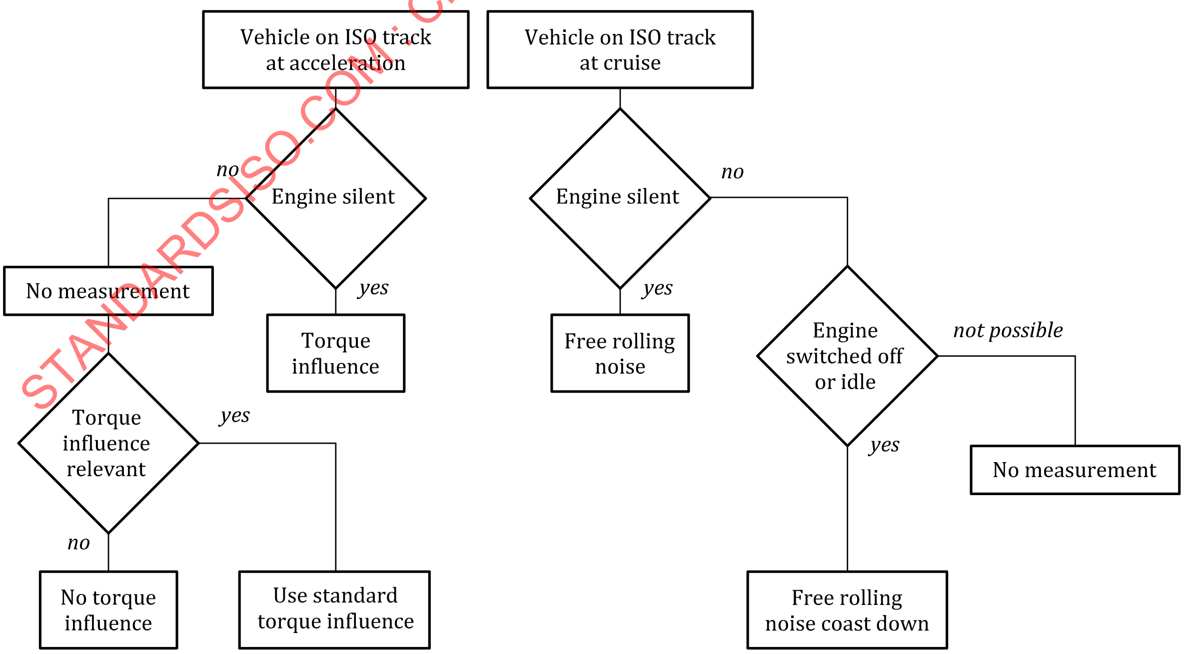


Figure B.7 — Example for a procedure for checking which method to use

B.5 Temperature correction

To adapt rolling noise testing conditions from track to indoor, a temperature correction of the tyre free rolling noise level L_{FRN} is needed. The temperature correction is conducted after the determination of the torque influence (B.4.3) and at the calculation of the tyre/road noise related to the power train noise measurement indoors (B.6). The correction uses the relationship given in Formula (B.12):

$$L_{FRN}(\vartheta_{REF}) = L_{FRN}(\vartheta_{FRN}) + 3{,}4 \cdot \lg\left(\frac{\vartheta_{FRN} + K}{\vartheta_{REF} + K}\right) \quad \text{(B.12)}$$

where

ϑ_{FRN} is the averaged air temperature from all runs of the free rolling noise measurement (see B.3.1), in degrees Celsius (°C);

ϑ_{REF} is the reference air temperature at the power train noise measurements indoor and can be used to normalize to different air temperatures, e.g. 20 °C, in degrees Celsius (°C);

K is the temperature correction constant specific for different tyre classes;

$L_{FRN}(\vartheta)$ is the measured sound pressure of the free rolling noise at the air temperature ϑ_{FRN} in decibels [dB(A)].

For C1 tyres:

$K = 3$

For C2 tyres:

$K = 15$

For C3 tyres no temperature correction is applied.

NOTE The tyre classes are defined in ISO 13325:2019, 4.2.

Figure B.8 shows the general workflow of the temperature correction of the free rolling noise component.

