INTERNATIONAL STANDARD

ISO 3095

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

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

Reference number
ISO 3095:2005(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 3095 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 3095:1975), 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 3095:2005) 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of an identical text or by endorsement, at the latest by February 2006, and conflicting national standards shall be withdrawn at the latest by February 2006.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 emitted by all kinds of vehicles operating 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 emitted by these trains;

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

— to collect basic source data for trains.

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

NOTE 1 Although this standard is for characterising noise emission for vehicles, the wheel-rail rolling noise often contains a significant and sometimes dominant noise contribution from the track.

NOTE 2 This Standard aims to specify the conditions for obtaining reproducible and comparable measurement results of noise emitted by railbound vehicles and the method described may also be used to monitor the noise emissions in ordinary traffic. In the latter case it is not necessary that track and vehicle conditions fulfil the requirements described in the standard. Therefore the results of such tests are only representative of a “particular” situation.

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

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

EN ISO 266, *Acoustics — Preferred frequencies (ISO 266:1997)*

3 Terms and definitions

NOTE Definitions from 3.7 to 3.14 apply to values measured either as a frequency spectrum or in a particular frequency band of centre *f* (expressed in Hz).

For the purposes of this European Standard, 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

[EN 13452-1]

3.2
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

3.3
monitoring test for noise emission of railbound vehicles
monitoring test
measurement performed to check if the noise of a vehicle has changed since initial delivery or after modification

3.4
environmental assessment test
measurement performed for collecting data to be utilised in prediction method for environmental assessment

3.5
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

3.6
roughness level
L_r
level given by the equation:

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

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)

3.7
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

3.8
sound pressure level
L_p
level given by the equation:

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

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 Adapted from ISO 1996-1:2003.

3.9
A-weighted sound pressure level
L_{pA}
sound pressure level obtained by using the frequency weighting A (see EN 61672 –1 and EN 61672-2), given by the following equation:

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

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.

3.10
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 F (fast)

[EN 61672-1]

3.11
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.

NOTE Adapted from ISO 1996-1:2003.

3.12
A-weighted equivalent continuous sound pressure level on the pass-by time
$L_{p\text{Aeq},T_\text{p}}$
A-weighted sound pressure level given by the following equation:

$$L_{p\text{Aeq},T_\text{p}} = 10 \text{ lg} \left(\frac{1}{T_2 - T_1} \int_{T_1}^{T_2} \frac{p_\text{A}^2(t)}{p_0^2} \text{d}t \right) \quad \text{dB} \qquad (5)$$

where

$L_{p\text{Aeq},T_\text{p}}$	is the A-weighted equivalent continuous sound pressure level on the pass-by time in dB;
$T_\text{p} = T_2 - T_1$	is the measurement pass-by time interval beginning at T_1 and ending at T_2 in s, see Figure 1;
$p_\text{A}(t)$	is the A-weighted instantaneous sound pressure in Pa;
p_0	the reference sound pressure; p_0 = 20 μPa.

3.13
single event level
SEL
A-weighted sound level of a single event measured for a time interval T and normalised to T_0 = 1 s. The time interval T will be long enough to include all the acoustic energy related to the event, considering at least the points at – 10 dB below the lower $L_{p\text{A}}$ during T. SEL is given by the following equation:

$$\text{SEL} = 10 \text{ lg} \left(\frac{1}{T_0} \int_{0}^{T} \frac{p_\text{A}^2(t)}{p_0^2} \text{d}t \right) \quad \text{dB} \qquad (6)$$

where

SEL	is the A-weighted sound exposure level in dB;
T_0 = 1 s	is the reference time interval;
T	is the measurement time interval in s;
$p_\text{A}(t)$	is the A-weighted instantaneous sound pressure in Pa;
p_0	the reference sound pressure; p_0 = 20 μPa.

single event level, SEL, is related to the A-weighted equivalent continuous sound pressure level, $L_{p\text{Aeq},T}$, by the following equation:

$$\text{SEL} = L_{p\text{Aeq},T} + 10 \text{ lg } (T/T_0) \text{ dB} \qquad (7)$$

3.14
transit exposure level
TEL
A-weighted sound level of a train passage, measured for a time interval T and normalised to the pass-by time T_p. The time interval T will be long enough to include all the acoustic energy related to the event, considering at least the points at – 10 dB below the lower $L_{p\text{A}}$ during T_p. TEL is given by the following equation:

$$\mathrm{TEL} = 10 \lg \left(\frac{1}{T_\mathrm{p}} \int_0^T \frac{p_\mathrm{A}^2(t)}{p_0^2} \mathrm{d}t \right) \quad \mathrm{dB} \tag{8}$$

where

TEL is the A-weighted transit exposure level in dB;

T is the measurement time interval in s;

T_p is the pass-by time of the train in seconds which is the overall length of the train divided by the train speed;

$p_\mathrm{A}(t)$ is the A-weighted instantaneous sound pressure in Pa;

p_0 the reference sound pressure; p_0 = 20 μPa.

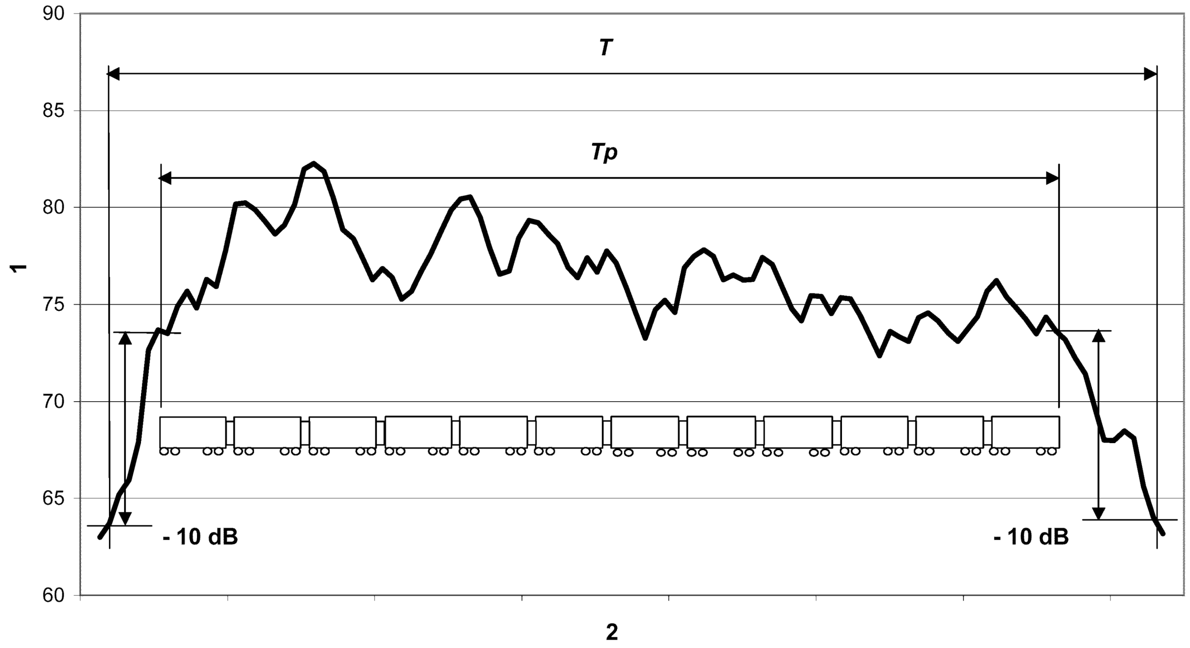
transit exposure level, TEL, is related to single event level, SEL, and to the A-weighted equivalent continuous sound pressure level, $L_{p\mathrm{Aeq},T}$ by the following equations:

$$\mathrm{TEL} = \mathrm{SEL} + 10 \lg_{10} (T_0/T_\mathrm{p}) \tag{9}$$ and

$$\mathrm{TEL} = L_{p\mathrm{Aeq},T} + 10 \lg (T/T_\mathrm{p}) \tag{10}$$

where T_0 = 1s is the reference time interval

3.15
measurement time interval T, and train pass-by time
T_p
measurement time interval, T, is chosen, so the measurement starts when the A-weighted sound pressure level is 10 dB lower than found when the front of the train is opposite the microphone position. The measurement is stopped when the A-weighted sound pressure level is 10 dB lower than found when the rear of the train is opposite the microphone position.



