INTERNATIONAL STANDARD

ISO 3095

Third edition
2013-08-01

Acoustics — Railway applications — Measurement of noise emitted by railbound vehicles

Acoustique — Applications ferroviaires — Mesurage du bruit émis par les véhicules circulant sur rails

Reference number
ISO 3095:2013(E)

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Foreword

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

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The committee responsible for this document is the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 3095:2005), which has been technically revised.

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Introduction

Railway exterior noise is encountered both along open track and in and around depots, stops, stations and other holding locations. It includes a number of different physical sources such as rolling noise, impact noise, traction noise, aerodynamic noise, curving noise, braking noise, horn noise and noise from auxiliary equipment and other components. The noise for any given train type strongly depends on the rolling stock design, operating conditions and the track type and condition.

Rolling noise is one of the main sources which contain a significant and sometimes dominant noise contribution from the track. This International Standard is intended to characterize the noise emission from the unit, minimizing the influence of the track.

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Acoustics — Railway applications — Measurement of noise emitted by railbound vehicles

1 Scope

This International Standard specifies measurement methods and conditions to obtain reproducible and comparable exterior noise emission levels and spectra for all kinds of vehicles operating on rails or other types of fixed track, hereinafter conventionally called “unit”.

This International Standard is applicable to type testing of units. It does not include all the instructions to characterize the noise emission of the other infrastructure related sources (bridges, crossings, switching, impact noise, curving noise, etc.).

This International Standard is not applicable to:

— the noise emission of track maintenance units while working;

— environmental impact assessment;

— noise immission assessment;

— guided buses;

— warning signal noise.

The results may be used, for example:

— to characterize the exterior noise emitted by units;

— to compare the noise emission of various units on a particular track section;

— to collect basic source data for units.

NOTE 1 The type testing procedures specified in this International Standard are of engineering grade (grade 2), that is the preferred one for noise declaration purposes, as defined in ISO 12001. If test conditions (e.g. vehicle and/or track conditions, measuring conditions) are relaxed (e.g. as done for trackside monitoring of in-service trains), then the results are no longer of engineering grade.

NOTE 2 The procedures specified for accelerating and decelerating tests are of survey grade, see ISO 12001.

NOTE 3 Additional guidance is provided in Annex D for measurements in the specific case of light rail vehicles.

2 Normative references

The following referenced 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.

IEC 60942:2003, *Electroacoustics — Sound calibrators*

IEC 61260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters*

IEC 61260:1995/Amd. 1:2001, *Electroacoustics — Octave-band and fractional-octave-band filters — Amendment 1*

IEC 61672-1:2002, *Electroacoustics — Sound level meters — Part 1: Specifications*

IEC 61672-2:2003, *Electroacoustics — Sound level meters — Part 2: Pattern evaluation tests*

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EN 15461:2011, *Railway applications — Noise emission — Characterization of the dynamic properties of track sections for pass by noise measurements (includes Amdendment 1:2010)*

EN 15610:2009, *Railway applications — Noise emission — Rail roughness measurement related to rolling noise generation*

ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
train
single vehicle or a number of coupled vehicles/units operating on a guided ground transport system

Note 1 to entry: See Table 1.

Table 1 — Definitions of rolling stock formations

Articulated	Non-articulated
Vehicle - see unit. Unit - minimum operational formation of articulated cars.	Vehicle - any single car on its running gear. Unit - minimum operational formation comprising of one or more vehicles coupled together.
Train - refers to any formation which may operate in service, it may comprise of one or more units coupled together.	Train - refers to any formation which may operate in-service, may be either a single unit or one or more units coupled together.

[SOURCE: EN 13452-1:2003]

3.2
car
single non-articulated element of a railbound vehicle or unit

3.3
type test for noise emission of railbound units
one or more tests performed to prove that a product is capable of conforming to all relevant requirements of a specification

[SOURCE: ISO 12576-1:2001, 3.27, modified — for noise emission of railbound units has been added.]

3.4
environmental impact assessment test
measurement performed for collecting data to be used in a prediction method for environmental assessment

3.5
acoustic rail roughness
r(x)
variation of the height of the rail running surface associated with rolling noise excitation, expressed as a function of distance *x* along the rail

Note 1 to entry: Acoustic rail roughness is expressed in μm.

[SOURCE: EN 15610:2009]

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3.6
acoustic roughness spectrum
$\tilde{r}(\lambda)$
amplitude of the acoustic roughness expressed as a function of the wavelength λ

Note 1 to entry: Acoustic roughness spectrum is expressed in µm and usually presented in terms of acoustic roughness level $\tilde{L}_r$ in dB re 1 µm.

[SOURCE: EN 15610:2009]

3.7
track decay rate
rate of attenuation of vibration amplitude of either vertical or lateral bending wave motion in the rail as a function of the distance along the rail

Note 1 to entry: It is represented by a one-third octave spectrum of values expressed in decibels per metre (dB/m) representing attenuation over distance.

[SOURCE: EN 15461:2011 and Amd. 1:2010]

3.8
test section
specific section of track associated with a particular set of measurements

[SOURCE: EN 15610:2009]

3.9
reference track section
portion of track on which the track decay rates and the acoustic roughness levels are controlled

3.10
sound pressure
p
difference between instantaneous total pressure and static pressure

Note 1 to entry: The quantity refers also to the rms value.

[SOURCE: ISO 80000-8:2007]

3.11
sound pressure level
L_p

$$L_p = 10 \lg \left(\frac{p}{p_0} \right)^2 \text{ dB}$$

where p is the sound pressure and the reference value in airborne acoustics is p_0 = 20 µPa.

Note 1 to entry: Because of practical limitations of the measuring instruments, p^2 is always understood to denote the square of a frequency-weighted, frequency-band-limited or time weighted sound pressure or both. If specific frequency and time weightings, as specified in IEC 61672-1:2002, or specific frequency bands or both are applied, this should be indicated by appropriate subscripts.

[SOURCE: ISO 80000-8:2007, modified — year added to IEC 61672-1 in Note 1 to entry]

3.12
AF-weighted sound pressure level history
$L_{p\mathrm{AF}}(t)$
A-weighted sound pressure level as a function of time with time weighting F (fast)

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3.13
AF-weighted maximum sound pressure level
$L_{\boldsymbol{p}\mathrm{AFmax}}$
maximum value of the A-weighted sound pressure level determined during the measurement time interval T by using time weighting F (fast)

[SOURCE: IEC 61672-1:2002]

3.14
A-weighted equivalent continuous sound pressure level
$L_{\boldsymbol{p}\mathrm{Aeq},\boldsymbol{T}}$
A-weighted sound pressure level given by the following Formula:

$$L_{p\mathrm{Aeq},T} = 10\,\lg\left(\frac{1}{T}\int_0^T \frac{{p_\mathrm{A}}^2(t)}{{p_0}^2}dt\right)\mathrm{dB}$$

where

$L_{p\mathrm{Aeq},T}$	is the A-weighted equivalent continuous sound pressure level in dB;
T	is the measurement time interval in s;
$p_\mathrm{A}(t)$	is the A-weighted instantaneous sound pressure at running time t in Pa;
p_0	is the reference sound pressure; p_0 = 20 μPa.

Note 1 to entry: Adapted from ISO 1996-1:2003.

3.15
impulsive sound
noise characterized by one or more brief bursts of sound pressure and is such that the duration of a single impulsive noise is usually less than 1 s

Note 1 to entry: Adapted from ISO 1996-1:2003.

Note 2 to entry: This definition does not apply to a whole pass-by event.

Note 3 to entry: Examples of impulsive noise sources: Blowoff valves, relay switches.

3.16
intermittent sound
noise that occurs at regular or irregular time intervals and is such that the duration of each such occurrence is more than about 5 s

Note 1 to entry: Adapted from ISO 1996-1:2003.

Note 2 to entry: This definition does not apply to a whole pass-by event.

Note 3 to entry: Intermittence should be assessed relatively to the duration of the event.

Note 4 to entry: Examples: compressor, cooling fans.

3.17
tonal sound
sound characterized by a single frequency component or narrow-band components that emerge audibly from the total sound

[SOURCE: ISO 1996-1:2003]

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4 Instrumentation and calibration

4.1 Instrumentation

Each component of the instrumentation system shall meet the requirements for a class 1 instrument specified in IEC 61672-1:2002.

In the case of measurements of survey grade this requirement is relaxed to class 2 instruments.

The sound calibrator shall meet the requirements of class 1 according to IEC 60942:2003.

Microphones with free field characteristics shall be used. A suitable microphone windscreen shall always be used.

Where one-third octave frequency band analysis is required, the filters shall meet the requirements of class 1, according to IEC 61260:1995.

The compliance of the calibrator with the requirements of IEC 60942:2003 shall be verified at least once a year. The compliance of the instrumentation system with the requirements of IEC 61672-1:2002 and IEC 61672-2:2003 shall be verified at least every 2 years. The date of the last verification of the compliance with the relevant standards shall be recorded.

4.2 Calibration

Before and after each series of measurements, a sound calibrator shall be applied to the microphone(s) for verifying the calibration of the entire measuring system at one or more frequencies over the frequency range of interest. If the difference between two consecutive calibrations is more than 0,5 dB, all of the measurement results in between shall be rejected.

5 Stationary test

5.1 General

The noise emitted by a stationary unit depends upon its operating conditions. These will differ according to the situation. The measurements shall be carried out only if noise sources are present at standstill with the operating conditions specified in 5.4.

NOTE For freight wagons, stationary tests are relevant only when auxiliary devices such as engines, generators, or cooling systems are present. This is mostly applicable, e.g. on refrigerated wagons.

5.2 Environmental conditions

5.2.1 Acoustical environment

In the triangular area between the track and the microphone extending along the track to a distance twice the microphone distance to either side, the test site shall be such that free sound propagation exists. To achieve this result:

— The level of the ground surface over this area shall be within 0 m to −2 m, relative to the top of rail;

NOTE The level of the ground and the nature of the ground surface can affect the spectral content of the measured sound.

— This area shall be free of sound absorbing matter such as lying snow, tall vegetation, and free of reflective covering such as water, ice, tarmac or concrete. No absorptive material shall be added to the propagation path for the purpose of the test;

— No person shall be present in this area, and the observer shall be in a position that does not influence the measured sound pressure level significantly;

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— The presence of other tracks is permissible in this area as long as the ballast bed height does not exceed the height of the rail surface of the test track.

Additionally, an area around the microphones having a radius which is at least three times the measurement distance shall be free of large reflecting objects like barriers, hills, rocks, bridges, buildings or other vehicles.

5.2.2 Meteorological conditions

The following weather parameters shall be recorded at representative times during the noise measurement exercise: wind speed and direction at the level of the highest microphone, temperature, humidity, barometric pressure. Any observed precipitation shall be noted.

NOTE Heavy rain or wind speed higher than 5 m/s can affect the background noise, see 5.2.3.

5.2.3 Background sound pressure level

Care shall be taken to ensure that the noise from other sources (e.g. other vehicles or industrial plants and due to wind) does not influence the measurements significantly.

The maximum value of $L_{p\text{Aeq},T}$ T = 20 s of background noise over all microphone positions shall be at least 10 dB below the final result (energy-mean of all the measuring positions, see 5.5.1.1, calculated according to 5.8.1) obtained when measuring the noise from the unit in the presence of background noise. For frequency analysis, this difference shall be at least 10 dB in each frequency band of interest.

5.3 Track conditions

The measurements shall be performed on ballasted track.

5.4 Vehicle conditions

5.4.1 General

Air management systems, including grilles, filters and fans, shall be clear of any obstruction.

During the measurements, the doors and windows of the unit shall be kept closed.

In the case of multi-voltage vehicles or units, the measurements shall be performed under the voltage system which is expected to produce the highest noise level.

NOTE If a unit is designed for AC and DC supply then the AC mode is usually the noisier one.

In the case of dual-mode vehicles or units (diesel and electric) the measurements shall be performed under both modes.

5.4.2 Normal operating conditions

The measurements shall be carried out in normal operating conditions defined as follows:

— All equipment that operates continuously when the unit is stationary shall be operating at normal load, which is the performance at an external temperature of 20°C. For heating, ventilating and air conditioning (HVAC) systems conditioning passenger areas and working places as well as system supplying energy for this function, climate influence parameters shall be set at: wind speed at 3 m/s, relative humidity at 50 %, 700 W/m^2 energy from sun radiation, one person per seat.

  NOTE 1 These settings are derived from EN 14750-1,[14] EN 14813-1,[15] and EN 13129-1[[11]] which apply to middle Europe (zone II).

— Traction equipment shall be in a stationary thermal condition with cooling equipment working at minimum condition. For units with internal combustion engines, the engine shall be idle.

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— Operational parameters in order to simulate these normal operating conditions shall be documented in the report.

NOTE 2 These parameters can be provided by the manufacturer.

5.4.3 Additional operating conditions

It is permissible to measure at other vehicle conditions, if required. For instance, to assess other load conditions or intermittent operation. In this case, these conditions shall be reported.

5.5 Measurement positions

5.5.1 Standard measurement positions

5.5.1.1 Measurement mesh

Each car (a multiple unit comprises a number of cars) shall be divided into equally distributed areas, each having an identical horizontal length, l_X, of between 3 m and 5 m. The length of the car is the distance between couplers or buffers or between structure ends in the case of a structure that surrounds couplers and buffers. Each measurement position is located at midlength along the relevant area on both sides of the car. Extra measurement positions shall be taken at the front and rear end of the unit: two microphones located at 30° from the centreline of the track, on a half circle having its centre in the midpoint of the unit end (including couplers or buffers) and a radius equal to 7,5 m, as illustrated in Figure 1. In the case of a trailer unit, these extra positions shall be measured only at ends which are equipped with a cab.

Each measurement position shall be located at a distance of 7,5 m from the centreline of the track at a height of 1,2 m above the upper surface of the rail.

The microphone axis shall be horizontal and directed perpendicularly to the contour of the unit.

5.5.1.2 Reduction of the number of measurement positions

Redundant measurements may be omitted, considering that some measurement positions are equivalent (and will lead to similar noise levels), in the following cases:

— If both sides of the unit are acoustically identical (i.e. with a symmetrical distribution of noise sources), then it is permissible to omit the measurement positions on one side of the unit;

— If several cars of the same type are present within a multiple unit or a fixed formation train, it is permissible to measure each type of car once.

The reduction of the number of measurement positions shall be justified in the report. Omitted positions shall be listed and their assumed equivalent location identified.

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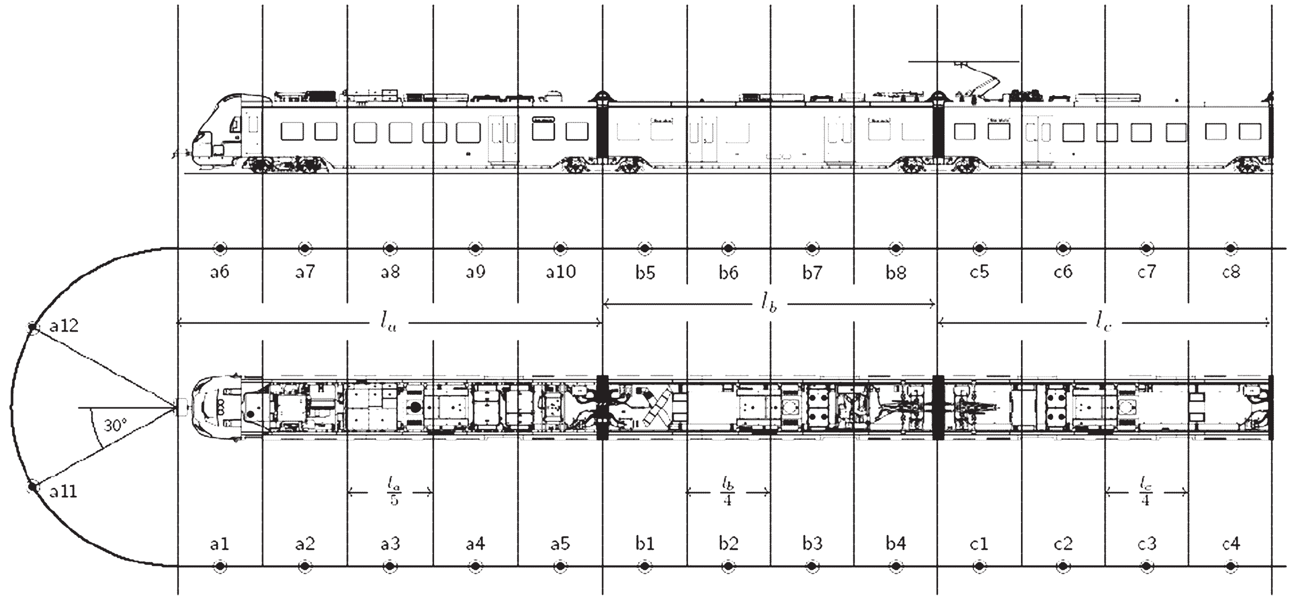

Figure 1 — Example of a mesh of measurement positions for the stationary noise measurement of a multiple unit

5.5.2 Additional measurement positions

If important sound sources are present in the upper part of the unit under test (e.g. with power units or low floor rolling-stock), a second mesh of measurement positions at a distance of 7,5 m from the centreline of the track at a height of 3,5 m above the top of rails is recommended.

If an assessment of single noise sources (e.g. converters, air compressor, doors) is required, additional measurement positions may also be located directly opposite the individual noise sources considered to be relevant, at a distance of 7,5 m from the centreline of the track and at a height of 1,2 m or 3,5 m.

