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Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering method for an essentially free field over a reflecting plane

Acoustique — Détermination des niveaux de puissance acoustique et des niveaux d'énergie acoustique émis par les sources de bruit à partir de la pression acoustique — Méthode d'expertise pour des conditions approchant celles du champ libre sur plan réfléchissant

[Revision of second edition (ISO 3744:1994) and ISO 4872:1978]

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ISO/CEN PARALLEL ENQUIRY

The CEN Secretary-General has advised the ISO Secretary-General that this ISO/DIS covers a subject of interest to European standardization. **In accordance with the ISO-lead mode of collaboration as defined in the Vienna Agreement, consultation on this ISO/DIS has the same effect for CEN members as would a CEN enquiry on a draft European Standard.** Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month FDIS vote in ISO and formal vote in CEN.

In accordance with the provisions of Council Resolution 15/1993 this document is circulated in the English language only.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3744 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This third edition of ISO 3744 cancels and replaces the second edition (ISO 3744:1994) and also ISO 4872:1978, which have been merged and technically revised.

Introduction

0.1 This International Standard is one of the series ISO 3740 to ISO 3747, that specifies methods for determining the sound power levels and sound energy levels of noise sources including machinery, equipment and their sub-assemblies. Guidelines to select one of those methods are provided in ISO 3740. The selection will depend on the environment of the available test facility and on the precision of the sound power level or sound energy level values required. It may be necessary to establish a test code for the individual noise source in order to select the appropriate sound measurement surface and microphone array from among those allowed in each standard, and to give requirements on test unit mounting, loading and operating conditions under which the sound power levels or sound energy levels are to be obtained. The sound power emitted by a given source into the test environment is calculated from the mean square sound pressure that is measured over a hypothetical measurement surface enclosing the source, and the area of that surface. The sound energy for a single machine event is calculated from this sound power and the time over which it existed.

0.2 This International Standard provides an engineering grade of accuracy (grade 2) as defined in ISO 12001 when the measurements are performed in a space that approximates an acoustically free field over a reflecting plane. Such an environment can be found in a specially-designed room, or within industrial buildings or outdoors. Ideally, the test source should be mounted on a sound reflecting plane located in a large open space. For sources normally installed on the floor of machine rooms, corrections are defined to account for undesired reflections from nearby objects, walls and the ceiling, and for the residual background noises that occur there.

0.3 The methods specified in this International Standard permit the determination of the sound power level and the sound energy level in frequency bands and/or with frequency weighting A applied.

0.4 For applications where greater accuracy is required, reference can be made to ISO 3745, ISO 3741 or an appropriate part of ISO 9614. If the relevant criteria for the measurement environment specified in this International Standard are not met, it might be possible to refer to another standard from this series, or to an appropriate part of ISO 9614.

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering method for an essentially free field over a reflecting plane

1 Scope

1.1 General

This International Standard specifies methods for determining the sound power level or sound energy level of a noise source from sound pressure levels measured on a surface enveloping the noise source (machinery or equipment) in an environment that approximates to an acoustic free-field near one or more reflecting planes. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source, in frequency bands or with frequency-weighting A applied, is calculated using those measurements.

NOTE Differently shaped measurement surfaces can yield differing estimates of the sound power level of a given noise source and a test code should give detailed information on the selection of the surface.

1.2 Types of noise and noise sources

The methods specified in this International Standard are suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001.

This International Standard is applicable to all types and sizes of noise source (e.g. stationary or slowly moving plant, installation, machine, component or sub-assembly), provided the conditions for the measurements can be met.

NOTE The conditions for measurements given in this International Standard could be impracticable for very tall or very long sources such as chimneys, ducts, conveyors and multi-source industrial plants. A test code for the determination of noise emission of specific sources can provide alternative methods in such cases.