Key

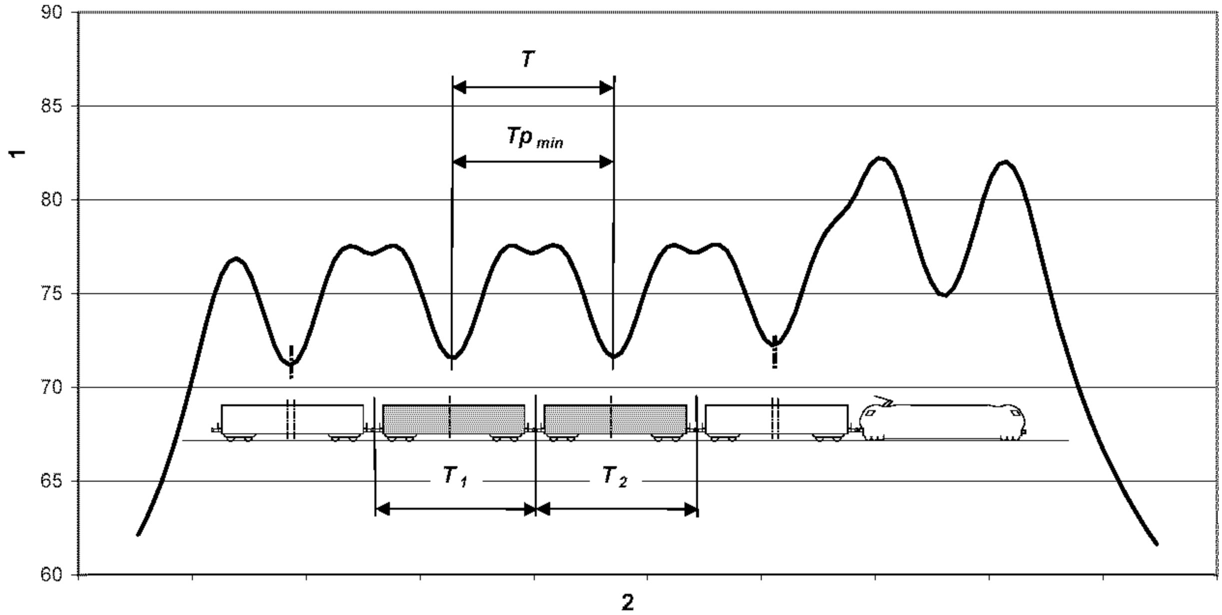
1 A-weighted sound pressure level, dB
2 Time

Figure 1 — Example of selection of measuring time interval, *T*, for a whole train

NOTE The example illustrates the need for an independent device for measuring the train passage time, as the time cannot be deduced from the sound pressure level versus time.

For measurement of vehicle(s), which form part of a train, the measurement time interval T is the passing time T_{p} of the vehicle(s) under test.

For the measurement of un-powered vehicles, the measurement time interval T begins when the centre of the first vehicle under test passes in front of the microphone position and ends when the centre of the last vehicle under test passes in front of the microphone position. Figure 2 shows the required measurement time interval T or the measurement of a single un-powered vehicle. Furthermore, it shows an example of the A-weighted sound pressure level, $L_{p\mathrm{A}}$, time history for the passage of a train.



Key

1 A-weighted sound pressure level, dB
2 Time

Figure 2 — Example of selection of measuring time interval, T, for parts of a train

3.16
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 $L_{p\text{AIeq},T}$ and $L_{\text{pAeq},T}$ is greater than 3 dB

[EN ISO 12001]

3.17
noise with tonal character
noise which contains audible tones

4 Measurement quantities

4.1 General

The quantities to be measured at all microphone positions are specified below.

4.2 The measurement quantities for trains moving at constant speed are:

a) for whole trains (this includes single vehicle trains), the Transit Exposure Level, TEL, or the A-Weighted equivalent continuous sound pressure level on the pass by time, $L_{pAeq,Tp}$ as the case may be.

b) for parts of trains, the A-weighted equivalent continuous sound pressure level on the pass-by time, $L_{\mathrm{pAeq},Tp}$.

4.3 The measurement quantity for stationary vehicles is the A-weighted equivalent continuous sound pressure level, $L_{\mathrm{pAeq,T}}$.

4.4 The measurement quantity for accelerating or braking tests shall be the maximum AF-weighted sound pressure L_{pAFmax}.

4.5 If frequency analysis is required, it shall be made at least in one third octave bands according to EN ISO 266: a typical frequency range could be 31,5 Hz to 8 kHz. 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.

4.6 In presence of noise with suspected tonal character, at each microphone position it is suggested to make frequency analysis measurements according to 4.5.

Currently no method exists to measure simply the tonal character of the noise from passing trains: conventionally, if the level of one frequency band exceeds the level of the arithmetic mean of its adjacent bands by more than 5 dB the tonal character may be confirmed; this method should be used when there are no other national methods for the evaluation of pure tones.

4.7 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 S (slow), the other with time weighting I (impulse) (see EN 61672-1).

Currently no method exists to measure impulsiveness of the noise from passing trains: conventionally, if the difference between the two is more than 5 dB the impulsive character may be confirmed; this method should be used when there are no other national methods for the evaluation of impulsiveness.

4.8 Additional measurements on stationary vehicles, at platforms and stopping points and on bridges are described in Annex B.

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 1/3 octave band filters shall meet the requirements of class 1 according to EN 61260.

A suitable windscreen shall always be used.

Before and after each series of measurements a sound calibrator meeting the requirements of class 1 according to EN 60942 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 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 and EN 61672-2 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 for type tests 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 should be such that free sound propagation exists; to achieve this result, the ground needs to be essentially flat and within a level from 0 m to -1 m, relative to the top of rail.

An area around the microphones having a radius which is at least 3 times the measurement distance on both sides shall be free of large reflecting objects like barriers, hills, rocks, bridges or buildings.

In the vicinity of the microphones, there shall be no obstacles which could disturb the sound field. Therefore, no person shall be between the microphones and the sound source, and the observer shall be in a position that does not influence the measured sound pressure level significantly.

The area between the vehicle and the microphones shall not be saturated and shall be as free as possible of sound absorbing matter (e.g. snow, tall vegetation, other tracks) or reflective covering (e.g. water, ice). The ground cover shall be described in the test report.

