

**Acoustics — Noise emitted by machinery  
and equipment — Determination of  
emission sound pressure levels at a work  
station and at other specified positions in  
an essentially free field over a reflecting  
plane with negligible environmental  
corrections**

*Acoustique — Bruit émis par les machines et équipements —  
Détermination des niveaux de pression acoustique d'émission au poste  
de travail et en d'autres positions spécifiées dans des conditions  
approchant celles du champ libre sur plan réfléchissant avec des  
corrections*

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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 11201 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 11201:1995), which has been technically revised. It also incorporates the Technical Corrigendum ISO 11201:1995/Cor.1:1997.

## Introduction

This International Standard specifies a method for determining the emission sound pressure levels at a work station and at other well defined positions, in the vicinity of a machine or piece of equipment, in an essentially free field over a reflecting plane. It is one of a series (ISO 11200<sup>[15]</sup> to ISO 11205<sup>[19]</sup>) which specifies various methods for determining the emission sound pressure level at a work station and at other specified positions of a machine or equipment. ISO 11200<sup>[15]</sup> gives guidance on the choice of the method to be used to determine the emission sound pressure levels of machinery and equipment.

The method specified in this International Standard differs from those in other International Standards in the ISO 11200<sup>[15]</sup> to ISO 11205<sup>[19]</sup> series in not applying any environmental correction. Requirements to be fulfilled by the environment are specified for accuracy grade 1 (precision) and grade 2 (engineering) measurements indoors and outdoors.

Precision measurements with accuracy grade 1 can generally be carried out in hemi-anechoic test rooms or outdoors provided that requirements on environmental conditions are met. With the specifications defined in the following it should be possible in some cases to provide such conditions in industrial ambience on larger plane areas outdoors free from reflecting objects.

ISO 11201:1995 provided results of accuracy grade 2 only. This edition of this International Standard provides a method of accuracy grade 2 that is essentially identical to that given in ISO 11201:1995. It also provides a more precise method of accuracy grade 1. Users and drafters of noise test codes referring to this International Standard should indicate clearly which method (accuracy grade 1 or accuracy grade 2) is used.

In general, the emission sound pressure levels are less than or equal to those that occur when the machinery or equipment is operating in its normal surroundings. This is because the sound pressure levels are determined by excluding the effects of background noise, as well as the effects of reflections other than those from the reflecting plane on which the machine under test is placed. For determination or calculation of the sound pressure level at the operator's position with the machine operating in a room, both sound power level and sound pressure level are required (as well as information on the room properties or reflections and noise from other sound sources or machines). A method of calculating the sound pressure levels in the vicinity of a machine operating alone in a workroom is given in ISO/TR 11690-3<sup>[20]</sup>. Commonly observed differences are 1 dB to 5 dB, but in extreme cases the difference may be even greater.

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# Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions in an essentially free field over a reflecting plane with negligible environmental corrections

## 1 Scope

### 1.1 General

This International Standard specifies a method for determining the emission sound pressure levels of machinery or equipment, at a work station and at other specified positions nearby, in an essentially free field over a reflecting plane. A work station is occupied by an operator and may be located in open space, in the room where the source under test operates, in a cab fixed to the source under test, or in an enclosure remote from the source under test. One or more specified positions may be located in the vicinity of a work station, or in the vicinity of an attended or unattended machine. Such positions are sometimes referred to as bystander positions.

Emission sound pressure levels are determined as A-weighted levels. Additionally, levels in frequency bands and C-weighted peak emission sound pressure levels can be determined in accordance with this International Standard, if required.

NOTE 1 The contents of the series ISO 11200<sup>[15]</sup> to ISO 11205<sup>[19]</sup> are summarized in ISO 11200<sup>[15]</sup>.

With the method specified in this International Standard, results of accuracy grade 1 (precision grade) or accuracy grade 2 (engineering grade) are obtained. Corrections are applied for background noise, but not for the acoustic environment. Instructions are given for the mounting and operation of the source under test and for the choice of microphone positions for the work station and for other specified positions. One purpose of the measurements is to permit comparison of the performance of different units of a given family of machines, under defined environmental conditions and standardized mounting and operating conditions.

NOTE 2 The data obtained can also be used for the declaration and verification of emission sound pressure levels as specified in ISO 4871<sup>[8]</sup>.

### 1.2 Types of noise and noise sources

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

The method specified in this International Standard is applicable to all types and sizes of noise sources.

NOTE Throughout this International Standard the words "machine" and "source under test" are used to represent either a machine or a piece of equipment.

### 1.3 Test environment

The type of test environment influences the accuracy of the determination of emission sound pressure levels. For the application of this International Standard, an essentially free field over a reflecting plane (indoors or outdoors) is required.

### 1.4 Work station and other specified positions

This International Standard is applicable to work stations and other specified positions where emission sound pressure levels are to be determined.

Appropriate positions where measurements may be made include the following:

- a) work station located in the vicinity of the source under test; this is the case for many industrial machines and domestic appliances;
- b) work station within a cab which is an integral part of the source under test; this is the case for many industrial trucks and earth-moving machines;
- c) work station within a partial or total enclosure (or behind a screen) supplied by the manufacturer as an integral part of the source under test;
- d) work station partially or totally enclosed by the source under test — this situation may be encountered with some large industrial machines;
- e) bystander positions occupied by individuals not responsible for the operation of the source under test, but who may be in its immediate vicinity, either occasionally or continuously;
- f) other specified positions, not necessarily work stations or bystander positions.

The work station may also lie on a specified path along which an operator moves (see 9.4).

## 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 3744, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane*

ISO 3745, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for anechoic and hemi-anechoic rooms*

ISO 3746, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

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

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* (amended by IEC 61260/Amd.1:2001)

IEC 61672-1:2002, *Electroacoustics — Sound level meters — Part 1: Specifications*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. More detailed definitions can be found in noise test codes for specific types of machines.

