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Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit — Lignes directrices pour l'utilisation des normes de base

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Foreword

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso .org/iso/foreword.html.

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

This third edition cancels and replaces the second edition (ISO 3740:2000), which has been technically revised. The main change compared to the previous edition is as follows:

— All of the basic standards covered by this document with the exception of the ISO 9614 series have been revised.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

For many users of machinery, equipment and products, the control of noise is a major issue which requires effective exchange of acoustical information. In this context, the main flow of information goes from the manufacturer to the purchaser, installer or user of the machines and products to describe the generated sound. In particular, information on source airborne noise emission is desired. Therefore, the sound power level, as the major parameter characterising airborne noise emission of sound sources, needs to be determined by measurement.

However, such measurements are only useful if the conditions under which they are carried out are specified; they yield defined acoustical quantities, and they are taken with standardized instruments.

Sound power levels are used for

— declaration of the noise emitted under defined conditions,

— verification of declared values,

— comparison of the noise emitted by machinery of various types and sizes,

— comparison with limits specified in a purchasing contract or a regulation,

— engineering work to control the noise emission of machinery,

— prediction of noise exposure of workers in indoor or outdoor work shops,

— prediction of noise in the environment.

International Standards describing basic methods for determining sound power level are

— ISO 3741 to ISO 3747 (sound power level determination using sound pressure level measurements),

— ISO 9614-1 to ISO 9614-3 (sound power level determination using sound intensity measurements),

— ISO/TS 7849-1 and ISO/TS 7849-2 (sound power level determination using vibration measurements).

These standards specify different methods for determination of sound power level and the achievable accuracy, characterized by the standard deviation of reproducibility of the method. Operating and mounting conditions, and the uncertainty associated with these conditions, are dealt with only in a very general manner. Specific and detailed requirements on the machinery or equipment under test are given in noise test codes prepared by machinery specific standards committees. They not only provide the necessary detailed information on the operating, installation and mounting conditions but also identify basic measurement standards that can be used and how a noise emission declaration and verification is made.

The standards mentioned above differ in their range of applications and their requirements with regard to the test environment. In practice, procedures that do not require special laboratory environments and additionally meet class 2 accuracy are particularly advantageous, especially to meet legal requirements. These include the procedures in standards ISO 3744, ISO 3747 and methods in ISO 9614-2.

To help technical committees in drafting noise test codes or to assist manufacturers of machines and equipment in determining the sound power level if a noise test code is not currently available, ISO 3740 introduces the set of twelve International Standards describing various methods for determining sound power levels of machinery, equipment and products taking into account the broad variety of practical situations for the sources under test (types of machinery, equipment and products), test environments, measurement instruments and the accuracy desired.

Some machinery, equipment and products emit high-frequency noise, which can be broad-band noise, narrow-band noise or discrete tones. ISO 9295 specifies four methods for the determination of sound power levels emitted by machinery, equipment and products in the frequency range covered by the 16 kHz octave band. In 5.6, ISO 9295 is briefly described.

More detailed definitions than those specified in this document can be found in ISO 3741, ISO 3743-1, ISO 3743-2, ISO 3744, ISO 3745, ISO 3746 and ISO 3747, in ISO 9614-1 to ISO 9614-3, ISO/TS 7849-1, ISO/TS 7849-2, and in noise test codes for specific types of machinery, equipment and products.

Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards

1 Scope

This document gives guidance for the use of a set of twelve basic International Standards (see Tables 1, 2 and 3) describing various methods for determining sound power levels from all types of machinery, equipment and products. It provides guidance on the selection of one or more of these standards, appropriate to any particular type of sound source, measurement environment and desired accuracy. The guidance given applies to airborne sound. It is for use in the preparation of noise test codes (see ISO 12001) and also in noise emission testing where no specific noise test code exists. Such standardized noise test codes can recommend the application of particular basic International Standard(s) and give detailed requirements on mounting and operating conditions for a particular family to which the machine under test belongs, in accordance with general principles given in the basic standards.

This document is not intended to replace any of the details of, or add any additional requirements to, the individual test methods in the basic International Standards referenced.

NOTE 1   Two quantities which complement each other can be used to describe the noise emission of machinery, equipment and products. One is the emission sound pressure level at a specified position and the other is the sound power level. The International Standards which describe the basic methods for determining emission sound pressure levels at work stations and at other specified positions are ISO 11200 to ISO 11205 (References [20] to [25]).

NOTE 2   The sound energy level mentioned in ISO 3741 to ISO 3747 is not addressed in this document as it is not mentioned in any legal requirement. Its application is limited to very special cases of a single burst of sound energy or transient sound defined in ISO 12001.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
emission
<acoustics> airborne sound radiated by a well-defined noise source (e.g. the machine under test) under specified operating and mounting conditions

Note 1 to entry: Emission values may be incorporated into a product noise declaration, product label and/or product specification. The basic noise emission quantities are the sound power level of the source itself and the emission sound pressure levels at the work station and/or at other specified positions (if any) in the vicinity of the source.

[SOURCE: ISO 12001:1996, 3.3, modified — Note 1 to entry "product noise declaration" added.]

3.2
sound power
P

through a surface, product of the sound pressure, *p*, and the component of the particle velocity, u_n, at a point on the surface in the direction normal to the surface, integrated over that surface

Note 1 to entry: Sound power is expressed in watts.

Note 2 to entry: The quantity relates to the rate at which airborne sound energy is radiated by a source.

[SOURCE: ISO 80000-8:2007, 8-16, modified — Notes 1 and 2 to entry added.]

3.3
sound power level
L_W

ten times the logarithm to the base 10 of the ratio of the *sound power*, *P* (3.2), of a source to a reference value, P_0, expressed in decibels

$$L_W = 10 \lg \frac{P}{P_0} \, \mathrm{dB}$$

where the reference value, P_0, is 1 pW

Note 1 to entry: If a specific frequency weighting as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; e.g. L_{WA} denotes the A-weighted sound power level.

Note 2 to entry: This definition is technically in accordance with ISO 80000-8:2007, 8-23.

Note 3 to entry: lg ( ) = $\lg_{10}$ ( ) in all relevant parts of the standard.

[SOURCE: ISO/TR 25417:2007, 2.9, modified — Note 3 to entry added.]

3.4
structure vibration generated sound
airborne sound caused by structural vibration in the audible frequency range

Note 1 to entry: In the ISO/TS 7849 series, structure vibration generated sound is determined either from the vibratory velocity or from the vibratory acceleration of the surface of the solid structure.

[SOURCE: ISO/TS 7849-1:2009, 3.1, modified — Expression "In the ISO/TS 7849 series" used for clarification instead of "For the purpose of this part of ISO/TS 7849".]

3.5
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

$$L_p = 10 \lg \frac{p^2}{p_0^2} \, \mathrm{dB}$$

where the reference value, p_0, is 20 µPa

[SOURCE: ISO/TR 25417:2007, 2.2, modified — Notes 1 and 2 deleted.]

3.6
time-averaged sound pressure level
$L_{p,T}$
ten times the logarithm to the base 10 of the ratio of the time average of the square of the sound pressure, p, during a stated time interval of duration, T (starting at t_1 and ending at t_2), to the square of a reference value, p_0, expressed in decibels

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

where the reference value, p_0, is 20 µPa

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

Note 2 to entry: 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}.

Note 3 to entry: Adapted from ISO/TR 25417:2007, 2.3.

[SOURCE: ISO 3744:2010, 3.3]

3.7
single event time-integrated sound pressure level
L_E
ten times the logarithm to the base 10 of the ratio of the integral of the square of the sound pressure, p, of an isolated single sound event (burst of sound or transient sound) over a stated time interval T (starting at t_1 and ending at t_2), to a reference value, E_0, expressed in decibels

$$L_E = 10\lg\left[\frac{\int_{t_1}^{t_2}p^2(t)\mathrm{d}t}{E_0}\right]\mathrm{dB}$$

where the reference value, E_0, is $(20\ \mu\text{Pa})^2$ s = 4×10^{-10} Pa^2 s

Note 1 to entry: This quantity can be obtained by

$$L_{p,T} + 10\lg\left[\frac{T}{T_0}\right]\mathrm{dB}$$

where T_0 = 1 s.

