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Acoustics — Description, measurement and assessment of environmental noise —

Part 1: Basic quantities and assessment procedures

Acoustique — Description, mesurage et évaluation du bruit de l'environnement —

Partie 1: Grandeurs fondamentales et méthodes d'évaluation

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Foreword

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This third edition cancels and replaces the second edition (ISO 1996-1:2003), which has been technically revised. In particular, the following subclauses and annexes have been added or revised: 3.6, 6.3.1, 6.5, 8.1, 8.2.1 i), Annex A, Annex D, Annex E, Annex F, Annex G, and Annex H.

ISO 1996 consists of the following parts, under the general title *Acoustics — Description, measurement and assessment of environmental noise*:

— *Part 1: Basic quantities and assessment procedures*

— *Part 2: Determination of sound pressure levels*

Introduction

To be of practical use, any method of description, measurement, and assessment of environmental noise is intended to be related in some way to what is known about human response to noise. Many adverse consequences of environmental noise increase with increasing noise, but the precise dose-response relationships involved continue to be the subject of scientific debate. In addition, it is important that all methods used be practicable within the social, economic, and political climate in which they are used. For these reasons, there is a very large range of different methods in use around the world for different types of noise, and this creates considerable difficulties for international comparison and understanding.

The broad aim of the ISO 1996 series is to contribute to the international harmonization of methods of description, measurement, and assessment of environmental noise from all sources.

The methods and procedures described in this part of ISO 1996 are intended to be applicable to noise from various sources, individually or in combination, which contribute to the total exposure at a site. At the stage of technology at the time of publication of this part of ISO 1996, the evaluation of long-term noise annoyance seems to be best met by adopting the adjusted A-weighted equivalent continuous sound pressure level, which is termed a “rating level”.

The aim of the ISO 1996 series is to provide authorities with material for the description and assessment of noise in community environments. Based on the principles described in this part of ISO 1996, national standards, regulations, and corresponding acceptable limits for noise can be developed.

Acoustics — Description, measurement and assessment of environmental noise —

Part 1: Basic quantities and assessment procedures

1 Scope

This part of ISO 1996 defines the basic quantities to be used for the description of noise in community environments and describes basic assessment procedures. It also specifies methods to assess environmental noise and gives guidance on predicting the potential annoyance response of a community to long-term exposure from various types of environmental noises. The sound sources can be separate or in various combinations. Application of the method to predict annoyance response is limited to areas where people reside and to related long-term land uses.

Community response to noise can vary differently among sound sources that are observed to have the same acoustic levels. This part of ISO 1996 describes adjustments for sounds that have different characteristics. The term "rating level" is used to describe physical sound predictions or measurements to which one or more adjustments have been added. On the basis of these rating levels, the long-term community response can be estimated.

The sounds are assessed either singly or in combination, allowing for consideration, when deemed necessary by responsible authorities, of the special characteristics of their impulsiveness, tonality, and low-frequency content, and for the different characteristics of road-traffic noise, other forms of transportation noise (such as aircraft noise), and industrial noise.

This part of ISO 1996 does not specify limits for environmental noise.

NOTE 1 In acoustics, several different physical measures describing sound can have their level expressed in decibels (e.g. sound pressure, maximum sound pressure, and equivalent continuous sound pressure). The levels corresponding to these physical measures normally will differ for the same sound. This often leads to confusion. Therefore, it is necessary to specify the underlying physical quantity (e.g. sound pressure level, maximum sound pressure level, and equivalent continuous sound pressure level).

NOTE 2 In this part of ISO 1996, quantities are expressed as levels in decibels. However, some countries validly express the underlying physical quantity, such as maximum sound pressure, in pascal or sound exposure in pascal-squared seconds.

NOTE 3 ISO 1996-2 deals with the determination of sound pressure levels.

2 Normative references

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

3 Terms and definitions

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

3.1 Expression of levels

NOTE For levels defined in 3.1.1 to 3.1.6, it is essential that frequency weighting or frequency bandwidth, as applicable, be specified, and time weighting, if applicable, be specified.

