INTERNATIONAL STANDARD

ISO 3381

Second edition
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Railway applications — Acoustics — Measurement of noise inside railbound vehicles

Applications ferroviaires — Acoustique — Mesurage du bruit à l'intérieur des véhicules circulant sur rails

Reference number
ISO 3381:2005(E)

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 3381 was prepared by 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).

Throughout the text of this document, read "...this European Standard..." to mean "...this International Standard...".

This second edition cancels and replaces the first edition (ISO 3381:1976), which has been technically revised.

For the purposes of this International Standard, the CEN annex regarding fulfilment of European Council Directives has been removed.

Contents

Foreword

This European Standard (EN ISO 3381:2005) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN, in collaboration with Technical Committee ISO/TC 43 "Acoustics".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2006, and conflicting national standards shall be withdrawn at the latest by February 2006.

This document has been prepared under a mandate given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 96/48.

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

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

1 Scope

This European Standard specifies the conditions for obtaining reproducible and comparable measurement results of levels and spectra of noise inside all kinds of vehicles on rails or other types of fixed track, hereinafter conventionally called “train”, except for track maintenance vehicles in operation.

This standard is applicable for:

— type testing;

— periodic monitoring testing.

The results may be used, for example:

— to characterise the noise inside these vehicles;

— to compare the internal noise of various vehicles on a particular track section.

The test procedures specified in this European Standard are of engineering grade (grade 2, with a precision of ± 2 dB), that is the preferred one for noise declaration purposes, as defined in EN ISO 12001.

The standard describes tests during different operating conditions, i.e. driving, accelerating, decelerating and standstill. The chosen operating conditions are decided by the relevant authority or the train owner/operator. It is not mandatory to perform tests at all conditions.

Infrasound and messages intelligibility are not treated in this standard.

The procedures specified for accelerating and decelerating tests are of survey grade.

2 Normative references

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

EN 60942, *Electroacoustics — Sound calibrators (IEC 60942:2003)*

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

EN 61672-1:2003, *Electroacoustics — Sound level meters — Part 1: Specifications (IEC 61672-1:2002)*

3 Terms and definitions

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

3.1
type test for noise emission of railbound vehicles
type test
measurement performed to prove that, or to check if, a vehicle delivered by the manufacturer complies with the noise specifications

3.2
monitoring test for noise emission of railbound vehicles
monitoring test
measurement performed to check that the noise of one or more vehicles, taken among individual units in a consignment of vehicles, is within prescribed limits or to check if the noise of the vehicle has changed since initial delivery or after modification

3.3
roughness
r
root mean square (RMS) value of the amplitude variation of the running surface of a rail in the direction of motion (longitudinal level) measured over a rail length, expressed in µm

3.4
roughness level
L_r
level given by the equation:

$$L_r = 10 \lg (r/r_0)^2 \text{ dB} \quad (1)$$

where

L_r is the roughness level in dB;

r is the RMS roughness in µm;

r_0 the reference roughness; r_0 =1 µm.

This definition applies to values measured either as a wavelength spectrum or in a particular wavelength band centred at λ (expressed in m)

3.5
sound pressure
$p(t)$
root mean square (RMS) value of a fluctuating pressure superimposed on the static atmospheric pressure measured over a certain time period, expressed in Pa

3.6
sound pressure level
L_p
level given by the equation:

$$L_p = 10 \lg (p(t)/p_0)^2 \text{ dB} \quad (2)$$

where

L_p is the sound pressure level in dB;

$p(t)$ is the RMS sound pressure in Pa;

p_0 the reference sound pressure; p_0. = 20 µPa.

NOTE Definitions from 3.6 to 3.11 apply to values measured either as a frequency spectrum or in a particular frequency band of centre *f* (expressed in Hz).

3.7
A-weighted sound pressure level

L_{pA}

sound pressure level obtained by using the frequency weighting A (see EN 61672-1), given by the following equation:

$$L_{pA} = 10 \lg \left(p_A(t) p_0 \right)^2 \quad \text{dB} \tag{3}$$

where

L_{pA} is the A-weighted sound pressure level in dB;

$p_A(t)$ is the RMS A-weighted sound pressure in Pa;

p_0 the reference sound pressure; p_0. = 20 μPa.

3.8
AF-weighted maximum sound pressure level

L_{pAFmax}

maximum value of the A-weighted sound pressure level determined during the measurement time interval T by using time weighting fast F

[EN 61672-1]

3.9
A-weighted equivalent continuous sound pressure level

$L_{pAeq,T}$

A-weighted sound pressure level given by the following equation:

$$L_{pAeq,T} = 10 \lg \left(\frac{1}{T} \int_0^T \frac{p_A^2(t)}{p_0^2} \mathrm{d}t \right) \quad \text{dB} \tag{4}$$

where

$L_{pAeq,T}$ is the A-weighted equivalent continuous sound pressure level in dB;

T is the measurement time interval in s;

$p_A(t)$ is the A-weighted instantaneous sound pressure in Pa;

p_0 the reference sound pressure; p_0= 20 μPa.

