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**Railway applications — Acoustics —  
Noise measurement inside railbound  
vehicles**

*Applications ferroviaires — Acoustique — Mesurage du bruit à  
l'intérieur des 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 (see [www.iso.org/directives](http://www.iso.org/directives)).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 256, *Railway applications*, in collaboration with ISO 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 3381:2005), which has been technically revised.

The main changes compared to the previous edition are as follows:

- new structure of the document to align it with the structure of ISO 3095;
- an improved selection process of the measurement positions – see [Clause 5](#);
- new measurement procedures for noise in driver's cab – see [Clause 7](#);
- improved specifications of the vehicle conditions for the different types of tests - see [6.4](#), [7.3](#), [8.4](#) and [9.4](#);
- an improved assessment of the tonality - see [6.7](#), [8.7](#) and [9.8.2](#).
- an improved indirect assessment of the track acoustic characteristics – see [8.3.4](#), [9.3](#) and [Annex C](#);
- precisions for measurement in specific environments (tunnels, ...) – see [Annex D](#);
- an assessment of measurement uncertainties – see [Annex E](#).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

# Railway applications — Acoustics — Noise measurement inside railbound vehicles

## 1 Scope

This document specifies the measurement method and conditions to obtain reproducible noise levels on-board all kinds of vehicles operating on rails or other types of fixed track, hereinafter conventionally called “unit”, except for track maintenance vehicles in working modes.

This document is applicable to type testing. It does not include all the instructions to carry out monitoring testing or evaluation of noise exposure of passengers or drivers over a whole journey.

This document is not applicable to guided buses.

It provides measurement procedures for vehicle interior noise (in general, a vehicle type test is carried out using only a selected subset of these tests):

- when the vehicle is moving at constant speed;
- when the vehicle is stationary;
- when the vehicle is accelerating or decelerating;
- in the driver's cab when an external warning horn is sounding (specifically required for European Union regulation application)

It does not provide measurement procedures for:

- audibility or intelligibility of any audible signals;
- assessment of warning devices other than warning horns.

The assessment of noise exposure of train crew due to operational conditions is not in the scope of this document.

The results can be used, for example:

- to characterise the noise inside these units;
- to compare the internal noise of various units on a particular track section;
- to collect basic source data for units.

The test procedures specified in this document are of engineering grade (grade 2), the preferred grade for noise declaration purposes as defined in ISO 12001. If test conditions are relaxed, for example as they are for monitoring of in-service trains, then the results are no longer of engineering grade.

The procedures specified for accelerating and decelerating tests are of survey grade (grade 3).

## 2 Normative references

The following referenced documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For undated references the latest edition of the referenced document (including any amendments) applies.

ISO 1996-1:2016, *Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment procedures*

ISO 1996-2:2017, *Acoustics — Description, measurement and assessment of environmental noise — Part 2: Determination of sound pressure levels*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61260-1, *Electroacoustics — Octave-band and fractional-octave-band filter — Part 1: Specifications*

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

EN 15153-2:2020, *Railway applications — external visible and audible warning devices — part 2: warning horns for heavy rail*

EN 15461:2008+A1:2010, *Railway applications — Noise emission — Characterization of the dynamic properties of track sections for pass by noise measurements*

EN 15610, *Railway applications — Acoustics — Rail and wheel roughness measurement related to noise generation*

### 3 Terms and definitions

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

ISO and IEC maintain terminological 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

##### **unit**

rolling stock which is subject to the application of this document

Note 1 to entry: A unit can be composed of several powered or unpowered vehicles, or cars.

#### 3.2

##### **type test**

<noise measurement inside railbound units> measurement performed to prove that, or to check if, a unit delivered by the manufacturer complies with the noise specifications

#### 3.3

##### **acoustic 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

[SOURCE: EN 15610:2019]

#### 3.4

##### **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: The track decay rate is represented by a one-third octave spectrum of values expressed in decibels per metre (dB/m) representing attenuation over distance.

[SOURCE: EN 15461:2008+A1:2010]

#### 3.5

##### **acoustic track characteristics**

##### **ATC**

characteristics of the track that are defined in terms of acoustic rail roughness and *track decay rates* (3.4)

**3.6****test section**

specific section of track that is associated with a particular set of measurements

**3.7****impulsive sound**

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

EXAMPLE Noise from blowoff valves, relay switches.

Note 1 to entry: The quantification of impulsiveness is set out in [Annex B](#).

[SOURCE: ISO 1996-1:2016, 3.4.8, modified – "brief bursts of sound pressure" replaced with "one or more brief bursts of sound pressure"; former Note 1 to entry is incorporated into the definition as "and that is such that the duration of a single impulsive noise is usually less than 1 s"; Example and new Note 1 to entry added.]

**3.8****intermittent source**

source that operate at regular or irregular time intervals and is such that its duration is short

EXAMPLE Noise from compressors, exhaust fans, door operation, toilet.

**3.9****tonal sound**

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

[SOURCE: ISO 1996-1:2016, 3.4.9]

**4 Instrumentation and calibration****4.1 Instrumentation**

The microphones, signal acquisition units and processing algorithms used shall each comply with the requirements of IEC 61672-1 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 IEC 60942.

Microphones with free-field or diffuse-field characteristics shall be used. A suitable microphone windscreen should be used.

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

The conformity of the calibrator with the requirements of IEC 60942 shall have been verified within one year of the test date. The conformity of the instrumentation system with the requirements of IEC 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.

**4.2 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 the two calibrations is more than 0,5 dB, all the measurement results in between shall be rejected.

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

## 5 Measurement positions

### 5.1 Division of the unit into areas

#### 5.1.1 General

The entire unit shall be divided into areas. Each area being defined by its type (see [5.1.2](#)) and acoustic characteristics (see [5.1.3](#)).

#### 5.1.2 Definition of area types

Area types are distinguished by their purpose, for example: passenger areas, seating (first class, standard class), standing areas (including aisles), gangway, driver's cab, train manager compartment, galley, lavatories, entrance, lobbies, restaurant, quiet, sleeping or resting areas.

The range of characteristics to be found within an area type depends upon the vehicle type and the proposed operation schemes.

NOTE For example, for trams and metros, it can be appropriate to define a 'passenger area' that does not distinguish between seating and standing areas.

#### 5.1.3 Definition of area acoustics

The acoustics characteristics of areas are distinguished by their acoustic boundaries.

Examples for acoustic boundaries are:

- partition walls;
- draught screens;
- internal doors;
- decks of double deckers.

#### 5.1.4 Selection of areas to be assessed

The number of discrete areas to be characterized by measurement may be reduced by identifying discrete areas that are similar in terms of their type and acoustics characteristics. See [Figures 1, 2 and 3](#).

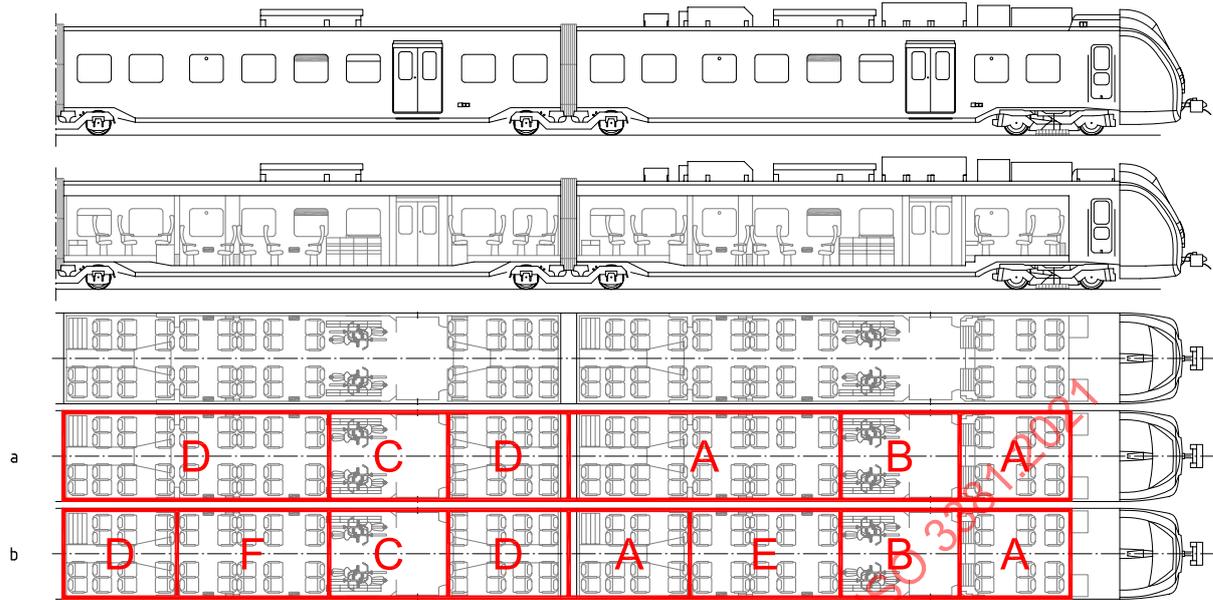
No area shall cross the boundaries of an acoustic space (partition, wall, doors, ...) and of a single vehicle.

For example, in double-deckers, decks shall be considered as separate areas.

Where there is no specification of the area types to be assessed, a minimum selection may be done assuming that the noise criteria apply only to areas of the types with permanent passenger seats.

