PD CEN/TS 16272-7:2015

BSI Standards Publication

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

Part 7: Extrinsic characteristics — In situ values of insertion loss

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National foreword

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

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INS, RST and ENE speed conversions	
km/h	**mph**
5	3
100	60
200	125

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Railway applications - Track - Noise barriers and related devices acting on airborne sound propagation - Test method for determining the acoustic performance - Part 7: Extrinsic characteristics - In situ values of insertion loss

Applications ferroviaires - Voie - Dispositifs de réduction du bruit - Méthode d'essai pour la détermination des performances acoustiques - Partie 7 : Caractéristiques extrinsèques - Valeurs in situ de la perte par insertion

Bahnanwendungen - Oberbau - Lärmschutzwände und verwandte Vorrichtungen zur Beeinflussung der Luftschallausbreitung - Prüfverfahren zur Bestimmung der akustischen Eigenschaften - Teil 7: Fremdspezifische Merkmale - In-situ-Werte zur Einfügungsdämpfung

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Contents

Page

European foreword

This document (CEN/TS 16272-7:2015) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

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 Technical Specification is one 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* [currently at Enquiry stage];

— *Part 5: Intrinsic characteristics — In situ values of sound reflection under direct sound field conditions*;

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

— *Part 7: Extrinsic characteristics — In situ values of insertion loss* [the present document].

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: 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

The purpose of insertion loss measurements is to have an indication of the “efficiency” of the complete installation in attenuating noise from a technical point of view, *as is usually done with calculations.* The insertion loss is not intended to compare products; in fact, it is site-dependent, so that the same product may give different results when installed on different sites.

In order to be representative, these measurements need to be done in well-defined conditions regarding:

— the noise source (number and type of trains, speed, etc.);

— the meteorological window;

— the measurement time;

— the reference time, i.e. the time over which the measured insertion loss is evaluated based on the measurement results.

When it is not possible to carry out measurements before the construction of the noise barrier, an “equivalent” site is used for the “before” measurements.

The assessment of insertion loss limiting values is out of the scope of this Technical Specification.

1 Scope

This Technical Specification specifies methods for the determination of insertion loss of outdoor noise barriers intended to shield railway noise. It specifies detailed procedures for *in situ* measurement of barrier insertion loss including microphone positions, source conditions and acoustic environments of the measurement sites.

This Technical Specification allows one to measure the insertion loss of a given noise barrier at a given site including given meteorological conditions. It does not make it possible to compare insertion loss values of an equivalent barrier at a different site. It can be used for comparing insertion loss values of different types of barriers at the same site under given meteorological conditions by the "direct method".

This Technical Specification gives a method for determining insertion loss:

a) from the level difference before and after the installation of noise barriers (the "direct method");

b) when the direct method is not applicable, because a barrier has already been installed, using an "indirect method" to estimate the sound pressure levels before installation of the barrier by measurement at another site which has been judged to be equivalent.

For equivalent sites, a close match is required in source characteristics, microphone locations, terrain profiles ground surface characteristics, surrounding artificial structures and meteorological conditions. This Technical Specification prescribes principles for ensuring that sufficiently equivalent conditions are maintained between "before" and "after" cases to permit certain, reliable and repeatable determination of barrier insertion loss.

This Technical Specification does not cover the determination of the intrinsic acoustic characteristics of the barrier, for example the sound insulation index and the sound absorption coefficient.

The equivalent continuous A-weighted sound pressure level and one-third-octave band sound pressure level are used as noise descriptors.

This Technical Specification can be used for routine determination of barrier performance or for engineering or diagnostic evaluation. It can be used in situations where the barrier is to be installed or has already been installed.

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 60942, *Electroacoustics — Sound calibrators (IEC 60942)*

EN 61260, *Electroacoustics — Octave-band and fractional-octave-band filters (IEC 61260)*

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 purpose 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 and which will typically span between posts and also may overhang the railway

Note 1 to entry: Noise barriers are generally made of acoustic and structural elements (see 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 (see 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

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

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

3.6
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure to the square of the reference sound pressure, in decibels

Note 1 to entry: The reference sound pressure is 20 μPa. The frequency weighting or the width of the frequency band used will be indicated.

