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Acoustics — Determination of high-frequency sound power levels emitted by machinery and equipment

Acoustique — Détermination des niveaux de puissance acoustique à haute fréquence émis par les machines et équipements

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

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

This second edition cancels and replaces the first edition (ISO 9295:1988), which has been technically revised.

Introduction

Some machinery and equipment emit high-frequency noise which might be broad-band noise (e.g. paper noise of high-speed printing) or narrow-band noise and discrete tones (e.g. noise of switching power supplies and video display units or medical devices).

This International Standard specifies methods for the determination of the sound power levels in the frequency range covered by the octave band centred at 16 kHz. The measured levels are not frequency-weighted. The principal objective of this International Standard is to prescribe methods for determining the sound power levels and frequencies of tones which are contained within the 16 kHz octave band.

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Acoustics — Determination of high-frequency sound power levels emitted by machinery and equipment

1 Scope

This International Standard specifies four methods for the determination of the sound power levels of high-frequency noise emitted by machinery and equipment in the frequency range covered by the octave band centred at 16 kHz, which includes frequencies between 11,2 kHz and 22,4 kHz. They are complementary to the methods described in ISO 3741 and ISO 3744. The first three methods are based on the reverberation test room technique. The fourth method makes use of a free field over a reflecting plane.

The test conditions which prescribe the installation and operation of the equipment are those specified in ISO 3741 or ISO 3744 as applicable.

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 3741, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms*

ISO 3744, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane*

ISO 6926, *Acoustics — Requirements for the performance and calibration of reference sound sources used for the determination of sound power levels*

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

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 3741 and ISO 3744 apply.

4 Conformity requirements

A method for the measurement of high-frequency noise is in conformance with this International Standard if it satisfies all the mandatory requirements of one of the four methods described herein specified in Clauses 6 to 9, and if the information recorded and reported is as specified in Clauses 12 and 13, respectively.

5 Requirements for measurements in a reverberation test room

5.1 General

This International Standard describes three methods using the reverberation test room technique of ISO 3741. The first and the second methods are usually called "direct methods" because they use directly measured or calculated reverberation times. The third method is a so-called "comparison method". A calibrated reference sound source is used from which the sound power levels of the equipment are determined by comparison.

All three methods require a determination of the mean time-averaged sound pressure level in the reverberant field.

As instrumentation and basic measurement techniques are the same for all three methods, they are summarized in 5.3 to 5.7. Additional requirements specific to each method are given separately. For additional requirements on instrumentation, see ISO 3741.

5.2   Meteorological conditions

The air absorption in the reverberation test room varies with temperature and humidity, particularly at frequencies above 1 000 Hz. The temperature, θ, in degrees Celsius (°C) and the relative humidity, h_r, expressed as a percentage, shall be controlled during the sound pressure level measurements.

The product, $h_r \times (\theta + 5\ °C)$, shall not vary by more than ±10 % during the measurements.

For equipment whose noise emissions intentionally vary with ambient temperature (e.g. by varying the speeds of air moving devices), the room temperature during the test measurement shall be 23 °C ± 2 °C or, if the room temperature is outside these limits, the fan shall be adjusted to the speed for an ambient temperature of 23 °C ± 2 °C.

The following conditions are recommended:

— Static pressure: 86 kPa to 106 kPa;

— Temperature: 15 °C to 30 °C;

— Relative humidity: 40 % to 70 %.

NOTE   As indicated in Tables 1 and 2 for the temperature range of 18 °C to 27 °C, higher temperatures and higher humidity will tend to minimize the effects of atmospheric absorption.

5.3   Instrumentation

The sound measuring system, including the microphone, should have a flat frequency response for random incident sound in the 16 kHz octave band. The microphone response shall be corrected to give a flat frequency response within in the 16 kHz octave band. The tolerances after correction shall be within ±1,0 dB in the frequency range of 11,2 kHz to 22,4 kHz.

NOTE 1   To meet this requirement, a microphone with a diameter of 13,2 mm or less is usually required.

