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Acoustics - Description, measurement and assessment of environmental noise -- Part 2: Determination of sound pressure levels

Acoustique - Description, évaluation et mesurage du bruit de l'environnement -- Partie 2: Détermination des niveaux de pression acoustique

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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

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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).

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).

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

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 1996-2:2007), of which it constitutes a technical revision.

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*

Introduction

Measurements of environmental noise are complicated because there is a very great number of variables to consider when planning and performing the measurements. As each measurement occasion is subject to current source and meteorological conditions which cannot be controlled by the operator it is often not possible to control the resulting uncertainty of the measurements. Instead the uncertainty has to be determined after the measurements based on an analysis of the acoustic measurements and collected data on source operating conditions and on meteorological parameters important for the sound propagation.

Because this standard has the ambition both to comply with new and stricter requirements on measurement uncertainty calculations and to cover all kinds of sources and meteorological conditions it has become rather complicated to use. The best use of the standard is to use it as a basis for developing more dedicated standards serving specific sources and aims.

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 intended as a basis for assessing environmental noise can be determined by direct measurement and by extrapolation of measurement results by means of calculation. This International Standard is primarily intended to be used outdoors but some guidance is given for indoor measurements as well. It is flexible and to a large extent the user determines the measurement effort and, accordingly, the measurement uncertainty, which has to be determined and reported in each case. Thus no limits for allowable maximum uncertainty are set up. Often the measurement results have to be combined with calculations to correct for reference operating or propagation conditions different from those during the actual measurement. This International Standard can be applied on all kinds of environmental noise sources, such as road and rail traffic noise, aircraft noise and industrial noise.

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.

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

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

ISO 20906, *Acoustics — Unattended monitoring of aircraft sound in the vicinity of airports*

ISO 20906:2009/Amd 1, *Acoustics — Unattended monitoring of aircraft sound in the vicinity of airports — Amendment 1*

ISO/PAS 20065[1)], *Acoustics — Objective method for assessing the audibility of tones in noise — Engineering method*

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/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

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

1) To be published

3.1
measurement time interval
time interval during which measurements are conducted

Note 1 to entry: For measurements of sound exposure level or equivalent-continuous sound pressure level, the measurement time interval is the time-period of integration.

Note 2 to entry: For measurements of maximum sound pressure level or percent exceedance level, etc., the measurement time interval is the time-period of observation.

3.2
observation time interval
time interval during which a series of measurements is conducted

3.3
prediction time interval
time interval over which levels are predicted

Note 1 to entry: It is now perhaps more common to predict sound levels using computers than to measure them for some sources such as transportation noise sources. The prediction time interval corresponds to the measurement time interval except, for the former, the levels are predicted, and for the latter, the levels are measured.

3.4
long-term measurements
measurements sufficiently long to encompass all emission situations and meteorological conditions which are needed to obtain a representative average

3.5
short-term measurements
measurements during measurement time intervals with well-defined emission and meteorological conditions

3.6
receiver location
location at which the noise is assessed

3.7
calculation method
set of algorithms to calculate the sound pressure level at a specified receiver location from measured or predicted sound power levels and sound attenuation data

3.8
prediction method
sub-set of a calculation method, intended for the calculation of future noise levels

3.9
meteorological window
set of weather conditions during which measurements can be performed with limited and known variation in measurement results due to weather variation

3.10
emission window
set of emission conditions during which measurements can be performed with limited and known variation in measurement results due to variations in operating conditions

3.11
sound path radius of curvature
R_{cur}
radius approximating the curvature of the sound paths, due to atmospheric refraction

Note 1 to entry: R_{cur} is given in m.

Note 2 to entry: Often the parameter used is $1/R_{cur}$ to avoid infinitely large values during straight ray propagation.

3.12
monitor
instrumentation used for a single automated continuous sound monitoring terminal which monitors the A-weighted levels, its spectra and all relevant meteorological quantities such as wind speed, wind direction, rain, humidity, atmospheric stability etc.

Note 1 to entry: Meteorological measurements need not be taken at each monitor provided such measurements are taken within an appropriate distance from the monitors and such distance is given in the report.

3.13
automated sound monitoring system
entire automated continuous sound monitoring system including all monitors, the base or central data collection position (host station) and all software and hardware involved in its operation

3.14
reference condition
condition to which the measurement results are to be referred (corrected)

Note 1 to entry: Examples of reference conditions are atmospheric sound absorption at yearly average temperature and humidity and yearly average traffic flows for day, evening and night respectively.

3.15
independent measurements
consecutive measurements carried out with a time space long enough to make both source operating conditions and sound propagation conditions statistically independent of the same conditions of other measurements in the series

Note 1 to entry: In order to achieve independent conditions for meteorological conditions a time space of several days is normally required.

3.16
low frequency sound
sound containing frequency components of interest within the range covering the one-third octave bands 16 Hz to 200 Hz.