Note 2 to entry: When used to measure sound immission, this quantity is usually called "sound exposure level" (see ISO/TR 25417:2007).

[SOURCE: ISO 3744:2010, 3.4]

3.8
sound intensity
$\vec{I}$

$$\vec{I} = p\cdot\vec{u}$$

where

p is the sound pressure, in Pa;

$\vec{u}$ is the sound particle velocity, in m/s.

Note 1 to entry: $\vec{u}$ and $\vec{I}$ are vectorial quantities.

3.9
vibratory velocity
v

root-mean square (RMS) value of the component of the velocity of a vibrating surface in the direction normal to the surface

Note 1 to entry: In ISO/TS 7849-1, the vibratory velocity is applied with an A-weighting, denoted v_A.

[SOURCE: ISO 7849-1:2009, 3.3, modified — Former Note 1 to entry deleted, expression "In ISO/TS 7849-1" used for clarification instead of "In this part of ISO/TS 7849" in former Note 2, now Note 1.]

3.10
vibratory velocity level
L_v

ten times the logarithm to the base 10 of the ratio of the square of the RMS value of the vibratory velocity, v, to the square of a reference value, v_0, expressed in decibels:

$$L_v = 10 \lg \frac{v^2}{v_0^2} \, \mathrm{dB}$$

where

v is the RMS value of the vibratory velocity, in metres per second;

v_0 is the reference value for the velocity and is equal to 5×10^{-8} m/s.

Note 1 to entry: For airborne and structure vibration generated sound, the reference value, $v_0 = 50$ nm/s has the property that it leads, together with $p_0 = 2 \times 10^{-5}$ Pa, to the reference value of the intensity level $I_0 = 1 \times 10^{-12}$ W/m^2 and to a characteristic impedance of air of $p_0/v_0 = 400$ Pa·s/m.

Note 2 to entry: In ISO/TS 7849-1, the vibratory velocity level is applied as A-weighted vibratory velocity level, L_{vA}, by substituting v^2 for the A-weighted RMS v_A^2 in ISO/TS 7849-1:2009, Formula (6).

Note 3 to entry: In ISO 1683, two reference values for the velocity level are mentioned: $v_0 = 10^{-9}$ m/s and 5×10^{-8} m/s. The latter is intended for cases of airborne and structure vibration generated sound and is therefore used in ISO/TS 7849-1 and ISO/TS 7849-2. A choice of $v_0 = 10^{-9}$ m/s results in a vibratory velocity level which is 34 dB higher than the level used in both parts of ISO/TS 7849. Therefore, if $v_0 = 10^{-9}$ m/s is used, subtract 34 dB from the right-hand sides of the first formula in 3.10.

3.11
radiation factor
ε

factor expressing the efficiency of airborne *sound power* (3.2) radiation from the vibrating surface

Note 1 to entry: See ISO/TS 7849-1:2009, 4.4.1 to 4.4.4.

3.12
background noise
noise from all sources other than the noise source under test

Note 1 to entry: Background noise includes contributions from airborne sound, noise from structure-borne vibration, and electrical noise in the instrumentation.

[SOURCE: ISO 3744:2010, 3.15]

3.13
background noise level
sound pressure level (3.5) measured when the source under test is not operating

Note 1 to entry: It is expressed in decibels.

3.14
extraneous vibratory velocity level
vibratory velocity level (3.10) caused by all sources other than the source under test

Note 1 to entry: Extraneous vibratory velocity levels originate, for example, from coupled assemblies.

[SOURCE: ISO/TS 7849-1:2009, 3.9]

3.15
background noise correction
K_1
correction applied to the mean (energy average) of the *time-averaged sound pressure levels* (3.6) over all the microphone positions on the measurement surface, to account for the influence of *background noise* (3.12)

Note 1 to entry: Background noise correction is expressed in decibels.

Note 2 to entry: The background noise correction is frequency dependent; the correction of a frequency band is denoted K_{1f}, where f denotes the relevant center frequency, and that in the case of A-weighting is denoted K_{1A}.

[SOURCE: ISO 3744:2010, 3.16]

3.16
environmental correction
K_2
correction applied to the mean (energy average) of the *time-averaged sound pressure levels* (3.6) over all microphone positions on the measurement surface, to account for the influence of reflected or absorbed sound

Note 1 to entry: Environmental correction is expressed in decibels.

Note 2 to entry: The environmental correction is frequency dependent; the correction in the case of a frequency band is denoted K_{2f}, where f denotes the relevant mid-band frequency, and that in the case of A-weighting is denoted K_{2A}.

Note 3 to entry: In general, the environmental correction depends on the area of the measurement surface and usually K_2 increases with S.

[SOURCE: ISO 3744:2010, 3.17]

3.17
systematic deviation
Δ_{sy}
deviation to account for a systematic difference between *sound power levels* (3.3) obtained using basic standards based on different physical rules

Note 1 to entry: Δ_{sy} is not covered in the basic standards. See 4.4 and Annex C.

Note 2 to entry: $\Delta_{sy,pI}$ describes specifically the systematic deviation between the sound power level yielded by the intensity method, $L_{W,I}$, compared with the result from free field sound pressure measurements, $L_{W,p}$: $\Delta_{sy,pI} = L_{W,p} - L_{W,I}$; otherwise $\Delta_{sy,pI}$ is also designated as near field error.

Note 3 to entry: Systematic deviations can also appear when environmental correction, K_2, is determined according to different procedures from the basic standards.

3.18
background noise index
ΔL_p
index denoting the difference, in decibels, between the *sound pressure levels* (3.5) from the noise source under test in operation and the sound pressure levels of the *background noise* (3.12), both measured using an array of microphone positions over the measurement surface

3.19
dynamic capability index
L_d
index given by

$$L_d = \delta_{pI_0} - K$$

where

δ_{pI_0} is the pressure-residual intensity index, in decibels;

K is the bias error, in decibels.

Note 1 to entry: The dynamic capability index is expressed in decibels.

Note 2 to entry: The dynamic capability index describes the quality of the intensity measurement system to suppress unwanted background noise. It is used to check the attainment of the desired accuracy level, where K is selected to be 10 dB for grade 1 and 2 measurements and 7 dB for grade 3 measurements.

3.20
standard deviation of reproducibility of the method
σ_{R0}
uncertainty associated with a *sound power* (3.2) measurement method excluding the uncertainty due to the instability of the sound power of the source under test

Note 1 to entry: σ_{R0} is determined from round robin tests on an extreme stable source. It does not include uncertainty components like σ_{omc} and Δ_{sy} and consequently does not represent the total uncertainty.

3.21
standard deviation due to operating and mounting conditions of the sound source
σ_{omc}
uncertainty associated with the instability of the operating and mounting conditions for the particular source under test

3.22
total standard deviation
σ_{tot}
square root of the sum of the squares of the *standard deviation of reproducibility of the method* (3.20) and the *standard deviation due to operating and mounting conditions* (3.21)

$$\sigma_{tot} = \sqrt{\sigma_{R0}^2 + \sigma_{omc}^2}$$

3.23
accuracy grade
grade characterising three different classes of uncertainty in determining *sound power levels* (3.3) based on the *standard deviations of reproducibility of the method*, σ_{R0} (3.20)

Note 1 to entry: The grade classification provides an indication of the required measurement effort.

Note 2 to entry: It is described by typical upper bound values.

Note 3 to entry: σ_{R0} does not include uncertainty components like σ_{omc} and Δ_{sy} and consequently does not represent the total uncertainty.

3.24
expanded measurement uncertainty
U
characteristic value identifying a range around the measurement result or calculation within which an estimate of values is expected to lie

4 Sound power level

4.1 Basic information

The sound power level characterizes the mean airborne acoustic energy flow from the source into the environment for a given mounting and operating condition and represents an intrinsic acoustic characteristic of the source that is independent of the environment in which it is installed. It is often denoted as an A-weighted sound power level, L_{WA}, in dB.

4.2 Reasons for the determination of sound power levels

Example situations where the A-weighted sound power level of a machine, equipment and product can be of interest are:

— manufacturer noise emission declarations in the instructions and the sales literature according to regulations for machinery safety;

— customer need for input to sound exposure prediction models which can support legal requirements for carrying out a noise exposure risk assessment;

— customer need for comparison with the state of the art of noise emission, for comparing the data of competing machinery, equipment and products to support the "Buy Quiet" objective;

— checking the noise emission level of machinery, equipment and products in specifications regardless of the environment in which they operate.