3.1.1
time-weighted and frequency-weighted sound pressure level
ten times the logarithm to the base 10 of the ratio of the time-mean-square of the sound pressure to the square of a reference value, being obtained with a standard frequency weighting and standard time weighting

Note 1 to entry: Sound pressure is expressed in pascal (Pa).

Note 2 to entry: The reference value is 20 µPa.

Note 3 to entry: Time-weighted and frequency-weighted sound pressure level is expressed in decibels (dB).

Note 4 to entry: The standard frequency weightings are A-weighting and C-weighting as specified in IEC 61672-1, and the standard time weightings are F-weighting and S-weighting as specified in IEC 61672-1.

3.1.2
maximum time-weighted and frequency-weighted sound pressure level
greatest time-weighted and frequency-weighted sound pressure level within a stated time interval

Note 1 to entry: Maximum time-weighted and frequency-weighted sound pressure level is expressed in decibels (dB).

3.1.3
***N* percentage exceedance level**
time-weighted and frequency-weighted sound pressure level that is exceeded for N % of the time interval considered

Note 1 to entry: N percentage exceedance level is expressed in decibels (dB).

EXAMPLE $L_{AF95,1h}$ is the A-frequency-weighted, F-time-weighted sound pressure level exceeded for 95 % of 1 h.

3.1.4
peak sound pressure level
ten times the logarithm to the base 10 of the ratio of the square of the peak sound pressure to the square of the reference value

Note 1 to entry: The reference value is 20 µPa.

Note 2 to entry: Peak sound pressure level is expressed in decibels (dB).

Note 3 to entry: Peak sound pressure should be determined with a detector as defined in IEC 61672-1. IEC 61672-1 only specifies the accuracy of a detector using C-weighting.

Note 4 to entry: The peak sound pressure is the maximum absolute value of the instantaneous sound pressure during a stated time interval.

3.1.5
sound exposure level
L_E
ten times the logarithm to the base 10 of the ratio of the sound exposure, E, being the integral of the square of the sound pressure, p, over a stated time interval or event of duration, T (starting at t_1 and ending at t_2), to a reference value, E_0

$$L_E = 10 \lg \frac{E}{E_0} \text{ dB}$$

where

$$E = \int_{t_1}^{t_2} p^2(t)\,\mathrm{d}t\ ;$$

E_0 = 400 µPa² s

Note 1 to entry: Sound exposure is expressed in pascal-squared seconds. Sound exposure level is expressed in decibels (dB).

Note 2 to entry: Because of practical limitations of the measuring instruments, p^2 is always understood to denote the square of a frequency-weighted and frequency band-limited sound pressure. If a specific frequency weighting as specified in IEC 61672-1 is applied, this should be indicated by appropriate subscripts; e.g. $E_{\mathrm{A},1\ \mathrm{h}}$ denotes the A-weighted sound exposure over 1 h.

Note 3 to entry: The duration, T, of the integration is included implicitly in the time integral and need not to be reported explicitly. For measurements of sound exposure over a specified time interval, the duration of integration should be reported and the notation should be $L_{E,T}$.

Note 4 to entry: For sound exposure levels of an event, the nature of the event should be stated.

Note 5 to entry: When applied to a single event, the sound exposure level is called "single-event sound exposure level".

3.1.6
equivalent continuous sound pressure level
$L_{\mathrm{eq},T}$
ten times the logarithm to the base 10 of the ratio of the time-average of the square of the sound pressure, p, during a stated time interval of duration, T (starting at t_1 and ending t_2), to the square of the reference sound pressure, p_0

Note 1 to entry: The A-weighted equivalent continuous sound pressure level is

$$L_{\mathrm{Aeq},T} = 10\lg \frac{\frac{1}{T}\int_{t_1}^{t_2} p_{\mathrm{A}}^2(t)\mathrm{d}t}{p_0^2}\ \mathrm{dB}$$

where

$p_{\mathrm{A}}(t)$ is the A-weighted instantaneous sound pressure at running time t;

p_0 is equal to 20 µPa.