NOTE In practice, the suitability of a test site may be checked with a relatively small sound source generating wide band noise. If the free field assumption is verified, the measured sound level should decrease by about 6 dB at the microphone height if the microphone distance is doubled.

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 and due to wind) 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.

Table 1 — Background noise correction for monitoring tests

Difference between the A-weighted sound pressure level obtained when measuring the noise from 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 noise from the vehicle in the presence of background noise dB
>10	0
6 to 9	–1
5	–2

6.3 Microphone positions

6.3.1 General

The microphone axis shall always be horizontal and directed perpendicularly to the track. The available standard microphone positions are shown in Figure 3. It may not always be possible or necessary to measure at all the positions, but the microphone positions selected shall be one or more of those defined. The permitted microphone positions are on both sides at a distance of 7,5 m from the track axis, at a height of 1,2 m ± 0,2 m above the top of rail, and on both sides at a distance of 25 m from the track axis, at a height of 3,5 m ± 0,2 m above the top of rail. If important sound sources (for example exhaust pipes or pantographs) are present in the upper part of the vehicle under test, additional microphone positions are on both sides at a distance of 7,5 m from the track axis and at a height of 3,5 m ± 0,2 m above the top of rail.

6.3.2 Measurement on stationary vehicles

The microphone shall be placed at a distance of 7,5 m from the centre line of the track at a height of 1,2 m ± 0,2 m above the upper surface of the rail and opposite the centre of the vehicle. (See Annex B)

6.3.3 Measurement on vehicles with constant speed

Where measurements on both sides are specified for type tests (e.g. for non-symmetric distribution of train noise sources), they do not need to be made at the same time.

Dimensions in metres

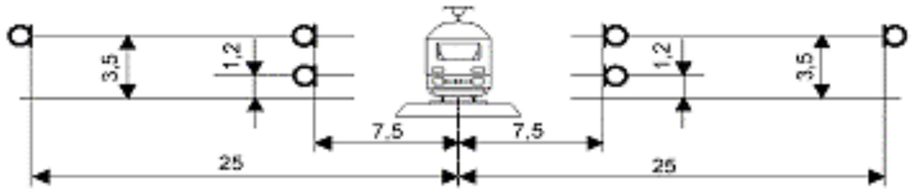


Figure 3 — Lateral microphone positions for measurements on vehicles with constant speed

6.3.4 Measurements on accelerating from standstill or decelerating vehicles

The vertical and lateral positions of the set of microphones are identical for all types of accelerating from standstill and decelerating tests and are identical to the positions described in 6.3.1 at 7,5 m from the track axis only.

The number of sets and their longitudinal position, i.e. the distance ahead of the front of the train at the moment when it starts accelerating or braking, depend on the type of train.

Given *L* the distance between the bogie centres of the vehicle, the sets of microphones will be placed:

a) one set 20 m ahead of the front of the train in the case of an individual power unit accelerating;

b) two sets, one at the front of the train and the other at *L*/2 m ahead of the front of the train, in the case of accelerating trains with distributed power or of decelerating trains of any kind.

The measurement shall end when the end of the unit is 20 m past the last set of microphones. For acceleration test, the measurement shall be stopped when either the rear of the power unit is 20 m past the last set of microphones or the speed exceeds 30 km/h.

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 or operating 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

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

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.

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 rail section 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.

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 D).

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

7.1.1 The measurement quantities according to Clause 4 and the associated time interval T shall be measured for each microphone position. The train pass-by time, T_p, shall be measured with an independent device, such as a light barrier or a wheel detector.

7.1.2 For type tests, at least three measurements shall be made at each microphone position and for each measuring condition. The arithmetic mean value of each set of measurements shall be determined and used 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.

7.1.3 If the sound pressure levels measured on each side of the vehicle are different; the higher sound pressure level shall be retained as measurement results.

7.1.4 For the measurement of a single trailed vehicle, there shall be at least one acoustically similar vehicle after the power unit, followed by at least two vehicles under test, and at least one acoustically similar vehicle.

7.1.5 All vehicle auxiliary equipment shall be in operation at its normal load during the test.

7.2 Measurement on vehicles with constant speed

7.2.1 The preferred speeds of testing are 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. Three cases apply:

a) type testing of trains with v_{max} = 200 km/h: tests shall be performed at v = 160 km/h and at v_{max}, or, preferably, at the highest possible speed of the train corresponding to one of the preferred speeds. Whenever possible, tests should be performed also at v = 80 km/h;

b) type testing of trains with 80 km/h < v_{max} < 200 km/h: tests shall be performed at v = 80 km/h and at v_{max}, or, preferably, at the highest possible speed of the train corresponding to one of the preferred speeds;

c) type testing of trains with v_{max} = 80 km/h: testing shall be performed at v = 40 km/h and at v_{max}.

Additional tests should be performed at one or more of the preferred speeds.

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 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.

7.2.2 For measurement of trailed vehicle(s) which form part of a train, the measurement time interval T shall be the passing time of the vehicle(s) under test measured with an independent device, such as a light barrier or a wheel detector.

The measurement time interval T is defined as the time elapsed between the passing in front of the microphone positions of the centres of the first and of the last vehicle under test.

7.2.3 The measured quantities are $L_{pAeq,Tp}$ and TEL for whole trains, $L_{pAeq,Tp}$ for single vehicles.

7.3 Measurements on accelerating vehicles from standstill

Tests shall be performed 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.

Two cases apply:

a) for trains with individual power unit, the train should accelerate from standstill up to 30 km/h. The measurement time interval T shall begin when the front of the starting power unit is 20 m ahead of the microphone position and shall end when the rear of the power unit under test is 20 m past the microphone position. The traction unit shall be at the head of the train. The operating conditions shall be described in the test report. The measured quantity is the highest L_{pAFmax};

b) for trains with distributed power, the train should accelerate from standstill with normal service acceleration up to 30 km/h and then maintain that constant speed. The measurement time interval T shall begin when the front of the train is 20 m ahead of the first set of microphones and shall end when the rear of the power unit is 20 m past the second set of microphones; the measured quantity is the highest L_{pAFmax}.

7.4 Measurements on decelerating vehicles

The train shall run with a constant speed of 30 km/h and start a normal service stop braking when the front of the vehicle under test is passing the first microphone position.

The measurement time interval *T* shall begin when the front of the vehicle under test reaches a position 20 m ahead of the first microphone position and shall end when the train stops; the measured quantity is the highest L_{pAFmax}.

The service braking should be performed as prescribed by the vehicle manufacturer including the foreseen bleed of the braking system.

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 and T_p when appropriate.

j) presence of impulsive or tonal noise.

k) loading of the vehicle.

l) 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.

