INTERNATIONAL STANDARD

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Acoustics — Description, measurement and assessment 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

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

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.

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

This second edition of ISO 1996-2, together with ISO 1996-1:2003, cancels and replaces the first edition (ISO 1996-2:1987), ISO 1996-1:1982 and ISO 1996-3:1987. It also incorporates the Amendment ISO 1996-2:1987/Amd.1:1998.

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 environmental noise levels*

Acoustics — Description, measurement and assessment 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. This part of ISO 1996 can be used to measure with any frequency weighting or in any frequency band. Guidance is given to evaluate the uncertainty of the result of a noise assessment.

NOTE 1 As this part of ISO 1996 deals with measurements under actual operating conditions, there is no relationship between this part of ISO 1996 and other ISO standards specifying emission measurements under specified operating conditions.

NOTE 2 For the sake of generality, the frequency and time weighting subscripts have been omitted throughout this part of ISO 1996.

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 1996-1:2003, *Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment procedures*

ISO 7196, *Acoustics — Frequency-weighting characteristic for infrasound measurements*

IEC 60942:2003, *Electroacoustics — Sound calibrators*

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

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

Guide to the expression of uncertainty in measurement (*GUM*), BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML, *1993 (corrected and reprinted, 1995)*

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 pressure level at arbitrary locations from measured or predicted sound emission and sound attenuation data

3.3
prediction method
subset of a calculation method, intended for the calculation of future noise levels

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

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

3.6
meteorological 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
soundpath radius of curvature
R
radius approximating the curvature of the sound paths due to atmospheric refraction

NOTE *R* is expressed in kilometres.

3.8
low-frequency sound
sound containing frequencies of interest within the range covering the one-third octave bands from 16 Hz to 200 Hz

4 Measurement uncertainty

The uncertainty of sound pressure levels determined as described in this part of ISO 1996 depends on the sound source and the measurement time interval, the weather conditions, the distance from the source and the measurement method and instrumentation. The measurement uncertainty shall be determined in accordance with the *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 2, providing a coverage probability of approximately 95 %. Table 1 refers to A-weighted equivalent continuous sound pressure levels only. Higher uncertainties can be expected on maximum levels, frequency band levels and levels of tonal components in noise.

NOTE 1 Table 1 is not complete. When preparing this part of ISO 1996, insufficient information was available. In many cases, it is appropriate to add more uncertainty contributions, e.g. the one associated with the selection of microphone location.

NOTE 2 Cognizant authorities can set other levels of confidence. A coverage factor of 1,3, for example, provides a level of confidence of 80 % and a coverage factor of 1,65, a level of confidence of 90 %.

In test reports, the coverage probability shall always be stated together with the expanded uncertainty.

Table 1 — Overview of the measurement uncertainty for L_{Aeq}

Standard uncertainty				Combined standard uncertainty	Expanded measurement uncertainty
Due to instrumentation [a]	**Due to operating conditions** [b]	**Due to weather and ground conditions** [c]	**Due to residual sound** [d]		
1,0	X	Y	Z	σ_t	$\pm 2{,}0\ \sigma_t$
				$\sqrt{1{,}0^2 + X^2 + Y^2 + Z^2}$	
dB	dB	dB	dB	dB	dB

[a] For IEC 61672-1:2002 class 1 instrumentation. If other instrumentation (IEC 61672-1:2002 class 2 or IEC 60651:2001/ IEC 60804:2000 type 1 sound level meters) or directional microphones are used, the value will be larger.

[b] To be determined from at least three, and preferably five, 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 are required to determine the repeatability standard deviation. For road-traffic noise, some guidance on the value of X is given in 6.2.

[c] The value varies depending upon the measurement distance and the prevailing meteorological conditions. A method using a simplified meteorological window is provided in Annex A (in this case $Y = \sigma_m$). For long-term measurements, it is necessary to deal with different weather categories separately and then combined together. For short-term measurement, variations in ground conditions are small. However, for long-term measurements, these variations can add considerably to the measurement uncertainty.

[d] The value varies depending on the difference between measured total values and the residual sound.