1.3 Test environment

The test environments that are applicable for measurements made in accordance with this International Standard may be located indoors or outdoors, with one or more sound-reflecting planes present on or near which the noise source under test is mounted. The ideal environment is a completely open space with no bounding or reflecting surfaces other than the reflecting plane(s) (such as that provided by a qualified hemi-free-field chamber) but procedures are given for applying corrections (within limits that are specified) in the case of environments that are less than ideal.

1.4 Measurement uncertainty

Information is given on the uncertainty of the sound power levels and sound energy levels determined in accordance with this International Standard, for measurements made in limited bands of frequency and with frequency weighting A applied. The uncertainty conforms with that of the engineering grade of accuracy (grade 2) defined in ISO 12001.

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 3382-2[1)] , *Acoustics — Measurement of the reverberation time — Part 2: Ordinary rooms*

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

ISO 7574-1, *Acoustics — Statistical methods for determining and verifying stated noise emission values of machinery and equipment — Part 1: General considerations and definitions*

ISO 12001, *Acoustics — Noise emitted by machinery and equipment — Rules for the drafting and presentation of a noise test code*

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). International Organization for Standardization, Geneva, Switzerland. ISBN 92-67-10188-9, First Edition 1993, corrected and reprinted 1995

3 Terms and definitions

For the purposes of this document, the following definitions apply.

3.1
sound pressure
p
a fluctuating pressure superimposed on the static pressure by the presence of sound, expressed in pascals

3.2
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, p, to the square of a reference value, p_0, expressed in decibels

$$L_p = 10 \lg \frac{p^2}{p_0^2} \text{ dB} \quad (1)$$

The reference value, p_0, is 20 μPa (2×10^{-5} Pa).

NOTE The frequency weighting or the midband frequency of the frequency band used should be indicated in the symbol.

1) In preparation

3.3
time-averaged sound pressure level
$L_{p,T}$
level of the time-averaged square of the sound pressure over the measurement time interval $T = t_2 - t_2$, expressed in decibels

$$L_{p,T} = 10 \lg \left[\frac{1}{T} \int_{t_1}^{t_2} \frac{p^2(t)}{p_0^2} \mathrm{d}t \right] \text{ dB} \tag{2}$$

NOTE 1 In general, the subscript "T" is omitted since time-averaged sound pressure levels are necessarily determined over a certain measurement time interval.

NOTE 2 Time-averaged sound pressure levels are often A-weighted, in which case they are denoted by $L_{pA,T}$, which is usually abbreviated to L_{pA}.

3.4
single-event sound pressure level
L_E
level of the time-integrated square of the sound pressure of an isolated single sound event (burst of sound or transient sound) of specified duration T (or specified measurement time interval $T = t_2 - t_1$) normalized to reference time interval T_0 = 1 s, expressed in decibels

$$L_E = 10 \lg \left[\frac{1}{T_0} \int_{t_1}^{t_2} \frac{p^2(t)}{p_0^2} \mathrm{d}t \right] \text{dB} = L_{p,T} + 10 \lg \frac{T}{T_0} \text{ dB} \tag{3}$$

3.5
measurement time interval
T

portion or a multiple of an operational period or operational cycle of the noise source under test, for which the time-averaged sound pressure level is determined, expressed in seconds

3.6
acoustic free field
sound field in a homogeneous, isotropic medium free of boundaries; in practice, it is a field in which reflections at the boundaries are negligible over the frequency range of interest

3.7
acoustic free field over a reflecting plane
acoustic free field in the half-space above an infinite reflecting plane in the absence of any other obstacles

3.8
reflecting plane
sound reflecting planar surface on which the noise source under test is located

3.9
frequency range of interest
for general purposes, the range of octave bands with nominal midband frequencies from 125 Hz to 8 000 Hz (including one-third octave bands with midband frequencies from 100 Hz to 10 000 Hz)

NOTE For special purposes, the range may be extended or reduced, provided that the test environment and instrument specifications are satisfactory for use over the modified range. For sources which emit sound at predominantly high or low frequencies, it might be desirable to extend or reduce the frequency range of interest in order to optimize the test facility and procedures, provided this is made clear in the test report.