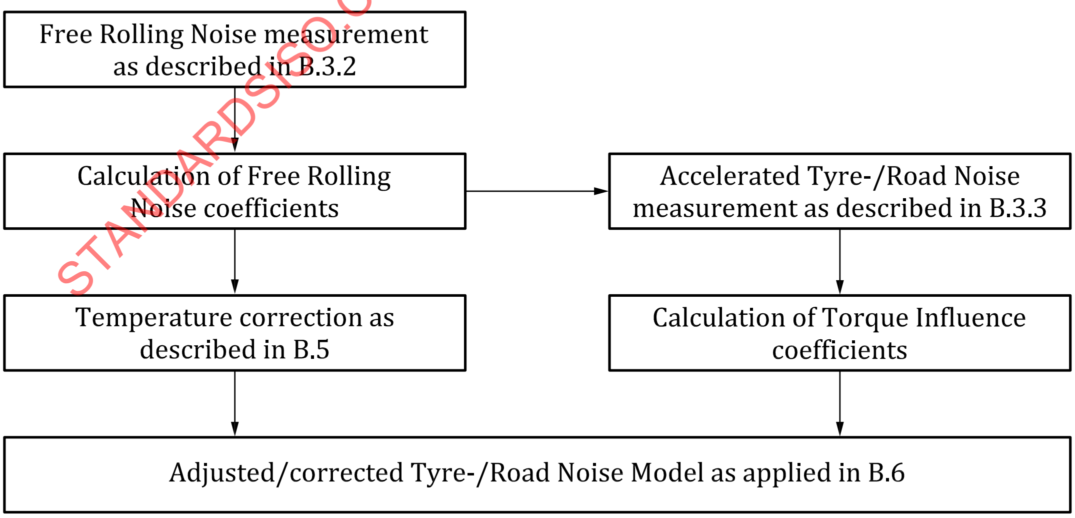


Figure B.8 — Procedure for tyre temperature correction

B.6 Calculation of the tyre/road noise, $L_{TRN\ indoor}$, related to the power train noise measurement indoor

This calculation requires the following:

— the set of coefficients of the tyre;

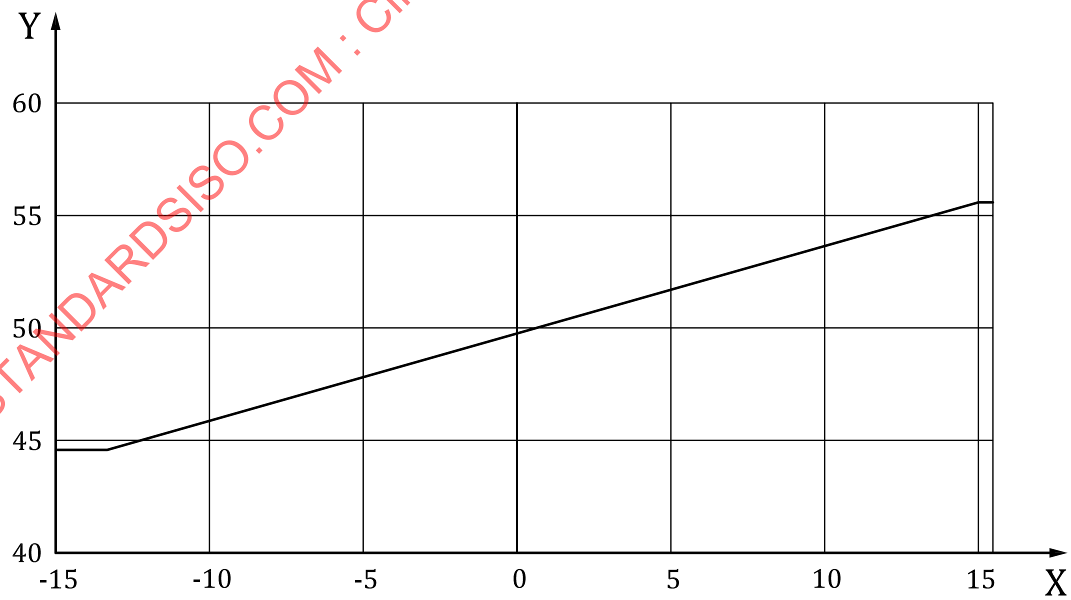
— the vehicle speed profile of the power train noise measurement of the vehicle to be tested indoor;

— the measured air temperatures of the tyre road noise measurements (see B.3.1).

Table B.2 and Figure B.9 show an example for the required input data.

Table B.2 — Set of tyre coefficients

x-position m	*α*	*β*	*γ*	*δ*
−10	34,51	5,84	0,70	−1,36
−9,8	34,68	5,55	0,56	−1,07
−9,6	34,29	6,27	0,34	−0,59
−9,4	34,64	5,69	0,15	0,01
−9,2	34,19	6,57	0,03	0,29
−9	34,38	6,33	0,11	0,03
−8,8	34,17	6,78	0,04	0,17
−8,6	33,58	7,91	−0,05	0,49
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–