Note 2 to entry: The equivalent continuous sound pressure level is also termed "time-averaged sound pressure level". It is expressed in decibels (dB).

3.2 Time intervals

3.2.1
reference time interval
time interval to which the rating of the sound is referred

Note 1 to entry: The reference time interval may be specified in national or international standards or by local authorities to cover typical human activities and variations in the operation of sound sources. Reference time intervals can be, for example, part of a day, the full day, or a full week. Some countries define even longer reference time intervals.

Note 2 to entry: Different levels or sets of levels may be specified for different reference time intervals.

3.2.2
long-term time interval
specified time interval over which the sound of a series of reference time intervals is averaged or assessed

Note 1 to entry: The long-term time interval is determined for the purpose of describing environmental noise as it is generally designated by responsible authorities.

Note 2 to entry: For long-term assessments and land-use planning, long-term time intervals that represent some significant fraction of a year should be used (e.g. 3 months, 6 months, and 1 year).

3.3 Ratings

3.3.1
adjustment
quantity, positive or negative, constant or variable, that is added to a predicted or measured acoustical level to account for some sound character, the time of day, or the source type

3.3.2
rating level
predicted or measured acoustic level to which an adjustment has been added

Note 1 to entry: Measurements such as day/night sound pressure level or day/evening/night sound pressure level are examples of rating levels because they are calculated from sound measured or predicted over different reference time periods, and adjustments are added to the reference time interval equivalent continuous sound pressure levels based on the time of day.

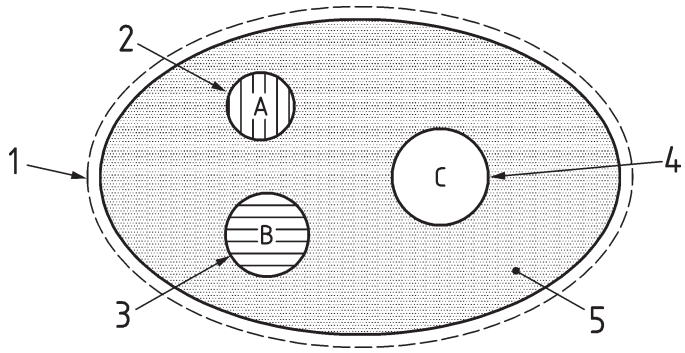
Note 2 to entry: A rating level may be created by adding adjustments to a measured or predicted level(s) to account for some character of the sound such as tonality or impulsiveness.

Note 3 to entry: A rating level may be created by adding adjustments to a measured or predicted level(s) to account for differences between source types. For example, using road traffic as the base sound source, adjustments may be applied to the levels for aircraft or railway sources.

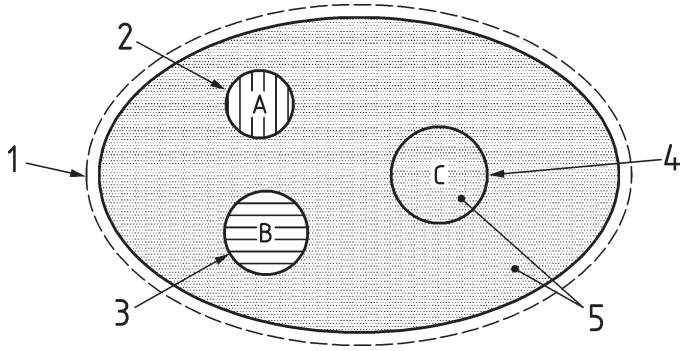
3.4 Sound designations

NOTE See Figure 1.