3.10
reference box
hypothetical rectangular parallelepiped terminating on the reflecting plane(s) on which the noise source under test is located, that just encloses the source including all the significant sound radiating components and any test table on which the source is mounted (see 6.2)

3.11
characteristic source dimension
d_0
distance from the origin of the co-ordinate system to the farthest corner of the reference box (see 7.1), expressed in metres

3.12
measurement distance
d
distance from the reference box to a measurement surface, expressed in metres

3.13
measurement radius
r
radius of a hemispherical measurement surface, expressed in metres

3.14
measurement surface
hypothetical surface of area S, on which the microphone positions are located at which the sound pressure levels are measured, enveloping the noise source under test and terminating on the reflecting plane(s) on which the source is located

3.15
background noise
noise from all sources other than the noise source under test

NOTE Background noise may include contributions from airborne sound, noise from structure-borne vibration, and electrical noise in the instrumentation.

3.16
background noise correction
K_1
correction applied to the measured time-averaged sound pressure levels to account for the influence of background noise, expressed in decibels

NOTE The background noise correction is frequency dependent; the correction in the case of a frequency band is denoted K_{1f}, where f denotes the relevant midband frequency, and that in the case of A-weighting is denoted K_{1A}.

3.17
environmental correction
K_2
correction applied to the mean (energy-average) of the time-averaged sound pressure levels at all the microphone positions on the measurement surface, to account for the influence of reflected or absorbed sound, expressed in decibels

NOTE 1 The environmental correction is frequency dependent; the correction in the case of a frequency band is denoted K_{2f}, where f denotes the relevant midband frequency, and that in the case of A-weighting is denoted K_{2A}.

NOTE 2 In general, the environmental correction depends on the area of the measurement surface and usually K_2 increases with S.

3.18
surface time-averaged sound pressure level

$\overline{L_p}$

mean (energy average) of the time-averaged sound pressure levels at all the microphone positions on the measurement surface, with the background noise correction, K_1, and the environmental correction, K_2, applied, expressed in decibels

3.19
surface single-event sound pressure level

$\overline{L_E}$

mean (energy average) of the single-event sound pressure levels at all the microphone positions on the measurement surface, with the background noise correction, K_1, and the environmental correction, K_2, applied, expressed in decibels

3.20
sound power

W

rate per unit time at which airborne sound energy is radiated by a source, expressed in watts

3.21
sound power level

L_W

ten times the logarithm to the base 10 of the ratio of the sound power of a source, W, to a reference value, W_0, expressed in decibels

$$L_W = 10 \lg \frac{W}{W_0} \text{ dB} \qquad (4)$$

The reference value, W_0, is 1 pW (10^{-12} W).

NOTE 2 The frequency weighting, or the midband frequency of the frequency band used, is indicated in the symbol. For example, the A-weighted sound power level is L_{WA}.

3.22
sound energy

J

energy of a single burst of sound or transient sound emitted by a source, expressed in joules

3.23
sound energy level

L_J

ten times the logarithm to the base 10 of the ratio of the sound energy of a source, J, to a reference value, J_0, expressed in decibels

$$L_J = 10 \lg \frac{J}{J_0} \text{ dB} \qquad (5)$$

The reference value, J_0, is 1 pJ (10^{-12} J).

NOTE The frequency weighting, or the midband frequency of the frequency band used, is indicated in the symbol. For example, the A-weighted sound energy level is L_{JA}.

3.24
apparent directivity index
$D^*_{\mathrm{I}i}$
measures of the extent to which a noise source under test radiates sound in the direction of the ith microphone position on a measurement surface, relative to the mean sound radiation over the measurement surface, in decibels

$$D^*_{\mathrm{I}i} = L_{pi(\mathrm{ST})} - \overline{L_{p(\mathrm{ST})}} \qquad (6)$$

where

$L_{pi(\mathrm{ST})}$ is the background noise corrected sound pressure level (respectively, time-averaged or single-event) for the ith microphone position on the measurement surface, with the noise source under test in operation, in decibels;

$\overline{L_{p(\mathrm{ST})}}$ is the mean (energy average) background noise corrected sound pressure level (respectively, time-averaged or single-event) over all the microphone positions on the measurement surface for the noise source under test, in decibels.

