INTERNATIONAL STANDARD

ISO 1996-2

Second edition
2007-03-15

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
ISO 1996-2:2007(E)

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

© ISO 2007

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

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

Published in Switzerland

Licensed to HHI Co. LTD. 2013-07-18. Any form of reproduction and redistribution are strictly prohibited.

Contents

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]	σ_t	
1,0 dB	X dB	Y dB	Z dB	$\sqrt{1{,}0^2 + X^2 + Y^2 + Z^2}$ dB	$\pm 2{,}0\ \sigma_t$ 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, $L_{\mathrm{eq}T}$, 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, $L_{\mathrm{eq}T}$, 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):

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

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:

$$\frac{h_\mathrm{s} + h_\mathrm{r}}{r} \geqslant 0{,}1 \tag{2}$$

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.

b) position with the microphone flush-mounted on the reflecting surface;

In this case, the correction applied to get the incident sound field is − 6 dB. Guidance on the conditions to meet is given in Annex B. For other conditions, it is necessary to use different corrections.

NOTE 1 + 6 dB is the difference between a façade-mounted microphone and a free-field microphone in an ideal case. In practice, minor deviations from this value do occur.

c) position with the microphone 0,5 m to 2 m in front of the reflecting surface;

In this case, the correction applied to get the incident sound field is − 3 dB. Guidance on the conditions to meet is given in Annex B. For other conditions, it is necessary to use different corrections.

NOTE 2 The difference between the sound pressure level at a microphone placed 2 m in front of the façade and at a free-field microphone is close to 3 dB in an ideal case where no other vertical reflecting obstacle influences sound propagation to the studied receiver. In complex situations, e.g. high building density on the site, canyon street, etc., this difference can be much higher. Even in the ideal case, there can be some restrictions. For near-grazing incidence, this position is not recommended as the deviations can be greater. For further guidance, see Annex B.

In principle, any of the positions described in this subclause can be used, provided that the position used is reported together with a statement of whether or not any correction to the reference condition was made. In some specific cases, the positions described in this subclause are subject to further restrictions. For further guidance see Annex B.

For general mapping, use a microphone height of (4,0 ± 0,5) m in multi-storey residential areas. In one-storey residential areas and recreational areas, use a microphone height of (1,2 ± 0,1) m or (1,5 ± 0,1) m.

For permanent noise monitoring, other microphone heights may be used.

Noise levels in grid points for use in noise mapping are normally calculated. If, in special cases, measurements are carried out, the density of grid points selected in an area depends on the spatial resolution required for the study concerned and the spatial variation of sound pressure levels of the noise. This variation is strongest in the vicinity of sources and large obstacles. The density of grid points should, therefore, be higher in these places. In general, the difference in sound pressure levels between adjacent grid points should not be greater than 5 dB. If significantly higher differences are encountered, intermediate grid points shall be added.

8.3.2 Indoors

Use at least three discrete positions evenly distributed in areas of the room where affected persons preferably spend time, or, as an alternative for continuous noise, use a rotating microphone system.

If dominant low-frequency noise is suspected (see 6.6), one of the three positions shall be in a corner and no rotating microphone is allowed. The corner position shall be 0,5 m from all boundary surfaces in a corner with the heaviest walls and without any wall openings nearer than 0,5 m.

The other microphones shall be positioned at least 0,5 m from walls, ceiling or floor, and at least 1 m from significant sound-transmission elements such as windows or air-intake openings. The distance between neighbouring microphone positions shall be at least 0,7 m. If a continuously moving microphone is used, its sweep radius shall be at least 0,7 m. The plane of traverse shall be inclined in order to cover a large portion of the permitted room space and shall not lie within 10° of the plane of any room surface. The above requirements concerning the distance from discrete microphone positions to walls, ceiling, floor and transmission elements also apply to moving microphone positions. The duration of a traverse period shall be not less than 15 s.

NOTE 1 In cases where there are only A-weighted measurements and only small contributions to the A-weighted level from low frequencies, it can, in some cases, be sufficient to use one microphone position.

The procedures in this subclause are primarily intended for rooms with volumes $< 300\ \text{m}^3$. For larger rooms, more microphone positions can be appropriate. In such cases, for low-frequency noise, one third of the extra positions should be corner positions.

8.4 Measurements

8.4.1 General

NOTE Variables and rating levels such as the yearly average, L_{day}, L_{evening} and L_{den}, are defined in ISO 1996-1.

8.4.2 Equivalent continuous sound pressure level, $L_{\text{eq}T}$

Normal measurement of L_{eq}: if the traffic density is low or the residual sound pressure level high, the L_{eq} levels shall, if possible, be determined from L_E measurements of individual pass-bys. This is often the case for rail- and air-traffic noise; see 6.3.1 and 6.4.1, respectively. For short-term averaging, unless the condition in Equation (2) is fulfilled, measure for at least 10 minutes to average weather-induced variations in the propagation path. If the condition in Equation (2) is fulfilled, 5 min is usually sufficient. It can be necessary to increase these minimum times in order to get a representative sample of source operating conditions (see Clause 6).

8.4.3 Sound exposure level, L_E

If it is not practicable to measure L_{eq} for the required number of events, measure L_E for each individual event. Measure a minimum number of events of the source operation as specified in Clause 6. Measure each event during a time period that is long enough to include all important noise contributions. For a pass-by, measure until the sound pressure level has dropped at least 10 dB below the maximum level.

8.4.4 N percent exceedance level, $L_{N,T}$

During the measurement time interval, record the short-term $L_{\text{eq}T}$ (where $T \leqslant 1$ s) or record the sound pressure level with a sampling time less than the time constant of the time weighting used. The class interval into which recorded results are placed shall be 1,0 dB or less. The parameter basis and, where applicable, time weighting, of the recording period and the class interval used to determine the $L_{N,T}$ shall be reported, e.g. “based on 10 ms sampling of L_{F} with a class interval of 0,2 dB” or “based on L_{eq1s}, class width 1,0 dB”.

8.4.5 Maximum time- and frequency-weighted sound pressure level, L_{Fmax}, L_{Smax}

Using time weighting F or S, as specified, measure L_{Fmax} or L_{Smax} for a minimum number of events of the source operating conditions as specified in Clause 6. Record each result.

NOTE Time weighting F correlates better with human perception than time weighting S. Using time weighting S, in general, improves the reproducibility.

8.4.6 Peak sound pressure level, L_{peak}

See ISO 10843 for sonic booms, blasts, etc.

NOTE IEC 61672-1 specifies the accuracy only of a peak detector using C-weighting.

8.4.7 Tonal sound

If the noise characteristics at the receiver location include audible tone(s), an objective measurement of the prominence of the tones should be carried out. The microphone positions with the most audible tone(s) should be selected and the analysis should be carried out as described in Annex C for the reference method and as described in Annex D for a simplified method.

NOTE In general, tonal analysis of indoor noise is not recommended due to the modal behaviour of tones in rooms. For some frequency bands, it is also problematical at microphones in front of a façade.

8.4.8 Impulsive sound

There is no generally accepted method to detect impulsive sound using objective measurements. If impulsive sound occurs, identify the source and compare it to the list of impulsive sound sources in ISO 1996-1. In addition, make sure that the impulsive sound is representative and present in the measurement time interval.

8.4.9 Low-frequency sound

Indoors, measure at three microphone positions as specified in 8.3.2. Outdoors, measure in the free field or directly on a façade; see Annex B.

The methods in this part of ISO 1996 are generally valid down to the 16 Hz octave band. However, for these low-frequency measurements, the microphone shall be at least 16 m from the nearest significant reflecting surface other than the ground in order to be a free-field (incident-sound field) measurement.

NOTE The microphone position in front of the reflecting surface mentioned in 8.3.1 c) has not been defined for low-frequency sound measurements.

8.4.10 Residual sound

When measuring environmental noise, residual sound as defined in ISO 1996-1, as all noise other than the specific sounds under investigation, is often a problem. One reason is that regulations often require that the noise from different types of sources be dealt with separately. This separation, e.g. of traffic noise from industrial noise, is often difficult to accomplish in practice. Another reason is that the measurements are normally carried out outdoors. Wind-induced noise, directly on the microphone and indirectly on trees, buildings, etc., may also affect the result. The character of these noise sources can make it difficult or even impossible to carry out any corrections. However, see 9.6 to carry out corrections if it is necessary to measure the residual sound.

8.4.11 Frequency range of measurements

If the frequency content of the noise is required, then, unless otherwise specified, measure the sound pressure level using octave-band filters having the following mid-band frequencies:

63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 000 Hz, 2 000 Hz, 4 000 Hz, 8 000 Hz

Optionally, the measurements can be made in one-third-octave bands with mid-band frequencies from 50 Hz to 10 000 Hz.

Frequency bands without significant influence (< 0,5 dB) on the A-weighted sound pressure level may be excluded and this exclusion should be reported.

For low-frequency sound, the frequency range of interest appears to be from about 5 Hz to about 100 Hz. In the range below about 20 Hz, the G-weighting in accordance with ISO 7196 is used in some countries to assess sound. Above about 15 Hz, octave-band or one-third-octave band analysis in the range from about 16 Hz to 100 Hz is used in several countries. For low-frequency sound, this part of ISO 1996 includes the extended frequency range from about 12 Hz to 200 Hz (the 16 Hz, 31 Hz, 63 Hz, 125 Hz and 160 Hz one-third-octave bands) and evaluation shall be made in accordance with ISO 7196.

9 Evaluation of the measurement result

9.1 General

Correct all measured outdoor values to the reference condition, if applicable, that is to the free-field level excluding all reflections but those from the ground.

9.2 Time-integrated levels, L_E and $L_{\mathrm{eq}T}$

For each microphone position and each category of source operating conditions determine the energy average of the measured values of L_E or $L_{\mathrm{eq}T}$.

NOTE Guidance on how to obtain rating levels such as L_{Rdn} and L_{Rden} is given in ISO 1996-1.

9.3 Maximum level, $L_{\max}$

For each microphone position and each category of source operating conditions, determine the following values, whenever relevant:

- the maximum;
- the arithmetic average;
- the energy average;
- the standard deviation;
- the statistical distribution of the measured values of $L_{\max}$.

