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Title: Draft BS EN 1793-5 Road traffic noise reducing devices - Test method for determining the acoustic performance. Part 5: Intrinsic characteristics. In situ values of sound reflection under direct sound field conditions.

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

English Version

Road traffic noise reducing devices - Test method for
determining the acoustic performance - Part 5: Intrinsic
characteristics - In situ values of sound reflection under
direct sound field conditions

Dispositifs de réduction du bruit du trafic routier -
Méthode d'essai pour la détermination de la
performance acoustique - Partie 5: Caractéristiques
intrinsèques - Valeurs in situ de réflexion acoustique
dans des conditions de champ acoustique direct

Lärmschutzeinrichtungen an Straßen - Prüfverfahren
zur Bestimmung der akustischen Eigenschaften - Teil
5: Produktspezifische Merkmale - In-situ-Werte der
Schallreflexion in gerichteten Schallfeldern

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 226.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (prEN 1793-5:2023) has been prepared under the direction of Technical Committee CEN/TC 226 “Road equipment”, by Working Group 6 “Noise reducing devices”, the secretariat of which is held by AFNOR.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 1793-5:2016.

EN 1793-5:2023 includes the following significant technical changes with respect to EN 1793-5:2016:

- The definitions from 3.1 to 3.7 have been updated to be in accordance to the last version of EN 14388.
- The single number rating DL_{RI} is now reported with one decimal digit.
- Annex A on the low-frequency limit and the window width has been added.
- One value for the standard deviation of reproducibility and repeatability in each one-third octave frequency band has been retained, in place of three values (min, max and median) as before (see Table B.1).
- Annex C (template of the test report) is now normative.
- The example in C.5 on the declaration of the measurement uncertainty has been updated accordingly.
- Annex C of EN 1793-5:2016 has been deleted.

EN 1793-5:2023 is part of a series and should be read in conjunction with the the following:

EN 1793-1:2023, *Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 1: Sound absorption under diffuse sound field conditions*

EN 1793-2:2023, *Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 2: Intrinsic characteristics - Airborne sound insulation under diffuse sound field conditions*

EN 1793-3:2023, *Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 3: Normalized noise spectrum*

EN 1793-4:2023, *Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 4: Intrinsic characteristics – Intrinsic sound diffraction*

EN 1793-5:2023, *Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 5: Intrinsic characteristics – Sound absorption under direct sound field conditions*

EN 1793-6:2023, *Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 6: Intrinsic characteristics – Airborne sound insulation under direct sound field conditions*

Introduction

This document describes a test method for determining the intrinsic characteristics of sound absorption of road traffic noise reducing devices designed for roads in non-reverberant conditions (a measure of intrinsic performance). The methodology assesses indirectly sound absorption by measuring sound reflection (the complementary characteristics). It can be applied indoors or outdoors. Indoors, it can be applied in a purposely built test facility (under direct sound field conditions). Outdoors, it can be applied in a purposely built test facilities, e.g. near a laboratory or a factory, as well as *in situ*, i.e. where the road traffic noise reducing devices are installed. The method can be applied without damaging the surface.

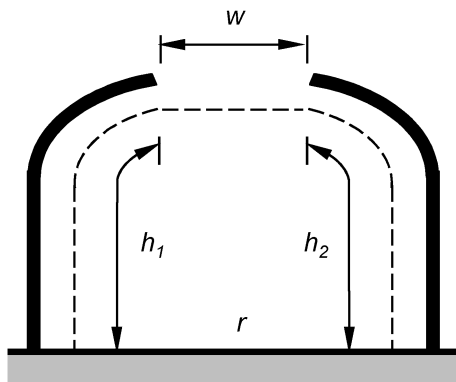
The method can be used to qualify products to be installed along roads as well as to verify the compliance of installed noise reducing devices to design specifications. Regular application of the method can be used to verify the long-term performance of noise reducing devices. The method requires the average of results of measurements taken in different points in front of the device under test and/or for specific angles of incidences. The method is able to investigate flat and non-flat products.

The measurement results of this method for sound absorption are not comparable with the results obtained under diffuse sound field conditions (EN 1793-1:2023), mainly because the present method uses a directional sound field, not a diffuse sound field. The test method described in the present document should not be used to determine the intrinsic characteristics of sound absorption of road traffic noise reducing devices to be installed in reverberant conditions, e.g. claddings inside tunnels or deep trenches.

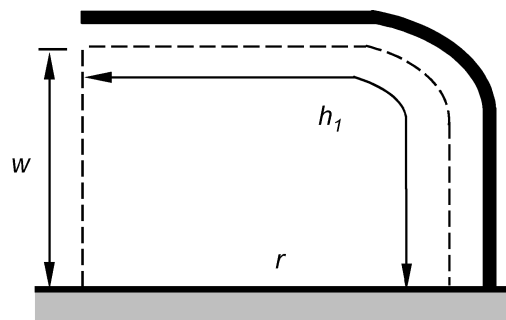
For the purpose of this document reverberant conditions are defined based on the envelope, e , across the road formed by the device under test, trench sides or buildings (the envelope does not include the road surface) as shown by the dashed lines in Figure 1. Conditions are defined as being reverberant when the percentage of open space in the envelope is less than or equal to 25 %, i.e. reverberant conditions occur when $w/e \leq 0,25$, where $e = (w+h_1+h_2)$.