Key

X *x*-position, m

Y vehicle speed, km/h

Figure B.9 — Vehicle speed profile of power train noise measurement indoor

The related tyre/road noise sound pressure level $L_{TRN\ indoor}$ is calculated from the data set as given by Formula (B.13):

total tyre road noise:

$$L_{TRN\ indoor}(F,v,x,\vartheta)= \tag{B.13}$$

free rolling noise:

$$\alpha(x)+\beta(x)\cdot\lg\left[\frac{v_{PTN}(x)}{v_{test}}\right]$$

temperature correction:

$$+3,4\cdot\lg\left(\frac{\vartheta_{FRN}+K}{\vartheta_{REF}+K}\right)$$

and either exact torque influence:

$$+\gamma(x)\cdot F_{PTN}(x)^2+\delta(x)\cdot F_{PTN}(x)$$

or standard torque influence:

$$+2\cdot\zeta\cdot F_{PTN}(x)^2+\zeta\cdot F_{PTN}(x)$$

where

F_{PTN} is the total propulsion force of the vehicle to be tested indoor, in newton (N) (see formula B.11);

K is the temperature correction constant specific for different tyre classes (see B.5);

v_{test} is the vehicle target speed, in kilometres per hour (km/h);

v_{PTN} is the vehicle speed at the power train noise measurement in kilometre per hour (km/h);

x is the x-position of the vehicle, in metres (m);

α, β are the coefficients of free rolling noise;

γ, δ are the coefficients of the exact torque influence;

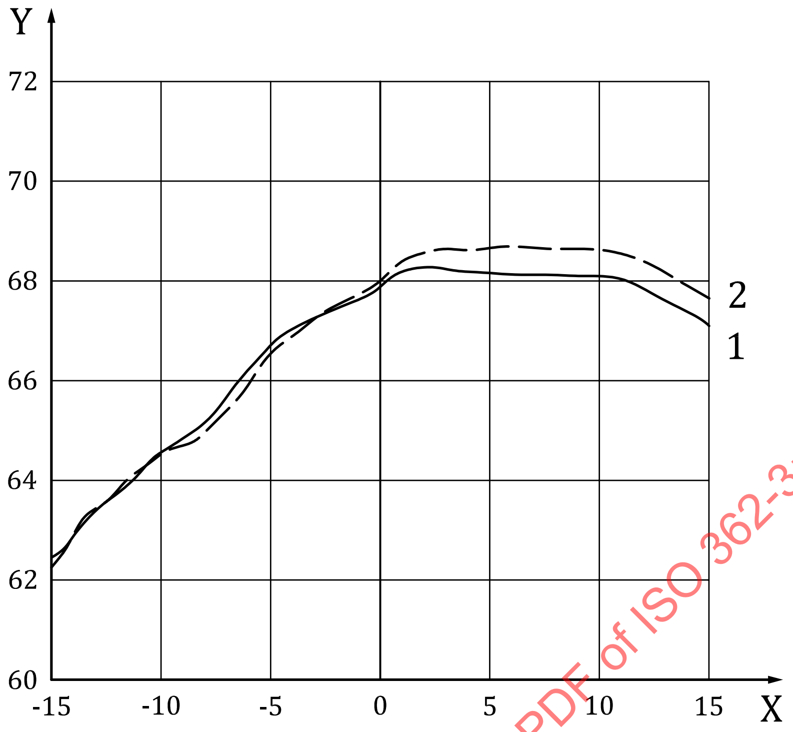
ζ is the coefficient of the standard torque influence model;

ϑ_{FRN} is the averaged air temperature from all runs of the free rolling noise measurement (see B.3.1), in degrees Celsius (°C);

ϑ_{REF} is the reference air temperature at the power train noise measurements indoor and can be used to normalize to different air temperatures, e.g. 20 °C, in degrees Celsius (°C).

NOTE For the validation of method (described in Annex A), the L_{TRN} indoor is normalized to the air temperature of the master measurement outdoors.

Figure B.10 shows an example for the calculated tyre/road noise and the related free rolling noise.



Key

X *x*-position, m

Y sound pressure level, dB(A)

1 free rolling noise

2 tyre/road noise

Figure B.10 — Example for calculated tyre/road noise and related free rolling noise

B.7 Disturbance noise correction of power train noise measurement

When evaluating the power train noise indoor, it shall be checked whether the remaining tyre/roller noise of the slicks is at least 10 dB below the measured maximum power train noise. If not, a correction shall be applied. This check should be carried out even if slick tyres are used to minimize that disturbance noise.

First step to check this is to determine the coefficients of free rolling noise indoor analogously to the procedure on the test track outside (see B.4.2). A determination of the torque influence coefficients is not necessary since the torque influence can be neglected for slicks.

