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Acoustics — Description, assessment and measurement of environmental noise —

Part 2: Determination of environmental noise levels

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

Partie 2: Détermination des niveaux de bruit de l'environnement

[Revision of first edition (ISO 1996-2:1987), its Amendment 1:1998 and ISO 1996-3:1987]

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 1996-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This part of ISO 1996 is the second in a series of two parts replacing ISO 1996 parts 1, 2 and 3 dating from 1982 and 1997.

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*

Acoustics — Description, assessment and measurement of environmental noise —

Part 2:
Determination of environmental noise levels

1 Scope

This part of ISO 1996 describes how sound pressure levels can be determined by direct measurement, by extrapolation of measurement results by means of calculation or exclusively by calculation, intended as a basis for assessing environmental noise. Recommendations are given regarding preferable conditions for measurement or calculation to be applied in cases where other regulations do not apply.

2 Normative references

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

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

ISO 5725, *Accuracy (trueness and precision) of measurement methods and results – Part 1-6*

ISO 9613-1, *Acoustics - Attenuation of sound during propagation outdoors - Part 1: Calculation of the absorption of sound by the atmosphere.*

ISO 9613-2, *Acoustics - Attenuation of sound during propagation outdoors - Part 2: A general method of calculation.*

ISO 10843*, Acoustics - Methods for the physical measurement of single impulses or bursts of noise*

ISO/DTS 13474, *Acoustics - Impulse sound propagation for environmental noise assessment.*

IEC 60942, *Electroacoustics - Sound calibrators*.

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

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

ISO, Guide for the expression of uncertainty in measurement (GUM)

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1996-1 and the following apply.

3.1
receiver location
location at which the noise is assessed

3.2
calculation method
set of algorithms to calculate the sound immission level from measured or predicted sound emission and sound attenuation data

3.3
prediction method
sub-set of a calculation method, intended for the calculation of future noise levels

3.4
measurement time interval
time interval during which single measurements is conducted

3.5
observation time interval
time interval during which a series of measurements is conducted

3.6
meteo-window
set of weather conditions during which measurements can be performed with limited and known variation in measurement results due to weather variation

3.7
sound path radius of curvature
R, in m, radius approximating the curvature of the sound paths, due to atmospheric refraction.

3.8
normalised sound path curvature

k, in $\frac{1}{\text{km}}$, the inverse of the sound path radius of curvature multiplied by 1 000, with R expressed in m

4 Measurement uncertainty

The uncertainty of sound pressure levels determined as described in this International Standard depends on the sound source and the measurement time interval, the weather conditions, the distance from the source and the measurement instrumentation and its method of operation at the chosen measurement site. The measurement uncertainty shall be determined in compliance with the ISO Guide to Uncertainty in Measurements (GUM). Some guidelines on how to estimate the measurement uncertainty are given in Table 1 where the measurement uncertainty is expressed as an expanded uncertainty based on a combined standard uncertainty multiplied by a coverage factor of 1,65 providing a level of confidence of approximately 90 %. Table 1 refers to A-weighted equivalent-continuous sound pressure levels only. Higher uncertainties are to be expected on maximum levels, frequency band levels and tonal levels.

NOTE Competent authorities may set other levels of confidence. A coverage factor of 1,3 will, e.g., provide a level of confidence of 80 % and one of 2 a level of confidence of 95 %.

Table 1 — Overview of the measurement uncertainty

Standard deviation of reproducibility[1)] in dB	Standard deviation due to operating conditions[2)] in dB	Standard deviation due to weather and ground conditions[3)] in dB	Standard deviation due to residual sound[4)] in dB	Combined standard uncertainty σ_t in dB	Expanded measurement uncertainty in dB
1,0[5)]	*X*	*Y*	*Z*	$\sqrt{1{,}0^2 + X^2 + Y^2 + Z^2}$	± 1,65 σ_t

[1)] Different operator, different equipment, same place but everything else constant, see ISO 5725. If type 2 sound level meters or directional microphones are used the value will be larger.

[2)] To be determined from at least 3, and preferably 5 measurements under repeatability conditions (the same measurement procedure, the same instruments, the same operator, the same place) and at a position where variations in meteorological conditions have little influence on the results. For long-term measurements more measurements will be required to determine the repeatability standard deviation. For road traffic some guidance on the value of *X* is given in 6.2.

[3)] The value will vary depending upon the measurement distance and the prevailing meteorology. A method using a simplified meteorological window is provided in Annex A (in this case $Y = \sigma_m$). For long-term measurements different weather categories will have to be dealt with separately and then combined together. For short-term measurements variations in ground conditions will be small. However, for long-term measurements, these variations may add considerably to the measurement uncertainty.

[4)] The value will vary depending on the difference between measured values and the residual sound.

[5)] This value refers to L_{Aeq}-measurements.

5 Instrumentation

5.1 Instrumentation system

The instrumentation system, including the microphone, cable and recorders if any, shall meet the requirements for a type 1 instrument laid down in IEC 61672-1. A wind shield shall always be used during outdoor measurements.