For homogeneous groups of single events with a Gaussian distribution of maximum sound pressure levels, use Equation (3) and Figure 1 to estimate percentiles of the distribution of maximum sound pressure levels.

$$L_{\max,p} = \bar{L}_{\max} + y \cdot s \tag{3}$$

where

$L_{\max,\mathrm{p}}$ is the maximum level exceeded by p % of the events;

$\bar{L}_{\max}$ is the arithmetic average of $L_{\max}$ from all events;

s is the standard deviation of the maximum levels from the events (an estimate of the standard deviation of the Gaussian distribution);

y is the number of standard deviations given by Figure 1.

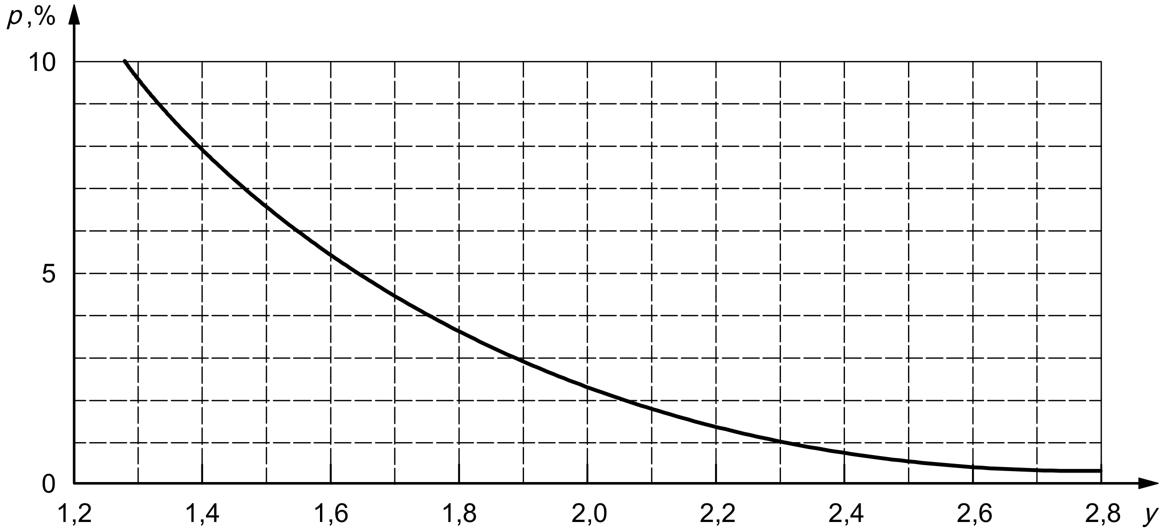


Figure 1 — Percentage, p, of single events with a maximum sound pressure level exceeding, by a certain number, y, of standard deviations, the (arithmetic) mean of a normal distribution of maximum sound pressure levels

EXAMPLE If the fifth highest maximum sound pressure level is required out of 500 vehicles passing, then the wanted percentile is (5/500) × 100 = 1 % and from Figure 1 the factor, y, to insert in Equation (3) is given by $y = 2{,}33 \cong 2{,}3$, that is:

$$L_{\text{max(5th highest)}} = \overline{L}_{\text{max(arithmatic average)}} + 2{,}3\ s$$

where s is the standard deviation of the maximum levels.

9.4 Exceedance levels, $L_{N,T}$

Analyse the sampled values statistically to obtain the statistical level, $L_{N,T}$, for N %.

9.5 Indoor measurements

Use a scanning microphone or discrete positions. If discrete microphone positions have been used, calculate the spatially averaged value of the equivalent continuous sound pressure level as given in Equation (4):

$$L_{\text{eq}} = 10 \lg \frac{1}{n} \sum_{j=1}^{n} 10^{L_{\text{eq}j}/10} \text{ dB} \tag{4}$$

where

n is the number of microphone positions, equal to or greater than 3;

$L_{\text{eq}j}$ is the equivalent continuous sound pressure level in position j, expressed in decibels.

If measurements are carried out during different measurement time intervals with different traffic conditions, each of the noise levels, $L_{\text{eq}j}$, should be converted to the same reference traffic conditions using an appropriate calculation method; see 11.2.

If the measurement room is normally furnished or has acoustical treatment on the ceiling, make no corrections of the measured values. If the room is empty and without acoustical treatment, subtract 3 dB from the measured values.

NOTE The 3 dB correction used to take into account the difference between furnished and unfurnished rooms is a simplification to avoid making measurements of the reverberation time. If regulations require otherwise, it can be necessary to measure the reverberation time and normalize the measured sound pressure levels to the reference state of the regulation.

9.6 Residual sound

If the residual sound pressure level is 10 dB or more below the measured sound pressure level, make no corrections. The measured value is then valid for the source under test.

If the residual sound pressure level is 3 dB or less below the measured sound pressure level, no corrections are allowed. The measurement uncertainty is then large. The results may, however, still be reported and may be useful for determining an upper boundary to the sound pressure level of the source under test. If such data are reported, it shall clearly be stated in the text of the report, as well as in graphs and tables of results, that the reported value cannot be corrected to remove the effect of the residual sound.

For cases when the residual sound pressure level is within a range from 3 dB to 10 dB below the measured sound pressure level, correct according to Equation (5):

$$L_{\text{corr}} = 10\lg\left(10^{L_{\text{meas}}/10} - 10^{L_{\text{resid}}/10}\right)\ \text{dB} \tag{5}$$

where

L_{corr} is the corrected sound pressure level;

L_{meas} is the measured sound pressure level;

L_{resid} is the residual sound pressure level.

10 Extrapolation to other conditions

10.1 Location

Extrapolation of measurement results is often used to estimate the sound pressure level at another location. Such extrapolation is useful, for example, when residual sound prevents direct measurement at the receiver location.

The noise measurements shall be carried out at a well defined location, neither too close (not in the near field of some part of the source) nor too far away (minor weather influence on transmission is desirable) from the source in relation to the extension of the source. By calculating the attenuation that has taken place during propagation from source to measuring position, an estimate of the source noise emission is established. This estimate is subsequently used to calculate the sound pressure level at a receiver further away from the noise source than the intermediate measurement position.

To perform the calculation of sound transmission attenuation, it is necessary to use a calculation method; see Clause 11. The intermediate measurement position shall be chosen so that reliable measurement and calculation is facilitated. For example, there should be no screening obstacles between the source and the microphone and a high microphone position is preferred as this minimizes the influence of the weather conditions during the measurement.

10.2 Other time and operating conditions

Often measurements are carried out during time periods shorter than the reference time interval and the results have to be adjusted to other time and operating conditions. Long-term averages are calculated from short-term measurements by taking into account such influences as other traffic flows, another vehicle composition, another distribution of weather conditions, etc. Sometimes different times of the day are weighted differently. It is necessary to base such adjustments on some kind of calculation method; see Clause 11.

11 Calculation

11.1 General

In many cases, measurements can be replaced or supplemented by calculations. Calculations are often more reliable than a single short-term measurement when long-term averages are to be determined and in other cases where it is impossible to carry out measurements because of excessive residual sound pressure levels. In case of the latter, it is sometimes convenient to carry out the measurements at a short distance from the source and then use a calculation method to calculate the result at a greater distance.

When calculating rather than measuring sound pressure levels, it is necessary to have data on source noise emission, preferably as a source sound power level (including source directivity), and the position of (a) point source(s) creating the same sound pressure levels in the environment as the real source. For traffic noise, sound power levels are often replaced by sound pressure levels determined under well defined conditions. Often such data are given in established calculation models but in other cases it is necessary that they be determined in each individual case.

Using a suitable model for the sound propagation from source to receiver, the sound pressure level at the assessment point can be calculated. It is necessary to relate the sound propagation to well defined meteorological and ground conditions. Most calculation models refer to neutral or favourable sound propagation conditions, as other propagation conditions are much more difficult to predict. The acoustic impedance of the ground is also important, in particular at small distances and low source and receiver heights. Most models distinguish only between hard and soft ground. It is, in general, easier to carry out accurate calculations with high source and receiver positions.

Various degrees of accuracy are required depending on the purpose of the calculation. The necessary density of grid points used as a basis for mapping the noise levels in an area depends on the purpose of the mapping. Noise-level variation is strongest in the vicinity of sources and large obstacles. The density of grid points should, therefore, be higher in such places. In general, for overall noise exposure, mapping the difference in sound pressure levels between adjacent grid points should not be larger than 5 dB. When selecting noise-mitigation measures in the form of either noise control hardware or economical compensation, grid-point density should be chosen so that variation between the adjacent points does not exceed 2 dB.

11.2 Calculation methods

11.2.1 General

There are no internationally recognized complete calculation methods, although there are some International Standards, such as ISO 9613-1, ISO 9613-2 and ISO/TS 13474, on sound propagation that can be applied for sources with known sound power output. A list of national calculation methods is given in Annex E.

11.2.2 Specific procedures

Separate calculation methods have been developed for the assessment of road-, rail- and air-traffic noise. In most countries, national methods are used. Many methods are limited to calculations of A-weighted sound pressure levels and are applicable for a specific frequency spectrum. Normally, an L_{Aeq}-based metric is calculated, and sometimes this metric is supplemented by L_{max}. There are, however, exceptions.

12 Information to be recorded and reported

For measurements, the following information shall, if relevant, be recorded and reported:

a) time, day and place for measurements;

b) instrumentation and its calibration;

c) measured and, if relevant, corrected sound pressure levels ($L_{\mathrm{eq}T}$, L_E, L_{max}), A-weighted (optionally C-weighted as well) and, optionally, in frequency bands;

d) measured N percent exceedance level ($L_{N,T}$) including the base on which it is calculated (sampling rate and other parameters);

e) estimate of the measurement uncertainty together with the coverage probability;

f) information on residual sound pressure levels during the measurements;

g) time intervals for the measurements;

h) thorough description of the measurement site, including ground cover and condition, and locations, including height above ground, of microphone and source;

i) description of the operating conditions, including number of vehicle/train/aircraft pass-bys specified for each suitable category;

j) description of the meteorological conditions, including wind speed, wind direction, cloud cover, temperature, barometric pressure, humidity and presence of precipitation and location of wind and temperature sensors;

k) method(s) used to extrapolate the measured values to other conditions.

For calculations, relevant information listed in a) to k), including calculation uncertainty, shall be given.