3.7
equivalent continuous sound pressure level
L_peqT
sound pressure level, in decibels, of a continuous steady sound that, within a measurement time interval T_p, has the same mean-square sound pressure as a sound under consideration whose level varies with time, and that is given by the following formula:

$$L_{\mathrm{peq},T_\mathrm{p}} = 10\lg\left[\frac{1}{T_\mathrm{p}}\int_{t_1}^{t_2}\frac{p^2(t)}{p_0^2}dt\right] \text{ dB} \quad (1)$$

where

t_1 and t_2	are times corresponding to the beginning and end of the train pass-by time interval, or the measurement duration in the case of source Type C (loudspeaker);
T_p	$= t_2 - t_1$;
$p(t)$	is an instantaneous sound pressure;
p_0	is the reference sound pressure (20 µPa)

Note 1 to entry: The frequency weighting or the width of the frequency band used is to be indicated; for example, equivalent continuous A-weighted sound pressure level L_{pAeqT}, equivalent continuous one-third-octave band sound pressure level, etc.

3.8
insertion loss of barriers
$\boldsymbol{D}_{IL}$
difference, in decibels, in sound pressure levels at a specified receiver position before and after the installation of a barrier provided that the noise source, terrain profiles, interfering obstructions and reflecting surfaces, if any, ground and meteorological conditions have not changed

Note 1 to entry: The frequency weighting or the width of frequency band and the time weighting used need to be indicated; for example, insertion loss of barrier corresponding to equivalent continuous A-weighted sound pressure levels (D_{ILA}).

3.9
background noise level
sound pressure level, in decibels, at a reference position or receiver position without any noise source in operation

3.10
source position
point at which the source is located (for stationary source), an area in which sources are located or move (for stationary and mobile sources), or a line along which sources are located or move (for stationary and mobile sources)

3.11
reference position
point at which the sound from the source is, or will be, minimally influenced by the installed barrier or planned barrier

Note 1 to entry: The reference position will be used to monitor the source level.

3.12
receiver position
point at which an insertion loss is to be determined

3.13
far field
region in which the sound pressure level for a simple point source decays six decibels per doubling of distance and, for an incoherent line source, three decibels per doubling of distance, without ground attenuation

3.14
train pass-by time period
time interval during which a train is passing in front of a location; it is equal to the time window between the instant t_1 when the train nose passes in front of the location, and the instant t_2 when the tail of the train passes in front of the same location

Note 1 to entry: The initial and final time instants of the train pass-by time interval can be detected by optical devices.

Note 2 to entry: The pass-by time window is given by Formula (2):

$$T_p = 3,6\frac{L}{v} \tag{2}$$

where

L is the train length in metres;

v is the train speed in km/h

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
$L_{peq,Tp}$	equivalent continuous sound pressure level during the train pass-by time interval	dB
D_{IL}	insertion loss of barriers	dB
H_S	source height	m
H_R	receiver height	m
H_B	barrier height	m
d_1	horizontal distance between source and barrier	m
d_2	horizontal distance between barrier and receiver	m
t_1	initial instant of the train pass-by time interval	s
t_2	final instant of the train pass-by time interval	s
T_p	train pass-by time interval	s
L	train length	m
v	train speed	km/h
$L_{ref,B}$	"before" sound pressure level at the reference position	dB
$L_{r,B}$	"before" sound pressure level at the receiver position	dB
$L_{ref,A}$	"after" sound pressure level at the reference position	dB
$L_{r,A}$	"after" sound pressure level at the receiver position	dB
C_r	correction factors for "hemi free-field" at receiver position	dB
C'_r	correction factors for "on reflecting surfaces" at receiver position	dB

5 Methods

5.1 General

This Technical Specification specifies two methods for the determination of insertion loss of outdoor noise barriers. The recommended method is the direct method. The alternative method is the indirect measurement method using measured "before" levels at an equivalent site.

The method to be adopted is chosen by considering several factors including the objectives of the measurement, the ability to make measurements prior to barrier installation, and the feasibility of equivalence of source, terrain profile, interfering obstructions and reflecting surfaces, if any, ground surface and meteorological conditions.

5.2 Direct measurement method

The direct method can only be used if the barrier has not yet been installed or can be removed for the "before" measurements. The sound pressure levels are measured at the reference and receiver positions for both "before" and "after" barrier installations. The same reference and receiver positions shall be used in both the "before" and "after" cases. Equivalence shall be established for sources, terrain profiles, interfering obstructions and reflecting surfaces, if any, ground surface and meteorological conditions.