#### 3.1

##### emission

*(acoustics)* airborne sound radiated by a well-defined noise source (e.g. the machine under test)

NOTE Noise emission descriptors can be incorporated into a product label and/or product specification. The basic noise emission descriptors are the sound power level of the source itself and the emission sound pressure levels at a work station and/or at other specified positions (if any) in the vicinity of the source.

#### 3.2

##### emission sound pressure

*p*

sound pressure, at a work station or another specified position near a noise source, when the source is in operation under specified operating and mounting conditions on a reflecting plane surface, excluding the effects of background noise as well as the effects of reflections other than those from the plane or planes permitted for the purpose of the test

NOTE Emission sound pressure is expressed in pascals.

#### 3.3

##### emission sound pressure level

$L_p$

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

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

where the reference value,  $p_0$ , is 20 µPa

NOTE The emission sound pressure level is determined at a work station or another specified position in accordance with either a noise test code for a specific family of machines or, if no noise test code exists, one of the standards of the ISO 11200<sup>[15]</sup> to ISO 11205<sup>[19]</sup> series.

#### 3.4

##### time-averaged emission 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 emission 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

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

where the reference value,  $p_0$ , is 20 µPa

NOTE 1 Adapted from ISO/TR 25417:2007<sup>[21]</sup>, 2.3, “time-averaged sound pressure level”.

NOTE 2 For simplicity of notation, the subscript  $T$  is omitted throughout the following text.

NOTE 3 If specific frequency and time weightings as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; e.g.  $L_{pA}$  denotes the A-weighted emission sound pressure level.

NOTE 4 Equation (2) is equivalent to that for the environmental noise descriptor “equivalent continuous sound pressure level” (ISO 1996-1<sup>[1]</sup>). However, the emission quantity defined above is used to characterize the noise emitted by a source under test and assumes that standardized measurement and operating conditions as well as a controlled acoustical environment are used for the measurements.

### 3.5 peak emission sound pressure

$p_{\text{peak}}$

greatest absolute emission sound pressure during a stated time interval

NOTE 1 Peak emission sound pressure is expressed in pascals.

NOTE 2 A peak emission sound pressure may arise from a positive or negative sound pressure.

### 3.6 peak emission sound pressure level

$L_{p,\text{peak}}$

ten times the logarithm to the base 10 of the ratio of the square of the peak emission sound pressure,  $p_{\text{peak}}$ , to the square of a reference value,  $p_0$ , expressed in decibels

$$L_{p,\text{peak}} = 10 \lg \frac{p_{\text{peak}}^2}{p_0^2} \text{ dB} \quad (3)$$

where the reference value,  $p_0$ , is 20  $\mu\text{Pa}$

NOTE The peak emission sound pressure level is usually C-weighted and denoted by  $L_{pC,\text{peak}}$ .

### 3.7 single event emission sound pressure level

$L_E$

ten times the logarithm to the base 10 of the ratio of the integral of the square of the emission sound pressure,  $p$ , of an isolated single sound event (burst of sound or transient sound) of specified duration,  $T$  (or specified measurement time interval  $T = t_2 - t_1$  covering the single event), to the square of a reference value,  $p_0$ , normalized to reference time interval  $T_0 = 1 \text{ s}$ , expressed in decibels

$$\begin{aligned} L_E &= 10 \lg \left[ \frac{1}{T_0} \int_{t_1}^{t_2} \frac{p^2(t)}{p_0^2} dt \right] \text{ dB} \\ &= L_{p,T} + 10 \lg \frac{T}{T_0} \text{ dB} \end{aligned} \quad (4)$$

NOTE Equation (4) is equivalent to that for the environmental noise descriptor “sound exposure level” (ISO/TR 25417:2007<sup>[21]</sup>, 2.7). However, the emission quantity defined above is used to characterize the noise emitted by a source under test and assumes that standardized measurement, mounting, and operating conditions as well as a controlled acoustical environment are used for the measurements.

**3.8****acoustic free field over a reflecting plane**

sound field in a homogeneous, isotropic medium in the half space above an infinite reflecting plane, in the absence of any other obstacles

**3.9****essentially free field over a reflecting plane**

environment approximating an acoustic free field over a reflecting plane on which the noise source under test is located

NOTE The requirements on the environment are specified in 5.2.

**3.10****frequency range of interest**

for general purposes, the frequency range of octave bands with nominal mid-band frequencies from 125 Hz to 8 000 Hz or the one-third octave bands with nominal mid-band frequencies from 100 Hz to 10 000 Hz

NOTE 1 Adapted from ISO 6926:1999<sup>[9]</sup>, 3.10.

NOTE 2 For special purposes, the frequency range may be extended or reduced, provided that the test environment and instrument specifications are satisfactory for use over the modified frequency range. Changes to the frequency range of interest should be made clear in the test report. For sources which emit sound at predominantly high or low frequencies, the frequency range of interest should be extended to include these frequencies.

**3.11****work station****operator's position**

position in the vicinity of the machine under test which is intended for the operator

**3.12****operator**

individual whose work station is in the vicinity of a machine and who is performing a work task associated with that machine

**3.13****specified position**

position defined in relation to a machine, including, but not limited to, an operator's position

NOTE 1 The position can be a single, fixed point, or a combination of points along a path or on a surface located at a specified distance from the machine, as described in the relevant noise test code, if one exists.

NOTE 2 Positions located in the vicinity of a work station, or in the vicinity of an unattended machine, are identified as "bystander positions".

NOTE 3 Throughout the text of this International Standard, the term "work station" applies to any possible specified position listed in 1.4.

**3.14****operational period**

interval of time during which a specified process is accomplished by the source under test

EXAMPLE For a dishwasher, when washing or rinsing or drying.

**3.15****operational cycle**

specific sequence of operational periods occurring while the source under test performs a complete work cycle, where each operational period is associated with a specific process that may occur only once, or may be repeated, during the operational cycle

EXAMPLE For a dishwasher, when washing and rinsing and drying.