Annex A
(informative)

Meteorological window and measurement uncertainty due to weather

A.1 Weather and measurement uncertainty

The variability of noise levels during measurements is influenced by the weather conditions. The weather conditions are characterised in this annex by the sound path radius of curvature. The values given for the standard deviation, σ_m, due to weather-induced variation in sound propagation attenuation are valid for specific sound-propagation conditions. Such values cannot be given for long-term average noise levels consisting of contributions from sound propagating under a variety of conditions. This annex is typically valid for measurement time intervals from 10 min up to a few hours.

A.2 Weather characterization

For nearly horizontal propagation the radius, R, approximating the curvature of the sound paths caused by atmospheric refraction, can be determined by Equation (A.1). R varies with the height above the ground.

$$R = \frac{c(\tau)}{\frac{k_\mathrm{const}}{\sqrt{\tau}}\frac{\partial \tau}{\partial z} + \frac{\partial u}{\partial z}} \tag{A.1}$$

where

$c(\tau)$ is the speed of sound in air, expressed in metres per second, equal to $c_0\sqrt{\tau}$, where $c_0 = 20{,}05 \frac{m}{s\sqrt{K}}$;

u is the wind speed component in the direction of propagation, expressed in metres per second;

k_const is a constant equal to $10 \frac{m}{s\sqrt{K}}$;

τ is the absolute temperature of the air, expressed in kelvin;

z is the height above the ground, expressed in metres.

Based on the differences in temperature and in wind speed at 10 m and 0,5 m above the ground, the numerical value of R, expressed in kilometres, can be approximated by Equation (A.2).

$$R = \frac{3{,}2}{0{,}6\Delta\tau + \Delta u \cos\theta} \tag{A.2}$$

where

$\Delta\tau$ is the numerical value of the difference between the air temperatures, expressed in kelvin, at 10 m and 0,5 m above the ground;

Δu is the numerical value of the difference between the wind speeds, expressed in metres per second, at 10 m and 0,5 m above the ground;

θ is the angle between the wind direction and the direction from source to receiver.

Care should be taken when measuring small temperature differences. Frequently the difference is smaller than the uncertainty in the calibration of the thermometers.

A.3 Favourable sound propagation conditions

The sound path radius of curvature, R, depends on the average gradient of wind speed and temperature and is the most important factor determining the sound propagation conditions. Positive values of R correspond to downward sound-ray curvature (e.g. during downwind or temperature inversion). Such sound propagation conditions are often referred to as “favourable”, that is, the sound pressure levels are high.

NOTE 1 Temperature inversion can occur, e.g. at night when the cloud cover is less than 70 %.

NOTE 2 $R = \infty$ corresponds to straight-line sound propagation (“no-wind”, homogeneous atmosphere) while negative values of R correspond to upward sound-ray curvature (e.g. during upwind or on a calm summer day).

A.4 Guidance on the radius of curvature required for favourable sound propagation and associated weather-induced uncertainty

Equation (2) requires microphone heights in excess of 5 m or 10 m at a distance of about 50 m to 100 m from the source in order to measure under any weather conditions. For measurements at more typically used microphone heights, Figure A.1 specifies the radius of curvature required for the sound propagation conditions to be “favourable” and states the associated standard deviation, σ_m, of measurement results expected as a consequence of weather variation in propagation over porous terrain such as grassland. The figure is not applicable to long-term measurements.

Distinction is made in Figure A.1 between so-called “high” and “low” situations, depending on the source height, h_s, and receiver height, h_r. Situations are “high” when both the source and the microphone are 1,5 m or more above the ground. When the source is less than 1,5 m above the ground, the microphone shall be at a 4 m height or more for the situation to be “high”. When the source is less than 1,5 m above the ground and the microphone height is 1,5 m or less, the situation is “low”. In “low” situations, the requirements on weather conditions during measurement are stricter than in “high” situations.

- high situation: $h_s \geqslant 1{,}5$ m and $h_r \geqslant 1{,}5$ m, or

  $h_s < 1{,}5$ m and $h_r \geqslant 4$ m

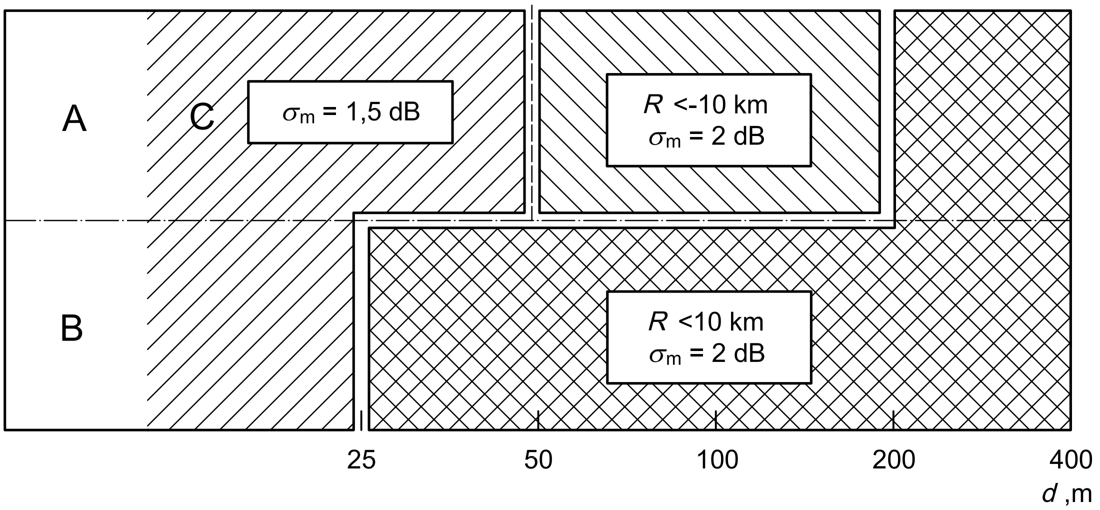
- low situation: $h_s < 1{,}5$ m and $h_r \leqslant 1{,}5$ m

When the whole terrain surface between the source and the measurement position is hard, the weather-induced standard deviation can be neglected as long as no sound shadow is formed, i.e. $\sigma_m \cong 0{,}5$ dB up to 25 m in “low” and up to 50 m in “high” situations.

NOTE 1 The guidance in A.3 is based on measurement data. Such data tend to originate from receivers located 4 m or higher when they do not originate from receivers at heights of 1,5 m or 2 m.

NOTE 2 In Figure A.1, a negative radius of curvature is accepted in “high” situations with propagation distances below 200 m.

Figure A.1 is valid for unscreened flat terrain. No quantitative information is available for screened receiver positions or terrain with complex topography. Until such information becomes available, it is recommended to use Figure A.1 for screened situations as well and to define screened positions to be “low” situations.



Key

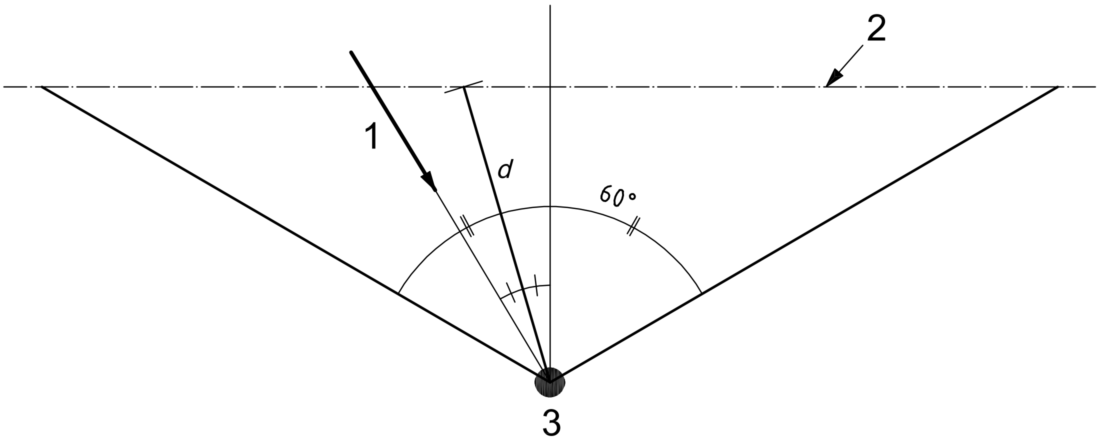
A high

B low

C no restriction

Figure A.1 — Sound path radius of curvature, R, and the associated measurement uncertainty contribution, expressed as the standard deviation, σ_m, due to weather influence, for various combinations of source/receiver heights (A to C) over porous ground
At distances, d, expressed in metres, of more than 400 m, the radius of curvature shall be smaller than 10 km and then the measurement uncertainty, σ_m, is equal to $\left(1+\frac{d}{400}\right)$ dB.

For roads or other extended sources, the curvature shall be determined in a vertical plane through the microphone position perpendicular to the road centreline (or perpendicular to a characteristic large dimension of the source, when applicable). The average wind direction shall be in the interval ± 60 degrees around the normal from the road through the microphone position. The effective source-receiver distance shall be determined along the bi-sector of the angle between the average wind speed vector and the normal from the road to the microphone position; see Figure A.2.



Key

1 mean wind direction

2 centreline

3 measurement position

Figure A.2 — Favourable propagation conditions from a road and the effective source-receiver distance, d

A.5 Guidance on when the sound path curvature satisfies the requirements in Figure A.1

Figures A.3 and A.4 show the limits of the sun's altitude, and hence the temperature gradient, for the time intervals of the day (on the ordinate) for each month of the year (on the abscissa):

- Area A corresponds to times when the sun is at an angle of 40° to 60° above the horizon;
- Area B corresponds to times when the sun is at an angle of 25° to 40° above the horizon;
- Area C
- Area D
- Area AA (Figure A.4) corresponds to times when the sun is at an angle exceeding 60° above the horizon.

Figures A.3 and A.4 are appropriate for sound propagation over urban grassland, e.g. grass, solitary trees and detached single family dwellings in an urban or rural setting.

Table A.1 indicates the smallest acceptable wind speed component (downwind component) in the direction of sound propagation that ensures that the radius of curvature of the sound path is less than – 10 km and less than 10 km for the "high" and "low" situations, respectively. The demand on the downwind component depends on the cloudiness and on the required radius of curvature, R.