4.3 Basic procedures for determining sound power levels

Sound pressure, sound intensity and vibratory velocity level measurements form the basis of different procedures to determine sound power level. These procedures include

— evaluation of the spatial mean-squared sound pressure built up in highly reflective environments (ISO 3741, ISO 3743-1, ISO 3743-2);

— comparison of the sound pressure levels in octave frequency bands of a noise source under test with those of a calibrated reference sound source (ISO 3747);

— evaluation of the flow of sound energy by a direct measurement of the sound intensity (ISO 9614-1, ISO 9614-2, ISO 9614-3) near the source or the free field approximation of the intensity through measurement of the squared sound pressure (ISO 3744, ISO 3745, ISO 3746) emitted by the source, both measurements carried out on an enveloping surface;

— evaluation of the partial flow of airborne sound energy emitted by vibrating solid structures of the machine, using measurements of the vibratory velocity over the surface of vibrating solid structures (ISO/TS 7849-1, ISO/TS 7849-2).

Microphones used to measure the sound pressure level at specific positions around the source under test measure the sum of the direct sound from the source and the contributions from other sound sources in the measurement room plus the sound which is reflected by walls, floor, ceiling and obstacles. Therefore, corrections to cope with these influences are required in practice. These are the background noise correction, K_1, and the environmental correction, K_2. Please refer to Annex D for examples of practical applications of ISO 3744 and ISO 3746.

In contrast to sound pressure measurements, sound intensity measurements used for determining the sound power level are less sensitive to steady state background noise and the environment, provided that the capacity of the measurement instrument is not exceeded. Background noise that fluctuates cyclically needs an adequately longer integration time at each measurement position. In principle, this measurement approach provides a measure of the sound power radiated directly into the air by all sources located within the enclosing surface, and excludes sound radiated by sources, including mirror sources resulting from sound reflections, located outside the enveloping surface.

Owing to differences in meteorological conditions, sound power level measurements at different test facilities can yield considerably different results. For example, measurements of sound power level at high altitude cause an underestimate of the sound power level when compared to measurements at sea level. Therefore, many of the above mentioned measurement procedures except ISO 9614-1 and ISO 9614-2 include corrections to allow for any differences that can exist between the meteorological conditions under which the tests are conducted and reference meteorological conditions. ISO/TS 7849-1 and ISO/TS 7849-2 yield by definition the sound power level under reference meteorological conditions.

4.4   Quality of determined sound power levels

Sound power levels determined according to different methods include different random and systematic deviations. Random deviations are clearly dealt with in the present sound power measurement standards but systematic ones are not addressed.

Assuming a repeated application of the same measurement standard, a randomly distributed spread of results can be expected. These deviations are caused

— by an inadequate approximation in practice of the relevant physical relations on which the measurement method is based, represented by σ_{R0}, and

— by inaccuracies when adjusting the machine, equipment, product to the predefined operating and mounting conditions, e.g. those specified in the relevant noise test code, represented by σ_{omc}.

For the set of basic International Standards, three different classes of accuracy grades (see 3.24) define the quality of the determined sound power value. These are:

— accuracy grade 1, called precision grade,

— accuracy grade 2, called engineering grade, and

— accuracy grade 3 ,called survey grade.

These correspond to different measurement efforts and conditions, e.g. characteristics of the measurement environment or background noise.

For legal reasons or contractual ones between a manufacturer and a customer, minimum requirements on the accuracy of the measured sound power level can be stated in the instructions, in sales catalogues containing performance data or in sales contracts. For most uses, the application of methods providing engineering grade (grade 2) results is expected to be satisfactory.

It is common to include information about the uncertainty of the determined quantity when providing measurement results. In practice, this is done through the expanded measurement uncertainty, U. Annex C provides detailed information on measurement uncertainty for sound power level determined according to one of the methods described in this document.

4.5   Noise emission declaration

The sound power level determined according to one of the methods described in this International Standard and the related uncertainty are two quantities that are used by manufacturers of machinery, equipment and products when preparing noise emission declarations according to noise test codes. Formats for noise emission declarations and procedures for declaration and verification are presented in ISO 4871.

5   Selection of the most appropriate method in the set of standards

5.1   Methods and quantities to be measured and determined

Tables 1, 2 and 3 give a rather detailed overview of the available basic International Standards describing methods for the determination of the airborne sound power level, either A-weighted or in frequency bands. The tables distinguish between those methods which are based on sound pressure level measurements (ISO 3741 to ISO 3747), sound intensity measurements (ISO 9614-1 to ISO 9614-3) and vibratory velocity measurements (ISO/TS 7849-1 and ISO/TS 7849-2). The ISO/TS 7849 methods only consider that part of the airborne sound power level which is caused by vibrating solid structures of the source under test and therefore exclude aerodynamically generated noise. Therefore, they will normally only be used in practice when other methods cannot reliably be applied or for machinery development purposes.

The sound power levels determined may be time-averaged, frequency-weighted, in frequency bands or time-weighted. The most commonly used frequency weighting is A-weighting.

Annex A provides an overview of the main facts and requirements of the basic International Standards for determining sound power levels of machines, equipment and products.

5.2   Considerations affecting the selection of a measurement method

There are many factors influencing a proper selection of basic International Standards for determining sound power level. Figure 1 provides a guide based on the selection via the different parameters and environment to be considered.
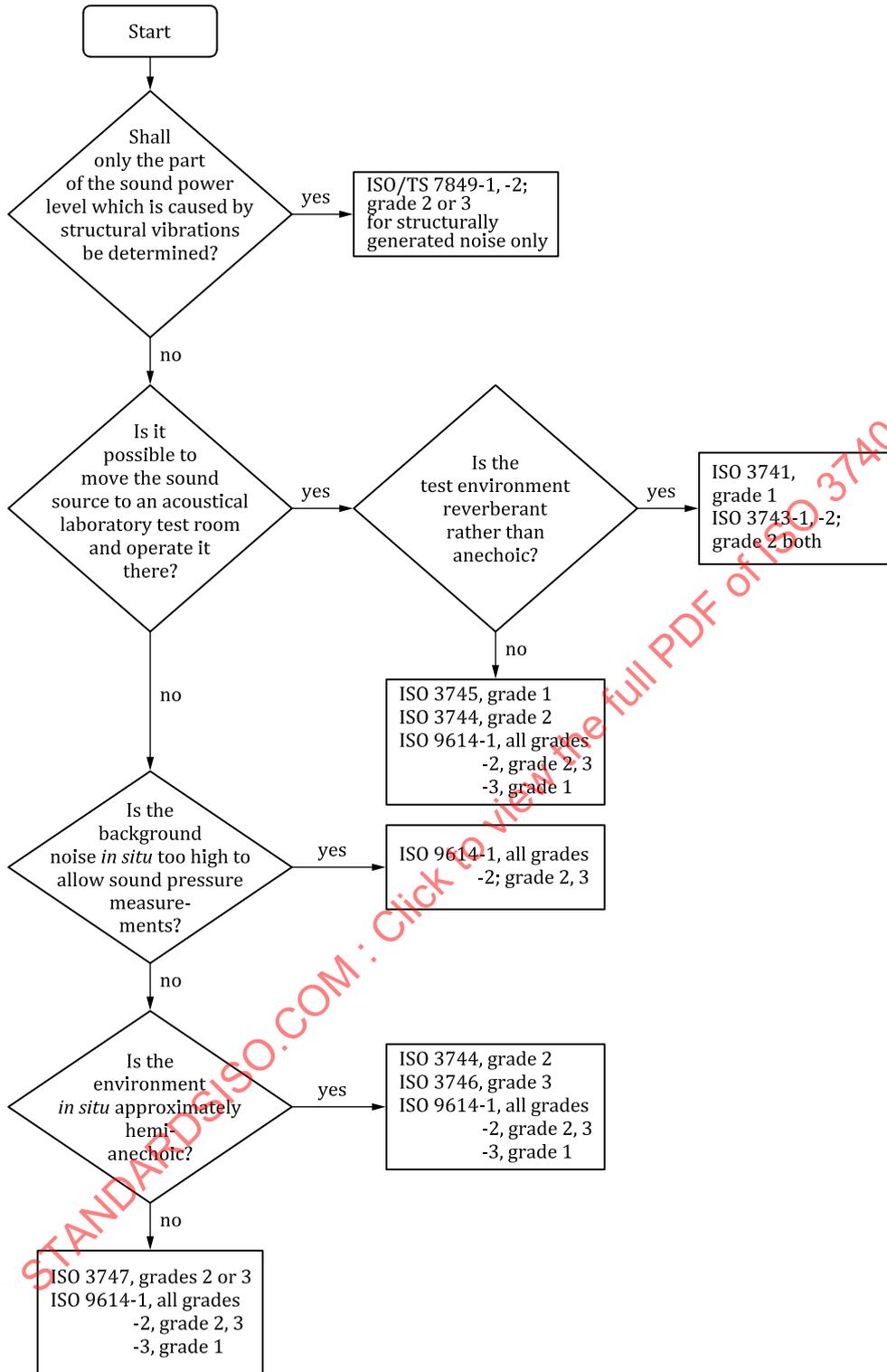
Figure 1 — Flowchart guiding the selection of appropriate International Standards for the determination of sound power levels