**3.16**

**measurement time interval**

portion or a multiple of an operational period or operational cycle of the source under test, for which the time-averaged emission sound pressure level is determined or over which the maximum emission sound pressure level is sought

**3.17**

**time history**

continuous recording of the emission sound pressure level, as a function of time, which is obtained during one or more operational periods of an operational cycle

**3.18**

**background noise**

noise from all sources other than the source under test

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

**3.19**

**background noise correction**

$K_1$

correction applied to the measured sound pressure levels to account for the influence of background noise

NOTE 1 Background noise correction is expressed in decibels.

NOTE 2 Background noise correction is frequency dependent. In the case of A-weighting, the correction,  $K_{1A}$ , is determined from A-weighted measured values.

**3.20**

**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 may be mounted

**3.21**

**reference measurement surface**

$S_M$

hypothetical surface defined by a rectangular parallelepiped enveloping the noise source under test, terminating on the reflecting plane(s) on which the source is located, and having sides parallel to those of the reference box with each side spaced at equal distance from the corresponding side of the reference box

**3.22**

**environmental correction**

$K_2$

term to account for the influence of reflected sound on the mean sound pressure level on the reference measurement surface, expressed in decibels

NOTE 1  $K_2$  is frequency dependent and can be determined in accordance with ISO 3744 or ISO 3746. In the case of A-weighting, it is denoted  $K_{2A}$ .

NOTE 2 For the purposes of this International Standard, the environmental correction,  $K_2$ , is only used as an indicator to qualify the environment and is determined for the reference measurement surface.

**3.23**

**local environmental correction**

$K_3$

correction applied to the measured sound pressure levels at the work station to account for the influence of reflected sound, expressed in decibels

NOTE 1 In the case of A-weighting, it is denoted  $K_{3A}$ .

NOTE 2 The local environmental correction is not applied in this International Standard, but appears in other standards of this series (ISO 11202<sup>[16]</sup>, ISO 11204<sup>[18]</sup>).

## 4 Instrumentation

### 4.1 General

The instrumentation system, including the microphones, cables, and windscreens if used, shall meet the requirements of IEC 61672-1:2002, class 1, and the filters shall meet the requirements of IEC 61260:1995, class 1.

### 4.2 Calibration

Before and after each series of measurements, a sound calibrator meeting the requirements of IEC 60942:2003, class 1, shall be applied to each microphone to verify the calibration of the entire measuring system at one or more frequencies within the frequency range of interest. Without any further adjustment, the difference between the readings at each end of the series of measurements shall be less than or equal to 0,5 dB. If the difference exceeds 0,5 dB, the results of the series of measurements shall be discarded.

The sound calibrator shall be calibrated, and the compliance of the instrumentation system with the requirements of IEC 61672-1 shall be verified at intervals in a laboratory making calibrations traceable to appropriate standards.

Unless national regulations dictate otherwise, the sound calibrator should be calibrated annually, and the compliance of the instrumentation system with the requirements of IEC 61672-1 should be verified at intervals not exceeding 2 years.

## 5 Test environment

### 5.1 General

This International Standard allows the determination of the emission sound pressure level with accuracy grade 1 (precision) and grade 2 (engineering) in a test environment under essentially free-field conditions over a reflecting plane, where no correction for environmental influence is necessary and permitted.

The user of this International Standard shall choose between these two grades of accuracy. The accuracy grade used shall be recorded and reported.

The test environment, therefore, has to meet strict requirements which are often impossible to comply with for installations *in situ*.

Determinations of the emission sound pressure level with accuracy grade 1 (precision) or accuracy grade 2 (engineering) is possible in a hemi-anechoic room as well as outdoors on a reflecting plane, with no reflecting objects influencing the result of the measurement.

Determinations of accuracy grade 2 in accordance with this International Standard are possible indoors and outdoors if background noise and influence from reflected sound do not exceed certain limits.

## 5.2 Criteria for the adequacy of the test environment

### 5.2.1 Accuracy grade 1 (precision)

#### 5.2.1.1 Indoors

A suitable test environment is a hemi-anechoic room as specified in ISO 3745.

#### 5.2.1.2 Outdoors

A suitable test environment is a plane area outdoors with hard ground (concrete, asphalt or similar surfaces) and no reflecting objects in the near vicinity.

For the purposes of this International Standard, an object is considered as sound-reflecting if three conditions are fulfilled:

- a) its width (e.g. diameter of a pole or supporting member) exceeds one-tenth its distance from the reference box;
- b) it is not covered with absorbing material;
- c) either, having an acoustically smooth surface, the object is arranged in such a way as to reflect sound like a mirror towards the microphone position or its surface texture gives rise to diffuse reflection (reflection of sound in many directions).

Assessment of item c) requires advanced expertise.

The distance between a reflecting object and the closest point of the sound source under test or the distance between a reflecting object and the microphone position shall be:

- a) at least twice the distance between the microphone position and the most remote point of the source under test;
- b) not smaller than 10 m.

With more complex conditions for sound propagation, e.g. more reflecting surfaces or with microphone positions screened from the sound radiating part of the source under test and reflecting objects in the vicinity, accuracy grade 1 can only be claimed if it is proven by simulation techniques or with a reference sound source that the influence of all reflecting objects does not exceed 0,3 dB at any microphone position.

NOTE The contributions of reflections can be calculated, e.g. by using the methods of ISO 9613-2<sup>[11]</sup>.

The influence of meteorological conditions like temperature, ambient pressure and humidity on sound propagation is negligible with a measuring distance of 1 m. Measurements shall not be made during periods of precipitation (e.g. rain, hail) or when wind speeds exceed 3 m/s.

### 5.2.2 Accuracy grade 2 (engineering)

#### 5.2.2.1 Indoors

Measurements with accuracy grade 2 may be made indoors in conformity with this International Standard provided that the environmental influence is negligible. This condition is met if both the following statements are true.