3.4.1
total sound
totally encompassing sound in a given situation at a given time, usually composed of sound from many sources near and far



a) Three specific sounds A, B, and C under consideration, the residual sound and the total sound



b) Two specific sounds A and B under consideration, the residual sound and the total sound

Key

1 total sound
2 specific sound A
3 specific sound B
4 specific sound C
5 residual sound

NOTE 1 The lowest residual sound level is obtained when all specific sounds are suppressed.

NOTE 2 The dotted area indicates the residual sound when sounds A, B, and C are suppressed.

NOTE 3 In Figure 1 b), the residual sound includes the specific sound C as it is not under consideration.

Figure 1 — Total, specific, and residual sound designations

3.4.2
specific sound
component of the total sound that can be specifically identified and which is associated with a specific source

3.4.3
residual sound
total sound remaining at a given position in a given situation when the specific sounds under consideration are suppressed

3.4.4
initial sound
total sound present in an initial situation before any change to the existing situation occurs

3.4.5
fluctuating sound
continuous sound whose sound pressure level varies significantly, but not in an impulsive manner, during the observation period

3.4.6
intermittent sound
sound that is present at the observer only during certain time periods that occur at regular or irregular time intervals and is such that the duration of each such occurrence is more than about 5 s

EXAMPLE Motor vehicle noise under conditions of small traffic volume, train noise, aircraft noise, and air-compressor noise.

3.4.7
sound emergence
increase in the total sound in a given situation that results from the introduction of some specific sound

3.4.8
impulsive sound
sound characterized by brief bursts of sound pressure

Note 1 to entry: The duration of a single impulsive sound is usually less than 1 s.

3.4.9
tonal sound
sound characterized by a single-frequency component or narrow-band components that emerge audibly from the total sound

3.5 Impulsive sound sources

NOTE At the time of publication of this part of ISO 1996, no mathematical descriptor exists which can define unequivocally the presence of impulsive sound or can separate impulsive sounds into the categories given in 3.5.1 to 3.5.3. These three categories, however, have been found to correlate best with community response. Thus, the sources of sound listed in 3.5.1 to 3.5.3 are used to define impulsive sound sources.

3.5.1
high-energy impulsive sound source
explosive source where the equivalent mass of TNT exceeds 50 g, or sources with comparable characteristics and degree of intrusiveness

Note 1 to entry: Sources of sonic booms include such items as aircraft, rockets, artillery projectiles, armour projectiles, and other similar sources. This category does not include the short duration sonic booms generated by small arms fire and other similar sources.

EXAMPLE Quarry and mining explosions, sonic booms, demolition, or industrial processes that use high explosives, explosive industrial circuit breakers, and military ordnance (e.g. armour, artillery, mortar fire, bombs, explosive ignition of rockets, and missiles).

3.5.2
highly impulsive sound source
source with highly impulsive characteristics and a high degree of intrusiveness

EXAMPLE Small arms fire, hammering on metal or wood, nail guns, drop-hammer, pile driver, drop forging, punch presses, pneumatic hammering, pavement breaking, or metal impacts in rail-yard shunting operations.

3.5.3
regular impulsive sound source
impulsive sound source that is neither highly impulsive nor high-energy impulsive sound source

Note 1 to entry: This category includes sounds that are sometimes described as impulsive, but are not normally judged to be as intrusive as highly impulsive sounds.

EXAMPLE Slamming of car door, outdoor ball games, such as football (soccer) or basketball, and church bells. Very fast pass-bys of low-flying military aircraft can also fall into this category.

3.6 Day, evening, night sound levels

3.6.1
day sound level
$L_{day,h}$
equivalent continuous sound pressure level when the reference time interval is the day

Note 1 to entry: Subscript h indicates the number of hours, e.g. $L_{day,12}$.

Note 2 to entry: A day is normally the 12 h between 7 h and 19 h or the 15 h between 7 h and 22 h. However, individual countries define day differently, e.g. 6 h to 18 h or 6 h to 22 h.