This method introduces a specific quantity as a function of frequency, called reflection index, to define the sound reflection in front of a road traffic noise reducing device and then calculate a single-number rating for sound absorption from it, while the measurements under diffuse sound field conditions (according to EN 1793-1:2023) gives a sound absorption coefficient as a function of frequency and then calculate a single-number rating for sound absorption from it. Values of the sound absorption coefficient measured under diffuse sound field conditions can be converted to conventional values of a reflection coefficient taking the complement to one. In this case, research studies suggest that some correlation exists between diffuse sound field data, measured according to EN 1793-1:2023 and direct sound field data, measured according to the method described in this document [6] [9] [17] [18] [19].

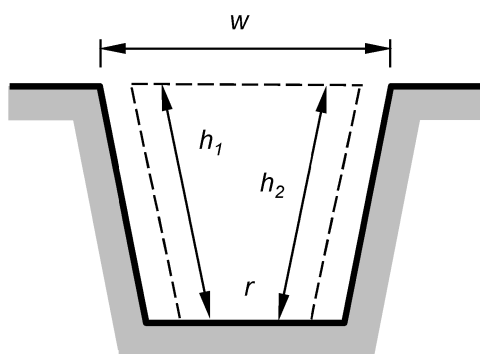
NOTE This method can be used to qualify noise reducing devices for other applications, e.g. to be installed nearby industrial sites. In this case, the single-number ratings can preferably be calculated using an appropriate spectrum.



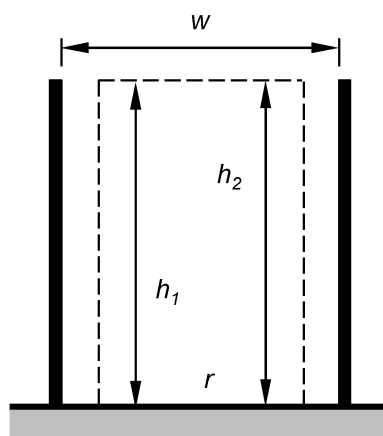
(a) Partial cover on both sides of the road; envelope, $e = w + h_1 + h_2$.



(b) Partial cover on one side of the road; $e = w + h_1$, $h_2 = 0$.



(c) Deep trench envelope, $e = w + h_1 + h_2$.



(d) Tall barriers or buildings; envelope, $e = w + h_1 + h_2$. In all cases r : road surface; w : width of open space

Figure 1 — (not to scale) Sketch of the reverberant condition check in four cases

1 Scope

This document describes a test method for measuring a quantity representative of the intrinsic characteristics of sound reflection from road noise reducing devices, the sound reflection index, and then calculate a single-number rating for sound absorption from it.

The test method is intended for the following applications:

- determination of the intrinsic characteristics of sound absorption of noise reducing devices to be installed along roads, to be measured either on typical installations alongside roads or on a relevant sample section;
- determination of the intrinsic characteristics of sound absorption of road traffic noise reducing devices in actual use under direct sound field conditions;
- comparison of design specifications with actual performance data after the completion of the construction work;
- verification of the long-term performance of road traffic noise reducing devices (with a repeated application of the method).

The test method is not intended for the following applications:

- determination of the intrinsic characteristics of sound absorption of road traffic noise reducing devices to be installed in reverberant conditions, e.g. inside tunnels or deep trenches.

Results for the sound reflection index are expressed as a function of frequency, in one-third octave bands, where possible, between 100 Hz and 5 kHz. If it is not possible to get valid measurements results over the whole frequency range indicated, the results should be given in a restricted frequency range and the reasons of the restriction(s) should be clearly reported.

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.

EN 1793-3:2023, *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 3: Normalized traffic noise spectrum*

EN 14389:2022, *Road traffic noise reducing devices - Procedures for assessing long-term performance*

EN 61672-1:2013, *Electroacoustics - Sound level meters - Part 1: Specifications*

ISO/IEC Guide 98-3:2008, *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 following terms and definitions apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp/>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 road traffic noise reducing device RTNRD

device designed to reduce the propagation of traffic noise away from the road environment

Note 1 to entry: An RTNRD can comprise acoustic elements (3.2) only or both structural (3.3) and acoustic elements.

Note 2 to entry: Applications of RTNRDs include noise barriers (3.5), claddings (3.6), covers (3.7) and added devices (3.8).

3.2 acoustic element

element whose primary function is to provide the acoustic performance of the device

3.3 structural element

element whose primary function is to support or hold in place the parts of the RTNRD.

3.4 self-supporting acoustic element

acoustic element including its own structural element to support itself

3.5 noise barrier

road traffic noise reducing device which obstructs the direct transmission of airborne sound emanating from road traffic

3.6 cladding

road traffic noise reducing device which is attached to a wall or other structure and reduces the amount of sound reflected

3.7 cover

road traffic noise reducing device which either spans or overhangs the road

3.8 added device

additional component that influences the acoustic performance of the original road traffic noise reducing device

Note 1 to entry: The added device is acting primarily on the diffracted energy.

