BS EN 16272-6:2014

BSI Standards Publication

Railway applications — Track — Noise barriers and related devices acting on airborne sound propagation — Test method for determining the acoustic performance

Part 6: Intrinsic characteristics — In situ values of airborne sound insulation under direct sound field conditions

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National foreword

This British Standard is the UK implementation of EN 16272-6:2014.

The UK participation in its preparation was entrusted to Technical Committee RAE/2, Railway Applications - Track.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Applications ferroviaires - Dispositifs de réduction du bruit - Méthode d'essai pour la détermination des performances acoustiques - Partie 6 : Caractéristiques intrinsèques - Valeurs in situ de l'isolation acoustique au bruit aérien dans des conditions de champ acoustique direct

Bahnanwendungen - Oberbau - Lärmschutzwände und verwandte Vorrichtungen zur Beeinflussung der Luftschallausbreitung - Prüfverfahren zur Bestimmung der akustischen Eigenschaften - Teil 6: Produktspezifische Merkmale - In-situ-Werte zur Luftschalldämmung in gerichteten Schallfeldern

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN 16272-6:2014) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2015 and conflicting national standards shall be withdrawn at the latest by April 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This European Standard is one part of the series EN 16272, *Railway applications — Track — Noise barriers and related devices acting on airborne sound propagation — Test method for determining the acoustic performance*, as listed below:

— *Part 1: Intrinsic characteristics — Sound absorption in the laboratory under diffuse sound field conditions*;

— *Part 2: Intrinsic characteristics — Airborne sound insulation in the laboratory under diffuse sound field conditions*;

— *Part 3-1: Normalized railway noise spectrum and single number ratings for diffuse field applications*;

— *Part 3-2: Normalized railway noise spectrum and single number ratings for direct field applications*;

— Part 4: *Intrinsic characteristics — In situ values of sound diffraction under direct sound field conditions*

— *Part 5: Intrinsic characteristics — In situ values of sound reflection under direct sound field conditions* (CEN/TS 16272-5)*;*

— *Part 6: Intrinsic characteristics — In situ values of airborne sound insulation under direct sound field conditions*.

It will be read in conjunction with:

— EN 16272-2;

— EN 16272-3-1;

— EN 16272-3-2.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Noise barriers installed along railways need to provide adequate sound insulation so that sound transmitted directly through the device is not significant compared to the sound diffracted over the top. This European Standard specifies a test method for assessing the airborne sound insulation performance of noise barriers and related devices acting on airborne sound propagation designed for railways in non-reverberant conditions (a measure of intrinsic performance). It can be applied *in situ*, i.e. where the noise barriers are installed. The method can be applied without damaging the surface.

The method can be used to qualify products to be installed along railways as well as to verify the compliance of installed noise barriers to design specifications. Regular application of the method can be used to verify the long term performance of noise barriers.

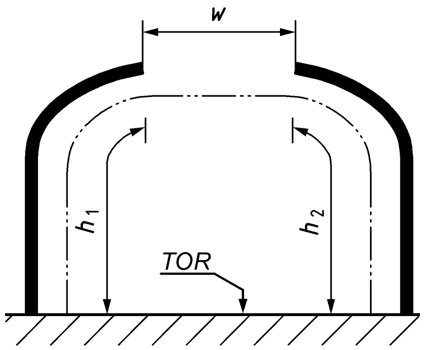
The method requires the averaging of results of measurements taken at different points behind the device under test. The method is able to investigate flat and non-flat products.

The measurement results of this method for airborne sound insulation are comparable but not identical with the results of the EN 16272-2 method, mainly because the present method uses a directional sound field, while the EN 16272-2 method assumes a diffuse sound field (where all angles of incidence are equally probable). The test method described in this European Standard should not be used to determine the intrinsic characteristics of airborne sound insulation for noise barriers to be installed in reverberant conditions, e.g. inside tunnels or deep trenches or under covers or very close to the rail track.

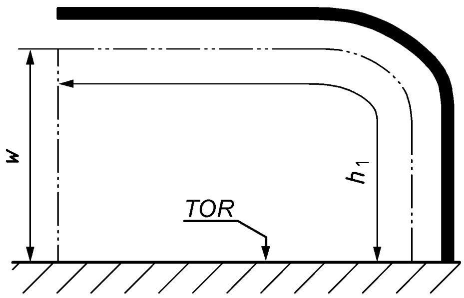
For the purpose of this European standard reverberant conditions are defined based on the geometric envelope, e, across the rail formed by the barriers, trench sides or buildings (the envelope does not include the railway surface) as shown by the dashed lines in Figure 1. Conditions are defined as being 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 $e = (w + h_1 + h_2)$

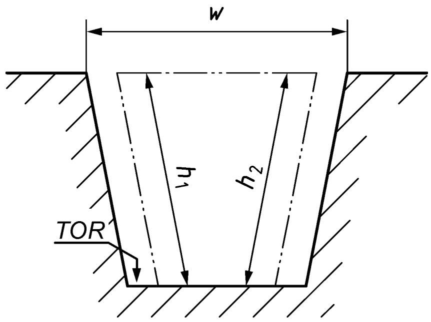
This criterion is applied also to the open space between the train body and the barrier surface.



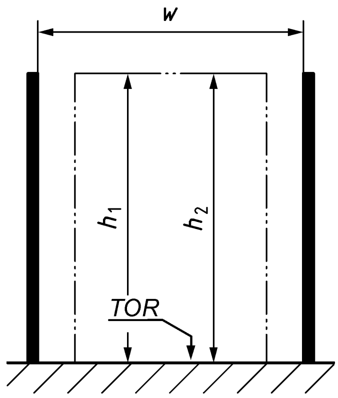
a) Partial cover on both sides of the railway; envelope, $e = w + h_1 + h_2$



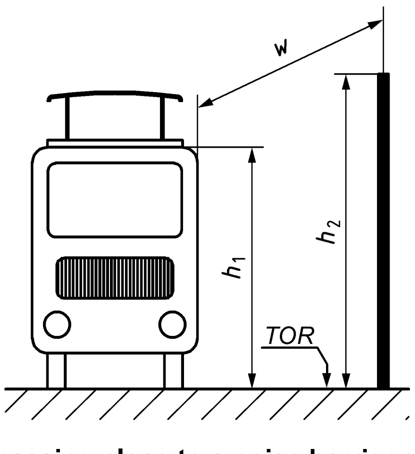
b) Partial cover on one side of the railway; $e = w + h_1$



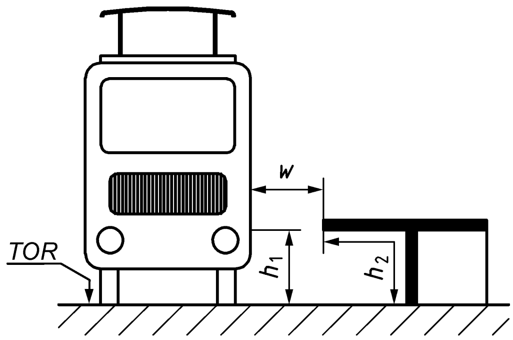
c) Deep trench envelope, $e = w + h_1 + h_2$



d) Tall barriers or buildings; envelope, $e = w + h_1 + h_2$



e) Train passing close to a noise barrier envelope, $e = w + h_1 + h_2$



f) Train passing close to a platform at the station, $e = w + h_1 + h_2$

Key

TOR Top of Rail (railway surface)

w width of open space

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

This European Standard introduces a specific quantity, called sound insulation index, to define the airborne sound insulation of a noise barrier. This quantity should not be confused with the sound reduction index used in building acoustics, sometimes also called transmission loss. Research studies suggest that a very good correlation exists between data measured according to EN 16272-2 and data measured according to the method described in the present document.

This method may be used to qualify noise barriers for other applications, e.g. to be installed along roads or nearby industrial sites. In this case the single-number ratings should be calculated using an appropriate spectrum.

1 Scope

This European Standard describes a test method for measuring a quantity representative of the intrinsic characteristics of airborne sound insulation for railway noise barriers: the sound insulation index.

The test method is intended for the following applications:

— determination of the intrinsic characteristics of airborne sound insulation of noise barriers to be installed along railways, to be measured either on typical installations alongside railways or on a relevant sample section;

— determination of the *in situ* intrinsic characteristics of airborne sound insulation of noise barriers in actual use;

— comparison of design specifications with actual performance data after the completion of the construction work;

— verification of the long term performance of noise barriers (with a repeated application of the method);

— interactive design process of new products, including the formulation of installation manuals.

The test method is not intended for the following applications:

— determination of the intrinsic characteristics of airborne sound insulation of noise barriers to be installed in reverberant conditions, e.g. inside tunnels or deep trenches or under covers.

Results 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 measurement results over the whole frequency range indicated, the results will be given in a restricted frequency range and the reasons for the restriction(s) will be clearly reported.

All noise reducing devices different from noise barriers and related devices acting on airborne sound propagation, e.g. devices for attenuation of ground borne vibration and on board devices are out of the scope of this European Standard.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 16272-2, *Railway applications — Track — Noise barriers and related devices acting on airborne sound propagation — Test method for determining the acoustic performance — Part 2: Intrinsic characteristics — Airborne sound insulation in the laboratory under diffuse sound field conditions*

EN 16272-3-2, *Railway applications — Track — Noise barriers and related devices acting on airborne sound propagation — Test method for determining the acoustic performance — Part 3-2: Normalized railway noise spectrum and single number ratings for direct field applications*

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

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 following terms and definitions apply.

3.1
noise barrier
noise reducing device, which obstructs the direct transmission of airborne sound emanating from railways

Note 1 to entry: It may either span or overhang the railway.

Note 2 to entry: Noise barriers are generally made of acoustic and structural elements (3.3 and 3.4).

3.2
cladding
noise reducing device, which is attached to a wall or other structure and reduces the amount of sound reflected

Note 1 to entry: Claddings are generally made of acoustic and structural elements (3.3 and 3.4).

3.3
acoustic element
element whose primary function is to provide the acoustic performance of the device

3.4
structural element
element whose primary function is to support or hold in place acoustic elements

Note 1 to entry: In some noise barriers the acoustic function and the structural function cannot be clearly separated and attributed to different components.

3.5
added device
added component that influences the acoustic performance of the original noise-reducing device (acting primarily on the diffracted energy)

3.6
rail side exposure
use of the product as a noise barrier installed alongside railways

3.7
sound insulation index
result of airborne sound insulation test

Note 1 to entry: The sound insulation index is given by Formula (1).

3.8
reference height
h_S
height equal to half the height, h_B, of the noise barrier 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 4.5.8).

Note 2 to entry: See Figures 2 and 3.

3.9
source reference plane for sound insulation index measurements
plane facing the sound source side of the noise barrier and touching the most protruding parts of the device under test within the tested area

Note 1 to entry: The device under test includes both structural and acoustical elements.

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

3.10
microphone reference plane
plane facing the receiver side of the noise barrier and touching the most protruding parts of the device under test within the tested area

Note 1 to entry: The device under test includes both structural and acoustical elements.

Note 2 to entry: See Figures 4 and 9.

3.11
source reference position
position facing the side to be exposed to noise when the device is in place, located at the reference height h_s and placed so that its horizontal distance to the source reference plane is the reference distance d_s

Note 1 to entry: d_s = 1 m

Note 2 to entry: The actual dimensions of the loudspeaker used for the background research on which this European Standard is based are: 0,40 m x 0,285 m x 0,285 m (length x width x height).