Some important parameters to consider because they influence the selection of a suitable method are:

— the existence of a relevant noise test code or procedure making reference to one or more basic standards;

— the kind of sound power level desired, i.e. the total radiated airborne sound power level or only that portion caused by radiated structural vibrations;

— the type of sound power level desired (frequency-weighted or in frequency bands, frequency range of interest);

— the grade of accuracy desired;

— the measurement environment to be used for the test (in situ, essential free field, laboratory rooms or special test rooms such as free field or reverberant rooms), together with the size and transportability of the source under test that determine the practicability of setting up and operating the source in an acoustical test laboratory;

— the background noise level;

— the character of the noise produced by the source (e.g. broad-band, narrow-band, discrete-frequency; steady, non-steady, impulsive);

— the acoustical instrumentation available (sound pressure level meters, sound intensity measurement systems);

— further acoustical information desired (e.g. directivity of source, time history of the generated sound).

In contrast to Tables 1 and 2, Table A.1 gives a more restricted overview on the set of standards concentrating on aspects like the grade of accuracy of the method, the required test environment, the volume of the source, the character of the noise and the obtainable sound power levels.

NOTE 1   The preferred grade of accuracy for the purpose of preparing a noise emission declaration is engineering (grade 2).

NOTE 2   All standards within a specific grade imply the same level of accuracy apart from systematic deviations existing between results of different measurement methods.

Table 1 — Overview of International Standards for the determination of sound power levels of machines, equipment and products using sound pressure

Parameter	Methods based on sound pressure level measurements						
	ISO 3741	ISO 3743-1	ISO 3743-2	ISO 3744	ISO 3745	ISO 3746	ISO 3747
Grade of accuracy	Precision	Engineering	Engineering	Engineering	Precision	Survey	Engineering or survey
Test environment	Reverberation test room	Hard-walled room	Special reverberation test room	Essentially free-field over a reflecting plane	Anechoic or hemi-anechoic test room	In situ over a reflecting plane	Essentially reverberant field in situ
Requirements on test environment	Room volume and reverberation to be qualified	Volume 40 times > than reference box volume, Volume >40 m³, Absorption coef. ≤ 0,20	70 m³ ≤ volume ≤ 300 m³	$K_{2A} \le 4$ dB	Measurement environment specifically qualified	$K_{2A} \le 7$ dB	Subject to qualification requirements
Volume of source under test	Preferably less than 2 % of test room volume	Preferably less than 1 % of test room volume	Preferably less than 1 % of test room volume	No restrictions; limited only by available test environment	Characteristic dimension less than half the measurement radius	No restrictions; limited only by available test environment	No restrictions; limited only by available test environment
Character of sound from the source	Steady, broad-band, narrow-band or discrete frequency	Any, but no isolated bursts	Any, but no isolated bursts	Any	Any	Any	Steady, broad-band, narrow-band or discrete frequency
Frequency range of interest	1/3-octave bands with center frequencies from 100 Hz to 10 000 Hz	Octave bands with center frequencies from 125 Hz to 8 000 Hz	Octave bands with center frequencies from 125 Hz to 8 000 Hz	1/3-octave bands with center frequencies from 100 Hz to 10 000 Hz	1/3-octave bands with center frequencies from 100 Hz to 10 000 Hz	Octave bands with center frequencies from 125 Hz to 8 000 Hz	Octave bands with center frequencies from 125 Hz to 8 000 Hz
Limitation for background noise	$\Delta L_p \ge 10$ dB, $K_1 \le 0{,}5$ dB	$\Delta L_p \ge 6$ dB, $K_1 \le 1{,}3$ dB	$\Delta L_p \ge 4$ dB, $K_1 \le 2$ dB	$\Delta L_p \ge 6$ dB, $K_1 \le 1{,}3$ dB	$\Delta L_p \ge 10$ dB, $K_1 \le 0{,}5$ dB	$\Delta L_p \ge 3$ dB, $K_1 \le 3$ dB	$\Delta L_p \ge 6$ dB, $K_1 \le 1{,}3$ dB
Instrumentation: Class of accuracy	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1

Table 1 (continued)

Methods based on sound pressure level measurements

Parameter	ISO 3741	ISO 3743-1	ISO 3743-2	ISO 3744	ISO 3745	ISO 3746	ISO 3747
Obtainable sound power levels	A-weighted and in one-third-octave or octave bands	A-weighted and in octave bands	A-weighted and in octave bands	A-weighted and in one-third-octave or octave bands	A-weighted and in one-third-octave or octave bands	A-weighted	A-weighted from octave bands
Standard deviation of reproducibility	$\sigma_{R0} \leq 0,5$ dB for A-weighted sound power levels	$\sigma_{R0} \leq 1,5$ dB for A-weighted sound power levels	$\sigma_{R0} \leq 2$ dB for A-weighted sound power levels	$\sigma_{R0} \leq 1,5$ dB for A-weighted sound power levels	$\sigma_{R0} \leq 0,5$ dB for A-weighted sound power levels	$\sigma_{R0} \leq 3$ dB for sound without significant tones	$\sigma_{R0} \leq 1,5$ dB for A-weighted sound power levels; 4 dB depending on a sound field indicator
Quantities to be measured	Sound pressure levels, time-averaged or single event time-integrated, in one-third-octave-frequency bands at specified fixed microphone positions or along specified paths. Measurements can be made using either the direct method or the comparison method using a reference sound source.	Sound pressure levels, time-averaged or single event time-integrated, A-weighted and/or in frequency bands, at specified fixed microphone positions or along specified paths	1. Sound pressure levels time averaged or single event time-integrated at fixed positions or on paths 2. Sound pressure levels in octave bands and A-weighted ones calculated from the band values if the comparison method was applied	Sound pressure levels, time-averaged or single event time-integrated, A-weighted and/or in frequency bands, at specified fixed microphone positions or along specified paths	Sound pressure levels in one-third-octave frequency bands, at specified fixed microphone positions or along specified paths	A-weighted sound pressure levels, time-averaged or single event time-integrated, at specified fixed microphone positions or along specified paths	Sound pressure levels, time-averaged or single event time-integrated, in octave bands at specified fixed microphone positions
Sound power levels that can be determined	Sound power levels in one-third octave bands, A-weighted calculated from band values if applicable	Sound power levels in one-third octave bands, A-weighted calculated from band values if applicable	Sound power levels: 1. Direct method: A-weighted 2. Comparison method: octave bands or A-weighted levels calculated from octave-bands	Sound power levels, A-weighted and/or in frequency bands	Sound power levels, A-weighted and/or in frequency bands	A-weighted sound power levels	Sound power levels in octave bands; A-weighted calculated from octave-band levels

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Table 2 — Overview of International Standards for the determination of sound power levels of machines, equipment and products applying sound intensity measurements