For measurements in octave or one-third-octave bands the instrumentation system shall meet the requirements of IEC 61260.

NOTE If directional microphones, e.g. cardioid microphones, are used they have to be calibrated properly.

5.2 Calibration

Immediately before and after each series of measurements, apply a class 1 sound calibrator according to IEC 60942 to the microphone for checking the calibration of the entire measuring system at one or more frequencies.

NOTE If measurements take place over longer periods of time, e.g. over a daytime period or more, then the measurement system should be checked either acoustically or electrically at regular periods, e.g. once or twice a day.

Verify the compliance of the calibrator with the requirements of IEC 60942 once a year and the compliance of the instrumentation system with the requirements of IEC 61672-1 at least every two years in a laboratory with traceability to a primary or national standard laboratory.

Record the date of the last check and confirmation of the compliance with the relevant IEC standard.

6 Operation of the source

6.1 General

The source operating conditions shall be statistically representative of the noise environment under consideration. To obtain a reliable estimate of the equivalent-continuous sound pressure level as well as the maximum sound pressure level the measurement time interval shall encompass a minimum number of noise events. For the most common types of noise sources guidance is given in 6.2 to 6.5. The number of vehicle pass-bys (vehicle, train, aircraft) needed to average the variation in individual vehicle noise emission depend on the required accuracy. The level of confidence and confidence interval shall be noticed.

6.2 Road traffic

When measuring L_{eq} the number of vehicle pass-bys shall be counted during the measurement time interval. At least the two categories of vehicles ‘heavy’ and ‘light’ shall be distinguished between if the measurement result shall be converted to other traffic conditions. In order to be able to determine the representativity of the conditions the speed has to be measured and the type of road surface has to be recorded.

The number of vehicle pass-bys needed to average the variation in individual vehicle noise emission depend on the required accuracy. The standard deviation denoted X in Table 1 to be expected as a function of the number of pass-bys, n, can, if no better information is available, be calculated by means of Equation (1)

$$X \cong \frac{10}{\sqrt{n}} \text{ dB} \qquad (1)$$

When L_E from individual vehicle pass-bys are registered and used together with traffic statistics to calculate L_{eq} over the reference time interval, the minimum number of vehicles per category shall be 30 and vehicles deviating extremely from the average (e.g. due to a defect exhaust silencer) shall be disregarded.

The maximum sound pressure levels differ between vehicle categories. Within each vehicle category a certain spread of maximum sound pressure levels is encountered due to individual differences between vehicles and due to variation in speed or driving pattern. The maximum sound pressure level should be determined based on the sound pressure level measured during at least 30 pass-bys of vehicles of the category considered.

6.3 Rail traffic

L_{eq} measurements shall comprise the pass-by noise from 10 or more of each category of train potentially contributing significantly to the overall L_{eq}. For freight trains a minimum number of 15 is recommended. If only one category of trains contributes to L_{eq} at least 20 pass-bys of that category shall be recorded. If necessary measurements shall be continued another day.

To determine the maximum sound pressure level for a certain category of train category record the maximum noise level during at least 20 pass-bys.

NOTE If it is not possible to obtain so many recordings it shall be stated in the report how many train pass-bys were analysed and the influence on the uncertainty shall be assessed.

6.4 Air traffic

When measuring L_{eq}, measure pass-by noise from 5 or more of each relevant type of aircraft. Ensure that traffic pattern (runway use, take-off and landing procedures, air fleet mix, time-of-day distribution of the traffic) is relevant for the issue under consideration.

If the purpose is to measure the maximum sound pressure level from air traffic in a specific residential area, ensure that the measurement period contains the aircraft types with the highest noise emission using the flight tracks of nearest proximity. Maximum sound pressure levels shall be determined from at least 5 and preferably 20 or more occurrences of the most noisy relevant aircraft operation. To estimate percentiles of the distribution of maximum sound pressure levels record at least 20 relevant events.

NOTE If it is not possible to obtain so many recordings it shall be stated in the report how many aircraft pass-bys were analysed and the influence on the uncertainty shall be assessed.

6.5 Industrial plants

The source operating conditions shall be divided into classes: For each class the time variation of the sound emission from the plant shall be reasonably stationary in a stochastical sense. If 5 minute to 10 minute L_{eq}-values measured near the plant during a certain operation condition turn out to vary considerably, a new categorisation of the operating conditions shall be made. Measure L_{eq} during each class of operating condition and calculate the resulting L_{eq} taking the frequency and duration of each class of operating condition into account.

If the purpose is to measure the maximum sound pressure level of noise from industrial plants, ensure that the measurement period contains the plant operating condition with the highest noise emission occurring at the nearest proximity to the receiver location. Maximum sound pressure levels shall be determined from at least 5 events of the most noisy relevant operation condition.

NOTE The operation condition is defined by the activity as well as its location.

7 Weather conditions

7.1 General

The weather conditions shall be representative of the noise exposure under consideration.