Next step is the calculation of the power train noise measurement related free rolling noise as mentioned in B.6. If the distance between the two curves in the area of the maximum level is less than 10 dB, the free rolling noise has to be subtracted from the measurement of the power train noise to achieve the corrected power train noise sound pressure level, L_{PTN}, as given by Formula (B.14):

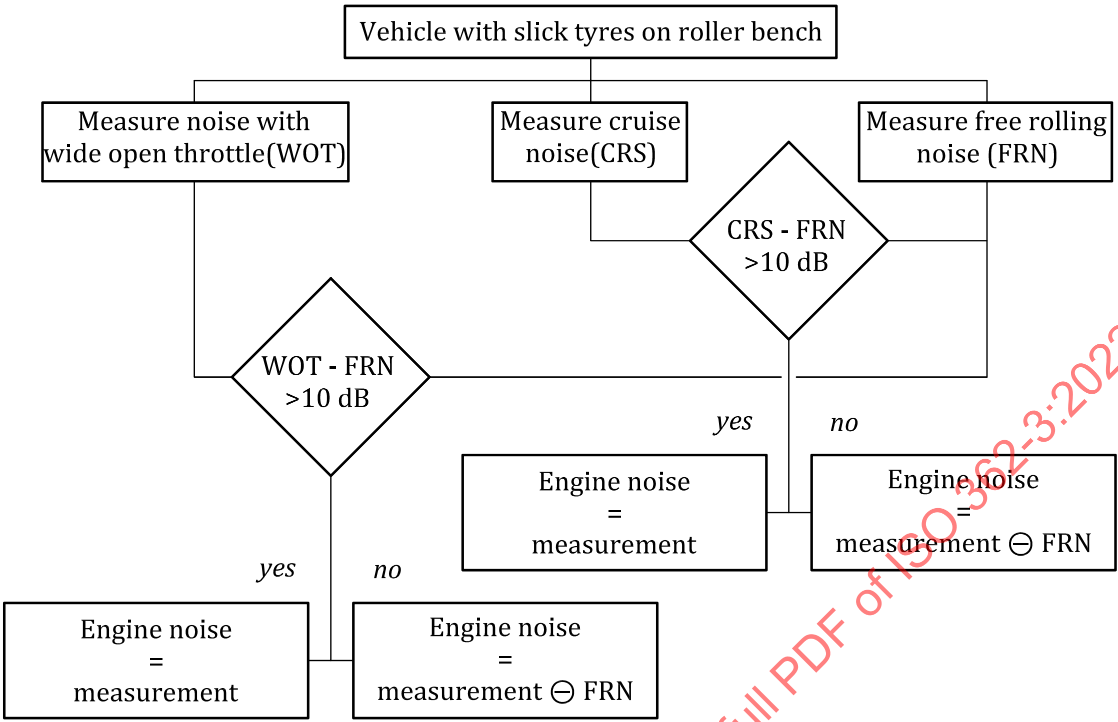
$$L_{PTN} = 10 \cdot \lg\left(10^{\frac{L_{TVNi}}{10}} - 10^{\frac{L_{FRN}}{10}}\right) \quad \text{(B.14)}$$

where

L_{TVNi} is the total vehicle noise sound pressure level indoors;

L_{FRN} is the free rolling noise sound pressure level.

Figure B.11 shows an example for a procedure to check if a disturbance noise correction is necessary.



NOTE ⊖ stands for energetical subtraction.

Figure B.11 — Example for a procedure to check if a disturbance noise correction is necessary

B.8 Data exchange format

An exchange of tire data sets between different software provider requires a defined common file format and a uniform structure.

The tyre data sets shall be converted to an EXCEL® - file and the structure shall be as follows:

— the file shall contain 9 sheets: General, A-FactorRight, A-FactorLeft, B-FactorRight, B-FactorLeft, C-FactorRight, C-FactorLeft, D-FactorRight, D-FactorLeft

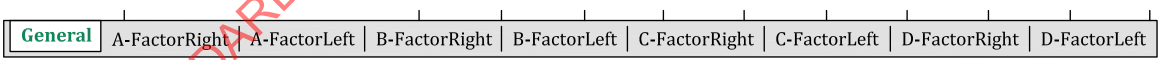


Figure B.12 — Example for the sheets of the EXCEL® - file

— the sheet “General” shall have the structure as described in the Table B.3. All cells in grey are for explanation only and are not part of the exchange format. The sheet contains 3 columns with the following criteria: column A – “Attribute”, column B – “Value” and column C – “Unit”. These 3 columns define 10 attributes (row 1 up to row 10). Table B.3 shows an example of the values for the 10 attributes.