5.3 Indirect measurement method

If the barrier has been installed and it cannot be readily removed to permit direct "before" measurement, an estimated "before" sound pressure level is obtained by measurement at a site that is equivalent to the study site.

Site equivalence refers to equivalence of the source, the terrain profiles, interfering obstructions and reflecting surfaces, if any, ground surface and meteorological conditions.

6 Instrumentation

6.1 Sound level meter and analyzer

Integrating averaging sound level meters meeting type 1 requirements of EN 61672-1 shall be used.

The measurement uncertainty shall always be estimated. In addition, a periodic verification of the instrumentation system shall be carried out in order to verify the conformity to the relevant specification standards. The interval between verifications shall be determined by the national standards or regulations in respective countries. At the beginning of the measurements, and following any warm-up time specified by the manufacturer, the overall sensitivity of the sound level meter shall be checked using a sound calibrator conforming to EN 60942. If necessary, it shall be adjusted according to the manufacturer's instructions. A further check shall be performed at the end of each measurement session. At least two measurement channels shall be used to permit simultaneous measurements at a reference and receiver position.

One-third-octave band filter sets, if used, shall meet the requirements of EN 61260.

6.2 Sound calibrator

A sound calibrator meeting the requirements of EN 60942 shall be used.

6.3 Windscreen

A windscreen as recommended by the manufacturer shall be used on each microphone during measurements.

6.4 Other instrumentation system

If other measurement systems are used, such as analogue or digital recorders or digital data acquisition systems, the system shall be verified to ensure it meets the requirements of the EN standards referenced above. The uncertainties associated with the use of the system shall be evaluated.

6.5 Meteorological equipment

An anemometer or other device for measuring wind speed and wind direction shall have a relative expanded uncertainty of not more than ± 10 %. The wind sampling rate shall be sufficient to represent wind conditions over the acoustic sampling period.

A thermometer or other temperature sensor for measuring ambient temperature shall have a relative expanded uncertainty of not more than ± 1 °C.

A hygrometer for measuring relative humidity shall have a relative expanded uncertainty of not more than ± 2 %.

A variable height support device is needed if wind and temperature profiles are being taken.

Attention should be given to the placement of meteorological sensors. Positioning at the height of the highest acoustic receiver is recommended.

7 Acoustic environment

7.1 General

To permit valid comparison of “before” and “after” sound pressure level measurements for insertion loss determination, the acoustic equivalence of terrain profile, interfering obstructions and reflecting surfaces, if any, ground and meteorological conditions between the “before” and “after” cases shall all be determined and shall be documented in the test report.

7.2 Terrain profile and ground surface equivalence

If the barrier has already been installed, measurements of the “before” levels shall be performed at sites acoustically equivalent to the actual “before” site.

The simulated “before” site is judged equivalent to the actual “before” site, if the following conditions are satisfied:

a) the simulated “before” site shall have a terrain profile, interfering obstructions and reflecting surfaces, if any, and ground surface acoustically equivalent to that of the real barrier site within a sector extending 60° on either side of the line connecting the receiver positions to the source position (area), so that similar sound propagation including ground reflection can be achieved;

b) the acoustic environment in the region within 30 m to the rear and to the side of the major receiver positions shall be equivalent;

c) the meteorological conditions shall be equivalent;

d) the rail traffic and the track conditions shall be equivalent.

These equivalencies shall also be preserved between “before” and “after” measurements in the direct method.

Ground surface equivalence shall preferably be described by determination of the specific ground impedance.

If the ground impedances cannot be determined, then it may be characterized (e.g. paved, long vegetation on packed or loose soil, short or no vegetation on loose or packed soil including sand, clay, gravel, etc.).

Extreme changes in the ground surface water content should be avoided.

7.3 Meteorological conditions

7.3.1 General

In order to provide measurement reproducibility some requirements of the meteorological conditions such as wind, temperature and cloud cover, are necessary.

7.3.2 Wind

Wind conditions are judged to be equivalent for the “before” and “after” acoustical measurements if the wind class (given in Table 2) remains unchanged and the vector components of the average wind velocity from the source to the receiver do not differ by more than 2 m/s.