Areas to be assessed may be selected taking into account additional criteria (e.g. contractual requirements in a project that can focus on seating area over a bogie, seating area close to a vestibule, ...). In dividing the unit into areas, bear in mind two objectives:

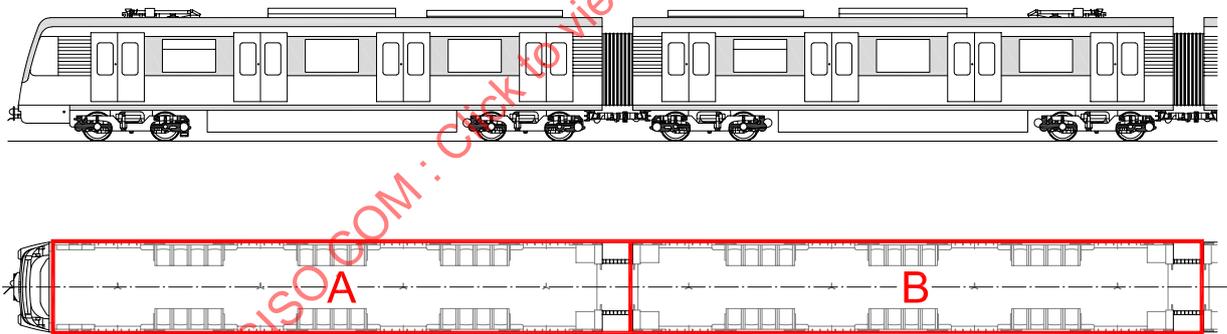
- a) the efficiency of identifying similar areas to reduce the measurement effort, and
- b) compatibility with the level of detail in the stated noise criteria.



**Key**

- a Selection as a function of seating (areas A and D), multipurpose and vestibule (areas B and C).
- b The same case as <sup>a</sup>, but include differentiation between floor heights (subdivision of areas A and D).

**Figure 1 — Example of a possible choice of areas to be assessed dividing 2 vehicles of a multiple unit**

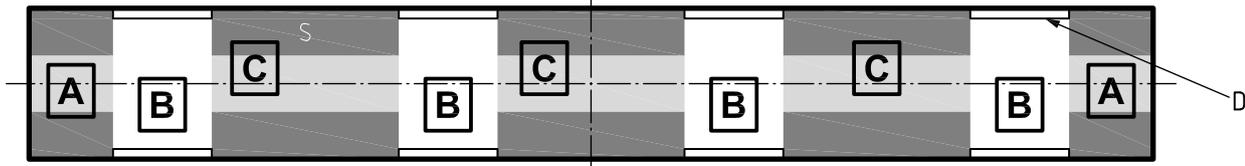


**Key**

- A first car
- B second car

NOTE The gangway between the 2 cars is open and not considered as a specific area but included in area A.

**Figure 2 — Example of definition of areas (A and B) in the case of a driverless metro**



**Key**

- A, B and C areas
- D passenger door
- S passenger seats

NOTE Areas with seats (A and C); Vestibule areas (B). Areas A are C differentiated in terms of their acoustic boundaries.

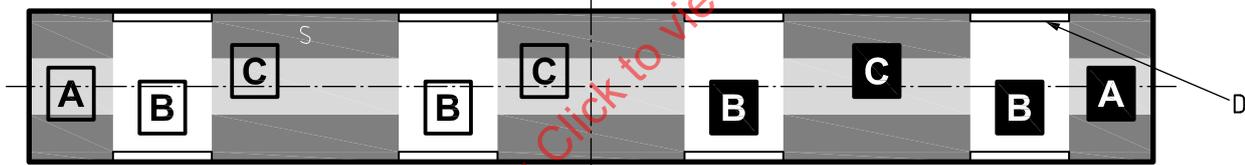
**Figure 3 — Example of passenger coach divided into areas**

**5.2 Measurement positions**

Measurements shall be carried out in at least one example of each similar area identified in 5.1 (e.g. one example of each of the areas “A”, “B” and “C” in Figure 3).

If measurements are carried out for multiple examples of similar areas, results shall be averaged.

NOTE 1 In that case, the symmetry of the vehicle can be used as a justification to minimize the number of similar areas to be measured (see Figure 4, in which the white character areas can be omitted based on symmetry of the layout.)



**Key**

- A, B and C areas
- D passenger door
- S passenger seats

**Figure 4 — Example of selection of similar measurement areas**

Each discrete area that is to be assessed shall be divided into equal segments of maximum length 5 m along the unit and each segment shall contain at least one measurement position (e.g. see Figure 5).

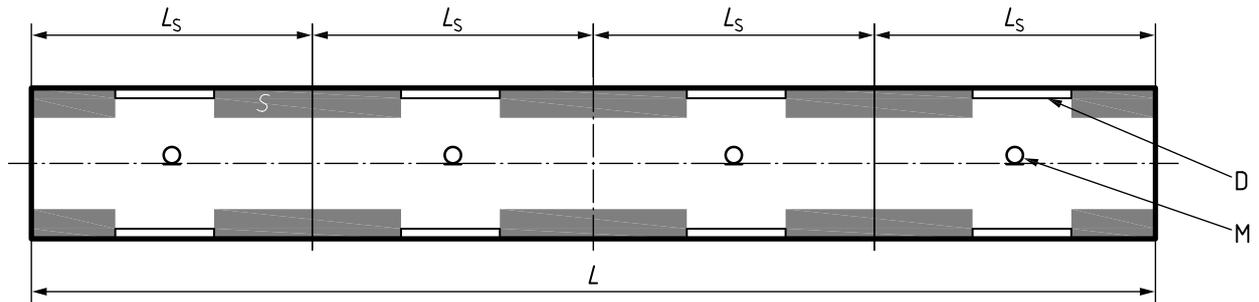
NOTE 2 This document leaves the freedom to choose measurement locations over a seat or between seats at the same height in order to provide a representative sample of an area.

Some measurement positions can be omitted.

Measurement positions shall not be located closer than 0,3 m to a wall, screen or door.

NOTE 3 Microphone positions at this distance from boundary surfaces are representing the sound field heard by passengers.

Additional measurement positions may be defined but shall be reported separately and not as part of the characterization of an area.



**Key**

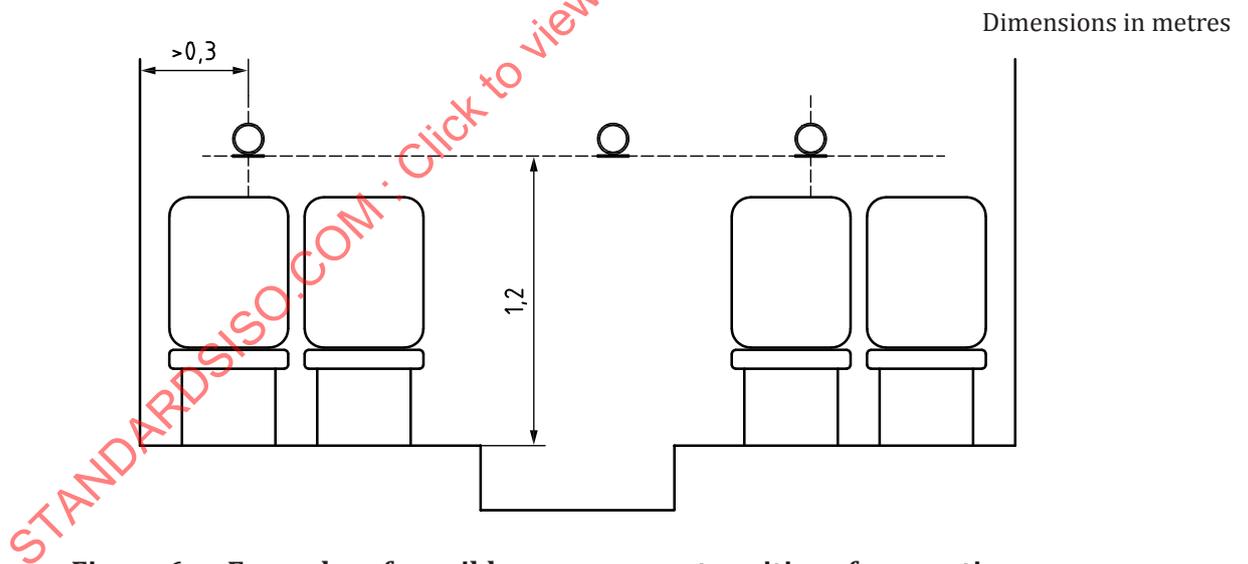
- |   |  |       |                            |
|---|--|-------|----------------------------|
| S | passenger seat (permanent longitudinal type) | L     | length of a unit           |
| D | passenger door                               | $L_s$ | length of a segment (<5 m) |
| M | measurement position                         |       |                            |

**Figure 5 — Example of definition of measurement positions for commuter units (measurement height  $H = 1,2$  m)**

**5.3 Measurement height**

**5.3.1 Seating position**

In areas, other than the driver's cab, that contain permanent seats, the measurement height shall be set to 1,2 m above the floor at the seat location. See [Figure 6](#).



**Figure 6 — Examples of possible measurement positions for a seating area**

**5.3.2 Standing position**

In standing areas, other than the driver's cab, measurements shall be located at a height of 1,6 m above the floor.

**5.3.3 Lying position**

At locations where people are supposed to rest in horizontal position, the microphone positions shall be 0,2 m above the support.

5.3.4 Driving position

When the cab contains more than one set of complete driving controls, the test shall be carried out at each of these positions. This is not necessary at auxiliary driving positions where a full set of controls is not present.

In a driver's cab area, the seated measurement position height shall be set at  $H=0,80\text{ m} \pm 0,05\text{ m}$  vertically above the centroid of the unloaded seat surface and offset  $0,25\text{ m} \pm 0,05\text{ m}$  laterally (see Figure 7).

