SLOVENSKI STANDARD
SIST EN 17936:2024

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Železniške naprave - Akustika - Merjenje osnovnih pogojev za izračun okoljskega hrupa

Railway applications - Acoustics - Measurement of source terms for environmental noise calculations

Bahnanwendungen - Akustik - Messung der Quellterme für Umgebungslärmberechnungen

Applications ferroviaires - Acoustique - Mesurage des termes sources pour le calcul du bruit en environnement

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17.140.30	Emisija hrupa transportnih sredstev	Noise emitted by means of transport
93.100	Gradnja železnic	Construction of railways

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English Version

Railway applications - Acoustics - Measurement of source terms for environmental noise calculations

Applications ferroviaires - Acoustique - Mesurage des termes sources pour le calcul du bruit en environnement

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN 17936:2024) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2025, and conflicting national standards shall be withdrawn at the latest by April 2025.

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Introduction

In Europe, various prediction methods for environmental noise exist. For noise mapping and planning of railway lines, the prediction methods are enshrined in national or European legislation such as Directive (EU) 2015/996 (CNOSSOS). An integral aspect to ensure realistic results is to use valid input data.

Environmental noise prediction models consist of noise source terms and a propagation model.

The calculation of railway traffic sources is based on traffic data such as train types, speeds and flow, and on the vehicle/track noise source terms.

In this document, measurement methods are specified for the acoustic input parameters for the vehicle/track noise source terms. The collection of traffic flow data are outside the scope of this document. The method can be used to collect data from different railway noise source types, within the practical constraints of widely available measurement equipment and railways in normal service.

The document covers the measurement of separate physical source types which are listed in the scope.

Each source type is characterized in terms of its frequency spectrum (up to one-third octave band details), source height and directivity.

The description of rolling noise goes one step further: it combines wheel and rail acoustics roughness (its generating mechanism) with vehicle and track transfer functions.

The derivation of these transfer functions is addressed in the standard. The complete process of an environmental prediction noise scheme showing different types of inputs is illustrated in Figure 1. It shows the different types of inputs: traffic data, acoustic parameters and geographical data.