Table A.1 — Characteristics influencing the radius of curvature, R

Time period of the day	Cloud cover	Smallest wind speed component at 10 m above the ground, in m/s, where	
		$R < -10$ km (high, $d > 50$ m)	$R < 10$ km (low, $d > 25$ m)
A	8/8 thick and dense	0,4	1,3
	6/8 to 8/8	1,2	2,0
	< 6/8	2,0	2,7
B	8/8 thick and dense	0,2	1,2
	6/8 to 8/8	0,9	1,7
	< 6/8	1,6	2,3
C	8/8 thick and dense	0	0,9
	6/8	0,3	1,3
	< 4/8	0,8	1,7
Night	6/8 to 8/8	0,1	> 0,5
	< 6/8	Wind speed > 2 m/s; component ⩾ 0,1	
D	Only measure near the source		
These requirements ensure that the radius of curvature, R, is less than -10 km and 10 km, for the “high” and “low” situations, respectively, for various times of day and cloud covers.			

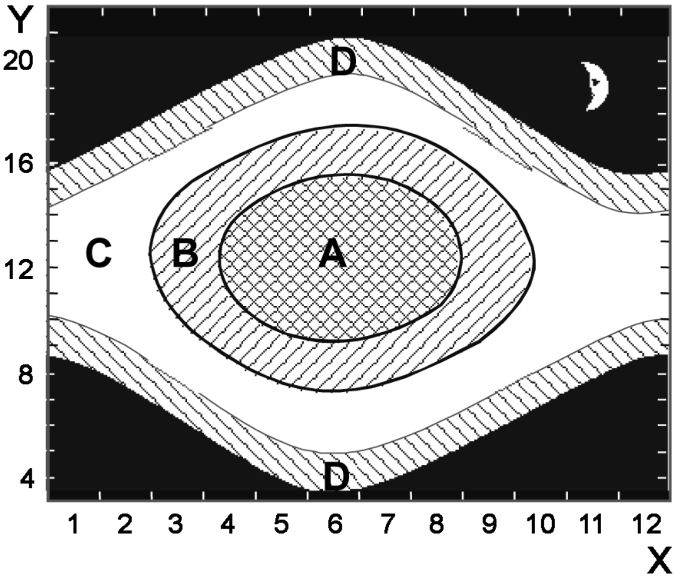
The area marked “A” corresponds to “in the middle of the day in summer”. With thick and dense clouds a downwind component of 1,3 m/s is required for the criterion, $R < 10$ km, to be fulfilled. For light cloud cover or bright weather, a downwind component of 2,7 m/s or more is necessary to ensure $R < 10$ km, which is the requirement in “low” conditions at source-receiver distances exceeding 25 m.

The area marked “B” represents morning and afternoon in summer and the time around noon in spring and autumn. For example, the criterion, $R < 10$ km, can be met by a downwind component of 2,3 m/s when the cloud cover is less than 6/8.

The area marked “C” comprises hours in a day outside the time designated either A or B. The criterion, $R < 10$ km, can for example be met in light cloud cover of 4/8 with a downwind of component wind speed of 1,7 m/s.

The hours marked ”D” indicate the time from sunrise to 1,5 h after sunrise and from 1,5 h before sunset until sunset. During these hours, large local variations in temperature can occur, and it is recommended that no weather-sensitive measurements be carried out during these time periods unless such conditions are decisive in special cases.

During the night (shown with black in Figures A.3 and A.4), only a small downwind component is required when the cloud cover is more than 6/8. If the cloudiness is less than 6/8 during the night, large local temperature gradients can occur and a wind speed of 2 m/s or more is required to avoid special sound-propagation effects, such as sound focusing under inversion conditions.



Key

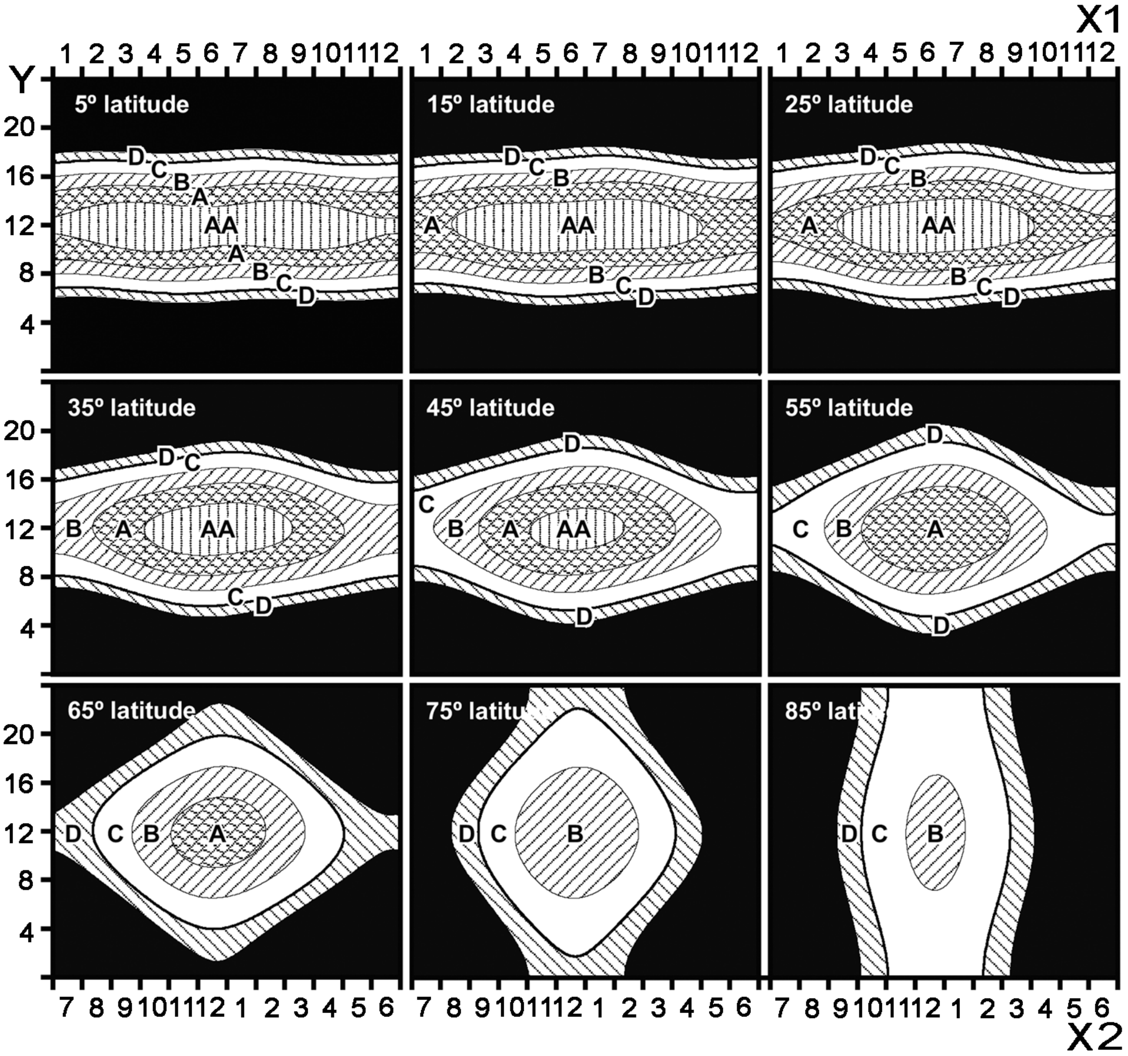
X months of the year (beginning with 1 for January)

Y time of the day in hours

NOTE 1 The data used to create Figure A.3 and Table A.1 were collected at approximately 56° north latitude.

NOTE 2 See Figure A.4 for data at other latitudes.

Figure A.3 — Time intervals when the sun's altitude, and hence the temperature gradient, is within certain limits at 56° north latitude



Key

X1	months of the year (beginning with 1 for January), north of Equator
X2	months of the year (beginning with 7 for July), south of Equator
Y	time of the day in hours

NOTE The data used to create Figure A.4 were collected at approximately 56° north latitude and generalized to be valid at other latitudes. Data on the downwind requirements in area AA are insufficient.

Figure A.4 — Time intervals when the sun's altitude, and hence the temperature gradient, is within certain limits at various latitudes

Annex B
(informative)

Microphone positions relative to reflecting surfaces

B.1 Free-field position

This is a position where there are no reflecting surfaces other than the ground close enough to influence the sound pressure level. The distance from the microphone to any sound-reflecting surface apart from the ground shall be at least twice the distance from the microphone to the dominating part of the sound source.

NOTE Exceptions can be made for small sound-reflecting surfaces and when it can be shown that the reflection has an insignificant effect. This can be based on calculations taking into account the major dimensions of the reflecting surface and the wavelength.

B.2 Microphone directly on the surface

Subject to the restrictions and requirements outlined below, this position aims at achieving a well defined + 6 dB increase of the sound pressure level of the incident sound (“free-field” level).

This position is on a reflecting surface and the direct and reflected sound are in phase below a certain frequency, f. For broadband traffic noise with sound incident from many angles, f is about 4 kHz for a microphone with a 13 mm diameter mounted on the reflecting surface. This position should be avoided if the sound arrives predominantly at a grazing incidence.