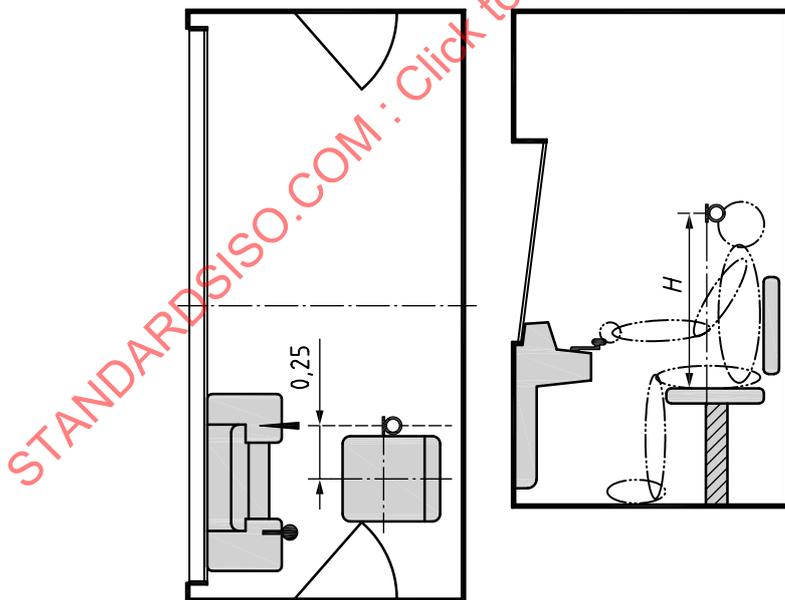
If the seat height is adjustable, this adjustment shall be set at midrange. For a suspended seat, the seated measurement height shall be taken from a reference of mid-stroke position. The height of this nominal position for the driver's seat above the floor shall be recorded.

In addition, a minimum distance of 0,3 m from the nearest wall shall be kept. The precise location of the microphone shall be recorded.

For the warning horn test (see Figure 8 and Clause 7), the measurement shall be carried out at eight evenly spaced microphone positions in a horizontal plane at the height of a seated measurement position ( $H=0,80\text{ m} \pm 0,05\text{ m}$ ), at a radius of  $0,25\text{ m} \pm 0,05\text{ m}$ , while the external warning horn is sounding. Where one or more of the required eight measurement positions is either not possible to realise because of the presence of structural elements, or where it is within 0,2 m of an acoustically-reflective surface, a measurement shall not be required at that position. The number of discrete measurement locations shall then be reduced accordingly to  $N < 8$ . In case a headrest presents a hindrance to mounting the microphones, it is permissible to remove the headrest or to use a measurement height as close as possible to the specified measurement height.

If not defined elsewhere, the level of the driver's ear for standing operation shall be taken as 1,6 m above the floor.

Dimensions in metres

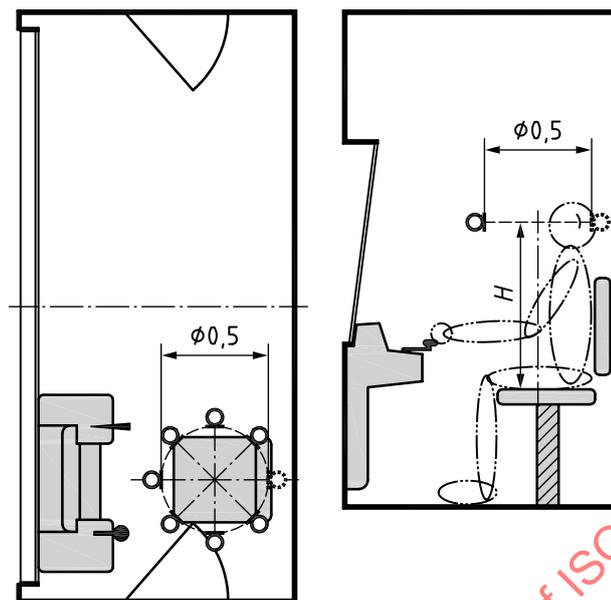


Key

H height of the measurement position

Figure 7 — Example of measurement positions in driver's cab for stationary test, constant speed test and acceleration/deceleration test

Dimensions in metres

**Key***H* height of the measurement positions**Figure 8 — Example of measurement positions in driver's cab for warning horn test****6 Stationary test****6.1 General**

The noise inside a stationary unit depends on its operating conditions and can be influenced by the environmental conditions. The measurements shall be carried out only if there are noise sources that normally operate at standstill. The conditions of operation are specified in [6.4](#).

**6.2 Environmental conditions****6.2.1 Acoustical environment**

The test site for stationary measurement shall be in approximately free-field conditions, i.e. such that the sound radiated by the unit to the exterior contributes to the interior noise only by reflection from the track, and not by reflection from buildings, walls or similar large objects adjacent to the track.

Additional measurements can be requested within tunnels, depots, stations and on elevated routes; these specific environments are considered separately in [Annex D](#). The results will be site-dependent and shall not be considered applicable to other environments.

No-one shall be present inside the tested area of the vehicle and the adjacent area to it, except for essential testing and operating personnel.

**6.2.2 Meteorological conditions**

The standard condition for measurements shall be: no falling rain, hail or snow. Any noise-relevant weather information (e.g. temperature, humidity, falling rain, hail, snow or high wind) outside the tested vehicle shall be reported before and after each series of measurements as a minimum.

**NOTE** Heavy rain or external wind speed higher than 5 m/s can affect the interior background noise, see [6.2.3](#).

### 6.2.3 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 external wind) does not influence the measurements significantly.

It is recommended to switch-off the unit under test in order to achieve an uncontaminated measurement of the background noise.

The maximum value of  $L_{pAeq,T}$  with  $T = 20$  s of background noise over each measurement position shall be at least 10 dB below the final result at each position obtained when measuring the noise inside 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.

### 6.3 Track conditions

The standard superstructure for the stationary test is a track with ballast bed and sleepers without any type of rail or track shielding.

There should be no acoustic covering or lying snow on the track bed.

In the case of normal vehicle operation on another track only or predominantly, the test may be carried out on this specific track.

NOTE Measurement results obtained on other track designs are only comparable with measurements made on that track design and therefore not compliant to the standard track conditions requirements.

### 6.4 Vehicle conditions

#### 6.4.1 General

The unit shall be stationary.

The vehicle shall be configured and operated during the test to represent the normal operating conditions at stationary (including software e.g.: for traction, auxiliaries, and HVAC configuration). Specifically, the acoustic properties of all surfaces shall not be affected by any kind of e.g. covering, lining or panelling which is not present in normal operation.

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 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 units (diesel and electric), the measurements shall be performed under both modes.

#### 6.4.2 Normal operating conditions

The measurements shall be carried out in normal operating conditions defined as follows (see also [Annex A](#)).

All equipment that operates continuously when the unit is stationary shall be operating at normal load. Normal load in this subclause means the performance at an external equivalent temperature of 20 °C except for HVAC systems. For the following systems this requires that:

- the cooling equipment of traction and auxiliary equipment shall be operated in the minimum necessary condition in stable thermal condition;
- the air compressor shall not operate where possible;

- for units with internal combustion engines, the engine shall be at idle with a load corresponding to the necessary power to operate the auxiliaries as defined in this paragraph;
- for heating, ventilating and air conditioning (HVAC) systems conditioning passenger areas and working places as well as for systems supplying energy for this function, normal load is defined as 50 % of the cooling power that is necessary under the maximum thermal load where the vehicle is regularly operated. In the case of discrete operating points, HVAC shall be operated at the lowest operation mode equal to or above 50 %. At least one compressor per HVAC unit shall be set to operate continuously. Operational parameters shall be defined and documented in the report, see [Annex A](#) for guidance.

Occasional sources of noise shall be excluded from the measurement (e.g. main switch, relay, sanding equipment, alarms, toilet flushing, passenger Information, doors signals and other warning signals etc.). Operational parameters shall be defined and documented in the report, see [Annex A](#) for guidance.

### 6.4.3 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.

NOTE In the case of regular changes to furniture in commercial operation (e.g. in sleeping cars or for seasonal changes in passenger rolling stock), it can be useful to measure each configuration.

## 6.5 Measured quantities

The main measurement acoustic quantity is the A-weighted equivalent continuous sound pressure level,  $L_{pAeq,T}$  with  $T \geq 20$  s.

Where an assessment of impulsiveness is required, the A-weighted maximum sound pressure level,  $L_{pAFmax}$ , shall be used. It can also be used for the assessment of intermittent sources.

Where frequency analysis is required, one-third octave band sound pressure level shall be measured over a one-third octave band centre frequency range of 25 Hz to 10 kHz.

## 6.6 Test procedure

The measurement time interval  $T$  shall be at least 20 s, acquired as a single record. If, however, it is exceptionally not possible to maintain the source of noise at its normal 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. A single measurement of  $T = 20$  s is sufficient in all the cases.

The measurement at the different positions shall be carried out either simultaneously or sequentially. The required vehicle conditions need to be established only in the vehicles currently affecting the measurements.

The validity of the measurements shall be assessed against the background sound pressure level, see [6.2.3](#).

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.

## 6.7 Data processing

### 6.7.1 Standard processing

The standard processing shall only include the results from the measurement positions used to characterize an area.

For each set of measurements corresponding to one area (one sample at each position), the A-weighted equivalent continuous sound pressure levels  $L_{pAeq,T}^i$  measured at all positions  $i$  shall be energy averaged as given in [Formula \(1\)](#) to derive a single noise indicator representative of the area:

$$\langle L_{pAeq,T} \rangle_{\text{area}} = 10 \log_{10} \left( \frac{1}{n} \sum_{i=1}^n 10^{L_{pAeq,T}^i / 10} \right) \quad (1)$$

where

$L_{pAeq,T}^i$  is the A-weighted equivalent continuous sound pressure level measured at the measurement position  $i$ ;

$n$  is the number of measurement positions;

$\langle L_{pAeq,T} \rangle_{\text{area}}$  shall be rounded to the nearest integer as the main result of the test. In addition, the full set of the  $L_{pAeq,T}^i$  measured at all measurement positions corresponding to an area shall be shown to one decimal place in the report.

### 6.7.2 Additional processing

If an assessment at additional measurement positions is required,  $L_{pAeq,T}$  with  $T \geq 20$  s measured at these specific positions shall be determined.

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  $L_{pAFmax}$ .

For those locations and conditions where an assessment of impulsiveness is required, the measurement quantity  $L_{pAFmax}$  shall be used. For investigation purpose, an additional evaluation is provided in [Annex B](#).