Parameter	ISO 9614-1	ISO 9614-2	ISO 9614-3
Grade of accuracy	Precision, engineering and survey depending on specialised ancillary tests	Engineering and survey depending on specialised ancillary tests	Precision, depending on specialised ancillary tests
Test environment	Any test environment satisfying specified requirements in relation to the instrumentation used	Any test environment satisfying specified requirements in relation to the instrumentation used	Any test environment satisfying specified requirements in relation to the instrumentation used
Requirements on test environment	Specified requirements on: — extraneous noise — wind, gas flow, temperature — test surroundings to remain unchanged during the performance of a test	Specified requirements on: — extraneous noise — wind, gas flow, temperature — test surroundings to remain unchanged during the performance of a test	Specified requirements on: — extraneous noise — wind, gas flow, temperature — test surroundings to remain unchanged during the performance of a test
Volume of source under test	No restrictions	No restrictions	No restrictions
Character of sound from the source	Broad-band, narrow-band or discrete frequency but stationary in time	Broad-band, narrow-band or discrete frequency but stationary in time	Broad-band, narrow-band or discrete frequency but stationary in time
Frequency range of interest	1/3-octave bands with center frequencies from 50 Hz to 6,3 kHz	1/3-octave bands with center frequencies from 50 Hz to 6,3 kHz	1/3-octave bands with center frequencies from 50 Hz to 6,3 kHz
Limitation for background noise respectively extraneous intensity or vibratory velocity	Level: given by the dynamic capability of the instrumentation (typically: $\Delta L \geq 10$ dB) Variability: specified requirement for field indicator F1	Level: given by the dynamic capability of the instrumentation (typically: $\Delta L \geq 10$ dB) Variability: specified requirement for repeatability check	Level: extraneous intensity to be minimized so that it does not unacceptably reduce measurement accuracy Variability: specified requirement for repeatability check
Instrumentation: Class of accuracy	Sound intensity instrument: class 1 for grade 1 and grade 2, class 2 for grade 3 of accuracy	Sound intensity instrument: class 1 for grade 1 and grade 2, class 2 for grade 3 of accuracy	Class 1 sound intensity instrument
Obtainable sound power levels	A-weighted and in one-third-octave or octave bands	A-weighted and in one-third-octave or octave bands	A-weighted and in one-third-octave or octave bands

Table 2 *(continued)*

Parameter	ISO 9614-1	ISO 9614-2	ISO 9614-3
Standard deviation of reproducibility	$\sigma_{R0} \leq 0{,}5$ dB for A-weighted sound power levels	$\sigma_{R0} \leq 1{,}5$ dB for A-weighted sound power levels	$\sigma_{R0} \leq 1$ dB for A-weighted sound power levels
Quantities to be measured	Sound intensity levels and sound pressure levels on a measurement surface enclosing the source	Sound intensity levels and sound pressure levels on a measurement surface enclosing the source	Sound intensity levels and sound pressure levels on a measurement surface enclosing the source
Sound power levels and other quantities that can be determined	Sound power levels and field indicators in octave of as one-third-octave frequency bands or band-limited or weighted levels	Sound power levels and field indicators in octave or one-third-octave frequency bands or band-limited or weighted levels	Sound power levels in one-third-octave frequency bands or as band-limited or weighted levels

Table 3 — Overview of International Standards for the determination of sound power levels of machines, equipment and products using vibration measurement

Parameter	ISO/TS 7849-1	ISO/TS 7849-2
Grade of accuracy	Survey	Engineering
Test environment	Any environment in situ	Any environment in situ
Requirements on test environment	Sources of extraneous vibratory velocity should be identified and the use of correlation measurements or the comparison of vibration spectra of coupled assemblies can be necessary.	Sources of extraneous vibratory velocity should be identified and the use of correlation measurements or the comparison of vibration spectra of coupled assemblies can be necessary.
Volume of source under test	No restrictions	No restrictions
Character of sound from the source	Any but with negligible aerodynamically generated sound	Any but with negligible aerodynamically generated sound
Frequency range of interest	Limited by the characteristics of the applied accelerometer	Limited by the characteristics of the applied accelerometer
Limitation for background noise respectively extraneous intensity or vibratory velocity	$\Delta L \geq 3$ dB for the difference between the averaged A-weighted extraneous vibratory velocity level and the mean vibratory velocity level due to the noise source under test in operation	At least $\Delta L \geq 3$ dB for the difference between the averaged A-weighted extraneous vibratory velocity level and the mean vibratory velocity level due to the noise source under test in operation, preferably $\Delta L \geq 15$ dB
Instrumentation: Class of accuracy	Specific requirements on vibration transducers and non-contacting transducers	Specific requirements on vibration transducers and non-contacting transducers
Obtainable sound power levels	A-weighted sound power levels emitted by vibrating surfaces of solid structures, noise generated aerodynamically is not included	Primarily sound power levels in frequency bands emitted by vibrating surfaces of solid structures, noise generated aerodynamically is not included
Standard deviation of reproducibility	A standard deviation of reproducibility $\sigma_{R0} \leq 3$ dB for A-weighted sound power levels	Given in octave bands center with frequencies from $\sigma_{R0} \leq 3$ dB for 100 Hz to 0,5 dB for 8 000 Hz, $\sigma_{R0} \leq 1,5$ dB for A-weighted results
Quantities to be measured	A-weighted vibratory velocity levels measured on the vibrating surface in the direction normal to the surface	A-weighted vibratory velocity levels measured on the vibrating surface in the direction normal to the surface plus measurements in frequency bands
Radiation factor	Radiation factor is taken as unity ($\varepsilon = 1$) independent of frequency, yielding an upper limit for the determined sound power level	Use of specific data of the radiation factor ε for the machines under test
Sound power levels and other quantities that can be determined	A-weighted sound power levels	Primarily sound power levels in frequency bands and A-weighted sound power level calculated from frequency band levels

5.3   Test environment

Annex B describes the test environments considered in the different measurement standards.

A general distinction is made between methods requiring acoustical laboratory rooms, or at least special test rooms, and those that are applicable in situ e.g., industrial production shops. For the latter, ISO 3744, ISO 3746, ISO 3747 and ISO 9614-2 are recommended. ISO/TS 7849-1 and ISO/TS 7849-2 are only applicable if the sound power level from sources without aerodynamic noise is to be determined.

When preparing a noise test code or in the case where the sound power level of an individual sound source is to be determined, a first step consists of choosing the place where the machine, equipment or product can be measured under practical operating and mounting conditions. If the machine, equipment or product can be transported to a special test site or acoustical laboratory room, the sound power level can be determined with a good accuracy to measurement effort ratio. Otherwise, only in situ measurements are practical.

5.4   Selection of basic standards appropriate for measurements in laboratory rooms and special test rooms

5.4.1   General

The determination of the airborne sound power level of a sound source requires the measurement of acoustical field quantities and the application of fundamental acoustic formulas. Hence measurement conditions such as well controlled and defined acoustic environments are beneficial. Laboratories provide such favourable environments. Optimal acoustic environments are:

— test sites providing reverberant sound fields using ISO 3741, ISO 3743-1 or ISO 3743-2;

— test sites providing an undisturbed propagation of sound within the space between the source under test and the measurement positions. The environments described by ISO 3745 and ISO 3744 which are designated as free field or free field over a reflective plane allow the determination of the sound power level under anechoic or hemi-anechoic conditions.

NOTE   The sound intensity measurement technique described in ISO 9614-1, ISO 9614-2, ISO 9614-3 has the advantage of suppressing undesired environmental influences such as room reflections and background noise, thus approximating free field laboratory conditions.

5.4.2   Acoustical requirements on the sound field in laboratories and special test rooms

Guidelines for the design of acoustic laboratories and special test rooms together with normative procedures for testing the required quality of these test sites are given in

— ISO 3741:2010, Annexes A, C and D for reverberation test rooms;

— ISO 3743-1:2010, 4.3 for hard-walled rooms, ISO 3743-2:2018, Annex B for special reverberation test rooms;

— ISO 3744:2010, Annex A for hemi-anechoic test rooms, (especially those with K_{2A} less than 4 dB);

— ISO 3745:2012, Annexes A and B for anechoic and hemi-anechoic test rooms.

5.4.3   Background noise limitation

The existence of background noise at the measuring location is an important factor influencing the applicability of the different measurement methods. This not only applies to those methods requiring the measurement of sound pressure levels to determine the sound power level but also, to a much lesser degree, to the sound intensity measurement methods. In both cases, a stationary background noise during the whole measurement time is essential. However, considering the sound power determination in acoustic laboratories and special test rooms, background noise is normally less problematic compared to measurements in situ. There are sound sources, e.g. hydraulic pumps or compressors,

where the determination of the sound power level can be seriously disturbed by the sound radiated from attached pipes, which in fact is background noise.