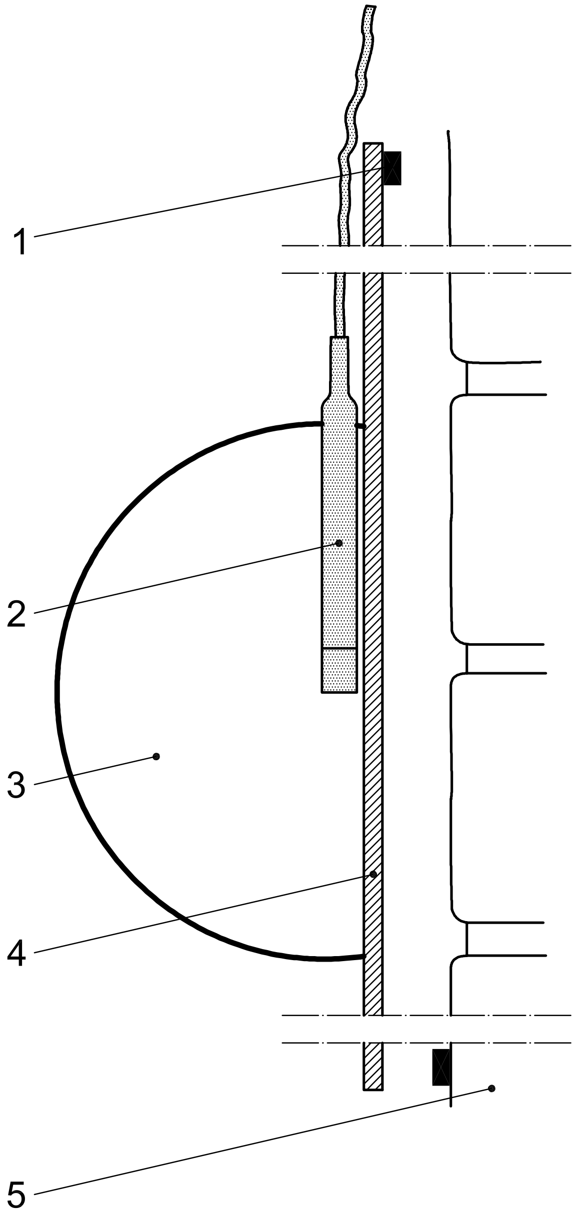
The façade within a distance of 1 m from the microphone shall be flat to within ± 0,05 m. The distance from the microphone to the surface edges of the façade wall shall be greater than 1 m. The microphone can be mounted as shown in Figure B.1 or with the microphone membrane flush with the surface of the mounting plate. The plate should not be thicker than 25 mm and its dimensions not less than 0,5 m × 0,7 m. The distance from the microphone to the edges and symmetry axes of the mounting plate shall be greater than 0,1 m to reduce the influence of diffraction at the plate edges.

The plate shall be of an acoustically hard and stiff material, such as painted chipboard thicker than approximately 19 mm or 5 mm aluminium plate with minimum 3 mm damping material on the side facing the wall, in order to avoid sound absorption and resonance in the frequency range of interest.

NOTE The plate in Figure B.1 rests on flexible rubber stripping to compensate for façade irregularities.

Care should be taken that no disturbing aerodynamic noise is created between the plate and a rough façade.

The microphone can be used without a plate when the wall is made of concrete, stone, glass, wood or similar hard material. In this case, the wall surface within a radius of 1 m from the microphone shall be flat to within ± 0,01 m. For octave-band measurements, a microphone of 13 mm diameter or smaller should be used. If the frequency range is expanded above 4 kHz, a 6 mm microphone should be used.



Key

1 rubber stripping

2 microphone

3 windscreen

4 mounting plate

5 wall or reflecting surface

Figure B.1 — Microphone mounting on reflecting surface

B.3 Microphone near reflecting surface

Subject to the restrictions and requirements outlined below, this position aims at achieving a well defined + 3 dB increase of the sound pressure level of the incident sound ("free-field" level).

When the microphone is at a distance from a reflecting surface, the direct and reflected sound is equally strong and, when the frequency band considered is wide enough, the reflection causes a doubling of the energy of the direct sound field and a 3 dB increase in sound pressure level.

The façade shall be plane within ± 0,3 m, and the microphone shall not be placed at positions where the sound field is influenced by the multiple reflection of sound between protruding building surfaces.

Windows shall be considered as part of the façade. They shall be closed during measurement but a small opening for the microphone cable is allowed.

The criteria in Clauses B.1 to B.3 ensure that the overall equivalent or maximum sound pressure level measured deviates less than 1 dB from the level of the incident sound plus 3 dB. Two cases are distinguished; see Figure B.2:

a) extended source, i.e. the source angle of view, α, is 60° or more;

b) point source, i.e. α is less than 60°.

For narrow-band sources or frequency-band measurements, free-field or + 6 dB positions are recommended.

The distance from the microphone at point M, perpendicular to the reflecting surface, to the point O is d; see Figure B.2. Point O is considered representative of the microphone position when determining the angle of view, α. The distances a' and d' are measured along the dividing line of the angle, α. M' is the point on the dividing line at a perpendicular distance, d, from the reflecting surface.

The distances from point O to the nearest edges of the reflecting surface are b (measured horizontally) and c (measured vertically). To avoid edge effects in the frequency range including the octave bands 125 Hz to 4 kHz, the criterion in Equation (B.1) for the horizontal measurement or in Equation (B.2) for the vertical measurement shall be fulfilled.

$$b \geqslant 4d \quad \text{(B.1)}$$

$$c \geqslant 2d \quad \text{(B.2)}$$

The criterion in Equation (B.3) for an extended source or Equation (B.4) for a point source ensure that the incident and reflected sounds are equally strong.

$$d' \leqslant 0{,}1a' \quad \text{(B.3)}$$

$$d' \leqslant 0{,}05a' \quad \text{(B.4)}$$

The criteria listed in Equations (B.5) to (B.8) ensure that the microphone is placed at a sufficient distance from the + 6 dB region near the façade.

— overall A-weighted sound pressure levels for an extended source, in accordance with Equation (B.5):

$$d' \geqslant 0{,}5\ \text{m} \quad \text{(B.5)}$$

— octave-band sound pressure levels for an extended source, in accordance with Equation (B.6):

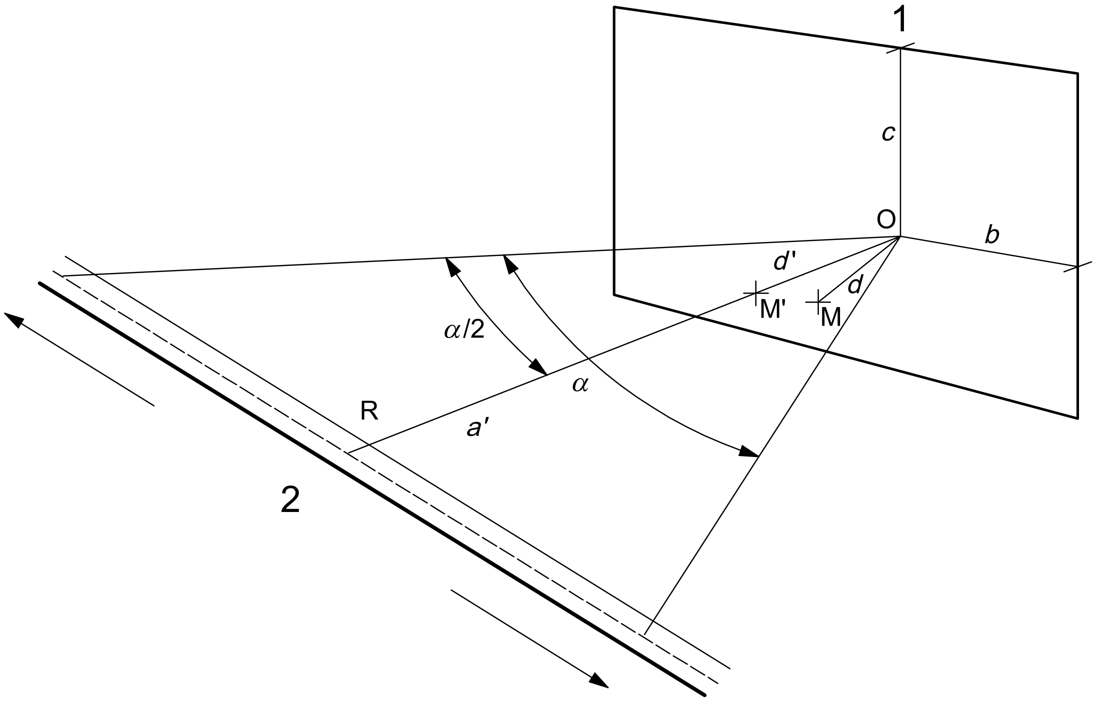
$$d' \geqslant 1{,}6\ \text{m} \quad \text{(B.6)}$$

— overall A-weighted sound pressure levels for a point source, in accordance with Equation (B.7):

$$d' \geqslant 1{,}0\ \text{m} \quad \text{(B.7)}$$

— octave-band sound pressure levels for a point source, in accordance with Equation (B.8):

$$d' \geqslant 5{,}4 \text{ m} \tag{B.8}$$



Key

1 building façade or other reflecting surface

2 extended source

M microphone position

d perpendicular distance from the microphone position to the reflecting surface, O

RO dividing line of the angle, α

Figure B.2 — Microphone near reflecting surface

Annex C
(informative)

Objective method for assessing the audibility of tones in noise — Reference method

C.1 Introduction

This annex provides measurement procedures to be used to verify the presence of audible tones if their presence is in dispute. Based on the prominence of the tones, this procedure also provides recommended levels of adjustment. The aim of the objective method is to assess the prominence of tones in the same way as listeners do on the average. The method is based on the psychoacoustic concept of critical bands, which are bands defined so that sound outside a critical band does not contribute significantly to the audibility of tones inside that critical band.

The method includes procedures for steady and varying tones, narrow-band noise, low-frequency tones, and the result is a graduated adjustment of 0 dB to 6 dB.

C.2 Objective method

C.2.1 General

The method has three steps:

a) narrow-band frequency analysis (preferably FFT-analysis);

b) determination of the average sound pressure level of the tone(s) and of the masking noise within the critical band around the tone(s);

c) calculation of the tonal audibility, ΔL_{ta}, and the adjustment, K_{t}.

C.2.2 Frequency analysis

A narrow-band A-weighted spectrum is measured by linear averaging for at least 1 min (“long-term average”).

The effective analysis bandwidth shall be less than 5 % of the bandwidth of the critical bands with tonal components. The widths of the critical bands are shown in Table C.1.

It is recommended that the measuring set-up, including the frequency analyser, be calibrated in dB re 20 µPa, and that Hanning weighting be used as the window function.

NOTE 1 With the recommended Hanning time window, the effective analysis bandwidth (or the effective noise bandwidth) is 1,5 times the frequency resolution. The frequency resolution is the distance between the lines in the spectrum.

NOTE 2 With an effective analysis bandwidth of 5 % of a critical band, just audible tones normally appear as local maxima of at least 8 dB above the surrounding masking noise in the averaged spectra.

NOTE 3 In rare cases of a complex tone with many closely spaced tone components, a finer resolution can be necessary to determine correctly the level of the masking noise.

NOTE 4 If the frequency of audible tones in the spectrum varies by more than 10 % of the frequency range of the critical band within the averaging time, it can be necessary to subdivide the long-term average into a number of shorter-term averages.