5 Instrumentation

5.1 Instrumentation system

The instrumentation system, including the microphone, wind shield, cable and recorders, if any, shall conform to the requirements of one of the following:

— a class 1 instrument as specified in IEC 61672-1:2002,

— a class 2 instrument as specified in IEC 61672-1:2002.

A wind shield shall always be used during outdoor measurements.

Cognizant authorities may require instruments conforming with IEC 61672-1:2002 class 1.

NOTE 1 IEC 61672-1:2002 class 1 instruments are specified over the range of air temperatures from − 10 °C to + 50 °C and IEC 61672-1:2002 class 2 instruments from 0 °C to + 40 °C.

NOTE 2 Most sound level meters that meet the requirements in IEC 60651 and IEC 60804 also meet the acoustic requirements of IEC 61672-1.

For measurements in octave or one-third-octave bands, the class 1 and class 2 instrumentation systems shall meet the requirements of a class 1 or class 2 filter, respectively, specified in IEC 61260:1995.

5.2 Calibration

Immediately before and after each series of measurements, a class 1, or, in the case of class 2 instruments, a class 1 or a class 2 sound calibrator in accordance with IEC 60942:2003 shall be applied to the microphone to check the calibration of the entire measuring system at one or more frequencies.

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

It is recommended to verify the compliance of the calibrator with the requirements of IEC 60942 at least once a year and the compliance of the instrumentation system with the requirements of the relevant IEC standards at least every two years in a laboratory with traceability to national standards.

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.

NOTE The operating conditions of this part of ISO 1996 are always the actual ones. Accordingly, they normally differ from the operating conditions stated in International Standards for noise emission measurements.

The equivalent continuous sound pressure level, $L_{\text{eq}T,}$ of noise from rail and air traffic can often be determined most efficiently by measuring a number of single event sound exposure levels, L_E, and calculating the equivalent continuous sound pressure level based on these. Direct measurement of the equivalent continuous sound pressure level, $L_{\text{eq}T}$, is possible when the noise is stationary or time varying, such as is the case with noise from road traffic and industrial plants. Single-event sound exposure levels, L_E, from road vehicles can be measured only at roads with a small traffic volume.

6.2 Road traffic

6.2.1 L_{eq} measurement

When measuring L_{eq}, the number of vehicle pass-bys shall be counted during the measurement time interval. If the measurement result is converted to other traffic conditions, distinction shall be made between at least the two categories of vehicles “heavy” and “light”. To determine if the traffic conditions are representative, the average traffic speed shall be measured and the type of road surface noted.

NOTE A common definition of a heavy vehicle is one exceeding the mass 3 500 kg. Often heavy vehicles are divided into several sub-categories depending on the number of wheel axles.

The number of vehicle pass-bys needed to average the variation in individual vehicle noise emission depends on the required accuracy of the measured L_{eq}. If no better information is available, the standard uncertainty denoted by X in Table 1 can be calculated by means of Equation (1):

$$X \cong \frac{10}{\sqrt{n}} \text{ dB} \tag{1}$$

where n is the total number of vehicle pass-bys.

NOTE Equation (1) refers to mixed road traffic. If only one category of vehicles is involved, the standard uncertainty will be smaller.

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.

6.2.2 L_{max} measurement

The maximum sound pressure levels as defined in ISO 1996-1 differ among vehicle categories. Within each vehicle category, a certain spread of maximum sound pressure levels is encountered due to individual differences among vehicles and variation in speed or driving patterns. 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

6.3.1 L_{eq} measurement

Measurements shall consist of the pass-by noise from at least 20 trains. Each category of train potentially contributing significantly to the overall L_{eq} shall be represented by at least five pass-bys. If necessary, measurements shall be continued on a subsequent day.

6.3.2 L_{max} measurement

To determine the maximum sound pressure level for a certain category of train, the maximum sound pressure level during at least 20 pass-bys shall be recorded. If it is not possible to obtain this 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

6.4.1 L_{eq} measurement

Measurements shall consist of the pass-by noise from five or more of each type of aircraft contributing significantly to the sound pressure level to be determined. Ensure that traffic pattern (runway use, take-off and landing procedures, airfleet mix, time-of-day distribution of the traffic) is relevant for the issue under consideration.