Note 3 to entry: See Figures 2, 5, 8, and 9.

3.12
measurement grid for sound insulation index measurements
a vertical measurement grid constituted of nine equally spaced points. A microphone is placed at each point

Note 1 to entry: See Figures 3, 5, 6, 8, 9 and 5.5.

3.13
barrier thickness for sound insulation index measurements
distance t_B between the source reference plane and the microphone reference plane at a height equal to the reference height h_S

Note 1 to entry: See Figures 4, 8, and 9.

3.14
free-field measurement for sound insulation index measurements
measurement taken with the loudspeaker and the microphone in an acoustic free field in order to avoid reflections from any nearby object, including the ground

Note 1 to entry: See Figure 6.

3.15
Adrienne temporal window
well defined composite temporal window

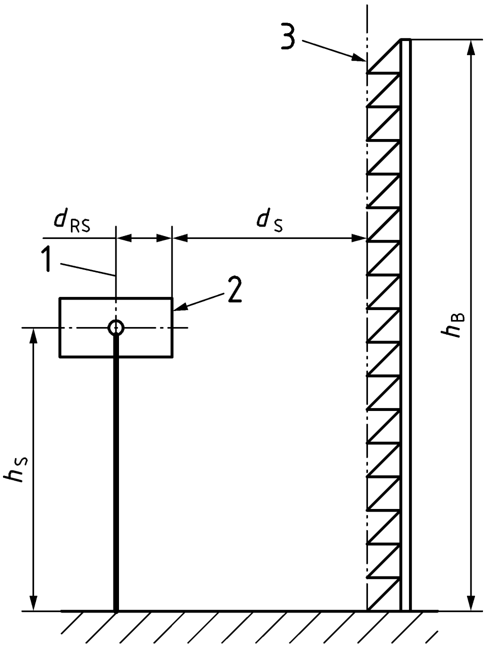
Note 1 to entry: The Adrienne temporal window is described in 5.5.6.

3.16
background noise
noise coming from sources other than the source emitting the test signal

3.17
signal-to-noise ratio
S/N
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)

3.18
impulse response
time signal at the output of a system when a Dirac function is applied to the input

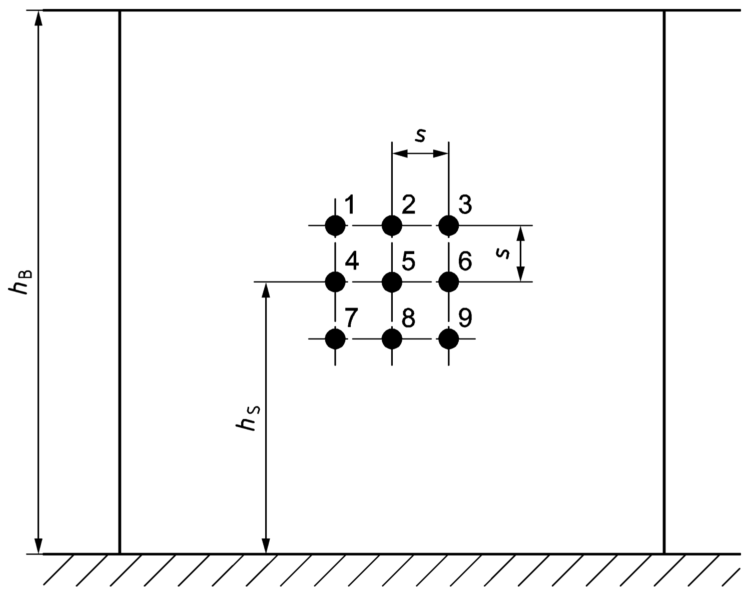
Note 1 to entry: The Dirac function, also called *δ* function, is the mathematical idealization of a signal that is infinitely short in time which carries a unit amount of energy.



Key

1	axis of rotation	d_{RS}	distance between the axis of rotation and the loudspeaker front panel [m]
2	loudspeaker front panel	h_B	noise barrier height [m]
3	source reference plane	h_s	reference height [m]
d_S	reference distance [m]		

Figure 2 — (not to scale) Sketch of the loudspeaker in front of the noise barrier under test for sound insulation index measurements



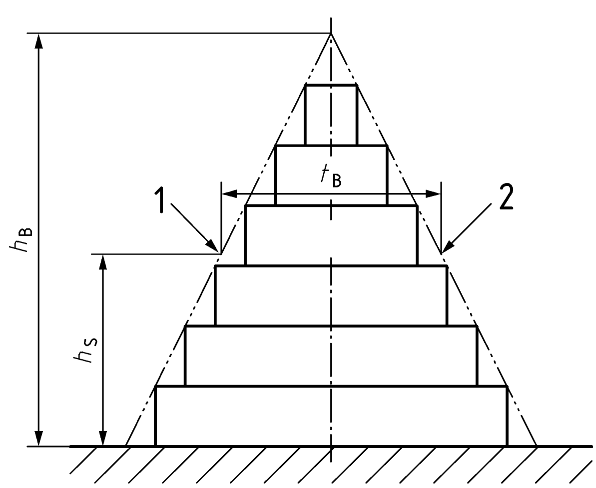
Key

h_B noise barrier height [m]

h_S reference height [m]

s half the side length of the measurement grid [m]

Figure 3 — Measurement grid for sound insulation index measurements (receiver side) and numbering of the measurement points (not to scale)



Key

1 sound source reference plane

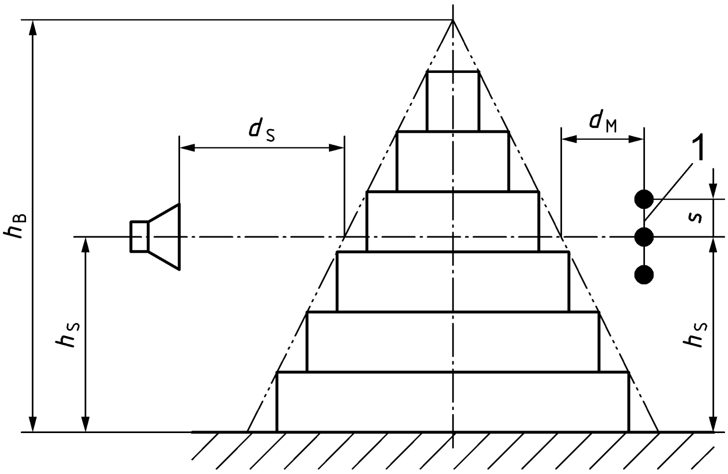
2 microphone reference plane

h_B noise barrier height [m]

h_S reference height [m]

t_B noise barrier thickness [m]

Figure 4 — (not to scale) Sound source and microphone reference planes (side view)



Key

1 measurement grid

h_B noise barrier height [m]

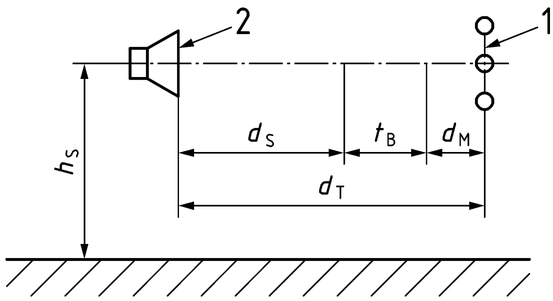
d_M horizontal distance from the measurement grid to the microphone reference plane [m]

h_S reference height [m]

d_S horizontal distance from the loudspeaker front panel to the source reference plane [m]

s half the side length of the measurement grid [m]

Figure 5 — (not to scale) Placement of the sound source and measurement grid for sound insulation index measurement (side view)



Key

1 measurement grid

2 loudspeaker front panel

d_M horizontal distance from the measurement grid to the microphone reference plane [m]

d_S horizontal distance from the loudspeaker front panel to the source reference plane [m]

d_T $d_T = d_S + t_B + d_M$ see Formula (3)

h_S reference height [m]

t_B noise barrier thickness [m]

Figure 6 — (not to scale) Sketch of the set-up for the reference “free-field” sound measurement for the determination of the sound insulation 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_0, a_1, a_2, a_3	Coefficient for the expression of the Blackman-Harris window	-
d_S	Horizontal distance from the loudspeaker front panel to the source reference plane	m
d_M	Horizontal distance from the measurement grid to the microphone reference plane	m
d_T	Horizontal distance from the loudspeaker front panel to the microphone position n. 5	m
$DL_{SI,E}$	Single number rating of airborne sound insulation for the acoustic elements	dB
$DL_{SI,P}$	Single number rating of airborne sound insulation for the post	dB
$DL_{SI,G}$	Single number rating of airborne sound insulation for the test sample (average of 'element' and 'post')	dB
δ_i	Any input quantity to allow for uncertainty estimates	-
Δf_j	Width of the *j*-th one-third octave frequency band	Hz
f	Frequency	Hz
F	Symbol of the Fourier transform	-
f_{min}	Low frequency limit of sound insulation index measurements	Hz
f_s	Sample rate	Hz
f_{co}	cut-off frequency of the anti-aliasing filter	Hz
h_B	Noise barrier height	m
h_S	Reference height	m
$h_i(t)$	Incident reference component of the free-field impulse response	dB
$h_{t,k}(t)$	Transmitted component of the impulse response at the *k*-th scanning point	dB
j	Index of the *j*-th one-third octave frequency band (between 100 Hz and 5 kHz)	-
k	Coverage factor	-
k_f	Constant used for the anti-aliasing filter	-
L	Distance between two posts of the minimum sample required for measurements in laboratory conditions	m
L_{tot}	Length of the minimum sample required for measurements in laboratory conditions	m
n	Number of scanning points	-
s	Half the side length of the measurement grid	m
SI_j	Sound insulation index in the *j*-th one-third octave frequency band	dB
t	Time	s or ms
t_B	Noise barrier (conventional) thickness, equal to the distance between the source reference plane and the microphone reference plane at a height equal to the reference height h_S	m
$T_{W,BH}$	Length of the Blackman-Harris trailing edge of the Adrienne temporal window	ms
$T_{W,ADR}$	Total length of the Adrienne temporal window	ms
u	Standard uncertainty	-
U	Expanded uncertainty	-

Symbol or abbreviation	Designation	Unit
$w_i(t)$	Reference free-field component time window (Adrienne temporal window)	-
$w_{t,k}(t)$	Time window (Adrienne temporal window) for the transmitted component at the *k*-th scanning point	-

5 Sound insulation index measurements

5.1 General principle

The sound source emits a transient sound wave that travels towards the device under test and is partly reflected, partly transmitted and partly diffracted by it. The microphone placed on the other side of the device under test receives both the transmitted sound pressure wave travelling from the sound source through the device under test, and the sound pressure wave diffracted by the top edge of the device under test (for the test be meaningful the diffraction from the lateral edges should be sufficiently delayed). If the measurement is repeated without the device under test between the loudspeaker and the microphone, the direct free-field wave can be acquired. The power spectra of the direct wave and the transmitted wave give the basis for calculating the sound insulation index.

The sound insulation index shall be the logarithmic average of the values measured at nine points placed on the measurement grid (scanning points). See Figure 3 and Formula (1).

The measurement shall take place in a sound field free from reflections within the Adrienne temporal window. 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 can be identified from their delay time and rejected.