For those locations and conditions where an assessment of tonality is required:

- for type testing purposes, the simplified method specified in ISO 1996-2:2017, Annex K, based on a one-third octave band spectral analysis of the whole measurement time shall be used. Where this method identifies a one-third octave band containing a tone, it shall be reported. It shall also be reported whether the difference in A-weighted level between this one-third octave band and the overall noise level,  $L_{pAeq,T}$  is less than 6 dB. In this case, it indicates that this one-third octave band is prominent and affects the A-weighted overall level of the noise.
- for investigation purposes, a method based on a narrow band spectral analysis is recommended. ISO 1996-2:2017, Annex J, or DIN 45681 are then preferred.

When spectra are required, they shall be supplied in one-third octave bands in the range of at least 25 Hz to 10 000 Hz.

## 7 Testing in cabs when sounding an external warning horn

### 7.1 Environmental conditions

#### 7.1.1 Acoustical environment

Unless otherwise defined for the test, the default conditions for the test site are approximately free-field conditions; except for the ground, there shall not be any acoustically reflective (hard) surfaces comprising such materials as steel or concrete, including other trains and fixed structures, within 10 m of the external surfaces of the sides of the cab within which tests are being undertaken. Similarly, there shall not be any acoustically reflective surfaces within 25 m of the external surface of the front end of the cab.

No-one shall be present inside the driver's cab, except for essential testing and operating personnel.

No-one shall occupy the driver's seat during these stationary tests.

### 7.1.2 Meteorological conditions

The following weather parameters shall be recorded outside the tested vehicle at representative times during the noise measurement: temperature, humidity, barometric pressure. Any noise-relevant weather information (e.g. temperature, humidity, falling rain, hail, snow or high wind) outside the tested vehicle shall be reported before and after each series of measurements as a minimum.

### 7.1.3 Background sound pressure level

The  $L_{pAeq,T}$  with  $T \geq 20$  s of background noise in the driver's cab shall be at least 10 dB below the final result obtained when measuring the noise inside 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.

## 7.2 Track conditions

The standard superstructure for the stationary test is a track with ballast bed and sleepers without any type of rail or track shielding.

There should be no acoustic covering or lying snow on the track bed.

In the case of normal vehicle operation on another track only or predominantly, the test may be carried out on this specific track.

NOTE Measurement results obtained on other track designs are only comparable with measurements made on that track design and therefore not compliant to the standard track conditions requirements.

## 7.3 Vehicle conditions

The vehicle shall be stationary.

During the measurements, the doors and windows of the vehicle shall be kept closed. The cab shall be in the condition that will apply when in service.

The horns shall be in its normal operating condition.

The sound source that is to be measured, the external warning horn, is inherently of high sound level, and therefore typical internal background noise levels in the cab when stationary are unlikely to interfere with the measured results. Nevertheless, it is advisable to run only those systems on the unit that are essential to allow the external warning horn to sound, and to avoid positioning the vehicle at locations where other high noise level sources are present.

## 7.4 Measured quantities

The basic measured acoustic quantity is the A-weighted equivalent continuous sound pressure levels,  $L_{pAeq,T}$  with  $T = 3$  s.

## 7.5 Test procedure

Measurement conditions shall comply with EN 15153-2:2020, Clause 6, for the measurement of horn performances. If the value of  $L_{pAeq,T}$  measured under these conditions is outside the range specified for this test within the applicable limit (e.g. EN 15153-2 in Europe), or if these measured levels before and after the stationary cab noise measurements differ by more than 3 dB, the cab noise results are invalid.

The stationary measurements require the noise level in the vicinity of the driver's ears to be quantified when the external warning horn is sounded.

When the external warning horn has more than one type of operating control, the test shall be carried out using each of these types of controls.

NOTE 1 This is only needed if different valves or supply types are used for the different operating controls.

Sound pressure levels shall be measured at an energy level, which is in the range of the normal operational conditions, e.g. air supply or electric supply, available on the vehicle. Operational parameters shall be documented in the report.

When there are two or more warning horns, they shall be activated as designed for operational service. (see EN 15153-2). When the acoustic warning has an option for a loud or quiet setting, at least the loud setting shall be assessed.

For each configuration (defined as a combination of a sounding and a type of control), three measurements shall be made for separate actuations of the horn. The measurement time shall not include the rising and fall time of the noise signal.

The measurements at the eight positions shall either be acquired simultaneously or sequentially.

NOTE 2 It is advantageous that the maximum possible number of channels be acquired simultaneously in order to minimise the number of horn soundings and hence reduce the environmental impact during testing.

If all driver's cabs are similar acoustic areas, only one driver's cab shall be tested.

## 7.6 Data processing

### 7.6.1 Standard processing

For each configuration, the arithmetic mean of the values of  $L_{pAeq,T}$  thus acquired at the discrete measurement positions shall be calculated. This process shall be repeated three times, and the arithmetic mean of the three resulting values shall be calculated and rounded to the nearest integer as the result of the test.

### 7.6.2 Additional processing

When spectra are required, they should be supplied:

- either in one-third octave bands in the range of at least 25 Hz to 10 000 Hz,
- or in terms of power spectrum with an appropriate frequency resolution.

## 8 Constant speed test

### 8.1 General

Constant speed testing is carried out for acoustic characterization of the interior of railway vehicles operating at an invariant speed. The speeds chosen are dependent on the purpose of the testing. The test speeds are specified in [8.6.2](#).

### 8.2 Environmental conditions

#### 8.2.1 Acoustical environment

The test site for constant speed measurement shall be in approximately free-field conditions, i.e. such that the sound radiated by the train to the exterior contributes to the interior noise only by reflection from the track, and not by reflection from buildings, walls or similar large objects adjacent to the track.

Measurements can be requested within tunnels, stations, on elevated routes and in curves; these specific environments are considered separately in [Annex D](#).

## 8.2.2 Meteorological conditions

The standard condition for measurements shall be: no falling rain, hail or snow. Any noise-relevant weather information (e.g. temperature, humidity, falling rain, hail, snow or high wind) outside the tested vehicle shall be reported before and after each series of measurements as a minimum.

NOTE Heavy rain, or strong wind conditions (cross-wind or wind gusts) can affect the measurement result.

## 8.2.3 Background sound pressure level

As the sound emitted by auxiliary equipment that normally runs continuously forms part of the constant speed internal environment, it is not necessary to quantify or eliminate this contribution. However, 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.

## 8.3 Track conditions

### 8.3.1 General

There should be no acoustic covering or lying snow on the track bed.

The rolling noise element of interior sound level contains contributions from the rolling stock and the track. Therefore, sound pressure levels are only comparable between sites where the track parameters are controlled to make them equivalent in terms of acoustic performance.

For conventional railway units with steel wheels running on steel rails, the track parameters, i.e. the acoustic roughness of the rail surface and the vertical and lateral track decay rate, shall be controlled according to [8.3.5](#). To ensure the comparability of the acoustic performance, the track characteristics shall comply with each of the criteria set in [8.3.5](#). The specifications in [8.3.5](#) ensure that the measurement procedure is of engineering grade and that the influence of the track on the vehicle type test result due to rail roughness or track decay rate is minimized. The results of tests under these conditions are deemed to be comparable from one compliant track to another.

In the case that comparability is not required, other track criteria may be used.

NOTE Where the track conditions deviate from the requirements given in [8.3.5](#), this can lead to results that are influenced by the characteristics of the test section. However, such results can be of interest e.g. for measurement on specific types of network or for monitoring purposes.

For systems other than conventional railway units (e.g.: people mover on pneumatic rubber tyres), the noise measurements shall apply on the track type where the unit is usually operated. In that case, no measurements of the track conditions are required and no status of comparability with noise results obtained on other tracks is conferred.

### 8.3.2 Track design

The radius of curvature  $R$  of the test section shall be:

- a)  $R \geq 1\,000$  m for tests at train speed  $V \leq 70$  km/h;
- b)  $R \geq 3\,000$  m for tests at train speed  $70 < V \leq 120$  km/h;
- c)  $R \geq 5\,000$  m for tests at train speeds  $V > 120$  km/h.

Where vehicles under test are fitted with traction equipment (e.g. engines, transformers, inverters), the gradient of the test section shall be no greater than 5 ‰.

For electrified vehicles, the power supply shall be continuous during this test. The test section shall avoid the gap of the 3<sup>rd</sup> rail or dead section of the catenary both for the powering section and regenerative brake section.

### 8.3.3 Track superstructure

The standard superstructure for the constant speed test is a plain track with ballast bed and sleepers without any type of rail or track shielding (use of rail dampers is accepted to comply with track decay rate limits, see 8.3.5). Where measurements are taken on track where a third rail is present, there shall not be any protective shielding boards in place.

The ballast shall be normally compacted without track sections containing slurried, choked or glued ballast by debris, ice or snow.

In the case of normal vehicle operation on another track only or predominantly, the test may be carried out on this specific track.

NOTE Measurement results obtained on other track designs are only comparable with measurements made on that track design and therefore not compliant to the standard track conditions requirements.

### 8.3.4 Track quality

The track at the test section shall be laid without rail joints and be free of visible surface defects such as corrugations, rail burns or pits and spikes. No audible impact noise due to welds, loose sleepers or third rail shall be present.

### 8.3.5 Rail roughness and track dynamic properties

A necessary condition to minimize the track contribution to the interior noise is that the acoustic track characteristics (ATC), which comprise the acoustic rail roughness and track decay rates, shall fulfil the default specifications of Annex C.

Annex C provides a description of the assessment of the ATC of the test section based on

- either direct measurement on the whole test section,
- or direct measurement only on part of the test section, then an extension of the ATC assessment to the remaining part of the test section on the basis of rolling noise or axle box vibration. This provides an estimation of the appropriateness of this remaining part for vehicle internal noise measurements. For the purposes of this document, this approach is called “indirect assessment”.