NOTE The apparent directivity index is determined using measured sound pressure levels from the noise source under test, corrected for background noise but with no corrections for the influence of the acoustic environment.

3.25
apparent surface sound pressure level non-uniformity index
V^*_{I}
measure of the variability of measured sound pressure levels over the measurement surface, expressed in decibels:

$$V^*_{\mathrm{I}} = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(L_{pi(\mathrm{ST})} - L_{p\mathrm{av}})^2} \qquad (7)$$

where

$L_{pi(\mathrm{ST})}$ is the background noise corrected sound pressure level (respectively, time-averaged or single-event) for the ith microphone position on the measurement surface, with the noise source under test in operation, in decibels;

$L_{p\mathrm{av}}$ is the arithmetic average of the background noise corrected sound pressure levels (respectively, time-averaged or single-event) over all the microphone positions on the measurement surface for the noise source under test, in decibels;

n is the number of microphone positions.

NOTE 1 V^*_{I} is determined over the specific measurement surface given by the measurement radius or measurement distance and the value is denoted $V^*_{\mathrm{I}r}$ or $V^*_{\mathrm{I}d}$, respectively.

NOTE 2 The apparent surface sound pressure level non-uniformity index is determined using measured sound pressure levels from the noise source under test, corrected for background noise but with no corrections for the influence of the acoustic environment.

4 Test environment

4.1 General

The test environments that are applicable for measurements according to this International Standard are:

a) a laboratory room or a flat outdoor area which is adequately isolated from background noise (see 4.2) and which provides a free field over a reflecting plane;

b) a room or a flat outdoor area which is adequately isolated from background noise (see 4.2) and in which an environmental correction can be applied to allow for a limited contribution from the reverberant field to the sound pressures on the measurement surface.

Environmental conditions having an adverse effect on the microphones used for the measurements (for example, strong electric or magnetic fields, wind, impingement of air discharge from the noise source being tested, high or low temperatures) shall be avoided. The instructions of the manufacturers of the measuring instrumentation regarding adverse environmental conditions shall be followed.

In an outdoor area, care shall be taken to minimize the effects of adverse meteorological conditions (for example, temperature, humidity, wind, precipitation) on the sound propagation and on sound generation over the frequency range of interest or on the background noise during the course of the measurements.

NOTE When a reflecting surface is not a ground plane or is not an integral part of a test room surface, particular care should be exercised to ensure that the plane does not radiate any appreciable sound due to vibrations.

4.2 Criteria for background noise

4.2.1 General

The mean sound pressure level of the background noise measured and averaged (see 8.3.3) over the microphone positions or traverses, shall be at least 6 dB, and preferably more than 15 dB, below the corresponding uncorrected mean sound pressure level of the noise source under test when measured in the presence of this background noise. For measurements in frequency bands, this requirement shall be met in each frequency band within the frequency range of interest. If this requirement is met, the background noise criteria of this International Standard are satisfied.

NOTE The noise associated with the microphone traversing mechanism, if one is used for the measurements, is considered to be part of the background noise. In such cases, the background noise should be measured with the traversing mechanism operating.

4.2.2 Absolute criteria for background noise

If it can be demonstrated that the background noise levels in the test room at the time of the measurements are less than or equal to those given in Table 1 for all bands within the frequency range of interest, the measurements can be taken as having met the background noise requirements of this International Standard, even if the 6-dB requirement (see 4.2.1) is not met for all bands. It can be assumed that the source emits little or no measurable noise in these frequency bands, and that the data reported represents an upper bound to the sound power level in these bands.