Table B.3 — Structure of the sheet “General” with sample values

	Attribute	Value	Unit	Data type	Possible Values (default in bold)
1	TyreType	225/50R17 (r = 0,319)		String	Name of the tyre noise model
2	TyreNoiseModel	Global		Enumerate	**Global** | Specific per Side

Table B.3 *(continued)*

	Attribute	Value	Unit	Data type	Possible Values (default in bold)
3	TractionNoiseCoefficient	0,15		Number	
4	ReferenceMass	1 645	kg	Number	
5	ReferenceSpeed	50	km/h	Number	
6	DataType	OA-level		Enumerate	**OA-level** | 3rd octave section
7	TemperatureCorrection	No correction		Enumerate	**No correction** Surface Temperature Ambient Temperature
8	Surface Temperature	36	°C	Number	
9	Air Temperature	24	°C	Number	
10	FreeRollingNoise	Global Tyre Noise Model Calculation		Enumerate	**Global Tyre Noise Model Calculation** Free Rolling Noise - Simplified Method

— the sheets "A-FactorRight" up to "D-FactorLeft" shall have the structure as described in the Table B.4. All cells in grey are for explanation only and are not part of the exchange format. The sheets contain 2 columns: column A is for attributes and column B is for the corresponding values. The first row (column A) defines the curve number. For the correct reading of the attributes and their values (from row 3 up to row 10) the row 2 shall be empty. After row 10, custom attributes may be added, followed by a mandatory empty row. After that, the data section starts with first 2 rows of data definition (rows 12 and 13 in case no additional attributes are added) followed directly by the data set (the length depends on the resolution of the data set). The resolution of the x – position shall be not more than 0,2 m (in the example of the Table B.4 the resolution is 0,05 m).

— For engineering purposes other than the application of tyre road noise according to B.6, the data model may be defined in 1/3 octave sections. In such a case, the sheets "A-FactorRight" to "D-FactorLeft" are extended such that each 2 columns define one 1/3 octave section. Table B.5 gives an example for several 1/3 octave sections. The attribute 'Section value' documents the center frequency of the 1/3 octave section. For each additional section the attribute on row 1, 'Curve', shall be incremented by 1.

Table B.4 — Structure of the coefficient sheets (example "A-FactorRight")

	Attribute	Value	Data Type	Possible Values (default in bold)
1	Curve 1			
2	empty row			
3	Function class	OA-level	Enumerate	**OA-level** | 1/3 octave section
4	Section value		Number	***empty*** for OA-level | Number for 1/3 octave section
5	Number of lines	701	Number	
6	Point id	Factor α:Right	String	
7	Value type	Real	Enumerate	Real
8	Weighting	A	Enumerate	**A** | Linear
9	X axis unit	m	String	m
10	Y axis unit	TRN	String	TRN
11	empty row			
12	m	TRN	String	**m | TRN**
13	Linear	Real	String	**Linear | Real**
14	-15,00	55,05	Number	Decimal or scientific notation
15	-14,95	55,09	Number	Decimal or scientific notation
16	-14,90	55,11	Number	Decimal or scientific notation
17	-14,85	55,15	Number	Decimal or scientific notation

Table B.4 *(continued)*

	Attribute	Value	Data Type	Possible Values (default in bold)
18	.	.		
	.	.		

Table B.5 — Structure of the coefficient sheets in 1/3 octave sections (example "A-FactorRight")

	Attribute	Value	Attribute	Value	Attribute	Value
1	Curve 1		Curve 2		Curve 3	
2	empty row		empty row		empty row	
3	Function class	1/3 octave section	Function class	1/3 octave section	Function class	1/3 octave section
4	Section value	200	Section value	250	Section value	315
5	Number of lines	701	Number of lines	701	Number of lines	701
6	Point id	Factor α:Right	Point id	Factor α:Right	Point id	Factor α:Right
7	Value type	Real	Value type	Real	Value type	Real
8	Weighting	A	Weighting	A	Weighting	A
9	X axis unit	m	X axis unit	m	X axis unit	m
10	Y axis unit	TRN	Y axis unit	TRN	Y axis unit	TRN
11	empty row		empty row		empty row	
12	m	TRN	m	TRN	m	TRN
13	Linear	Real	Linear	Real	Linear	Real
14	-15,00	55,05	-15,00	55,05	-15,00	55,05
15	-14,95	55,09	-14,95	55,09	-14,95	55,09
16	-14,90	55,11	-14,90	55,11	-14,90	55,11
17	-14,85	55,15	-14,85	55,15	-14,85	55,15
18	.	.	.	.	.	.
	.	.	.	.	.	.

Annex C
(informative)

Procedure for description of tyre torque influence by an energetic model

C.1 General

The torque influence is mainly caused by the tyre itself and is due to the rubber deformation and the snapping out of the tread blocks of the tyre. The use of an arithmetic model for the description of the tyre torque influence leads to the fact that the analysed coefficients appear to be dependent on the test track. The coefficients vary between louder and quieter test tracks (see B.4.4). This can lead to misinterpretations and makes a comparability between different coefficients impossible.