### 8.3.6 Special conditions

For non-conventional units tested on dedicated tracks, the track structure shall be described in the test report.

## 8.4 Vehicle conditions

### 8.4.1 General

The vehicle shall be configured and operated during the test to represent the normal operating conditions at constant speed (including software e.g.: for traction, auxiliaries and HVAC configuration). Specifically, the acoustic properties of all surfaces shall not be affected by any kind of e.g. covering, lining or panelling which is not present in normal operation.

During the measurements, all doors and all windows of the unit shall be kept closed, unless they are designed to remain open under normal operating conditions.

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

For cab noise measurements, windscreen wipers shall not be in operation.

In the case of multi-voltage 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 units (diesel and electric) the measurements shall be performed under both modes.

#### 8.4.2 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 running at constant speed shall be operating at normal load, which is the performance at an external temperature of 20 °C, except for HVAC systems. For the following systems this implies that:

- the cooling equipment of traction and auxiliary equipment shall be operated in the minimum necessary condition in stable thermal condition;
- the air compressor shall not operate where possible;
- for heating, ventilating and air conditioning (HVAC) systems conditioning passenger areas and working places as well as for systems supplying energy for this function, normal load is defined as 50 % of the cooling power that is necessary under the maximum thermal load where the vehicle is regularly operated. In the case of discrete operating points, HVAC shall be operated at the lowest operation mode equal or above 50 %. At least one compressor per HVAC unit shall be set to operate continuously. Operational parameters shall be defined and documented in the report, see [Annex A](#) for guidance.

#### 8.4.3 Occupancy and load

The vehicles shall be unoccupied except for essential train crew and testing personnel.

If the unit is an Electrical Multiple Unit (EMU) or Diesel Multiple Unit (DMU) or a passenger car, a minimum tractive effort to maintain the required constant speed of the train shall be continuously applied. If the unit being tested is a locomotive, the tractive effort used at any test speed shall be at least two-thirds of the maximum tractive effort at the maximum speed.

Where appropriate meters and displays are available within the cab of the traction vehicle under test, the required testing condition can be ensured by operating the traction vehicle with an indicated tractive effort of at least two-thirds of the maximum available tractive effort. This condition can be more reliably ensured by including an instrumented brake vehicle within the hauled set of vehicles, thus allowing the tractive effort to be controlled precisely during the test period by brake application.

The test report shall describe the state of the traction equipment during the test and, in the case of locomotives, either the hauled load or the tractive effort applied.

#### 8.4.4 Wheel tread conditioning

The unit shall have run under representative operating conditions (traction and speed) for at least 1 000 km (or 500 km for trams and metros) in order to condition the wheels.

Wear of the wheel tread can tend to reduce the roughness of freshly reprofiled or new wheels. Care should be taken to present units for test with in-service conditioned wheels.

The wheel treads shall be as free as possible from noise-generating irregularities such as flats. For units with tread brakes or scrubber (tread cleaning brakes), the block/tread pair shall be in a run-in condition where block and tread have bedded in sufficiently. Before starting the measurements (typically immediately before, but not more than 24 h before, their commencement), such units shall be braked to a standstill at least twice. Braking shall start at 80 km/h or at the maximum unit speed in

the case where it is lower than 80 km/h. The unit shall be braked to a complete stop with a deceleration which is typical of normal operation, but which ensures that no wheel flats are generated.

If the wheel is reprofiled more than once between setting the new wheel and the noise test, the wheel diameter shall be listed on the report.

**8.4.5 Additional 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.

NOTE In the case of regular changes to furniture in commercial operation (e.g. in sleeping cars or for seasonal changes in passenger rolling stock), it can be useful to measure each configuration.

**8.5 Measured quantities**

The main measurement quantities for trains running at constant speed are the A-weighted equivalent continuous sound pressure level,  $L_{pAeq,T}$  and train speed,  $V$ .

Where frequency analysis is required, one-third octave band sound pressure level shall be measured over a one-third octave band centre frequency range of 25 Hz to 10 kHz.

**8.6 Test procedure**

**8.6.1 General**

Noise data shall be recorded at each test speed, over a sufficient length of time from which to select the samples to be processed according to 8.7.

**8.6.2 Test speeds**

Tests shall be performed at the maximum operational speed of the unit under test.

Additional tests, if required, should be performed at one or more of the suggested speeds given in Table 1.

**Table 1 — Additional tests**

Locomotives and heavy rail passengers vehicles km/h	Metros km/h	Trams and light rail vehicles km/h
80	60	40
120	80	60
160		
200		
250		
300		

Over the test section, the unit under test shall be run at the chosen speeds stabilized to within ±5 %. The speed shall be measured by a device with a maximum permissible measurement error of 3 %. The speedometer of the train may be used if it meets this criterion.

**8.6.3 Measurement time intervals**

Measurement of trains running at constant speed shall be performed at each measurement position with a measurement time interval of  $T \geq 20$  s.

It is permissible to assemble a sample of at least 20 s from a set of shorter samples of at least 5 s duration.

Recording shall be carried out over a time period that enables the collection of a minimum of 20 s of data on track that is compliant with the ATC requirements given in [Annex C](#).

The collection of 20 s of valid data may use non-contiguous 5 s record segments. This might also be necessary when the test track includes sections that are in tunnels or deep cuttings, or when internal or external acoustic warnings are sounded.

## 8.7 Data processing

### 8.7.1 Standard processing

The value of  $L_{pAeq,T}^i$  measured over at least  $T = 20$  s shall be calculated for all measurement positions,  $i$ , used to characterize an area.

For each set of measurements corresponding to one area (one sample at each position), the A-weighted equivalent continuous sound pressure levels  $L_{pAeq,T}^i$  measured at all positions  $i$  shall be energy averaged as given by [Formula \(2\)](#) to derive a single noise indicator representative of the area:

$$\langle L_{pAeq,T} \rangle_{\text{area}} = 10 \log_{10} \left( \frac{1}{n} \sum_{i=1}^n 10^{L_{pAeq,T}^i / 10} \right) \quad (2)$$

where

$L_{pAeq,T}^i$  is the A-weighted equivalent continuous sound pressure level measured at the measurement position  $i$ ;

$n$  is the number of measurement positions;

In addition, the full set of  $L_{pAeq,T}^i$  measured at all measurement positions shall be presented in the report and shall comprise:

- the value of  $L_{pAeq,T}^i$  ( $T \geq 20$  s) rounded to the nearest integer;  $T$  can be composed of samples as described in [8.6.3](#);
- the  $L_{pAeq,T}^i$  ( $T \geq 5$  s) values of each sample (rounded to one decimal place);
- the corresponding values of  $L_{\text{extend},pAeq,5s} - L_{\text{direct},pAeq,T}$  or  $L_{\text{extend},aAeq,5s} - L_{\text{direct},aAeq,T}$  for the ATC monitoring signal (see [Annex C](#)), rounded to one decimal place.

The measurement data collected at that track section with directly-measured ATC shall be identified. The ATC assessment as described in [Annex C](#) shall be used to identify the measurement samples for the composition of the measurement time.

All vehicle speed data of the composed sample of at least 20 s shall be within that speed range defined in [8.6.2](#).

### 8.7.2 Additional processing

If an assessment at additional measurement positions is required,  $L_{pAeq,T}$  ( $T \geq 20$  s) measured at these specific positions shall be determined.

In the case of intermittent sources, the  $L_{pAeq,T}$  should be calculated over the duration of the operating cycle.

For those locations and conditions where an assessment of impulsiveness is required, the measurement quantity  $L_{pAFmax}$  shall be used. For investigation purpose, an additional evaluation is provided in [Annex B](#).

For those locations and conditions where an assessment of tonality is required:

- for type testing purposes, the simplified method specified in ISO 1996-2:2017, Annex K, based on a one-third octave band spectral analysis of the whole measurement time shall be used. Where this method identifies a one-third octave band containing a tone it shall be reported. It shall also be reported whether the difference in A-weighted level between this one-third octave band and the overall noise level,  $L_{pAeq,T}$ , is less than 6 dB. In this case it indicates that this one-third octave band is prominent and affects the A-weighted overall level of the noise;
- for investigation purposes, a method based on a narrow band spectral analysis is recommended. The ISO 1996-2:2017, Annex J, or DIN 45681 are then preferred.

When spectra are required, they should be supplied in one-third octave bands in the range of at least 25 Hz to 10 000 Hz.

## 9 Acceleration from stand-still test and deceleration to stand-still test

### 9.1 General

The purpose of the acceleration test is an assessment of the traction noise during an acceleration. Therefore, this test shall not be applied where traction noise is not present (e.g. a trailer car).

The deceleration test shall be applied to all units including trailer cars.

NOTE In most cases, where traction or braking noise is significant, the ATC does not influence the test.

For the assessment of the acceleration test from stand-still and deceleration test to stand-still, two alternative methods are specified:

- one provides an assessment in terms of  $L_{pAFmax}$  at measurement positions; it shall be used to characterize the maximum interior noise during the event;
- the other, in terms of  $L_{pAeq,T}$  at measurement positions, it shall be used to characterize the total acoustic energy during the event.

These are called the “maximum level method”, see 9.7, and the “averaged level method”, see 9.8.

### 9.2 Environmental conditions

#### 9.2.1 Acoustical environment

The test site for acceleration/deceleration measurement shall be in approximately free-field conditions, i.e. such that the sound radiated by the train to the exterior contributes to the interior noise only by reflection from the track, and not by reflection from buildings, walls or similar large objects adjacent to the track.

Measurements can be requested within tunnels, depots, stations and on elevated routes, these specific environments are considered separately in Annex D.

No-one shall be present inside the tested area of the vehicle, except for essential testing and operating personnel.

#### 9.2.2 Meteorological conditions

The standard condition for measurements shall be: no falling rain, hail or snow. Any noise-relevant weather information (e.g. temperature, humidity, falling rain, hail, snow or high wind) outside the tested vehicle shall be reported before and after each series of measurements as a minimum.