This information is not to be included in the averaging process described in 5.8.1.

5.6 Measured quantities

The basic measured acoustic quantity is $L_{p\text{Aeq},T}$, with T = 20 s. If required other acoustic quantities such as frequency spectrum, $L_{p\text{AFmax}}$, tonality, impulsiveness may be determined.

5.7 Test procedure

The unit shall be stationary.

At least three valid measurement samples at each position are required, taken either sequentially at each position or sequentially from position to position. The validity of the measurements shall be assessed against the background sound pressure level, see 5.2.3, and the acceptable spread of the measurement samples, see 9.3.

The measurement time interval T shall be at least 20 s. If, however, as an exception it is not possible to maintain the source of noise at its nominal load for 20 s, the measurement time interval T may be reduced to a minimum of 5 s. This reduction shall be specified and justified in the test report.

Where additional measurements are required for equipment that works intermittently, the measurement shall be carried out during an operating cycle including the start-up, the steady state and the shut down. The duration of the operation shall then be registered.

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5.8 Data processing

5.8.1 Standard processing

The standard processing shall only include the results from the standard measurement positions (height of 1,2 m).

For each set of measurements (one sample at each position), the noise levels $L^i{}_{p\text{Aeq},T}$ measured at all positions i shall be energy averaged as follows to derive a single noise indicator representative of the unit:

$$\left\langle L_{p\text{Aeq},T} \right\rangle_{\text{unit}} = 10\lg\left(\sum_{i=1}^{n} \frac{l_i}{l_{\text{tot}}} 10^{L^i_{p\text{Aeq},T}/10} \right) \tag{1}$$

where

$L^i{}_{p\text{Aeq},T}$ is the sound pressure level measured at the measurement position i;

n is the number of measurement positions;

l_i is the length associated with the measurement position i. For the additional measuring positions at the front, this length is equal to (π/2) × 7,5 m.

$$l_{\text{tot}} = \sum_{i=1}^{n} l_i \tag{2}$$

The n measurement positions used in the summation shall correspond to the whole mesh defined in 5.5.1.1, before any possible reduction, see 5.5.1.2. Where appropriate, the noise levels of measured equivalent positions shall be assigned to omitted positions.

A $\left\langle L_{p\text{Aeq},T} \right\rangle_{\text{unit}}$ shall then be produced for each of the three sets of measurements.

The test result shall be the arithmetic mean of the $\left\langle L_{p\text{Aeq},T} \right\rangle_{\text{unit}}$ values, rounded to the nearest integer decibel.

The individual $\left\langle L_{p\text{Aeq},T} \right\rangle_{\text{unit}}$ as well as the mean shall be presented in the report. In addition, the full set of $L^i{}_{p\text{Aeq},T}$ measured at all measurement positions shall be presented in the report.

5.8.2 Additional processing

If important sources are present in the upper part of the unit under test, a $\left\langle L_{p\text{Aeq},T} \right\rangle_{\text{unit}}$ should also be determined for the secondary measurement mesh position at a height of 3,5 m.

If required, the noise emission level of a single car within a unit shall be calculated by energy averaging the $L^i{}_{p\text{Aeq},T}$ corresponding to that car only according to Formula (3):

$$\left\langle L_{p\text{Aeq},T} \right\rangle_{\text{car}} = 10\lg\left(\sum_{i=1}^{n_{\text{car}}} \frac{l_i}{l_{\text{tot car}}} 10^{L^i_{p\text{Aeq},T}/10} \right) \tag{3}$$

where n_{car} is the number of measurement positions for the car.

If an assessment of single noise sources is required, the arithmetic mean of the three samples of $L_{p\text{Aeq},T}$ measured at specific positions should be determined. Moreover, in the case of intermittent sources, the $L_{p\text{Aeq},T}$ should be calculated over the duration of the operating cycle. Additionally, the maximum noise level may be determined using the $L_{p\text{AFmax}}$.

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When spectra are required, they should be supplied in one-third octave bands in the range of at least 31,5 Hz to 8 000 Hz.

If an assessment of tonality is required, the tonal difference (ΔL) shall be calculated.

NOTE ΔL can be calculated according to ISO 1996-2:2007,[3] Annex C or DIN 45681:2005,[10] the latter standard providing more detailed guidance on application especially for non stationary sounds.

If an assessment of the impulsive character of the sound is required, it shall be calculated according to Annex A.

6 Constant speed test

6.1 Environmental conditions

6.1.1 Acoustical environment

In the triangular area between the track and the microphone extending along the track to a distance twice the microphone distance to either side, the test site shall be such that free sound propagation exists. To achieve this result:

— The level of the ground surface over this area shall be within 0 m to −2 m, relative to the top of rail;

NOTE The level of the ground and the nature of the ground surface can affect the spectral content of the measured sound.

— This area shall be free of other tracks, of sound absorbing matter such as lying snow or tall vegetation, and free of reflective covering such as water, ice, tarmac or concrete. No absorptive material shall be added to the propagation path for the purpose of the test;

— No person shall be present in this area, and the observer shall be in a position that does not influence the measured sound pressure level significantly.

Additionally, an area around the microphones having a radius which is at least three times the measurement distance shall be free of large reflecting objects like barriers, hills, rocks, bridges or buildings.

6.1.2 Meteorological conditions

The following weather parameters shall be recorded at representative times during the noise measurement exercise: wind speed and direction at the level of the highest microphone, temperature, humidity, barometric pressure. Any observed precipitation shall be noted.

NOTE Heavy rain or wind speed higher than 5 m/s can affect the background noise, see 6.1.3.

6.1.3 Background sound pressure level

Care shall be taken to ensure that the noise from other sources (e.g. other vehicles or industrial plants and due to wind) does not influence the measurements significantly.

The maximum value of the $L_{pAeq,T}$ $T = 20$ s of background noise over all microphone positions shall be at least 10 dB below the $L_{pAeq,Tp}$ obtained when measuring the noise from the unit in the presence of background noise. For frequency analysis this difference shall be at least 10 dB in each frequency band of interest.

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6.2 Track conditions

6.2.1 General

The noise emission contains contributions from the rolling stock and the track. Therefore noise emission values are only comparable between sites where the track parameters are controlled to make them equivalent in terms of acoustic performance.

Default specifications for these parameters, i.e. the acoustic roughness of the rail surface and the vertical and lateral dynamic responses of the track, are supplied hereafter. They ensure that the measurement procedure is of engineering grade and that the influence of the track from roughness or dynamic response on the vehicle type test result is minimized.

NOTE 1 All the track specifications contained within Clause 6 apply specifically to the situation where the unit has steel wheels running on steel rails.

NOTE 2 Annex E presents a procedure to assess whether two test situations can be considered to provide comparable test conditions in terms of acoustic roughness.

NOTE 3 Where other track specifications are used for noise emission measurements of railway units, they can lead to test site dependent results. However, they can be of interest e.g. for measurement on specific types of network or monitoring purposes. In such cases it is advisable to measure the track parameters and to supply them together with the noise measurements.

The reference track shall have a consistent superstructure over a minimum length of twice the microphone distance to either side. This includes geometry of the line, track quality, acoustic rail roughness and track decay rates as described hereafter.

NOTE 4 In some situations inconsistency of the track superstructure such as gauge variations or curves further up the reference track section can increase the noise emission at the measuring position.

6.2.2 Geometry of the line

The radius of curvature r of the track shall be:

a) $r \geq 1\,000$ m for tests at train speed $v \leq 70$ km/h;

b) $r \geq 3\,000$ m for tests at train speed $70 < v \leq 120$ km/h;

c) $r \geq 5\,000$ m for tests at train speeds $v > 120$ km/h.

Where powered units are tested, the level gradient at the track shall be 5:1 000 at the most.

6.2.3 Track superstructure

The standard superstructure for the constant speed test is a track with ballast bed and wooden or reinforced concrete sleepers without any type of rail or track shielding (use of rail dampers is accepted to comply with track decay rate limits, see 6.2.6). Where measurements are taken on track where a third rail is present, there shall not be any protective shielding boards in place.

NOTE 1 If other track designs are used under normal operating conditions for the unit they can be used for the test.

NOTE 2 Measurement results made on other track designs are only comparable with measurements made on that track design.

The ballast shall be loose i.e. not bound together by ice or glue and not blocked by debris, snow or ice.

6.2.4 Track quality

The track at the measuring section shall be laid without rail joints and be free of visible surface defects such as corrugations, rail burns or pits and spikes. No audible impact noise due to welds or loose sleepers shall be present.

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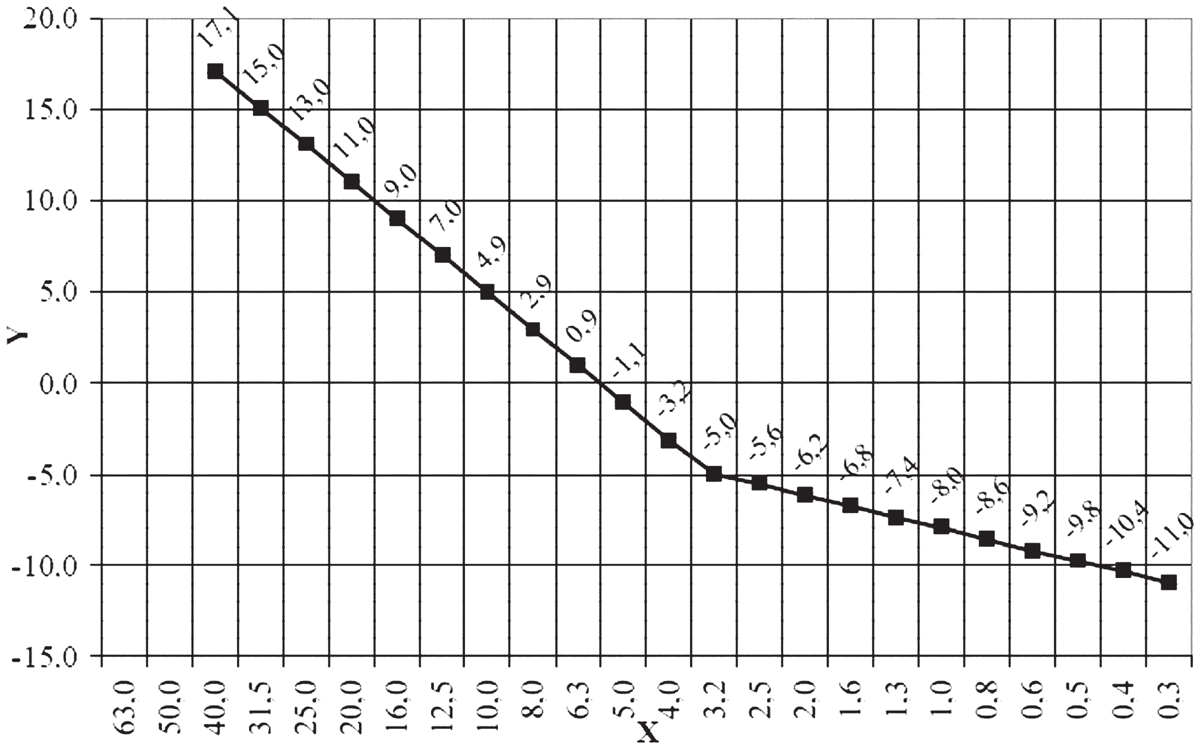
6.2.5 Acoustic rail roughness of the test track

The acoustic rail roughness of the test section shall be assessed according to EN 15610:2009. For type test measurements, the default upper limit provided in Figure 2 shall apply, taking into account, if necessary, the flexibility process described in Annex C.

For train speeds up to 190 km/h, the wavelength bandwidth shall be at least 0,003 m to 0,10 m. For higher speeds, at least 0,003 m to 0,25 m.



Key

Y one-third-octave-band roughness level re 1 μm, in dB

X wavelength, λ, in cm

Figure 2 — Default upper limit curve for the acoustic rail roughness level

6.2.6 Dynamic properties of the test track

The dynamic properties of the track shall be assessed according to EN 15461:2011. For type test measurements the default lower limits of the vertical and lateral track decay rates provided in Figure 3 shall apply.

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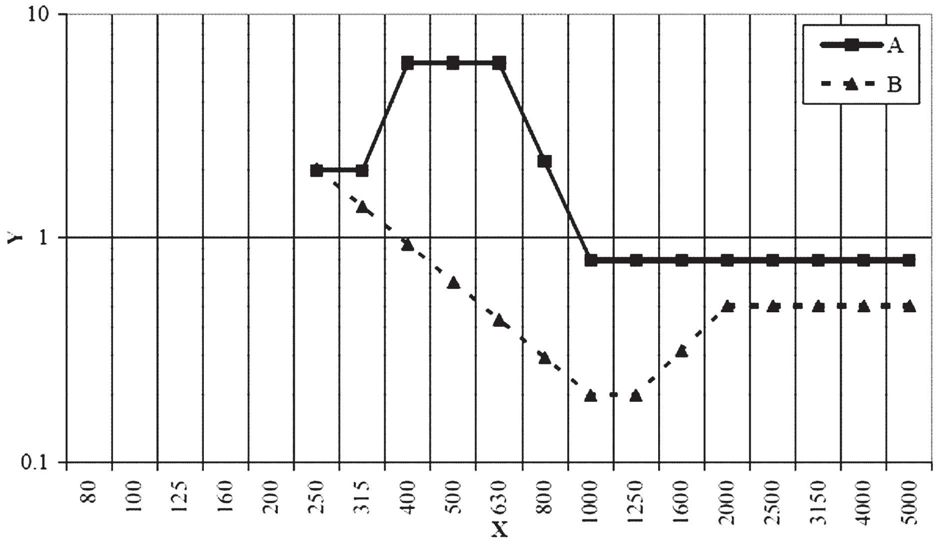

X	A	B
250	2.00	2.04
315	2.00	1.38
400	6.00	0.94
500	6.00	0.64
630	6.00	0.43
800	2.19	0.29
1000	0.80	0.20
1250	0.80	0.20
1600	0.80	0.32
2000	0.80	0.50
2500	0.80	0.50
3150	0.80	0.50
4000	0.80	0.50
5000	0.80	0.50

Key

Y track decay rate (TDR), dB/m

X frequency, Hz

A TDR limit in the vertical direction

B TDR limit in the lateral direction

Figure 3 — Default lower limit curves for the track decay rates

6.2.7 Special conditions

For non-conventional units tested on dedicated tracks, the track structure shall be described in the test report.

6.3 Vehicle conditions

6.3.1 General

Air management systems, including grilles, filters and fans shall be clear of any obstruction.

During the measurements, the doors and windows of the unit shall be kept closed.

In the case of multi-voltage vehicles or units, the measurements shall be performed under the voltage system which is expected to produce the highest noise level.

NOTE If a unit is designed for AC and DC supply then the AC mode is usually the noisier one.

In the case of dual-mode vehicles or units (diesel and electric) the measurements shall be performed under both modes.

6.3.2 Loading and operating conditions

The measurements shall be carried out in normal operating conditions, defined as follows.

All auxiliary equipment that operates continuously when the unit is running at constant speed shall be operating at normal load, which is the performance at an external temperature of 20 °C. For HVAC systems conditioning passenger areas and working places as well as system supplying energy for this

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function, climate influence parameters shall be set at: wind speed at 3 m/s, relative humidity at 50 %, 700 W/m^2 energy from sun radiation, one person per seat.

NOTE 1 These settings are derived from EN 14750-1,[14] EN 14813-1,[15] and EN 13129-1[11] which apply to middle Europe (zone II).

Adjustments for forcing the operation in order to simulate this 20 °C condition shall be documented in the report.

NOTE 2 Adjustments should be provided by the manufacturer.

Additionally, for fixed units a minimum tractive effort to maintain a constant speed shall be applied during the pass-by noise measurement. To ensure a steady operating condition, it might be required to operate the unit a certain time in advance in this operating condition.

If the unit being tested is a locomotive, the hauled load shall be at least two-thirds of the maximum permissible value. For the purposes of this International Standard, it is permissible to use the maximum tractive effort that can be generated at maximum speed as a proxy for maximum permissible hauled load, see Figure 4. Where appropriate meters and displays are available within the cab of the locomotive under test, the required testing condition may be ensured by operating the locomotive with an indicated tractive effort of at least two-thirds of the maximum available tractive effort. This condition may be more reliably ensured by including an instrumented brake vehicle within the hauled set of vehicles, thus allowing the tractive effort to be controlled precisely during the test period by brake application.

The test report shall describe the state of the traction equipment during the test.