5.2 Measured quantity

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

$$SI_j = -10 \times \lg \left\{ \frac{1}{n} \sum_{k=1}^{n} \left[\frac{\int_{\Delta f_j} \left| F\left[h_{tk}(t) w_{tk}(t) \right] \right|^2 df}{\int_{\Delta f_j} \left| F\left[h_{ik}(t) w_{ik}(t) \right] \right|^2 df} \right] \right\} \tag{1}$$

where:

$h_{ik}(t)$ is the incident reference component of the free-field impulse response at the *k*-th scanning point;

$h_{tk}(t)$ is the transmitted component of the impulse response at the *k*-th scanning point;

$w_{ik}(t)$ is the time window (Adrienne temporal window) for the incident reference component of the free-field impulse response at the *k*-th scanning point;

$w_{tk}(t)$ is the time window (Adrienne temporal window) for the transmitted component at the *k*-th scanning point;

F is the symbol of the Fourier transform;

j is the index of the *j*-th one-third octave frequency band (between 100 Hz and 5 kHz);

Δf_j is the width of the *j*-th one-third octave frequency band;

$n = 9$ is the number of scanning points.

5.3 Test arrangement

The test method can be applied both *in situ* and on a sample of barrier purposely built to be tested using the method described here. In the second case the specimen shall be built as follows (see Figure 7):

— a first part, composed of acoustic elements;

— a post (if applicable for the specific noise reducing device under test);

— a second part, composed of acoustic elements.

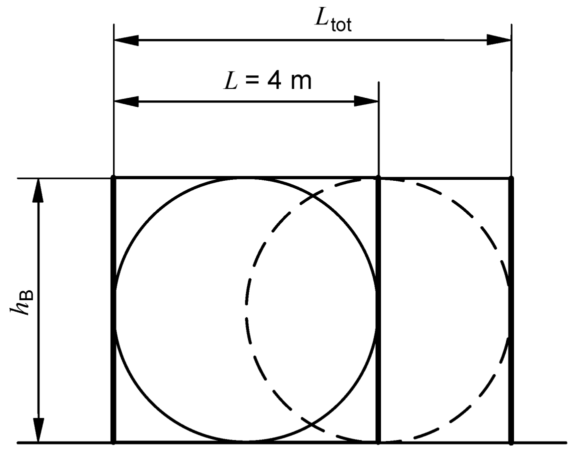
The test specimen shall be mounted and assembled in the same manner as the manufactured device is used in practice with the same connections and seals.

The tested area is a circle having a radius of 2 m centred on the middle of the measurement grid. The sample shall be built large enough to completely include this circle for each measurement.

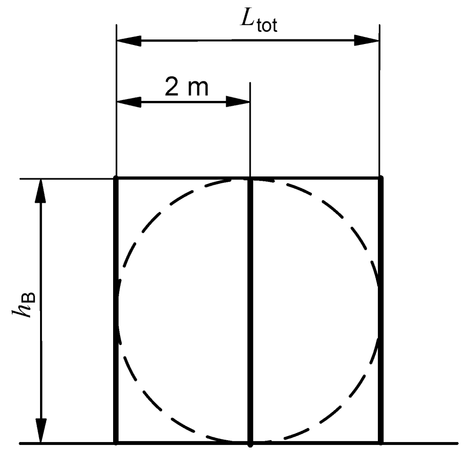
The distance between two posts of the minimum sample required for measurements in laboratory conditions shall be $L = 4$ m. The length of the minimum sample required for measurements in laboratory conditions shall be $L_{tot} = 6$ m (Figure 7 a)).

For qualifying the sound insulation index of posts only, it is only necessary to have acoustic elements that extend 2 m or more on either side of the post, so that $L_{tot} = 4$ m. (see Figure 7 b)).

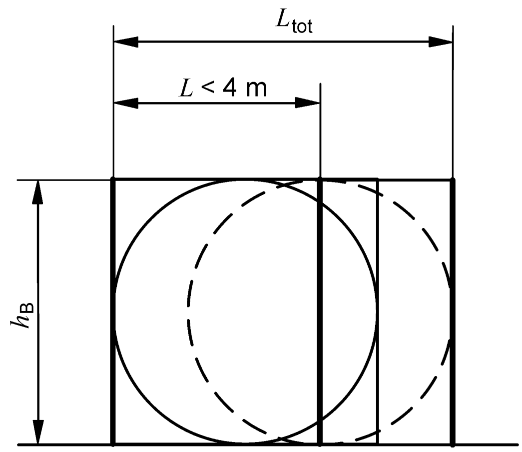
If the device under test has a post separation less than 4 m, the separation between posts should be reduced accordingly ($L < 4$ m) but the overall minimum length of the construction should be $L_{tot} = 6$ m, as shown in Figure 7 c).



a) Sound insulation index measurements for elements and posts



b) Sound insulation index measurements in front of a post only

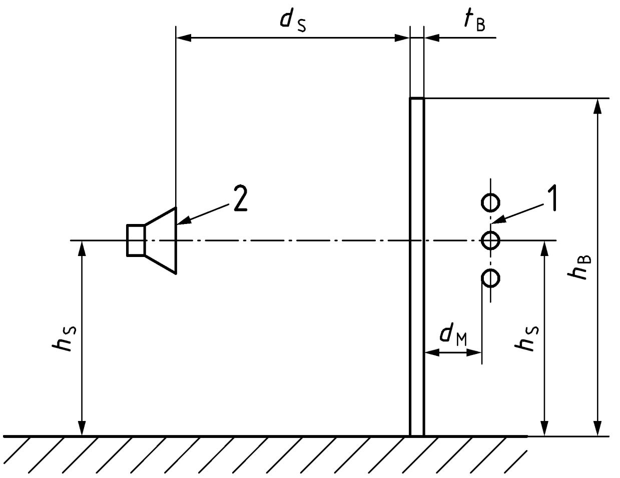


c) Sound insulation index measurements in front of a sample having a post separation smaller than 4 m

Key

dotted circles:	tested area for posts	L	distance between two posts
thin circles:	tested area for elements	L_{tot}	overall minimum length [m]
h_B	barrier height [m]		

Figure 7 — Sketch of the minimum sample required for measurements in laboratory conditions



Key

1 measurement grid

2 loudspeaker front panel

d_M distance nois barrier to measurment = 0,25 m

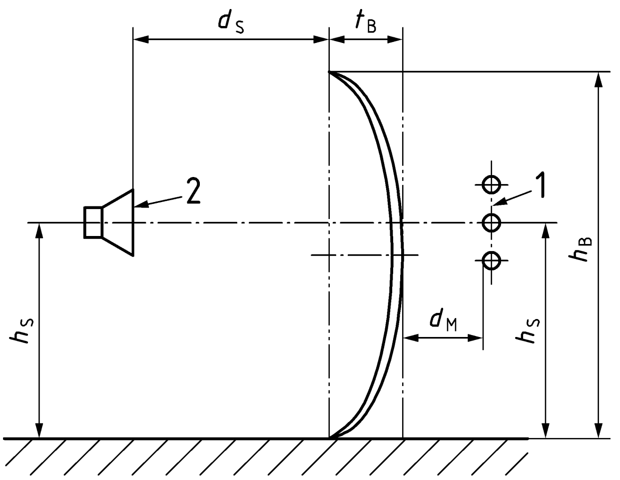
d_S distance noise barrier to speaker = 1 m

h_B noise barrier height [m]

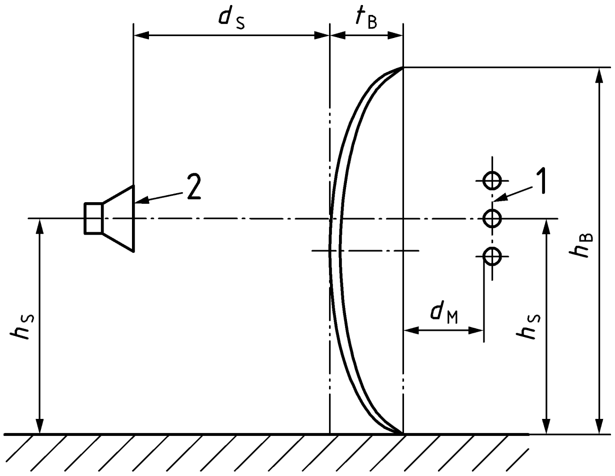
h_S reference height [m]

t_B noise barrier thickness [m]

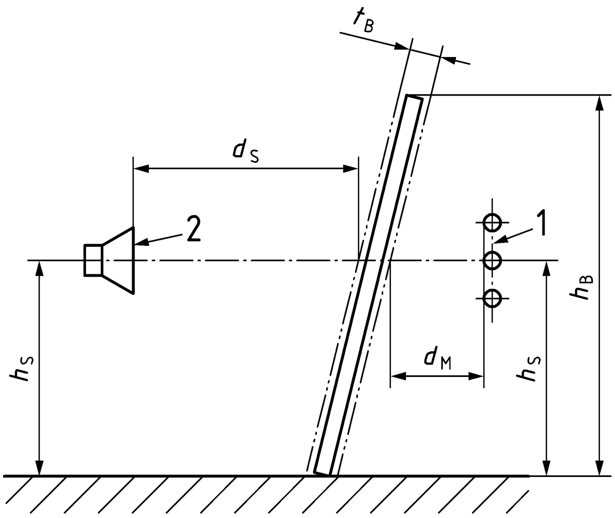
Figure 8 — (not to scale) Sketch of the set-up for the sound insulation index measurement — Normal incidence of sound on the sample — Transmitted component measurement in front of a flat noise barrier



a) Transmitted component measurements in front of a concave noise barrier



b) Transmitted component measurements in front of a convex noise barrier



c) Transmitted component measurements in front of an inclined noise barrier

Key

1 measurement grid

2 loudspeaker front panel

d_S distance noise barrier to speaker = 1 m

d_M distance noise barrier to measurement = 0,25 m

h_B noise barrier height [m]

h_S reference height [m]

t_B noise barrier thickness [m]

Figure 9 — (not to scale - informative) Examples of the set-up for the sound insulation index measurement — Normal incidence of sound on the sample