Note 1 to entry: This definition is specific for this standard. Other definitions may apply in different national regulations.

4 Measurement uncertainty

The uncertainty of sound pressure levels determined as described in this document 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 compliance with the ISO/IEC Guide 98-3 (GUM). Choose one of the following approaches that all are GUM-compatible:

i) The modelling approach that consists in identifying and quantifying all major sources of uncertainty (the so-called uncertainty budget). This is the preferred method.

ii) The inter-laboratory approach that consists in carrying out a round robin test in order to determine the standard-deviation of reproducibility of the measurement method.

iii) The hybrid approach that consists in using jointly the modelling approach and the inter-laboratory approach. In this case, the inter-laboratory approach is used for components of the uncertainty budget which contribution cannot be quantified using the mathematical model of the modelling approach because of lack of technical knowledge.

According to the modelling approach each significant source of uncertainty has to be identified. Systematic effects shall be eliminated or reduced by the application of corrections wherever possible. If the quantity to be measured is *L*, which is a function of the quantities x_j the formula becomes

$$L = f(x_1, x_2, x_3, \ldots\ldots, x_j) \tag{1}$$

If each quantity has the standard uncertainty u_j the combined standard uncertainty is given by

$$u(L) = \sqrt{\sum_1^n (c_j u_j)^2} \tag{2}$$

assuming that the input quantities x_j are independent. Under the same assumptions the sensitivity coefficient c_j is given by

$$c_j = \frac{\partial f}{\partial x_j} \tag{3}$$

The measurement uncertainty to be reported is the uncertainty associated with a chosen coverage probability. By convention, a coverage probability of 95 % is usually chosen, with an associated coverage factor of 2. This means that the result becomes $L \pm 2\,u$.

NOTE Cognizant authorities may set other coverage probabilities. A coverage factor of 1,3 will, e.g., provide a coverage probability of 80 %.

For environmental noise measurements $f(x_j)$ is extremely complicated and it is hardly feasible to put up exact equations for the function f. Following the principles given in ISO 3745 [1], some important sources of uncertainty can be identified; for an individual measurement, Formula (4) applies:

$$L = L' + 10\lg\left(1 - 10^{-0,1(L' - L_{\mathrm{res}})}\right)\mathrm{dB} + \delta_{\mathrm{sou}} + \delta_{\mathrm{met}} + \delta_{\mathrm{loc}} \tag{4}$$

where

- L is the estimated value during the specified conditions for which a measured value is wanted,
- L' is the measured value including residual sound, L_{res},
- δ_{sou} is an input quantity to allow for any uncertainty due to deviations from the expected operating conditions of the source,
- δ_{met} is an input quantity to allow for any uncertainty due to meteorological conditions deviating from the assumed meteorological conditions,
- δ_{loc} is an input quantity to allow for any uncertainty due to the selection of receiver location.

Often $\delta_{\mathrm{sou}} + \delta_{\mathrm{met}}$ is determined directly from measurements, see 10.5.

L' and L_{res} are both dependent on δ_{slm} which is an input quantity to allow for any uncertainty of the measurement chain (sound level meter in the simplest case). In addition L_{res} depends on δ_{res} wich is an input quantity to allow for any uncertainty due to residual sound. Table 1 explains further the relationship between the quantities in Formula (4) and their estimate and uncertainty.

Formula (4) is very simplified and each source of uncertainty is a function of several other sources of uncertainty. In principle Formula (4) could be applied on any measurement lasting from seconds to years. In 6.1 and 6.2 the measurements are divided into long- and short-term measurements respectively. A short-term measurement may typically range between 10 minutes and a few hours whereas a typical long-term measurement may range between a month and a year.

In Table 1 guidance is given how to determine c_j and u_j for insertion into Formula (2).

Table 1 — Example of an uncertainty budget for a measured value

Quantity	Estimate	Standard uncertainty, u_j dB	Magnitude of sensitivity coefficient, c_j dB	Clause for guidance
$L'+\delta_{\mathrm{slm}}$	L'	$u(L')$ 0,5[1)]	$\dfrac{1}{1-10^{-0,1(L'-L_{\mathrm{res}})}}$	Annex F
δ_{sou}	0	u_{sou}	1	7.2 – 7.5 Annex D
δ_{met}	0	u_{met}	1	8, Annex A
δ_{loc}	0,0 - 6,0	u_{loc}	1	Annex B
$L_{\mathrm{res}}+\delta_{\mathrm{res}}$	L_{res}	u_{res}	$\dfrac{10^{-0,1(L'-L_{\mathrm{res}})}}{1-10^{-0,1(L'-L_{\mathrm{res}})}}$	Annex F

[1)] 0,5 refers to a class 1 sound level meter. A class 2 sound level meter would have the standard uncertainty 1,5 dB.