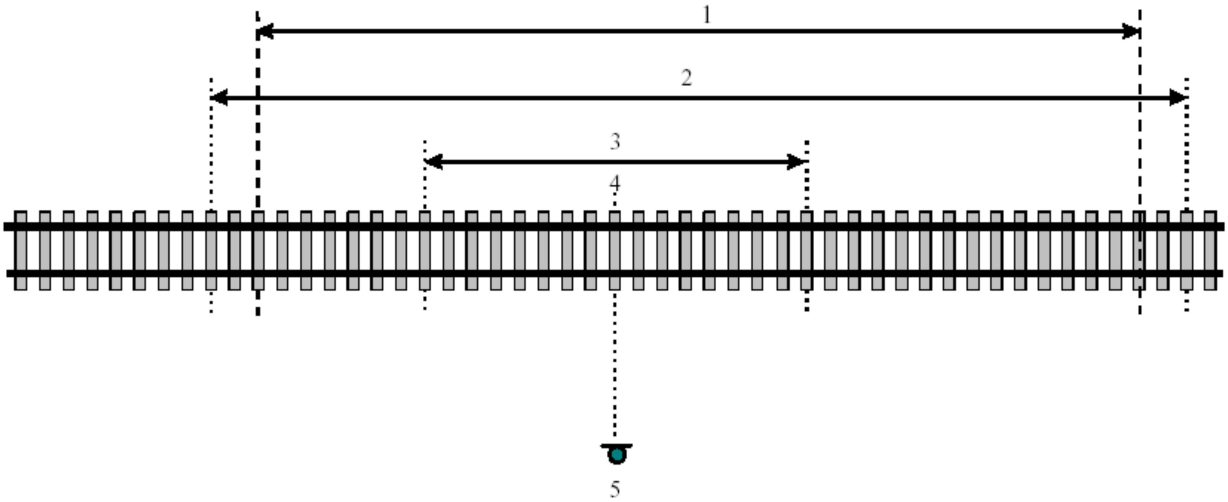
Width and position of the running band shall be checked on different cross sections of the test site to comply with variations along the test track.

A.1.2 Position along the track

A.1.2.1 Background information

For external and internal noise measurements, the roughness of the track in the vicinity of the noise measurement location and 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 relative to the external noise measurement section.



Key

1 Test track
2 Indirect roughness measurements
3 Direct roughness measurements
4 Reference section
5 External noise microphone

Figure A.1 — Track description for roughness measurements

There are two options to perform the roughness measurements:

a) direct roughness measurements (aimed at external noise measurements);

b) indirect roughness measurements, combined with direct roughness measurements (aimed at internal noise measurements).

The second option provides an alternative to taking direct measurement samples along the entire test track, by combining direct roughness measurements at the external noise measurement location 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.

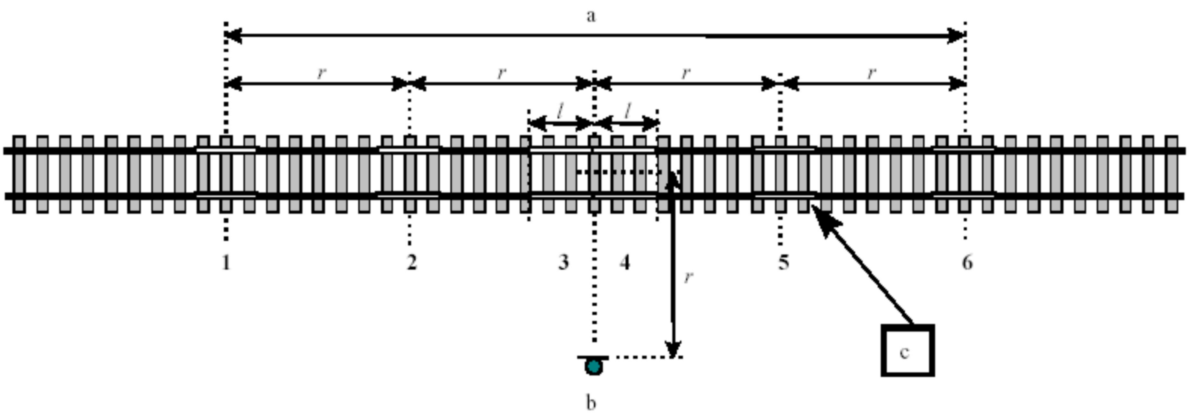
Direct roughness measurements are taken over the reference section, whose length is proportional to the microphone distance r from the track and varies from $-2r$ to $+2r$ relative to the centre of the reference section where the noise measurement microphone is positioned.

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 0,008m ÷ 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 external noise measurements are performed for sections of the track differing from the reference section, or if (simultaneously) interior noise measurements are performed, 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.

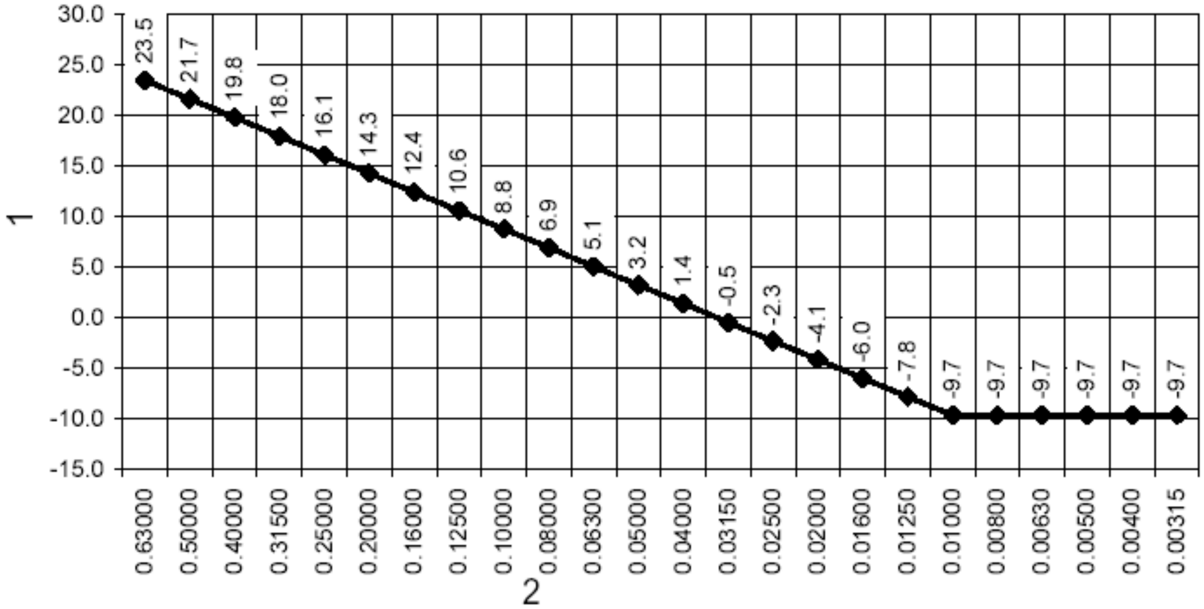
Indirect data measured for the reference track section shall be subtracted to indirect data measured for an alternative section. This difference is added to the average direct measured roughness spectrum of the reference section and compared to the limit roughness spectrum.

To convert frequency spectra to wavelength spectra, the relation *.* = *v* / *f* is used, with *.* 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.