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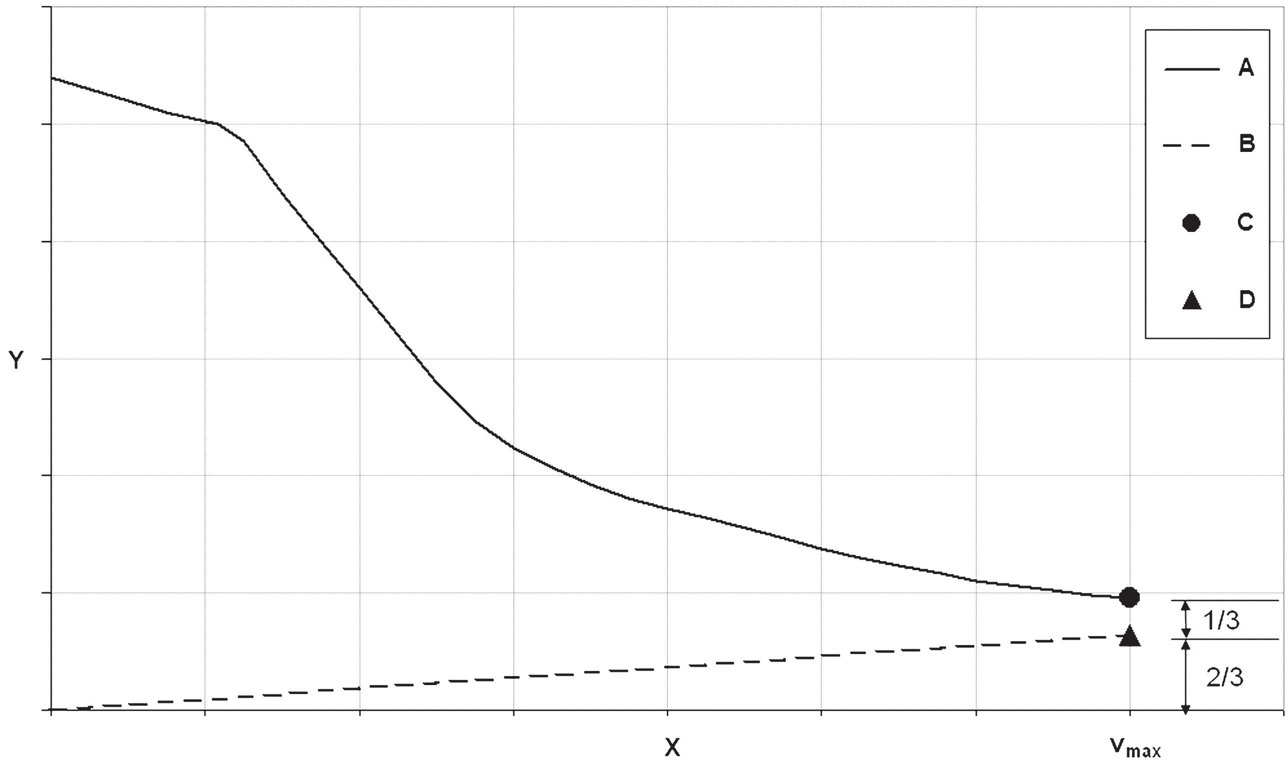

Key

Y tractive effort F [N]

X train speed v [km/h]

A tractive effort curve

B simplified resistance curve (straight line)

C maximum tractive effort at maximum speed v_{max}

D 2/3 of maximum tractive effort at maximum speed v_{max}

Figure 4 — Example of tractive effort versus train speed for the case of a locomotive

6.3.3 Wheel tread conditioning

The unit shall be in its normal operating conditions and its wheels shall have run for at least 1 000 km. The wheel treads shall be as free as possible from irregularities such as flats.

For units with tread brakes or scrubber (tread cleaning brakes), the block/tread pair shall be in a run-in condition where block and tread have bedded in sufficiently. Before starting the pass by measurements (typically just before starting the measurements, but not more than 24 h before starting the measurements) such units shall be braked to standstill two times. Braking shall start at 80 km/h or at the maximum unit speed in the case where it is lower than 80 km/h. The unit shall be braked until a complete stop with a deceleration which is typical in normal operation, but which ensures that no wheel flats are generated.

NOTE For units with a UIC brake it is advisable to brake with a main pipe pressure of 4 bars.

6.3.4 Train composition (adjacent vehicles)

Noise from other parts of the train shall not influence the measurements of the unit(s) under test. Therefore, for the measurement of a trailed unit, there shall be an acoustically neutral vehicle on one

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side of at least two units under test, and no vehicle or an acoustically neutral vehicle on the other side, see Figure 5. For the measurement of locomotives, the adjacent vehicle shall be acoustically neutral.

An adjacent vehicle shall be considered to be acoustically neutral if:

— Either it is a vehicle of the same class as the unit(s) under test;

— Or, the $L_{p\text{Aeq},Tp1}$ is no more than 2,0 dB greater than $L_{p\text{Aeq},Tp}$ where the passing times T_{p1} and T_p are indicated in Figure 5 (for this evaluation round values to one decimal place).

This condition shall be verified and documented at least once for each tested speed.

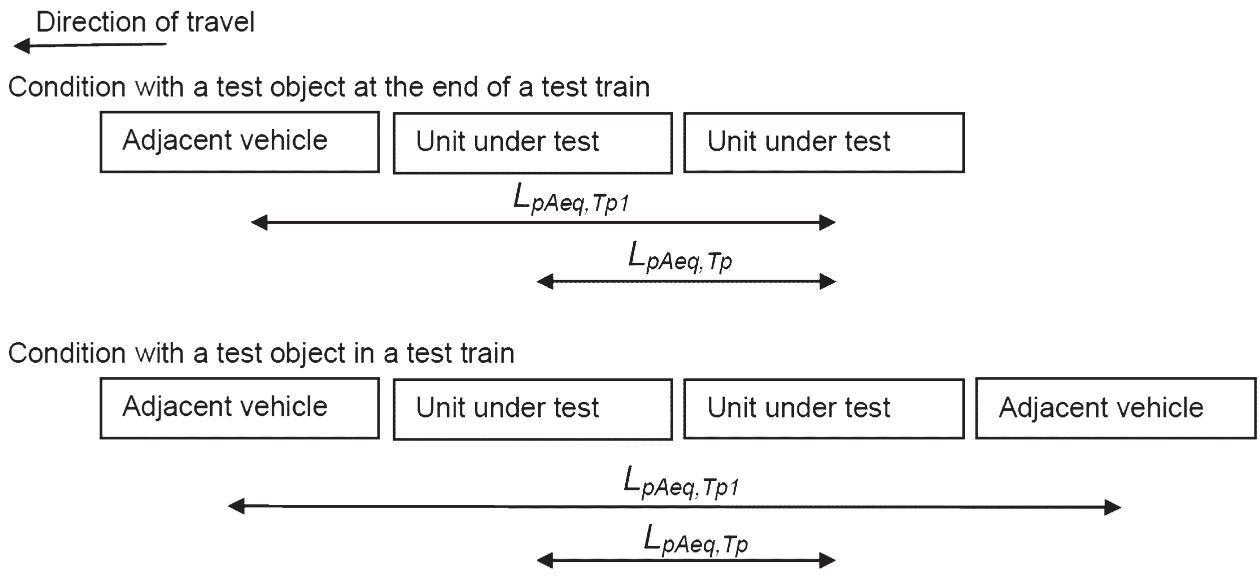

Figure 5 — Passing time for assessing acoustic neutrality of adjacent vehicle(s)

6.4 Measurement positions

6.4.1 Standard measurement positions

The measurement position, see Figure 6, depends on the train speed:

— The measurement positions shall be located at a distance of 7,5 m from the centreline of the track at a height of 1,2 m above the upper surface of the rail;

— Alternatively, for speeds greater than or equal to 200 km/h, the measurement position may be located at a distance of 25 m from the centreline of the track at a height of 3,5 m above the upper surface of the rail.

Measurement shall be carried out on both sides of the unit. If both sides of the unit are acoustically identical (i.e. with a symmetrical distribution of noise sources) then it is permissible to omit the measurement positions on one side of the unit.

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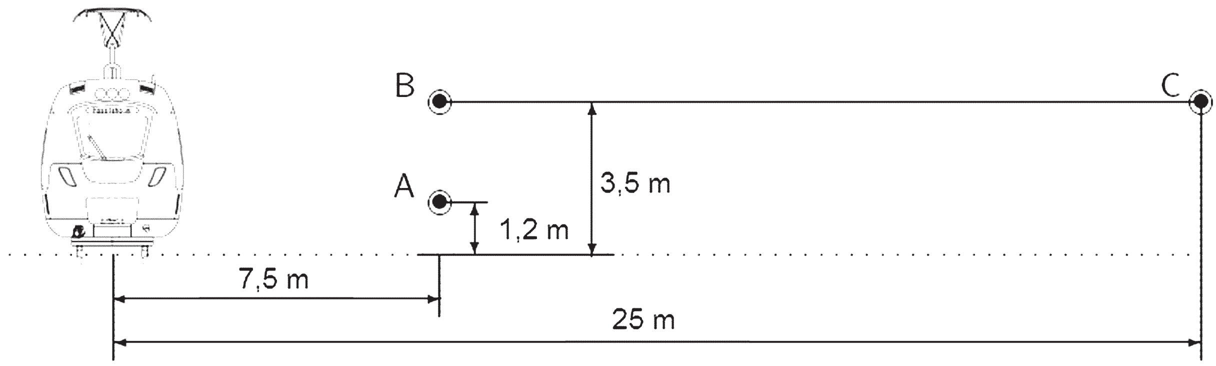

Key
A, B, C lateral measurement positions

Figure 6 — Lateral microphone positions for measurements on units at constant speed

6.4.2 Additional measurement positions

If important sound sources are present in the upper part of the unit under test (e.g. with power units or low floor rolling-stock), a measurement position at a distance of 7,5 m from the centreline of the track at a height of 3,5 m above the top of rails is recommended.

Additional measurements at platforms, stopping points and on bridges are described in Annex F.

6.5 Measured quantities

The basic measured quantities are $L_{pAeq,Tp}$, train speed and pass-by time T_p. If required, other quantities such as frequency spectrum and tonality may be determined.

6.6 Test procedure

6.6.1 General

A series of at least three measurements shall be made at each measurement position and for each measurement condition (one vehicle condition at one speed).

The validity of the measurements shall be assessed against the background noise level, see 6.1.3, as well as the acceptable spread of the measurement samples, see 9.3.

6.6.2 Pass-by speeds

Two cases apply:

a) type testing of units with v_{max} > 80 km/h: tests shall be performed at v = 80 km/h and at v_{max};

b) type testing of units with v_{max} ≤ 80 km/h: testing shall be performed at v_{max}.

Additional tests, if required, should be performed at one or more of the following preferred speeds: 20 km/h, 40 km/h, 60 km/h, 80 km/h, 100 km/h, 120 km/h, 140 km/h, 160 km/h, 200 km/h, 250 km/h, 300 km/h, 320 km/h and 350 km/h.

Where required, periodic monitoring testing shall be performed at the preferred speeds except when otherwise agreed by the owner of the rolling stock and the authority defining the measurement.

Over the measurement section of the track, the unit under test shall be run at the chosen speeds stabilized within ±5 %. The speed shall be measured by a device with a maximum permissible measurement error

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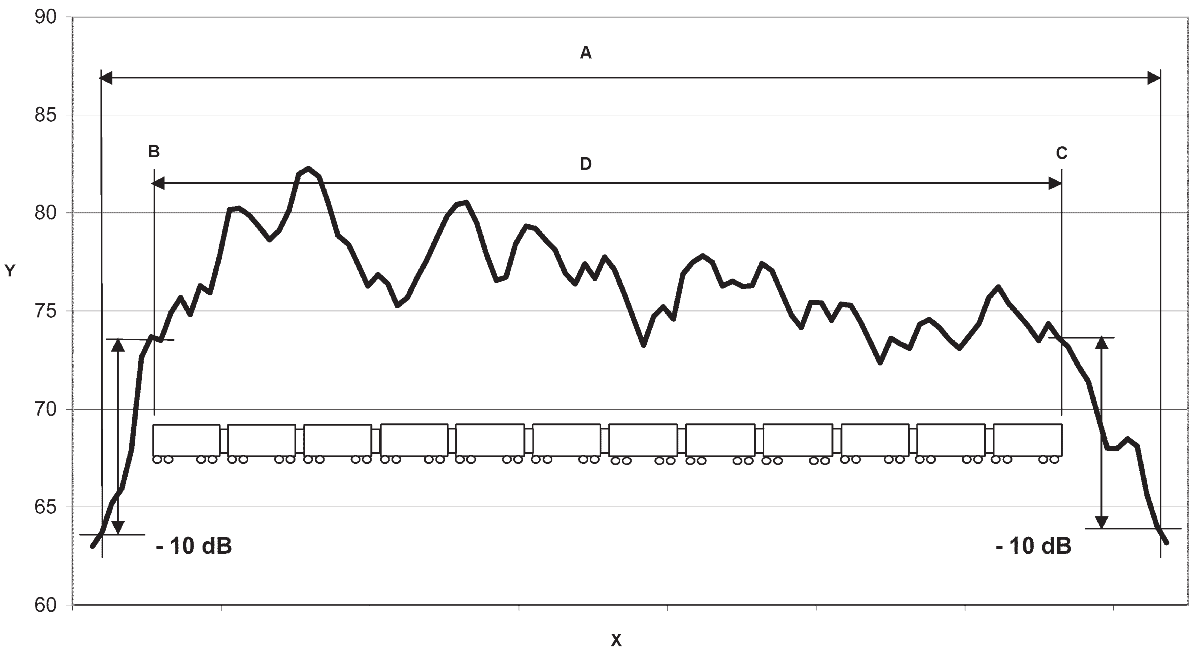
of 3 %. The speedometer of the train may be used, provided a calibration with a target measurement uncertainty of 3 %.

6.6.3 Recording and measurement time intervals

Irrespective of the type of rolling stock being measured, the recording time interval T_{rec} shall be chosen, so the record starts when the AF-weighted sound pressure level history $L_{pAF}(t)$ *or* the *short term* $L_{pAeq,125ms}(t)$ is at least 10 dB lower than found when the front of the train is opposite the microphone position. The record shall not end before the A-weighted sound pressure level is 10 dB lower than found when the rear of the train is opposite the microphone position, see Figure 7.



Key

Y A-weighted sound pressure level, dB

X time

A recording time interval T_{rec}

B T_1: start of the measurement time interval

C T_2: end of the measurement time interval

D measurement time interval $T = T_p$

Figure 7 — Example of selection of recording time interval T_{rec}, for a fixed train formation

For multiple units or fixed train formations, the measurement time interval T shall coincide with the pass-by time T_p of the whole unit past the measuring position.

Locomotives or driving trailers shall always be tested at the head of a test train. The measurement time interval T shall coincide with the pass-by time T_p of the whole unit (over buffers) past the measuring position, see Figure 8.

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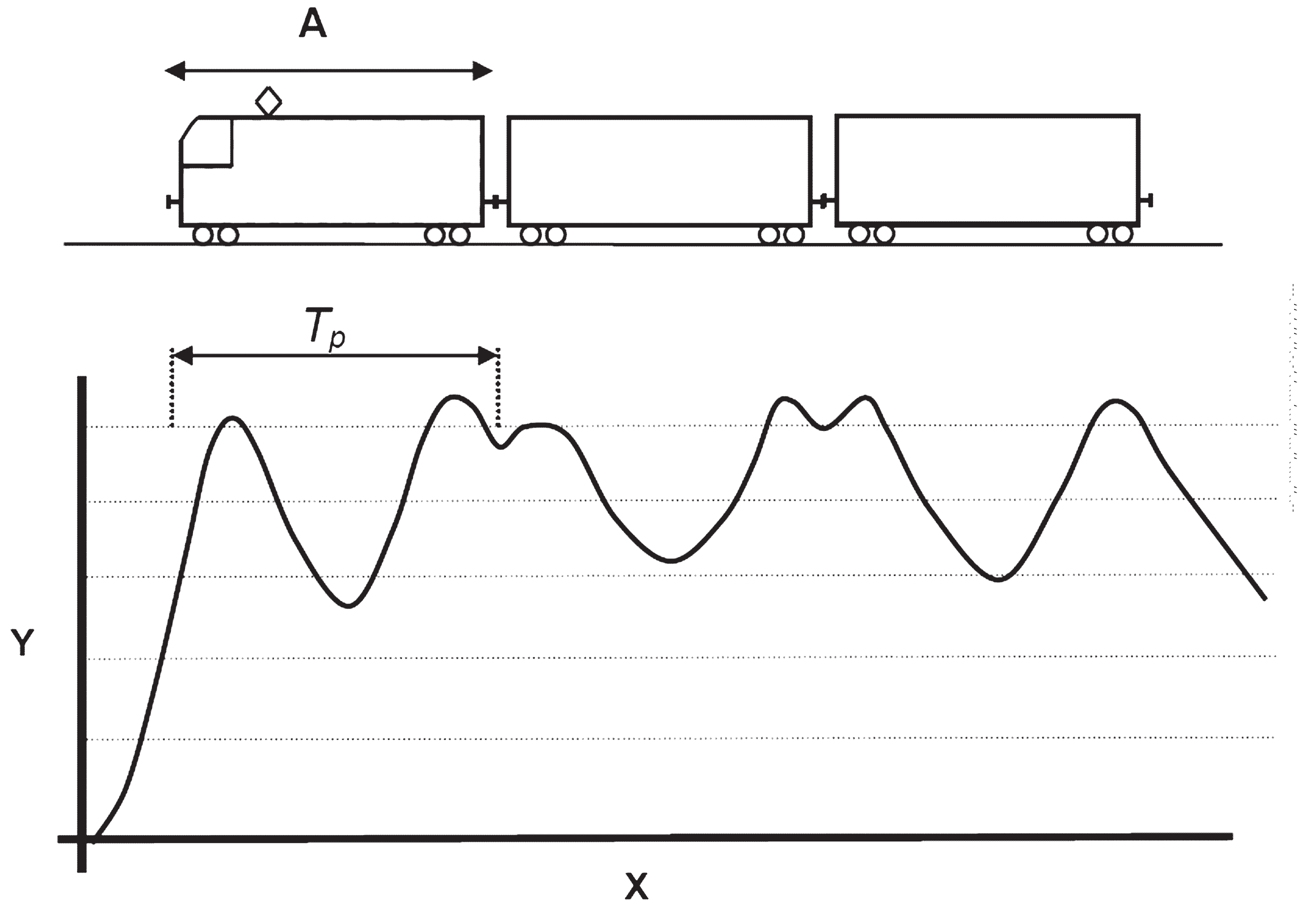

Key

Y A-weighted sound pressure level

X time

A unit under test

Figure 8 — Measurement time interval of locomotives or driving trailer

For trailed unit(s) which form(s) part of a train, the measurement time interval T shall start when the centre of the first unit passes the measurement position (T_1) and shall end when the centre of the last unit passes the measurement position (T_2). This procedure is only applicable where at least two units of the type under test are available. Annex B provides some guidance for special cases of trailer units.