3.10
A-weighted short-term equivalent continuous sound pressure level

$L_{pAeq,1s}$

A-weighted equivalent continuous sound pressure level (see 3.9) where the measurement time interval T is one second (T = 1s)

3.11
A-weighted equivalent continuous impulsive sound pressure level

$L_{pAIeq,T}$

A-weighted equivalent continuous sound pressure level determined by using time weighting impulse I (see EN 61672-1) given by the following equation:

$$L_{p\mathrm{AIeq},T} = 10 \ \lg \left(\frac{1}{T} \int_0^T \frac{p_{\mathrm{AI}}^2(t)}{p_0^2} \mathrm{d}t \right) \quad \mathrm{dB} \tag{5}$$

where

$L_{p\mathrm{AIeq},T}$ is the A-weighted equivalent continuous impulsive sound pressure level in dB;

T is the measurement time interval in s;

$p_{\mathrm{AI}}(t)$ is the A-weighted instantaneous sound pressure using time weighting I (Impulse) in Pa;

p_0 the reference sound pressure; p_0. = 20 μPa.

3.12
noise with impulsive character
noise which contains an isolated event or a series of such events. The impulsive character is conventionally confirmed if the difference between $L_{p\mathrm{AIeq},T}$ and $L_{p\mathrm{Aeq},T}$ is greater than 3 dB

3.13
noise with tonal character
noise which contains audible tones

4 Measurement quantities

4.1 General

The quantities to be measured at all microphone positions for both type and monitoring tests are specified below.

4.2 Frequency analysis is required for type tests while it is optional for monitoring tests. The typical 1/3 octave band frequency range is from 31,5 Hz to 8 kHz according to EN ISO 266. It is important, however, that the lower frequency limit is chosen to ensure that the product of the lowest bandwidth and signal duration exceeds unity.

4.3 In presence of noise with suspected impulsive character, both $L_{\mathrm{pAIeq,T}}$ and $L_{\mathrm{pAeq,T}}$ shall be measured. If they differ by more than 3 dB the impulsive character is conventionally confirmed.

4.4 In presence of noise with suspected tonal character, at each microphone position it is suggested to make frequency analysis measurements according to 4.2.

4.5 The measurement quantity for trains running at constant speed is the A-weighted equivalent continuous sound pressure level, $L_{\mathrm{pAeq,T}}$.

Additionally, the A-weighted short-term equivalent continuous sound pressure level, $L_{\mathrm{pAeq,1s}}$ may be measured.

4.6 For measurements on stationary vehicles, in presence of noise with suspected impulsive character, at each microphone position it is suggested to make two measurements: one with time weighting slow S, the other with time weighting impulse I (see EN 61672-1).

4.7 The measuring quantities for accelerating or braking tests shall be the maximum AF-weighted sound pressure level, L_{pAFmax}, and the A-weighted equivalent continuous sound pressure level, $L_{\mathrm{pAeq,T}}$. The measurement time interval, T is defined in Clause 7.

5 Instrumentation

The instrumentation system, including the microphones, cables and recording devices shall meet the requirements for a type 1 instrument specified in EN 61672-1.

The microphones shall have an essentially flat frequency response in a free sound field.

The one-third-octave band filters shall meet the requirements of class 1 according to EN 61260.

A windscreen shall always be fitted on the microphone.

Before and after each series of measurements, a sound calibrator with a class 1 accuracy according to EN 60942 shall be applied to the microphone(s) in order to verify the calibration of the entire measuring system at one or more frequencies over the frequency range of interest. If the difference between the two calibrations is more than 0,5 dB, all the measurement results shall be rejected.

The compliance of the calibrator with the requirements of EN 60942 shall be verified at least once a year. The compliance of the instrumentation system with the requirements of EN 61672-1 shall be verified at least every 2 years.

The date of the last verification of the compliance with the relevant European Standards shall be recorded.

6 Test conditions

6.1 Deviations from the requirements

The conditions prescribed for each test shall be complied with as closely as possible. Slight deviations from the specified test conditions are permissible, but shall be described in the test report and in general, will lower the reproducibility.

6.2 Test environment

6.2.1 Acoustical environment

The test site for chiefly outside-moving vehicles shall be such that the sound radiated by the vehicle to the outside contributes to the inside noise only by reflections from the track and not by reflections from buildings, walls or similar large objects outside the track.