C.2.3 Determination of sound pressure levels

C.2.3.1 Sound pressure level of tones, $L_{p\mathrm{t}}$

The tones may be identified from the narrow-band frequency spectrum by visual inspection. The sound pressure levels of the tones are determined from the spectrum.

All local maxima with a 3 dB bandwidth smaller than 10 % of the bandwidth of the actual critical band are regarded as a tone.

The levels, $L_{p\mathrm{t}i}$, of all tones, i, in the same critical band shall be added on an energy basis to give the total tone level for that band, $L_{p\mathrm{t}}$, as given in Equation (C.1):

$$L_{p\mathrm{t}} = 10 \lg \sum 10^{\frac{L_{p\mathrm{t}i}}{10}} \text{ dB} \tag{C.1}$$

NOTE If a “tone” is a narrow band of noise, or if the frequency of a tone varies, the tone appears as several lines in the averaged spectrum. In such cases, the tone level, $L_{p\mathrm{t}i}$, is the energy sum of all lines, with levels within 6 dB of the local maximum level and corrected for the influence of the applied window function. (For Hanning weighting, this is the energy sum of the lines minus 1,8 dB.)

In cases where tones appear at low frequencies, it is advisable to investigate whether the total tone level is above the hearing threshold (ISO 389-7). If the total tone level in a critical band is below the hearing threshold, this critical band should be disregarded in the assessment of tonal audibility.

C.2.3.2 Bandwidth and centre frequency of critical bands

The widths of the critical bands are shown in Table C.1:

Table C.1 — Widths of critical bands

Centre frequency, f_c, Hz	50 to 500	Above 500
Bandwidth, Hz	100	20 % of f_c

The critical band shall be positioned with its centre frequency, f_c, at the tone frequency. When a number of tones are present in the range of a critical band, the critical band shall be positioned symmetrically around the most significant tones in such a way that the difference between the total tone level, $L_{p\mathrm{t}}$, and the level of the masking noise, $L_{p\mathrm{n}}$, (see C.2.3.3) is maximized.

For the definition of the centre frequency of a critical band, only tones with levels 10 dB or less below the level of the tone with the maximum level should be regarded as significant.

NOTE The centre frequency, f_c, of the critical bands can vary continuously over the frequency range of interest. The lowest critical band is 0 Hz to 100 Hz.

C.2.3.3 Sound pressure level of the masking noise within a critical band, L_{pn}

The average noise level, $L_{p\mathrm{n,avg}}$, in a critical band may be found by visually averaging the levels of the “noise lines” in the narrow-band frequency spectrum in a range extending from the centre frequency, f_c to approximately ± 0,5 critical band to 1 critical band on each side. The “noise lines” are found by disregarding all maxima in the spectrum resulting from tones and their possible side bands in that range.

The total sound pressure level of the masking noise, L_{pn}, is calculated from the average noise level within the critical band, $L_{pn,avg}$, as given in Equation (C.2):

$$L_{pn} = L_{pn,avg} + 10 \lg \frac{B_{crit}}{B_{eff}} \text{ dB} \tag{C.2}$$

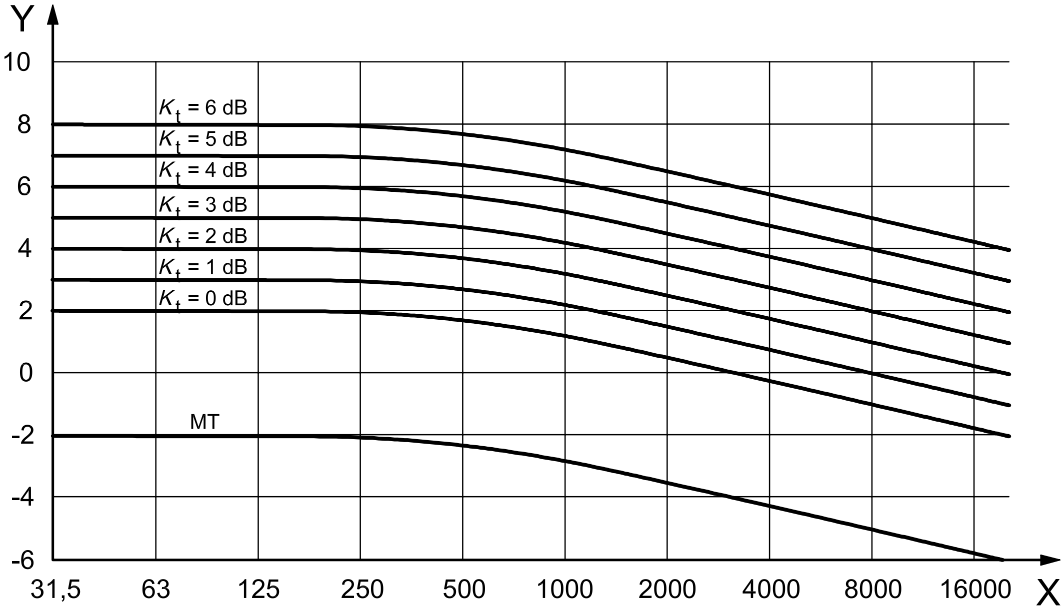
where

B_{crit} is critical band width, expressed in hertz;

B_{eff} is effective analysis band width, expressed in hertz.

C.2.4 Calculation of the tonal audibility, ΔL_{ta}, and the adjustment, K_t

The tonal audibility, ΔL_{ta}, is expressed in decibels above the masking threshold, MT; see Figure C.1. The adjustment, K_t, is the value to be added to the value of L_{Aeq} for a time interval to give the tone-corrected rating level for that interval. From the difference between tone level and noise level in a critical band, $L_{pt} - L_{pn}$, both ΔL_{ta} and K_t can be determined by means of Figure C.1. A given centre frequency, f_c, of the critical band and a given level difference, $L_{pt} - L_{pn}$, determine a point in Figure C.1. The tonal audibility, ΔL_{ta}, is determined as the difference between ($L_{pt} - L_{pn}$) and the masking threshold shown in the figure. K_t is read by interpolating between the lines marked with different values of K_t in the figure. Alternatively, ΔL_{ta} can be calculated by means of Equation (C.3), and K_t can be calculated by means of Equation (C.4).



Key

X $L_{pt} - L_{pn}$, expressed in decibels

Y centre frequency of the critical band, expressed in hertz

NOTE L_{pt} is the total sound pressure level of the tones in the critical band, and L_{pn} is the total sound pressure level of the masking noise in the critical band.

Figure C.1 — Masking threshold, MT, and curves for determining the adjustment, K_t

$$\Delta L_{\mathrm{ta}} = L_{p\mathrm{t}} - L_{p\mathrm{n}} + 2\,\mathrm{dB} + \lg\left[1 + \left(\frac{f_{\mathrm{c}}}{502}\right)^{2,5}\right]\mathrm{dB} \quad \text{(C.3)}$$

where

$L_{p\mathrm{t}}$ is the total sound pressure level of the tones in the critical band;

$L_{p\mathrm{n}}$ is the total sound pressure level of the masking noise in the critical band;

f_{c} is the centre frequency of the critical band, expressed in hertz.

The adjustment, K_{t}, expressed in decibels, is determined by Equations (C.4) to (C.6):

- For 10 dB < ΔL_{ta}, in accordance with Equation (C.4):

$$K_{\mathrm{t}} = 6\ \mathrm{dB} \quad \text{(C.4)}$$

- For 4 dB $\leqslant \Delta L_{\mathrm{ta}} \leqslant$ 10 dB, in accordance with Equation (C.5):

$$K_{\mathrm{t}} = \Delta L_{\mathrm{ta}} - 4\ \mathrm{dB} \quad \text{(C.5)}$$

- For ΔL_{ta} < 4 dB, in accordance with Equation (C.6):

$$K_{\mathrm{t}} = 0\ \mathrm{dB} \quad \text{(C.6)}$$

NOTE K is not restricted to integer values.

When several tones (or groups of tones) occur simultaneously in different critical bands, separate assessments shall be made for each of these bands. The critical band containing the most dominant tone(s) (i.e. giving the highest value of ΔL_{ta}) is decisive for the value of ΔL_{ta} and the adjustment, K_{t}.

C.3 Documentation

As documentation for the analysis, the following information shall be given:

a) For the analysis:

  - number of averaged spectra, measurement time period and effective analysis bandwidth,
  - time window (e.g. Hanning), time weighting (Lin), and frequency weighting (A),
  - one typical spectrum (at least) with an indication of the position of the critical band and the average noise level in that band;

b) For the calculations in the decisive critical band:

  - statement regarding whether the results were obtained by visual inspection or by automatic calculation,
  - frequency limits of the critical band and the range for the visual averaging or linear regression (see C.4.3),
  - frequencies and levels of the tones and the total tone level (L_{pti} and $L_{p\mathrm{t}}$ re 20 µPa in decibels),

- masking noise level in the critical band (L_{pn} re 20 µPa in decibels),
- audibility of the tones (ΔL_{ta} in decibels above the masking threshold),
- size of the adjustment (K_t in decibels).