In ISO 3741 and ISO 3745, the requirement is that the difference between the level of the background noise and that of the source under test be at least

— 6 dB for one-third-octave bands of center frequency 200 Hz and below, and 6 300 Hz and above, and

— 10 dB for one-third-octave bands of center frequency from 250 Hz to 5 000 Hz.

In ISO 3743-1, the requirement is that this difference in octave bands be at least 6 dB and preferably more than 15 dB.

In ISO 3743-2, the requirement is that this difference in frequency bands or with A-weighting be at least 4 dB and preferably more than 10 dB.

ISO 9614 (all parts) is dependent on the dynamic capability index of the sound intensity measurement system which must satisfy the requirements of the actual sound field conditions. For stationary background noise, it can be possible to obtain reliable measurement results even if the background noise levels exceed the noise levels produced by the source under test.

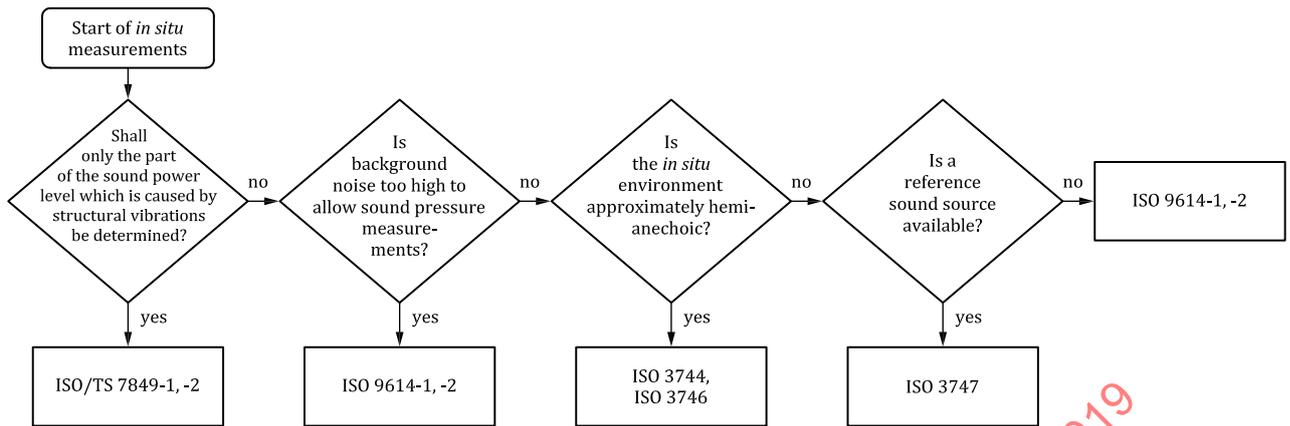## 5.5 Selection of basic standards appropriate for in-situ measurements

5.5.1 General

Sound power levels of machines, equipment and products can also be determined by measurements in the environment where the sources are usually installed and operated. Unlike laboratory or special test room measurements, such in situ measurements are characterised by unknown properties of the test environment. Consequently, procedures for applying corrections and the observation of specific limits are specified. Facts relating to in situ measurements are:

— a higher measurement effort is required due to the necessity of determining environmental corrections to achieve a good approximation of hemi-anechoic sound field conditions when e.g. applying ISO 3744 or ISO 3746;

— ISO 3744 or ISO 3746 can yield higher sound power levels compared to those obtained using a sound intensity method when measuring on a parallelepiped measurement surface;

— if a calibrated reference sound source is available, measurements of sound pressure levels in a sufficiently reverberant sound field can be made using ISO 3747 resulting in typically less measurement effort than other methods;

— the use of the sound intensity measurement method, ISO 9614 (all parts), requires a stationary background noise over the measurement time;

— vibration measurements according to ISO/TS 7849 (all parts) only yield the partial sound power radiated by the vibrating surface of solid structures (structure vibration generated sound).

A flowchart guiding the selection of adequate standards describing methods for the sound power level under in situ conditions is given in Figure 2.

NOTE 1   Grade 1 (precision grade) measurement methods are not explicitly mentioned in the flowchart as it is unlikely that they will be applicable under in situ conditions. However, in special cases, e.g. for the purpose of verifying noise emission declarations, the application of ISO 3745 or ISO 9614-3 can be possible depending on the magnitude of the environmental and background noise corrections.

Figure 2 — Flowchart guiding the selection of International Standards for the determination of sound power levels appropriate for in situ measurements

Measurements carried out in the presence of background noise distort the values of the measured sound pressure levels and — to a limited extent — those of measured sound intensity levels. Therefore, in order to minimize the effect of background noise, corrections are required. However, the magnitude of corrections restricts the application of the standards in practice.

This limitation is caused by the difficulty to separate the two sound components, the one which is radiated by the source under test and the other caused by noise from all other sources. The additional uncertainty due to greater background noise corrections affects the total measurement uncertainty.

Sound pressure methods in ISO 3744 and ISO 3746 require background noise levels $L_{p(\mathrm{B})}$ to remain significantly below the level L'_p measured when both the noise from the source under test and the undesired background noise are present. The difference $\Delta L_p = L'_p - L_{p(\mathrm{B})}$ is defined differently depending on the sound power determination method applied. Hence, it may be determined for each measurement position i, for a subset of these data, or as an average over all these data.

The requirements for the basic sound pressure standards are given in Table 4.

Table 4 — Applicability of different methods taking into account the background noise level

ΔL_p > 6 dB in each frequency band of interest	ΔL_p > 6 dB in each octave band of interest	ΔL_p > 3 dB for A-weighted quantities
ISO 3744	ISO 3747	ISO 3746

For the sound intensity measurement methods, ISO 9614 (all parts), the dynamic capability index L_d must satisfy the requirements stated in 5.4.3.

NOTE 2 L_d is supplied by the manufacturer of the instrumentation as a function of frequency. It can be checked using a procedure described in IEC 61043.

5.5.2   Hemi-anechoic sound field check

The sound field generated by machines in situ may approximate the ideal hemi-anechoic sound field as mentioned in 5.4.2. This is valid especially for measurement positions close to machines (sources under test) which are installed in large rooms or even in rooms containing a lot of objects, where the radiated sound is scattered and partly absorbed.

Basic standards ISO 3744 and ISO 3746 prescribe a check of this approximation in respect to the in situ applicability of these standards. This check includes different procedures to determine environmental corrections K_2 for the chosen measurement surface around the source under test in the room and gives

a range of K_2 values for which these standards can be applied. The upper limit of the environmental corrections for A-weighted quantities, K_{2A}, is:

— $K_{2A} \leq 4$ dB for ISO 3744

— $K_{2A} \leq 7$ dB for ISO 3746

Intensity methods in ISO 9614 (all parts) are in principle applicable to all sound fields within the required grade of accuracy, provided that the background noise limitation is fulfilled.

NOTE   For ISO 3744, K_2 can alternatively be determined unweighted for each frequency band over the frequency range of interest.

5.6   Determination of high-frequency sound power levels

ISO 9295 specifies four methods for the determination of the sound power levels of high-frequency noise emitted by machinery, equipment and products in the frequency range covered by the octave band centered at 16 kHz, which includes frequencies between 11,2 kHz and 22,4 kHz. The methods in ISO 9295 are complementary to the methods described in ISO 3741 and ISO 3744. The first three methods are based on the reverberation test room technique, and the fourth method makes use of a free field over a reflecting plane. Special precautions are necessary for measuring sound power levels in the 16 kHz octave band because of the effects of increased air absorption and sources with high directivity.

ISO 9295 is an engineering grade procedure, thus a grade 2 method. Measurements carried out in accordance with ISO 9295 yield standard deviations of reproducibility for the sound power level in the 16 kHz octave band equal to or less than 3 dB. The quantities to be measured are time-averaged sound pressure levels in the 16 kHz octave band. The measurement is performed by using a rotating boom traversing a circle or the sound pressure levels are measured at specified fixed microphone positions as described in ISO 3741 and ISO 3744, respectively.