This document describes the use of an energetical model for the evaluation of the torque influence coefficients and the calculation of the tyre/road noise.

NOTE On working with this annex: C.2 replace B.4.3 and C.3 replace B.6.

C.2 Calculation of torque influence coefficients

The coefficients γ, δ of the exact torque influence cannot be determined directly from the measurement. Before the torque influence sound pressure level, L_{TI}, can be described (using a logarithmic regression model), it has to be determined from the measured tyre/road noise, L_{TRN} (as described in B.3.2), and the corresponding calculated free rolling noise, L_{FRN}, by an energetical subtraction. The associated free rolling noise is determined from the coefficients α, β (see B.4.2), and the vehicle speed profile of the torque influence measurement. To get stable results for the torque influence sound pressure level L_{TI}, only measurements at an acceleration of equal or more than 1m/s^2 shall be used for the calculation as given by Formula (C.1):.

$$L_{TI}(a,x)=10\cdot\lg\left[10^{\frac{L_{TRN}(a,v,x)}{10}}-10^{\frac{\left\{\alpha(x)+\beta(x)\cdot\lg\left(\frac{v_{TRN}(x)}{v_{test}}\right)\right\}}{10}}\right] \quad \text{(C.1)}$$

where

L_{TRN} is the tyre/road noise sound pressure level from B.3.3 in decibels (dB);

α, β are the coefficients of free rolling noise in decibels (dB);

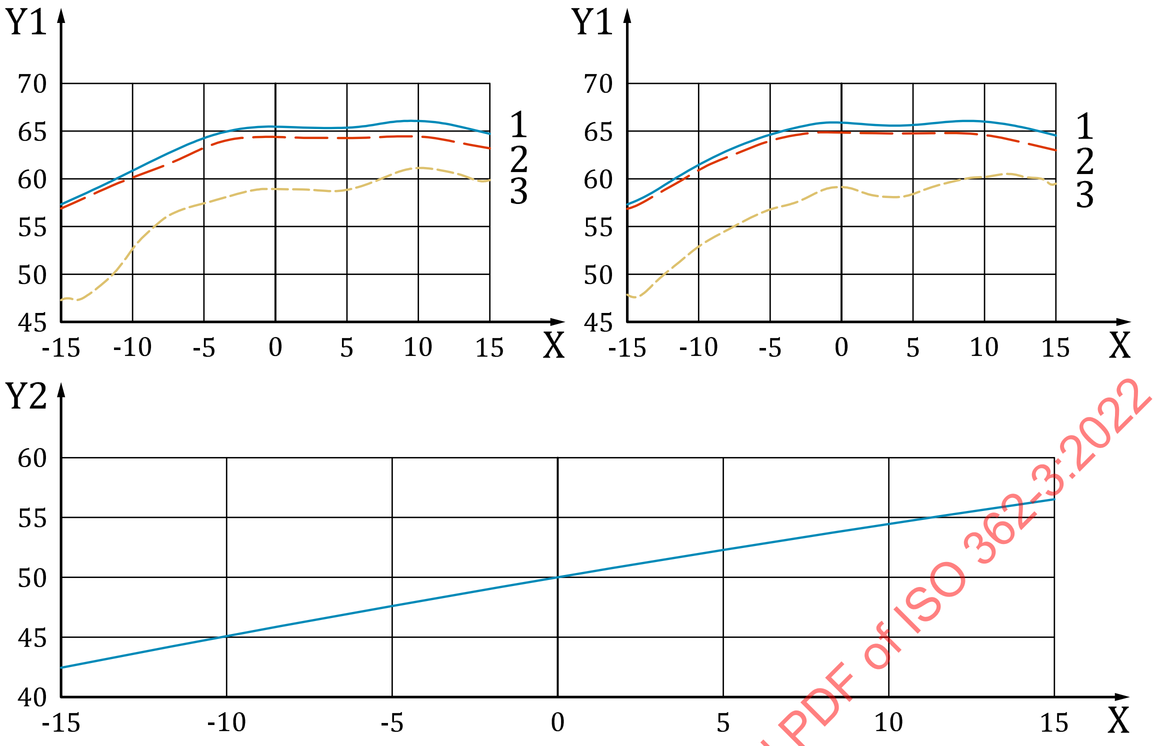
a is the acceleration of the tyre test vehicle in metres per square second (m/s^2);

v_{test} is the vehicle target speed, in kilometres per hour (km/h);

v_{TRN} is the speed of the tyre test vehicle at the tyre/road noise measurement outdoor in kilometres per hour (km/h);

x is the x-position of the vehicle in metres (m).