For vehicles moving inside tunnels (like underground) the measurement shall be carried out in real operating conditions.

In the immediate vicinity of the track, there shall be no additional absorbent covering or snow.

6.2.2 Meteorological conditions

Measurements shall be made only if the wind speed measured at the microphone height is below 5 m/s and there is no falling rain or snow. Temperature, humidity, barometric pressure, wind speed and direction shall be described (possibly with measured values) in the test report.

6.2.3 Background sound pressure level

Care shall be taken to ensure that the noise from other sources (for example other vehicles or industrial plants) does not influence significantly the measurements.

For type tests, the A-weighted background sound pressure level shall be at least 10 dB below the reading of the A-weighted sound pressure level obtained when measuring the noise from the vehicle in the presence of background noise. For frequency analysis this difference shall be at least 10 dB in each frequency band of interest.

For monitoring tests, the A-weighted background sound pressure level shall be at least 5 dB below the reading of the A-weighted sound pressure level obtained when measuring the noise from the vehicle in the presence of background noise. If this difference is less than 10 dB the reading shall be corrected according to Table 1.

NOTE If the above-mentioned difference is less than 5 dB a measurement of engineering grade (grade 2) is no longer possible.

Table 1 — Background noise correction for monitoring tests

Difference between the A-weighted sound pressure level obtained when measuring the noise inside the vehicle in the presence of background noise and the A-weighted background sound pressure level alone dB	**Correction to be added to the A-weighted sound pressure level obtained when measuring the interior vehicle noise in the presence of background noise** dB
>10	0
6 to 9	–1
5	–2

6.3 Microphone positions

6.3.1 General

The measured sound pressure level inside a vehicle may vary considerably with location.

In particular, above the wheelsets or underfloor auxiliary equipment a higher sound level is likely. Therefore, the number of measuring points selected shall be such that the sound level distribution in the vehicle is adequately represented.

In general, five to seven measuring points, which include the middle and the ends of the vehicle, will be sufficient. The exact microphone positions shall be indicated on a plan. Examples are shown in Figure 1.

Dimensions in metres

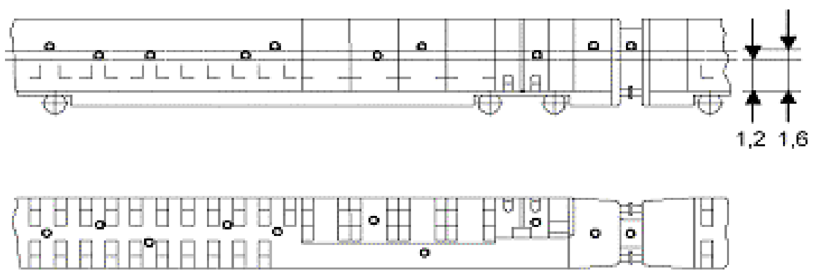


Figure 1 — Examples of usual microphone positions

6.3.2 Seated positions

The microphone is located at a height of 1,2 m above the vehicle floor in the centre of a closed compartment and in the centre line of the open car and midway between two rows of seats.

6.3.3 Standing positions

The microphone is located at a height of 1,6 m above the floor in the centre of areas accessible to standing passengers.

6.3.4 Working positions

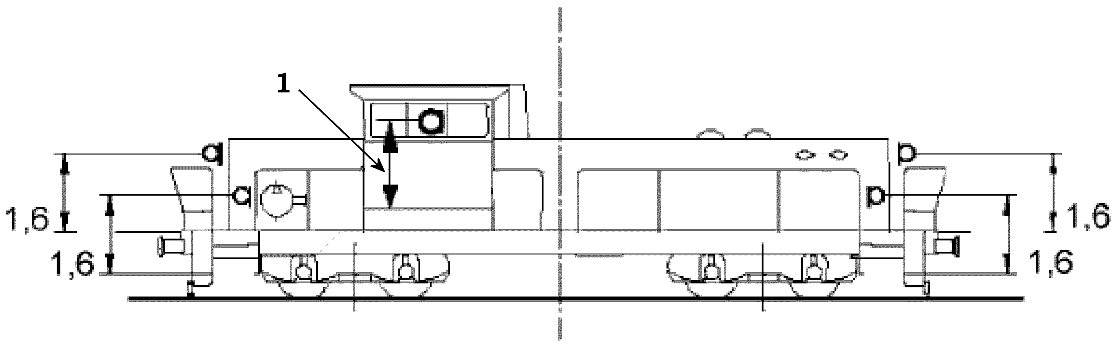
The microphone is located:

a) in the centre of the compartment at a height of 1,6 m above the floor for working positions located in a coach;

b) at ear level, at a distance of 0,1 m from the ear most exposed of the driver or of any other person who normally occupies the driver's cab; in this case, any orientation of the microphone is allowed;

c) in additional positions (see Figure 2).