In any case, no acoustical measurements shall be made when the average wind velocity exceeds 5 m/s, regardless of the direction. Strong wind with a small vector component in the direction of sound propagation should also be avoided because of the possibility of large errors due to wind fluctuation.

Table 2 — Class of wind conditions

Wind class	**Vector component of wind velocity** m/s
For all distances	
Downwind	+1 to +5
Calm	−1 to +1 [a]
For short distances	
Downwind	+1 to +5
Calm	−1 to +1
Upwind	+1 to −5
[a] Only in the case of temperature inversion.	

“Short distance” criteria are considered to apply when the following conditions are met:

— “before” measurement:

$$\frac{H_S + H_R}{d_1 + d_2} > 0,1 \qquad (3)$$

— “after” measurement:

$$\frac{H_S + H_B}{d_1} > 0,1 \quad (4)$$

$$\frac{H_B + H_R}{d_2} > 0,1 \quad (5)$$

where:

H_S is the source height, in m;

H_R is the receiver height, in m;

H_B is the barrier height, in m;

d_1 is the distance between source and barrier, in m;

d_2 is the distance between barrier and receiver, in m.

7.3.3 Temperature

There are no specific temperature requirements, provided that its value is recorded for each test. However, the “before” and “after” measurements shall be made with average temperatures within 10 °C of each other.

The air temperature gradient conditions as a function of the height above the ground, which influence noise propagation, shall be similar for the “before” and “after” acoustical measurements.

No attempt shall be made to adjust measured sound pressure levels based on the temperature data.

7.3.4 Humidity

Humidity affects predominantly high-frequency sources (major sound components over 3 kHz). Therefore, in principle “before” and “after” measurements should be restricted to equivalent conditions of relative humidity.

Calculations based on ISO 9613-1 air absorption data, using the reference spectrum in EN 16272-3-1, show that for source-receiver distances not greater than 25 m the overall sound level attenuation due to air absorption has a maximum value of 0,7 dB (at 10 % relative humidity). Therefore, for the purpose of this Technical Specification air humidity is not a critical issue.

No attempt shall be made to adjust measured sound pressure levels based on the humidity data.

7.3.5 Cloud cover

The “before” and “after” measurements shall be performed for the same class of cloud cover, as determined in Table 3.

Table 3 — Cloud cover class

Class	Description
1	Heavily overcast day or night (80 % cloud cover or more, for 100 % of the measurement time)
2	Moderately overcast day or night (50 % to 80 % cloud cover for at least 80 % of the measurement time)
3	Lightly overcast or sunny day or clear night (either with continuous sun or less than 50 % cloud cover for at least 80 % of the measurement time)
4	Clear night

7.3.6 Others

Measurements in rainy or snowy weather conditions shall be avoided.

7.3.7 Background noise

The sound pressure level of background noise including instrument noise should be 10 dB or more below the sound pressure level obtained from measurements.

The sound pressure level of background noise may be estimated on the basis of measurement results in the absence of source. If the difference between the sound pressure level from measurements and the background noise level is between 4 dB and 9 dB, a correction should be applied to the measurement results according to Table 4. If the difference between the sound pressure level from measurements and the background noise level is below 4 dB the measurement results are not valid.

Table 4 — Correction for background noise

Difference between measured sound pressure level with and without sound source, dB	Correction to be made to measured sound pressure with sound source, dB
4 and 5	−2
6, 7, 8, 9	−1

8 Sources and source equivalence

8.1 Source type

8.1.1 General

Three types of source can be used for the *in situ* determination of barrier insertion loss: source type A, B and C (see below). If source types A and B have insufficient sound power output to complete “after” measurements, type C sources should be used; for example this may happen when large distances, high background noise levels or high barriers are involved.

8.1.2 Source type A

The naturally occurring railway traffic for which the barrier is designed is normally the best source to be used for the purpose of this Technical Specification. Unless acoustic stability of the source can be clearly established and documented, continual monitoring of the source at the reference position during measurements is required.

8.1.3 Source type B

If conditions of the occurring railway traffic have changed, or are expected to change, between the “before” and “after” measurements, the use of railway traffic in controlled conditions should be considered. For example, if the railway traffic conditions such as number, type and speed of trains at a rail traffic noise barrier site is expected to change significantly, it may be necessary to select one or several test trains to be typical sources and to use them as a controlled natural source for the “before” and “after” measurements.

