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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

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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/s²	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 micro-phones
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'):

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

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.

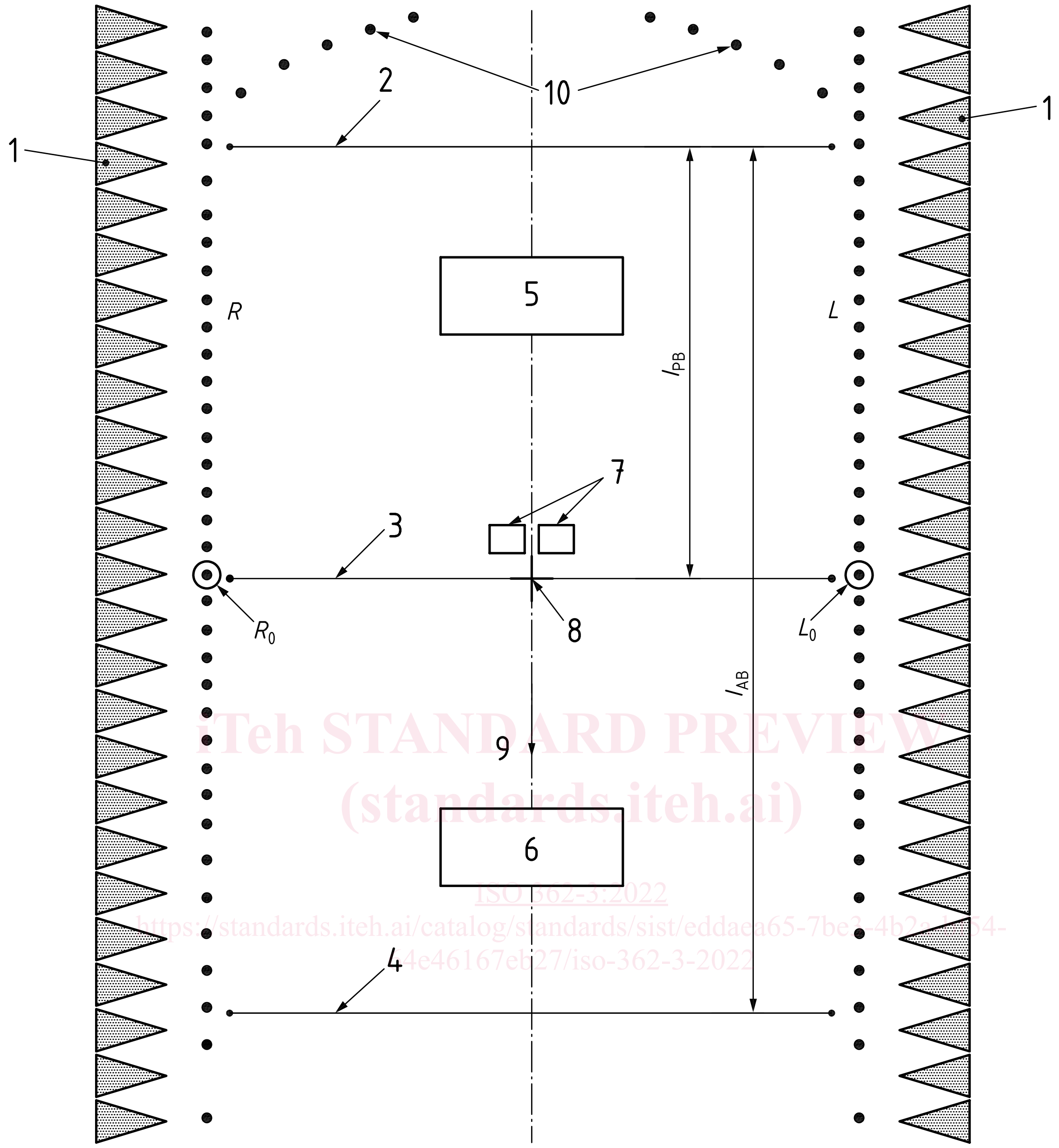
7 Test room requirements

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, $l_{\text{min, room}}$ (base size), is recommended as given in Formula (2):

$$l_{\text{min,room}} = 20\,\text{m} + l_{\text{veh}} + 2 \cdot d_{\text{absorb}} + 2 \cdot \frac{1}{4} \cdot \lambda_{\text{cut off}} \tag{2}$$

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;
$1/4\ \lambda_{\text{cut off}}$	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, $w_{\text{single,room}}$, of single-sided facilities is as given in Formula (3):

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

where

7,5 m	is the original distance from the centreline to the microphone line;
d_{absorb}	is the thickness of absorbing elements;
$1/4\ \lambda_{\text{cut off}}$	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, $w_{\text{dual,room}}$, of dual-sided facilities is as given in Formula (4):

$$w_{\text{dual,room}} = 2 \cdot 7{,}5\,\text{m} + 2 \cdot d_{\text{absorb}} + 2 \cdot \frac{1}{4} \cdot \lambda_{\text{cut off}} \tag{4}$$