Dimensions in metres



Key

1 Ear level

Figure 2 — Additional microphone positions for shunting locomotives

6.3.5 Lying positions

In couchettes and sleeping-cars, one of the microphone positions shall be 0,2 m above the pillow.

6.4 Vehicle conditions

6.4.1 General

The vehicle shall be in its normal operating conditions and, for test with constant speed, its wheels shall have run in normal conditions at least 3 000 km (or 1 000 km for tramways and metros) on track with normal traffic. For vehicles with tread brakes and block/tread pair shall be in ground conditions (a run-in condition where block and tread have ground themselves sufficiently). The wheel treads shall be as free as possible from irregularities, such as flats.

When trailed vehicles are to be tested, all efforts shall be made to ensure that the measurements are not influenced by noise from other parts of the train, like power unit adjacent vehicles.

6.4.2 Loading conditions

The vehicles shall be unloaded or unoccupied except for the train crew. For power units (for example locomotives), their normal load under working conditions (tractive effort) shall be used.

6.4.3 Doors, windows, auxiliary equipment, convertible furnishings

During the measurements, gangway doors between coaches, entry doors, intermediate doors and windows of the vehicle shall be kept closed, unless their influence upon the sound level inside the vehicle is to be investigated.

Auxiliary equipment on the test vehicle that normally operates during the run shall be in action. However, if the auxiliary equipment noise appears infrequently for only a short time (less than 2 % of the operating time) and if it affects the sound pressure level from other sources by less than 5 dB, it shall not be considered in the measurements.

The test report shall describe the state of the auxiliary equipments during the test.

If the disposition of furnishing inside the vehicle can be changed, for example berths in sleeping-cars, the measurements shall be repeated in each of the different furnishing conditions.

6.5 Track conditions

6.5.1 General

For conventional vehicles, the measurements shall be made with ballast bed and wooden or reinforced concrete sleepers, or with the track normally used by the train. The track shall be dry and not frozen. These tests shall be done on a railsection and sleeper design in common use on the particular railway network. If other track designs are integral with the operation of vehicles, they should be used for the tests.

The track shall be well maintained. The level gradient at the track shall be 3:1 000 at the most and the radius of curvature r shall be:

a) r = 1 000 m for tests at train speed v = 70 km/h;

b) r = 3 000 m for tests at train speed 70 < v = 120 km/h;

c) r = 5 000 m for tests at train speeds v > 120 km/h.

The track at the measuring section shall be laid without rail joints (welded rail) and free of visible surface defects such as rail burns or pits and spikes caused by the compression of external material between wheel and rail: no audible impact noise due to welds or loose sleepers should be present.

For testing in tunnels, the track type and the type and cross sectional area of the tunnel shall be described in the test report.

NOTE Noise generated by rolling stock is influenced by surface roughness of rail head and track dynamic characteristics. While the track roughness has to be measured at the measurement section by using this standard, track dynamic characteristics are still under study (see Annex C).

6.5.2 Rail roughness

The condition of the rail shall be considered suitable for type test measurements if the 1/3 octave band roughness levels throughout the test section fulfils the requirements of Annex A.

6.5.3 Special conditions

For non-conventional vehicles tested on their tracks, the track construction shall be described in the test report.

7 Test procedure

7.1 General

For type tests at least three measurements shall be made. The arithmetic mean value of each set of measurements shall be retained as the test result and shall be rounded to the nearest integer decibel. If the spread of the readings is larger than 3 dB, a new series of measurements shall be made.

For monitoring tests, it is sufficient to perform one measurement.

7.2 Measurement on trains with constant speed

Measurement on trains running at constant speed shall be performed at each microphone position and for each measuring condition with a measurement time interval $T = 20$ s. Shorter measurements time, in any case $T = 5$ s, shall be specified and justified in the test report.

The test speed(s) will be agreed by the owner of the rolling stock and the authority defining the measurement.

If additional tests are required they may be performed preferably at one or more of the 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.

Over the measurement section of the track, the vehicle under test shall be run at the chosen speeds stabilised within ± 5 %. The speed shall be measured by a device with an accuracy better than 3 %. The speedometer of the train may be used, provided a calibration with accuracy better than 3 % is performed.

7.3 Measurements on accelerating trains from standstill

Measurements on accelerating trains from standstill shall be performed with the train accelerating with maximum tractive effort without wheel skid; if the train under test is not a fixed configuration, the load shall be defined. It shall be typical of the normal service.