NOTE Heavy rain or external wind speed higher than 5 m/s can affect the interior background noise, see 9.2.3.

### 9.2.3 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.

NOTE It is usually necessary to switch-off the unit under test in order to achieve an uncontaminated measurement of the background noise inside the unit.

The maximum value of the  $L_{pAeq,T}$  with  $T \geq 20$  s of background noise over all microphone positions shall be at least 10 dB below the  $L_{pAFmax}$  (or  $L_{pAeq,T}$ ) obtained when measuring the noise from the unit at stand-still in the presence of background noise. For frequency analysis, this difference shall be at least 10 dB in each frequency band of interest.

### 9.3 Track conditions

There should be no acoustic covering or lying snow on the track bed.

The track at the measuring section shall be laid without rail joints and be free of visible surface defects such as corrugations, rail burns, pits and spikes. The rail running surface shall be free of contamination like rust and dirt. No audible impact noise due to welds or loose sleepers should be present.

The gradient of the track shall not be greater than 5 ‰.

For electrified vehicles, the power supply shall be continuous during this test. I.e. the test section shall avoid the gap of the 3<sup>rd</sup> rail or dead section of the catenary both for the powering section and regenerative brake section.

Additional ATC measurement can be used to confirm that the traction noise state is not significantly affected by rolling noise (see [Annex C](#)).

NOTE If the rail is wet, this can lead to wheel slip and modify the acoustic behaviour of the vehicle.

### 9.4 Vehicle conditions

#### 9.4.1 General

The vehicle shall be configured and operated during the tests to represent the normal operating conditions when accelerating from stand-still or deceleration to stand-still (including software e.g.: for traction, auxiliaries and HVAC configuration). Specifically, the acoustic properties of all surfaces shall not be affected by any kind of e.g. covering, lining or panelling which is not present in normal operation.

Traction equipment shall be in stationary thermal condition before the test. For example, engines shall have been warmed up and there shall be no high level of cooling operation from previous braking.

During the measurements, all doors and all windows of the unit shall be kept closed, unless they are designed to remain open under normal operating conditions.

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

For cab noise measurements, windscreen wipers shall not be in operation.

In the case of multi-voltage 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 units (diesel and electric), the measurements shall be performed under both modes.

Occasional sources of noise shall be excluded from the measurement (e.g. door operation, main switch, sanding equipment, alarms, ...). Any part of a measurement that is excluded shall be identified in an  $L_{pAF}(t)$  plot.

#### 9.4.2 Normal operating conditions

The measurements shall be carried out in normal operating conditions defined as follows (see [Annex A](#)).

All equipment that operates continuously when the unit is accelerating or decelerating shall be operating at normal load, which is the performance at an external temperature of 20 °C, except for HVAC systems. For the following systems this implies that:

- the cooling equipment of traction and auxiliary equipment shall be operated in the minimum necessary condition in stable thermal condition;
- the air compressor shall not operate where possible;
- for heating, ventilating and air conditioning (HVAC) systems conditioning passenger areas and working places as well as for systems supplying energy for this function, normal load is defined as 50 % of the cooling power that is necessary under the maximum thermal load where the vehicle is regularly operated. In the case of discrete operating points, HVAC shall be operated at the lowest operation mode equal or above 50 %. At least one compressor per HVAC unit shall be set to operate continuously. Operational parameters shall be defined and documented in the report, see [Annex A](#) for guidance.

#### 9.4.3 Occupancy and load

The principle shall be to achieve an acceleration or deceleration event representative of normal operation avoiding wheel spin and without macro slip.

The unit shall be unoccupied except for essential train crew and testing personnel.

##### 9.4.3.1 Acceleration

For locomotives, the hauled load shall be defined and shall be sufficient to ensure that at least 90% of the speed dependent maximum tractive effort is maintained throughout the measurement. The load shall be applied either by a braking locomotive or by a number of wagons with a sufficient mass or by a combination of both. The locomotive shall be at the head of the train.

To avoid the noise produced by the automatic couplers, it may be necessary to limit the tractive effort.

For all units, the power lever shall in general be shifted to the maximum position. Where there is a controlled automatic acceleration procedure, it shall be used. In the exceptional case where there is no controlled automatic acceleration, a fixed power lever position shall be used and the acceleration shall be as high as possible but limited to 1,1 m/s<sup>2</sup>.

##### 9.4.3.2 Deceleration

The test condition of the unit shall correspond to normal service braking, not to emergency braking or automatic safety braking. Where applicable, the brake blending (proportions of dynamic brake and pneumatic brake) shall be noted.

#### 9.4.4 Wheel tread conditions

The wheel treads shall be as free as possible from noise-generating irregularities such as flats. No other requirements regarding the roughness of the wheel treads are specified.

## 9.5 Test procedure for the acceleration test

Three valid measurement samples at each position are required. The validity assessment of the measurements against the background noise level, see 9.2.3, and against the acceptable spread of the measurement samples, see 10.3, shall be performed using the measurement quantity determined according to 9.7.2 or 9.8.2.

The unit shall accelerate continuously from standstill without wheel slip. The measurement time interval  $T$  shall begin when the unit under test starts to move and shall end when the unit reaches a speed of 40 km/h for all units except for units with a top speed less than 90 km/h for which the measurement interval ends when the unit reaches 30 km/h.

The driver should not reduce traction effort until the measurement interval has ended.

## 9.6 Test procedure for the deceleration test

Three valid measurement samples at each position are required. The validity assessment of the measurements against the background noise level, see 9.2.3, and against the acceptable spread of the measurement samples, see 10.3, shall be performed using the measurement quantity determined according to 9.7.2 or 9.8.2.

A full-service braking shall be performed, beginning at a constant speed of 30 km/h, ending at standstill.

NOTE The full-service braking is given in EN 13452-1.

The measurement time interval  $T$  shall begin when the driver initiates the braking and shall end when the unit stops.

## 9.7 Maximum level method

### 9.7.1 Measured quantities

The main measurement acoustic quantity is  $L_{pAF}(t)$  to derive the  $L_{pAFmax}$ .

Where frequency analysis is required, one-third octave band sound pressure level shall be measured over a one-third octave band centre frequency range of 25 Hz to 10 kHz.

### 9.7.2 Data processing

The value of  $L_{pAFmax}$  shall be calculated for each measurement (for each starting or braking event and each measurement position  $i$ , used to characterize an area).

For each set of measurements corresponding to one area (one sample at each position), the maximum noise levels  $L_{pAFmax}^i$  measured at all positions  $i$  shall be energy averaged as given by Formula (3) to derive a single noise indicator representative of the area:

$$\langle L_{pAFmax} \rangle_{area} = 10 \log_{10} \left( \frac{1}{n} \sum_{i=1}^n 10^{L_{pAFmax}^i / 10} \right) \quad (3)$$

where

$L_{pAFmax}^i$  is the sound pressure level measured at the measurement position  $i$ ;

$n$  is the number of measurement positions;

A  $\langle L_{pAFmax} \rangle_{area}$  shall then be produced for each of the three sets of measurements.

The test result shall be the arithmetic mean of the  $\langle L_{pAFmax} \rangle_{area}$  values, rounded to the nearest integer decibel.

The individual  $\langle L_{pAFmax} \rangle_{area}$  as well as the mean shall be presented in the report. In addition, the full set of  $L_{pAFmax}^i$  values measured at all measurement positions rounded at one-decimal place shall be presented in the report.

For those locations where an assessment of tonality is required, the methods specified in 9.8.2 shall be used, using the  $L_{pAeq,T}$  averaged over the whole event record.

## 9.8 Averaged level method

### 9.8.1 Measured quantity

The main measurement acoustic quantity is the A-weighted equivalent continuous sound pressure  $L_{pAeq,T}$ .

Where frequency analysis is required, one-third octave band sound pressure level shall be measured over a one-third octave band centre frequency range of 25 Hz to 10 kHz.

### 9.8.2 Data processing

The value of  $L_{pAeq,T}$  shall be calculated for each measurement (for each starting event and each measurement position  $i$  used to characterize an area).

For each set of measurements corresponding to one area (one sample at each position), the A-weighted equivalent continuous sound pressure levels  $L_{pAeq,T}^i$  measured at all positions  $i$  shall be energy-averaged as given by Formula (4) to derive a single noise indicator representative of the area:

$$\langle L_{pAeq,T} \rangle_{area} = 10 \log_{10} \left( \frac{1}{n} \sum_{i=1}^n 10^{L_{pAeq,T}^i / 10} \right) \quad (4)$$

where

$L_{pAeq,T}^i$  is the A-weighted equivalent continuous sound pressure level measured at the measurement position  $i$ ;

$n$  is the number of measurement positions;

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

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

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

For those locations and conditions where an assessment of tonality is required:

- for type testing purposes when there is no requirement to assess the time variation of tones, the simplified method specified in ISO 1996-2:2017, Annex K, based on a one-third octave band spectral analysis of the whole measurement time shall be used. Where this method identifies a one-third octave band containing a tone it shall be reported. It shall also be reported whether the difference in A-weighted level between this one-third octave band and the overall noise level,  $L_{pAeq,T}$ , is less than 6 dB. In this case it indicates that this one-third octave band is prominent and affects the A-weighted overall level of the noise;

- for investigation purposes when there is no requirement to assess the time variation of tones, a method based on a narrow band spectral analysis is recommended. The ISO 1996-2:2017, Annex J, or DIN 45681:2005 are then preferred.

## 10 Quality of the measurements

### 10.1 Deviations from the requirements

The conditions specified for the tests given in [Clauses 5 to 9](#) shall be met as closely as possible. Slight deviations from the specified test conditions for type tests can be unavoidable. In this case, they shall be described in the test report and, in general, will worsen the reproducibility. This applies particularly to the background noise level requirement.

### 10.2 Positional tolerances

All positional distances mentioned in this document shall be considered with a tolerance of 3 % if no requirement is specified with a lower bound of 0,05 m.