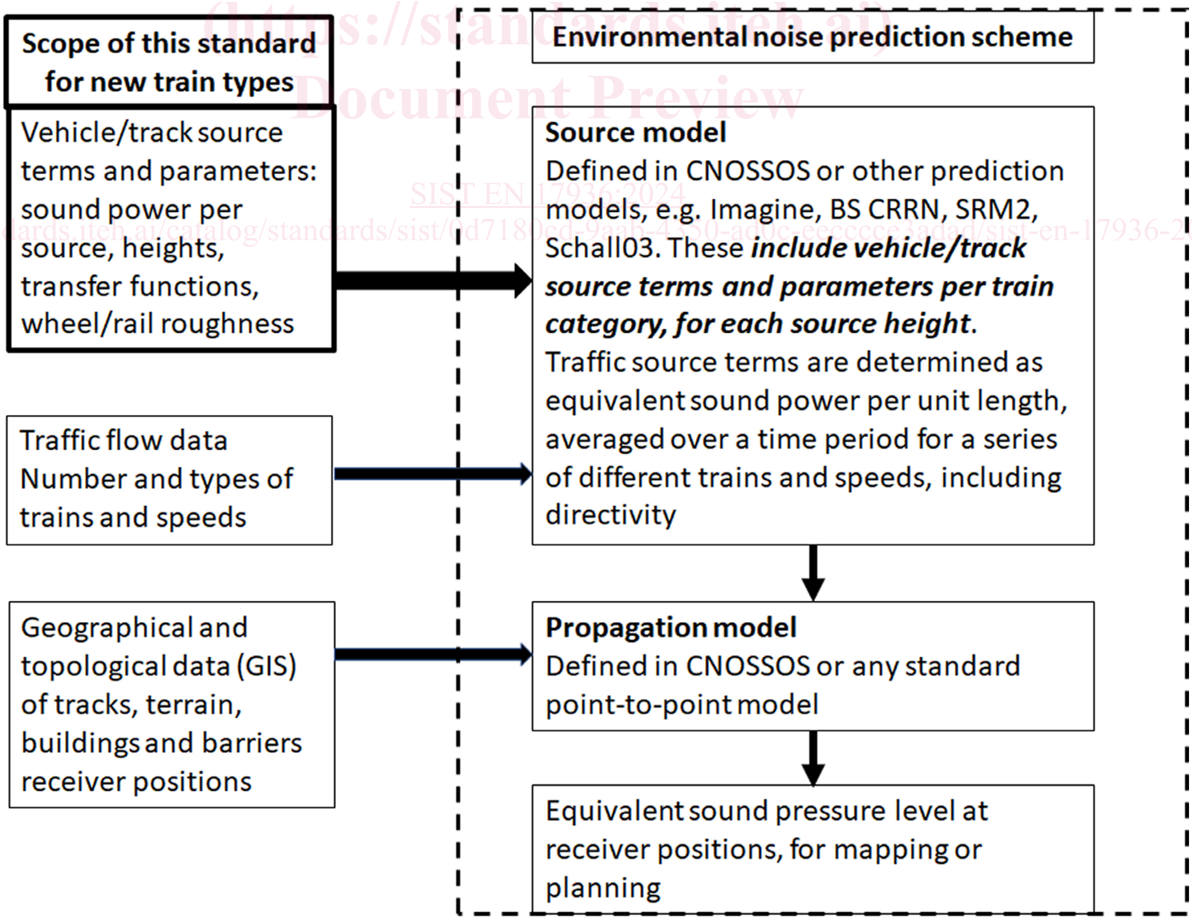

Figure 1 — Elements of an environmental noise prediction scheme

1 Scope

This document addresses the measurement of source terms for environmental noise calculation for rail traffic (including light rail, such as trams, metros, etc.). It is applicable to the measurement of in-service trains on operational tracks.

It is not applicable to type acceptance testing of rolling-stock or tracks, or to derive source terms for time domain models.

The following rail traffic noise source types are in the scope:

— rolling noise;

— traction and equipment noise;

— aerodynamic noise;

— impact noise (e.g. rail joints, switch and crossings, wheel flats);

— braking noise;

— bridge noise;

— squeal noise.

Noise from rail vehicles at standstill, such as stationary engine idling and auxiliary equipment at yards and stations, is covered by EN ISO 3095:2013 for measurement procedures and operating conditions, and by EN ISO 3740:2019 and EN ISO 3744 for the determination of sound power. It is therefore not in the scope of this document.

The calculation of the propagation of sound is part of generally standardized propagation models which are not addressed in this document.

Noise from fixed installations (e.g. stations, depots, electricity sub-stations) is not in the scope of this document.

Source terms are specific to a vehicle and track type. The scope includes measurement procedures and conditions and sampling requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 15610:2019, *Railway applications — Acoustics — Rail and wheel roughness measurement related to noise generation*

EN 17343, *Railway applications — General terms and definitions*

CEN/TR 16891:2016, *Railway applications — Acoustics — Measurement method for combined roughness, track decay rates and transfer functions*

EN IEC 60942:2018, *Electroacoustics — Sound calibrators (IEC 60942:2017)*

EN 61094-4:1995, *Measurement microphones — Part 4: Specifications for working standard microphones (IEC 61094-4:1995)*

EN 61260-1:2014, *Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications (IEC 61260-1:2014)*

EN 61672-1:2013, *Electroacoustics — Sound level meters — Part 1: Specifications (IEC 61672-1:2013)*

EN 61672 (all parts), *Electroacoustics — Sound level meters*

EN ISO 3095:2013, *Acoustics — Railway applications — Measurement of noise emitted by railbound vehicles (ISO 3095:2013)*

EN ISO 3744, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane (ISO 3744)*

ISO 5725-2:2019, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 3095:2013, EN 17343, and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
number of axles
$\mathbf{N_{ax}}$
number of axles in the selected train or part of train

3.2
third octave band frequency
$\mathbf{f}$
centre frequency of a third octave frequency band in Hz

3.3
third octave wavelength
$\boldsymbol{\lambda}$
centre wavelength of a third octave wavelength band in m

3.4
acceleration signal
$\mathbf{a(t)}$
time signal of the rail acceleration in m/s^2

3.5
equivalent vertical rail vibration level spectrum
$\mathbf{L_{aeq,Tp}\ (f)}$
third octave spectrum of the rail head acceleration energy averaged over pass-by time T_p, in dB re 1 μm/s^2

3.6
rolling noise transfer function
$L_{HpR,tot,nl}$ (f)
transfer function in third octave bands between the sound pressure at a fixed point, 7,5 m, and the combined effective roughness frequency spectrum, normalised to the axle density N_{ax}/ℓ, in dB re 20 Pa/√m

[SOURCE: CEN/TR 16891:2016 definition 3.14]

3.7
combined effective roughness
roughness function that excites rolling noise

[SOURCE: EN 15610:2019, definition 3.4]

Note 1 to entry: The combined roughness is the RMS of the rail and wheel roughness spectra. It becomes the combined effective roughness when the effect of the contact patch filter is included.