Figure C.1 shows an example for tyre/road noise and its corresponding free rolling noise and the torque influence.



Key

X	*x*-position, m	1	TRN
Y1	sound pressure level, dB(A)	2	TRN without torque
Y2	vehicle speed, km/h	3	TI

Figure C.1 — Example for tyre/road noise TRN at 2m/s² and its corresponding free rolling noise FRN and the torque influence TI

For the description of the torque influence sound pressure level, L_{TI}, a logarithmic model is used. It can be expressed by the following Formula (C.2):

$$L_{TI}(a,x)=\gamma(x)+\delta(x)\cdot\lg\left(\frac{a_{TRN}(x)}{2}\right) \tag{C.2}$$

where

a_{TRN} is the acceleration of the tyre test vehicle, in metres per square second (m/s²);

x is the *x*-position of the vehicle in metres(m);

γ, δ are the coefficients of the exact torque influence.

The coefficients γ and δ are determined using the following Formulae (C.3), (C.4) and (C.5):

$$\gamma(x)=\overline{L_{TI}(x)}-\delta(x)\cdot\frac{1}{n}\sum_{i=1}^{n}\lg\left[\frac{a_i(x)}{2}\right] \tag{C.3}$$

where δ is the slope of the regression line, in decibels per speed decade, with:

$$\delta(x)=\frac{\sum_{i=1}^{n}\left\{\lg\left[\frac{a_i(x)}{2}\right]-\frac{1}{n}\sum_{i=1}^{n}\lg\left[\frac{a_i(x)}{2}\right]\right\}\cdot\left[L_{\mathrm{TI},i}(x)-\overline{L_{\mathrm{TI}}(x)}\right]}{\sum_{i=1}^{n}\left\{\lg\left[\frac{a_i(x)}{2}\right]-\frac{1}{n}\sum_{i=1}^{n}\lg\left[\frac{a_i(x)}{2}\right]\right\}^{2}} \qquad \text{(C.4)}$$

$\overline{L_{\mathrm{TI}}}$ is the arithmetic mean value of sound pressure levels of the torque influence for all runs and speed steps at the position x, in decibels (dB) with:

$$\overline{L_{\mathrm{TI}}(x)}=\frac{1}{n}\sum_{i=1}^{n}L_{\mathrm{TI},i}(x) \qquad \text{(C.5)}$$

$L_{\mathrm{TI},i}$ is the sound pressure level of the torque influence for the run or speed step *i* at the position x, in decibels (dB);

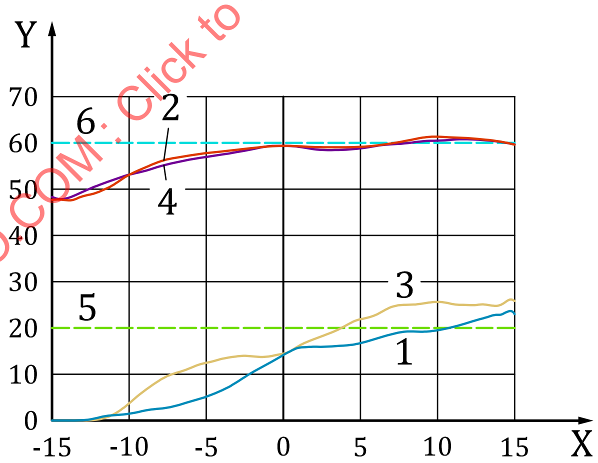
a_i is the acceleration for the run or speed step *i at the position* x, in kilometres per hour (km/h);

x is the *x*-position of the vehicle in metres (m).

It is important to note that the coefficient $\delta(x)$ shall be not less than 0. In case of results for $\delta(x)$ less than 0, the coefficient $\delta(x)$ is set to 0 (most at the beginning of the test track, see Figure C.2). The goodness of fit for this regression shall be not less than 0,7 in the area of the maximum of the tyre torque influence.

NOTE 1 The use of smoothing and weighting functions is recommended to obtain stable results.

NOTE 2 Previous investigations resulted in typical values for the coefficients in the area the maximum of the torque influence: 58 – 62 for γ and 18 – 25 for δ. This can be helpful in defining a simplified method using mean coefficients in future.