- The environmental correction,  $K_{2A}$ , does not exceed 2 dB for the reference measurement surface on which the microphone positions are located.
- The radiation of the source is not directed mainly upwards or to opposite directions of the work station.

Alternatively, there is negligible environmental influence if all three of the following statements are true.

- The ratio  $A/S_M$ , where  $A$  is the equivalent absorption area determinable, for example, in accordance with methods given in ISO 3744;  $S_M$  is the area of the reference measurement surface including the work station of the source under test, exceeds 30. In hard-walled rooms without absorption, this is the case if the ratio  $S_R/S_M$ , where  $S_R$  is the area of the room surfaces, exceeds 250.

NOTE 1 The parameter  $S_M$  defined here is different from that used in ISO 3744 since the reference measurement surface is passing through the work station.

NOTE 2 A ratio  $A/S_M$  exceeding 30 is only valid for rooms that are normally considered to provide a free field over a reflecting plane.

- The height of the room exceeds 5 times the height of the source under test if the ceiling is not highly absorbent.
- The distance between a reflecting object and the sound source under test or the microphone position is not smaller than the distance between the microphone position and the most remote point of the source under test.

This International Standard cannot be used if the sound level at the work station is dominated by radiating parts of the machine that are not in direct line of sight to the microphone position.

Alternatively, a hemi-anechoic room as specified in ISO 3745 can be used.

The environmental correction,  $K_{2A}$ , describing the deviations of the test environment from ideal conditions shall be determined in accordance with one of the methods given in ISO 3744 or ISO 3746.

If it is necessary to make measurements in spaces not in accordance with these requirements, then ISO 11202<sup>[16]</sup>, ISO 11204<sup>[18]</sup> or ISO 11205<sup>[19]</sup> may be applicable.

#### 5.2.2.2 Outdoors

Measurements with accuracy grade 2 may be made outdoors in conformity with this International Standard provided that the environmental influence is negligible. This condition is met if the following two statements are true.

- The source under test is located on a reflecting plane ground.
- The distance between a reflecting object and the sound source under test or the microphone position is not smaller than the distance between the microphone position and the most remote point of the source under test.

If approximately parallel reflecting surfaces produce higher order reflections, one of each pair shall be removed or covered with absorbing material.

Measurements shall not be made during periods of precipitation (e.g. rain, hail) or when wind speeds exceed 3 m/s.

#### 5.3 Enclosed work station positions

When the operator is located in an enclosed cab or in an enclosure separate from the source under test, the cab or enclosure is regarded as an integral part of the source under test and, consequently, sound reflections inside the cab or enclosure are considered contributions to the emission sound pressure level.

During noise emission measurements, doors and windows of the cabin or enclosure shall be open or closed as defined in the relevant noise test code, if one exists.

The emission sound pressure level at an enclosed work station position can be determined with accuracy grade 1 or 2. The criteria referenced in Annex A for both grades of accuracy are determined using an additional work station position outside the cab or cabin, but at a comparable distance (distance from the

source under test to the centre of the cabin) from the source under test. This is necessary in all cases when the noise inside the cabin is due to airborne sound transmission into the cabin enclosure, i.e. the noise level at the ears of the operator in the cabin is due to the sound field outside the cabin. If levels inside the cabin are strongly dependent on the microphone position, at least four measurement points shall be used to sample the sound field in the relevant part of the cabin. These positions shall be reported in accordance with 12.6.

## 5.4 Criteria for background noise

### 5.4.1 General

At the microphone position(s), the background noise (including wind noise at the microphone) measured as A-weighted sound pressure level or (if results in frequency bands are required) in each of the frequency bands of interest shall be at least 10 dB for accuracy grade 1 (precision) or 6 dB for accuracy grade 2 (engineering) below the uncorrected level of the source under test measured in the presence of this background noise.

If the 10 dB criterion or 6 dB criterion in the previous paragraph is not satisfied, data may still be taken and reported, but the accuracy of the results may be reduced. In this case, the report shall clearly state that the background noise requirements of this International Standard have not been met, and (if frequency band data are reported) 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 conformity" with this International Standard.

For measurements in frequency bands, further criteria for background noise are given in Annex B.

### 5.4.2 Corrections for background noise

The measured sound pressure levels (A-weighted or in frequency bands) shall be subject to a correction for the presence of background noise,  $K_1$ , calculated according to Equation (5):

$$K_1 = -10 \lg(1 - 10^{-0,1 \Delta L}) \text{ dB} \quad (5)$$

where  $\Delta L$  is the difference between the sound pressure levels measured (A-weighted or in frequency bands), at the work station, with the source under test in operation and turned off, respectively.

For the purposes of this International Standard, if  $\Delta L > 15$  dB, assume  $K_1 = 0$ .

For accuracy grade 1, if  $\Delta L < 10$  dB for one or more octave or one-third-octave frequency bands, the accuracy of the result(s) may be reduced and the value of  $K_1$  to be applied in the case of these bands is 0,46 dB, which is the value for  $\Delta L = 10$  dB.

For accuracy grade 2, if  $\Delta L < 6$  dB for one or more octave or one-third-octave frequency bands, the accuracy of the result(s) may be reduced and the value of  $K_1$  to be applied is 1,3 dB, which is the value for  $\Delta L = 6$  dB.

In both cases, it shall be clearly stated in the text of the report, as well as in graphs or tables of results, that the data in such bands represent upper bounds to the emission sound pressure level of the noise source under test for the relevant grade of accuracy. If the background noise requirements for accuracy grade 1 are not met, it is still possible that the requirements for accuracy grade 2 are fulfilled. In this case, the final result can be reported claiming for accuracy grade 2 in accordance with this International Standard (if all other requirements are also fulfilled).

Determine  $K_1$  for each work station.