Key

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

Figure A.3 — Rail roughness limit spectrum

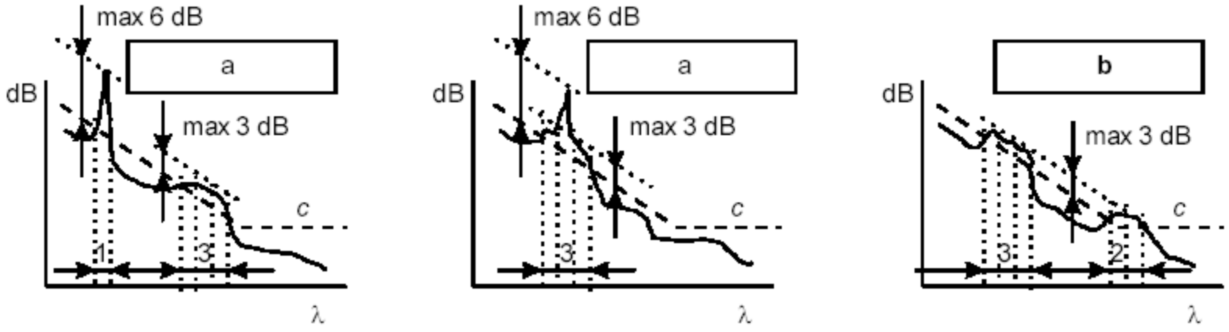
The demand of homogeneity of the test track implies that the roughness levels measured at the different sections along the track should not exceed the limit roughness spectrum. However, as small variations are inevitable, the following criterion is applicable when the limit roughness spectrum is partly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

Additional measurements

B.1 Additional measurements on stationary vehicles

Microphone position

The microphone shall be placed at a distance of 7,5 m from the track axis at a height of 1,2 m ± 0,2 m above the upper surface of the rail and in front of the centre of the vehicle.

A second microphone position at a height of 3,5 m ± 0,2 m above the top of rails is recommended if important sound sources are present in the upper part of the vehicle under test (for example with power units).

The distance *x* resulting between the microphone and the side of the vehicle shall be maintained around the contour of the vehicle in accordance with Figure B.1. The spacing, *a*, between the microphone positions parallel to the side walls of the vehicle shall be between 3 m and 5 m to obtain three microphone positions for each side, if possible. For vehicle lengths exceeding 20 m, more than six microphone positions parallel to the sidewalls shall be used in addition to the six positions in front and at the rear end of the vehicle.

The microphone positions shall include positions on the transverse axes of the driver's cabin and of the power unit.

The microphone axis shall be directed perpendicularly to the contour of the vehicle (see Figure B.1).

Dimensions in metres

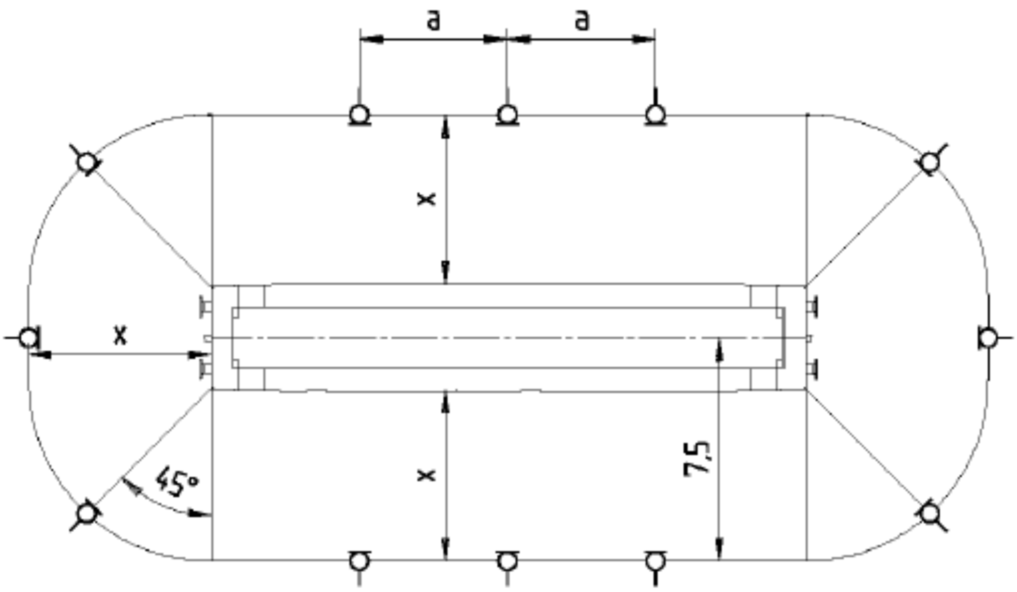
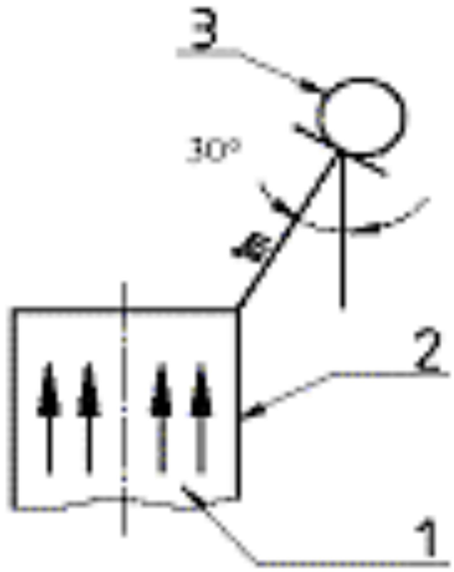


Figure B.1 — Microphone positions around stationary vehicles

If the sound pressure levels at the intake and exhaust of the engine or the air-conditioning and cooling system are to be measured, it is recommended that the microphone be placed outside the gas stream at a distance of

1 m from the edge of the intake or exhaust opening at an angle of 30° to the direction of the gas stream (see Figure B.2) and as far as possible from reflecting surfaces. If the controller of the engine is fully actuated and an intense sound pressure level is produced shortly before reaching regulation, this sound pressure level shall be recorded and declared separately. For evaluation of fan noise, the fan shall be operated at its minimum and maximum speeds; if possible intermediate conditions may also be chosen.



Key

1 Gas stream
2 Intake or exhaust pipe
3 Measuring microphones

Figure B.2 — Microphone position at the intake or exhaust opening

B.2 Additional measurements of noise at platforms and stopping points

B.2.1 General

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

B.2.2 Microphone position

The microphone shall be placed on the platform at a distance of 3 m from the centre line of the nearest track at a height of 1,5 m ± 0,2 m above the platforms in those places where there is an interest in the sound pressure level.

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

The AF-weighted maximum sound pressure level, L_{pAFmax}, shall be measured.

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

B.2.3 Vehicle conditions

During the tests, the vehicles 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, for example by stating the throttle or controller notch position together with the notch range of the unit (for example: "Notch 4th position of a range from 1 to 8").

B.3 Additional measurements of noise on bridges

The microphone shall be placed opposite the middle of the bridge if possible at a height of 1,2 m ± 0,2 m above the upper surface of the rails at a distance of 7,5 m from the centre line of the track in the case of bridges and viaducts.

For bridges a further microphone position at a distance of 25 m (and, if possible, at distances of 50 m and of 100 m) from the centre line of the track and at a height of 3,5 m ± 0,2 m above the ground is recommended.

The height of the microphone with respect to the upper surface of the rails and the vehicle conditions shall be stated in the test report. The length of the bridge and the position of the microphone along should also be stated.

Annex C
(informative)

Procedure for determining the rail roughness limit spectrum

C.1 General

The development of a standard for the measurement of noise generated by moving railway vehicles requires the rail roughness conditions of the test site to be specified. If a qualitative description of the acceptable rail roughness, expected to be “free from rail corrugation”, has been felt sufficient in the past, a more comprehensive understanding of the rolling noise excitation mechanism now requires the required rail roughness to be defined in quantitative terms. The aim of this Annex is to show how the rail roughness spectrum presented in A.3 has been obtained, in order to specify acceptable values for the track roughness for the noise generation measurement.