When measuring a unit within a train, the unit shall be located using an independent device, such as an optical trigger or a wheel detector.

Figure 9 shows the minimum measurement time interval $T_{p,min}$ required for the measurement of a trailer unit.

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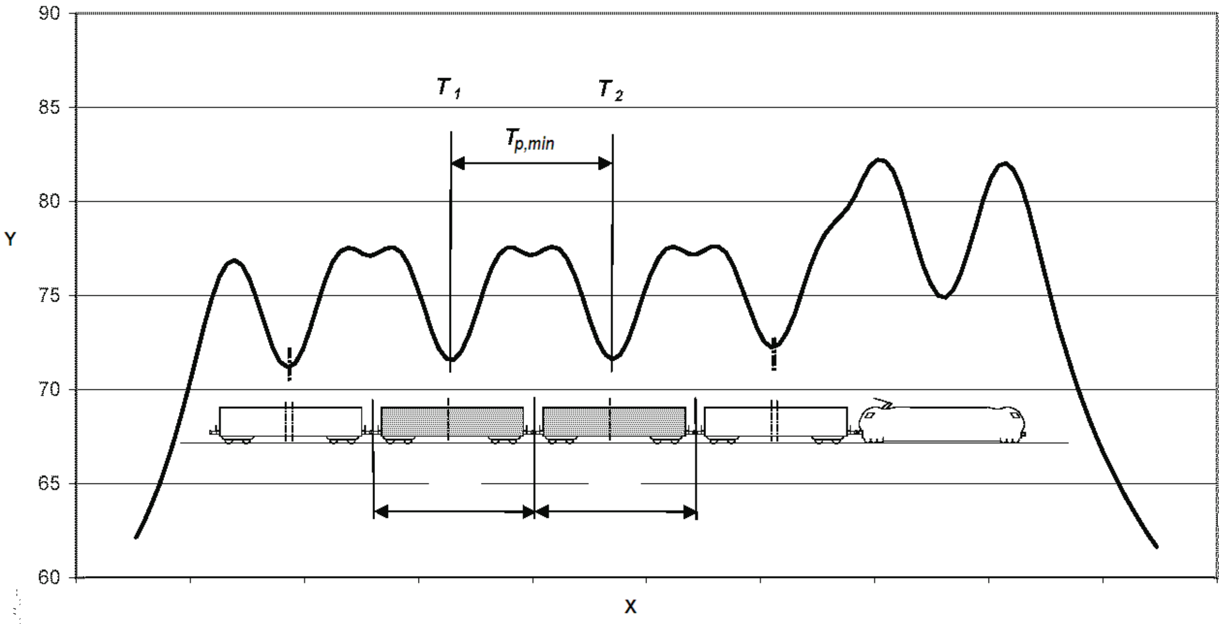

Key
Y A-weighted sound pressure level, dB
X time

Figure 9 — Example of selection of measurement time interval *T* for parts of a train

NOTE In the case of short units at high speeds the determination of T_1 becomes critical because of the very short measurement time interval. Not all instrumentation allows sufficiently precise definition of this time interval.

6.7 Data processing

6.7.1 Standard processing

The value of $L_{p\text{Aeq},Tp}$ shall be calculated for each measurement position. The test result shall be the arithmetic mean value of each series of measurements rounded to the nearest integer decibel.

Where a normalization of the pass-by noise to a reference speed is required, this shall be performed before rounding.

If the sound pressure levels measured on each side of the unit are different; the higher sound pressure level shall be retained as final test results.

6.7.2 Additional processing

When spectra are required, they should be supplied in one-third octave bands in the range of at least 31,5 Hz to 8 000 Hz.

If an assessment of tonality is required, then the tonal difference (ΔL) shall be calculated.

NOTE ΔL can be calculated according to ISO 1996-2:2007,[3] Annex C or DIN 45681:2005,[10] the latter standard providing more detailed guidance on application, especially for non-stationary sounds.

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7 Acceleration test from standstill

7.1 General

For the assessment of the acceleration test from standstill two different methods are specified:

— one provides an assessment in terms of L_{pAFmax} at 7,5 m from the centreline of the track and should be used to characterize the maximum noise emitted by the train during the event;

— the other, in terms of $L_{pAeq,T}$ at 25 m, quantifies the total acoustic energy emitted by the train during the event.

These are called the "maximum level method", see 7.5, and the "averaged level method", see 7.6.

7.2 Environmental conditions

7.2.1 Acoustical environment

In the triangular area between the track and the microphone extending along the track to a distance twice the microphone distance to either side, the test site shall be such that free sound propagation exists. To achieve this result:

— The level of the ground surface over this area shall be within 0 m to −2 m, relative to the top of the rail;

NOTE The level of the ground and the nature of the ground surface can affect the spectral content of the measured sound

— This area shall be free of sound absorbing matter such as lying snow or tall vegetation, and free of reflective covering such as water, ice, tarmac or concrete. No absorptive material shall be added to the propagation path for the purpose of the test;

— No person shall be present in this area, and the observer shall be in a position that does not influence the measured sound pressure level significantly;

— The presence of other tracks is permissible in this area as long as the ballast bed height does not exceed the height of the rail surface of the test track.

Additionally, an area around the microphones, having a radius which is at least three times the measurement distance on both sides, shall be free of large reflecting objects like barriers, hills, rocks, bridges or buildings.

7.2.2 Meteorological conditions

The following weather parameters shall be recorded at representative times during the noise measurement exercise: Wind speed and direction at the level of the highest microphone, temperature, humidity, barometric pressure. Any observed precipitation shall be noted.

NOTE Heavy rain or wind speed higher than 5 m/s can affect the background noise, see 7.2.3.

7.2.3 Background sound pressure level

Care shall be taken to ensure that the noise from other sources (e.g. other vehicles or industrial plants and due to wind) does not influence the measurements significantly.

The maximum value of the $L_{pAeq,T}$ T = 20 s of background noise over all microphone positions shall be at least 10 dB below the L_{pAFmax} (or $L_{pAeq,T}$) obtained when measuring the noise from the unit in the presence of background noise. For frequency analysis, this difference shall be at least 10 dB in each frequency band of interest.

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7.3 Track conditions

The track at the measuring section shall be laid without rail joints and be free of visible surface defects such as corrugations, rail burns, pits and spikes. No audible impact noise due to welds or loose sleepers should be present.

NOTE If the rail is wet, this can lead to wheel slip and modify the acoustic behaviour of the vehicle.

7.4 Vehicle conditions

7.4.1 General

Air management systems, including grilles, filters and fans shall be clear of any obstruction.

During the measurements the doors and windows of the unit shall be kept closed.

The measurements shall be carried out in normal operating conditions defined as follows:

All equipment that operates continuously when the unit is starting shall be operating at normal load, which is the performance at an external temperature of 20 °C. For HVAC systems conditioning passenger areas and working places as well as system supplying energy for this function, climate influence parameters shall be set at: wind speed at 3 m/s, relative humidity at 50 %, 700 W/m^2 energy from sun radiation, one person per seat.

NOTE 1 These settings are derived from EN 14750-1,[14] EN 14813-1,[15] and EN 13129-1[11] which apply to middle Europe (zone II).

Adjustments for forcing the operation in order to simulate this 20 °C condition shall be documented in the report.

NOTE 2 These parameters can be provided by the manufacturer.

If the noise of an item of auxiliary equipment contributes significantly to the result and is not repeatable, it shall not be considered part of this measurement. Any part of a measurement that is excluded shall be identified in an $L_{pAF}(t)$ plot.

In the case of multi-voltage vehicles or units the measurements shall be performed under the voltage system which is expected to produce the highest noise level.

NOTE 3 If a unit is designed for AC and DC supply then the AC mode is usually the noisier one.

In the case of dual-mode vehicles or units (diesel and electric) the measurements shall be performed under both modes.

7.4.2 Loading or operating conditions

Tests shall be performed with maximum tractive effort without wheel spin and without macro slip.

If the train under test does not comprise a fixed formation, the hauled load has to be defined and shall be sufficient to ensure that the maximum tractive effort will be developed during the measurement.

When applicable the traction unit shall be at the head of the train.

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7.5 Maximum level method

7.5.1 Measurement positions

7.5.1.1 Standard measurement positions

For standard acceleration tests the measurement positions shall be located at 7,5 m from the centreline of the track at 1,2 m height.

One measurement position shall be located at the front measurement cross section, which is defined as being 10 m ahead of the front of the unit.

Further measurement positions shall be located along the unit depending on the unit length, *l*, see Figure 10:

— For units less than or equal to 50 m in length, no further measurement positions are needed;

— For units longer than 50 m, at least one position at 10 m ahead of the centre of the unit shall be indicated. If the distance between the two measurement positions is greater than 50 m, additional measurement positions are required. The distance, *D*, between adjacent measurement positions shall be constant and no greater than 50 m.

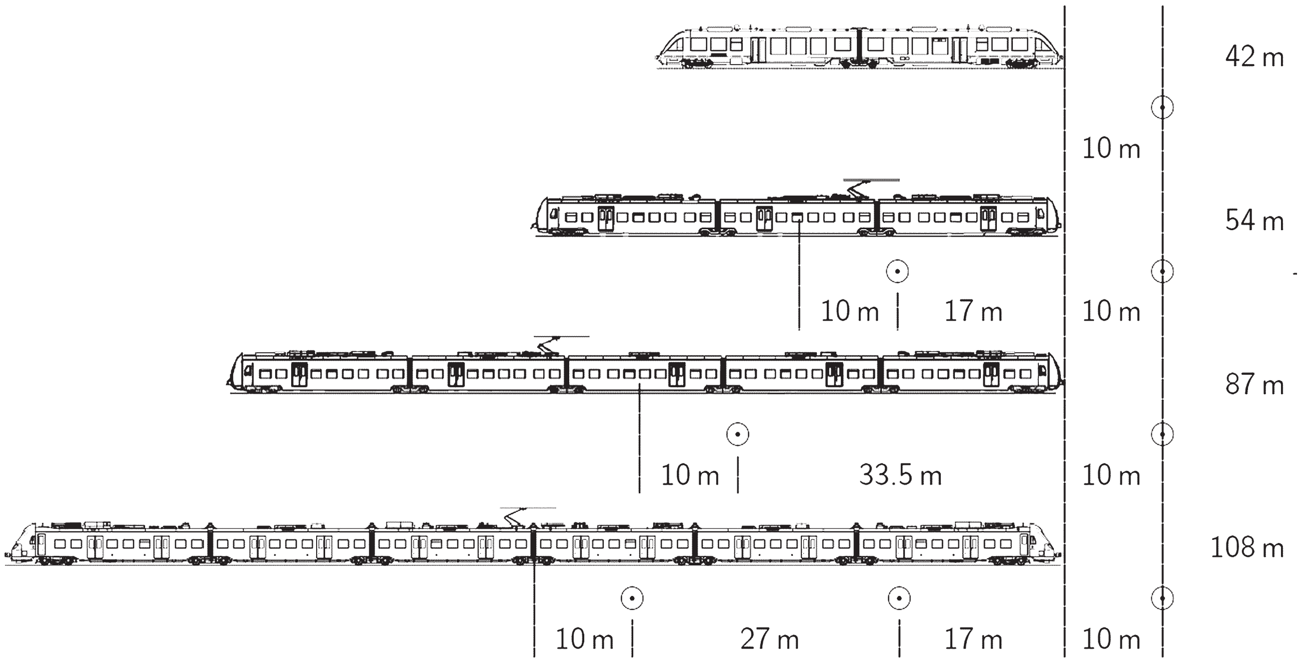

Figure 10 — Examples for different configurations of measurement positions for acceleration test

Measurement shall be carried out on both sides of the unit and for both driving directions. It is permissible to omit some of the measuring configurations when the relevant sound sources are arranged symmetrically, see Figure 11.

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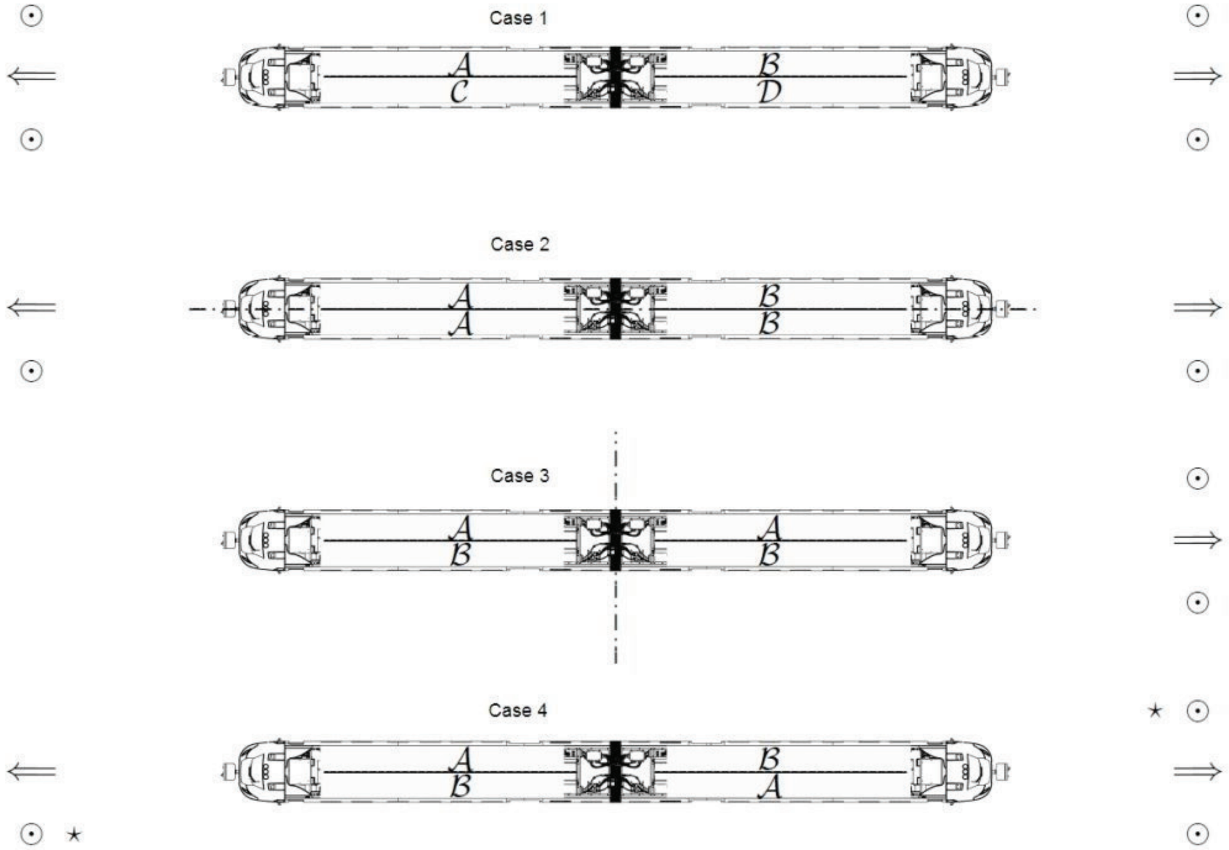

Key

⊙ measurement position

A, B, C, D subdivisions of the unit: where the label is the same, the subdivisions are deemed to be acoustically equivalent.

Figure 11 — Measurement positions for different cases of unit layout symmetries

In case 4 of Figure 11, only two positions are needed. Either those at the same side or those at the same driving direction. One of those marked with a star can be omitted, see Figure 11.

7.5.1.2 Additional measurement positions

If important sound sources are present in the upper part of the unit under test (e.g. with power units or low floor rolling-stock) a second mesh of measurement positions at a distance of 7,5 m from the centreline of the track at a height of 3,5 m above the top of rails is recommended.

7.5.2 Measured quantities

The basic measured acoustic quantity is $L_{\text{pAF}}(t)$. If required other acoustic quantities such as frequency spectrum, tonality, or impulsiveness may be determined.

7.5.3 Test procedure

Three valid measurement samples at each position are required. The validity assessment of the measurements against the background noise level, see 7.2.3, and against the acceptable spread of the measurement samples, see 9.3, shall be performed using the $L_{p\text{AFmax}}$ determined according to 7.5.4.

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The train shall accelerate continuously from standstill up to a target speed of 40 km/h and then reduce traction effort to maintain speed.

NOTE The speed of 40 km/h can not be reached by all units (e.g. locomotives).

The measurement time interval T shall begin when the unit under test starts to move and shall end when it is 10 m past the front measurement cross section.

7.5.4 Data processing

Determine the L_{pAFmax} for each measurement (for each starting event and each measurement position).

Calculate the arithmetic average of the three valid measurements at each measurement position, rounded to the nearest integer decibel.

The final result is the maximum of these averaged values.

When spectra are required, they should be supplied in one-third octave bands in the range of at least 31,5 Hz to 8 000 Hz.

If an assessment of tonality is required, then the tonal difference (ΔL) shall be calculated.