3.6.2
evening sound level
$L_{\text{evening},h}$
equivalent continuous sound pressure level when the reference time interval is the evening

Note 1 to entry: Subscript h indicates the number of hours, e.g. $L_{\text{evening},4}$.

Note 2 to entry: An evening is normally the 4 h between 19 h and 23 h. However, individual countries define evening differently, e.g. 18 h to 22 h.

3.6.3
night sound level
$L_{\text{night},h}$
equivalent continuous sound pressure level when the reference time interval is the night

Note 1 to entry: Subscript h indicates the number of hours, e.g. $L_{\text{night},8}$.

Note 2 to entry: A night is normally the 8 h between 23 h and 7 h or the 9 h between 22 h and 7 h. However, individual countries define night differently, e.g. 22 h to 6 h.

3.6.4
day-evening-night sound level
L_{den}
day-evening-night-weighted sound pressure level is defined by

$$L_{\text{den}} = 10\ \text{lg}\left[\frac{1}{24\,\text{h}}\left(t_{\text{day}} \cdot 10^{0{,}1 L_{\text{day},12}} + t_{\text{evening}} \cdot 10^{0{,}1(L_{\text{evening},4}+5\,\text{dB})} + t_{\text{night}} \cdot 10^{0{,}1(L_{\text{night},8}+10\,\text{dB})}\right)\right]\text{dB}$$

where t_{day}, t_{evening}, and t_{night} are expressed in hours and $t_{\text{day}} + t_{\text{evening}} + t_{\text{night}} = 24$ h.

Note 1 to entry: The default values for t_{day}, t_{evening}, and t_{night} are 12 h, 4 h, and 8 h, respectively, but individual countries, e.g. EU member states, reduce the evening period.

3.6.5
day-night sound level
L_{dn}
day-night-weighted sound pressure level is defined by

$$L_{\text{dn}} = 10\ \text{lg}\left[\frac{1}{24\,\text{h}}\left(t_{\text{day}} \cdot 10^{0{,}1 L_{\text{day},15}} + t_{\text{night}} \cdot 10^{0{,}1(L_{\text{night},9}+10\,\text{dB})}\right)\right]\text{dB}$$

where t_{day} and t_{night} are expressed in hours and $t_{\text{day}} + t_{\text{night}} = 24$ h.

Note 1 to entry: The default values for t_{day} and t_{night} are 15 h and 9 h, respectively.

3.6.6
community tolerance level
L_{ct}
day-night sound level at which 50 % of the people in a particular community are predicted to be highly annoyed by noise exposure

Note 1 to entry: L_{ct} is used as a parameter that accounts for differences between sources and/or communities when predicting the percentage highly annoyed by noise exposure.

Note 2 to entry: Annex H provides further information on L_{ct}.

4 Symbols

Symbols are given in Table 1 where the A-frequency weighting and F-time weighting are indicated for illustrative purposes only (except for L_{Cpeak} where C-weighting normally is used but some other

weighting, except A-weighting, could be used). Other frequency and time weightings as defined in IEC 61672-1 shall be substituted as appropriate and/or as required by responsible authorities.

Table 1 — Symbols for sound pressure and sound exposure levels

Quantity	Symbol
Time-weighted and frequency-weighted sound pressure level	L_{pAF}
Maximum time-weighted and frequency-weighted sound pressure level	L_{AFmax}
Percentage exceedance level	L_{AFNT}
Peak sound pressure level	L_{Cpeak}
Sound exposure level	L_{EA}
Equivalent-continuous sound pressure level	$L_{Aeq,T}$
Rating sound exposure level	L_{RE}
Rating equivalent continuous level	$L_{Req,T}$

5 Descriptors for environmental noise(s)

5.1 Single events

5.1.1 Descriptors

Sounds from single events (such as the pass-by of a truck, the fly-by of an aircraft, or an explosion at a quarry) are all examples of single-event sounds. A single-event sound can be characterized by many descriptors. These descriptors include physical quantities and the corresponding levels in decibels. Three descriptors are often used to describe the sound of single events. Frequency weighting A is used except for high-energy impulsive sounds or sounds with strong low-frequency content. The preferred three descriptors are the following:

a) the sound exposure level with specified frequency weighting;

b) the maximum sound pressure level with specified time weighting and frequency weighting;

c) the peak sound pressure level with specified frequency weighting.