6.4.2 L_{max} measurement

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 five 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. If it is not possible to obtain this many recordings, it shall be stated in the report how many aircraft pass-bys are analysed and the influence on the uncertainty shall be assessed.

NOTE Pass-by noise can be caused by aircraft in flight or on the ground, e.g. taxiing.

6.5 Industrial plants

6.5.1 L_{eq} measurement

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. The variation shall be less than the variation in transmission-path attenuation due to varying weather conditions (see Clause 7). The time variation of the sound emission from the plant shall be determined from 5 min to 10 min L_{eq} values measured at a distance long enough to include noise contributions from all major sources and short enough to minimize meteorological effects (see Clause 7) during a certain operating condition. If the source is cyclic, the measurement time shall encompass a whole number of cycles. A new categorization of the operating conditions shall be made if the criterion is exceeded. If the criterion is met, measure L_{eq} during each class of operating condition and calculate the resulting L_{eq}, taking into account the frequency and duration of each class of operating condition.

6.5.2 L_{max} measurement

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 five events of the most noisy relevant operation condition.

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

6.6 Low-frequency sound sources

Examples of low-frequency sound sources are helicopters, sound from bridge vibrations, subway trains, stamping plants, pneumatic construction equipment, etc. ISO 1996-1:2003, Annex C, contains a further discussion on low-frequency sound. Procedures to measure low-frequency noise are given in 8.3.2 and 8.4.9.

7 Weather conditions

7.1 General

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

The road or rail surface shall be dry and the ground surface shall not be covered with snow or ice and should be neither 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 Equation (2) applies:

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

where

h_s is the source height;

h_r is the receiver height;

r is the distance between the source and receiver.

If the ground is hard, larger distances are acceptable.

The meteorological conditions during measurement shall be described or, if necessary, monitored. When the condition in Equation (2) is not fulfilled, the weather conditions can seriously affect the results of the measurement. General guidance is given in 7.2 and 7.3, while more precise guidance is given in Annex A. Upwind of the source, measurements have large uncertainties and such conditions are not usually suitable for short-term environmental-noise measurements.

7.2 Conditions favourable to sound propagation

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 sound paths are refracted downwards, for example during downwind, meaning high sound pressure levels and moderate level variation. The sound path radius of curvature, R, is positive and its value depends on the wind speed and temperature gradients near the ground, as expressed in Equation (A.1).

With one dominant source, choose meteorological conditions with downward sound-ray curvature from the source to the receiver and adopt measurement time intervals corresponding to the conditions given in Annex A, for example R < 10 km.

As a guidance, the condition R < 10 km holds 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°),

— 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 during the daytime or more than 0,5 m/s at night-time,

— no strong, negative temperature gradient occurs near the ground, e.g. when there is no bright sunshine during the daytime.

7.3 Average sound pressure levels under a range of weather conditions

Estimating average environmental noise levels as they occur over a range of weather conditions requires long measurement time intervals, often several months. Alternatively, well monitored, short-term measurements representing different weather conditions can be combined with calculations taking weather statistics into account to determine long-term averages.

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

To determine a long-term average noise level as it can occur during a year, it is necessary to take into account the variations in source emission and sound propagation during a whole year.

8 Measurement procedure

8.1 Principle

For the selection of appropriate observation and measurement time intervals, it can be necessary to take survey measurements over relatively long time periods.

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.

When measuring the noise from single events (e.g. aircraft fly-over, during which the noise varies during the fly-over but is absent during a considerable portion of the reference time interval), measurement time intervals shall be chosen so that the sound exposure level, L_E, of the single event can be determined (see 8.4.3).

8.3 Microphone location

8.3.1 Outdoors

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

For other purposes, use one of the following positions:

a) free-field position (reference condition);

This case is either an actual case or a theoretical case for which the hypothetical free field over ground sound pressure level of the incident sound field outside a building is calculated from results of measurements made close to the building [see 8.3.1 b) and 8.3.1 c)]. The incident field notation refers to the fact that all reflections, if any, from any building behind the microphone are eliminated. A position behind a house that acts as a barrier is also considered to be an incident field position but in this case positions 8.3.1 b) and 8.3.1 c) are not relevant and reflections from the back side of the building are included.