The source equivalence shall be estimated as described in 8.2.

8.1.4 Source type C

When “before”/“after” equivalence for source types A and B cannot be established, the indirect method shall be used. The same type of source shall be used for both the “before” and “after” measurements.

Source type C shall not be used for testing noise barriers along high speed lines, except at locations where trains are running at speeds lower than 200 km/h.

Source type C is a loudspeaker. It should have characteristics as close as possible to a point source and emit a noise spectrum according to EN 16272-3-2. The overall sound power level shall be at least 120 dB.

For a test of the directional radiation of a source, measure the sound pressure levels around the source at a fixed distance of about 1,5 m in a free field. The source shall be driven with a noise signal, and measurements made in one-third-octave bands. Measure the level difference between the energetic mean value for the arc of 360° (L_{360}) and the “gliding” mean values of all arcs of 30° ($L_{30,i}$). The directivity indices are:

$$DI_i = L_{360} - L_{30,i} \qquad (6)$$

Uniform omnidirectional radiation can be assumed if the DI_i values are within the limits of ± 2 dB in the frequency range from 100 Hz to 630 Hz. In the range of 630 Hz to 1 000 Hz, the limits increase linearly from ± 2 dB to ± 8 dB. They are ± 8 dB for frequencies of 1 000 Hz to 5 000 Hz.

Carry out the test in the different planes to ensure inclusion of the “worst case” condition. At least two perpendicular planes are needed.

The selected track(s) shall be specified. The loudspeaker shall be placed at a vertical height of 0,5 m above the mean rail head height of the selected track, mid-way between the two rails.

Unless stability of the source can be clearly established and documented, continual monitoring of the source during “before” and “after” measurements is required.

When a type C source (loudspeaker) is used it is recommended that the test sound be emitted intermittently in order to check the influence of background noise. This method is especially effective if the level of background noise fluctuates from time to time.

8.2 Source equivalence

8.2.1 General

For a valid determination of insertion loss, the source shall be equivalent for the “before” and “after” cases, that is, source characteristics shall be sufficiently similar so as not to introduce unacceptable error into the determination.

Source characteristics that affect the insertion loss include spectral content, directivity, spatial and temporal patterns and operating conditions, as well as the number and types of individual sources for composite sources.

NOTE This supposes in particular that the number, type and speed of trains are more or less the same for “before” and “after” acoustical measurements.

It is important to determine the key operating parameters that affect insertion loss and to determine allowable variations in these parameters. For this purpose, two steps shall be followed during the insertion loss determination:

— **step 1:** these key operational parameters shall be identified to establish whether or not any monitored variations are acceptable;

— **step 2:** the sound shall be monitored at a reference position as described in 8.2.3.

Source equivalence is less critical when one-third-octave band level measurements are being made than when A-weighted sound pressure levels are being measured for the determination of insertion loss.

8.2.2 Operational parameters

8.2.2.1 Train categories and speed classes:

The measured trains should be divided into categories and speed classes. The train categories are:

a) passenger trains exclusively with disc-braked coaches;

b) passenger trains with at least one cast iron block-braked coach;

c) freight trains.

If necessary, additional train categories can be chosen (e.g. high-speed trains, regional trains).

Each train category is to be further divided into speed classes, which are determined according to the following:

— for speeds below 100 km/h the deviation in speed from the mean value may amount to 5 % within the class;

— for speeds above 100 km/h the deviation in speed from the mean value may amount to 5 km/h within the class.

The rail traffic conditions shall be similar during the before and after measurements.

A minimum number of valid train pass-by measurements for the evaluation per train category and speed class shall be taken into account in order to have similar situations for the before and after measurements.

In order to ensure the statistical representativeness of the sample, the minimum number of valid train pass-by measurements is 10.

The track conditions shall be the same during the before and after measurements.

The speed of a train should be determined when entering as well as on leaving the test site. The measurement is only valid if the speed-difference between the two measurements is less than 5 %.

8.2.2.2 Loudspeakers:

The same loudspeaker, radiating the same sound power level, shall be used in both “before” and “after” measurements.