It is not recommended to use A-weighted peak sound levels (see Clause 4).

5.1.2 Event duration

Event duration shall be specified relative to some characteristic of the sound, such as the number of times that some fixed level was exceeded.

EXAMPLE The duration of a sound event can be defined as the total time that the sound pressure level is within 10 dB of its maximum sound pressure level.

NOTE While the sound exposure level combines sound level and duration, the concept of event duration can be useful to differentiate events. For example, an aircraft pass-by can have a duration of 10 s to 20 s, while the duration of a gunshot is less than 1 s.

5.2 Repetitive single events

Repetitive single-event environmental sounds are typically re-occurrences of single-event sounds. For example, aircraft noise, railway noise, or road-traffic noise with a low traffic volume, can be considered as the sum of the sound from multiple individual events. Also, the sound from gunfire is the sum of the sound from multiple individual gunshot sounds. In this part of ISO 1996, the description of all repetitive single-event sound sources utilizes the sound exposure levels of the single-event sounds and the corresponding number of events to determine the rating equivalent continuous sound pressure levels.

5.3 Continuous sound

Transformers, fans, and cooling towers are examples of continuous sound sources. The sound pressure level of the sound from a continuous sound source can be constant, fluctuating, or slowly varying over a time interval. Continuous sound is preferably described by the A-weighted equivalent continuous sound pressure level over a specified time interval. For fluctuating and intermittent sounds, the A-weighted maximum sound pressure level with a specified time weighting can also be used.

NOTE Depending on the situation, road-traffic noise can be classified as a continuous source or as the sum of many repetitive single-event sounds.

6 Noise annoyance

6.1 Descriptors for community noise

This part of ISO 1996 provides guidance on the assessment of environmental noise from individual sources or any combination of sources. Responsible authorities may decide what sources, if any, are to be combined, and what adjustments, if any, are to be applied. If the sound has special characteristics, then the rating equivalent continuous sound pressure level shall be the primary measure used to describe the sound. Other measures such as the maximum sound pressure level, the (adjusted) sound exposure level, or the peak sound pressure level also may be specified.

Research has shown that the frequency weighting A, alone, is not sufficient to assess sounds characterized by tonality, impulsiveness, or strong low-frequency content. To estimate the long-term annoyance response of a community to sounds with some of these special characteristics, an adjustment, in decibels, is added to the A-weighted sound exposure level or A-weighted equivalent continuous sound pressure level. Also, research has shown that different transportation sounds or industrial sounds evoke different community annoyance responses for the same A-weighted equivalent continuous sound pressure level. The Bibliography contains a list of reports and publications describing the technical basis of the assessment and prediction methods of this part of ISO 1996.

6.2 Frequency weightings

Frequency weighting A is generally used to assess all sound sources except high-energy impulsive sounds or sounds with strong low-frequency content. Frequency weighting A shall not be used to measure peak sound pressure levels.

6.3 Adjusted levels

6.3.1 Adjusted sound exposure levels

When the sound exposure levels of single events can be measured separately or calculated, then the following method shall be used. If, in a measurement situation, sounds from single events cannot be distinguished from other sources, then the method of 6.3.2 shall be used.

For any single-event sound except high-energy impulsive sound or sounds having strong low-frequency content, the adjusted sound exposure level L_{REij} is given by the sound exposure level L_{Eij} for the ith single-event sound plus the level adjustment K_j for the jth type of sound, expressed in decibels. Guidance on adjustments for specific source categories and specific situations is given in Annexes A, B, E, and F.

In mathematical notation,

$$L_{REij} = L_{Eij} + K_j \tag{1}$$