NOTE ΔL can be calculated according to ISO 1996-2:2007,[3] Annex C or DIN 45681:2005,[10] the latter standard providing more detailed guidance on application, especially for non stationary sounds.

If an assessment of the impulsive character of the sound is required, it shall be calculated according to Annex A.

7.6 Averaged level method

7.6.1 Measurement positions

One microphone position at a distance of 25 m from the centreline of the track at a height of 3,5 m above the top of the rails shall be located at the front measurement cross section, which is defined as being 10 m ahead the front of the unit.

Measurement shall be carried out on both sides of the unit and for both driving directions. It is permissible to omit some of the measuring configurations when the relevant sound sources are arranged symmetrically, see Figure 11.

7.6.2 Measurement quantity

The basic measured acoustic quantity is $L_{p\text{Aeq},T}$. If required, other acoustic quantities such as frequency spectrum, $L_{p\text{AFmax}}$, tonality, or impulsiveness may be determined.

7.6.3 Test procedure

Three valid measurement samples at each position are required. The validity assessment of the measurements against the background noise level, see 7.2.3, and against the acceptable spread of the measurement samples, see 9.3, shall be performed using the $L_{p\text{Aeq},T}$ determined according to 7.6.4.

The train shall accelerate continuously from standstill up to a target speed of 40 km/h and then reduce traction effort to maintain speed.

NOTE The speed of 40 km/h can not be reached by all units (e.g. locomotives).

The measurement time interval T shall begin when the front of the unit under test passes the measurement cross section and shall end when the tail of the unit passes it.

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7.6.4 Data processing

The value of $L_{p\text{Aeq},T}$ shall be calculated for each measurement position. The test result shall be the arithmetic mean value of each series of measurements, rounded to the nearest integer decibel.

If the sound pressure levels measured on each side of the unit are different, the higher sound pressure level shall be retained as the final test results.

When spectra are required, they should be supplied in one-third octave bands in the range of at least 31,5 Hz to 8 000 Hz.

If an assessment of tonality is required the tonal difference (ΔL) shall be calculated.

NOTE ΔL can be calculated using ISO 1996-2:2007,[3] Annex C or DIN 45681:2005,[10] the latter standard providing more detailed guidance on application especially for non-stationary sounds.

If an assessment of the impulsive character of the sound is required, then it shall be calculated according to Annex A.

8 Braking test

8.1 Environmental conditions

8.1.1 Acoustical environment

In the triangular area between the track and the microphone extending along the track to a distance twice the microphone distance to either side, the test site shall be such that free sound propagation exists. To achieve this result, then:

— The level of the ground surface over this area shall be within 0 m to −2 m, relative to the top of the rail;

  NOTE The level of the ground and the nature of the ground surface can affect the spectral content of the measured sound.

— This area shall be free of sound absorbing matter such as lying snow or tall vegetation, and free of reflective covering such as water, ice, tarmac or concrete. No absorptive material shall be added to the propagation path for the purpose of the test;

— No person shall be present in this area, and the observer shall be in a position that does not influence the measured sound pressure level significantly;

— The presence of other tracks is permissible in this area as long as the ballast bed height does not exceed the height of the rail surface of the test track.

Additionally, an area around the microphones having a radius which is at least three times the measurement distance on both sides shall be free of large reflecting objects like barriers, hills, rocks, bridges or buildings.

8.1.2 Meteorological conditions

The following weather parameters shall be recorded at representative times during the noise measurement exercise: Wind speed and direction at the level of the highest microphone, temperature, humidity, barometric pressure. Any observed precipitation shall be noted.

NOTE Heavy rain or wind speed higher than 5 m/s can affect the background noise, see 8.1.3.

8.1.3 Background sound pressure level

Care shall be taken to ensure that the noise from other sources (e.g. other vehicles or industrial plants and due to wind) does not influence significantly the measurements.

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The maximum value of the $L_{pAeq,T}$ T = 20 s of background noise over all microphone positions shall be at least 10 dB below the L_{pAFmax} obtained when measuring the noise from the unit in the presence of background noise. For frequency analysis, this difference shall be at least 10 dB in each frequency band of interest.

8.2 Track conditions

The track at the measuring section shall be laid without rail joints and be free of visible surface defects such as corrugations, rail burns, pits and spikes; no audible impact noise due to welds or loose sleepers should be present.

NOTE If the rail is wet, this can lead to wheel slip and modify the acoustic behaviour of the vehicle.

8.3 Vehicle conditions

8.3.1 General

Air management systems, including grilles, filters and fans shall be clear of any obstruction.

During the measurements, the doors and windows of the unit shall be kept closed.

The measurements shall be carried out in normal operating conditions defined as follows:

All equipment that operates continuously when the unit is braking shall be operating at normal load, which is the performance at an external temperature of 20 °C. For HVAC systems conditioning passenger areas and working places as well as system supplying energy for this function, climate influence parameters shall be set at: wind speed at 3 m/s, relative humidity at 50 %, 700 W/m^2 energy from sun radiation, one person per seat.

NOTE 1 These settings are derived from EN 14750-1,[14] EN 14813-1,[15] and EN 13129-1[11] which apply to middle Europe (zone II).

Adjustments for forcing the operation in order to simulate this 20 °C-condition shall be documented in the report.

NOTE 2 These parameters can be provided by the manufacturer.

If the noise of an item of auxiliary equipment contributes significantly to the result and is not repeatable it shall not be considered part of this measurement. Any part of a measurement that is excluded shall be identified in an $L_{pAF}(t)$ plot.

In the case of multi-voltage vehicles or units the measurements shall be performed under the voltage system which is expected to produce the highest noise level.

NOTE 3 If a unit is designed for AC and DC supply the AC mode is usually the noisier one.

In the case of dual-mode vehicles or units (diesel and electric) the measurements shall be performed under both modes.

8.3.2 Loading or operating conditions

The test condition of the train shall correspond to normal service braking, not emergency braking or forced braking. Where applicable, the brake blending (proportions of dynamic brake and mechanic brake) shall be noted.

When applicable, the traction unit shall be at the head of the train.

8.4 Measurement positions

For standard brake tests the measurement positions shall be located at 7,5 m distance from the centre of the track at 1,2 m height either side of the unit.

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The measurement positions shall be located at the measurement cross section, which is defined as being opposite the centre of the first car of the unit when it stops. Because of the difficulty in predicting the precise braking distance, a tolerance of ± 10 m is allowed, see Figure 12.

Additional measurement positions shall be defined where more than one type of pneumatic brake actuator (e.g. axle or wheel mounted disc brake, tread brake) is present on the unit. The additional positions shall be located opposite the centre of one of the cars equipped with each of the alternative brake systems when the train stops.

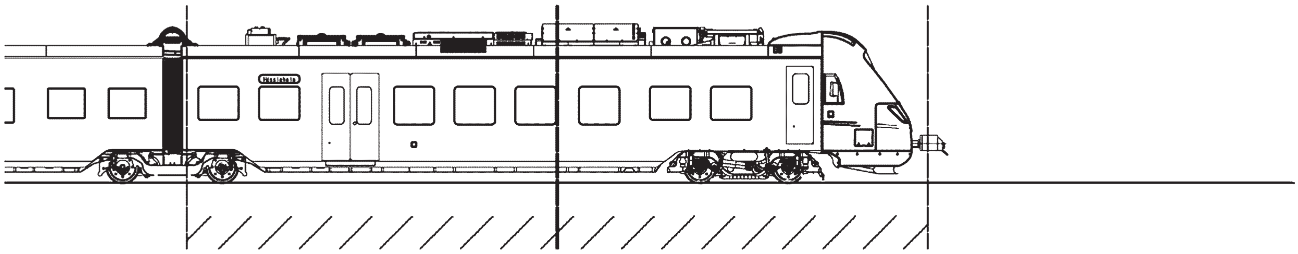

Figure 12 — Vehicle position at standstill after the break procedure

The ruled area demonstrates the possible spread of location of the measurement position at standstill. The thick line at the vehicle centre indicates the target position of the measurement position, see Figure 12.

8.5 Measurement quantity

The basic measured acoustic quantity is $L_{\text{pAF}}(t)$. If required other acoustic quantities such as $L_{p\text{Aeq},T}$, frequency spectrum, tonality, impulsiveness may be determined. For each test run a subjective assessment of whether or not brake squeal occurs shall be recorded.

8.6 Test procedure

Three valid measurement samples at each position are required. The validity of the measurements shall be assessed against the background noise level, see 8.1.3, and the acceptable spread of the measurement samples, see 9.3.

A full service braking shall be performed, beginning at a speed of 30 km/h, ending at standstill.

NOTE The full service braking is defined in EN 13452-1.[13]

The measurement time interval T shall begin when the rolling stock under test passes a point 20 m from the measurement position and shall stop when the train stops.

8.7 Data processing

The L_{pAFmax} shall be determined for each measurement (for each braking event and each measurement position).

The arithmetic average of the three valid measurements at each measurement position shall be rounded to the nearest integer decibel.

NOTE 1 When brake squeal occurs a greater spread of results than that required under 9.3 can arise. In this case, all individual results can be reported but the average can not be calculated.

The final result is the maximum of these averaged values.

When spectra are required, they should be supplied in one-third octave bands in the range of at least 31,5 Hz to 8 000 Hz.

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If an assessment of tonality is required, then the tonal difference (ΔL) shall be calculated.

NOTE 2 ΔL can be calculated using ISO 1996-2:2007,[3] Annex C or DIN 45681:2005,[10] the latter standard providing more detailed guidance on application especially for non-stationary sounds.

If an assessment of the impulsive character of the sound is required, it shall be calculated according to the Annex A.

9 Quality of the measurements

9.1 Deviations from the requirements

The conditions prescribed for the tests described in Clauses 5 to 8 shall be complied with as closely as possible. Slight deviations from the specified test conditions for type tests may be unavoidable. In this case, they shall be described in the test report and, in general, will deteriorate the reproducibility.

9.2 Measurement tolerances

All measurement distances mentioned in this International Standard shall be considered with a tolerance of ± 0,2 m if no requirement is specified.

9.3 Measurement spread

Where a series of three measurement samples are required a spread of less than or equal to 3 dB shall be fulfilled for the measurement to be considered as valid. Otherwise, additional measurements shall be made.

9.4 Measurement uncertainties

The measurement uncertainty shall be evaluated. It is recommended to state the measurement uncertainty in the report. Annex G provides a model to evaluate the uncertainty of the result according to ISO/IEC Guide 98-3:2008.[8]

10 Test report

The test report shall include a reference to this International Standard and all relevant details concerning:

a) nature of the tests, date, location, name and address of the organization performing the measurements (see also ISO/IEC 17025:2005);

b) description of the test site:

    1) location;

    2) environmental conditions:

        i) acoustical environment (presence of obstacles, ground cover, etc.);

        ii) meteorological conditions: ambient temperature, humidity, barometric pressure, wind speed and direction;

        iii) background sound pressure level.

    3) Track conditions:

        i) geometry of the line (cross section and position along the track);

        ii) track superstructure (including sleepers, rail pad, fasteners and rail geometry);

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iii) acoustic rail roughness and track decay rates, when required;

c) description of the unit (type and serial number(s)), the traction system and the speed during the test, the different types of pneumatic brake actuators and their location along the train confirmation of the mileage criterion and a statement that the unit is representative of the type;

d) description of the vehicle test conditions:

1) operating condition of the unit;

2) auxiliary equipment and its operating conditions;

3) loading of the unit (e.g. hauled load, configuration of the brake unit, etc.);

e) declaration that the instrumentation fulfils the requirements of 4.1 of this International Standard;

f) measurement positions;

g) measurement quantities;

h) presence of impulsive or tonal noise, when required;

i) other useful information.

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Annex A
(normative)

Method to characterize the impulsive character of the noise

The impulsiveness of the noise can be characterized by the rise speed s in the following manner. $L_{p\mathrm{AF}}(t)$ is measured. The rising slopes in the level history $L_{p\mathrm{AF}}(t)$ are selected. Only those slopes are included where the $L_{p\mathrm{AF}}(t)$ continuously increases by 10 dB or more. For each of these slopes, j, the maximum derivative (the rise speed) is determined:

$$s_j = \max[\mathrm{d}L_{p\mathrm{AF}}(t)/\mathrm{d}t] \text{ [dB/s]} \tag{A.1}$$

The final result is the highest value of these j rise speeds: $s = \max(s_j)$.

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Annex B
(normative)

Tests at constant speed — Special cases

B.1 General

In some specific cases, the general approach described in Clause 6 specifying how to process pass-by noise measurements of units which are part of a test train may not be applicable. This Annex provides a non-exhaustive list of examples of specific unit configurations and specifies how to process them. If none of the cases listed below can be applied, then a pragmatic approach considering the following general rules shall apply:

— In any case, adjacent vehicle(s) shall be acoustically neutral and therefore fulfil the conditions specified in 6.3.4.

— The measurement time interval chosen shall allow the assessment of the whole acoustic signature of the unit under test. Therefore the minimum measurement time interval T_{min} shall correspond to the pass-by time (or a multiple of it) of this unit past the measurement position.

— The measurement time interval shall begin when the centre of the longest segment between two consecutive wheelsets passes the microphone and ends after the same position of the last unit under test passes the microphone.

NOTE A difficulty that occurs while processing pass-by noise measurements is in identifying the exact instant at which the centre of the first unit passes the measurement position. The deviation from the requirements set out in 6.6.3 described above aims to minimize error in the pass-by noise level which can arise from the determination of T_1.

B.2 Units with wheelsets located at or close to their centre

In some configurations, the wheelsets are located close to or directly at the centre of the unit under test. In such a case, the minimum measurement time interval $T_{p,min}$ shall not begin at the centre of the first unit under test, but at the centre of the longest segment between two consecutive wheelsets of this unit which passes the measurement position. It ends after the equivalent location on the last unit passes the measurement position, see examples in Figure B.1 and Figure B.2.

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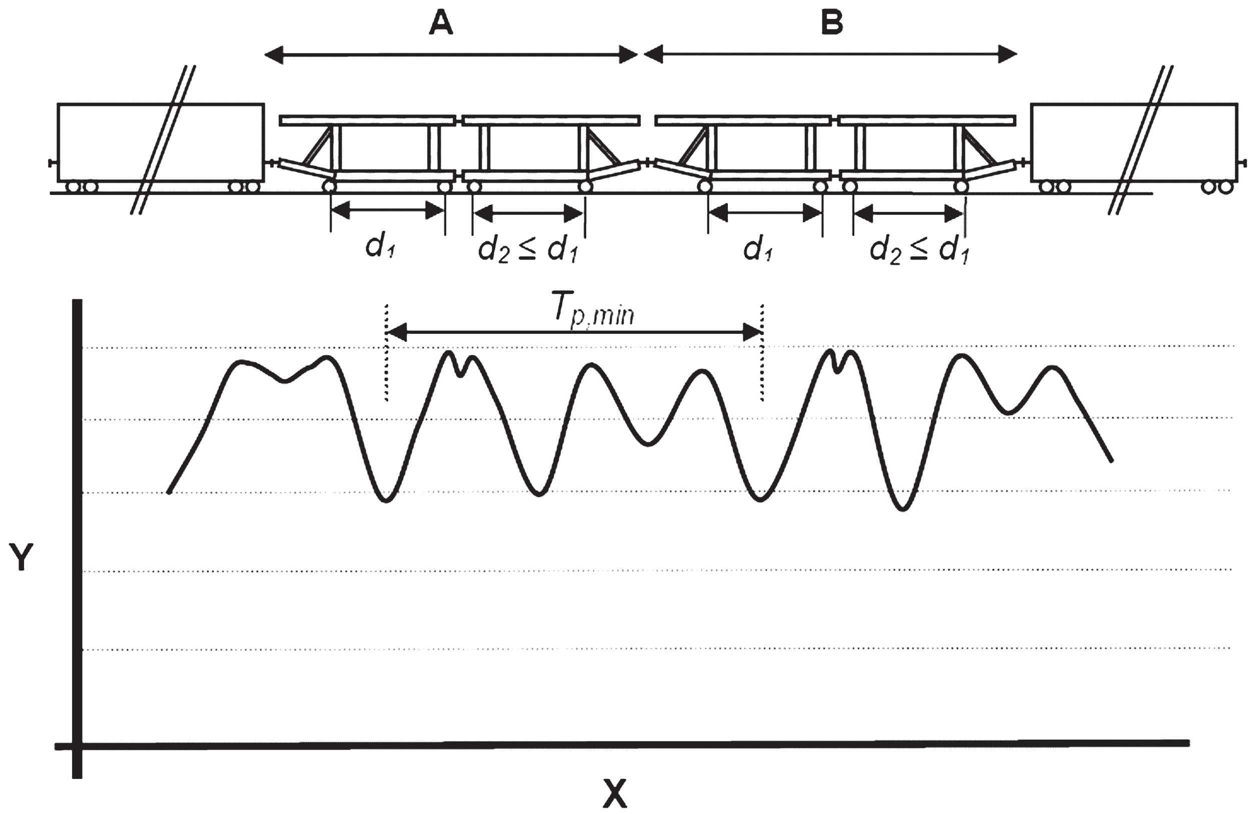

Key

Y A-weighted sound pressure level

X time

A first unit under test

B second unit under test

Figure B.1 — Minimum measurement time interval of units with wheelsets located close to their centre