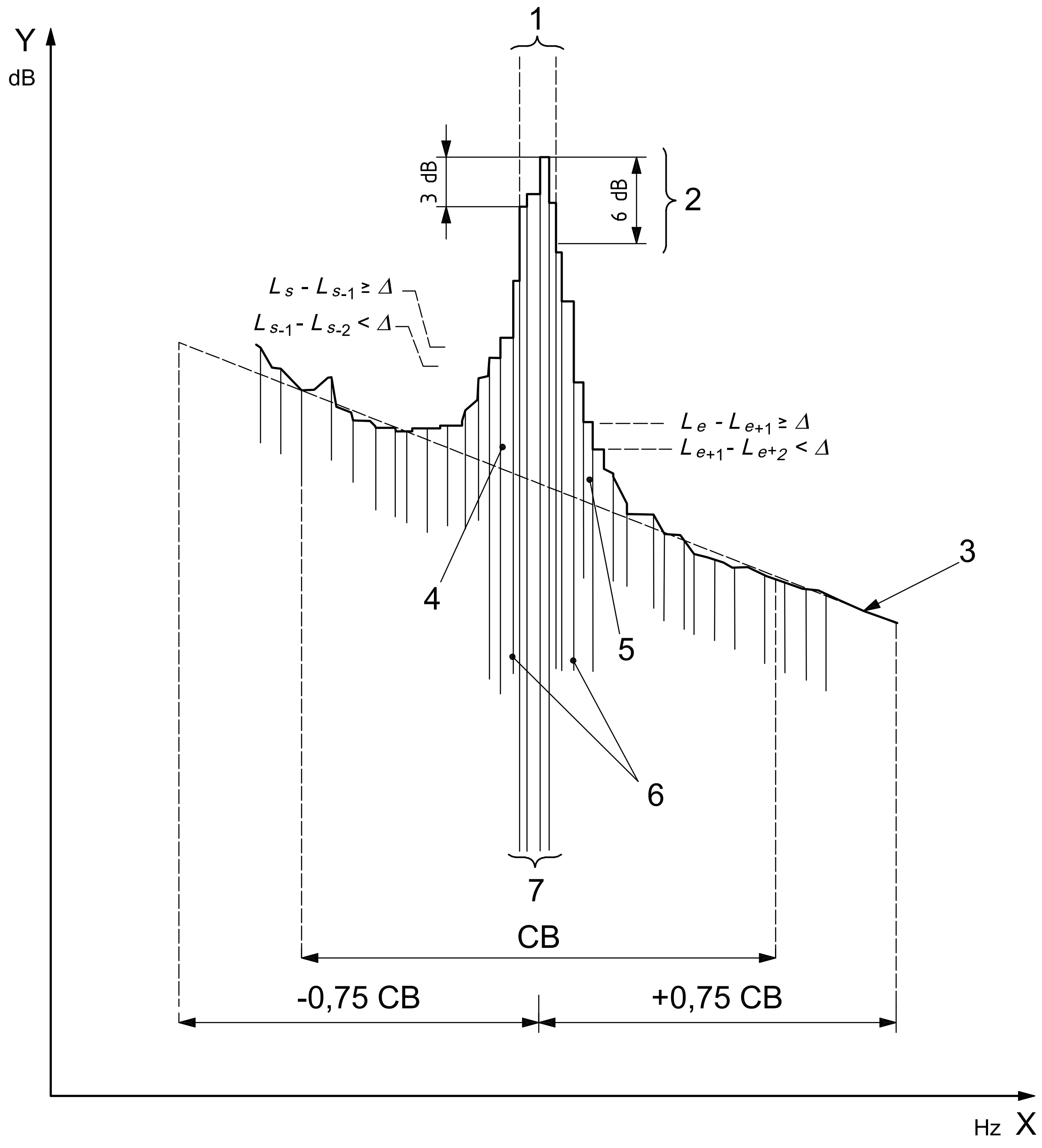
c) Tones in other critical bands that may cause an adjustment should be mentioned by their frequencies.

C.4 Detailed definitions of tone and masking noise levels

C.4.1 General

With a view to computer implementations of the method, more comprehensive definitions of tones and noise are given in Clause C.4.

NOTE The technician performing the analysis has the final responsibility for the correctness of the results. It is, therefore, important that software implementations make it possible to visually inspect the results. It is necessary to have a spectrum with at least the lines defined as the tones indicated, together with the corresponding critical bands and regression lines. Furthermore, separate colouring of spectrum lines characterized as noise, noise pause and tones is helpful.



Key

1 tone when the 3 dB bandwith is less than 10 % of the critical band
2 tonal energy
3 linear regression line of the noise level
4 noise-pause start
5 noise-pause end
6 neither tone nor noise
7 tone
CB critical band

Figure C.2 — Definitions of tones, noise and noise pause (neither tone nor noise). Δ is the tone-seek criterion and is normally chosen as 1 dB

C.4.2 Noise pauses

Noise pauses are local maxima with a probability of a tone. The noise pauses are defined and found according to the following principle.

The start of a noise pause is found on the positive slope of a local maximum as the line, s, where the conditions in Equations (C.7) and (C.8) are met:

$$L_s - L_{s\text{-}1} \geqslant \Delta \text{ dB} \tag{C.7}$$

$$L_{s\text{-}1} - L_{s\text{-}2} < \Delta \text{ dB} \tag{C.8}$$

L_s is the level of line number s and $L_{s\text{-}1}$ is the level of line number $s-1$, etc. Δ is the tone-seek criterion and is normally chosen as 1 dB.

For normal and smooth spectra, a tone-seek criterion of $\Delta = 1$ dB works without problems. For irregular spectra (e.g. spectra with short averaging time as mentioned in C.2.2), values of up to 3 dB or 4 dB can give better results. It is recommended that this parameter is user-defined in software implementations of the method.

The end of a noise pause is defined on the negative slope of a local maximum as the line, e, where the conditions in Equations (C.9) and (C.10) are met:

$$L_e - L_{e+1} \geqslant \Delta \text{ dB} \tag{C.9}$$

$$L_{e+1} - L_{e+2} < \Delta \text{ dB} \tag{C.10}$$

A preliminary noise pause interval is defined as all the lines s to e including both.

The search for the next noise pause starts at line number $e + 1$.

A noise pause can only contain one noise pause start and one noise pause end. A procedure similar to the above-mentioned shall be performed by investigating the lines in the spectrum from high towards lower frequencies.

Final noise pause intervals are lines defined as preliminary noise pause in both the forward and backward procedure and are included in the final noise pause intervals.

C.4.3 Tones

Tones are found within noise pauses. A tone may exist when the level of any line in the noise pause is 6 dB or more above the levels of lines number $s - 1$ and $e + 1$.

Tones are defined in C.2.3.1. This definition includes tones as well as narrow bands of noise. The bandwidth of the detected peak in the spectrum is defined as the 3 dB bandwidth relative to the maximum line in the noise pause.

When the 3 dB bandwidth is smaller than 10 % of the critical bandwidth, all lines with levels within 6 dB of the maximum level are classified as tones. The tone frequency is defined as the frequency of the line with the maximum level in the noise pause.

NOTE When this 3 dB bandwidth is larger than 10 % of the critical bandwidth, the lines are regarded as neither tones nor narrow-band noise. No adjustment is given for this phenomenon, unless it is caused by a tone with varying frequency, in which case a shorter averaging time is necessary.

Tones with varying frequency can appear as broad maxima in the long-term average spectrum. The width of these maxima depends on the range of the frequency variation of the tone and the averaging time. When the frequency of a tone varies more than 10 % of the width of the critical band during the averaging period, the

10 % bandwidth criterion (see C.2.3.1) should be overruled, and all lines within the broad maximum of the tone should be classified as tones or a shorter averaging time should be used.

C.4.4 Masking noise

All lines not characterized as noise pauses are defined as masking noise, designated “noise lines” in C.2.3.3.

The masking noise level within a critical band is defined by making a first-order linear regression through all lines defined as noise. The range of the regression should usually be chosen as ± 0,75 critical bandwidth around the centre frequency of the critical band.

For irregular spectra or for spectra with broad tonal maxima, the range of the linear regression may be extended to plus or minus one or two critical bands. This can bring the regression line in better correspondence with the general shape of the noise floor. It is recommended for the range of the regression analysis to be user-defined in software implementation.

A noise level, L_n, shall be assigned to each spectral line within the actual critical band as predicted by the regression line. The total masking noise level, $L_{p\text{n}}$, in the critical band is determined as the sum on an energy basis of the assigned levels, L_n, for all lines in the critical band with correction for the applied window function. The total masking noise level, $L_{p\text{n}}$, can be determined as given in Equation (C.11):

$$L_{p\text{n}} = 10\ \lg\left(\sum 10^{\frac{L_\text{n}}{10}}\right)\text{dB} + 10\ \lg\frac{\Delta f}{B_\text{eff}}\ \text{dB} \tag{C.11}$$

where

Δf is the frequency resolution, expressed in hertz;

B_eff is the effective analysis band width, expressed in hertz.

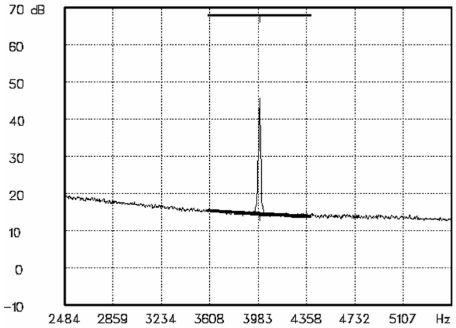
C.5 Examples

The examples in this subclause have been analysed with an automatic procedure based on 350 spectra and a measurement time of 2 min.

EXAMPLE 1 See Figure C.3.

- Critical band: 3,6 kHz to 4,4 kHz;
- Tones, 4 kHz: 46,7 dB;
- Tonal level, $L_{p\text{t}}$: 46,7 dB;
- 3 dB bandwidth of tone: 0,5 % of 800 Hz;
- $L_{p\text{n}}$ in critical band: 37,3 dB;
- Tonal audibility, ΔL_ta re MT: 13,7 dB;
- Adjustment, K_t: 6 dB.

Figure C.3

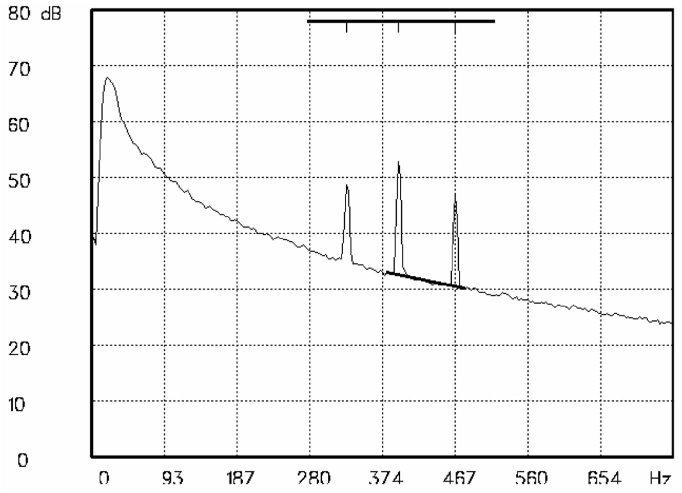


EXAMPLE 2 See Figure C.4.

- Critical band: 380 Hz to 480 Hz;
- Tones: 395 Hz: 53,1 dB,
  468 Hz, 47,0 dB;
- Tonal level, L_{pt}: 54,1 dB;
- 3 dB bandwidth of tone: 3,1 % of 100 Hz;
- L_{pn} in critical band: 45,2 dB;
- Tonal audibility, ΔL_{ta} re MT: 11,1 dB;
- Adjustment, K_t: 6 dB;

NOTE The two tones with the highest frequencies give the highest ΔL_{ta}.