3.8
combined effective roughness wavelength spectrum
L_{Rtot} (λ)
wavelength spectrum in third octave bands of the combined effective wheel-rail roughness including the contact filter, in dB re 1 µm

[SOURCE: CEN/TR 16891:2016, definition 3.12]

3.9
combined effective roughness frequency spectrum at speed v
L_{Rtot} (f,v)
frequency spectrum in third octave bands of the combined effective wheel-rail roughness at a given speed v, including the contact filter, in dB re 1 µm

[SOURCE: CEN/TR 16891:2016, definition 3.13]

3.10
direct roughness measurement method
refers to an acoustic roughness measurement method for which the sensor measures the running surface roughness so that either the rail or the wheel roughness is measured independently of any effect of wheel-rail interaction

[SOURCE: EN 15610:2019, definition 3.5]

3.11
indirect roughness measurement method
refers to an acoustic roughness measurement method that measures a quantity that is the result of wheel-rail interaction, such as noise, rail or axle box vibration, whereby the original excitation by the combined effective wheel and rail roughness is inferred

[SOURCE: EN 15610:2019, definition 3.6]

3.12
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the sound power, P, of a source to a reference value, P_0, expressed in decibels, where the reference value, P_0, is 1 pW

[SOURCE: EN ISO 3740:2019, definitions 3.2 and 3.3]

Note 1 to entry: In this context, this is the sound power level as derived from a specific field measurement point. It is the sound power level required to produce the sound pressure level in the measurement point at the trackside in third octave or octave bands.

3.13
integration length
ℓ length of vehicle (buffer-to-buffer) or track over which the sound pressure is integrated, in m

3.14
sound power level per unit length
$L_{W'}$
sound power level L_W normalized to the length ℓ

$$L_W' = L_W - 10 \lg (\ell / \ell_0) \text{ in dB re 1 pW/m} \quad (1)$$

where ℓ_0 is 1 m

3.15
sound power transfer function
$L_{HWR,n}$
third octave transfer function of sound power per unit (combined) effective roughness, per axle, in one third octave bands, in dB re 1 W/m², in analogy with [1], formulas 2.3.8 - 2.3.10

$$L_{HWR,n}(f) = L_W(f) - L_R(f,v) - 10 \lg N_{ax} \text{ in dB re 1 W/m}^2 \quad (2)$$

Note 1 to entry: This depends also on vehicle length.

3.16
sound pressure transfer function
$L_{HpR,nl}(f)$
third octave transfer function of sound pressure at the trackside, per unit (combined) effective roughness, normalised to the axle density N_{ax}/ℓ

$$L_{HpR,nl}(f) = L_{peq,Tp}(f) - L_R(f,v) - 10 \lg (N_{ax}/\ell) \text{ in dB re 20 Pa/m}^{0,5} \quad (3)$$

[SOURCE: CEN/TR 16891:2016, definition 3.14]

Note 1 to entry: In principle, this is independent of the train or vehicle length and speed if rolling noise is the main source.

3.17
acoustic transfer function from sound pressure to sound power
L_{HpW}(f)
transfer function between the measured pass-by sound pressure level $L_{peq,Tp}$ and the sound power level per meter $L_{W'}$, in one third octave bands or octave bands

Note 1 to entry This only includes geometric divergence and ground attenuation and results from integration over the pass-by of single or multiple sound sources for a vehicle or group of vehicles.

3.18
distribution function
D(f)
set of two or more frequency spectra in one-third octave bands, used to quantify the contributions of individual sources, such as vehicle and track, or rolling noise and other sources

Note 1 to entry: The energy sum of these spectra is always 0 dB in each one-third octave band. The contribution of each source is obtained by subtraction of the distribution function from the total sound spectrum.

3.19
unweighted pass-by sound pressure level
$L_{peq,Tp}$(f)
unweighted sound pressure level integrated over pass-by time T_p, in one third octave bands, in dB re 20 μPa

3.20
source term
sound power level per unit length either for a vehicle and track or for a traffic flow, as used in environmental noise prediction models

Note 1 to entry: For each vehicle and track, source terms are defined at specific heights and represent different physical sources (e.g. rolling noise, traction noise and others).

Note 2 to entry: Source terms for a whole traffic flow are based on the mix of trains and their speeds at a given site.

4 Instrumentation and calibration

4.1 General

Measurements can be taken with temporary, supervised setups as well as with stationary mounted, automated, non-supervised setups. While most instrumentation and calibration requirements are necessary for both types of setups, some extra requirements are necessary for stationary ones. Furthermore, some tasks conducted by the supervisor for temporary setups also have to be executed by instrumentation for stationary mounted setups.

Depending on the type of measurement, only a selection of the following instrumentation might be needed.

4.2 Acoustic instrumentation

The microphones, signal acquisition units and processing algorithms used shall each comply with the requirements of EN 61672-1:2013 specifications for class 1 measuring equipment.