3.9

roadside exposure

use of the product as a noise reducing device installed alongside roads

3.10

sound reflection index

quantity representing the amount of sound not absorbed by the device under test

Note 1 to entry: Formula (1) specifies how to calculate the sound reflection index.

Note 2 to entry: The sound reflection index values in one-third octave bands are the result of a test according to the present document.

3.11

measurement grid for sound reflection index measurements

measurement grid constituted of nine equally spaced microphones in a 3x3 squared configuration

Note 1 to entry: The orthogonal spacing between two subsequent microphones, either vertically or horizontally, is $s = 0,40$ m.

Note 1 to entry: See Figure 3, 5 and 6.

Note 2 to entry: Microphones are numbered like in Figure 3.

3.12

reference height

height h_S equal to half the height, h_B , of the road traffic noise reducing device under test: $h_S = h_B/2$

Note 1 to entry: When the height of the device under test is greater than 4 m and, for practical reasons, it is not advisable to have a height of the source $h_S = h_B/2$, it is possible to have $h_S = 2$ m, accepting the corresponding low frequency limitation (see 5.6.2 and 5.6.4).

Note 2 to entry: See Figures 2 and 3.

3.13

source and microphone reference surface for sound reflection index measurements

ideal, smooth surface facing the sound source side of the road traffic noise reducing device under test and just touching the most protruding and significant parts of it within the tested area

Note 1 to entry: The reference surface is as smooth as possible, and follows the inclination or curve of the device under test within the tested area. For vertical and flat road traffic noise reducing devices, the reference surface is a vertical plane. For inclined and flat road traffic noise reducing devices, the reference surface is a plane with the same inclination. For curve and flat noise reducing devices, the reference surface is a curve surface with the same curvature.

Note 2 to entry: See Figures 2, 4, 7, 8, and 9.

3.14

source reference position

position facing the side to be exposed to noise when the road traffic noise reducing device is in place, located at the reference height h_S and placed so that the horizontal distance of the source front panel to the reference surface is $d_S = 1,50$ m

Note 1 to entry: See Figures 2 and 3.

3.15

measurement grid reference position

position of the measurement grid during the test

Note 1 to entry: the conditions and distances for a correct measurement reference position are specified in 5.6.2.1.

Note 2 to entry: for flat noise reducing devices, see Figures 2, and 3. For non-flat noise reducing devices, see Figure 7. For inclined or curved noise reducing devices, see Figures 8 and 9.

3.16

reference loudspeaker-measurement grid distance

distance between the front panel of the loudspeaker and the central microphone (microphone n. 5) of the measurement grid

Note 1 to entry: The reference loudspeaker-measurement grid distance is equal to $d_{SM} = 1,25$ m (see Figures 2 and 4).

3.17

free-field measurement for sound reflection index measurements

measurement taken with the loudspeaker and the measurement grid in an acoustic free field in order to avoid reflections from any nearby object, including the ground, keeping the same geometry as when measuring in front of the noise reducing device under test

Note 1 to entry: See Figure 4.

3.18

maximum sampled area

surface area, projected on a front view of the road traffic noise reducing device under test for reflection index measurements, which must remain free of reflecting objects causing parasitic reflections

3.19

Adrienne temporal window

analysis window in the time domain to be used for the data processing

Note 1 to entry: Data processing according to the present document.

Note 1 to entry: The Adrienne temporal window is described in 5.5.6.

3.20

background noise

noise coming from sources other than the sound source emitting the test signal

3.21

signal-to-noise ratio

difference in decibels between the level of the test signal and the level of the background noise at the moment of detection of the useful event (within the Adrienne temporal window)

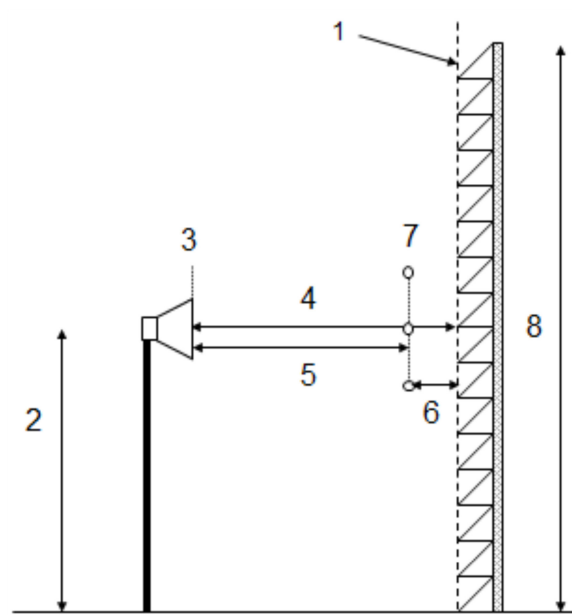
3.22

impulse response

time signal at the output of a system when a Dirac function is applied to the input

Note 1 to entry: The Dirac function, also called δ function, is the mathematical idealisation of a signal infinitely short in time that carries a unit amount of energy.