## 5.5 Ambient conditions during measurements

### 5.5.1 General

Ambient conditions may have an adverse effect on the microphone used for the measurements. Such conditions (e.g. strong electric or magnetic fields, wind, high or low temperatures, or impingement of air discharge from the source under test) shall be avoided by proper selection or positioning of the microphone.

### 5.5.2 Accuracy grade 1 — normalizing to reference meteorological conditions

The emission sound pressure level,  $L_p$ , in decibels, determined with accuracy grade 1 shall be normalized to the reference meteorological conditions:

$$p_{\text{amb}, 0} = 1,013\,25 \times 10^5 \text{ Pa}$$

$$\theta_0 = 296 \text{ K}$$

by using Equation (6) to obtain the emission sound pressure level for the reference meteorological conditions,  $L_{p, 0}$ , in decibels:

$$L_{p, 0} = L_p - 20 \lg \frac{p_{\text{amb}}}{p_{\text{amb}, 0}} \text{ dB} + 20 \lg \frac{\theta}{\theta_0} \text{ dB} \quad (6)$$

where

$p_{\text{amb}}$  is the ambient pressure, in pascals, at the time and place of the test;

$\theta$  is the air temperature, in kelvins, at the time and place of the test.

### 5.5.3 Accuracy grade 2

At altitudes less than or equal to 500 m above sea level and in the temperature range  $-20^{\circ}\text{C}$  to  $40^{\circ}\text{C}$ , no normalization to reference meteorological conditions is required. At altitudes greater than 500 m above sea level or temperatures outside the above range, the measured sound pressure level shall be normalized to the reference meteorological conditions using Equation (6).

## 6 Measured quantities

The basic quantities to be measured at each work station over the specified operational periods or operational cycle of the source under test are:

- the A-weighted sound pressure level,  $L'_{pA}$  (the prime indicates measured values);
- the C-weighted peak sound pressure level,  $L_{pC, \text{peak}}$ , if required.

Sound pressure levels using other frequency weightings or in octave or one-third-octave frequency bands, as well as other entities relating to the time-history of the noise emission (sound pressure level as a function of time, etc.) may also be measured, as required, e.g. for the design of low-noise machines.

## 7 Quantities to be determined

The quantity to be determined is the A-weighted emission sound pressure level. Additionally, emission sound pressure levels in frequency bands may be determined.

In order to obtain emission sound pressure levels at the work station(s), only background noise corrections,  $K_1$ , shall be applied to measured sound pressure levels, except peak sound pressure levels,  $L_{pC, peak}$ , for which no corrections are permitted.

Corrections  $K_1$  to be considered are those relevant to the frequency weighting or frequency bands for which sound pressure levels have been determined. For frequency bands and A-weighting, respectively:

$$\begin{aligned} L_p &= L'_p - K_1 \\ L_{pA} &= L'_{pA} - K_{1A} \end{aligned} \quad (7)$$

where primes indicate measured values; no prime indicates emission values.

If the source under test produces isolated single event sounds, the single event emission sound pressure level at the work station,  $L_E$  (see 3.7), should be determined with a background noise correction applied to the measured values.

## 8 Mounting and operation of source under test

### 8.1 General

The manner in which the source under test is mounted and operated may have a significant influence on the emission sound pressure levels at the work station(s). This clause specifies conditions that are intended to minimize variations in the noise emission due to the mounting and operating conditions of the source under test. Relevant instructions of the relevant noise test code, if one exists, shall be followed. The same mounting and operating conditions of the source under test shall be used for the determination of emission sound pressure levels and sound power levels. The noise test code may make an exception to this requirement on identical mounting conditions for machines that are used on tables. Such machines may be mounted on the floor during sound power determinations and mounted on a table during emission sound pressure level tests. The relevant noise test code, if one exists, describes the mounting and operating conditions in detail.

Particularly for large machines, it is necessary to make a decision as to which components, sub-assemblies, auxiliary equipment, power sources, etc., belong to the source under test.

For sources for which the noise level depends on ambient temperature (e.g. those containing speed-controlled cooling fans), the ambient temperature in the test environment in the immediate vicinity of the source under test shall be maintained at  $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ .

### 8.2 Location of source

The source under test shall be mounted with respect to the reflecting plane in one or more locations as if it were being mounted for normal usage. If not typically mounted against a wall, the source under test shall be remote from any wall, ceiling or other reflecting object.

Typical mounting conditions for some machines involve two or more reflecting surfaces (e.g. an appliance installed against a wall) or free space (e.g. a hoist) or an opening in an otherwise reflecting plane (so that radiation may occur on both sides of the vertical plane). Detailed information on mounting conditions should be based on the general requirements of this International Standard and on the relevant noise test code, if one exists.

## 8.3 Mounting of source

### 8.3.1 General

In many cases, the noise emission at the work station of the source under test depends upon the support or mounting conditions of the source. Whenever a typical mounting condition exists for a source, that condition shall be used or simulated, if practicable.

If a typical mounting condition does not exist or cannot be utilized for the test, care shall be taken to avoid changes in the sound emission of the source under test caused by the mounting system used for the test. Steps shall be taken to reduce any sound radiation from the structure on which the source is mounted.

Many small machines, although themselves poor radiators of low-frequency sound, may, as a result of the method of mounting, radiate more low-frequency sound when their vibrational energy is transmitted to surfaces large enough to be efficient radiators. Resilient mounting shall be interposed, if possible, between the source under test and the supporting surfaces so that the transmission of vibration to the support and the reaction of the source are both minimized. In this case, the mounting base should be rigid (i.e. have a sufficiently high mechanical impedance) to prevent it from vibrating excessively and radiating sound. However, resilient mounts shall be used only if the source under test is resiliently mounted in typical field installations.

NOTE Coupling conditions (e.g. between prime movers and driven machines) can exert a considerable influence on the sound radiation of the source under test.