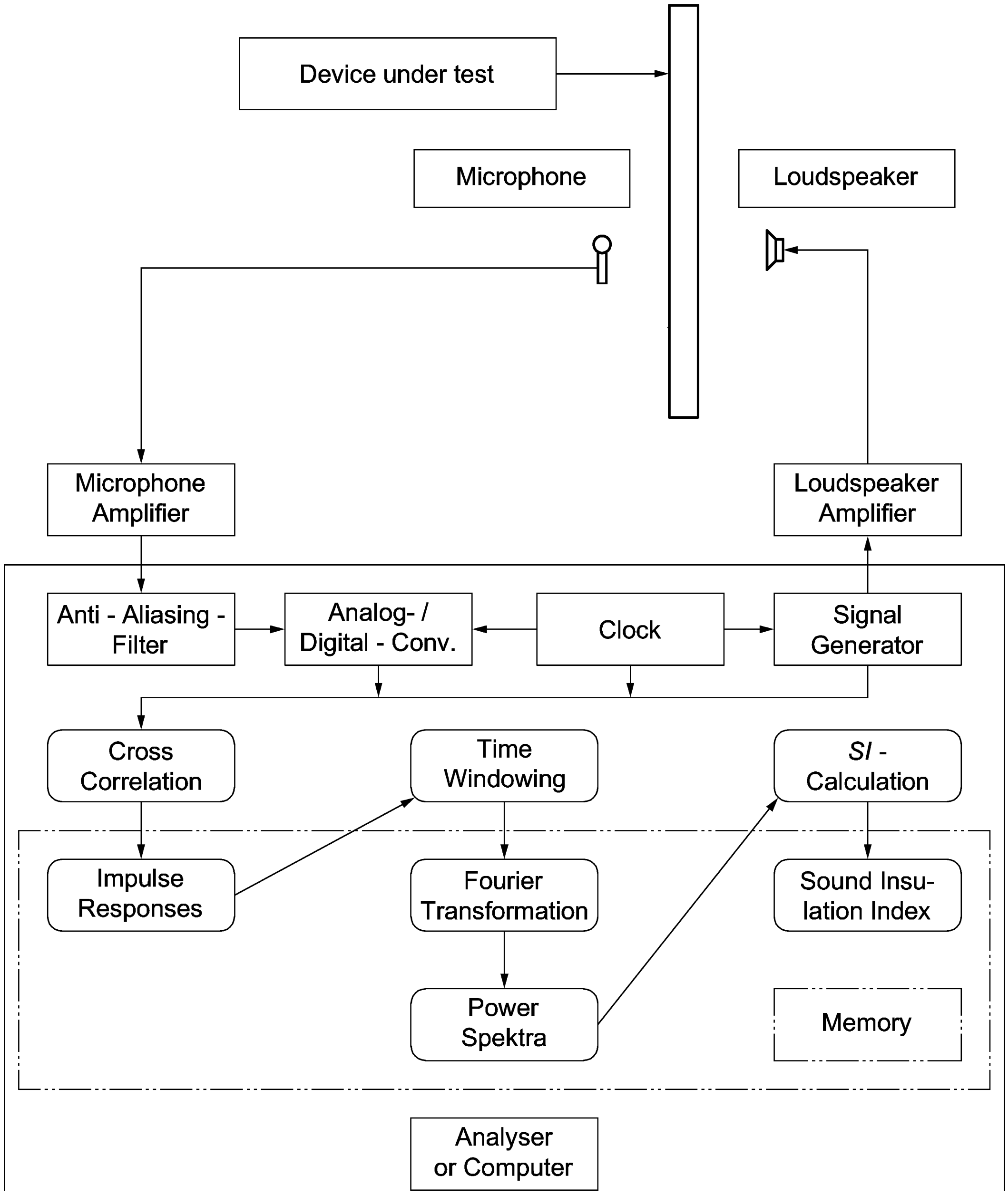


Figure 10 — Sketch representing the essential components of the measuring system

5.4 Measuring equipment

5.4.1 Components of the measuring system

The measuring equipment shall comprise: an electro-acoustic system, consisting of an electrical signal generator, a power amplifier and a loudspeaker, a single microphone (or nine microphones) with its (their) microphone amplifier(s) and a signal analyser capable of performing transformations between the time domain and the frequency domain.

NOTE Some of these components can be integrated into a frequency analyser or a personal computer equipped with specific add-on board(s).

The essential components of the measuring system are shown in Figure 10.

The complete measuring system shall meet the requirements of at least a type 1 instrument in accordance with EN 61672-1, except for the microphone which shall meet the requirements for type 2 and have a diameter of 1/2" maximum.

The measurement procedure here described is based on ratios of the power spectra of signals extracted from impulse responses sampled with the same equipment in the same place under the same conditions within a short time. Furthermore, a high accuracy in measuring sound levels is not of interest here. Strict requirements on the absolute accuracy of the measurement chain are, therefore, not needed. The microphones should be sufficiently small and lightweight in order to be fixed on a frame to constitute the microphone grid without moving. The microphones are allowed to meet the requirements for type 2.

5.4.2 Sound source

The electro-acoustic sound source shall meet the following characteristics:

— have a single cone full range driver (from 100 Hz to 5 kHz in one-third octave bands);

— be constructed without any port, e.g. to enhance low frequency response;

— have a smooth magnitude of the frequency response without sharp irregularities throughout the measurement frequency range, resulting in an impulse response under free-field conditions with a length not greater than 3 ms.

5.4.3 Test signal

The electro-acoustic source shall receive an input electrical signal which is deterministic and exactly repeatable. The input signal has to be set in order to avoid any nonlinearity of the loudspeaker.

The *S/N* ratio is improved by repeating the same test signal and synchronously averaging the microphone response. At least 16 averages shall be kept.

This European Standard recommends the use of a MLS signal as test signal. A different test signal may be used, e.g. sine sweep, if results can be shown to be exactly the same. This means that it shall be clearly demonstrated that:

— the generation of the test signal is deterministic and exactly repeatable;

— impulse responses are accurately sampled (without distortion) on the whole frequency range of interest (one-third octave bands between 100 Hz and 5 kHz);

— the test method maintains a good background noise immunity, i.e. the effective *S/N* ratio can be made higher than 10 dB over the whole frequency range of interest within a short measurement time (no more than 5 min per impulse response) ;

— the sample rate can be chosen high enough to allow an accurate correction of possible time shifts in the impulse responses between the measurement in front of the sample and the free-field measurement due to temperature changes;

— the test signal is easy-to-use, i.e. it can be conveniently generated and fed to the sound source using only equipment which is available on the market.

5.5 Data processing

5.5.1 Calibration

The measurement procedure here described is based on ratios of the power spectra of signals extracted from impulse responses sampled with the same equipment in the same place under the same conditions. An absolute calibration of the measurement chain with regard to the sound pressure level is therefore not needed. It is nevertheless recommended to check the correct functioning of the measurement chain from the beginning to the end of the measurement exercise.

5.5.2 Sample rate

The frequency at which the microphone response is sampled depends on the specified upper frequency limit of the measurement and on the anti-aliasing filter type and characteristics.

The sample rate f_s shall have a value greater than 43 kHz.

NOTE Although the signal is already unambiguously defined when the Nyquist criterion is met, higher sample rates facilitate a clear reproduction of the signal and the knowledge of the exact wave form. Therefore, with the prescribed sample rates errors can be detected and corrected more easily, such as time shifts in the impulse responses between the measurement in front of the sample and the free-field measurement due to temperature changes.

The sample rate shall be equal to the clock rate of the signal generator.

The cut-off frequency of the anti-aliasing filter, f_{co}, shall have a value:

$$f_{co} \leq k_f f_s \quad (2)$$

where

k_f is 1/3 for the Chebyshev filter and k_f = 1/4 for the Butterworth and Bessel filters.

For each measurement, the sample rate, the type and the characteristics of the anti-aliasing filter shall be clearly stated in each test report.

5.5.3 Background noise

The effective signal-to-noise ratio S/N, taking into account sample averaging, shall be greater than 10 dB over the frequency range of measurements.

NOTE Coherent detection techniques, such as the MLS cross-correlation, provide high S/N ratios.

5.5.4 Scanning technique using a single microphone

The sound source shall be positioned as described in 3.11.

The measurement grid shall be square, with a side length 2 s of 0,80 m. Its centre shall be located at the reference height h_S. The grid shall be placed facing the side of the noise barrier under test opposite to the side to be exposed to noise when the device is in place, so that its horizontal distance to the microphone reference plane is d_M = 0,25 m (see Figures 3, 5, 6, 8 and 9). The grid shall be placed at a distance as large as possible from the edges of the noise barrier under test.

A single microphone shall be subsequently placed at the nine scanning points; the nine resulting impulse responses shall be then measured. Each of these consists of the direct component, the transmitted component through the device under test, diffracted components and other parasitic reflections (Figure 12).

A “free-field” impulse response shall be measured for each microphone position, keeping the supporting frame with the same geometrical configuration of the set-up and without the barrier present.

In particular, the distance d_T of the microphone position n. Five from the sound source shall be kept constant (see Figure 6):

$$d_T = d_s + t_B + d_M = 1{,}25 + t_B \quad (3)$$

where

t_B is the barrier thickness (see 3.10).

Care shall be taken that the supporting frame does not alter the measurement result.

5.5.5 Scanning technique using nine microphones

Alternatively to the procedure described in 5.5.4, the procedure described here may be used, leading to the same results.

The sound source shall be positioned as described in 3.11.

The measurement grid shall be square, with a side length 2 *s* of 0,80 m. Its centre shall be located at the reference height h_S. The grid shall be placed facing the side of the noise barrier under test opposite to the side to be exposed to noise when the device is in place, so that its horizontal distance to the microphone reference plane is d_M = 0,25 m (see Figures 3, 5, 6, 8 and 9). The grid shall be placed at a distance as large as possible from the edges of the noise barrier under test.

A set of nine microphones supported by a rigid frame shall be placed at the nine scanning points corresponding to the measurement grid and the nine impulse responses are measured simultaneously or in sequence. Each of these consists of the direct component, the transmitted component through the device under test, diffracted components and other parasitic reflections (Figure 12).

A "free-field" impulse response shall be measured for each microphone position, keeping the supporting frame with the same geometrical configuration of the set-up and without the barrier present.

In particular, the distance d_T of the microphone position n. Five from the sound source shall be kept constant (see Figure 6):

$$d_T = d_s + t_B + d_M = 1{,}25 + t_{\boldsymbol{B}} \qquad (3)$$

where

t_B is the barrier thickness (see 3.10)

Care shall be taken that the supporting frame does not alter the measurement result.

5.5.6 Adrienne temporal window

For the purpose of this European Standard, windowing operations in the time domain shall be performed using a temporal window, called Adrienne temporal window, with the following specifications (see Figure 11):

— a leading edge having a left-half Blackman-Harris shape and a total length of 0,5 ms ("pre-window");

— a flat portion having a total length of 5,18 ms ("main body");

— a trailing edge having a right-half Blackman-Harris shape and a total length of 2,22 ms.

The total length of the Adrienne temporal window is $T_{W,ADR} = 7{,}9$ ms.