Table 1 — Maximum background noise levels in test room for absolute criteria

One-third-octave midband frequency in Hz	Maximum band sound pressure level in dB
50	44
63	38
80	32
100	27
125	22
160	16
200	13
250	11
315	9
400	8
500	7
630	7
800	7
1 000	7
1 250	7
1 600	7
2 000	7
2 500	8
3 150	8
4 000	8
5 000	8
6 300	8
8 000	12
10 000	14
12 500	11
16 000	46
20 000	46

4.2.3 Relative criteria for frequency band measurements

The requirements of 4.2.1 may not be achievable in all frequency bands, even when the background noise levels in the test room are extremely low and well-controlled. Therefore, any band within the frequency range of interest in which the A-weighted sound power level of the noise source under test is at least 15 dB below the highest A-weighted band sound power level may be excluded from the frequency range of interest for the purposes of determining compliance with the above criterion for background noise.

4.2.4 Relative criteria for A-weighted measurements

If the A-weighted sound power level is to be determined from frequency band levels and reported, the following steps shall be followed to determine whether or not this quantity meets the background noise criteria of this International Standard:

a) The A-weighted sound power level is computed according to the procedures in this International Standard using the data from every frequency band within the frequency range of interest;

b) The computation is repeated, but excluding those bands for which ΔL_p is less than 6 dB.

If the difference between these two levels is less than 0,5 dB, the A-weighted sound power level determined from the data for all bands shall be considered as conforming to the background noise criteria of this Standard.

NOTE If it is necessary to make measurements where the difference between the sound pressure levels of the background noise and the source together with the background noise is less than 3 dB, ISO 9614-1 or ISO 9614-2 may be used to give results of accuracy grade 2.

4.2.5 Failure to meet relevant criteria

If the background noise criteria are not satisfied, the report shall clearly state that the background noise requirements of this International Standard have not been met, and, in the case of frequency band measurements, shall identify the particular frequency bands that do not meet the criteria. Furthermore, the report shall not state or imply that the measurements have been made "in full conformance" with ISO 3744.

4.3 Criterion for acoustic adequacy of test environment

A test room shall provide a measurement surface that lies inside a sound field that is essentially free of undesired sound reflections from the room boundaries or nearby objects (apart from the floor).

As far as is practicable, the test environment shall be free from reflecting objects other than the reflecting plane(s).

NOTE 1 An object in the proximity of the noise source under test may be considered to be sound reflecting if its width (for example, diameter of a pole or supporting member) exceeds one-tenth of its distance from the reference box.

The reflecting plane(s) shall extend at least 0,5 m beyond the projection of the measurement surface on the plane(s). The sound absorption coefficient of the reflecting plane(s) shall be less than 0,1 over the frequency range of interest.

NOTE 2 ISO 10534-1, ISO 10534-2 and ISO 13472-1 give procedures by which the sound absorption coefficient of the reflecting plane may be determined.

NOTE 3 Smooth concrete or smooth sealed asphalt surface(s) should be satisfactory.

Annex A describes procedures for determining the magnitude of the environmental correction, K_2, to account for deviations of the test environment from the ideal condition. Measurements according to this International Standard are only valid where K_{2A} is numerically less than or equal to 4 dB (see 8.1).

NOTE 4 If the environmental correction K_{2A} exceeds 4 dB, ISO 3743, ISO 3747, ISO 9614-1 or ISO 9614-2 may be used for results of accuracy grade 2, or ISO 3746 may be used for results of accuracy grade 3.

NOTE 5 In some specific cases, the horizontal plane cannot be reflecting (e.g. lawnmowers, some types of earth-moving machines). In such cases, the relevant noise test code should describe in detail the nature of the plane on which the noise source is mounted and indicate the possible consequences on the measurement uncertainty.

The environmental correction, K_2, is assumed to be zero for measurements made in hemi-free-field rooms which meet the requirements of ISO 3745:2003.

For an outdoor space which consists of a hard, flat ground surface, such as asphalt or concrete, with no sound-reflecting objects within a distance from the noise source equal to ten times the greatest distance from the source centre to the lowest measurement points, it shall be assumed that the environmental correction K_2 is zero over the frequency range of interest.