### 8.3.2 Hand-held machines

Such machines shall be suspended or guided by hand, so that no structure-borne sound is transmitted via any attachment that does not belong to the source under test. If the source under test requires a support for its operation, the support structure shall be small, considered to be a part of the source under test, and as described in the relevant noise test code, if one exists.

Power tools tested in the loaded condition, e.g. cutting material, in the manner typical of use, with materials and mounting conditions typical for that power tool may cause vibrations and noise emissions from the work piece and this may be typical of power tool usage.

### 8.3.3 Base-mounted and wall-mounted machines

Such machines shall be placed on a reflecting (acoustically hard) plane (floor or wall). Base-mounted machines intended exclusively for mounting in front of a wall shall be installed on an acoustically hard surface in front of an acoustically hard wall. Table-top machines shall be placed on a table or stand as required for operation in accordance with the relevant noise test code, if one exists. The table or stand shall be at least 1,5 m from any absorptive surface of the test room. Such machines shall be placed at the centre of the top of the standard test table. A suitable design for a test table is shown in Annex E.

## 8.4 Auxiliary equipment

Care shall be taken to ensure that any electrical conduits, piping or air ducts connected to the source under test do not radiate significant amounts of sound energy into the test environment.

If practicable, all auxiliary equipment necessary for the operation of the source under test that is not a part of it (see 8.1) shall be located outside the test environment. If this is impracticable, the auxiliary equipment shall be included in the test configuration and its operating conditions shall be recorded in the test report.

## 8.5 Operation of source during test

The emission sound pressure level produced by a source can be affected by the load applied, the running speed, and the conditions under which it is operating. The source shall be tested, wherever possible, under conditions that are reproducible and representative of the noisiest operation in typical usage. The

specifications given in the relevant noise test code, if one exists, shall be followed, but in the absence of a noise test code one or more of the following modes of operation shall be selected for the test:

- a) source under specified load and conditions;
- b) source under full load (if different from above);
- c) source under no load (idling);
- d) source at maximum operating speed under defined conditions;
- e) source operating under conditions corresponding to maximum sound generation representative of normal use;
- f) source with simulated loading, under defined conditions;
- g) source undergoing a characteristic work cycle under defined conditions.

The source shall be stabilized in the desired operating condition, with any power source or transmission system running at a stable temperature, prior to the start of measurements for emission sound pressure level determination. The load, speed, and operating conditions shall be either held constant during the test, or varied through a defined cycle in a controlled manner.

If the emission sound pressure level depends on secondary operating parameters, e.g. the type of material being processed or the design of cutting tool, those parameters shall be selected, as far as is practicable, that give rise to the smallest variations and that are typical of normal use. If simulated loading conditions are used, they shall be chosen such that the emission sound pressure level of the source under test is representative of normal use.

## 9 Microphone positions

### 9.1 General

The measurement positions shall be chosen from the alternatives specified in 9.2, 9.3, 9.4 and 9.5.

The microphone shall be oriented in such a way that the angle of incidence of the sound coincides with the reference direction of the microphone as specified by the manufacturer to meet the requirements of IEC 61672-1.

Whenever practical, the emission sound pressure level shall be measured with the source under test unattended and with the microphone reference direction oriented towards the dominant sound source.

Generally, for free-field response microphones (calibrated for “normal incidence” to the microphone diaphragm), the axis of the microphone-preamplifier body should be oriented towards the dominant sound source. For diffuse-field response microphones, the axis of the microphone-preamplifier body should be oriented at a right angle with respect to the direction towards the dominant sound source.

The operator(s), if present, shall not wear clothing with abnormal sound-absorptive properties, or any hat or scarf (other than a protective helmet required for safety reasons, or a helmet or frame used to support a microphone) which might influence the sound measurements.

If an operator is present, the microphone shall be located  $0,20\text{ m} \pm 0,02\text{ m}$  to the side of the centre plane of the operator's head, on a line with the eyes, with its axis parallel to the operator's line of vision, and on that side where the higher value of the A-weighted sound pressure level,  $L'_{pA}$ , is observed.

If the measured sound pressure level is strongly position dependent, it is recommended that the space average be taken on a small measuring surface (e.g.  $0,5\text{ m} \times 0,5\text{ m}$ ) parallel to the reference box and centred at the work station.

Unless otherwise required in the relevant noise test code, if one exists, the operator position(s) shall be as specified in 9.2 to 9.5.

## 9.2 Microphone position(s) for a seated operator

If an operator is not present, and if the seat is attached to the source under test, the microphone shall be located  $0,80\text{ m} \pm 0,05\text{ m}$  above the middle of the seat plane, unless a particular noise test code states otherwise.

If an operator is not present, and if the seat is not attached to the source under test, the microphone position(s) shall be as described in the relevant noise test code, if one exists. If there is no noise test code, the microphone position(s) shall be described in the test report.

If an operator is present, the adjustment of the seat shall allow the operator to reach the controls comfortably, and the requirements of 9.1 apply.

## 9.3 Microphone position(s) for a standing, stationary operator

If the operator is present, the requirements of 9.1 apply. If the measurements are made with the operator or bystander absent or if no other location is specified for a standing operator in the relevant noise test code, if one exists, the microphone location is defined relative to a reference point on the ground plane on which the operator normally stands. This reference point is the point on the floor directly below the centre of the operator's head. The microphone shall be located directly above the reference point at a specified height in the range  $1,55\text{ m} \pm 0,075\text{ m}$ . The specified height is usually to be found in the relevant noise test code, if one exists.

## 9.4 Microphone position(s) for an operator moving along a specified path

In those situations where an operator moves along a specified path in the vicinity of the source under test, a sufficient number of microphone positions or a moving microphone shall be used to determine the sound pressure level along the specified path. This shall be done either by using continuous integration along the length of the path, or by making a sufficient number of measurements at discrete positions and defined intervals of time, and then applying Equation (8).