### 10.3 Measurement spread

Where a series of three measurement samples are required, a spread of less than or equal to 3 dB shall be fulfilled for the measurement to be considered as valid. Otherwise, additional measurements shall be made.

### 10.4 Measurement uncertainties

The measurement uncertainty shall be evaluated.

It is recommended to state the measurement uncertainty in the report.

NOTE [Annex E](#) provides a model to evaluate the uncertainty of the result according to ISO/IEC Guide 98-3.

## 11 Test report

The test report shall include all relevant details concerning the following:

- a) reference to this international standard, including its year of publication;
- b) nature of the tests, date, location, name and address of the organization performing the measurements;
- c) description of the test site:
  - 1) location;
  - 2) environmental conditions:
    - i) acoustical environment (major reflectors outside the vehicle, etc.);
    - ii) meteorological conditions;
    - iii) background sound pressure level.
- d) track conditions of the test sections:
  - 1) track design and location (track cross section and position along the track);
  - 2) track superstructure (including sleeper type, fastening system and rail type, presence of under sleeper pads);

- 3) result of the acoustic track characteristics evaluation when required; this should include:
  - i) results of the directly measurement track section (tabulated numerical values and graphs of the acoustic rail roughness and track decay rates);
  - ii) graph showing the result of the indirect measurement over the whole test section of track;
  - iii) a statement of the status of conformity of the acoustic track characteristics with the default specification of [Annex C](#);
- e) description of the unit (type and serial number(s)), the traction system and the speed during the test, the different type of friction brakes (e.g. composite tread brake, disc brake) and their location along the train, confirmation of the mileage criterion and a statement that the unit is representative of the type, nominal wheel diameters of unit and diameter of the reprofiled wheels;
  - 1) operating condition of the unit as specified in [6.4](#), [7.3](#), [8.4](#) and [9.4](#) (see also [Annex A](#));
  - 2) auxiliary equipment and its operating conditions;
  - 3) loading of the unit (e.g. hauled load, configuration of the brake unit, etc.);
- f) declaration that the instrumentation fulfils the requirements of [4.1](#) of this document;
- g) measurement positions and areas defined (including the specification of areas types and similar areas). A graphical representation of all the measurement positions shall be provided;
- h) measurement results;
- i) presence of impulsive sound or tonal sound, when required;
- j) quality of the measurement according to [10.1](#), [10.2](#) and [10.3](#);
- k) all other useful information.

NOTE 1 The acoustic rail roughness (EN 15610) and track decay rates (EN 15461:2008+A1:2010) standards have their own reporting requirements.

NOTE 2 Useful general requirements of test reports are presented in ISO/IEC 17025.

## Annex A (informative)

### Guidance on the definition and reporting of vehicle conditions

This annex provides information on how to ensure a sufficient representation of vehicle conditions in line with the requested environmental thermal condition.

The required conditions are defined in the main text of this document. This Annex is provided to identify all information that is needed to ensure the vehicle conditions comply with the definition given in the document. Additionally, a method for reporting all information is suggested.

For all air conditioning equipment and all heat exchange equipment, the acoustically relevant parameters need to be controlled and reported. If a vehicle or components are operated in an automatic mode, this will contradict this strategy.

During the preparation of the noise measurements, the manufacturer of the train determines the information needed to operate the relevant components in conformity with the predefined environmental and vehicle operating conditions (standstill, acceleration, deceleration, constant speed).

The operational conditions of all relevant components should be appropriately adjusted and kept constant during the measurement. This is necessary in order to obtain a reproducible and comparable noise measurement result.

This procedure can be applied over a wide range of weather conditions, for the cooling mode of air conditioning systems operating over an exterior temperature range from 10 °C to 40 °C.

For measurements with air conditioning systems in cooling mode within the low exterior temperature range, it is recommended to preheat the interior of the car and to continue, if possible, the heating during the cooling mode measurements. This procedure avoids icing of the evaporator.

The minimum noise measurement time is 20 s. During this time, the HVAC-compressor shall be set to operate continuously. If it is not possible to operate during 20 s, the measurement time interval  $T$  may be reduced to a minimum of 5 s.

## Annex B (informative)

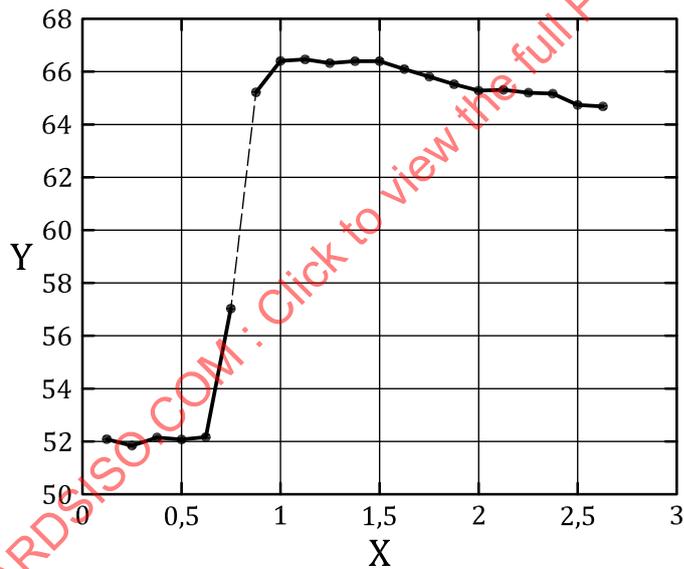
### Method to characterize the impulsive character of the noise

The rate of impulsiveness can be characterised by the rise speed  $s$  in dB/s in the following manner.  $L_{pAF}(t)$  is measured at a sample rate of at least 8 samples/second. The rising slopes in the level history  $L_{pAF}(t)$  are selected. In these slopes, the slope, or derivative  $dL_{pAF}(t)/dt$ , is continuously positive. Only those slopes are included that continuously increase by 10 dB or more. If the increase is less, the rise speed is not determined. For each of these slopes,  $j$ , the maximum derivative (the rise speed) is determined by [Formula \(B.1\)](#):

$$s_j = \max \left[ \frac{dL_{pAF}(t)}{dt} \right] \tag{B.1}$$

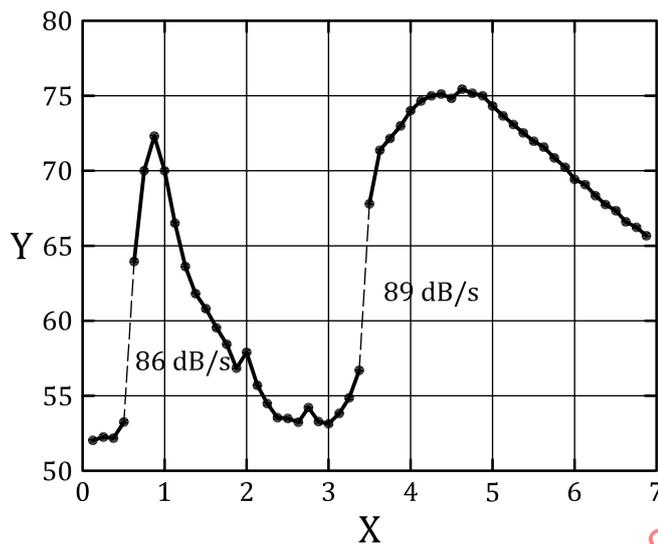
The final result is the highest value of these  $j$  rise speeds:  $s = \max(s_j)$ .

This procedure locates and rates the most startling moment of the sound pressure level time history.



**Key**  
 X time (in seconds)  
 Y  $L_{pAF}$  (in dB re  $2 \cdot 10^{-5}$  Pa)

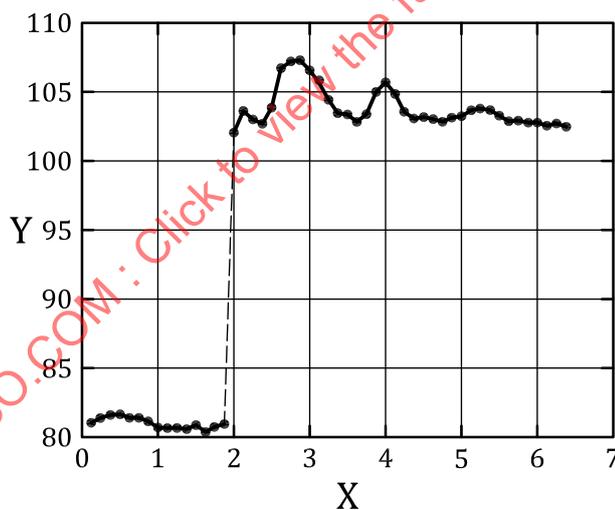
**Figure B.1 — Blow-off of a safety valve - dashed line: detected rise slope - rise speed=65 dB/s**



**Key**

- X time (in seconds)
- Y  $L_{pAF}$  (in dB re  $2 \cdot 10^{-5}$  Pa)

**Figure B.2 — Brake release - dashed line: detected rise slopes - rise speed=89 dB/s**



**Key**

- X time (in seconds)
- Y  $L_{pAF}$  (in dB re  $2 \cdot 10^{-5}$  Pa)