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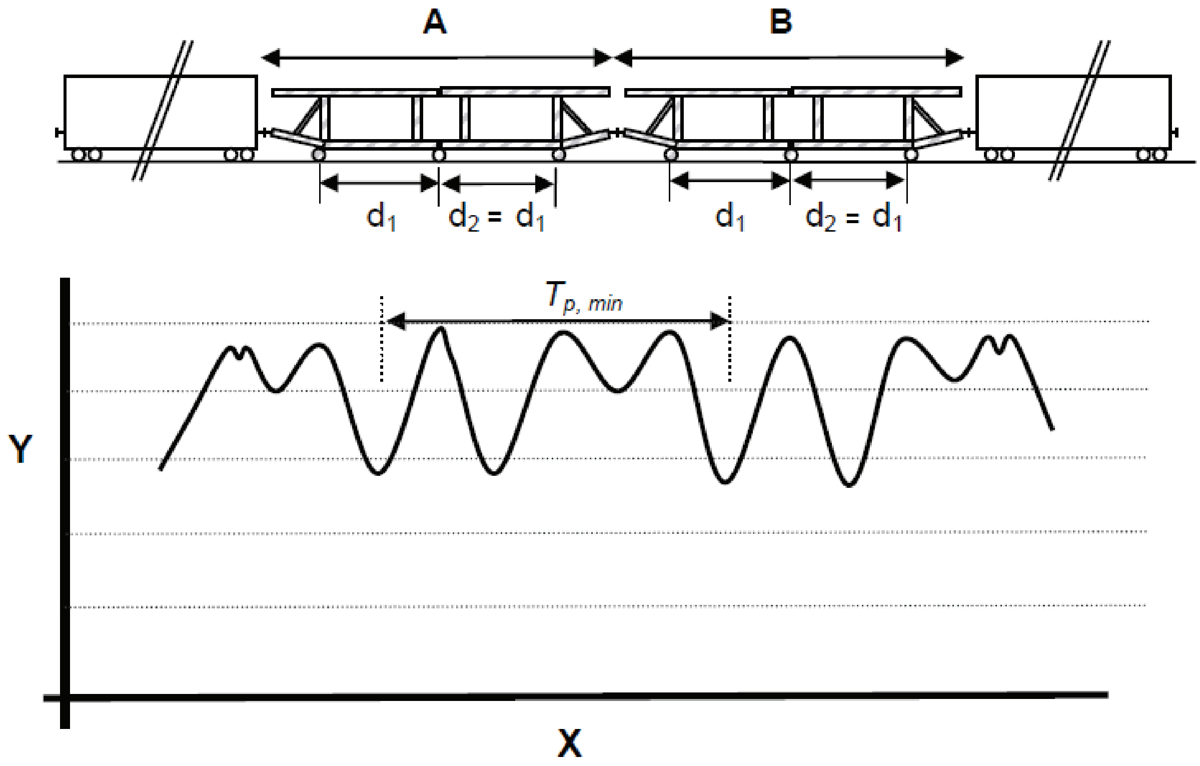

Key

Y A-weighted sound pressure level

X time

A first unit under test

B second unit under test

Figure B.2 — Minimum measurement time interval of units with wheelsets located at their centre

B.3 Permanently coupled unit composed of two vehicles

Where the unit under test is composed of two permanently coupled vehicles, not necessarily identical, it is permissible to measure only one unit, provided that both vehicles are point symmetric. In such a case T_1 corresponds to the passing of the centre of the first vehicle and T_2 corresponds to the passing of the centre of the last vehicle of the unit. See Figure B.3.

NOTE It is advisable to test such a unit at the end of the test train.

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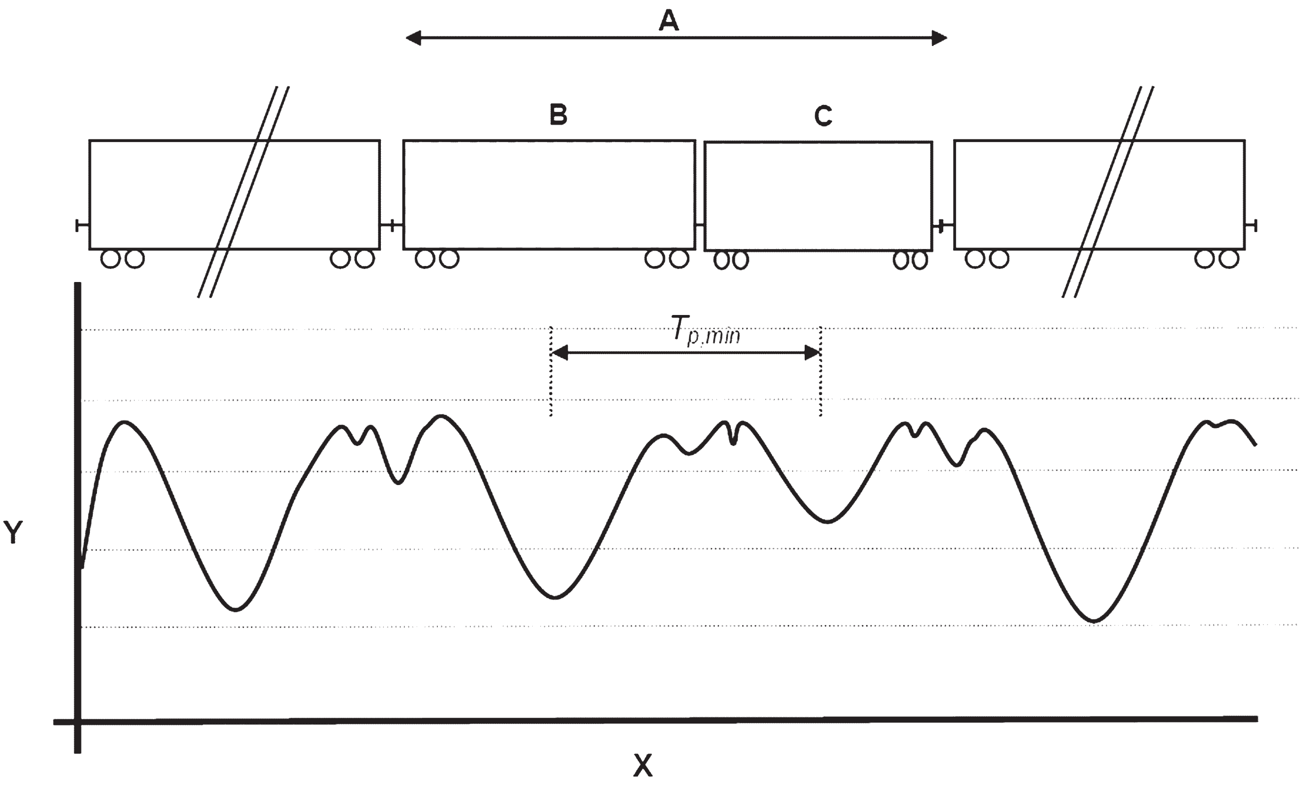

Key

Y A-weighted sound pressure level

X time

A unit under test

B vehicle type B

C vehicle type C

Figure B.3 — Minimum measurement time interval for a unit composed of two different and permanently coupled vehicles

B.4 Measurement of a single trailer unit

When a series consists of one unit, it might occur that only one car or wagon can be provided by the manufacturer for type testing. In such a case, it is permissible to measure this single unit provided that it is acoustically point symmetric. This shall, however, be considered as an exception since the procedure described below leads to an increased measurement uncertainty compared with the standard one.

This procedure shall not apply to driving trailers, see 6.6.3.

The unit under test shall be positioned at the end of the train. The measurement time interval *T* shall begin when the centre of the unit passes the measurement position and ends when the noise level measured at the measurement position has decreased by at least 10 dB compared to the maximum noise level measured during pass-by of the unit. See Figure B.4.

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The A-weighted equivalent pass-by noise level shall then be assessed according to

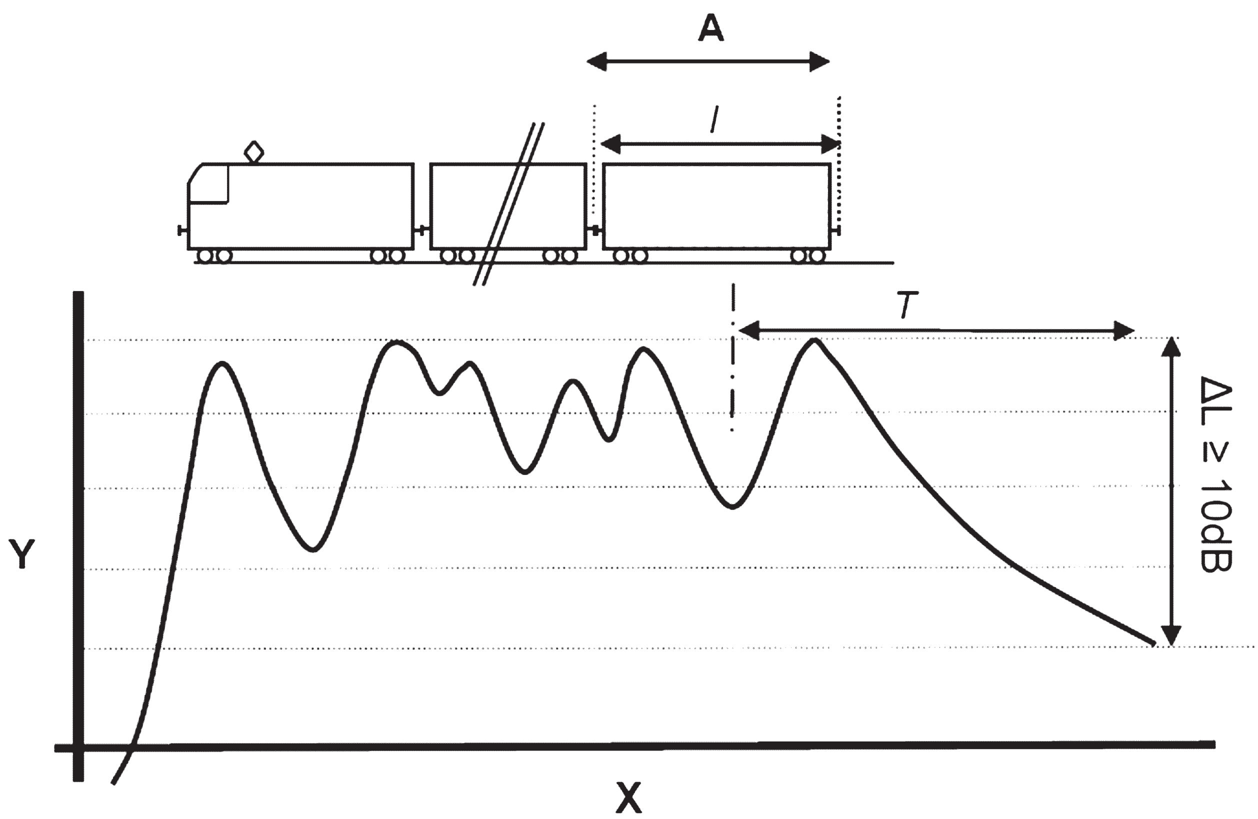
$$L_{pAeq,T_p} = 10\lg\left(\frac{1}{T_p}\int_0^T \frac{p_a^2(t)}{p_0^2}dt\right) \quad \text{(B.1)}$$

where

$T_p = \frac{l}{2} \times \frac{1}{v}$ pass-by time of half of the unit in s

l length of the unit in m

v train speed in m/s



Key

Y A-weighted sound pressure level

X time

A unit under test

Figure B.4 — Measurement time interval for the situation where only one unit is being tested at the end of the train

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Annex C
(normative)

Method to assess acceptable small deviations from acoustic rail roughness requirements

C.1 Principle

The “small deviations” method aims at introducing some flexibility in the conformity assessment of a test track section towards *an upper* limit curve of acoustic rail roughness within the frame of constant speed tests. Both the limit curve and the measured acoustic rail roughness spectra are assumed to be one-third octave band wavelength spectra.

The method relies on a calculation of a correction to the measured level based on the effect of any exceedence of a specified spectrum of acoustic rail roughness. The difference between the corrected pass-by noise level and the measured one is then compared to an acceptance criterion.

If the criterion is fulfilled, the acoustic impact of the rail roughness deviations is deemed “small” and the measured pass-by noise level is considered to be valid.

This method is train speed dependent.

C.2 Data Processing

C.2.1 Generate a “just compliant” corrected spectrum from the measured acoustic rail roughness wavelength spectrum (step 1)

The measured acoustic rail roughness spectra shall be quadratically averaged.

A corrected spectrum shall be derived from the measured acoustic rail roughness wavelength spectrum and from the limit spectrum according to the following formula:

$$\tilde{L}_{r,\text{rail}}^{\text{corrected}}(\lambda)=\min\left[\tilde{L}_{r,\text{rail}}^{\text{measured}}(\lambda),\tilde{L}_{r,\text{rail}}^{\text{limit}}(\lambda)\right] \quad \text{(C.1)}$$

where

$\tilde{L}_{r,\text{rail}}^{\text{measured}}(\lambda)$ is the one-third octave band wavelength spectrum of the measured acoustic rail roughness;

$\tilde{L}_{r,\text{rail}}^{\text{limit}}(\lambda)$ is the one-third octave band wavelength limit spectrum;

$\tilde{L}_{r,\text{rail}}^{\text{corrected}}(\lambda)$ is the one-third octave band wavelength spectrum of the corrected acoustic rail roughness;

NOTE 1 The corrected acoustic rail roughness spectrum is equivalent to the measured one except in the wavelength bands where the measured spectrum exceeds the limits.

NOTE 2 The corrected acoustic rail roughness spectrum complies with the limit spectrum.

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C.2.2 Quantify the deviations in the acoustic rail roughness frequency spectrum (step 2)

Transform the one-third octave band wavelength spectra (corrected and measured acoustic rail roughness) into the frequency domain to synthesize one-third octave band frequency spectra compliant with IEC 61260:1995. This shall be carried out in two stages:

— Firstly, derive frequencies from wavelengths using the formula $f = v/\lambda$ where λ is the wavelength and f is the corresponding frequency at train speed v. This leads to a non-normalized one-third octave frequency roughness spectrum;

— Secondly, distribute the energy in each frequency band over the normalized ones according to an algorithm based on the one supplied in EN 15610:2009, Annex C but adapted to non-constant frequency bandwidths.

The impact of the deviations on the acoustic rail roughness frequency spectrum is then quantified through a correcting spectrum which is calculated as follows:

$$\Delta L_{r,\mathrm{rail}}(f) = L_{r,\mathrm{rail}}^{\mathrm{measured}}(f) - L_{r,\mathrm{rail}}^{\mathrm{corrected}}(f) \quad \text{(C.2)}$$

where

$L_{r,\mathrm{rail}}^{\mathrm{measured}}(f)$	is the one-third octave frequency spectrum of the measured rail acoustic roughness;
$L_{r,\mathrm{rail}}^{\mathrm{corrected}}(f)$	is the one-third octave frequency spectrum of the corrected rail acoustic roughness;
$\Delta L_{r,\mathrm{rail}}(f)$	is the one-third octave frequency correcting spectrum.

C.2.3 Calculate a revised noise spectrum (step3)

A revised noise spectrum shall be calculated from the measured noise level and the correcting roughness spectrum, according to the following formula:

$$L_{p\mathrm{Aeq},Tp}^{\mathrm{revised}}(f) = L_{p\mathrm{Aeq},Tp}^{\mathrm{measured}}(f) - \Delta L_{r,\mathrm{rail}}(f) \quad \text{(C.3)}$$

The revised noise spectrum is derived from a simplified process. This procedure cannot be considered to be a prediction method.

NOTE Since it has been assumed in the method of calculation that the acoustic rail roughness exceedence directly applies to the total noise, the revised noise spectrum is the minimum that could have been measured with the just compliant roughness spectrum.

An upper bound of the noise impact of the acoustic rail roughness deviations shall then be derived from the measured and revised noise spectra by:

$$\Delta L_{p\mathrm{Aeq},Tp} = \underset{i}{\oplus}\left\{L_{p\mathrm{Aeq},Tp}^{\mathrm{measured}}(f_i)\right\} - \underset{i}{\oplus}\left\{L_{p\mathrm{Aeq},Tp}^{\mathrm{revised}}(f_i)\right\} \quad \text{(C.4)}$$

where $\underset{i}{\oplus}\{\ \}$ stands for the energy sum of all the one-third octave band levels considered.

C.3 Acceptance criterion

The track shall be considered to be compliant regarding the acoustic rail roughness spectrum if the noise impact $\Delta L_{p\mathrm{Aeq},Tp}$ calculated according to C.2.3 is less than or equal to 1 dB.

This compliance shall be examined for one pass-by at each speed.

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Annex D
(informative)

Guidance for light rail vehicles measurement

D.1 General

The scope of this International Standard includes all kinds of vehicles operating on rails including light rail vehicles. Nevertheless, the standard procedures in the document focus on heavy rail vehicle type testing. This Annex gives guidance on how to address differing conditions that may arise on light rail networks.

D.2 Rail acoustic roughness

The acoustic roughness spectrum, as defined in 6.2.5, for constant speed type tests may be difficult to achieve at a possible test site. In this case, it may still be of benefit to acquire informative data at such a site. The test site roughness spectrum shall be included in the test report.

As the pass-by results are dependent on the test situation, they shall always be reported in combination with the acoustic roughness spectrum and are not to be accepted as a general type test result. Comparison of the data with results from another test situation may be possible if the test situations are considered to be comparable when applying the method described in Annex E.

D.3 Track decay rates

The track decay rate spectra, as defined in 6.2.6, for constant speed type tests may be difficult to achieve at a possible test site. In this case it may still be of benefit to acquire informative data at such a site. The test site track decay rate spectra shall be included in the test report.