When the noise of the equipment under test is broad-band in character without any significant discrete tone, an analyser with a bandwidth of one-third-octave or less shall be used. When the noise of the equipment under test contains discrete tone(s), a narrow-band analyser, which provides bandwidths of less than one-third-octave in width, shall be used to determine the frequency of the tone(s).

NOTE 2   For narrow-band analysis, an analyser with a bandwidth equal to, or less than, one twelfth octave is appropriate. Digital analysers using fast Fourier transform (FFT) or equivalent techniques can be useful, particularly when the analyser combines narrow-band analysis and averaging.

5.4   Installation and orientation of microphone

The microphone shall be mounted at the end of a rotating boom traversing a circle with a diameter of at least 2 m. In order to reduce the influence of the direct field on the measured sound pressure level, the microphone shall be mounted pointing in such a way that the normal to its diaphragm is parallel to the axis of rotation with the microphone diaphragm perpendicular to direction of the equipment under test. The period of rotation shall be as required by ISO 3741.

Longer paths and traversing periods than the minimum values can be used to reduce the background noise of the drive mechanism, and to minimize modulation of any discrete tone(s) due to the moving microphone.

Care shall be taken to ensure that there is no electrical pick-up by the measurement instrumentation which can interfere with the sound pressure level measurement.

NOTE   A test with a dummy microphone, and with the equipment under test in operation, can determine the influence on the noise floor of the instrumentation. Alternatively, if no dummy microphone is available without moving the microphone from the measurement position, this influence can be determined by sealing the microphone and pressure equalization vent in an electrical non-conductive enclosure providing an acoustical attenuation of at least 10 dB at all frequencies of interest.

5.5   Installation and orientation of equipment

Equipment shall be placed on the floor of the reverberation test room, at least 1 m from any wall, and at least 1,8 m from the point of closest approach of the microphone.

Four orientations of the equipment shall be used as follows.

— Operator side facing the centre of the microphone path.

— Equipment turned clockwise by 90° from its initial position about a vertical axis through its centre.

— Equipment turned clockwise by 180° from its initial position about a vertical axis through its centre.

— Equipment turned clockwise by 270° from its initial position about a vertical axis through its centre.

Alternatively, equipment shall be placed on a turntable and the turntable shall be revolved during the measurements. The motion of the turntable shall not be synchronous with the rotation of the microphone boom.

5.6   Calibration of measurement system

Before the measurement of the equipment noise, the measurement set-up shall be calibrated in accordance with ISO 3741. Calibration at a single frequency is sufficient if the frequency response of the entire system, including the frequency range of the 16 kHz octave band, is checked at intervals of not more than two years.

If an FFT analyser is calibrated with a single-frequency calibrator, care shall be taken to have all major sideband levels included in the calibration level.

5.7   Measurement of sound pressure level

The sound pressure level is measured in one-third-octave bands or, if discrete tones are present, in narrow bands which include the discrete tones. Measurements of the time-averaged sound pressure level along the circular microphone path shall be carried out for each frequency band within the frequency range of interest. The following data shall be obtained:

a)   the band time-averaged sound pressure level with the equipment in operation;

b)   the band time-averaged sound pressure levels of the background noise (including noise produced by ancillary equipment, if any); and

c)   the band time-averaged sound pressure levels of the reference sound source (if required, see Clause 8).

True integration-averaging during a full sweep of the microphone is the preferred method. When using a narrow-band analyser that performs the analysis in consecutive time periods, each time period shall correspond to one revolution. The influence of measurement duration and corrections for background noise shall be taken into account in accordance with ISO 3741.

When FFT analysers are used, the analysis time is typically greater than the individual time window. For this reason, the total measurement time shall be increased, or individual measurements shall be repeated for three revolutions of the boom, each for a different starting point.

The mean value, $\overline{L_p}$, of N measurements of the time-averaged sound pressure level shall be calculated using Formula (1):

$$\overline{L_p} = 10\lg\left[\frac{1}{N}\sum_{i=1}^{N}10^{0,1L_i}\right]\text{dB} \tag{1}$$

where

L_i is the band time-averaged sound pressure level (reference: 20 µPa), in decibels, for the ith measurement.