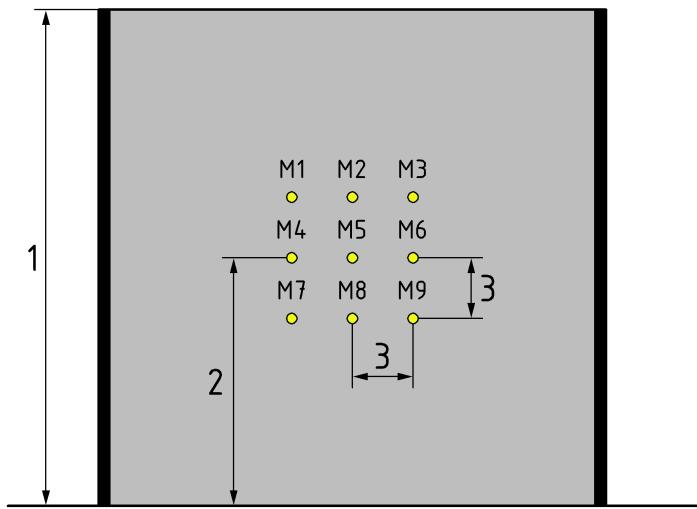
Note 2 to entry: It is impossible in practice to create and radiate true Dirac delta functions. Short transient sounds can offer close enough approximations but are not very repeatable. An alternative measurement technique, generally more accurate, is to use a period of deterministic, flat-spectrum signal, like maximum-length sequence (MLS) or exponential sine sweep (ESS), and transform the measured response back to an impulse response.



Key

- | | |
|---|---|
| 1 Source and microphone reference surface | 2 Reference height h_s [m] |
| 3 Loudspeaker front panel | 4 Distance between the loudspeaker front panel and the reference surface, d_s [m] |
| 5 Distance between the loudspeaker front panel and the measurement grid, d_{SM} [m] | 6 Distance between the measurement grid and the reference surface, d_M [m] |
| 7 Measurement grid | 8 Road traffic noise reducing device height, h_B [m] |

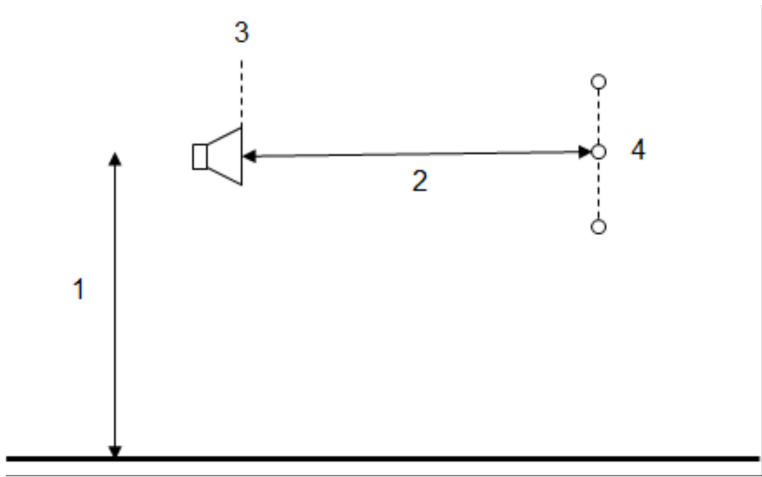
Figure 2 — (not to scale) Sketch of the sound source and the measurement grid in front of the road traffic noise reducing device



Key

- 1 road traffic noise reducing device height h_B [m]
- 2 Reference height h_S [m]
- 3 Orthogonal spacing between two subsequent microphones s [m]

Figure 3 — (not to scale) Measurement grid for sound reflection index measurements in front of the device under test (sound source side); the yellow circles indicate the microphone positions, labelled from M1 to M9



Key

- 1 Reference height h_S [m]
- 2 Distance between the loudspeaker front panel and the measurement grid d_{SM} [m]
- 3 Loudspeaker front panel
- 4 Measurement grid

Figure 4 — (not to scale) Sketch of the set-up for the reference “free-field” sound measurement for the determination of the sound reflection index