The road or rail surface shall be dry, the ground surface shall not be covered with snow or ice, and it should neither be frozen nor soaked by excessive amounts of water, unless such conditions are to be investigated.

Sound pressure levels vary with the weather conditions. For soft ground such variation is modest when

$$\frac{h_s + h_r}{r} \geq 0{,}1 \qquad (2)$$

h_s = source height, h_r = receiver height and r = distance between the source and receiver.

NOTE If a barrier is present Equation (2) should be applied on both the source and the receiving side by inserting the barrier height as receiver and source respectively.

If the ground is hard larger distances are acceptable.

When condition (2) is not fulfilled the meteorological conditions shall be described or, if necessary, monitored, and the requirements below shall be fulfilled. Upwind of the source, measurements have large uncertainties and such conditions are not usually suitable for short time environmental noise measurements.

7.2 Weather characterisation

For nearly horizontal propagation the radius *R* approximating the curvature of the sound paths caused by atmospheric refraction can be determined by Equation (3).

$$R = \frac{c}{\frac{const}{\sqrt{T}}\frac{\partial T}{\partial z} + \frac{\partial u}{\partial z}} \qquad (3)$$

where

c = speed of sound in air = 20,05 $\sqrt{T}$, in m/s

u = wind speed component in the direction of propagation, in m/s

const = $10 \quad , in \left[\frac{m}{s\sqrt{K}}\right]$

T = absolute temperature of the air, in K

z = height above the ground, in m

The curvature *k* of the sound paths can be determined by Equation (4)

$$k = \frac{1}{R} \cdot 10^3, \text{ in } \frac{1}{\text{km}} \qquad (4)$$

Based on the differences in temperature and in wind speed at 10 m and 0,5 m above the ground, respectively, *k* can be approximated by Equation (5)

$$k = \frac{0{,}6\,\Delta T + \Delta u \cos(\Theta)}{3{,}2}, \text{ in } \frac{1}{\text{km}} \qquad (5)$$

ΔT is the difference between the air temperatures, in degrees K, Δu is the difference, in m/s, between the wind speeds , at 10 m and 0,5 m above the ground, respectively, and θ is the wind direction relatively to the direction from source to receiver.

NOTE Positive values of *k* correspond to downward sound ray curvature (for example downwind or temperature inversion); *k* = 0 corresponds to straight-line sound propagation (‘no-wind’, homogeneous); negative values of *k* correspond to upward sound propagation (for example upwind or on a calm summer day). Temperature inversions occur e.g. at night time when the cloud cover is less than 70%.

7.3 Favourable downwind conditions

To facilitate the comparison of results, it is convenient to carry out measurements under selected meteorological conditions, so that the results are reproducible. This is the case under rather stable sound propagation conditions.

Such conditions exist when the normalized sound path curvature *k* is positive (for example during downwind), meaning high sound pressure levels and moderate level variation. *k* depends on the wind speed and temperature gradient near the ground, as expressed in Equation (5).

With one dominant source, it is convenient to choose meteorological conditions with downward sound ray curvature from the source to the receiver, and to adopt measurement time intervals corresponding to the conditions given in Annex A, for example *k* > 0,1.

As a guidance, $k > 0{,}1$ when

— the wind is blowing from the dominant sound source to the receiver (daytime within an angle of ± 60°, night-time within an angle of ± 90°), and

— the wind speed, measured at a height of 3 m to 11 m above the ground, is between 2 m/s and 5 m/s at daytime or more than 0,5 m/s at night-time, and

— no strong negative temperature gradient occurs near the ground (at daytime e.g. when there is no bright sunshine).

7.4 Average weather conditions

To make measurements averaging over statistically representative weather conditions requires very long measurement time intervals, often several months. Alternatively, well monitored short time measurements representing different weather conditions can be combined with calculations taking weather statistics into account to determine long time averages.

The combination of source operating conditions and weather dependant sound propagation shall be taken into account, so that every important component of sound exposure is represented in the measurement results.

To determine the yearly average a whole standard year source emission and sound propagation variation has to be taken into account.

8 Test procedure

8.1 Principle

For the selection of appropriate observation and measurement time intervals, it may be necessary to investigate relatively long time periods during which survey measurements are taken.

8.2 Selection of measurement time interval

Select the measurement time interval to cover all significant variations in noise emission and propagation. If the noise displays periodicity, the measurement time interval should cover an integer number of at least three periods. If continuous measurements over such a period cannot be made, measurement time intervals shall be chosen so that each represents a part of the cycle and so that, together, they represent the complete cycle. Representative measurement results can be extended in time to cover the period for which they are representative and combined to provide new results.

If the noise is from single events (e.g. aircraft fly-over in which the noise varies during the fly-over and is absent during a considerable portion of the reference time interval), measurement time intervals shall be chosen so that the sound exposure level, L_{ET}, of the single event can be determined.

8.3 Microphone location

8.3.1 Outdoors

Select one of the following kinds of position:

a) To assess the situation at a specific location use a microphone at that specific location.

For other purposes use one of the following positions:

b) incident sound field (reference condition)