C.2 Background data

Recent work performed for European Rail Research Institute (ERRI) at an European level (BR Research Report no. RR-SPS-97-012 Issue 1, 27 March 1997) included statistical analysis of a range of rail roughness spectra for tracks whose quality was considered to be “typically good”. These data were provided by different European railway networks and thus the analysis of the data, contained in this Annex, is considered to be typical of operational tracks in Europe.

For each wavelength a mean and standard deviation was determined and presented in Figure C.1.

C.3 Numerical simulations of roughness influence on noise emission levels

In order to determine the range of noise levels resulting from these values of rail roughness, a prediction, using the Track Wheel Interaction Noise Software (TWINS) [1)], has been carried out using the mean ± 1 standard deviation rail roughness as input. As the noise from a smooth wheel is most sensitive to changes in rail roughness, the predictions were carried out for a disc braked wheel for a train speed of 40 m/s (144 km/h). The wheel roughness used in the prediction is also shown in Figure C.1.

The results of that analysis have been used to determine the influence of rail roughness at different levels on rolling noise in order to prepare recommendations for the roughness range to be included in the measurement standard.

Figure C.2 (a) gives the 1/3 octave band sound power levels and the overall A-weighted sound power level resulting from this calculation. It indicates a range of 4 dB in the A-weighted sound power, when summing the wheel, rail and sleeper contributions.

C.4 Procedure leading to a rail roughness limit

This range of 4 dB in the A-weighted sound power is related to the specific combined (wheel + rail) surface roughness range used in the TWINS prediction (see Figure C.2 (b)).

---

1) See Bibliography [1] to [4].

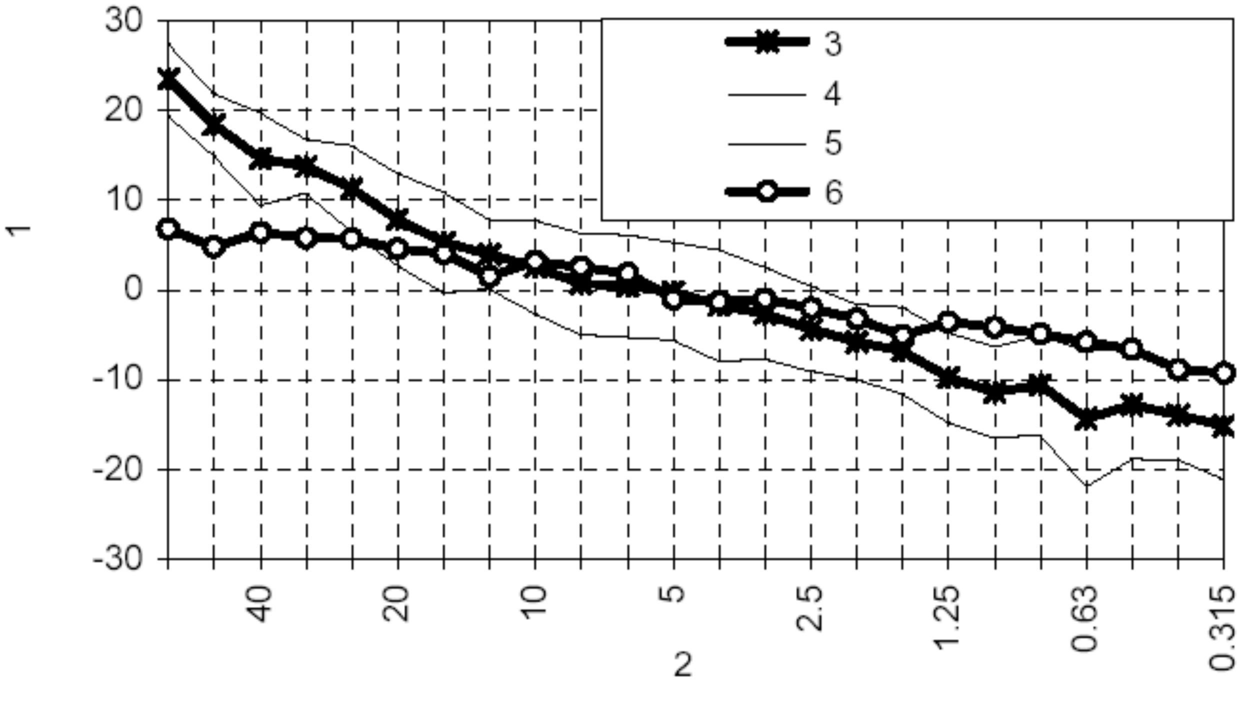
Figure C.3 (a) presents the wheel roughness spectrum which has been used in the TWINS prediction, and of another wheel, selected for its low roughness level (operated disc braked wheel): this figures shows that this wheel is smoother than the wheel used in the TWINS prediction, in the wavelength range [1 cm; 6,3 cm] (associated to the frequency range [630 Hz ; 4 000 Hz] at the speed of 144 km/h), being quite influencing the rolling noise.

Then, the combination of the roughness of both this smooth wheel and the rail (see Figure C.1) is presented in Figure C.3 (b). The A-weighted difference between the combined roughness is larger than 4 dB, and then, the rail roughness used in TWINS prediction does not insure an adequate reproducibility of the noise measurement (within 4 dB) with the smooth wheel.

Then the rail roughness spectrum has been adjusted for this typical smooth wheel roughness spectrum, so the A-weighted difference in noise creation would be less than 4 dB.

This adjustment is being performed, using the combined roughness of both the smooth wheel roughness, and the maximum rail roughness compatible with an A-weighted noise sound power variation of 4 dB. In lower wavelengths, the rail roughness is limited to – 10 dB, to take into account the resolution of the available measurement devices. This resulting rail spectrum is presented in Figure C.4.

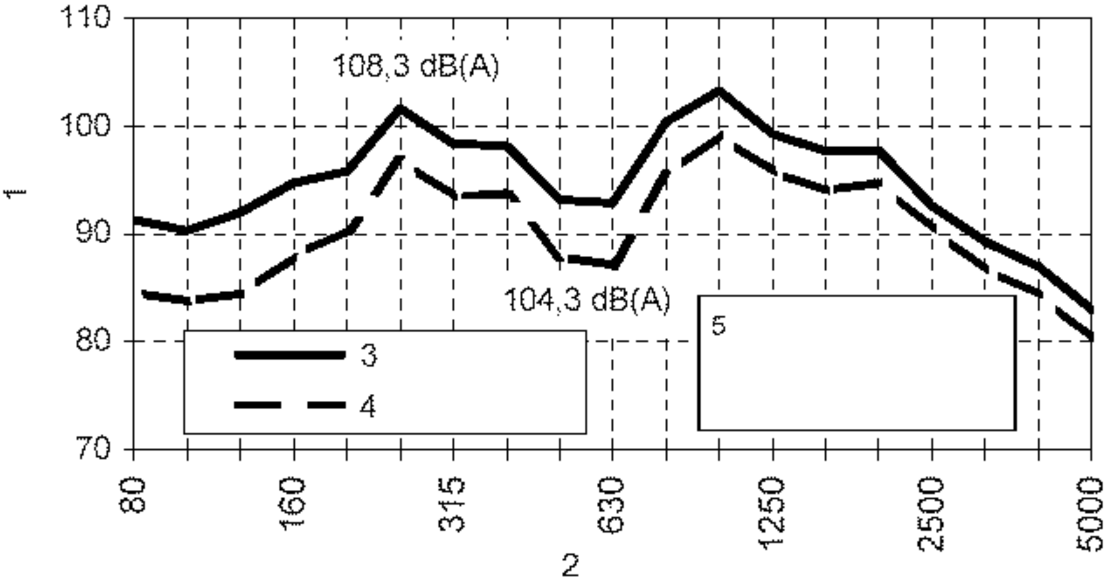
Finally, a linear approximation is applied, which gives the result presented in Figure C.5. This maximum level of rail roughness is recommended for the standard as defining "good quality" track and is shown in Annex A. It ensures a practical noise creation uncertainty range of 0 + 4 dB, whatever the wheel roughness may be (for available wheel roughness in Europe).