The measurement time interval T is defined as the time needed to reach $v = 30$ km/h from standstill.

7.4 Measurement on decelerating vehicles

Measurements on decelerating trains train shall be performed with the train braking with a normal service stop braking starting at $v = 30$ km/h.

The measurement time interval T is defined as the stopping time.

7.5 Measurement on stationary vehicles

For all stationary vehicles tests three consecutive measurements at each position are not required.

For all stationary vehicles the measurement time interval T shall be at least 20 s. But if as an exception it is not possible to maintain the source of noise at its maximum level 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.

The following cases apply:

a) coaches, wagons and electric power units: all equipment that can be operating with the stationary vehicle, including the main traction equipment where relevant, shall be operating. The auxiliary equipment shall be operated at maximum load;

b) power units with internal combustion engines:

- engine idling loaded by auxiliary equipment, cooling fans at minimum speed, auxiliary equipment with minimum load, compressor not operating, if possible;

- engine idling loaded by auxiliary equipment, cooling fans at a speed sufficient to maintain a stable engine temperature, auxiliary equipment with normal service load, compressor operating;

- if required engine at maximum possible speed unloaded (given by the speed governor), fan at maximum speed if possible, auxiliary equipment with normal service load, compressor operating;

c) power units with turbines and other engines: these shall be tested under conditions comparable to those specified above. The operating conditions shall be described in the test report.

8 Test report

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

a) nature of the tests, date, location, name and address of organisation performing the measurements (see also EN ISO/IEC 17025).

b) test site location, geometry (cross section and position along the track), vegetation, track type (including sleepers, railpad, fasteners and rail geometry and type and performances), environmental temperature, humidity, barometric pressure, wind speed and direction. For type tests measurements and rail roughness (requested, see Annex A).

c) measuring equipment and the type of microphones with the most recent calibration date.

d) background sound pressure level.

e) vehicle(s) and serial number(s), the traction system and its speed during the test. Statement that the vehicles are representative of a specific batch of vehicles.

f) operating conditions during the test.

g) auxiliary equipment and its operating conditions.

h) microphone positions.

i) measurement quantities described in Clause 4, *T* when appropriate.

j) presence of impulsive or tonal noise.

k) loading of the vehicle.

l) meteorological conditions

m) any other useful information.

Annex A
(normative)

Rail roughness measurement specifications

A.1 Measurement location and protocol

A.1.1 Lateral position on the railhead

On a straight track the wheel runs on a clearly visible running band, usually situated near the centre of the railhead. The running band can be as wide as 60 mm (for old track) or as narrow as 10 mm (for new track).

Rail roughness shall be measured on a line in the centre of this running band.

If the running band is wide enough, two supplementary parallel, equidistant lines at either side of the centre line shall be measured. The distance between the centre of the running band and the supplementary measurement lines depends on the width of the running band:

a) running band width = 10 mm: measurement of 1 line;

b) 10 mm < running band width = 20 mm: measurement of 3 lines, 5 mm equidistant;

c) running band width > 20 mm: measurement of 3 lines, 10 mm equidistant.

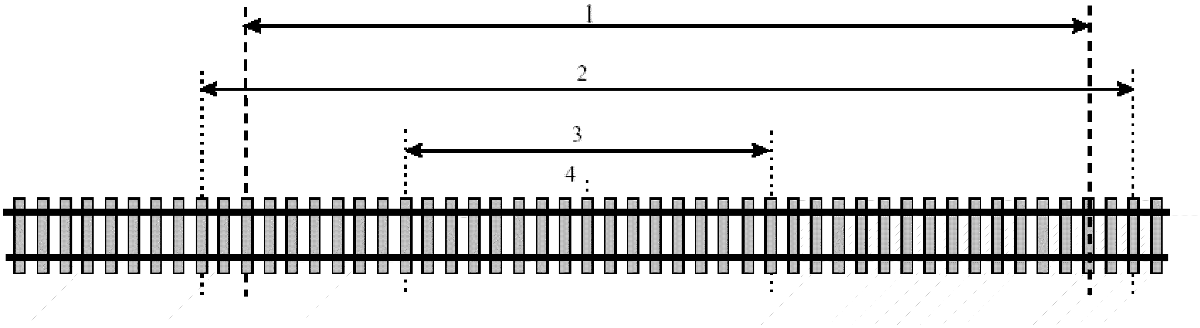
Width and position of the running band shall be checked on different cross sections of the test site to comply with variations along the test track.

A.1.2 Position along the track

A.1.2.1 Background information

For internal noise measurements, the roughness of the track section at which the internal noise measurements are performed shall be determined.

