INTERNATIONAL STANDARD

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Third edition
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# Acoustics — Railway applications — Measurement of noise emitted by railbound vehicles

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



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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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



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

# Introduction

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

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

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

## 1 Scope

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

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

This International Standard is not applicable to:

— the noise emission of track maintenance units while working;

— environmental impact assessment;

— noise immission assessment;

— guided buses;

— warning signal noise.



The results may be used, for example:



— to characterize the exterior noise emitted by units;

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

— to collect basic source data for units.

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

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

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

## 2 Normative references

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

IEC 60942:2003, *Electroacoustics — Sound calibrators*

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

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

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

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

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

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

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

## 3 Terms and definitions

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

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

Note 1 to entry: See Table 1.

**Table 1 — Definitions of rolling stock formations**

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



[SOURCE: EN 13452-1:2003]



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

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

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

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

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

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

[SOURCE: EN 15610:2009]

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

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

[SOURCE: EN 15610:2009]

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

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

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

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

[SOURCE: EN 15610:2009]



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



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

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

[SOURCE: ISO 80000-8:2007]

**3.11**
**sound pressure level**
$L_p$

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

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

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

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

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

**3.13**
**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)

[SOURCE: IEC 61672-1:2002]

**3.14**
**A-weighted equivalent continuous sound pressure level**
$L_{pAeq,T}$
A-weighted sound pressure level given by the following Formula:

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

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 at running time $t$ in Pa;

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



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

**3.15**
**impulsive sound**

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

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

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

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

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

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

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

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

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

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

[SOURCE: ISO 1996-1:2003]

# 4 Instrumentation and calibration

## 4.1 Instrumentation

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

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

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

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

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

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

## 4.2 Calibration

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



# 5 Stationary test



## 5.1 General

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

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

## 5.2 Environmental conditions

### 5.2.1 Acoustical environment

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

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

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

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

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

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

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

### 5.2.2 Meteorological conditions

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

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

### 5.2.3 Background sound pressure level

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

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

## 5.3 Track conditions



The measurements shall be performed on ballasted track.

## 5.4 Vehicle conditions



### 5.4.1 General

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

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

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

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

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

### 5.4.2 Normal operating conditions

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

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

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

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

 

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

NOTE 2 These parameters can be provided by the manufacturer.

#### 5.4.3 Additional operating conditions

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

### 5.5 Measurement positions

#### 5.5.1 Standard measurement positions

##### 5.5.1.1 Measurement mesh

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



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



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

##### 5.5.1.2 Reduction of the number of measurement positions

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

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

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

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

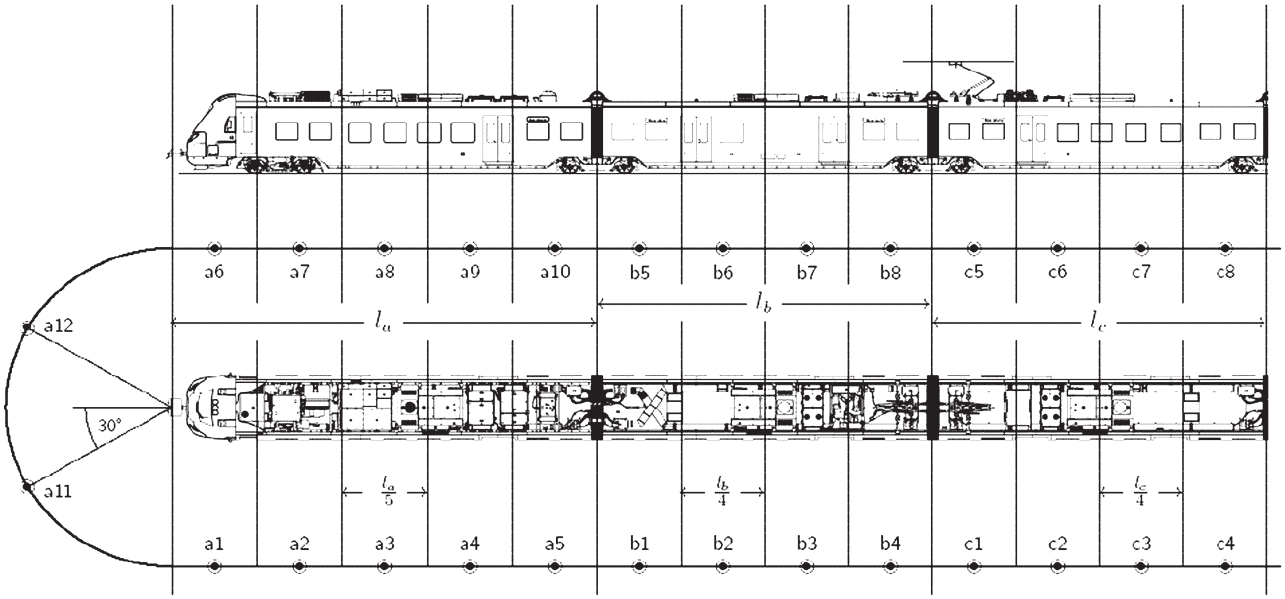


**Figure 1 — Example of a mesh of measurement positions for the stationary noise measurement of a multiple unit**



### 5.5.2 Additional measurement positions

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



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

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

## 5.6 Measured quantities

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

## 5.7 Test procedure

The unit shall be stationary.

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

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

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

## 5.8 Data processing

### 5.8.1 Standard processing

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

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

$$\left\langle L_{pAeq,T} \right\rangle_{unit} = 10 \lg \left( \sum_{i=1}^{n} \frac{l_i}{l_{tot}} 10^{L^{i}_{pAeq,T}/10} \right) \quad (1)$$

where

$L^{i}_{pAeq,T}$ is the sound pressure level measured at the measurement position $i$;

$n$ is the number of measurement positions;

$l_i$ is the length associated with the measurement position $i$. For the additional measuring positions at the front, this length is equal to $(\pi/2) \times 7{,}5$ m.

$$l_{tot} = \sum_{i=1}^{n} l_i \quad (2)$$



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



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

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

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

### 5.8.2 Additional processing

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

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

$$\left\langle L_{pAeq,T} \right\rangle_{car} = 10 \lg \left( \sum_{i=1}^{n_{car}} \frac{l_i}{l_{tot\,car}} 10^{L^{i}_{pAeq,T}/10} \right) \quad (3)$$

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

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