NOTE A four-term full Blackman-Harris window of length $T_{W,BH}$ is:

$$w(t) = a_0 - a_1 \cos\left(\frac{2\pi t}{T_{W,BH}}\right) + a_2 \cos\left(\frac{4\pi t}{T_{W,BH}}\right) - a_3 \cos\left(\frac{6\pi t}{T_{W,BH}}\right) \qquad (4)$$

where:

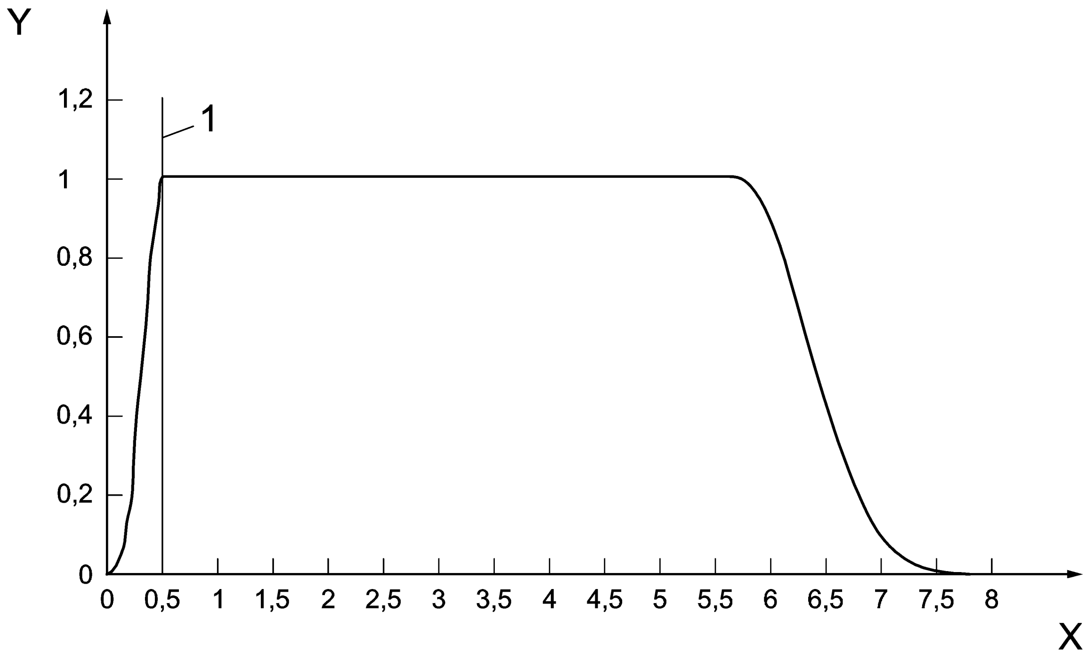
a_0 = 0,358 75;

a_1 = 0,488 29;

a_2 = 0,141 28;

a_3 = 0,011 68;

$0 \le t \le T_{W,BH}$



Key

1 marker point ***MP***

X time [ms]

Y adrienne window function *w(t)* [relative units]

Figure 11 — The Adrienne temporal window, with the marker point *MP*

If the window length $T_{W,ADR}$ has to be varied (this occurs only in exceptional cases) the lengths of the flat portion and the right-half Blackman-Harris portion shall have a ratio of 7/3. As an example, when testing very large samples the window length can be enlarged in order to achieve a better low frequency limit.

The point where the flat portion of the Adrienne temporal window begins is called the marker point (*MP*).

5.5.7 Placement of the Adrienne temporal window

For the “free-field” direct component, the Adrienne temporal window shall be placed as follows:

— the first peak of the impulse response, corresponding to the direct component, is detected;

— a time instant preceding the direct component peak of 0,2 ms is located;

— the direct component Adrienne temporal window is placed so that its marker point corresponds to this time instant.

In other words, the direct component Adrienne temporal window is placed so that its flat portion begins 0,2 ms before the direct component peak.

For the transmitted component, the Adrienne temporal window shall be placed as follows:

— the time instant when the transmission begins is located, possibly with the help of geometrical computation (conventional beginning of transmission);

— a time instant preceding the conventional beginning of transmission of 0,2 ms is located;

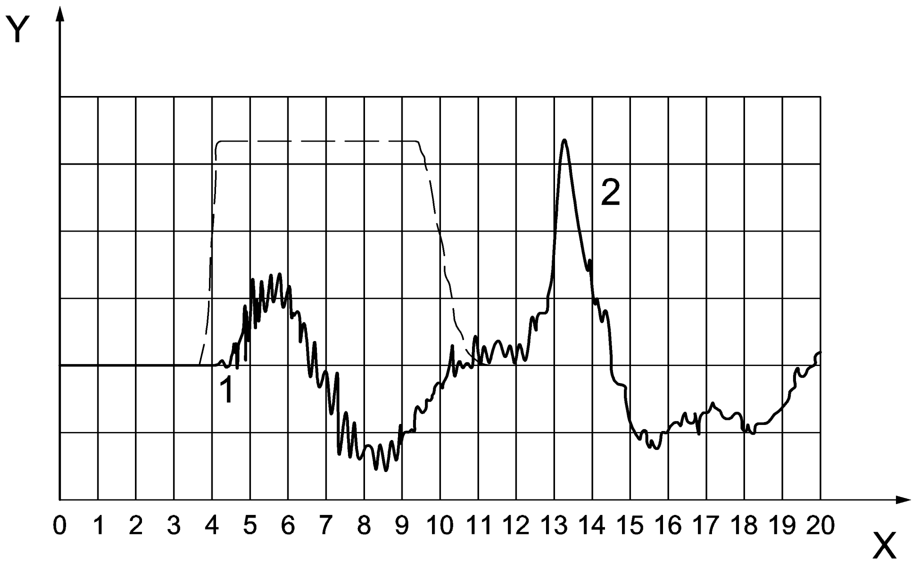
— the transmitted component Adrienne temporal window is placed so that its marker point corresponds to this time instant;

— the time instant when the diffraction begins is located, possibly with the help of geometrical computation (conventional beginning of the diffraction);

— the transmitted component Adrienne temporal window stops 7,4 ms after the marker point or at the conventional beginning of the diffraction, whichever of the two comes first.

In other words, the transmitted component Adrienne temporal window is placed so that its flat portion begins 0,2 ms before the first peak of the transmitted component and its tail stops before the beginning of the diffraction (see Figure 12).

In computations involving the speed of sound *c*, its temperature dependent value shall be assumed.



Key

1	transmitted component	X	time [ms]
2	diffracted component	Y	impulse response [relative units]

Figure 12 — Example of application of the Adrienne temporal window to the transmitted component of an impulse response

5.5.8 Low frequency limit and sample size

The method described in the present document can be used for different sample sizes.

The low frequency limit f_{min} of sound insulation index measurements depends on the shape and width of the Adrienne temporal window. The width in turn depends on the smallest dimension (height or length) of the noise barrier under test. In fact, the following unwanted components shall be kept out of the Adrienne temporal window for the transmitted components:

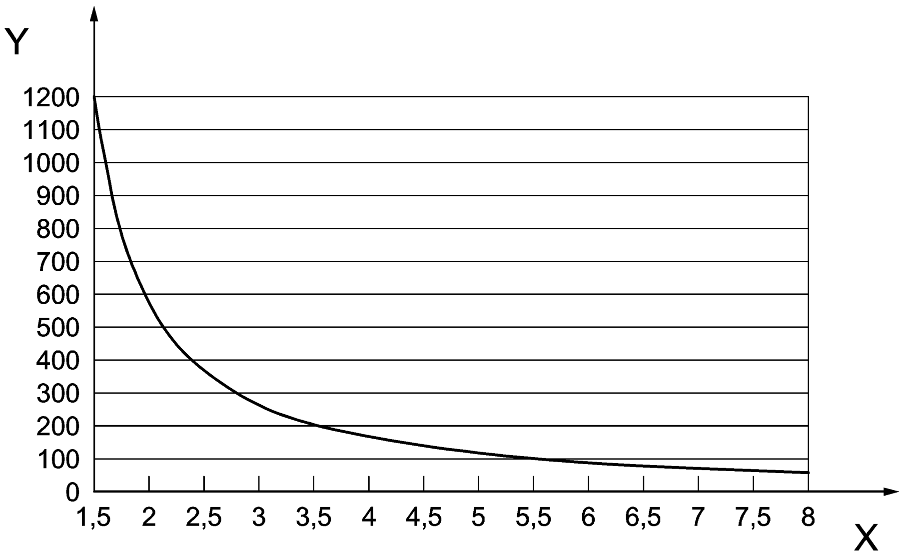
— the sound components diffracted by the edges of the noise barrier under test;

— the sound components reflected by the ground on the receiver or source side of the noise barrier under test.

For noise barriers having a height smaller than the length, the most critical component is that diffracted by the top edge and therefore the critical dimension is the height.

For noise barriers having a height smaller than the length, the low frequency limit f_{min} for sound insulation index measurements as a function of the height of the noise barrier under test is given in Figure 13. The graph holds for an acoustic barrier with negligible thickness; for noise barriers with a greater thickness, the low frequency limit assumes smaller values.

For qualification tests, the sample shall have the minimum dimensions specified in 5.3 (see Figure 7). These conditions give a low frequency limit for the sound insulation index of about 166 Hz, i.e. measurements are valid down to the 200 Hz one-third octave band. Measurement values below 166 Hz could be kept for information.



Key

X noise barrier height h_B [m]

Y low frequency limit f_{min} [Hz]

Figure 13 — Low frequency limit of sound insulation index measurements as a function of the height of the noise barrier under test

5.6 Positioning of the measuring equipment

5.6.1 Selection of the measurement positions

The measuring equipment shall be placed near the noise barrier to be tested in positions selected according to the following rules.

In any case, distances shall be measured with a relative uncertainty not greater than 1 % of their nominal values.

a) The loudspeaker is placed in the *source reference position* (see 3.11).

b) The measurement grid is located on the opposite side of the noise barrier under test (see 3.12).

c) If a single microphone is used, it is subsequently placed at each of the nine measurement points of the measurement grid and an impulse response is sampled at each measurement point.

When the microphone is in the central position of the measurement grid (Figure 3, position no. 5), the acoustic centre of the sound source and the acoustic centre of the microphone shall lie on the same horizontal line.

A “free-field” impulse response shall be measured for each microphone position, keeping the supporting frame with the same geometrical configuration of the set-up and without the barrier present (Figure 6).

The nine measurements taken on the measurement grid plus the corresponding free-field measurements shall be processed and averaged according to the sound insulation index Formula (1).

d) If a set of nine microphones supported by a rigid frame is used, it is placed at the nine scanning points on the other side of the device under test and the nine impulse responses are measured simultaneously or in sequence.

A “free-field” impulse response shall be measured for each microphone, keeping the supporting frame with the same geometrical configuration of the set-up and without the barrier present (Figure 6).

5.6.2 Post measurements

For noise barriers having intermediate posts, like acoustic barriers constituted by one or several acoustic elements supported by vertical posts at fixed distances, a set of nine measurements on the measurement grid plus a set of free-field measurements shall be performed both in the middle of a representative acoustic element, and in front of a representative post.

5.6.3 Additional measurements

If it is suspected that sound leaks may exist at a different position, e.g. at the bottom edge of the barrier under test, a further set of nine measurements on the measurement grid plus a set of free-field measurements can be performed placing the measuring equipment close to that position. In this particular case, the sound signal coming from the bottom edge is no more a “parasitic” signal: it is of course the “transmitted” signal one is looking for. The Adrienne temporal window shall then be enlarged so as to include this signal and to avoid other parasitic signals, on the basis of a geometrical computation to be shown on the test report. Amongst the possible parasitic signals, the ground reflection on the receiver side is not of concern, as the apparent sound source, i.e. the leak, is located on the ground.

5.6.4 Reflecting objects

Any object other than the device under test, shall be considered a reflecting object which could cause parasitic reflections (e.g. safety rails, fences, rocks, parked cars, etc.). These objects should remain as far as possible from the microphone(s) and in any case they shall be fully described in the test report.

Care shall be taken that the microphone stand does not influence the measurement.

5.6.5 Safety considerations

This test method may involve hazardous operations when measurements are made on or aside railways in use. This document does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices based on a risk assessment and determine the applicability of regulatory limitations prior to use.

5.7 Sample surface and meteorological conditions

5.7.1 Condition of the sample surface

Unless the measurement specifically aims at determining the influence of weather or other environmental conditions on sound propagation, measurements shall be carried out only when the sample surfaces is dry. If the sample surface can be expected to have a significant void content, then measurement shall not be made until it has been verified that the pores are dry.

The sample surface temperature shall be within 0 to 70 °C during the measurement.

5.7.2 Wind

Wind speed at microphone positions shall not exceed 5 m/s during the measurements.