The numbers given in Table 1 refer to A-weighted equivalent-continuous sound pressure levels only. Higher uncertainties are to be expected on maximum levels, frequency band levels and levels of tonal components in noise. In many cases the measured values have to be corrected to other source operating conditions not representing the measured cases but the yearly average. Similarly other measurements may have to be corrected to other meteorological conditions in order to make L_{den}-calculations possible. Uncertainty calculations for such cases are given in Annex F.

NOTE Some examples, including a spread sheet, of complete uncertainty calculations are given in Annex G.

5 Instrumentation

5.1 Instruments for acoustical measurements

5.1.1 General

The instruments for measuring sound pressure levels, including microphone(s) as well as cable(s), windscreen(s), recording devices and other accessories, if used, shall meet the requirements for a class 1 instrument according to IEC 61672-1 for free field or random incidence application, as appropriate. Filters shall meet the requirements for a class 1 instrument according to IEC 61260. A windscreen shall always be used during outdoor measurements.

NOTE Class 1 tolerance limits of IEC 61672-1 apply over a temperature range of -10°C to +50°C. If the instrument is to be used in temperatures outside the range -10°C to +50°C, then there may be an increase in measurement uncertainty.

5.1.2 Calibration

At the beginning and at the end of every measurement the entire sound pressure level measuring system shall be checked at one or more frequencies by means of a sound calibrator meeting the requirements for a class 1 instrument according to IEC 60942. Without any further adjustment, the difference between the readings of two consecutive checks shall be less than or equal to 0,5 dB. If this value is exceeded, the results of measurements obtained after the previous satisfactory check shall be discarded. For long-term monitoring of several days or more, the requirements of ISO 20906:2009/Amd 1 apply.

5.1.3 Verification

Compliance of the sound pressure level measuring instrument, the filters and the sound calibrator shall be verified by the existence of a valid certificate of compliance with the measurement parameters specified in the relevant test methods in IEC 61672-3 [5], IEC 61260 and IEC 60942.

All compliance testing shall be conducted by a laboratory being accredited or otherwise nationally authorized to perform the relevant tests and calibrations and ensuring metrological traceability to the appropriate measurement standards. The recommended time interval for testing of system performance is once a year. The maximum allowable interval is two years.

5.1.4 Long-term monitoring

The maximum permissible error for instruments used for meteorological measurements shall be

— ± 0,5 K for temperature measuring devices,

— ± 5,0 % for relative humidity measuring devices,

— ± 0,5 hPa for barometric pressure measuring devices,

— ± 0,5 m/s for wind speed measuring devices,

— ± 5º for wind direction measuring devices.

Meteorological classes shall be given according to Clause 8.

NOTE Some modern sonic anemometers are suitable for direct measurement of parameters to be used to determine meteorological classes

6 Principles

6.1 General

There are two main strategies for environmental noise measurements:

1) Make a single measurement under very well-defined meteorological conditions while monitoring the source operating conditions carefully;

2) Make a long term measurement, or many sampled measurements, spread out over time while monitoring the meteorological conditions.

Both types of measurements require post processing of measured data.

Each result and each type of measurement will have a certain uncertainty, which has to be determined. It is up to the user of the results to determine which accuracy to aim for. No upper limits of the measurement uncertainty are given.

The long term L_{eq}, L_{long}, is given by

$$L_{long} = 10\lg\left(\sum_{k=1}^{n_k} p_k 10^{0,1L_k}\right)\mathrm{dB} \tag{5}$$

where

p_k is the frequency of occurrence of the emission and meteorological conditions of window k yielding the L_{eq}-level L_k,

n_k is the number of windows used.

Normally L_k is determined by several measurements:

$$L_k = 10\lg\left(\frac{1}{n_i}\sum_{i=1}^{n_i} 10^{0,1L_i}\right)\mathrm{dB} \tag{6}$$

where

L_i is an independent measurement within window k,

n_i is the number of measurements within this window.

In order to be able to calculate L_{den}, day, evening and night periods have to be separated.

NOTE A window is a combination of emission (e.g. day, evening, night) and meteorological conditions (e.g. four different classes, as shown in the matrix below). Preferably a window should include constant emission and propagation conditions. In many cases the emission conditions are independent of the meteorological conditions and in other cases, such as for aircraft noise, there is a strong interrelationship.

Stratification of emission conditions and meteorological conditions during measurements:

Meteorological window / Emission window	1	2	3	4
1				
2				
N				

The uncertainty has to be determined for p_k and L_k. Ideally the uncertainty of L_k is determined directly from a large number of independent measurements, see 10.5. If only one or few measurements are carried out the uncertainty has to be determined using other available information. If values of L_k are missing they have to be estimated using a prediction method. This estimate shall also include an estimate of the uncertainty.

For meaningful single measurements the minimum requirement is that L_k is determined during favourable propagation conditions as defined in Annex A and that the source operating conditions are monitored during these measurements.