As the pass-by results are dependent on the test situation, they have always to be reported in combination with the track decay rate spectra and are not to be accepted as a general type test result.

For embedded track test situations, lateral track decay rates are not relevant and do not need to be measured.

D.4 Track design

Light rail vehicles operate on a large variety of track designs. These include different types of track bed, track bed support systems, sleepers, rail support systems, rail fasteners, rail pads, rail types and covering of the track superstructure.

The standard track design for type testing is ballasted track with wooden or reinforced concrete sleepers. Nevertheless measurement results for other configurations may be required, e.g. for embedded rails. Details of the track design shall be included in the test report.

As the pass-by results are dependent on the test situation they have always to be reported in combination with the test site track design description and are not to be accepted as a general type test result.

D.4.1 Propagation conditions

The propagation conditions, as defined in 5.2.1, 6.1.1, 7.2.1 and 8.1.1, may be difficult to achieve at a possible test site. In this case it may still be of benefit to acquire informative data at such a site. The test site acoustical environment shall be described in the test report.

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As the results are dependent on the test situation, they shall always be reported in combination with the acoustical environment description and are not to be accepted as a general type test result.

In the case of measurements on embedded rail, it is recommended that the level of the triangular ground surface between the near boundary of the test track structure and the microphone position extending along the track to a distance twice the microphone distance to either side shall be within +0,2 m to −0,2 m, relative to the top of rail.

In the case of measurements on embedded rail, it is also recommended, that the ground shall be of consistent characteristics within the part of the defined triangular area that is not part of the test track. For reasons of reproducibility it may be useful to describe the acoustic absorption properties of this surface.

D.4.2 How to handle high background noise levels?

The background noise level requirements, as defined in 5.2.3, 6.1.3, 7.2.3 and 8.1.3, may be difficult to achieve at a possible test site. In this case it may still be of benefit to acquire informative data at such a site.

As the results are dependent on the test situation, they have always to be reported in combination with the background noise level and are not to be accepted as a general type test result.

An additional procedure that may be applied in the case of stationary background noise is to assess its impact by using the formula:

$$\Delta L = L_{\text{meas}} - 10\lg\left(10^{L_{\text{meas}}/10} - 10^{L_{\text{bg}}/10}\right) \quad \text{(D.1)}$$

where

ΔL is the assessed level increase due to background noise;

L_{meas} is the measured vehicle noise level;

L_{bg} is the measured background noise level.

This procedure requires $L_{\text{meas}} - L_{\text{bg}}$ to be greater than 3 dB, if unacceptable uncertainty is to be avoided.

For frequency analysis, the same procedure may be applied for each frequency band of interest.

D.5 Additional interest in curving noise

D.5.1 General

Though the scope of this International Standard focuses on vehicle type tests, the combined acoustic behaviour of track and vehicle in curves is a major topic of interest for light rail vehicles.

Curving noise comprises broad-band and tonal components. It is not symmetrical in terms of the inner and outer rail of a curved track section.

On-board measurement will enable the localization of track sections where curving noise occurs. These measurements could also be used to indicate the increase in level in comparison with the noise on straight track.

Clause 6 of this International Standard provides advice that remains appropriate for measuring curving noise at the trackside. However, it is possible to augment or replace such measurements with on-board equipment. Trackside measurements will provide results which can be compared to pass-by measurements on straight track sections.

Measurements should be carried out under dry weather conditions only.

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The track section where the measurements are performed should be defined by at least:

— Precise description of the curve geometry (nominal radius, parabolic transition, cant, length of sections, geometry of check rail if present);

— gauge deviations;

— type of rail, rail supports, etc.;

— friction modifiers or lubricants if present.

These procedures may be used to define indicators of curving noise occurrence and severity, e.g. level, tonality, frequencies of tonal components etc. The proportion of test situations where a chosen indicator of curving noise is triggered should be reported.

In specific cases auxiliary devices emitting tonal noises need to be shut down to avoid misinterpretation of test results.

D.5.2 On-board measurements

The microphone position will depend on the vehicle design and practical considerations. The preferred location is outside the vehicle close to or inside the bogie area.

The measurement procedure shall include straight track sections as well as curves. If comparison between straight and curved track sections is required the vehicle conditions as given in 6.3 and 6.6, especially speed and traction effort shall be the same in both cases.

The following parameters and data should be recorded:

— $L_{p\text{AF}}(t)$;

— A storage of time history to enable detailed frequency analysis. The sampling frequency should be sufficient to allow a frequency analysis for all audible frequencies. In the case of tonality assessments the requirements of 6.7.2 apply;

— Vehicle speed, traction effort and localization data synchronized with the sound pressure data.

If measurements shall detect presence or absence of curve noises a measurement of survey grade is appropriate. This will relax the measurement equipment requirements to type 2 instruments.

D.5.3 Trackside measurements

The pass-by measurement setup defined in 6.4 needs to be modified to take into account the geometrical situation at the test site. The distance of the microphone position to the centre of the track is recommended to be 7,5 m. In the case of an extended length of track being of interest it may be necessary to define several microphone positions along the track.

The technique to identify appropriate microphone positions may need a preliminary measurement to evaluate the curving noise occurrence related to a specific stretch of track. This task may use a microphone placed at a distance other than 7,5 m.

Nevertheless the test result is related to the specific test situation. A general result concerning curve noise behaviour cannot be obtained from measurements at one test site.

The following parameters and data should be recorded:

— $L_{p\text{AF}}(t)$;

— a storage of time history to enable detailed frequency analysis. The sampling frequency should be sufficient to allow a frequency analysis for all audible frequencies. In the case of tonality assessments the requirements of 6.7.2 apply;

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— the time at which the microphone cross-section is passed, synchronized with the sound pressure data.

Recording intervals shall be chosen so that the entire noise event is captured.

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Annex E
(informative)

Comparability of test situations in terms of acoustic rail roughness

E.1 General

The preferred condition for measurement of pass-by noise emission of railway vehicles is the reference condition as defined in 6.2. This is the standard situation for type testing. It aims to reduce the test site dependency of the measurements as far as possible and to enhance the reproducibility of the measurements.

However, noise emission measurements with other track specification may be of interest, e.g. measurements on specific types of network or monitoring purposes. They will lead to test site dependent results. The following procedure provides a technique to assess whether two test situations may be considered to provide comparable test conditions in terms of acoustic roughness where all other factors that influence sound emission remain the same.

For the purpose of comparing test tracks the impact of different acoustic roughness will be assessed on the basis of the worst case scenario. Minimum and maximum envelopes of the acoustic roughness spectra of both test situations are used to calculate the maximum possible difference in terms of the pass-by level.

The test situations are accepted as being comparable if the variation of pass-by level due to acoustic roughness differences does not exceed an acceptance criterion.

The procedure does not change any measurement results; it establishes the comparability of measurement results under two acoustic roughness situations.

The procedure defined in this Annex produces an approximate bound to the difference in noise that might be measured at two sites because of a change in roughness only. It cannot be considered to give a prediction of that difference and it takes no account of any difference in decay rates or other factors.

E.2 Procedure

E.2.1 Generate the minimum and maximum envelope spectrum from the measured acoustic rail roughness wavelength spectra of the two test situations (step 1)

The envelope spectra shall be derived according to the following formulae:

$$\begin{aligned} \tilde{L}_{r,\text{rail}}^{\text{envelope,min}}(\lambda) &= \min\left[\tilde{L}_{r,\text{rail}}^{\text{meas,1}}(\lambda), \tilde{L}_{r,\text{rail}}^{\text{meas,2}}(\lambda)\right] \\ \tilde{L}_{r,\text{rail}}^{\text{envelope,max}}(\lambda) &= \max\left[\tilde{L}_{r,\text{rail}}^{\text{meas,1}}(\lambda), \tilde{L}_{r,\text{rail}}^{\text{meas,2}}(\lambda)\right] \end{aligned} \tag{E.1}$$

where

$\tilde{L}_{r,\text{rail}}^{\text{meas},i}(\lambda)$ is the one-third octave band wavelength spectrum of the measured acoustic rail roughness at test situation i;

$\tilde{L}_{r,\text{rail}}^{\text{envelope,min}}(\lambda)$, $\tilde{L}_{r,\text{rail}}^{\text{envelope,max}}(\lambda)$ is the minimum or maximum one-third octave band wavelength envelope spectrum of the two measured acoustic rail roughness spectra.

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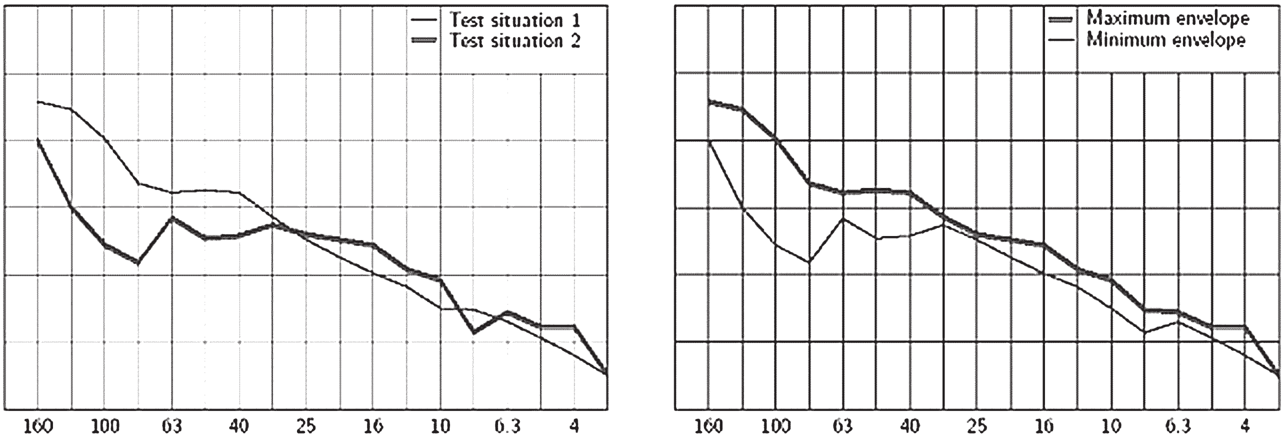

Figure E.1 — Envelope spectra of the measured acoustic rail roughness of two situations

E.2.2 Quantify the differences in the acoustic rail roughness frequency spectra (step 2)

Derive one-third octave band frequency spectra from the minimum and maximum envelope one-third octave wavelength spectra and the measured acoustic roughness spectra. The frequency bands should be as defined in IEC 61260:1995. This shall be carried out in two stages:

— Firstly, derive frequencies from wavelengths using the formula $f = v/\lambda$ where λ is the wavelength and f is the corresponding frequency at train speed v. This leads to four non-normalized one-third octave frequency roughness spectra;

— Secondly, distribute the energy in each frequency band over the normalized ones according to the algorithm according to EN 15610:2009, Annex C.

The impact of the differences between measured and envelope acoustic rail roughness frequency spectra is then quantified by applying “correcting spectra” which are calculated as follows:

$$\begin{aligned} \Delta L_{r,\mathrm{rail}}^{\mathrm{min},1}(f) &= L_{r,\mathrm{rail}}^{\mathrm{meas},1}(f) - L_{r,\mathrm{rail}}^{\mathrm{envelope,min}}(f) \\ \Delta L_{r,\mathrm{rail}}^{\mathrm{max},1}(f) &= L_{r,\mathrm{rail}}^{\mathrm{meas},1}(f) - L_{r,\mathrm{rail}}^{\mathrm{envelope,max}}(f) \\ \Delta L_{r,\mathrm{rail}}^{\mathrm{min},2}(f) &= L_{r,\mathrm{rail}}^{\mathrm{meas},2}(f) - L_{r,\mathrm{rail}}^{\mathrm{envelope,min}}(f) \\ \Delta L_{r,\mathrm{rail}}^{\mathrm{max},2}(f) &= L_{r,\mathrm{rail}}^{\mathrm{meas},2}(f) - L_{r,\mathrm{rail}}^{\mathrm{envelope,max}}(f) \end{aligned} \qquad \text{(E.2)}$$

where

$L_{r,\mathrm{rail}}^{\mathrm{meas},i}(f)$ is the one-third octave frequency spectrum corresponding to the measured rail roughness;

$L_{r,\mathrm{rail}}^{\mathrm{envelope,min}}(f)$, $L_{r,\mathrm{rail}}^{\mathrm{envelope,max}}(f)$ is the minimum or maximum one-third octave band frequency envelope spectrum of the two measured acoustic rail roughness spectra;

$\Delta L_{r,\mathrm{rail}}^{\mathrm{min},i}(f)$, $\Delta L_{r,\mathrm{rail}}^{\mathrm{max},i}(f)$ is the minimum or maximum one-third octave frequency correcting spectra.

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E.2.3 Calculate the revised noise spectra (step 3)

A maximum and minimum revised noise spectrum shall be calculated for each test situation from the measured noise level and the two corresponding correcting roughness spectra according to the following formula:

$$L_{pAeq,Tp}^{\text{revised,min}}(f) = L_{pAeq,Tp}^{\text{meas},i}(f) - \Delta L_{r,\text{rail}}^{\text{min},i}(f)$$
$$L_{pAeq,Tp}^{\text{revised,max}}(f) = L_{pAeq,Tp}^{\text{meas},i}(f) - \Delta L_{r,\text{rail}}^{\text{max},i}(f) \quad \text{(E.3)}$$

where

$L_{pAeq,Tp}^{\text{meas},i}(f)$ is the A-weighted noise spectrum measured at the test situation *i*.

The revised noise spectra are derived from a simplified process.

Two separate upper bounds of the noise level difference due to the acoustic rail roughness differences shall then be derived for each test situation *i* from the measured and revised noise spectra by:

$$\Delta L_{pAeq,Tp}^{\text{min},i} = \underset{i}{\oplus}\left\{L_{pAeq,Tp}^{\text{meas},i}(f_i)\right\} - \underset{i}{\oplus}\left\{L_{pAeq,Tp}^{\text{revised,min}}(f_i)\right\}$$
$$\Delta L_{pAeq,Tp}^{\text{max},i} = \underset{i}{\oplus}\left\{L_{pAeq,Tp}^{\text{meas},i}(f_i)\right\} - \underset{i}{\oplus}\left\{L_{pAeq,Tp}^{\text{revised,max}}(f_i)\right\} \quad \text{(E.4)}$$

where $\underset{i}{\oplus}\{\ \}$ stands for the energy sum of all the one-third octave band levels considered.

NOTE It is advisable to note that $\Delta L_{pAeq,Tp}^{\text{min},i} \geq 0$ and $\Delta L_{pAeq,Tp}^{\text{max},i} \leq 0$.

An upper bound of the noise level difference of the acoustic rail roughness differences between the two test situations shall then be derived by:

$$\Delta L_{pAeq,Tp} = \max\left(\left|\Delta L_{pAeq,Tp}^{\text{min},1}\right|, \left|\Delta L_{pAeq,Tp}^{\text{max},1}\right|, \left|\Delta L_{pAeq,Tp}^{\text{min},2}\right|, \left|\Delta L_{pAeq,Tp}^{\text{max},2}\right|\right) \quad \text{(E.5)}$$

E.2.4 Maximum influence of roughness variation on the noise level

The two test situations shall be considered as comparable regarding the acoustic rail roughness spectrum within a possible variation according to the noise impact $\Delta L_{pAeq,Tp}$, calculated according to E.2.3.

The procedure should be applied for one pass-by at each speed.

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Annex F
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Additional measurements

F.1 Additional measurements of noise at platforms and stopping points

F.1.1 General

These measurements shall evaluate the noise on platforms caused by the passing, arrival and departure of units at platforms in stations and at stopping points.

F.1.2 Measurement position

The microphone should be placed on the platform at a distance of 3 m from the centreline of the nearest track at a height of 1,5 m above the platforms in those places where there is an interest in the sound pressure level.

The microphone position should be set taking geometrical features like reflecting walls into account. The microphone should be placed as far as possible but at least at a distance of 1 m from any reflecting object.

The microphone axis should be horizontal and directed perpendicularly to the track. Other measurements may be made at corresponding positions on neighbouring platforms.

The measurement quantities should be chosen according to the procedures in Clauses 5, 6, 7 and 8.

For the measurements on underground stations, a drawing of the cross-section should be given in the test report.

NOTE When free field conditions are not fulfilled the measurement conditions prescribed above do not enable to determine the sound emission level of the unit. They can, however, be used for comparison purposes between different types of unit measured under the same conditions.

F.1.3 Vehicle conditions

During the tests, the units shall accelerate and decelerate in a normal way. The driving conditions shall be kept as constant as possible and shall be described in the test report, e.g. by stating the throttle or controller notch position together with the notch range of the unit (e.g. “Notch 4th position of a range from 1 to 8”).

F.2 Additional noise measurements on bridges and other elevated structures

The microphones shall be placed between 1/3 and 1/2 of a span of the bridge.

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Annex G
(informative)

Quantification of measurement uncertainties according to ISO/IEC Guide 98-3:2008[8]

G.1 General

The measurement uncertainty of each of the reported acoustic quantities should be derived and reported as the standard uncertainty. The combined standard uncertainty is then calculated as the energy sum of the standard uncertainties. Objective of the calculation is the expanded uncertainty U. Additional guidance on applying the methods is contained in ISO/IEC Guide 98-3:2008.[8]

The following terms are used:

— measurand Y, value of the particular quantity to be measured;

— input quantities X_i upon which the value of measurand Y depends, $Y = f(X_i)$;

— input estimates x_i;

— output estimate y (measurement result);

— uncertainty (of measurement): parameter, associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand Y;

— standard uncertainty u: uncertainty of the result of a measurement expressed as a standard deviation

— sensitivity coefficient $\partial f/\partial x_i$: the sensitivity coefficients describe how the output estimate y varies with the changes in the values of the input estimates x_i;

— combined standard uncertainty u_c: standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variances or covariances of these other quantities weighted according to how the measurement result varies with changes in these quantities;

— coverage factor k: numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty;

— expanded uncertainty U: quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand.