5.7.3 Air temperature

The ambient air temperature shall be within (0 to 40) °C during the measurements. In calculations involving the sound speed value, its temperature-dependent value shall be taken, using the actual temperature value around the test area.

6 Measurement uncertainty

The uncertainty of results obtained from measurements according to this European Standard shall be evaluated, preferably in compliance with ISO/IEC Guide 98-3. If reported, the expanded uncertainty together with the corresponding coverage factor for a stated coverage probability of 95 % as defined in ISO/IEC Guide 98-3 shall be given. More information on measurement uncertainty is given in Annex A.

7 Measuring procedure

The measurement shall be carried out as follows:

a) the sample surface and meteorological conditions are checked to ensure they comply with the specifications in 5.7; if not, the measurement cannot be carried out;

b) the measuring equipment is placed on site as specified in 5.6; the safety considerations in 5.6.5 apply;

c) the test signal is selected;

d) the test signal is generated;

e) the total signal as received by the microphone(s) is sampled with a sample rate selected according to 5.5.2;

f) the total signal as received by the microphone(s) is processed in order to obtain the overall impulse response at the selected measurement position(s);

g) if it is suspected that the measurement may be contaminated by the background noise, the overall impulse response data are further averaged, until a given degree of accuracy is obtained in each one-third frequency band of interest; in any case, at least 16 averages shall be kept (see 5.4.3);

h) for each set of nine measurements on the measurement grid a corresponding set of free-field impulse responses with the measurement set-up in the free field is acquired;

i) the direct component from the sound source and the components transmitted through the device under test are isolated using Adrienne temporal windows (see 5.5.6 and 5.5.7);

j) the power spectra of the windowed signals are computed;

k) the sound insulation index is computed according to Formula (1);

l) if the single-number rating(s) for elements, for posts (if applicable) and globally are to be calculated, this shall be done in accordance to EN 16272-3-2;

m) the measurement uncertainty is evaluated (see Annex A);

n) the test report is written.

8 Test report

8.1 Expression of results

The test results shall be given in the form of a graph and a table, showing the values of the sound insulation index in one-third octave frequency bands between 100 Hz and 5 kHz. If it is not possible to get valid measurements results over the whole frequency range indicated, the results shall be given in a restricted frequency range and the reasons for the restriction(s) shall be clearly reported.

The values of the sound insulation index shall be rounded off to one decimal place.

The measurement uncertainty of the sound reduction index SI shall be given at all frequencies of measurement.

If the single-number rating(s) for elements, for posts (if applicable) and globally are to be calculated, this shall be done in accordance to EN 16272-3-2.

8.2 Further information

The test report shall contain (see Annex B):

a) reference to this document;

b) name and address of testing organization;

c) date and place of the test;

d) description of the test site: drawing or pictures showing the device under test, measurement set-up, reflecting or diffracting objects nearby the maximum sampled area (if any);

e) description of the noise barrier under test: brand, type, dimensions, age, actual conditions, composition (number of layers, thickness(es), material specification, etc.);

f) surface conditions of the noise barrier with regard to dryness and temperature;

g) meteorological conditions prevailing during the test (wind speed and direction, air temperature);

h) test arrangement, indicating, on a scale drawing or a sketch with dimensions marked on it, the reference positions of the source and the microphone and the number of measurements;

i) equipment used for measurement and analysis, including name, type, serial number and manufacturer;

j) type and characteristics of the anti-aliasing filter and sample rate of the sampling/analysis device;

k) length of the Adrienne temporal windows used for the analysis;

l) low frequency limit of the measurement and its relationship with the smallest dimension of the noise barrier under test (see 5.5.8);

m) result of measurements, including:

   1) result of measurements in front of an acoustic element;

   2) result of measurements in front of a post (if any);

   3) result of measurements at selected locations (if any);

n) measurement uncertainty;

o) single-number rating(s) of the above result(s), if calculated;

p) signature of the person responsible for the measurements.

Annex A
(informative)

Measurement uncertainty

A.1 General

The accepted format for expression of uncertainties generally associated with methods of measurement is that given in ISO/IEC Guide 98-3. This format incorporates an uncertainty budget, in which all the various sources of uncertainty are identified and quantified, from which the combined total uncertainty can be obtained.

The intention of this Annex is to provide a basis for the development of suitable information by which the ISO/IEC Guide 98-3 could be applied. However, the information in this annex has not been validated through round robin testing, and further research could reveal additional considerations. It remains the final responsibility of a laboratory performing a measurement to determine its uncertainty (which might be higher or lower than the data given) and this annex should only be regarded as a guide.

A.2 Expression for the calculation of sound insulation index

At the present stage, no information exists to develop an analytical model of the sound insulation index as a function of (many) input variables. Preliminary estimations show that the sound insulation index of a noise reducing device, SI_j, determined according to this European Standard, is a function of a number of parameters, indicated by the following Formula:

$$SI_j = \overline{SI}_j + \delta_1 + \delta_2 + \delta_3 + \delta_4 + \delta_5 + \delta_6 \quad \text{(A.1)}$$

where

$\overline{SI}_j$ is the time and space averaged sound insulation index in the *j*-th one-third-octave frequency band;

δ_1 is an input quantity to allow for any uncertainty in the incident reference component of the free-field impulse response acquisition;

δ_2 is an input quantity to allow for any uncertainty in the transmitted components of the impulse response acquisition;

δ_3 is an input quantity to allow for any uncertainty in the measuring equipment;

δ_4 is an input quantity to allow for any uncertainty due to the finite number of microphone and source positions;

δ_5 is an input quantity due to fluctuations in air temperature;

δ_6 is an input quantity due to fluctuations in air humidity.

A probability distribution (normal, rectangular, Student's t, etc.) is associated with each of the input quantities. Its expectation (mean value) is the best estimate for the value of the input quantity and its standard deviation is a measure of the dispersion of values. The uncertainty in the estimate of the input quantity is termed the standard uncertainty. It is a function of the standard deviation, probability distribution and number of degrees of freedom.

A.3 Contributions to measurement uncertainty

The combined uncertainty associated with the value of the sound insulation index depends on each of the input quantities, their respective probability distributions and sensitivity coefficients, c_i. The sensitivity coefficients are a measure of how the values of the sound insulation index are affected by changes in the values of the respective input quantities. Mathematically, these coefficients are equal to the partial derivatives of the function SI_j (Formula (A.1)) with respect to the relevant input quantities. The contributions of the respective input quantities to the overall uncertainty are then given by the products of the standard uncertainties and their associated sensitivity coefficients.

Table A.1 — Template for the uncertainty budget

Quantity	**Estimate**	**Standard uncertainty**	**Probability distribution**	**Sensitivity coefficient**
sound insulation index in the *j*-th one-third octave frequency band	$\overline{SI}_j$	$u\left(\overline{SI}_j\right)$	normal	
incident reference component of the free-field impulse response at the *k*-th scanning point	$h_{i,k,j}(t)$	δ_1		
transmitted component of the impulse response at the *k*-th scanning point	$h_{t,k,j}(t)$	δ_2		
uncertainty in the measuring equipment	-	δ_3		
uncertainty due to the finite number of microphone and source positions	-	δ_4		
uncertainty due to fluctuations in air temperature	-	δ_5		
uncertainty due to fluctuations in air humidity	-	δ_6		
Combined standard uncertainty	$u\left(SI_j\right)=\sqrt{\sum_{i=1}^{6}\left(c_i u_i\right)^2}$		normal	-
Expanded uncertainty (*k* is a coverage factor)	$U = k\,u$			-

For the case of negligible correlation between the input quantities, the combined standard uncertainty of the determination of the sound insulation index, $u(SI_j)$, is given by the following Formula:

$$u\left(SI_j\right)=\sqrt{\sum_{i=1}^{6}\left(c_i u_i\right)^2} \qquad \text{(A.2)}$$

The standard uncertainties from the various contributions remain to be established by research. An example of the type of information needed to derive the overall uncertainty of the method is given in Table A.1.

A.4 Expanded uncertainty of measurement

The ISO/IEC Guide 98-3 requires an expanded uncertainty, U, to be specified, such that the interval [$SI_j - U$, $SI_j + U$] covers e.g. 95 % of the values of SI_j that might reasonably be attributed to SI_j. To that purpose, a coverage factor, k, is used, such that $U = k\,u$. The coverage factor depends on the probability distribution associated with the measurand.

A.5 Measurement uncertainty based upon reproducibility data

In the absence of data for uncertainty contributions, values for the standard deviation of reproducibility, when available, may be used as an estimate of the combined standard uncertainty of determinations of sound insulation index. A value may then be selected for the coverage factor, and the product of the two will yield an estimate of the expanded measurement uncertainty, with the chosen coverage probability. By convention, a coverage probability of 95 % is usually chosen. To avoid any misinterpretations, the chosen coverage probability should always be stated in test reports together with the expanded measurement uncertainty.

The information on measurement reproducibility can be helpful towards the derivation of measurement uncertainties, but it is incomplete. In particular, it does not give an analysis of the various components of measurement uncertainty and their magnitudes.

Annex B
(informative)

Template of test report on airborne sound insulation of railway noise barriers

B.1 Template of test report

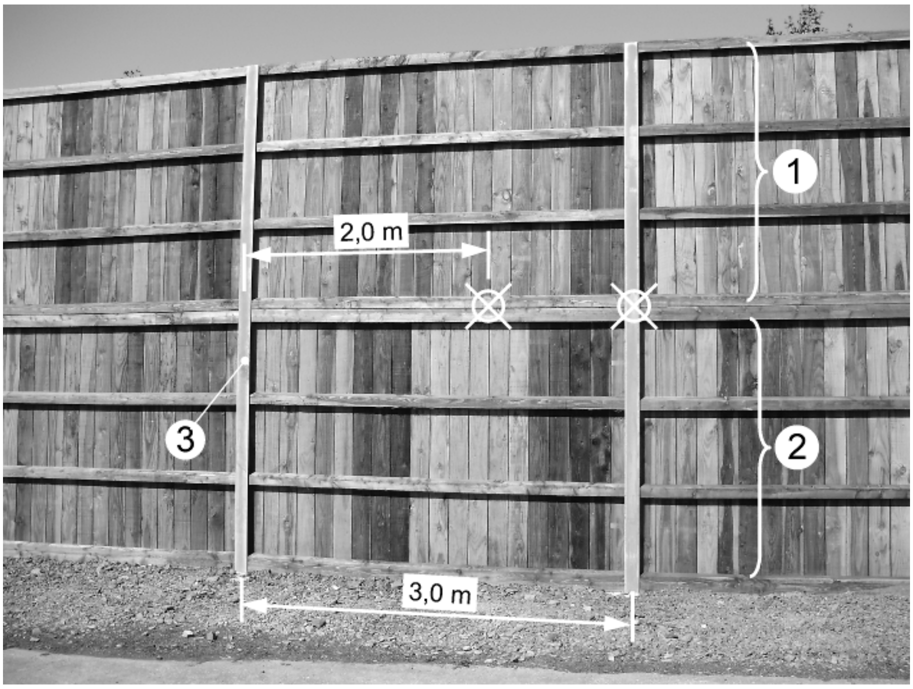
for product xxxx produced by the firm yyyyy