8.2.3 Reference microphone position

The reference position shall be chosen in such a way that an unaffected sound pressure level at the barrier position from the source to be used is obtained. The reference microphone shall be located at a point on a vertical plane including the barrier to monitor the source equivalence in both “before” and “after” measurements. The height of the reference microphone shall be at least 1,0 m above the top edge of the barrier. For complex-shaped barriers such as cupped barriers or berms, the reference microphone position shall be at least 1,0 m above the highest point on the barrier.

If the horizontal distance from the closer end of the source region to the barrier is less than 15 m, the reference microphone should be raised as high as possible in order that the elevation angle from the closer end of the source region to the reference microphone is 10° greater than to the top of the barrier.

9 Measurement procedure

9.1 General planning

9.1.1 Measurement

The measurement procedures are based on simultaneous measurements of sound pressure levels at the reference position and at the receiver positions chosen.

9.1.2 Receiver positions

The receiver positions are to be placed at nine locations, forming a grid, in order to measure the insertion loss of a given noise barrier at a given site including given meteorological conditions. This approach can be used for comparing insertion loss values of different types of barriers at the same site under given meteorological conditions by the direct method. It is not appropriate for the comparison of insertion loss values of an equivalent barrier at a different site.

For rail track and noise barrier both on flat ground, the receiver positions should be placed, if possible:

— at a distance from the nearest track centre of: 7,5 m, 12,5 m and 25 m;

— at a height above the mean rail head height of the nearest track of: 3,5 m, 6,0 m and 9,0 m.

Outside the receiver grid defined above, the insertion loss may be evaluated by calculation, provided that the calculation model has been validated against the measured values at the receiver grid positions. In this case, a table comparing measured and calculated values at the nine receiver positions shall be shown.

The receiver positions shall represent an open space behind the barrier (i.e. on the side of the barrier opposite to the source). The following are general guidelines for the choice of the receiver positions:

a) Hemi free-field conditions: Hemi free-field conditions are obtained if the distance between a receiver position and vertical sound reflecting surfaces is at least 30 m, or twice the barrier-receiver distance, whichever is shorter.

b) On reflecting surfaces: This applies to receiver positions directly attached to building surfaces. The wall surface shall be solid and sound-reflecting, and flat to within ± 0,05 m over a measuring area of at least 0,5 m × 0,7 m. A mounting plate of this size is usable in most cases when the façade surface is judged less suitable. The mounting plate shall be made of an acoustically hard and stiff material. The distance from the microphone to any other wall (or roof) surface edge shall be at least 1 m. The microphone shall be mounted as close to the surface as possible by using a cut-down microphone windscreen. The microphone axis shall be oriented vertically.

9.1.3 Quantities to be measured

Continuous equivalent sound pressure levels during the train pass-by, or during emission of the controlled spectrum of sound from the loudspeaker in the case of a Type C test, shall be measured at reference and receiver positions for all situations.

The frequency range of measurement shall be from 50 Hz to 5 000 Hz (one-third-octave bands). In some special cases when it is required to extend the frequency range of measurement to higher frequencies, measurements at 6 300 Hz, 8 000 Hz and 10 000 Hz (one-third-octave bands) are recommended. A-weighted sound pressure levels shall be measured or calculated from one-third-octave band data.

The time sampling interval shall be not greater than 20 ms.

9.2 Determination of barrier insertion loss

9.2.1 Direct measurement method

If the sound pressure levels can be measured directly in both "before" and "after" situations, this will give the directly-measured barrier insertion loss.

The barrier insertion loss, D_{IL}, is given by:

$$D_{IL} = \left(L_{ref,A} - L_{ref,B}\right) - \left(L_{r,A} - L_{r,B}\right) \tag{7}$$

where

$L_{ref,B}$ is the "before" sound pressure level at the reference position;

$L_{r,B}$ is the "before" sound pressure level at the receiver position;

$L_{ref,A}$ is the "after" sound pressure level at the reference position;

$L_{r,A}$ is the "after" sound pressure level at the receiver position.

9.2.2 Indirect measurement method

In many cases, the "before" sound pressure level has not been measured. It may be estimated by measurements at a substitute site that is equivalent to the barrier site prior to barrier installation. A measurement of this type gives an estimate of the barrier insertion loss which, however, may be less accurate than the barrier insertion loss determined according to the direct method in 9.2.1.