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

Table 1 – Symbols and abbreviations

Symbol or abbreviation	Designation	Unit
a	major axis of the ellipsoid of revolution used to define the maximum sampled area at oblique incidence	m
a_0, a_1, a_2, a_3	Coefficient for the expression of the four-term full Blackman-Harris window	-
b_s	Depth of the surface structure of the sample under test	m
α_k	Angle between the line connecting the centre of the front panel of the loudspeaker to microphone 5 and the line connecting the centre of the front panel of the loudspeaker to microphone k	-
β_k	Angle between the line connecting the centre of the front panel of the loudspeaker to microphone 5 and the line connecting the centre of the front panel of the loudspeaker to the specular reflection path to microphone k	-
b_m	Width of a portion of material of the sample under test	m
c	Speed of sound in air	m/s
$C_{geo,k}$	Correction factor for the geometrical divergence	-
$C_{dir,k}$	Correction factor for the sound source directivity	-
$C_{gain,k}$	Correction factor for changes in the sound source gain	-
d_M	Horizontal distance from the source and microphone reference surface to the measurement grid; it is equal to $d_M = 0,25$ m	m
d_S	Horizontal distance from the front panel of the loudspeaker to the source and microphone reference surface; it is equal to: $d_S = 1,50$ m	m
d_{SM}	Horizontal distance from the front panel of the loudspeaker to the measurement grid; it is equal to: $d_{SM} = 1,25$ m	m
DL_{RI}	Single number rating of sound reflection	dB
δ_i	Any input quantity to allow for uncertainty estimates	-
Δf_g	Frequency range encompassing the one-third octave frequency bands between 500 Hz and 2 kHz	Hz
Δf_j	Width of the j -the one-third octave frequency band	Hz
Δt	temporal step between the discrete points of the acquired data (linked to the given sample rate by $\Delta t = 1/f_s$)	ms
$\Delta \tau$	moving step of the free field impulse response in the adjustment procedure included in the generalized signal subtraction technique (see 5.5.4)	ms
Δt_{k5}	Time delay gap between the arrival of direct sound at microphone k ($k \neq 5$) and microphone 5	s
Δt_k	Time delay gap between the arrival of direct and reflected sound at microphone k	s

Symbol or abbreviation	Designation	Unit
Δd_{k5}	Path length difference between the arrival of direct sound at microphone k ($k \neq 5$) and microphone 5	m
Δd_k	Path length difference between the arrival of direct and reflected sound at microphone k	m
ε_k	Tolerance on the path length difference at microphone k	m
F	Symbol of the Fourier transform	-
f	Frequency	Hz
f_{min}	Low frequency limit of sound reflection index measurements	Hz
f_s	Sample rate	Hz
f_{co}	cut-off frequency of the anti-aliasing filter	Hz
h_B	Noise reducing device height	m
h_s	Reference height	m
$h_{i,k}(t)$	Incident reference component of the free-field impulse response at the k -th measurement point	-
$h_{r,k}(t)$	Reflected component of the impulse response at the k -th measurement point	-
j	Index of the j -th one-third octave frequency band (between 100 Hz and 5 kHz)	-
$h_{i,k,FF}(t)$	Incident reference component of the impulse response taken in front of the sample under test at the k -th measurement point (before the signal subtraction)	-
$h_{i,k,RES}(t)$	Residual incident reference component of the impulse response taken in front of the sample under test at the k -th measurement point (after the signal subtraction)	-
k	Index of the k -th measurement point ($k = 1 \dots n_j$)	-
k_p	Coverage factor	-
k_f	Constant used for the anti-aliasing filter	-
L_p	Sample period length of a non-homogeneous noise reducing device	m
n_j	Number of measurement points on which to average	-
n_R	Number of reference positions of the measurement grid	-
q	Number of discrete data points of the acquired data used in the accurate alignment procedure to define the range where to apply the least square procedure (see 5.5.5)	-
r	Radius of the maximum sampled area at normal incidence	m
R_{sub}	Reduction factor	dB
RI_j	Sound reflection index in the j -th one-third octave frequency band	-
RI_{ij}	Sound reflection index in the j -th one-third octave frequency band when the measurement grid is in the i -th reference position	-
s	Orthogonal spacing between two subsequent microphones	m
s_r	Standard deviation of repeatability	-

Symbol or abbreviation	Designation	Unit
s_R	Standard deviation of reproducibility	-
S/N	Signal to noise ratio	dB
t	Time	s
t_c	Air temperature	°C
$T_{W,BH}$	Length of the Blackman-Harris trailing edge of the Adrienne temporal window	s
$T_{W,ADR}$	Total length of the Adrienne temporal window	s
u	Standard uncertainty	-
U	Expanded uncertainty	-
$w_{i,k}(t)$	Reference free-field component time window (Adrienne temporal window) at the k -th measurement point	-
$w_{r,k}(t)$	Time window (Adrienne temporal window) for the reflected component at the k -th measurement point	-

5 Sound reflection index measurements

5.1 General principle

The sound source emits a transient sound wave that travels past the measurement grid (microphone) position to the device under test and is then reflected on it (Figures 2 and 3). Each microphone, being placed between the sound source and the device under test, receives both the direct sound pressure wave travelling from the sound source to the device under test and the sound pressure wave reflected (including scattering) by the device under test. The direct sound pressure wave can be better acquired with a separate free field measurement (see Figure 4). The ratio of the power spectra of the direct and the reflected components gives the basis for calculating the sound reflection index.

The measurement shall take place in an essentially free field in the direct surroundings of the device, i.e. a field free from reflections coming from surfaces other than the surface of the device under test. For this reason, the acquisition of an impulse response having peaks as sharp as possible is recommended: in this way, the reflections coming from other surfaces than the tested device can be identified from their delay time and rejected.