(a)	*Remark:* The present test is based on the test method according to CEN/TS 16272-5. If the single-number rating is to be calculated, this is done in accordance to EN 16272-3-2.
(b)	**Name and address of testing organization:**
(c)	**Date of test:** **Place of test:**
(d)	**Test situation:** see description and photographic presentation in B.1
(e)	**Test object** **Manufacturer:** **Type:** **Dimensions:** height, length, distance between support posts or ribs **Date of manufacture:** **Date of installation:** **Exposure classes according to** EN 60721-3-4**:** **Physical condition during test (by visual inspection):** **Composition:** see description and photographic presentation in B.2. Drawings and photographs clearly show how the product is built; include at least front view, side view, back view.
(f)	**Surface conditions of the test object** **Dryness:** **Temperature:**
(g)	**Meteorological conditions prevailing during the test** **Wind speed:** **Wind direction:** **Air temperature:**
(h)	**Test arrangement:** see description and photographic presentation in B.2. Note that this representation should include the exact positions of the microphone with respect to the sample e.g. showing the microphone positions opposite a ridge on a non-flat product.
(i)	**Equipment used for measurement and analysis** **Sound source:**

	Manufacturer: ***Type:*** ***Serial number:*** **Microphone:** ***Manufacturer:*** ***Type:*** ***Serial number:*** **Analyzer:** ***Manufacturer:*** ***Type:*** ***Serial number:***
(j)	**Filtering and sampling** **Type and characteristics of the anti-aliasing filter:** **Sample rate:**
(k)	**Adrienne temporal window** **Length:**
(l)	**Test frequency range** **Low frequency limit:** **Smallest dimension of the test object:**
(m)	**Test results:** see tables and figures in B.3
(n)	**Measurement uncertainty** **Combined standard uncertainty:** **Expanded uncertainty:** **Coverage factor:** **Confidence level:**
(o)	**Single-number rating (optional)** **The single-number rating for the sound reflection index amounts to:** **DL_{RI} = ___ dB**
(p)	**Signature of the person responsible for the measurements** **Name:** **Place, date:** .... **signature**

B.2 Test setup (example)

The barrier under test is a single-leaf, reflective timber barrier constructed in two sections, each section comprising 3,0 m wide x 2,0 m high panels, supported in between steel I-section posts which are at 3,0 m centres. This is representative of the construction arrangement used alongside highways. The overall dimensions of the test configuration are height = 4,0 m and width = 9,0 m. Figure B.1 shows the barrier viewed from the front (traffic side).



Key

1 upper panel (3 m wide x 2 m high)

2 lower panel (3 m wide x 2 m high)

3 I-section post

Figure B.1 — (Example) General view of test barrier (from front (rail) side) – Crosses mark measurement positions based on the post spacing of 3 m

The source is at a height of 2,0 m above the ground. The prescribed measurement grid is applied midway between posts and also in front of a post (the crosses in Figure B.1 show the approximate positions of the loudspeaker/centre microphone axis).

The barrier thickness at the height of measurement is 0,100 m midway between the posts and the post thickness at the height of measurement is 0,205 m.

There are no sound reflecting nor sound diffracting parasitic objects acting in the sample area.

The test situation including the loudspeaker and microphone array is shown in Figure B.2.

a)

b)

Figure B.2 — (Example) Test arrangement showing loudspeaker and microphone array when measuring across the panel

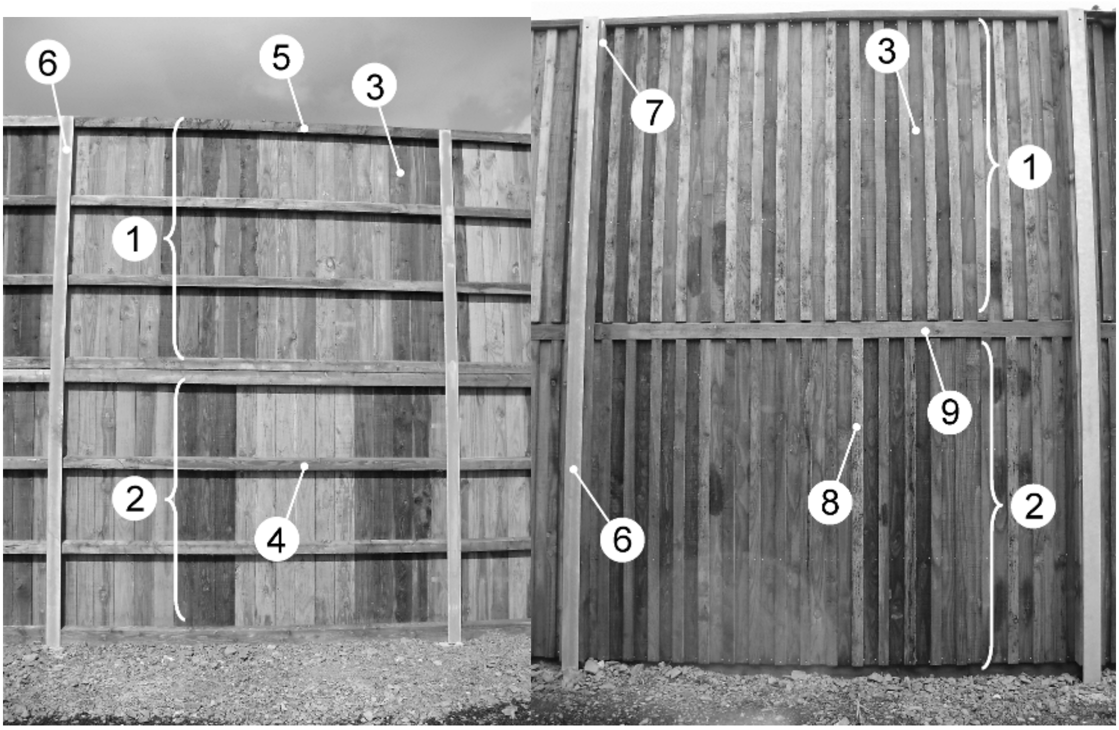
B.3 Test object and test situation (example)

Figure B.3 shows the basic composition of the single elements of this single-leaf reflective timber noise barrier. Each panel of the barrier is constructed from vertical timber fence boards held in position by horizontal rails on the rear. The expansion gaps in between the planks are covered on the front of the barrier by vertical cover strips. The panels are 3,0 m wide and 2,0 m high.

The barrier is constructed in two sections. On the front of the barrier, the joint between the upper and lower section is sealed by a wide horizontal cover strip.

The posts are steel ‘I-section’ columns with a width of 0,105 m and a depth of 0,205 m. The panels are held in place between the posts by means of large timber wedges at the rear.

The measuring points were on the rear of the barrier on a vertical measurement grid of 3 × 3 points with equal horizontal and vertical distances of 0,40 m. This measurement grid was located midway between the posts and in front of the centre of a post (the centre positions being approximately at the height of the joint between the upper and lower sections).



a) View of front of the barrier **b) View of rear of the barrier**

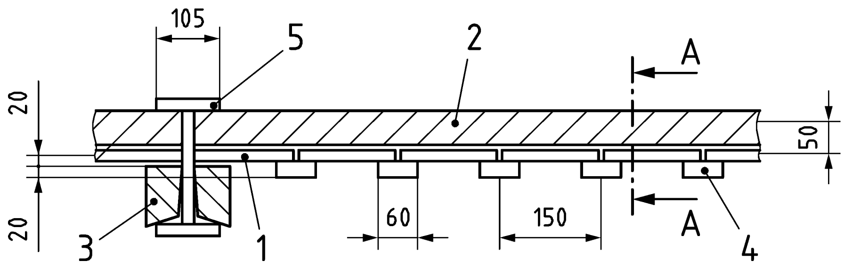
Key

1 upper panel
2 lower panel
3 main planks
4 horizontal rail
5 capping piece
6 I-section post
7 timber wedge
8 vertical cover strip
9 horizontal cover strip

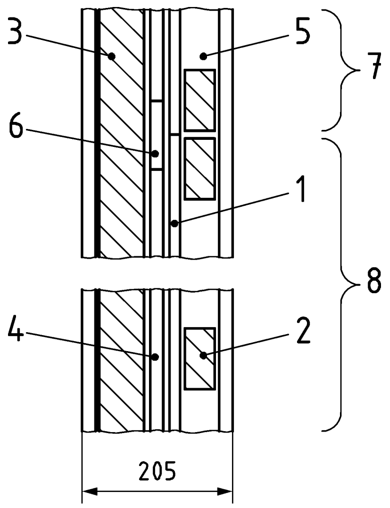
Figure B.3 — (Example) Basic composition of the single elements of the noise barrier

Figure B.4 shows a typical cross-section through the barrier, including the dimensions of the different elements.

Dimensions in millimetres



a) Plan view of noise barrier



b) Cross-section through A-A

Key

1 fence board
2 horizontal rail
3 timber wedge
4 cover strip
5 I-section post
6 horizontal cover strip at joint between upper and lower panels
7 upper panel
8 lower panel

Figure B.4 — (Example) Cross-section through noise barrier

B.4 Results (example)

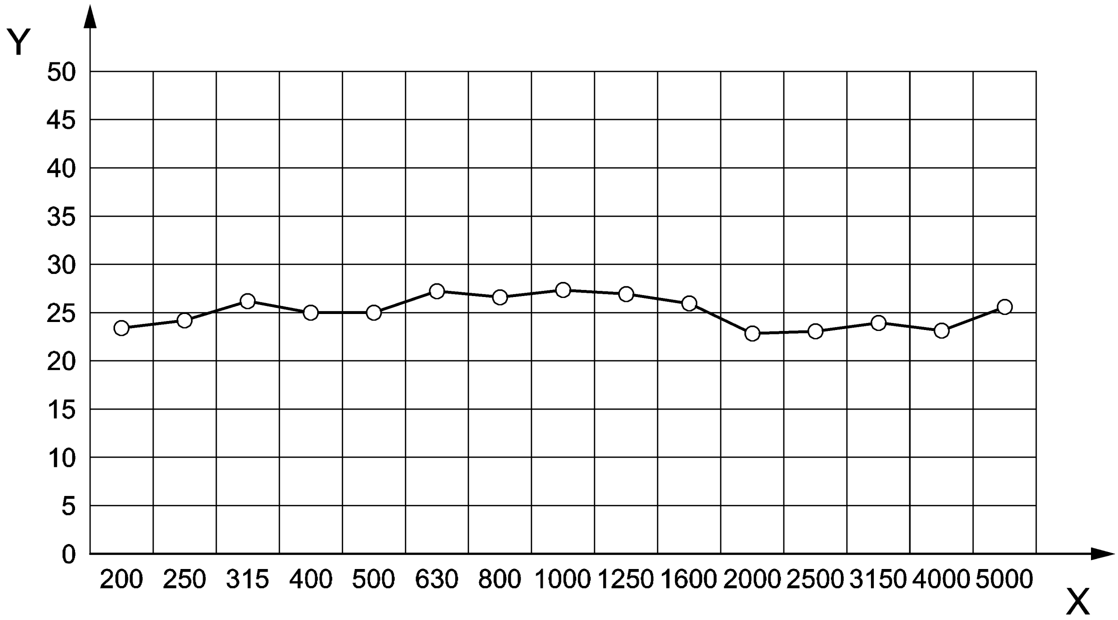
B.4.1 Part 1 – Results for 'element' in tabular form