Key

1 Roughness level (dB re 1 ∝m)
2 Wavelength (cm)
3 Rail (mean)
4 Rail (mean + 1 SD)
5 Rail (mean – 1 SD)
6 Disc braked wheel

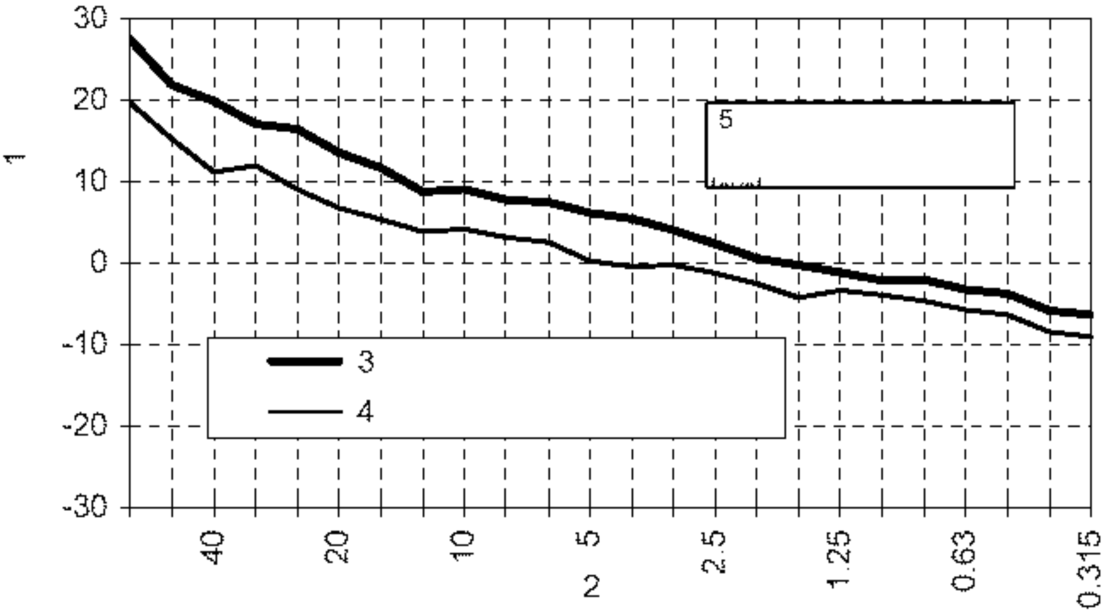
Figure C.1 — Roughness of "typically good" European rails and of reference wheel



Key

1 Sound power level (dB re 1 pW)
2 Frequency (Hz)
3 Mean + 1 SD
4 Mean – 1 SD
5 Range of 4 dB in the A-weighted sound power level

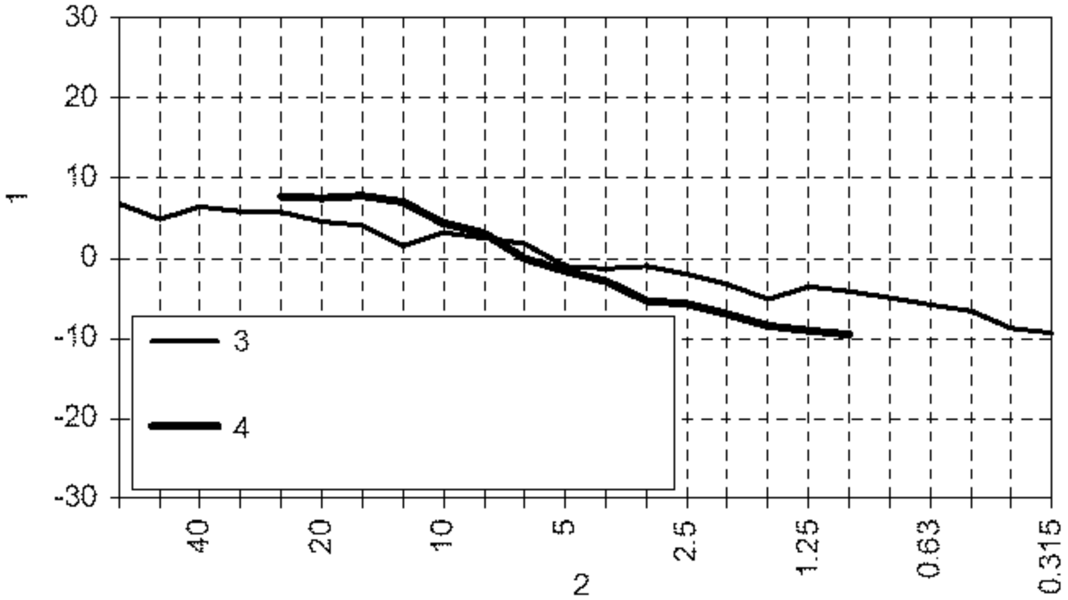
Figure C.2 (a) — TWINS prediction for different rail roughness (BR Research Report n° RR-SPS-97-012 Issue 1, 27 March 1997)



Key

1 Roughness level (dB re 1 ∝m)
2 Wavelength (cm)
3 Wheel + rail (mean + 1 SD)
4 Wheel + rail (mean – 1 SD)
5 Range of 4 dB in the A-weighted sound power level