5.2 Measured quantity

The expression used to compute the reflection index RI as a function of frequency, in one-third octave bands, is:

$$RI_j = \frac{1}{n_j} \sum_{k=1}^{n_j} \left\{ \frac{\int_{\Delta f_j} |F[h_{r,k}(t) \cdot w_{r,k}(t)]|^2 df}{\int_{\Delta f_j} |F[h_{i,k}(t) \cdot w_{i,k}(t)]|^2 df} \cdot C_{geo,k} \cdot C_{dir,k}(\Delta f_j) \cdot C_{gain,k}(\Delta f_g) \right\} \quad (1)$$

where

$h_{i,k}(t)$	is the incident reference component of the free-field impulse response at the k -th measurement point;
$h_{r,k}(t)$	is the reflected component of the impulse response taken in front of the sample under test at the k -th measurement point;
$w_{i,k}(t)$	is the time window (Adrienne temporal window) for the incident reference component of the free-field impulse response at the k -th measurement point;
$w_{r,k}(t)$	is the time window (Adrienne temporal window) for the reflected component at the k -th measurement point;
F	is the symbol of the Fourier transform;
j	is the index of the one-third octave frequency bands (between 100 Hz and 5 kHz, where possible);
Δf_j	is the width of the j -th one-third octave frequency band;
k	is the microphone number according to Figure 3.b ($k = 1, \dots, 9$);
n_j	is the number of microphone positions on which to average ($n_j \geq 6$; see 5.6);
$C_{geo,k}$	is the correction factor for geometrical divergence at the k -th measurement point;
$C_{dir,k}(\Delta f_j)$	is the correction factor for sound source directivity at the k -th measurement point.
$C_{gain,k}(\Delta f_g)$	is the correction factor to account for a change in the amplification settings of the loudspeaker and in the sensitivity settings of the individual microphones when changing the measurement configuration from free field to in front of the sample under test or vice versa, if any (see 5.5.1 and Formula (4));
Δf_g	is the frequency range encompassing the one-third octave frequency bands between 500 Hz and 2 kHz.

The correction factors for geometrical divergence, $C_{geo,k}$, are given by:

$$C_{geo,k} = \left(\frac{d_{r,k}}{d_{i,k}} \right)^2 \quad (2)$$

where

$d_{i,k}$	is the distance from the front panel of the loudspeaker to the k -th measurement point;
$d_{r,k}$	is the distance from the front panel of the loudspeaker to the source and microphone reference plane and back to the k -th measurement point following specular reflection;
k	is the microphone number according to Figure 3 ($k = 1, \dots, 9$).

NOTE 1 For the microphone n. 5, $d_{i,5} = d_{SM} = 1,25$ m

The distances $d_{i,k}$, $d_{r,k}$ and the correction factors $C_{geo,k}$ are given in Table 2 for a plane reference surface.

Table 2 – Distances $d_{i,k}$, $d_{r,k}$ and correction factors $C_{geo,k}$ for a plane reference surface

k	$d_{i,k}$, m	$d_{r,k}$, m	$C_{geo,k}$
1	1,37	1,84	1,80
2	1,31	1,80	1,87
3	1,37	1,84	1,80
4	1,31	1,80	1,87
5	1,25	1,75	1,96
6	1,31	1,80	1,87
7	1,37	1,84	1,80
8	1,31	1,80	1,87
9	1,37	1,84	1,80

NOTE 2 The reflections from different portions of the surface of the device under test arrive at the microphone position at different times, depending on the travel path from the loudspeaker to the position of each test surface portion and back. The longer the travel path from the loudspeaker to a specific test surface portion and back, the greater the time delay. Thus, the amplitude of the reflected sound waves from different test surface portions, as detected at the microphone positions, is attenuated in a manner inversely proportional to the travel time. For non-flat, complex devices it is difficult to predict the exact travel path of each wave, considering also non specular scattering; therefore, the geometrical divergence correction factors are calculated on the basis of specular reflection on an ideal flat reflecting surface.

The correction factors for sound source directivity are given by:

$$C_{dir,k}(\Delta f_j) = \frac{\int_{\Delta f_j} \left| F[h_{i,k}(t, \alpha_k) \cdot w_{i,k}(t)] \right|^2 df}{\int_{\Delta f_j} \left| F[h_{i,k}(t, \beta_k) \cdot w_{i,k}(t)] \right|^2 df} \quad (3)$$

where

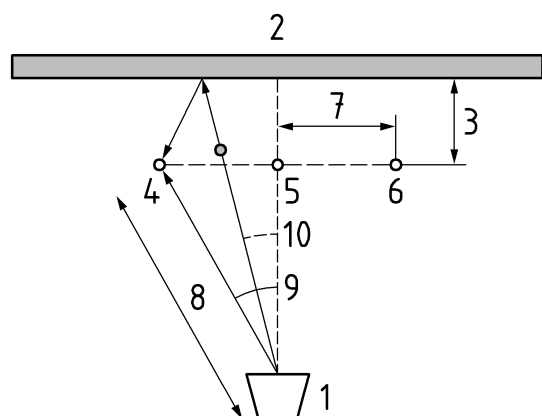
- α_k is the angle between the line connecting the centre of the front panel of the loudspeaker to microphone 5 and the line connecting the centre of the front panel of the loudspeaker to microphone k (see Figure 6.a);
- β_k is the angle between the line connecting the centre of the front panel of the loudspeaker to microphone 5 and the line connecting the centre of the front panel of the loudspeaker to the specular reflection path to microphone k (see Figure 6.a);
- $h_{i,k}(t, \alpha_k)$ is the incident reference component of the free-field impulse response at the k -th measurement point;
- $h_{i,k}(t, \beta_k)$ is the incident reference component of the free-field impulse response at a point on the specular reflection path for microphone k and at distance $d_{i,k}$ from the centre of the front panel of the loudspeaker;
- $w_{i,k}(t)$ is the time window (Adrienne temporal window) for the incident reference component of the free-field impulse response at the k -th measurement point;

