SLOVENSKI STANDARD
oSIST prEN 17936:2023

01-februar-2023

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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ICS:

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

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

DRAFT
prEN 17936

December 2022

ICS

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

Bahnanwendungen - Akustik - Messung der Eingangsparameter für Umgebungslärmberechnungen

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 256.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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European foreword

This document (prEN 17936:2022) has been prepared by Technical Committee CEN/TC 256 “Railway Applications”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

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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 2015/996/EU (CNOSSOS). An integral aspect to ensure realistic results is to use valid input data.

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

This calculation of railway traffic sources is based on traffic data (e.g. train types, speeds, flow, operational data) and 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 may be used to collect data from different railway source types, within the practical constraints of widely available measurement equipment and operational railways.

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. Rolling noise is described in terms of its generating wheel and rail roughness along with the vehicle and track transfer functions.

Where it is required, the document details the derivation of transfer functions that allow rolling noise to be calculated from wheel/rail acoustic roughness.

The complete process showing different types of inputs to an environmental prediction noise scheme is illustrated in Figure 1.

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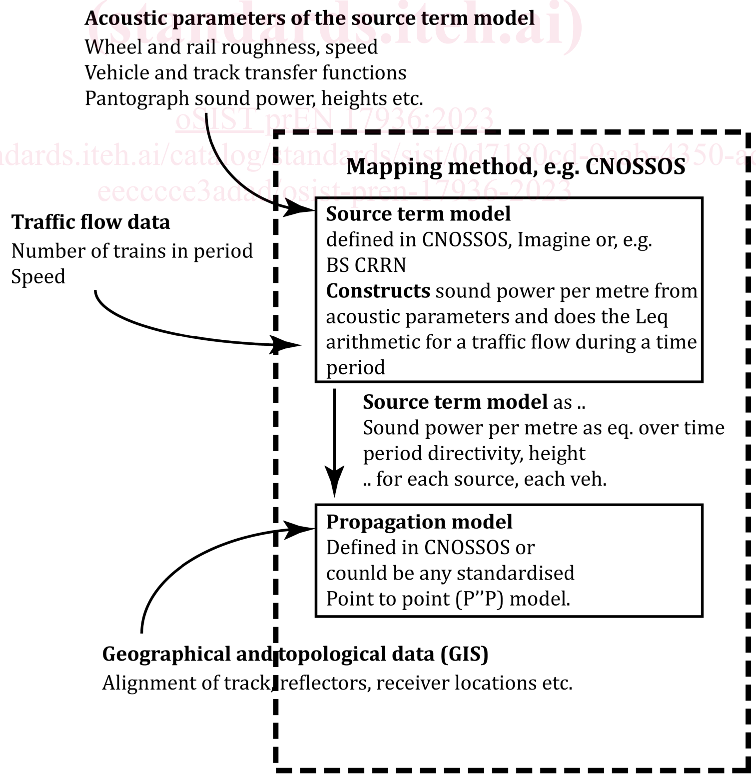

Figure 1 — Elements of an environmental noise prediction scheme

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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 noise ;
- Aerodynamic noise ;
- Impact noise (e.g. rail joints, switch and crossings, wheel flats) ;
- Braking noise ;
- Bridge noise ;
- Squeal noise.

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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 ISO 3740:2019, and ISO 3744:2010 for the determination of sound power.

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

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Noise from fixed installations (e.g.: stations, depots, electricity sub-stations) are 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 ISO 3095:2013, *Acoustics - Railway applications - Measurement of noise emitted by railbound vehicles (ISO 3095:2013)*

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 61672-1:2013, *Electroacoustics - Sound level meters - Part 1: Specifications*

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EN 61672-2:2013, *Electroacoustics - Sound level meters - Part 2: Pattern evaluation tests*

EN IEC 60942:2018, *Electroacoustics - Sound calibrators*

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

ISO 3740:2019, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards*

ISO 3744:2010, *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 5725-2:2019, *Application of statistics – 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 terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

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

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3.2
third octave band frequency
f
centre frequency of a third octave frequency band in [Hz]

3.3
third octave wavelength
centre wavelength of a third octave wavelength band in [m]

3.4
acceleration signal
a(t)
time signal of the rail acceleration in [m/s^2]

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

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3.6
rolling noise transfer function
LHpR,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 Nax/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

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.

[SOURCE: EN 15610:2019, definition 3.4]

3.8
combined effective roughness wavelength spectrum
LRtot (λ)
wavelength spectrum in third octave bands of the combined effective wheel-rail roughness including the contact filter, in dB re 1 [µm]

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

3.9
combined effective roughness frequency spectrum at speed v
LRtot (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]

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[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]

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3.12
sound power level
LW (or apparent sound power level)
ten times the logarithm to the base 10 of the ratio of the sound power, P (3.2), of a source to a reference value, P0, expressed in decibels, where the reference value, P0, is 1 pW

[SOURCE: ISO 3740:2019, definition 3.3]

Note 1 to entry The apparent sound power level is the sound power level as derived from a specific field measurement point. In this context, 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 i.

3.13
sound power level per unit length
LW
(apparent) sound power level LW normalized to the train length in Watt/m

$$L_{W'} = 10 \lg (W/W_0) - 10 \lg (l/l_0) \quad (1)$$

where

l_0 is 1m.

3.14
integration length
l
length of vehicle or track over which the sound pressure is integrated

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3.15
sound power transfer function
LHWR,n
apparent sound power per unit (combined) effective roughness, per axle, in one third octave bands, in analogy with [1], formulas 2.3.8 - 2.3.10

Note 1 to entry This depends also on vehicle length.