The reference line shall be defined as a line on the floor directly below the centre of the operator's head for a typical specified path. If no other height is specified for a moving operator in the relevant noise test code, if one exists, the microphone positions shall be located directly above the reference line at a specified height in the range  $1,55\text{ m} \pm 0,075\text{ m}$ .

In the case of fixed microphone positions, these shall be evenly spaced along the specified path. The spacing of the microphone positions shall not exceed 2 m. The microphone positions or the path shall be those defined in the relevant noise test code, if one exists. If no noise test code exists, the microphone positions shall be recorded and reported. The energy average of the levels from the fixed microphone positions shall be recorded and reported as the emission sound pressure level of the source under test.

## 9.5 Microphone positions for bystanders and for unattended machines

If no operator's position can be identified, a hypothetical work station or one or more bystander positions shall be defined. Noise test codes usually specify a hypothetical work station or bystander position(s).

Unless otherwise stated in the relevant noise test code, if one exists, measurements shall be made at four or more microphone positions located 1 m away from each side of the reference box (see 3.20) at a height of  $1,55\text{ m} \pm 0,075\text{ m}$  above the ground plane. The value of the highest emission sound pressure level shall be

recorded and reported as the emission sound pressure level of the source under test. The position where this value is measured shall be recorded and reported.

Instead of using discrete positions, it may be satisfactory to use the surface sound pressure level calculated from the sound power level in accordance with ISO 11203[17].

A noise test code may require that the energy average of the levels from the four or more positions is recorded and reported as the emission sound pressure level of the source under test.

## 10 Measurements

### 10.1 Measurement time interval

#### 10.1.1 General

The measurement time interval shall be chosen in such a way that the emission sound pressure level and, if required, the time characteristics of sound emission at a work station can be determined for the specified operating conditions.

For machines with a specified operational cycle, it is usually necessary to extend the measurement time interval to an integral number of consecutive operational cycles.

The measurement time interval shall correspond only to the operational periods for which the emission sound pressure level and, if required, the time characteristics of sound emission are desired.

Values of the measurement time interval, possible sub-measurement time intervals and number of operational cycles contained in the measurement time interval are usually to be found in the relevant noise test code, if one exists. In any case, these values shall be identical to those defined for determining the sound power level of the source under test.

#### 10.1.2 Steady noise

If the noise emission at a work station is steady for the specified operating conditions (see ISO 12001), the measurement time interval shall be at least 10 s.

#### 10.1.3 Non-steady noise

If the noise emission at a work station is not steady for the specified operating conditions, the measurement time interval and operational periods of the source under test shall be carefully defined and reported in the test results. They are normally specified in the relevant noise test code, if one exists.

#### 10.1.4 Measurements in frequency bands

If measurements are to be made in octave or one-third-octave frequency bands, the minimum period of observation shall be 30 s for the frequency bands centred on or below 160 Hz; for the frequency bands centred on or above 200 Hz the measurement time interval shall be at least 10 s. For non-steady noise, 10.1.3 also applies.

#### 10.1.5 Summarization of sub-measurement time intervals

For a given source under test, the measurement time interval,  $T$ , may be composed of a number of sub-measurement time intervals,  $T_i$ , each of which corresponds to a specified operational period of the source under test. In this case, a single emission sound pressure level,  $L_p$ , is usually desired. It is obtained by energy averaging the individual averaged emission sound pressure levels (A-weighted or in frequency bands) related to sub-time intervals according to Equation (8):

$$L_p = 10 \lg \left[ \frac{1}{T} \sum_{i=1}^N T_i 10^{0,1L_{p,T_i}} \right] \text{dB} \quad (8)$$

where

$T$  is the total measurement time interval,

$$T = \sum_{i=1}^N T_i$$

$T_i$  is the  $i$ th sub-measurement time interval;

$N$  is the total number of sub-measurement time intervals or operational periods;

$L_{p,T_i}$  is the emission sound pressure level (A-weighted or in frequency bands) over a sub-measurement time interval,  $T_i$ .

## 10.2 Measurement procedure

### 10.2.1 General

Sound pressure level(s) shall be measured at the work station(s) of the source under test over a typical period of operation (see 10.1). Background noise corrections shall be applied [see Equation (7)]. The instrumentation used shall comply with the requirements of Clause 4.

### 10.2.2 Repetition of measurements

In order to reduce the uncertainty of the determination of emission sound pressure levels at the work station(s), it may be necessary, for a specific type of source, to repeat the measurement a number of times as specified in the relevant noise test code, if one exists. The value (e.g. average or maximum) to be used after repeated measurements shall be that defined in the relevant noise test code, if one exists. Repeating measurements involves the following procedure:

- the source under test is turned off and on again, if feasible;
- the microphone is moved away and set again at the work station;
- the measurement is carried out again in the same environment, with the same instrumentation over the same measurement time interval and for the same mounting and operating conditions.

### 10.2.3 Procedure for impulsive noise

If the sound emission is impulsive, particular care shall be taken when measuring the sound pressure level to ensure that the dynamic range of the instrumentation is sufficiently large, and that the sound level meter is equipped with an overload indicator.

For measurement of the time characteristics of impulsive sound emissions (e.g. peak values), in addition to the repetition procedure specified in 10.2.2, the measurement time interval shall include at least 10 impulsive events, unless otherwise specified in the relevant noise test code, if one exists.

The final value retained is usually the average, unless the peak value is measured. In this case, the highest of the peak values is retained. If a more precise procedure is specified in the relevant noise test code, that procedure shall be used.

If the source under test produces isolated single event sounds, the single event emission sound pressure level at the work station position (see 3.7),  $L_E$ , shall be determined.