The objective of the track measurement protocol is to characterise the rail roughness at a certain track section without measuring the roughness of the entire track in detail. Therefore the test track is divided into sections located at specified intervals.



Key

1 Test Track
2 Indirect roughness measurements
3 Direct roughness measurement
4 Reference section

Figure A.1 — Track description for roughness measurements

There are two options to perform the roughness measurements:

a) direct roughness measurements (aimed at interior noise measurements on a short distance);

b) indirect roughness measurements, combined with direct roughness measurements (aimed at interior noise measurements on longer distances).

The second option provides an alternative to taking direct measurement samples along the entire test track, by combining direct roughness measurements at the reference section with indirect roughness measurements on the entire test track. In this procedure, the section where the direct roughness measurements are performed acts as a reference section. Indirect roughness can also be measured via railhead vibration.

A.1.2.2 Direct roughness measurement

As currently a standard on roughness measurement instruments is not available, the specifications of the used device shall be reported, in particular, the type of instrument, the type of transducer, the wavelength range, the amplitude range, the data processing technique (name and version of software) and the last calibration date.

The protocol described here is adapted from EN ISO 3095, which is aimed at external noise measurements. All references to external microphones are therefore not necessary but can provide a guideline on how to select the rail roughness measuring lengths and positions.

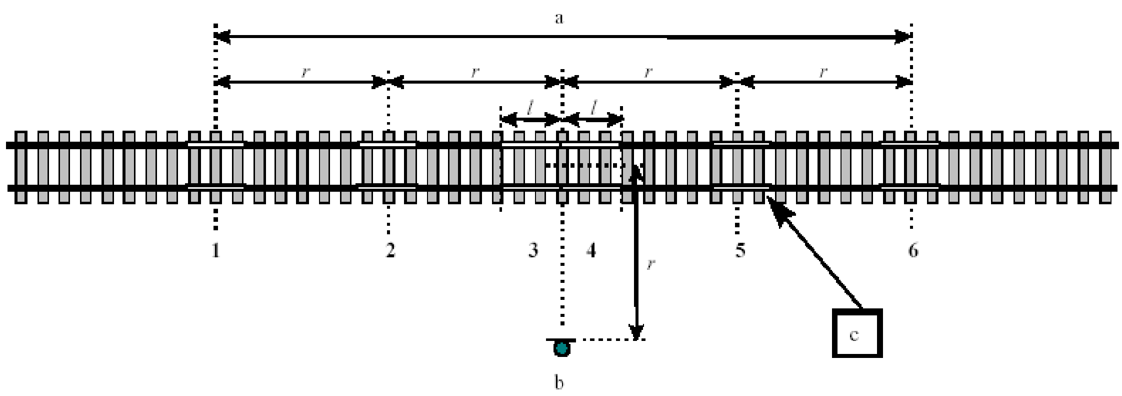
Direct roughness measurements are taken over the reference section, whose length is proportional to a conventional distance (microphone distance in EN ISO 3095) r = 25 m from the track and varies from $-2r$ to $+2r$ relative to the centre of the reference section where the noise measurement microphone is positioned.

Rail roughness shall be measured on the whole reference section, on 1 or 3 lines on each rail depending on the running band width, by using an instrument capable to cover wavelengths corresponding to the desired frequency range at the train speed(s) of interest. The recommended measurement range is:

a) 1/3 octave band wavelength range 0,008 ÷ 0,500 m;

b) amplitude range -20 ÷ + 30 dB re 1 ∝m in 1/3 octave wavelength bands.

Measurements with equipment capable to measure only limited lengths *l*, with a minimum of *l* = 1 m, are accepted and can be performed with the protocol shown in the Figure A.2. While the measurable wavelength lower limit depends only on equipment features, the upper limit depends also on the measured length *l*; for example, *l* = 1 m produces acceptable results only up to wavelengths around 0,100 m. Roughness samples of length *l* are taken on 3 parallel lines (1 if running bandwidth = 10 mm) at each rail in each cross section giving a total of 36 measurements (12 if running bandwidth = 10 mm).



Key

1 Cross section
2 Cross section
3 Cross section
4 Cross section
5 Cross section
6 Cross section

a Reference section
b Exterior noise microphone
c Measurement length *l*
3 parallel, equidistant lines

Figure A.2 — Sampling rail roughness sections for limited length equipment

A.1.2.3 Indirect roughness measurement

When interior noise measurements are performed for sections of the track differing from the reference section, direct roughness measurements have also to be performed for the applicable track sections where these noise measurements are performed.

Alternatively, if direct roughness measurements are performed only for the reference section, data may be collected for alternative parts of the test track by indirect measurements.