**Figure B.3 — Starting of a diesel engine - dashed line: detected rise slope - rise speed=169 dB/s**

## Annex C (normative)

### Acoustic track characteristics

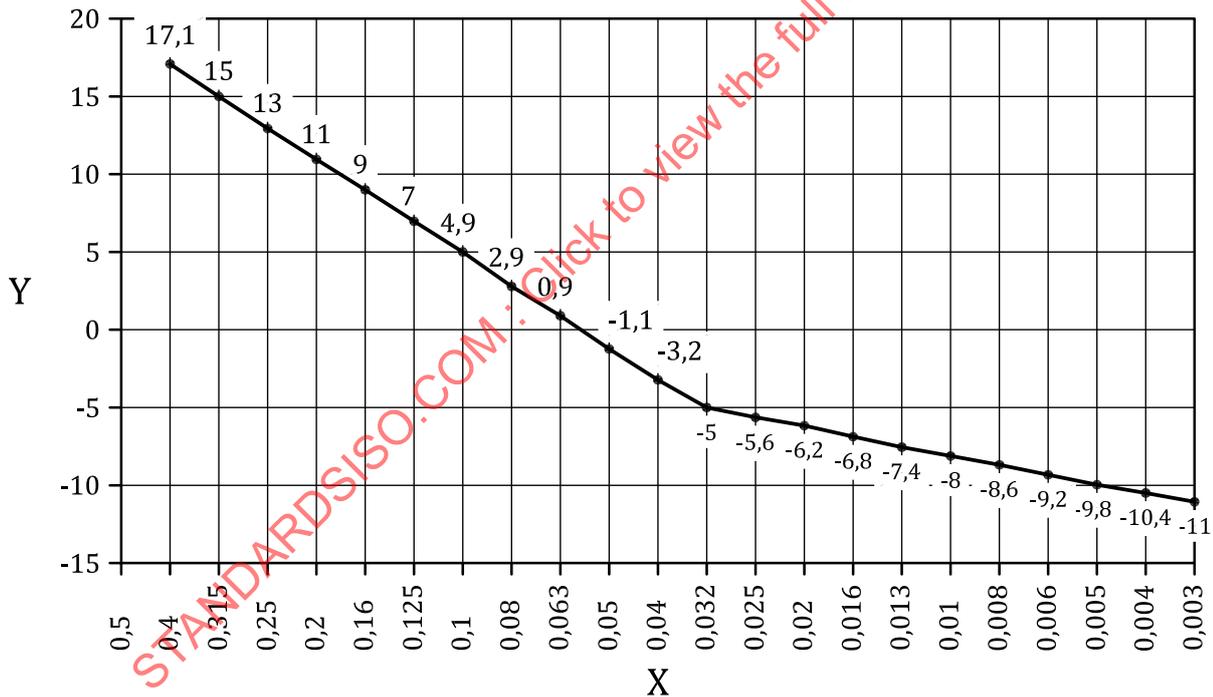
#### C.1 General

All the track specifications contained within this Annex apply specifically to the situation where the unit has steel wheels running on steel rails.

#### C.2 Default specifications

##### C.2.1 Rail roughness of the test track

In order to meet the default specification for acoustic rail roughness, the one-third octave band spectra measured according to EN 15610 shall not exceed the following upper limit according to the acceptance criteria of EN 15610.



**Key**

- X wavelength, m
- Y one-third octave band roughness level, dB re 1 μm

**Figure C.1 — Default upper limit curve for the acoustic rail roughness**

The objective wavelength varies with the train speed. The roughness level shall not exceed the value shown in [Figure C.1](#) of the wavelengths between  $\lambda_1$  and  $\lambda_2$  where:

- $\lambda_1$  is the shorter of 0,25 m or equivalent wave length of 25 Hz of the running speed (round down to 1/3 octave wavelength);

- $\lambda_2$  is the longer of 0,003 m or equivalent wave length of 10 kHz of the running speed (round up to 1/3 octave wavelength).

For example, when the train speed is 250 km/h,  $\lambda_1 = 0,25$  m and  $\lambda_2 = 0,008$  m.

NOTE  $\lambda_1$  has been limited to the longest wavelength mandated in EN 15610.

It is nevertheless recommended to use a value of  $\lambda_1$  defined by the 25 Hz and train running speed where possible.

### C.2.2 Dynamic properties of the test track

In order to meet the default specification for track decay rate, the one-third octave band spectra measured in accordance with EN 15461:2008+A1:2010 shall be above or equal to the limits provided in Figure C.2.

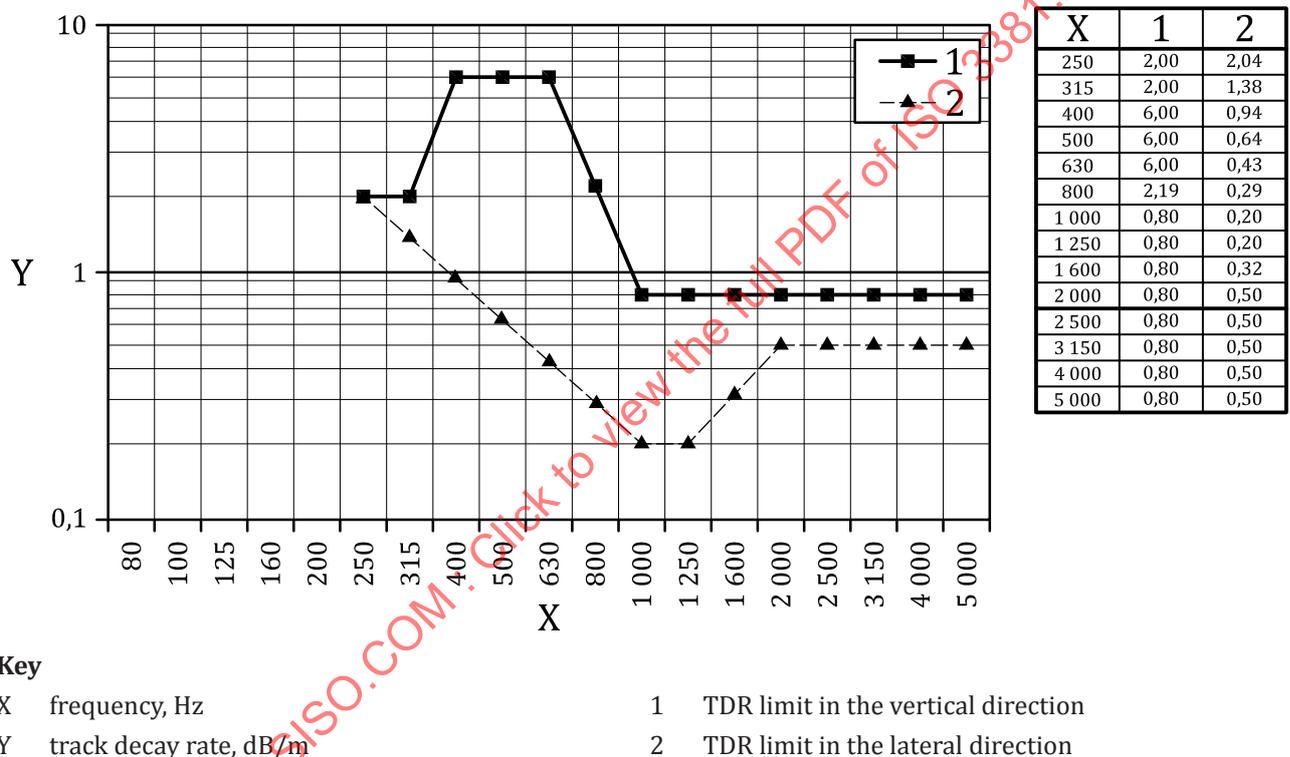


Figure C.2 — Default lower limit curves for the track decay rates

### C.3 Evaluation of the acoustic track characteristics

#### C.3.1 General

The internal noise measurements require test sections with homogeneous ATC over the required measurement distance which is dependent on the train speed. In some cases, it cannot be practical to carry out direct measurements of ATC over the entire test section. Then an extension of the test section beyond the track section where the ATC has been directly measured is needed. The extension shall be based on measurements of sound or vibration at the bogie of at least 5 s duration.

#### C.3.2 Direct measurement

Where the ATC of the test section is directly measured:

- the acoustic rail roughness of the test section shall be measured in accordance with EN 15610; and

- the track decay rates of the test section shall be measured in accordance with EN 15461:2008+A1:2010.

NOTE For long track sections, the sampling techniques presented in these two standards remain applicable.

### C.3.3 Extension of the test section based on indirect assessment

The extension of the test section is based on:

- the direct measurement of ATC on a part of the test section;
- the measurement of sound pressure or acceleration at a trailer bogie, which are both directly related to rolling noise,
- the comparison of this sound pressure or acceleration between the directly-measured section and the remaining part of the test section.

The measurements can be carried out synchronously with the interior noise measurements or during other runs of the same unit or on another unit. Any measurement from another run than that one used for collection of interior noise samples is called non-synchronous.

Measurement positions: the measurements are obtained from sensors mounted at a trailer bogie. The sensors shall measure the sound pressure at trailer bogie or the acceleration at axle box in vertical direction. In case of using a bogie, which is not part of the unit to be measured, the running surfaces of the wheels influencing the measurement shall be free of any noise generating features like corrugation or flats.

### C.4 Test procedure

The measurements shall take place along the directly-measured test section and the proposed extension.

The measured quantities on the directly-measured track section shall be  $L_{\text{direct},pAeq,T}$  or  $L_{\text{direct},aAeq,T}$  ( $T$  represents the time to pass the complete directly-measured track section with a minimum of 5 s.).

The measured quantities on the remaining part of the test section are  $L_{\text{extend},pAeq;5s}$  or  $L_{\text{extend},aAeq;5s}$ . They are acquired as series of contiguous (i.e.: adjacent without gaps) 5 s samples of sound or vibration.

Any part of the remaining test section is a valid extension of the directly-measured track section if the following criterion is met: the difference  $L_{\text{extend},pAeq;5s} - L_{\text{direct},pAeq,T}$  or  $L_{\text{extend},aAeq;5s} - L_{\text{direct},aAeq,T}$  is less than or equal to + 1,0 dB.

As a consequence, any of the samples of interior noise acquired on the extended test section may be used for assembling a valid 20 s measurement.

In the case where there is a non-continuous valid extended test section (see [Figures C.3](#) and [C.4](#)), care shall be taken to ensure that the selected samples of the interior noise measurement are representative of travel over such valid sections. For synchronous measurements this means to consider the time delay between bogie and interior sensors and for non-synchronous measurements this means to consider the time delay between interior sensors and the result of position detection of the unit as well as the positioning of the train along the track section.