G.2 Mathematical model

The objective of a measurement is to determine the value of the measurand Y that is the value of the particular quantity to be measured. In general, the result of a measurement y is only an approximation or estimate of the value of the measurand Y as variations of the influence parameters to y occur. The result y is thus only complete when accompanied by a statement of the uncertainty of that estimate.

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The measurand Y of a sound pressure level can be described by n linear uncorrelated contributions as follows

$$Y = \sum_{i=1}^{n} X_i \qquad \text{(G.1)}$$

The possible uncertainties X_i influence the measurement result Y.

G.3 Determination of the standard uncertainties

$$u(x_i) = a/\sqrt{3} \qquad \text{(G.2)}$$

where the standard uncertainties $u(x_i)$ of all input quantities are to be considered.

If the standard uncertainties are unknown, it may be possible to estimate only upper and lower limits for X_i. In this case the probability that the value of X_i lies within the interval $a-$ to $a+$ for all practical purposes is equal to one and the probability that X_i lies outside this interval is essentially zero. Then a rectangular distribution of possible values can be assumed. Then the standard uncertainty is

$$u(X_i) = a/\sqrt{3}$$

Examples of possible *input quantities* and their uncertainties that are relevant for the uncertainty of measurements of noise emitted by rail bound vehicles are given in Table G.1.

The specifications of the devices result from IEC 61672 and IEC 60942:2003. The mentioned ranges and standard uncertainties are valid for a device according to class 1. These values may be used for uncertainty considerations where no better values are known (e. g. from the manufacturer).

Table G.1 — Examples of possible input quantities and their uncertainties that are relevant for the uncertainty of measurements of noise emitted by rail bound vehicles

Input quantity X_i	Description	Uncertainty interval	Standard uncertainty/ mean value correction $u(x_i)/\Delta L_p$
L_p	Reading value	0 dB	0 dB
$\delta_{\text{cal, reference}}$	Variations of the sound pressure level of the calibrator under reference conditions	±0,25 dB	0,14 dB
$\delta_{\text{cal, long term}}$	Variations of the sound pressure level of the calibrator since its last calibration	±0,07 dB	0,04 dB
$\delta_{\text{cal, supply voltage}}$	Change in the supply voltage	±0,10 dB	0,06 dB
$\delta_{\text{cal, distortion factor}}$[a]	Maximum increase of the sound pressure level due to the distortion factor of the calibrator	[−0,21 dB; 0 dB]	0,06 dB ΔL_p = 0,105 dB
$\delta_{\text{slm, direction}}$[b]	Direction of the angle of incidence of the sound (max ± 30°)	±0,44 dB	0,25 dB

[a] Unsymmetrical ranges [a; b] can be considered as symmetric ranges taking the mean value of the range [(a + b)/2] into account. The use of the mean value correction for $\delta_{\text{cal, distortion facto}}$, $\delta_{\text{slm, Impuls}}$ and $\delta_{\text{slm, wind screen}}$ increases the average sound level.

[b] The parameters of $\delta_{\text{slm, direction}}$ $\delta_{\text{slm, Impuls}}$ depend on the frequency content of the noise record. The given values are calculated out of typical noise records from different trains. The determined maximum values are given in the table.

[c] In the case of impulses, $\delta_{\text{slm, Impuls}}$ shall be considered. Analysed signals indicate that time duration of approximately 1 ms is reasonable for impulsive contributions. This was assumed in order to calculate the range of $\delta_{\text{slm, Impuls}}$.

[d] An increase of the sound pressure level over a time span of 2 ms was assumed on the basis of measurements for the estimation of the range of uncertainty.

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Table G.1 *(continued)*

Input quantity X_i	Description	Uncertainty interval	Standard uncertainty/ mean value correction $u(x_i)/\Delta L_p$
$\delta_{\text{slm frequency}}$[b]	Frequency dependent transfer factor	±0,44 dB	0,25 dB
$\delta_{\text{slm, level linearity}}$	Nonlinearity of the sound level meter at other sound levels than the calibration sound level	±0,8 dB	0,46 dB
$\delta_{\text{slm, impuls}}$[ac]	Error level of the fast evaluation of short term impulses[d]	[−1,5 dB; 1 dB]	0,72 dB ΔL_p = 0,25 dB
$\delta_{\text{calibrator, meteorological,}}$	Meteorological influences to the calibrator	±0,25 dB	0,14 dB
$\delta_{\text{slm, air pressure}}$	Influences of the air pressure to the sound level meter	±0,9 dB	0,52 dB
$\delta_{\text{slm, temperature}}$	Influences of the temperature to the sound level meter	±0,5 dB	0,29 dB
$\delta_{\text{slm, humidity}}$	Influences of the humidity to the sound level meter	±0,5 dB	0,29 dB
$\delta_{\text{slm, wind screen}}$[a]	Damping of the wind screen	[0,12 dB; 0 dB]	0,03 dB ΔL_p = 0,06 dB
δ_{tripod}	Wave reflection of the tripod	±0,6 dB	0,35 dB
$\delta_{\text{train speed}}$	Inaccuracies of the train speed and/or the tachometer (range of ±8 %)	±0,3 dB	0,17 dB
δ_{distance}	Variation in the sound pressure level due to inaccuracies in the microphone distance of ±5 %	- for a microphone distance of 25 m: ±0,07 dB - for a microphone distance of 7,5 m: ±0,23 dB	- for a microphone distance of 25 m: 0,004 dB - for a microphone distance of 7,5 m: 0,13 dB
$\delta_{\text{ground level,7,5}}$[a]	Variation of the ground surface level within 0 m to −2 m at a microphone distance of 7,5 m	[0 dB; 1,03 dB]	0,55 dB ΔL_p = 0,515 dB
$\delta_{\text{ground level,25}}$[a]	Variation of the ground surface level within 0 m to −2 m at a microphone distance of 25 m	[0 dB; 0,33 dB]	0,10 dB ΔL_p = 0,165 dB
δ_{rounding}	Rounding to the nearest integer	±0,5 dB	0,29 dB

[a]Unsymmetrical ranges [*a*; *b*] can be considered as symmetric ranges taking the mean value of the range [(*a* + *b*)/2] into account. The use of the mean value correction for $\delta_{\text{cal, distortion facto}}$, $\delta_{\text{slm, Impuls}}$ and $\delta_{\text{slm, wind screen}}$ increases the average sound level.

[b]The parameters of $\delta_{\text{slm, direction}}$ $\delta_{\text{slm, Impuls}}$ depend on the frequency content of the noise record. The given values are calculated out of typical noise records from different trains. The determined maximum values are given in the table.

[c]In the case of impulses, $\delta_{\text{slm, Impuls}}$ shall be considered. Analysed signals indicate that time duration of approximately 1 ms is reasonable for impulsive contributions. This was assumed in order to calculate the range of $\delta_{\text{slm, Impuls}}$.

[d]An increase of the sound pressure level over a time span of 2 ms was assumed on the basis of measurements for the estimation of the range of uncertainty.

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G.4 Determination of the combined standard uncertainty

The combined standard uncertainty $u_c(y)$ is calculated by:

$$u_c(y) = \sqrt{\sum_{i=1}^{N} \left(\frac{\partial f}{\partial x_i} \right)^2 u^2(x_i)} \tag{G.3}$$

From G.1 follows that the sensitivity factor can therefore be assumed to be 1 for all input quantities.

$$\frac{\partial f}{\partial x_i} = 1 \tag{G.4}$$

In this case the combined standard uncertainty $u_c(y)$ is then calculated by

$$u_c(y) = \sqrt{\sum_{i=1}^{N} u^2(x_i)} \tag{G.5}$$

G.5 Determination of the expanded uncertainty

The expanded uncertainty is obtained by multiplying the combined standard uncertainty $u_c(y)$ by a coverage factor.

$$U = k\, u_c(y) \tag{G.6}$$

k should be chosen to 2, so that the interval $[y - U; y + U]$ has a level of confidence of approximately 95 %.

G.6 Example

The following example, see Table G.2, shows the calculation of the uncertainty of a standstill noise measurement result. It is assumed that the noise contains no impulsiveness and that the different contributions are not correlated. The level of the ground over a distance of 7,5 m varies between 0 and 2 m below to the top of the rail.

Table G.2 — Example of the uncertainty budget of a stand still noise measurement result

Quantity	Possible typical range	Standard uncertainty $u(x_i)$	Sensitivity coefficient $\partial f/\partial x_i$	Contribution to the uncertainty
L_{pAeq}, reading value	55 dB		—	—
$\delta_{\text{cal, reference}}$	0 dB	0,14 dB	1	0,14 dB
$\delta_{\text{cal, long term}}$	0 dB	0,04 dB	1	0,04 dB
$\delta_{\text{cal, supply voltage}}$	0 dB	0,06 dB	1	0,06 dB
$\delta_{\text{cal, distortion factor}}$	0,105 dB	0,06 dB	1	0,06 dB
$\delta_{\text{slm, direction}}$	0 dB	0,25 dB	1	0,25 dB
$\delta_{\text{slm frequency}}$	0 dB	0,25 dB	1	0,25 dB
$\delta_{\text{slm, level linearity}}$	0 dB	0,46 dB	1	0,46 dB
$\delta_{\text{calibrator, meteorological,}}$	0 dB	0,14 dB	1	0,14 dB
$\delta_{\text{slm, wind screen}}$	0,06 dB	0,03 dB	1	0,03 dB
δ_{tripod}	0 dB	0,35 dB	1	0,35 dB
δ_{distance}	0 dB	0,06 dB	1	0,06 dB

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Table G.2 *(continued)*

Quantity	Possible typical range	Standard uncertainty $u(x_i)$	Sensitivity coefficient $\partial f/\partial x_i$	Contribution to the uncertainty
$\delta_{\text{ground level}}$	0,515 dB	0,30 dB	1	0,30 dB
δ_{rounding}	0 dB	0,29 dB	1	0,29 dB
$L_{p\text{Aeq}}$	55,68	0,83		

The combined standard uncertainty is $u_c(y) = \sqrt{\sum_{i=1}^{N} u^2(x_i)} = 0{,}83\,\text{dB}$.

The expanded uncertainty for $k = 2$ is: $U = 2u_c(y) = 1{,}66$ dB.

The ratios of the variance of the input quantities to the variance of the measurement result are shown in Figure G.1.

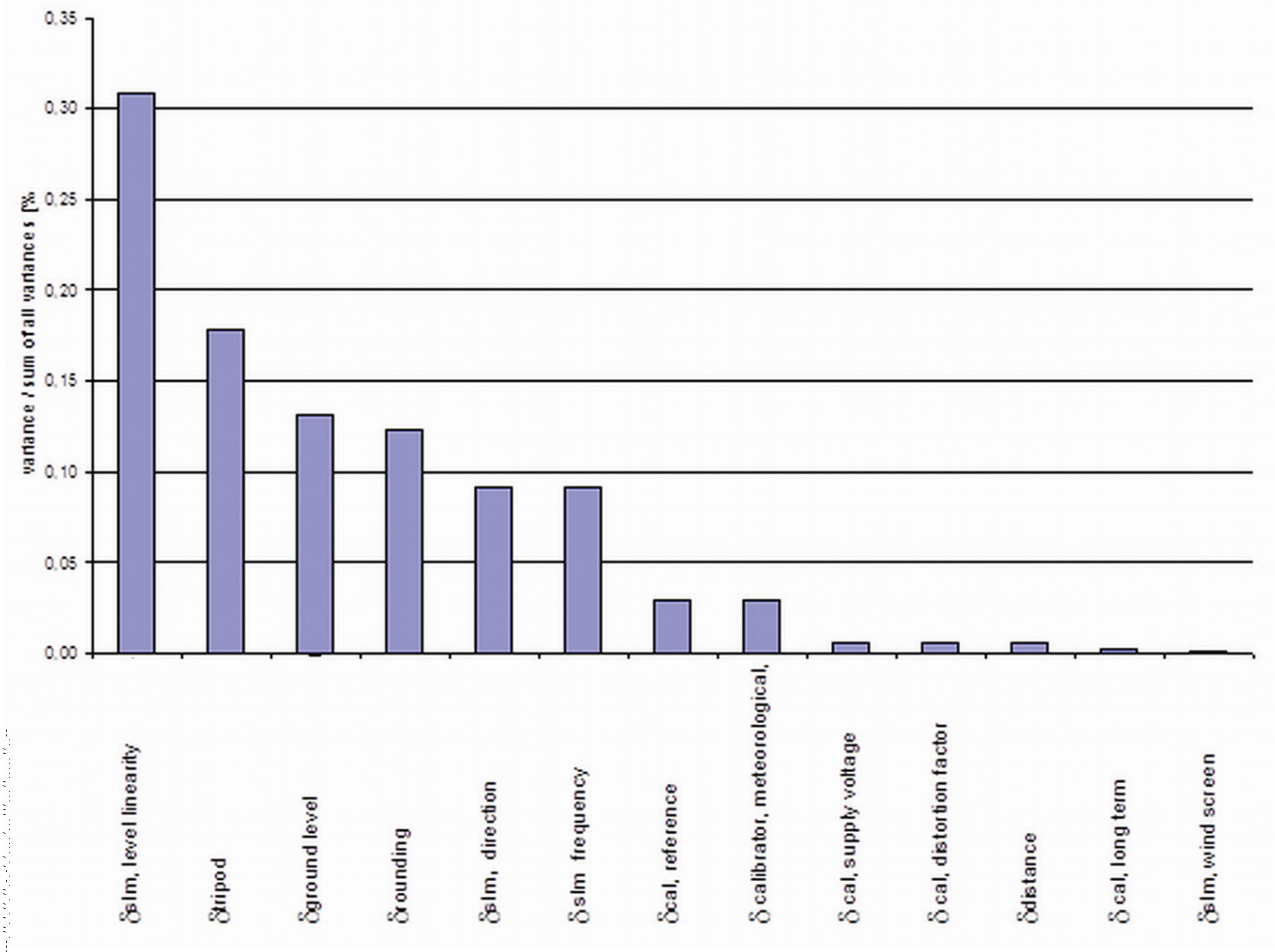

Figure G.1 — Ratio of the variance of the input quantities to the variance of the measurement result

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Bibliography

[1] ISO 266:1997, *Acoustics — Preferred frequencies*

[2] ISO 1996-1:2003, *Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment procedures*

[3] ISO 1996-2:2007, *Acoustics — Description, measurement and assessment of environmental noise — Part 2: Determination of environmental noise levels*

[4] ISO 3381:2005, *Railway applications — Acoustics — Measurement of noise inside railbound vehicles*

[5] ISO 9613-2:1996, *Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation*

[6] ISO 12576-1:2001, *Thermal insulation — Insulating materials and products for buildings — Conformity control systems — Part 1: Factory-made products*

[7] ISO 80000-8:2007, *Quantities and units — Part 8: Acoustics*

[8] ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

[9] IEC 60263:1999, *Scales and sizes for plotting frequency characteristics and polar diagrams*

[10] DIN 45681:2005, *Acoustics — Determination of tonal components of noise and determination of a tone adjustment for the assessment of noise immissions*

[11] EN 13129-1:2002, *Railway applications — Air conditioning for main line rolling stock — Part 1: Comfort parameters*

[12] ISO 12001:1996, *Acoustics — Noise emitted by machinery and equipment — Rules for the drafting and presentation of a noise test code*

[13] EN 13452-1:2003, *Railway applications — Braking — Mass transit brake systems — Part 1: Performance requirements*

[14] EN 14750-1:2006, *Railway applications — Air conditioning for urban and suburban rolling stock — Part 1: Comfort parameters*

[15] EN 14813-1:2011, *Railway Applications — Air conditioning for driving cabs — Part 1: Comfort parameters*

[16] EN 1793-3:1998, *Road traffic noise reducing devices — Test method for determining the acoustic performance — Part 3: Normalized traffic noise spectrum*

[17] Kraak W.Vorausbestimmung der Gehörbeeinträchtigung durch Lärm. In: *Taschenbuch der Akustik*, (Fasold W., Kraak W., Schirmer W.eds.). Verlag Technik, Berlin, 1984, pp. 284.

[18] Létourneaux F., Meunier N., Fodiman P.Proceedings of IWRN 2010 — Small deviations procedure:a new way to introduce flexibility in the conformity assessment of reference tracks for pass-by acoustic tests. ISBN n°9784431539261

[19] Report E.R.R.I.C163/RP21 Railway rolling noise modelling. Description of the TWINS model and validation of the model vs. experimental data

[20] Sound Analysis Software BZ 7201, Technical Documentation, Brüel & Kjaer – 1997

[21] Thompson D.J. Wheel-rail noise generation, part 1, 1993. *J. Sound Vibrat.* 1993, **161** pp. 387–400

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[22] Thompson D.J., Hemsworth B., Vincent N. Experimental Validation of the TWINS prediction program for rolling noise, part 1: description of the model and method. *J. Sound Vibrat.* 1996, **193** pp. 123–135

[23] Thompson D.J., Fodiman P., Mahé H. Experimental Validation of the TWINS prediction program for rolling noise, part 2: results. *J. Sound Vibrat.* 1996, **193** pp. 137–147

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