3.16
sound pressure transfer function
LHpR,nl
transfer function of combined effective roughness to sound pressure at the trackside, normalised to the axle density Nax/l

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

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

3.17
acoustic transfer function from sound pressure to sound power
LHpW
transfer function between the measured pass-by sound pressure level Lpeq,Tp and the apparent sound power level per meter LW', 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.

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3.18
distribution function D(f)
set of two or more frequency spectra in 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 zero dB in each third octave band. The contribution of each source is obtained by subtraction of the distribution function from the total sound spectrum.

4 Acoustic basics for this standard

4.1 Accuracy / uncertainties

The following factors can affect the uncertainty in source terms results:

— sample selection of trains or rail vehicles, including roughness variation of wheels

— measurement sites, including rail roughness variation, geometry and propagation factors

— operating conditions of trains or rail vehicles including speed and active noise sources.

Further details on uncertainty are covered in Clause 10.

4.2 Frequency range and spectral bands

Source terms for prediction models are most commonly defined in octave bands from 63 to 8000 Hz. Data are collected in third octave bands for 50-10000 Hz and converted into octave bands at the final processing step.

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4.3 Type of measurements

Sound pressure measurements are performed *in situ* with single microphones, from which a sound power quantity is derived. The sound power is derived using the actual prediction model for which the source terms are required, or a more detailed model. Methods for this calculation are described in Annex B.

NOTE Model requirements include a non-local reacting ballast reflection and diffraction over the ballast.

5 Instrumentation and calibration

5.1 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.

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5.2 Acoustic instrumentation

Each component of the acoustic instrumentation system shall meet the requirements for a class 1 instrument specified in EN 61672-1:2013.

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

Microphones with free field characteristics shall be used. A suitable microphone windscreen shall always 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 compliance of the calibrator with the requirements of EN IEC 60942:2018 shall be verified at least once a year. The compliance of the instrumentation system with the requirements of EN 61672-1:2013 and EN 61672-2:2013 shall be verified at least every 2 years. The date of the last verification of compliance with the relevant standards shall be recorded.

5.3 Calibration of the acoustic instrumentation

5.3.1 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.

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5.3.2 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.

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1. 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.

2. 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.

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5.4 Non-acoustic instrumentation

5.4.1 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 with a precision of better than +-0,05s.

The pass-by time T_p can be determined 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.

5.4.2 Speed, track and direction

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

5.4.3 Meteorological parameters

Weather conditions influencing the measurements shall be recorded, including temperature and wind speed. Where rail temperature may significantly exceed the ambient temperature by more than 10 degrees due to sunlight it shall be registered.

NOTE Temperature can affect the rolling noise level up to 4 dB in the range 0 – 30 degrees.

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5.4.4 Wheel and track parameters

Where possible, the track decay rate 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. If direct wheel roughness is to be assessed, it shall be measured in accordance with EN 15610. Wheel and rail roughness measurements should be made, where possible, within 3 months before or after the pass-by measurements and without track maintenance or wheel profile in the meantime.

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5.4.5 Combined roughness

The combined roughness shall be measured according to the requirements in CEN/TR 16891:2016.

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

6 How to derive source terms

6.1 General

The Apparent 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 L_{eq} arising from a flow of traffic along a route. An apparent 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 an apparent sound power therefore includes a statement of the DIs assumed in its estimation from measurements. They may therefore differ depending on the prediction model.

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

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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.

6.2 Procedure

The procedure to derive the ‘apparent’ sound power level from sound pressure is as follows.

Measure $L_{peq,Tp}$ at either the 3,5 m or 1,2 m microphone height above the top of rails. 7,5 m from the centreline of the track for each vehicle (*i.e.* each separate coach or wagon). The vehicle should be similar on both sides of the train for measurement of sources that are repeated on vehicles (e.g. rolling noise). ‘Quiet vehicles’ are required for unique sources (e.g. cooling fans or engines).

Measurement shall be over a flat ballast layer (defined ± 0,1 m in ballast height to at least 4,5 m from the track centreline), including rails. Embankments sloping upwards from the track are always to be avoided.

NOTE The ground attenuation effect can be determined with greater certainty if there is a ballast shoulder and ground geometry beyond the ballast shoulder.

Measurements shall be taken by any of the following options, depending on uncertainty requirements and practical considerations:

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For the least uncertainty, quality A, the microphone position at 3,5 height is preferred. The uncertainty in the step of estimating L_W from L_p is evaluated as σ_H = ± 3 dB for 0,5 m source height, ± 2 dB for 1 m, 2 m, or 4 m source heights. For trams with shielded wheels and undercarriage, the lower microphone position of 1,2 m height is acceptable.

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The1,2 m microphone position, which results in greater uncertainty. Results shall be reported as of quality B, uncertainty of {σ_H = ± 4 dB for all source heights} in any one-third octave band.

If measurements are taken at sites of other geometry than (2), calculation of L_{HpW} is required. The uncertainty is then undefined by the standard, and shall be reported as of quality C (=individual, expected to be of smaller uncertainty if calculated for the exact geometry), including the method applied.

The ‘apparent sound power’ $L_{W'}(f)$ shall be estimated as a one-third octave spectrum as

$$L_{W'}(f_{to}) = Lp(f) - L_{HpW}(f) \tag{2}$$

The transfer function L_{HpW} is obtained as described below and in Annex B.

The measurement should be repeated for at least 3 trains or rail vehicles of the same type travelling at speeds within ± 8 %. [8 % is 1 dB following 30 log10(v)]. The standard deviation, σ_M of the measured levels of $L_{peq,Tp}$ shall be calculated for the total A-weighted level.

The uncertainty in the measurement of the apparent sound power spectrum shall then be calculated as

$$\sigma_W = \sqrt{(\sigma_H^2 + \sigma_M^2)} \tag{3}$$