Indirect roughness measurements can be performed by measuring noise or vibration with an axle-box accelerometer or a microphone located under the train or a microphone located in a passenger coach. The wheels of the train should be permanently smooth, disc or sinter-block braked or unbraked, to minimise the influence of wheel roughness. If possible the wheel roughness should be measured directly.

The indirect roughness signals shall be recorded along the entire track where the noise measurements are performed, including the reference section where the direct measurements have been performed.

A.2 Processing of roughness data

A.2.1 Direct roughness measurement data

A 1/3-octave roughness wavelength spectrum is calculated from each measured roughness line. The average direct roughness spectrum valid for the reference track section is the energy average of all calculated roughness spectra.

NOTE 1 Large differences in roughness level may result from different processing methods. Beyond a certain depth and width, pits and spikes that occur due to rail head defects will not be followed by the wheels that hence will not vibrate accordingly. Neglecting to correct for these pits and spikes during processing will cause artificially high roughness levels resulting in non valid analysis values and possibly a rejection of the test track as a result of exceeding the limit roughness values. Methods that can be used for the removal of pits and spikes are not yet standardised (see for example refs. [1 ÷ 3, 5]).

NOTE 2 Methods that take into account the influence of rail roughness at different distances from the measurement section are currently under study (see ref. [3]).

A.2.2 Indirect roughness measurement data

The indirect measured signal for each alternative measurement section is analysed separately and the energy average is calculated.

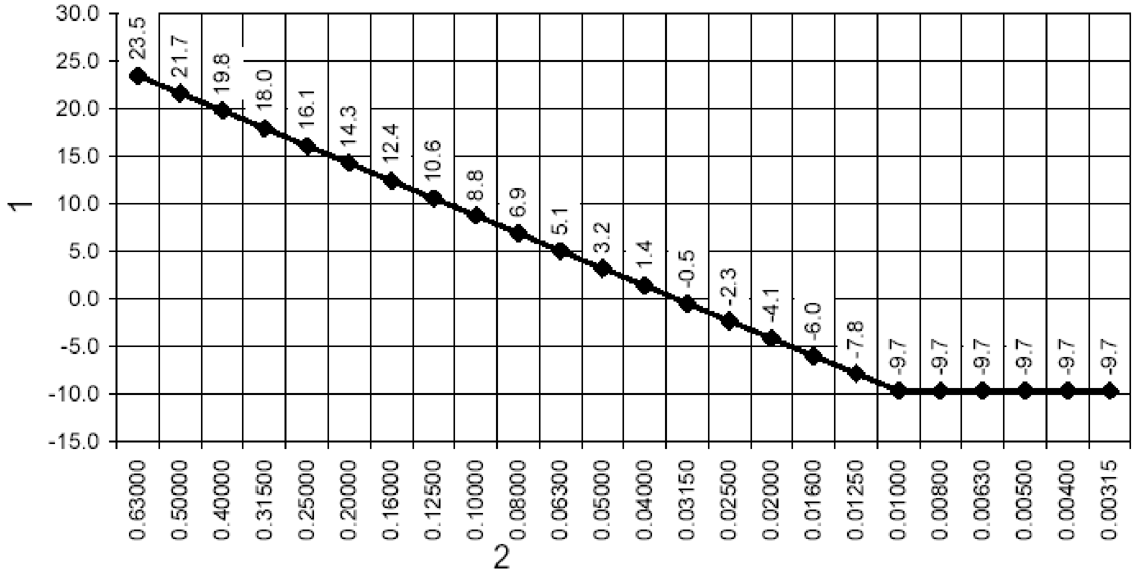
Indirect data measured for the reference track section shall be subtracted to indirect data measured for an alternative section. This difference is added to the average direct measured roughness spectrum of the reference section and compared to the limit roughness spectrum.

To convert frequency spectra to wavelength spectra, the relation $\lambda = v / f$ is used, with λ in m, v the recorded average train speed in m/s and f in Hz.

NOTE To be able to cover a wavelength range of 0,01 ÷ 0,1 m for measurements in frequency bands up to and including 10 kHz, the maximum allowable train speed for indirect measurements is 360 km/h. For assessment of wavelengths lower than 0,01 m (down to and including 0,002 5 m), train speed is restricted to a maximum of 90 km/h.

A.3 Test section approval

The average direct roughness spectrum is compared to the limit roughness spectrum shown in Figure A.3. The methods used to obtain the rail roughness limit spectrum are presented in Annex C of EN ISO 3095:2005.