Reference position and receiver positions are the same as those of the direct method. However, in the indirect measurement methods, "before" sound pressure levels are measured at a substitute site that is essentially equivalent in terrain profile, ground conditions and source to the barrier site. Equivalence of measurement sites for "before" and "after" levels shall be checked carefully. The sound pressure level difference ΔL between the reference position and the receiver position is given, for the "before" and "after" conditions respectively, by:

$$\Delta L_B = L_{ref,B} - \left(L_{r,B} - C_r\right) \tag{8}$$

$$\Delta L_A = L_{ref,A} - \left(L_{r,A} - C'_r\right) \tag{9}$$

where:

$L_{ref,B}$ is the "before" sound pressure level at the reference position (equivalent site);

$L_{r,B}$ is the "before" sound pressure level at receiver position (equivalent site);

$L_{ref,A}$ is the "after" sound pressure level at reference position;

$L_{r,A}$ is the "after" sound pressure level at receiver position;

C_r and C'_r are correction factors for the type of receiver position:

for "hemi free-field": C_r = 0 dB and C'_r = 0 dB;

for "on reflecting surfaces": C_r = 6 dB and C'_r = 6 dB.

NOTE It is preferable to choose receiver positions where corrections C_r and C'_r are essentially the same.

The indirectly measured barrier insertion loss, D_{IL}, is given by:

$$D_{IL} = \Delta L_A - \Delta L_B \tag{10}$$

10 Measurement uncertainty

The uncertainty of results is obtained from measurements. 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.

11 Test report

11.1 Information to be recorded

11.1.1 Type of method

a) Direct measurement method, or

b) Indirect measurement method.

11.1.2 Instrumentation

a) Equipment used for measurements, including name, type, serial number and manufacturer.

b) Method used for evaluation and periodic verification of the microphones and other system components.

c) Type of windscreen.

11.1.3 Acoustic environment

a) Description of the test environment: drawings or pictures showing the terrain profile, the ground surface and the buildings, other reflecting objects around the source, receiver and barrier regions.

b) Air temperature and relative humidity.

c) Wind speed and direction. Class of cloud cover.

11.1.4 Sound source

a) Source type: A, B or C.

b) Verification of the source equivalence for the “before” and “after” measurements (when the sound source is represented by train pass-by measurements, a fully detailed report on rail traffic shall be provided, including train type, composition, length, brakes, loadings, speed, etc.).

11.1.5 Barrier to be tested

Description of barrier with drawing including size, thickness mass per unit area, added devices (if any) and material specifications including sound absorption coefficient, sound reduction index, sound reflection index, sound insulation index (if applicable).

11.1.6 Site layout

a) A plan view showing the source areas, receiver positions, barrier under test, any nearby sound reflectors and any other natural barriers.

b) For each receiver position, an elevation view constructed from the vertical plane including the receiver position and the source position, and showing the source position, the receiver position, the reference microphone position, the barrier under test, any nearby sound reflectors and any other natural barriers.

11.1.7 Acoustical data

All sound pressure level measurement results at reference position and receiver positions.

Insertion loss; octave-band or one-third-octave bands values and A-weighted.

11.2 Expression of results

The report shall include all the information listed in 11.1.

The report shall state whether or not the reported insertion losses have been obtained in full conformity with the requirements of this Technical Specification.

The mean insertion loss shall be reported to the nearest whole decibel. The insertion loss given in octave or one-third-octave bands shall be given in the form of a table and, preferably, a graph. For graphs with the level in decibels plotted against frequency on a logarithmic scale, the length for a 10:1 frequency ratio shall be equal to the length for 25 dB on the ordinate scale, e.g. one-third-octave shall correspond to 5 mm and 10 dB to 20 mm.

The measurement uncertainty of the insertion loss shall be given at all frequencies of measurement.

When the test includes verifications, the minimum and maximum insertion loss shall also be reported to the nearest whole decibel.

11.3 Further information

The test report shall contain:

a) reference to this Technical Specification;

b) the name and address of the organization which performed the measurements;

c) signature of the person responsible for the test;

d) date of the test.

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.

A.2 Measurement uncertainty based upon reproducibility data

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.

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 absorption coefficient. 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.

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