F	is the symbol of the Fourier transform;
j	is the index of the one-third octave frequency bands (between 100 Hz and 5 kHz, where possible);
Δf_j	is the width of the j -th one-third octave frequency band;
k	is the microphone number according to Figure 3 ($k = 1, \dots, 9$).

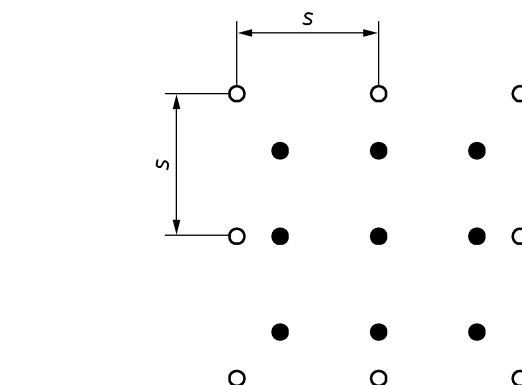
When measuring the sound source directivity correction factors, the numerator and denominator of the ratio in Formula (3) shall be measured in two different points at the constant distance $d_{i,k}$ (see Table 2) from the centre of the front panel of the loudspeaker. The first point is placed at the microphone position and the second point is placed on the specular reflection travel path of the sound emitted by the loudspeaker (see Figure 5).

NOTE 3 For non-flat complex devices it is difficult to predict the exact travel path of each wave, considering also non specular scattering; therefore, the correction factors for sound source directivity are calculated on the basis of specular reflection on an ideal flat reflecting surface.

The sound source directivity correction factors shall be measured in the free field. The sound source directivity correction factors shall be measured only once for each sound source, assuming that the source directivity patterns don't change. For the sake of accuracy, they may be measured again from time to time (e.g. once a year).



(a) microphone positions 4, 5, and 6 (white circles), angles α_4 and β_4 for microphone 4 and the point, at a distance $d_{i,4}$ from the loudspeaker centre plate, where measurements to get the correction factor $C_{dir,4}$ shall be done (grey circle)



(b) front view of the nine microphone positions (white circles) and the nine positions where the specular reflection travel path of the sound emitted by the loudspeaker intersect the plane of the measurement grid (black circles)

Key

1	Loudspeaker	2	Sample under test
3	Horizontal distance from the source and microphone reference surface to the measurement grid, d_M [m]	4	Microphone 4
5	Microphone 5	6	Microphone 6
7	Orthogonal spacing between two subsequent microphones, s [m]	8	Distance $d_{i,4}$ from the loudspeaker centre plate to mic. n. 4, where measurements to get the correction factor $C_{dir,4}$ shall be done [m]
9	Angle α_4 between the line connecting the centre of the front panel of the loudspeaker to microphone n. 5 and the line connecting the centre of the front panel of the loudspeaker to microphone n. 4	10	Angle β_4 between the line connecting the centre of the front panel of the loudspeaker to microphone n. 5 and the line connecting the centre of the front panel of the loudspeaker to the specular reflection path to microphone n. 4

Figure 5 (not to scale) — Sketch showing microphone positions and angles for the calculation of the correction factor $C_{dir,k}$

5.3 Test arrangement

The test method can be applied either on noise reducing devices installed alongside roads or on full-size samples purposely assembled to be tested (indoors or outdoors) using the method described here.

5.3.1 Tests on purposely built full -size samples

For applications on full-size samples purposely built to be tested using the method described here, e.g. in an outdoor test facility, the specimen shall be built as follows (see Figure 6):

- a part, composed of acoustic elements, that extends at least 4 m and is at least 4 m high.

The test specimen shall be mounted and assembled in the same manner as the manufactured device is used in practice with the same connections and seals between components parts.

For the results to be valid on the frequency range 200 Hz – 5 kHz, in one-third octave bands, the minimum dimensions of the sample shall be as follows (see Figure 6):

- a part, composed of acoustic elements, 4 m wide and 4 m high;

- one post 4 m high at both sides (if applicable for the specific noise reducing device under test).

In all cases, if the sample under test is non-flat with a periodic spatial corrugation in the vertical direction, then whenever possible the sample shall be extended in the vertical direction with one full period of the corrugation (see Figure 7). In the same way, if the sample under test is non-flat with a periodic spatial corrugation in the horizontal direction, then whenever possible the sample shall be extended in the horizontal direction with one full period of the corrugation.