Key

1 Roughness level (dB)
2 1/3 octave wavelength (m)

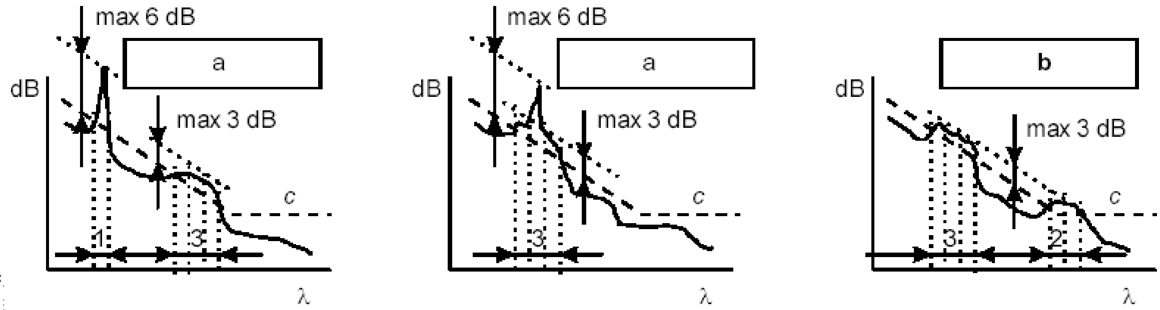
Figure A.3 — Rail roughness limit spectrum

The demand of homogeneity of the test track implies that the roughness levels measured at the different sections along the track should not exceed the limit roughness spectrum. However, as small variations are inevitable, the following criterion is applicable when the limit roughness spectrum is partly exceeded.

The test section is approved if the following criterion is met:

For each section and third octave band, the level of the average roughness spectrum with third octave band centres at wavelengths between 1 cm and 8 cm shall not exceed the limit roughness spectrum with more than 6 dB peak level in case of a single band or 3 dB peak level in case of a maximum of 3 adjacent bands over the wavelength range, or the combination of both. Only one event of a single band, 3 adjacent bands or a combination of these bands exceeding the limit is allowed.

Examples of application of the criterion are shown in Figure A.4.



Key

1	Max. 1 band	a	Approved
2	2 bands	b	Rejected
3	3 bands	c	Limit

Figure A.4 — Examples of application of the rail roughness spectrum approval criterion

A.4 Data presentation

Roughness spectra shall be presented in third octave bands with rail roughness level as a function of wavelength, in decreasing order, together with the limit spectrum.

The wavelength range will contain at least the 1/3-octave bands for the wavelengths between 0,100 m and 0,008 m.

The ratio of the horizontal and vertical axis shall be 3:4 (1 octave: 10 dB). Numbering of the wavelength labels should comply with the preferred frequencies of EN ISO 266.

Annex B
(informative)

Major influence parameters on track noise including track dynamics

Although wheel and rail roughness are major influence factors for rolling noise, also other parameters related to track dynamics are relevant. Table C.1 shows a list of influence parameters and their potential effect on the noise radiated by the track. If the track noise changes it can affect the total noise level. The values given in the table were obtained from a particular study and are indicative, and valid for conventional track systems.

At a specific site, the values for pad and fastener behaviour may vary from nominal values, depending on local variations due to alignment, age and maintenance. Also rail temperature, which can differ from air temperature due to heat radiation, can influence pad temperature and thereby pad stiffness and damping.

As shown in the table, the behaviour of rail pads and rail fastening systems can have substantial influence on the track noise contribution to total noise, potentially causing variations of up to 6 dB in noise radiated by the track.

It is therefore required to clearly describe the pads and fastening system used for any type test. The information specified in Clause 8 for track parameters is a minimum and any available additional information on track dynamic parameters should be included.

Particularly if the measured noise levels are compared with measurement data on other tracks this data is required.

Table B.1 — Major influence parameters on track noise

Parameter	Parameter value for minimum noise level	Parameter value for maximum noise level	Level difference for min. and maximum parameter value (dB)
Rail type	UIC 54 E1	UIC 60 E1	0,7 dB
Pad Stiffness	5 000 [MN/m]	100 [MN/m]	5,9 dB
Pad Loss Factor	0,5	0,1	2,6 dB
Sleeper type	Bi-bloc	Wooden	3,1 dB
Sleeper distance	0,4 m	0,8 m	1,2 dB
Ballast stiffness	100 MN/m	30 MN/m	0,2 dB
Ballast Loss Factor	2,0	0,5	0,2 dB
Wheel offset	0 m	0,01 m	0,2 dB
Rail offset	0 m	0,01 m	1,3 dB
Wheel Roughness	Smoothest	Roughest	8,5 dB
Roughness of uncorrugated rails	Smoothest	Roughest	0,7dB to 3,9 dB
Train Speed	80 km/h	160 km/h	9,4 dB
Axle load	25 t	10 t	1,1 dB
Air temperature	10 °C	30 °C	0,2 dB

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