Table B.1 — Results for 'element' in tabular form

Third-octave band centre frequency (Hz)	Particular values of sound insulation index *SI* for "element" for the 9 microphone positions and the logarithmic average									
	Particular values									Logarithmic average
	SI_1 dB	SI_2 dB	SI_3 dB	SI_4 dB	SI_5 dB	SI_6 dB	SI_7 dB	SI_8 dB	SI_9 dB	SI dB
200	24,5	23,5	23,9	24,3	25,1	22,3	21,9	24,4	22,6	23,5
250	25,1	29,3	20,8	25,8	31,4	22,9	22,1	31,4	23,5	24,4
315	25,2	25,9	23,1	29,5	26,1	28,8	24,8	30,5	27,1	26,2
400	30,5	27,9	30,1	21,9	21,7	22,0	28,7	30,9	28,6	25,3
500	30,2	22,3	28,8	24,5	23,6	22,7	25,9	23,9	32,7	25,0
630	25,7	23,7	26,2	34,7	33,0	35,3	27,4	25,3	29,7	27,4
800	25,0	24,8	27,3	24,3	25,1	28,9	30,3	27,6	32,0	26,6
1 000	32,3	30,5	31,7	21,4	25,8	27,6	29,9	27,7	35,9	27,3
1 250	30,9	30,2	28,3	23,5	23,0	28,6	27,9	29,7	36,0	27,2
1 600	25,8	26,3	29,1	24,3	27,1	28,0	26,0	23,4	28,5	26,1
2 000	20,7	27,0	20,2	22,7	28,5	30,3	25,1	21,1	22,9	23,1
2 500	22,0	28,1	26,2	28,0	26,3	27,5	20,5	19,2	23,0	23,3
3 150	23,0	26,5	26,4	26,7	28,2	28,7	21,0	21,4	23,3	24,2
4 000	23,1	22,5	21,3	29,4	33,3	29,8	22,3	21,4	21,6	23,4
5 000	29,2	27,1	30,6	30,1	30,6	28,7	23,0	23,9	20,7	25,6

Single number rating of airborne sound insulation for the acoustic element, $DL_{SI,E}$ = 26 dB.

B.4.2 Part 2 – Results for 'element' in graphic form



Key

X third-octave band centre frequency [Hz]

Y sound insulation index [dB]

Figure B.5 — Results in graphic form

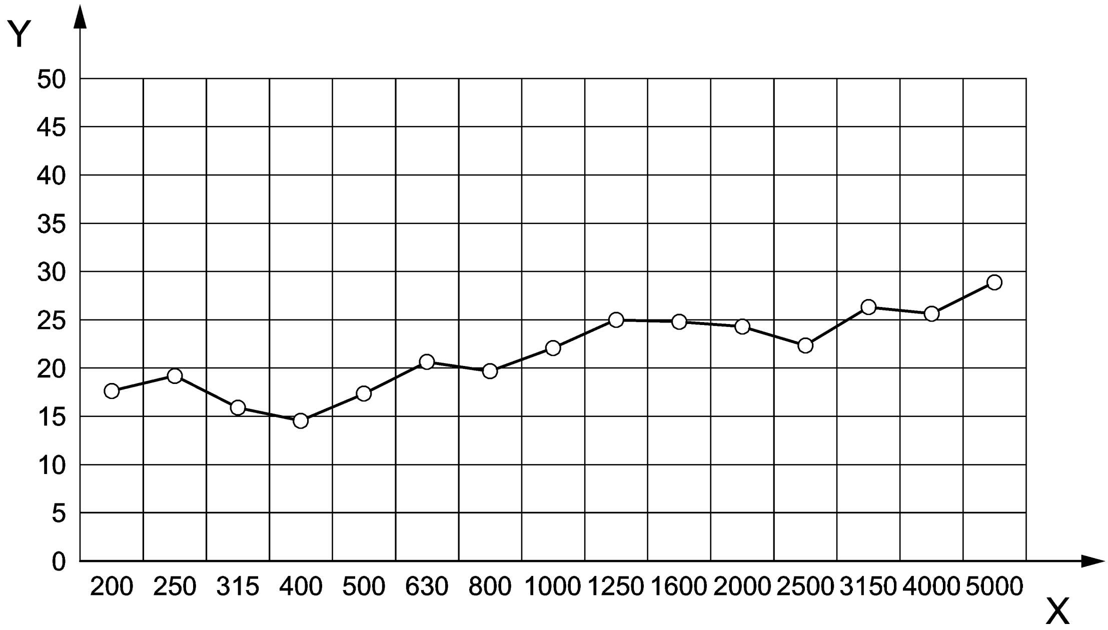
B.4.3 Part 3 – Results for ‘post’ in tabular form

Table B.2 — Results for ‘post’ in tabular form

Third-octave band centre frequency (Hz)	Particular values of sound insulation index SI for “post” for the 9 microphone positions and the logarithmic average									
	Particular values									Logarithmic average
	SI_1 dB	SI_2 dB	SI_3 dB	SI_4 dB	SI_5 dB	SI_6 dB	SI_7 dB	SI_8 dB	SI_9 dB	SI dB
200	15,6	16,2	19,3	15,9	16,8	18,9	18,7	17,0	24,2	17,5
250	15,3	17,0	22,3	16,0	18,0	21,9	24,0	19,1	33,1	18,8
315	13,3	13,5	19,7	14,9	15,2	24,6	18,9	14,7	36,4	16,2
400	13,9	12,6	21,3	13,7	13,0	20,1	14,6	13,0	23,7	14,8
500	19,0	18,9	26,3	14,1	14,7	24,6	15,9	19,5	19,9	17,7
630	18,3	16,2	27,3	22,6	19,9	27,9	24,6	20,4	23,9	20,8
800	19,0	19,2	20,2	20,4	19,6	20,1	19,8	19,6	27,0	20,1
1 000	19,5	25,2	26,1	19,2	20,9	20,2	27,5	23,7	26,9	22,2
1 250	21,4	28,2	23,9	27,7	26,8	21,5	23,8	34,7	28,7	24,9
1 600	18,7	30,6	33,2	23,8	31,0	24,9	22,5	30,9	28,0	24,6
2 000	20,3	25,7	21,7	25,0	29,0	27,4	22,1	29,5	29,2	24,3
2 500	22,4	20,5	21,2	27,9	31,2	27,5	26,6	18,7	25,8	23,0
3 150	24,1	28,4	26,4	28,8	31,5	27,9	27,2	30,3	23,3	26,8
4 000	30,0	30,0	27,8	29,2	30,6	27,1	28,5	24,6	19,7	25,9
5 000	33,7	32,1	28,0	30,6	34,0	32,0	30,2	27,9	24,9	29,4

Single number rating of airborne sound insulation for the post, $DL_{SI,P}$ = 21 dB.

B.4.4 Part 4 – Results for 'post' in graphic form



Key

X third-octave band centre frequency [Hz]

Y sound insulation index [dB]

Figure B.6 — Results in graphic form

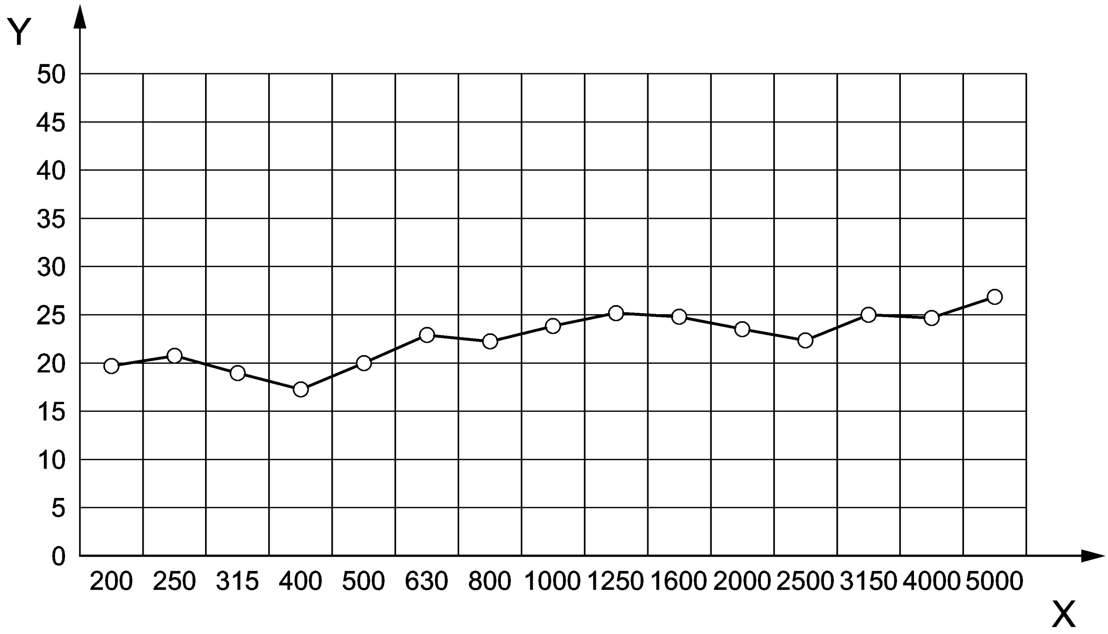
B.4.5 Part 5 – Results for global condition (average of 'element' and 'post') in tabular form

Table B.3 — Results for global condition in tabular form

Third-octave band centre frequency (Hz)	Particular values of sound insulation index *SI* for "global" condition (average of element and post) for the 9 microphone positions and the logarithmic average									
	Particular values									Logarithmic average
	SI_1 dB	SI_2 dB	SI_3 dB	SI_4 dB	SI_5 dB	SI_6 dB	SI_7 dB	SI_8 dB	SI_9 dB	SI dB
200	18,1	18,5	21,0	18,3	19,2	20,3	20,0	19,3	23,3	19,5
250	17,9	19,8	21,5	18,6	20,8	22,4	22,9	21,9	26,1	20,8
315	16,0	16,3	21,1	17,8	17,9	26,2	20,9	17,6	29,6	18,8
400	16,8	15,5	23,8	16,1	15,5	20,9	17,4	15,9	25,5	17,4
500	21,7	20,3	27,4	16,7	17,2	23,5	18,5	21,2	22,7	20,0
630	20,6	18,5	26,7	25,4	22,7	30,2	25,8	22,2	25,9	23,0
800	21,0	21,2	22,4	21,9	21,5	22,6	22,4	22,0	28,8	22,2
1 000	22,3	27,1	28,1	20,2	22,7	22,5	28,5	25,3	29,4	24,0
1 250	23,9	29,1	25,6	25,1	24,5	23,7	25,4	31,5	31,0	25,9
1 600	20,9	27,9	30,7	24,0	28,6	26,2	23,9	25,7	28,2	25,3
2 000	20,5	26,3	20,9	23,7	28,7	28,6	23,3	23,5	25,0	23,7
2 500	22,2	22,8	23,0	27,9	28,1	27,5	22,6	18,9	24,2	23,1
3 150	23,5	27,3	26,4	27,6	29,5	28,3	23,1	23,9	23,3	25,3
4 000	25,3	24,8	23,4	29,3	31,7	28,2	24,4	22,7	20,5	24,5
5 000	30,9	28,9	29,1	30,3	32,0	30,0	25,3	25,5	22,3	27,1

Global single number rating of airborne sound insulation for the test sample, $DL_{SI,G}$ = 23 dB.

B.4.6 Part 6 – Results for global condition (average of 'element' and 'post') in graphic form



Key:

X third-octave band centre frequency [Hz]

Y sound insulation index [dB]

Figure B.7 — Results in graphic form

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