5.3.2 Installed road traffic noise reducing devices

For applications on noise reducing devices that are already installed along roads, the test specimen shall be constructed as follows:

- *for installed road traffic noise reducing devices using single acoustic elements to achieve full height:*
 - the test specimen shall be constructed as a single element which is representative of the specific application;
 - where the test specimen cannot be constructed as a single element or where the installed noise reducing device is lower than 4 m, the test specimen shall be centred on the loudspeaker axis (at reference height $h_s = 2$ m above the ground) and built up to 4 m high using smaller height acoustic elements at the base and top as appropriate;
- *for installed road traffic noise reducing devices using stacked elements to achieve full height:*
 - the test specimen shall be constructed as used in the specific application.

For applications on road traffic noise reducing devices that are already installed along roads, if there is a plinth under the road traffic noise reducing device, it shall not be considered part of the “sample under test” unless it is a part of the road traffic noise reducing device product.

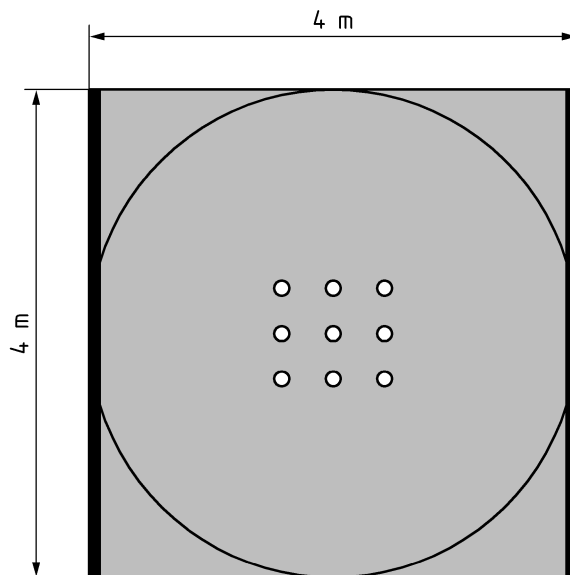
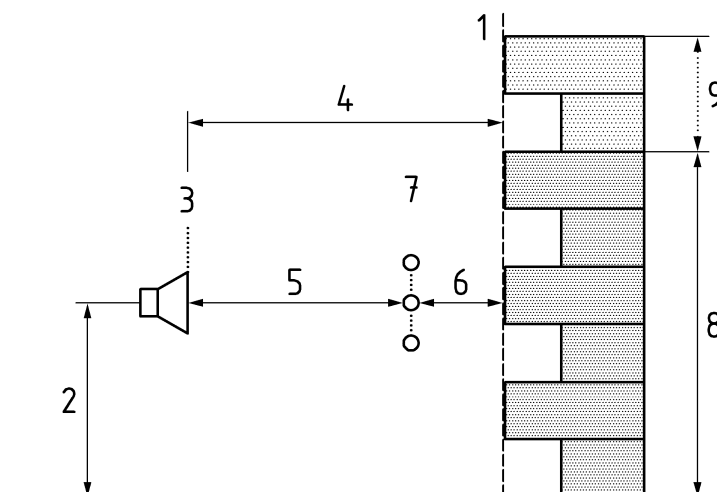


Figure 6 — Sketch of the minimum flat sample required for reflection index measurements in the 200 Hz – 5 kHz frequency range (see 5.5.7). The nine white dots represent the measurement grid. The thin circle represents the maximum sampled area for the central microphone (5.5.8)

**Key**

- | | |
|---|---|
| 1 Source and microphone reference plane | 2 Reference height, h_s [m] |
| 3 Loudspeaker front panel | 4 Distance between the loudspeaker front panel and the reference surface, d_s [m] |
| 5 Distance between the loudspeaker front panel and the measurement grid, d_{SM} [m] | 6 Distance between the measurement grid and the reference surface, d_M [m] |
| 7 Measurement grid | 8 Road traffic noise reducing device height, h_B [m] |
| 9 Spatial period length of the corrugation in the vertical direction, L_p [m] | |

Figure 7 — (not to scale) Sketch of the set-up for sound reflection index measurement in front of a non-flat sample with a spatially periodic corrugation in the vertical direction (period length L_p in the vertical direction); one additional period of the structure, added on the top of the sample, is shown in lighter grey colour

5.3.3 Inclined or curve road traffic noise reducing devices

For flat or curved, vertical or inclined road traffic noise reducing devices, Figures 8 and 9 apply. For cases not covered by these figures, measurements should be carried out in accordance with the following general principles:

- the microphone grid is perpendicular to the axis loudspeaker-microphone 5;
- the axis loudspeaker-microphone 5 is perpendicular to the reference surface;
- microphone 5 is as close as possible to the mid-height of the screen;
- the shortest distance of microphone 5 to the reference surface is $d_M = 0,25$ m.

Road traffic noise reducing devices consisting of a horizontal or vertical juxtaposition of several distinct types of screens (composition of shapes or structures of very large dimensions) must be characterized in detail: each shape or structure must be specifically characterized under the conditions described in this document.

For structures that do not allow the unequivocal application of these rules, measurements may be carried out in strict compliance with the provisions of this document. The responsibility for adapting the method is left to the operator. A clear justification of all choices made shall be included in the test report. However, the results obtained under these conditions may in no case be used for the declaration of performance.