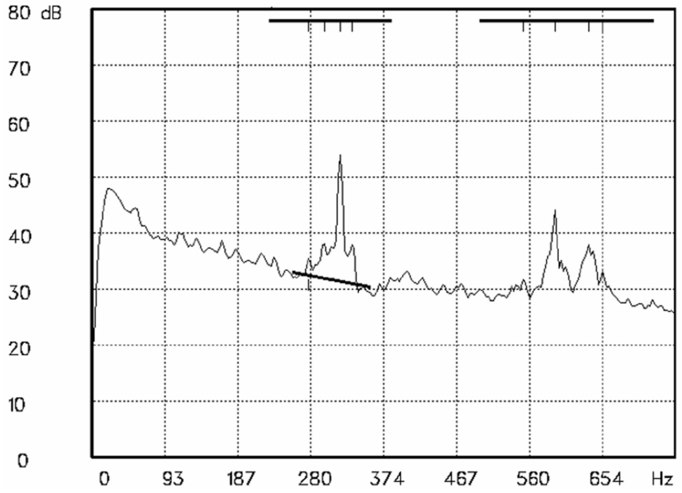
Figure C.4



EXAMPLE 3 See Figure C.5.

- Critical band: 258 Hz to 358 Hz;
- Tones: 278 Hz: 33,3 dB,
  299 Hz: 38,4 dB,
  319 Hz: 54,3 dB,
  334 Hz: 37,1 dB;
- Tonal level, L_{pt}: 54,6 dB;
- 3 dB bandwidth of tone: 3,4% of 100 Hz;
- L_{pn} in critical band: 45,5 dB;
- Tonal audibility, ΔL_{ta} re MT: 10,6 dB;
- Adjustment, K_t: 6,0 dB.

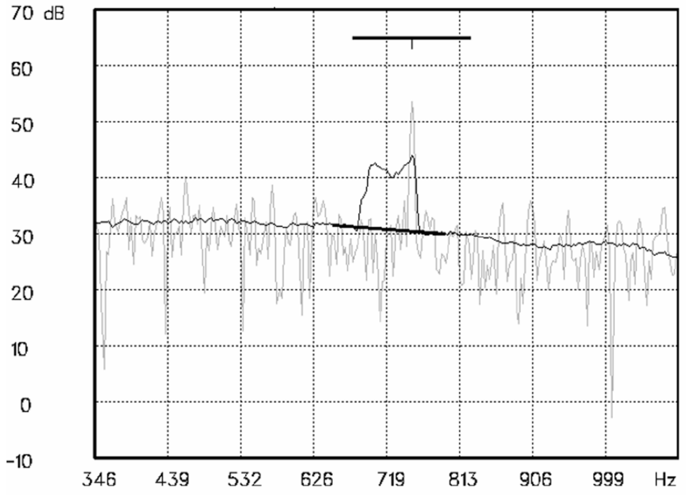
Figure C.5



EXAMPLE 4 See Figure C.6.

- Critical band: 680 Hz to 830 Hz;
- Tone: varying between
  680 Hz and 758 Hz;
- Tonal level, L_{pt}: 53,6 dB;
- L_{pn} in critical band: 45,5 dB;
- Tonal audibility, ΔL_{ta} re MT: 10,7 dB;
- Adjustment, K_t: 6 dB.

Figure C.6



NOTE Figure C.6 shows both an averaged spectrum and an instantaneous spectrum. According to C.2.3.1 and C.4.2 the tonal level can be found either by energy summation of the lines in the broad maximum in the averaged spectrum or by averaging the tone levels from a number of spectra measured with short averaging time, giving the same total averaging time.

Annex D
(informative)

Objective method for assessing the audibility of tones in noise — Simplified method

The test for the presence of a prominent, discrete-frequency spectral component (tone) typically compares the time-average sound pressure level in some one-third-octave band with the time-average sound pressure levels in the adjacent two one-third-octave bands. For a prominent, discrete tone to be identified as present, the time-average sound pressure level in the one-third-octave band of interest is required to exceed the time-average sound pressure levels of both adjacent one-third-octave bands by some constant level difference.

The constant level difference may vary with frequency. Possible choices for the level differences are

- 15 dB in the low-frequency one-third-octave bands (25 Hz to 125 Hz),
- 8 dB in middle-frequency bands (160 Hz to 400 Hz),
- 5 dB in high-frequency bands (500 Hz to 10 000 Hz).

NOTE The band limits in this annex are not exactly the same as in 8.4.11 because the latter subclause deals with the human response to sound while the band limits in this annex are based on the physical effects, i.e. largely atmosphere-induced fluctuations as affected by filter bandwidth.

Annex E
(informative)

National source-specific calculation methods

E.1 Road traffic

Austria: RVS 04.02.11 Lärmschutz, March 2006.

Denmark, Finland, Iceland, Norway, Sweden:

- Road Traffic Noise — Nordic Prediction Method, TemaNord 1996:525, ISBN 92 9120 836 1, ISSN 0908-6692.
- Nord 2000. New Nordic Prediction Method for Road Traffic Noise.

NOTE This document can be downloaded from www.delta.dk but it has not yet been officially adopted.

European Union: Harmonoise Model.

NOTE This document can be downloaded from www.imagine-project.org but it has not yet been officially adopted.

France: NMPB, 1997.

NOTE Partly based on ISO 9613-2 and yearly one-octave-band average weather statistics.

Germany: RLS-90.

Japan: ASJ RTN-Model 2003.

The Netherlands: Reken- en Meetvoorschrift Wegverkeerslawaai 2002, specifying a basic method (Standaard Rekenmethode I) and an advanced method (Standaard Rekenmethode II)

Switzerland: StL-86. Swiss road traffic noise model, 1986.

NOTE A new method, SonRoad, Swiss road traffic noise model, 2004, is expected to be introduced shortly after the publication of this part of ISO 1996.

United Kingdom: CRTN-88.

NOTE The 18 h day time, L10, is calculated, ISBN 0115508473.

USA: TNM 1998: Geometrical ray theory and diffraction theory — one-third-octave-band spectra.

E.2 Rail traffic

Austria: Berechnung der Schallimmission durch Schienenverkehr, Zugverkehr, Verschub- und Umschlagbetrieb.

Denmark, Finland, Iceland, Norway, Sweden:

— Railway Traffic Noise — Nordic Prediction Method, TemaNord 1996:524, ISBN 92 9120 837 X, ISSN 0908-6692,

— Nord 2000 Road. New Nordic Prediction Method for Rail Traffic Noise.

NOTE This document can be downloaded from www.vejdirektoratet.dk/dokument.asp?page=document&objno=89873.org but it has not yet been officially adopted.

European Union: Harmonoise Propagation Model.

NOTE This document can be downloaded from www.vejdirektoratet.dk/dokument.asp?page=document&objno=89873.org but it has not yet been officially adopted.

France: NMPB-fer, French standard S 31-133

NOTE Draft standard Pr S31-133, as of the publication date of this part of ISO 1996.

Germany: Schall 03, Richtlinie zur Berechnung der Schallimmisionen von Schienenwegen.

Japan: K.Nagakura & Y. Zenda, Prediction model of wayside noise level of Shinkansen, Wave 2002, 237-244, BALKEMA PUBLISHERS.

The Netherlands: Reken- en Meetvoorschrift Railverkeerslawaai '96, specifying a basic method (Standaard Rekenmethode I) and an advanced method (Standaard Rekenmethode II).

Switzerland: Schweizerisches Emissions- und Immissionsmodell für die Berechnung von Eisenbahnlärm (SEMIBEL).

United Kingdom: Calculation of Railway Noise (CRN), ISBN 0115517545, ISBN 0115518738.

E.3 Air traffic

Canada: Transport Canada NEF 1.8.

Denmark: DANSIM based on ECAC doc 29.

European Union: ECAC doc 29: Standard Method of Computing Noise Contours around Civil Airports.

Switzerland: FLULA2 , Swiss aircraft noise program.

USA: FAA INM 6.0 for Fixed Wing Civilian Aircraft; FAA HNM 2.2 for Civilian Helicopters. USAF — NOISEMAP for Military Aircraft.

E.4 Industrial noise

Austria: ÖAL-Richtlinie 28 Schallabstrahlung und Schallausbreitung, 1987.

Denmark, Finland, Iceland, Norway, Sweden:

— Environmental noise from industrial plants. General Prediction method.

NOTE Industrial Noise — Nordic Prediction Method similar to ISO 9613-2.

Germany: VDI-Richtlinie: VDI 2714 Schallausbreitung im Freien (Outdoor sound propagation), 1988.

Japan: Construction noise prediction model of ASJ CN-Model 2002, Acoustical Society of Japan, 2002.

The Netherlands: Handleiding Meten en rekenen industrielawaai 1999, specifying a basic method (Methode I) and an advanced method (Methode II).

Bibliography

[1] ISO 389-7, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions*

[2] ISO 6190, *Acoustics — Measurement of sound pressure levels of gas turbine installations for evaluating environmental noise — Survey method*

[3] ISO 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

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

[5] ISO 9613-2, *Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation*

[6] ISO 10843, *Acoustics — Methods for the description and physical measurement of single impulses or series of impulses*

[7] ISO/TS 13474, *Acoustics — Impulse sound propagation for environmental noise assessment*

[8] IEC 60651:2001, *Sound level meters*

[9] IEC 60804:2000*, Integrating-averaging sound level meters*

[10] STOREHEIER, S.Å., *Measurement of noise emmission from road traffic* (in Norwegian), SINTEF Report No. STF44 A78025, Trondheim, 1978

[11] FISK, D.J., *Statistical sampling in community noise measurement*, J. SVib, **39** (2) (1973)

[12] Danish Environmental Protection Agency, *Guidelines for Measurements of Environmental Noise*, 6/1984 (in Danish), Nov. 1984

[13] ZWICKER, E. and FASTL, H., *Psycho-acoustics — Facts and models*, Springer, Jan. 1999

[14] SØNDERGAARD, M., HOLM PEDERSEN, T. and KRAGH, J., *Method for Assessing Tonality of Wind Turbine Noise*, DELTA Acoustics & Vibration, Dec. 1999

ICS 13.140; 17.140.1

Price based on 40 pages