Annex A
(informative)

Basic International Standards specifying methods for determining sound power levels of machines, equipment and products — Main facts and requirements

Table A.1 — Basic International Standards specifying various methods for determining sound power levels of machines, equipment and products

International Standard	Grade of accuracy of the method	Test environment	Volume of source	Character of noise	Sound power levels obtainable
ISO 3741	Grade 1 (precision)	Reverberation test room meeting specified requirements	Less than 2 % of test room volume	Steady, non-steady, fluctuating, isolated bursts of sound energy, broadband, discrete frequency	A-weighted and in octave bands or one-third-octave bands
ISO 3743-1	Grade 2 (engineering)	Hard-walled room	Less than 2,5 % of test room volume	Steady, non-steady, fluctuating, isolated bursts of sound energy	A-weighted and in octave bands
ISO 3743-2	Grade 2 (engineering)	Special reverberation test room	Preferably less than 1 % of test room volume	Steady, non-steady, fluctuating, broad-band, narrow-band, discrete frequency	A-weighted and in octave bands
ISO 3744	Grade 2 (engineering)	Hemi-anechoic test rooms, outdoors or in large rooms	No restrictions; limited only by available test environment	Any	A-weighted and in octave bands or one-third-octave bands
ISO 3745	Grade 1 (precision)	Anechoic- or hemi-anechoic test room, specified requirements	Characteristic dimension less than half the measurement radius	Any	A-weighted and in one-third-octave bands
ISO 3746	Grade 3 (survey)	No special test environment	No restrictions; limited only by available test environment	Any	A-weighted
ISO 3747	Grade 2 and 3 (engineering and survey)	No special test environment, but sufficiently reverberant; source under test non-movable	No restrictions; limited only by available test environment	Steady, non-steady, fluctuating, isolated bursts of sound energy, primarily broad-band	A-weighted and in octave bands
a Method to determine the sound power of airborne noise caused by machinery surface vibration specifically.					
b For measurements in anechoic or hemi-anechoic rooms limited by the size of the test room.					

Table A.1 *(continued)*

International Standard	Grade of accuracy of the method	Test environment	Volume of source	Character of noise	Sound power levels obtainable
ISO 9614-1	Grade 1, 2 and 3 (precision, engineering and survey)	No special test environment	No restrictions[b]	Any, but stationary in time	A-weighted and in octave bands or one-third-octave bands
ISO 9614-2	Grade 2 and 3 (engineering and survey)	No special test environment	No restrictions[b]	Any, but stationary in time	A-weighted and in octave bands or one-third-octave bands
ISO 9614-3	Grade 1 (precision)	No special test environment	No restrictions[b]	Any, but stationary in time	A-weighted and in octave bands or one-third-octave bands
ISO 7849-1[a]	Grade 3 (survey)	No special test environment	No restrictions	Any	A-weighted
ISO 7849-2[a]	Grade 2 (engineering)	No special test environment	No restrictions	Any	A-weighted and in octave bands or one-third-octave bands
[a] Method to determine the sound power of airborne noise caused by machinery surface vibration specifically.					
[b] For measurements in anechoic or hemi-anechoic rooms limited by the size of the test room.					

Annex B
(informative)

Acoustical test environments

B.1 Environments provided by acoustic test laboratories

B.1.1 General

The use of a laboratory room with defined acoustical properties yields the highest accuracy. However, laboratory facilities are costly and only machines that are transportable and small compared with the dimensions of the room can be tested. Moreover, the type of room that can be used depends on the character of the noise radiated by the machine under test. Facilities of the test room should allow for installing, mounting and operating the source under test in a manner that is typical for its normal use.

B.1.2 Reverberation test rooms

Reverberation test rooms as described in ISO 3741 are particularly suitable when it is necessary to conduct a large number of tests on machines (with volumes less than 2 % of the room volume) and when the sound emitted is predominantly steady in character. For larger machines, the reverberation test room needs to be substantially larger than the machine, equipment or product to be tested.

Reverberation test rooms do not provide information on directivity and are not suitable for measurements on impulsive noise sources. These rooms should be used with caution if the sound emitted by the source contains significant discrete-frequency and/or low-frequency components.

B.1.3 Special reverberation test rooms

Special reverberation test rooms which are constructed to meet the requirements of ISO 3743-2 are less expensive to build than the laboratory reverberation test rooms described in ISO 3741. The methods described in ISO 3743-2 provide measurements of engineering grade. These special reverberation test rooms are particularly suited for direct measurement of A-weighted sound levels; they are also useful for series measurements on small noise sources (volume less than 1 % of room volume). No information is obtained on the directivity characteristics of the sound sources under test.

B.1.4 Anechoic and hemi-anechoic test rooms

Anechoic and hemi-anechoic test rooms as described in ISO 3745 and hemi-anechoic test rooms as described in ISO 3744 are useful for measurements on small noise sources which emit different types of noise. Such rooms are particularly appropriate for measurements on sources which radiate impulsive noise or noise which contains discrete tones. The directivity characteristics of a source are preferably measured in such rooms.

Measurements which are carried out according to the requirements of ISO 3745 are of precision grade; hemi-anechoic rooms can also be used for measurements of engineering grade, according to the requirements of ISO 3744. In this case, measurements are also possible on considerably larger noise sources.

B.2 Environments in situ

B.2.1 Precision method (accuracy grade 1)

The methods described in ISO 9614-1 and ISO 9614-3 can provide, according to the results of specified ancillary tests and calculations performed in association with the measurements, results of precision grade of accuracy in ordinary rooms and under limited conditions outdoors. These methods are particularly suitable in the presence of stationary high background noise generated by sources other than that under test and sound reflections by the environment.

B.2.2 Engineering methods (accuracy grade 2)

Essentially free-field conditions over a reflecting plane are to be found when the source is located outdoors or in a large room. The engineering method of measurement is described in ISO 3744. This method is also applicable for many types of machines in their normal environments when operating indoors. The acoustical environment is qualified by following the procedures described in ISO 3744.

Hard-walled test rooms are described in ISO 3743-1. Most ordinary, unfurnished rooms without special acoustical treatment comply with the requirements of this standard. This method is particularly suitable for small, movable sources.

An essentially reverberant field can be found in situ. An engineering comparison method is described in ISO 3747. This method applies to non-movable sound sources in situ, preferentially those which radiate broad-band noise.

Methods described in ISO 9614-1 and ISO 9614-2 can provide results of engineering grade accuracy in ordinary rooms and outdoors provided the sound intensity equipment is adequate (ISO 9614-1:1993, Annex B). These methods are particularly suitable in the presence of high background noise and/or high sound reflections by the environment. These methods avoid overestimated results by automatic elimination of systematic deviations.

B.2.3 Survey methods (accuracy grade 3)

Conditions approximating a free-field over a reflecting plane, i.e. a measuring region with one or more reflecting planes present, are to be found when the source is located outdoors or in a large room. A survey method of measurement is described in ISO 3746, where procedures are indicated to qualify the particular environment.

ISO 3747 yields grade 3 results, in those cases where specified criteria for grade 2 accuracy are not fulfilled.

These methods place no restriction on the type or size of machines that are operated outdoors and are applicable to many types of machines in their normal environments when operating indoors.

Methods described in ISO 9614-1 and ISO 9614-2 can provide results of survey grade of accuracy in ordinary rooms and outdoors provided the sound intensity equipment is adequate (ISO 9614-1:1993, Annex B).

Annex C
(informative)

Measurement uncertainty

C.1 General aspects

The clauses on measurement uncertainty in ISO 3741, ISO 3743-1, ISO 3743-2, ISO 3744, ISO 3745, ISO 3746 and ISO 3747 are based on ISO/IEC Guide 98-3, which establishes general rules for evaluating and expressing uncertainty in measurement.

Based on this guide, this set of standards clearly distinguishes between the two main components of measurement uncertainty, i.e. the uncertainty associated with the method, expressed in terms of the standard deviation of reproducibility of the method, σ_{R0}, and the uncertainty due to the possible instability of mounting and operating conditions of the machine under test, expressed in terms of σ_{omc}.

In general, the standards deal with uncertainty by:

— using accuracy grades 1 to 3, which are defined on the basis of the uncertainty of the method;

— providing upper values of the uncertainty of the method σ_{R0}, to be used when no data specific to a particular family of machines is available.