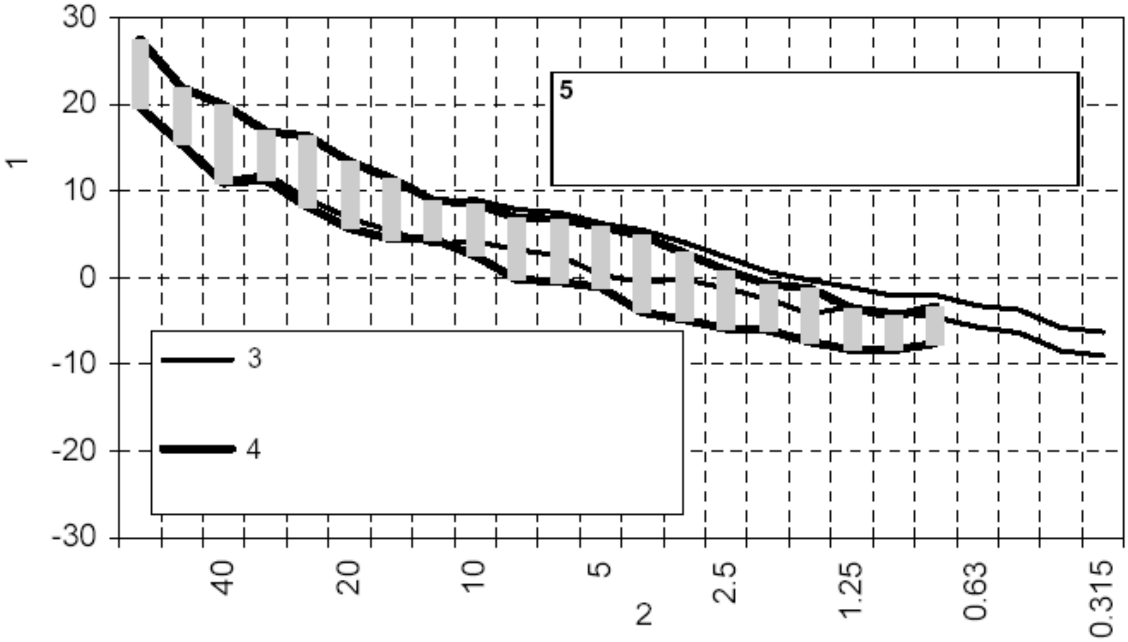
Figure C.2 (b) — Combined roughness used in TWINS prediction roughness (BR Research Report n° RR-SPS-97-012 Issue 1, 27 March 1997)



Key

1 Roughness level (dB re 1 ∝m)
2 Wavelength (cm)
3 Wheel roughness used in TWINS prediction
4 New wheel roughness leading to the rail roughness limit

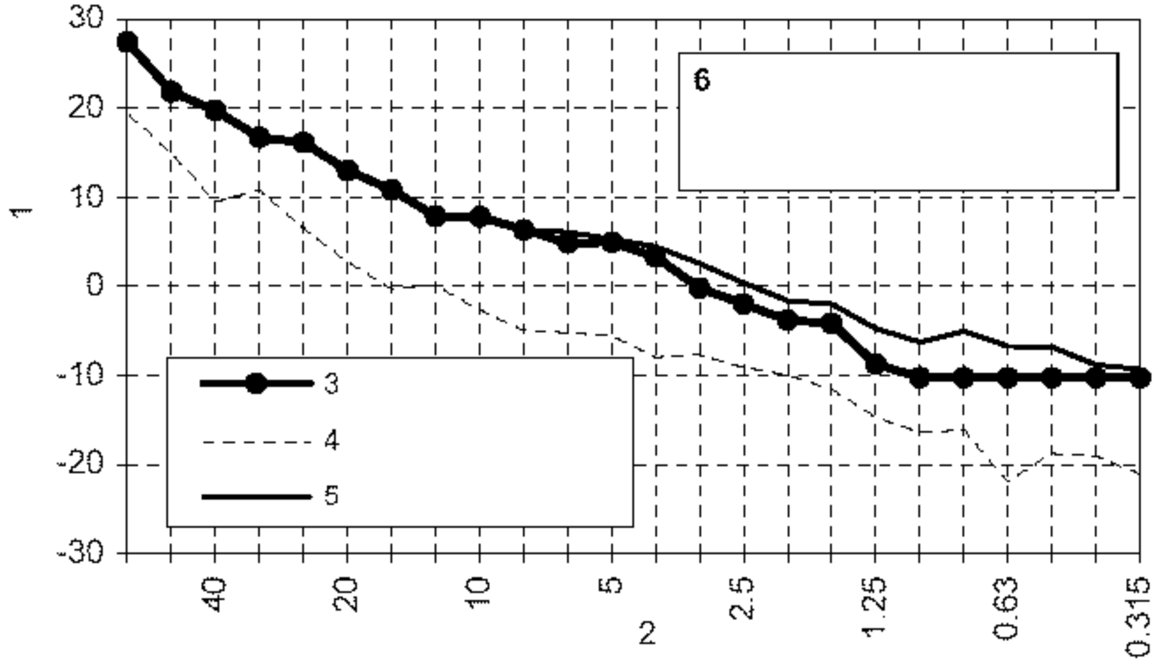
Figure C.3 (a) — Smooth wheel leading to the rail roughness limit



Key

1 Roughness level (dB re 1 ∝m)
2 Wavelength (cm)
3 Combined roughness used in TWINS prediction
4 New combined roughness
5 **New combined roughness**
Range > 4 dB in the A-weighted sound power level

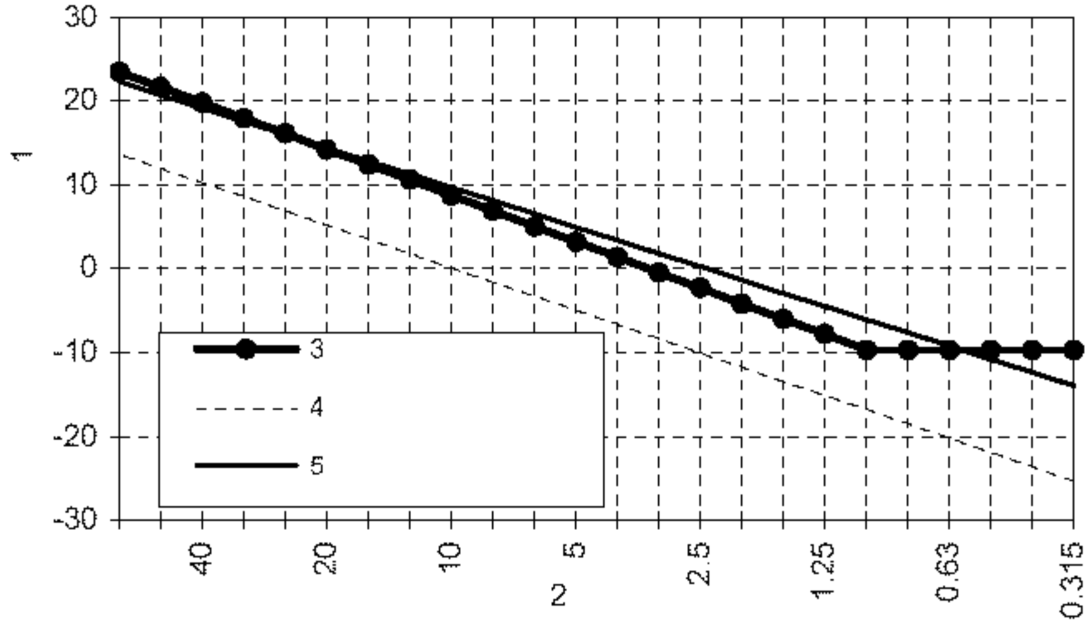
Figure C.3 (b) — New combined roughness



Key

1 Roughness level (dB re 1 ∝m)
2 Wavelength (cm)
3 Adjusted rail roughness
4 Rail (mean – 1 SD)
5 Rail (mean + 1 SD)
6 New rail roughness limit
Range of 4 dB in the A-weighted sound power level

Figure C.4 — New rail roughness limit



Key

1 Roughness level (dB re 1 ∝m)
2 Wavelength (cm)
3 Adjusted rail roughness
4 Rail (mean – 1 SD)
5 Rail (mean + 1 SD)

Figure C.5 — Final rail roughness limit

Annex D
(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 D.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 D.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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