Where measurement equipment other than type-approved sound level meter is used, microphones shall comply with the requirements of EN 61094-4:1995 specifications for class 1 measuring equipment.

NOTE Multichannel acquisition systems are generally used to record data.

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

The sound calibrator shall meet the requirements of class 1 according to EN IEC 60942:2018.

Microphones with free-field or diffuse-field characteristics shall be used. A suitable microphone windscreen should be used. Stationary mounted setups shall be suitable for permanent outdoor usage and shall include bird spikes.

Where one-third octave frequency band analysis is required, the filters shall meet the requirements of class 1, according to EN 61260-1:2014.

The conformity of the calibrator with the requirements of EN IEC 60942:2018 shall have been verified within one year of the test date. The conformity of the instrumentation system with the requirements of the EN 61672 series shall have been within two years of the test date. The date of the last verification of the conformity with the relevant standards shall be recorded.

4.3 Calibration of the acoustic instrumentation

4.3.1 Temporary setup

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

The sensitivity of the measurement chain actually applied in the field shall be documented.

4.3.2 Automated calibration

For stationary-mounted setups, the manual test with a calibrator, as described above, shall be conducted at least once a year. Additionally, automated daily tests shall be conducted by one of the two following procedures.

Testing the instrumentation by supplying a known electric signal. The difference between the measured value and the nominal value shall be not more than 1,1 dB. This can be done by built-in acoustic sources in the microphone (signal at the microphone output has to be equal to a signal of at least 80 dB), charge-injection-calibration, electrostatic calibration or any other equivalent procedure.

Testing the instrumentation by additional measurements (other microphones or sources). For this, a second microphone is installed. The difference between the measured values of both microphones shall not exceed 1,5 dB.

If the daily test of the instrumentation fails, all of the measurements taken since the last successful daily test shall be rejected.

4.4 Non-acoustic instrumentation

4.4.1 Time and duration

The date and local time of each pass-by shall be recorded. The duration of the pass-by of the considered train/unit (over buffers) shall be measured.

The pass-by time T_p can be determined from the front and rear axle peaks in the time signal of rail or sleeper vibration or sound pressure, plus a time increment proportional to the distance of the first and last axle to the front or rear of the train respectively. Alternatively, an optical presence detector can be used to directly determine T_p.

4.4.2 Speed, track and direction

The track number used by the train together with the direction of travel shall be recorded. The speed of the train shall be measured during the pass-by with a precision of better than ±3 km/h for velocities up to 100 km/h and better than 3 % of the measured value for velocities above 100 km/h.

4.4.3 Meteorological parameters

Weather conditions influencing the measurements shall be recorded, including temperature and wind speed. Where possible, rail temperature can also be registered.

NOTE Temperature can affect the rolling noise level.

4.4.4 Combined roughness

The combined roughness shall be measured according to the requirements in CEN/TR 16891:2016. Figure 2 shows under which circumstances this measurement is necessary.

In this case track decay rates and a threshold value for rail roughness can be obtained from rail vibration of multiple pass-bys.

4.4.5 Wheel and track parameters

Where the track decay rate is required, it should be measured within 1 year before or after the measurements according to the requirements in EN 15461. If direct rail roughness is to be measured, this should be in accordance with EN 15610. Figure 2 shows under which circumstances this measurement is necessary. Rail roughness measurements should be made, where possible, within 3 months before or after the pass-by measurements. Sound and rail roughness measurements should be made a sufficient period after grinding, typically around three months, to ensure that rail roughness has stabilized.

If direct wheel roughness is to be assessed, it shall be measured in accordance with EN 15610.

NOTE Wheel roughness immediately following reprofiling might not be representative of normal operation.

5 Approach to derive source terms

5.1 General

The sound power, used for source terms in prediction models, is a measure of the strength of a source suitable for estimations of environmental noise in terms of long term equivalent sound pressure level arising from a flow of traffic along a route. A sound power is an estimate calculated from sound pressure level measurements made at a limited range of angle from the source and makes use of a directivity index (DI) assumed for all sources of similar type by the convention of a particular environmental noise calculation scheme. The definition of a sound power therefore includes a statement of the DIs assumed in its estimation from measurements. They can therefore differ depending on the prediction model.

The symbol L_W is used here for the sound power, taking into account that it has a different definition for specific prediction models.

NOTE There is no attempt to integrate the actual sound power over an enclosing surface and no normalization of the assumed directivity to account for the complete sound power of the source. The assumed sound power is therefore not directly related to the true sound power of the source.

As source terms are derived from one or more microphone positions, propagation back to the required source height is done by means of a transfer function L_{HpW}, which is either tabulated or calculated.

This clause therefore sets out the requirement for estimating a sound power source spectrum from the sound pressure measurements.