Each of these standards has a clause on uncertainty in its main body, supplemented by an informative annex that gives guidelines on the development of data on uncertainty. In particular, this annex lists all presently identified components of the uncertainty associated to the method (the so-called uncertainty budget). Whenever possible, it gives quantitative estimations for each component. A methodology to determine the magnitude of σ_{R0} and σ_{omc} is provided.

Noise test codes are expected to provide data on σ_{R0} and σ_{omc} specific to the machinery family concerned. It is the task of technical committees drafting machinery specific noise test codes to determine such data.
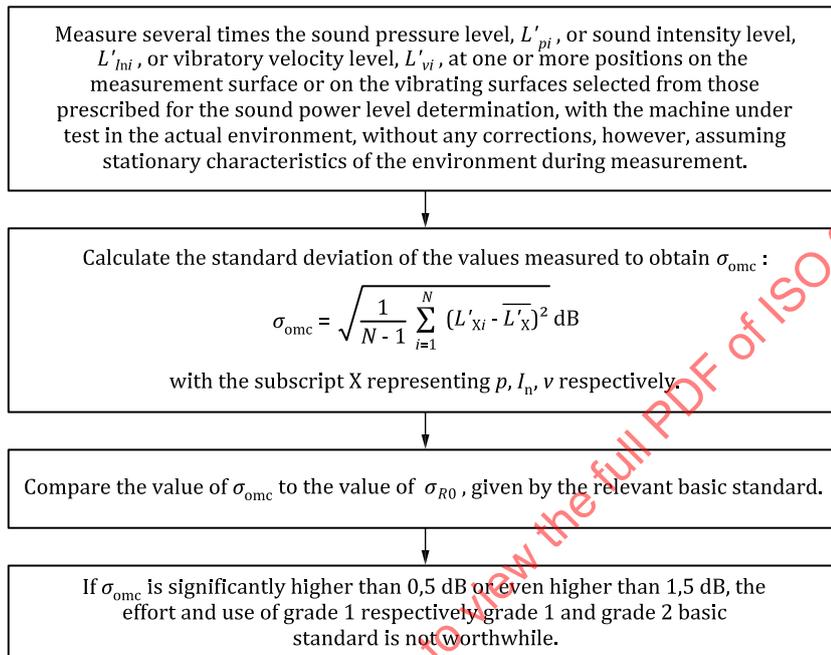
Generally, sound power levels determined in accordance with each of the basic standards listed in 4.3 include two different types of deviations, i.e.:

— deviations arising from randomly distributed values when applying the same standard several times for the same machine in the same environment. These deviations are described by σ_{omc} (see Figure C.1). They result from the instability of the sound emission of the source caused by the operating and mounting conditions;

— deviations caused by an inadequate measurement procedure and problems in the practical implementation of the procedure; these deviations are described by the standard deviation of reproducibility of the method, which is specific to each basic standard. These deviations cover the great variety of radiation patterns and frequency spectra of sound sources. For a well-defined specific machinery family, the range of variation of parameter values of the method can be considerably smaller. Therefore, for measurements on a specific machine family, the value of σ_{R0} is likely to be smaller than that specified in the basic standard.

For a certain family of machines, σ_{R0} can be calculated from the total standard deviation, σ_{tot}, as provided by an interlaboratory test carried out according to ISO 5725 on one or more machines that are typical for the sound emission of the relevant machine family, considering σ_{omc}, as per Formula (C.1):

$$\sigma_{R0} = \sqrt{\sigma_{\text{tot}}^2 - \sigma_{\text{omc}}^2} \tag{C.1}$$

When preparing a noise test code, such tests and determinations are strongly recommended to establish the appropriate value of σ_{R0}.

Measure several times the sound pressure level, L'_{pi}, or sound intensity level, L'_{Ini}, or vibratory velocity level, L'_{vi}, at one or more positions on the measurement surface or on the vibrating surfaces selected from those prescribed for the sound power level determination, with the machine under test in the actual environment, without any corrections, however, assuming stationary characteristics of the environment during measurement.

Calculate the standard deviation of the values measured to obtain σ_{omc}:

$$\sigma_{\text{omc}} = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (L'_{Xi} - \overline{L'_X})^2} \text{ dB}$$

with the subscript X representing p, I_n, v respectively.

Compare the value of σ_{omc} to the value of σ_{R0}, given by the relevant basic standard.

If σ_{omc} is significantly higher than 0,5 dB or even higher than 1,5 dB, the effort and use of grade 1 respectively grade 1 and grade 2 basic standard is not worthwhile.

Figure C.1 — Flowchart to assist determining σ_{omc}, together with a guideline for the selection of the appropriate grade of accuracy

Different measurement methods can produce different results due to systematic deviations, Δ_{sy}, of the determined sound power levels. The differences are related to the nearfield error and to the environmental correction, K_2. These systematic differences are typically unique to each measurement situation and cannot be generally corrected.

Concerning e.g. ISO 3744 to ISO 3746:

— The nearfield error depends both on the measurement distance and the frequencies of the sound (impedance error), and on the shape of the measurement surface (angle error).

— The second error is related to the application of the environmental correction, K_2, which is partly based on an assumed law of sound propagation which departs in many cases from the sound propagation in situ.

By repeating the determination of sound power levels for the same machine in the same environment several times, following the sound pressure and sound intensity standards, the relevant systematic deviation, Δ_{sy}, is given by the difference of the resulting levels.

Meteorological or elevation differences can additionally create systematic differences because the meteorological correction is based on the assumption of a monopole sound radiation characteristic of the source under test, which is only an approximation of the variety of possible sound radiation patterns of practical sound sources. These deviations can be quantified by determination of sound power levels for the same machine under appropriate extreme environmental conditions.

Environmental conditions can affect the machinery, or the processed material (i.e, printer paper) sufficiently to change the associated acoustical characteristics and the operating conditions.

If the machine under test can be regarded as typical for a certain family of machines for what regards noise, it is strongly recommended to publish Δ_{sy} in a relevant noise test code following the general requirements of ISO/IEC Guide 98-3.

Sound power levels obtained from vibratory velocity measurements (ISO/TS 7849-1 and ISO/TS 7849-2) differ from those determined by using ISO 3741 to ISO 3747 and ISO 9614-1 to ISO 9614-3. These differences are systematic in nature because they represent only that portion of the sound power level that is caused by the vibrating surfaces of the source. Thus, any sound power caused by aerodynamic sources is excluded from the measurement result.

C.2   Determination of the expanded measurement uncertainty

The expanded measurement uncertainty, denoted by U, is calculated from the combined standard uncertainty, σ_{tot}, and the coverage factor, k, according to Formula (C.2):

$$U = k \cdot \sigma_{tot} \tag{C.2}$$

σ_{tot} is determined from the standard deviation of reproducibility of the method, σ_{R0}, and the standard deviation due to the operating and mounting conditions, σ_{omc}, by applying Formula (C.3):

$$\sigma_{tot} = \sqrt{\sigma_{omc}^2 + \sigma_{R0}^2} \tag{C.3}$$

Assuming a normal distribution of the determined sound power level values from repeated measurements on a machine with a specific confidence level, the coverage factor, k, can be derived. k is then dependent on one or two sided statistical tests; see Table C.1. Two-sided tests indicate a result with an expanded uncertainty. One-sided tests are for instance used in cases of checking the measurement result against a limit value or any other requirement.

Table C.1 — Coverage factor for different confidence levels during one-sided and two-sided tests

Coverage factor k	Confidence level for two-sided tests	Confidence level for one-sided tests
1,6	90 %	95 %
2,0	95 %	97,5 %
NOTE These values are based on an assumed normal distribution of the determined sound power levels.		

For an A-weighted sound power level, the indication of the result assuming a specific confidence level, e.g. 95 %, looks like Formula (C.4):

$$L_{WA} = (83,7 \pm 3,0) \text{ dB } (k = 2) \tag{C.4}$$

For the purpose of comparing a measured noise emission value to a limit value, it is good practice to take k equal to 1,6 with a confidence level of 95 %. Then the result can be as given in Formula (C.5):

$$L_{WA} = (83,7 + 2,4) \text{ dB } (k = 1,6) \tag{C.5}$$