For the four orientations of the equipment under test, the mean value, $\overline{L_p}$, is obtained with $N = 4$. For the three revolutions of the boom, $\overline{L_p}$ is obtained using $N = 3$.

When a discrete tone is analysed, the moving microphone distributes the energy of the tone into sidebands of the tone frequency. In order to obtain the total tone level, the analyser bandwidth shall not be less than:

$$\Delta f = 2f\frac{v}{c} \tag{2}$$

where

Δf is the minimum value of the analyser bandwidth, in hertz;

f is the centre frequency of the tone, in hertz;

c is the speed of sound, in metres per second;

v is the speed of the traversing microphone, in metres per second.

When using FFT or equivalent techniques for the analysis of the discrete tone(s), the bandwidth can be significantly narrower than given in Formula (2). In this case, the levels in the sidebands adjacent to the tone centre frequency which contribute to the tone level shall be added on an energy basis to obtain the total sound pressure level of the tone using Formula (3):

$$L_{\text{tot}} = 10\lg\sum_{i=1}^{N_{\text{sb}}}10^{0,1L_i}\ \text{dB} \tag{3}$$

where

L_{tot} is the total sound pressure level (reference: 20 µPa) of the tone, in decibels;

L_i is the sound pressure level (reference: 20 µPa) in an individual band, in decibels;

N_{sb} is the number of sideband levels to be combined.

6   Method using measured reverberation time

6.1   General

A basic assumption of this method is that the reverberant component dominates the sound field at the microphone positions. Experiments show that in the 16 kHz octave band, the direct field might still be present. However, the microphone orientation specified in 5.4 significantly reduces the direct field contribution, and, therefore, the measured sound pressure level is determined by the reverberant field. From the measured reverberation time which is determined by the absorption in air and by the room surfaces, the total room absorption is calculated. Although air absorption is the major part of

the two, wall absorption can contribute to the total room absorption. At frequencies above 10 kHz, the absorption coefficient of the room, α_{room}, cannot be considered small compared to unity. Therefore, the Eyring equation [see Formula (5)] shall be used for the calculation of the room absorption instead of the simpler Sabine equation.

6.2 Measurement of reverberation time

The reverberation time, T, in seconds, of the reverberation test room with the equipment under test present shall be determined in those one-third-octave bands with centre frequencies between 12,5 kHz and 20 kHz which are of interest for the measurement of the equipment noise. When the equipment under test emits discrete tones, the reverberation time shall be measured at those frequencies in narrower bands, e.g. in one-twelfth octave bands. For each frequency band of interest, the average value of the reverberation times measured at three or more locations, equally spaced on the microphone path, shall be determined. The response time of the measuring instrument (e.g. a level recorder) shall be such that reverberation times shorter than 0,7 s can be measured.

6.3 Calculation of room absorption

The numerical value of the room constant, R, in square metres, for each band is calculated from the measured reverberation time as follows:

$$R = \frac{S \cdot \alpha_{room}}{1 - \alpha_{room}} \tag{4}$$

$$\alpha_{room} = 1 - e^{-0,16 \cdot V/(S \cdot T)} \tag{5}$$

where

S	is the numerical value of the total surface area, in square metres, of the room;
V	is the numerical value of the volume, in cubic metres, of the room;
T	is the numerical value of the measured average reverberation time, in seconds;
α_{room}	is the absorption coefficient of the room.

6.4 Installation of microphone and equipment

The microphone and the equipment under test shall be installed as described in 5.4 and 5.5, respectively.

6.5 Measurement of sound pressure level

Before the measurement of the equipment noise, the measurement set-up shall be calibrated as described in 5.6. The mean time-averaged sound pressure level, $\overline{L_p}$, shall be measured as described in 5.7. When the noise of the equipment under test is broad-band in character, a one-third-octave band analyser shall be used. When the noise of the equipment under test contains discrete tones, a narrow-band analyser providing analysis bandwidths of less than one-third-octave in width shall be used if the frequency of the tone is to be determined and/or when multiple tones are present.