Key

- X *x*-position, m
- Y values of the coefficients of the exact torque influence
- 1 coefficient δ left
- 2 coefficient γ left
- 3 coefficient δ right
- 4 coefficient γ right
- 5 Mean at max δ
- 6 Mean at max γ

Figure C.2 — Example for the coefficients of the tyre torque influence TI and the typical values in the area of the maximum level (~at 10 m, dashed lines)

C.3 Calculation of the tyre/road noise related to the power train noise measurement

This calculation requires the following:

— the set of coefficients of the tyre;

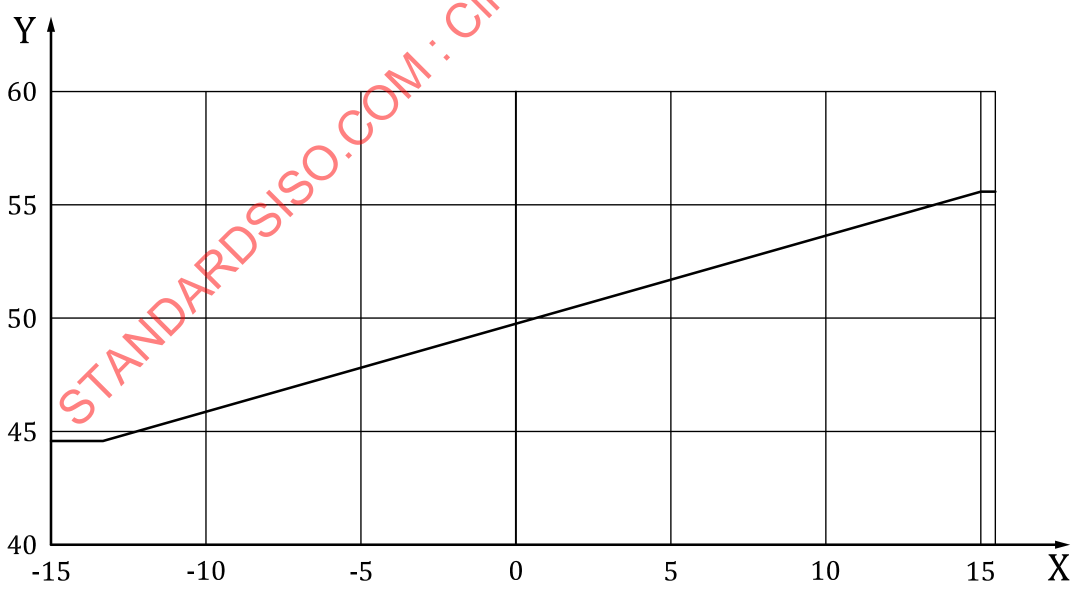
— the vehicle speed profile of the power train noise measurement and the corresponding acceleration;

— the measured air temperatures of the tyre road noise measurements (see B.3.1).

Table C.1 and Figure C.3 show an example for the required input data.

Table C.1 — Set of tyre coefficients

x-position m	α	β	γ	δ
8	63,34	34,50	60,33	19,15
8,2	63,32	34,43	60,45	19,20
8,4	63,31	34,36	60,57	19,21
8,6	63,29	34,29	60,69	19,20
8,8	63,26	34,22	60,81	19,19
9	63,24	34,16	60,91	19,17
9,2	63,21	34,11	60,99	19,18
9,4	63,18	34,06	61,05	19,21
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–



Key

X *x*-position, m

Y vehicle speed, km/h

Figure C.3 — Vehicle speed profile of power train noise measurement indoor

The related tyre/road noise sound pressure level L_{TRN} is calculated from the data set as given by Formula (C.6):

$$L_{TRN}(v,a,x)=10\cdot\lg\left[10^{\frac{\left\{\alpha(x)+\beta(x)\cdot\lg\left(\frac{v_{PTN}(x)}{v_{test}}\right)+3{,}4\cdot\lg\left(\frac{\vartheta_{TRN}+K}{\vartheta_{REF}+K}\right)\right\}}{10}}+10^{\frac{\left\{\gamma(x)+\delta(x)\cdot\lg\left(\frac{a_{PTN}(x)}{2\,\mathrm{m/s^2}}\cdot\frac{m_{ro\ indoor\ test}}{m_{tyre\ test}}\right)\right\}}{10}}\right] \quad \text{(C.6)}$$

where

a_{PTN}	is the vehicle acceleration at the power train noise measurement;
K	is the temperature correction coefficient (see B.5);
$m_{ro\ indoor\ test}$	mass in running order of the vehicle to be tested indoors;
$m_{tyre\ test}$	mass in running order of the tyre test vehicle;
v_{PTN}	is the vehicle speed at the power train noise measurement;
v_{test}	is the vehicle target speed, in kilometres per hour (km/h);
x	is the *x*-position of the vehicle;
α, β	are the coefficients of free rolling noise;
γ, δ	are the coefficients of the exact torque influence;
ϑ_{FRN}	is the averaged air temperature from all runs of the free rolling noise measurement (see B.3.1), in degrees Celsius (°C));
ϑ_{REF}	is the reference air temperature at the power train noise measurements indoors and can be used to normalize to different air temperatures, e.g. 20 °C, in degrees Celsius (°C).