## 11 Measurement uncertainty

### 11.1 Methodology

The uncertainty,  $u(L_p)$ , in decibels, associated with the emission sound pressure level determined in accordance with this International Standard is estimated by the total standard deviation,  $\sigma_{\text{tot}}$ , in decibels:

$$u(L_p) \approx \sigma_{\text{tot}} \quad (9)$$

This total standard deviation is obtained using the modelling approach described in ISO/IEC Guide 98-3. This requires a mathematical model, which in the case of lack of knowledge can be replaced by results from measurements, including results from round robin tests.

In this context, this standard deviation is expressed by the standard deviation of reproducibility of the method,  $\sigma_{R0}$ , in decibels, and the standard deviation,  $\sigma_{\text{omc}}$ , in decibels, describing the uncertainty due to the instability of the operating and mounting conditions of the source under test according to Equation (10):

$$\sigma_{\text{tot}} = \sqrt{\sigma_{R0}^2 + \sigma_{\text{omc}}^2} \quad (10)$$

Equation (10) shows that variations of operating and mounting conditions expressed by  $\sigma_{\text{omc}}$  should be taken into account before a measurement procedure with a certain grade of accuracy (characterized by  $\sigma_{R0}$ ) is selected for a specific machine family (see 11.5 and C.3).

**NOTE** If different measurement procedures offered by the ISO 11200 series are used, systematic numerical deviations (biases) can additionally occur.

Derived from  $\sigma_{\text{tot}}$ , the expanded uncertainty,  $U$ , in decibels, shall be calculated from

$$U = k \sigma_{\text{tot}} \quad (11)$$

The expanded uncertainty depends on the degree of confidence that is desired. For a normal distribution of measured values, and for a confidence level of 95 %, the confidence interval is  $[L_p - U]$  to  $[L_p + U]$ . This corresponds to a coverage factor of  $k = 2$ .

If the purpose of determining the emission sound pressure level is to compare the result with a limit value, it may be more appropriate to apply the coverage factor for a one-sided normal distribution. In that case, the coverage factor  $k = 1,6$  corresponds to a level of confidence of 95 %.

### 11.2 Determination of $\sigma_{\text{omc}}$

The standard deviation,  $\sigma_{\text{omc}}$  [see Equation (C.1)], which quantifies the uncertainty associated with the instability of the operating and mounting conditions for the particular source under test, shall be taken into account when determining the measurement uncertainty. It can be determined separately from repeated measurements carried out on the same source at the same location by the same persons, using the same measuring instruments and the same measurement position(s). To determine  $\sigma_{\text{omc}}$ , the measured sound pressure levels,  $L'_p$ , do not require any correction. For each of these repeated measurements, the mounting of the machine and its operating conditions are to be readjusted. The symbol  $\sigma_{\text{omc}}$  is modified to  $\sigma'_{\text{omc}}$  for the individual sound source under test. A noise test code may provide a value of  $\sigma_{\text{omc}}$  representative for the machine family concerned. This value should take into account all possible variations of operating and mounting conditions that are within the scope of the noise test code.

**NOTE** If the sound emission does not vary or varies only a little with time and the measuring procedure is defined properly, a value of 0,5 dB for  $\sigma_{\text{omc}}$  can be applicable. In cases for example of a large influence of the material flow in and out of the machine or where this flow may vary in an unforeseeable manner, a value of 2 dB can be appropriate. However, in extreme cases where for example process noise generated by the material processed varies strongly (stone breaking machines, metal cutting machines, and presses operating under load) even a value of 4 dB can result.

## 11.3 Determination of $\sigma_{R0}$

### 11.3.1 General

Most conditions and situations allowed by this International Standard (different radiation characteristics of the source under test, different instrumentation, different realizations of the measurement procedure) are covered by  $\sigma_{R0}$ . An exception is the influence of the instability of the sound emission of the source under test, which is considered separately by  $\sigma_{omc}$ .

The values of  $\sigma_{R0}$  given in Table 1 reflect knowledge at the time of publication. They are typical upper bounds taking into consideration the great variety of machines and equipment being covered by this International Standard. Machinery-specific values may be derived from round robin tests (see 11.3.2) or by using the modelling approach (see 11.3.3). They should be given in noise test codes specific to machinery families (see 11.2 and Annex C).

### 11.3.2 Round robin test

The round robin test for determining  $\sigma_{R0}$  shall be carried out in accordance with ISO 5725, where the emission sound pressure level of the source under test is determined under reproducibility conditions, i.e. different persons carrying out measurements at different testing locations with different measuring instruments. Such a test provides the total standard deviation,  $\sigma'_{tot}$ , relevant to the individual sound source which has been used for the round robin test. Participating laboratories in round robin tests should cover all possible practical situations.

This total standard deviation,  $\sigma'_{tot}$ , in decibels, of all results obtained with a round robin test includes the standard deviation,  $\sigma'_{omc}$ , and allows  $\sigma'_{R0}$  to be determined by using

$$\sigma'_{R0} = \sqrt{\sigma'_{tot}^2 - \sigma'_{omc}^2} \quad (12)$$

If  $\sigma'_{R0}$  values obtained from many different pieces of machinery belonging to the same family deviate within a small range only, their mean value can be regarded as typical for the application of this International Standard to this particular family and used as  $\sigma_{R0}$ . Whenever available, such a value should be given in the noise test code specific to the machine family concerned (together with  $\sigma_{omc}$ ) and used in particular for the purpose of declaring noise emission values.

If no round robin test has been carried out, existing knowledge about the noise emission from a particular family of machines may be used to estimate realistic values of  $\sigma_{R0}$ .

For certain applications, the work involved in the round robin test can be reduced by omitting measurements for different locations, e.g. if machines under test are usually installed under conditions with a small background noise correction,  $K_1$ , and a small or similar local environmental correction,  $K_3$ , or if the noise emission of a machine should be checked at the same location again. Results of such delimited tests should be denoted by  $\sigma_{R0, DL}$ , and this designation should also be used for tests on large machines which are not movable in space.

NOTE Values for  $\sigma_{R0, DL}$  can be expected to be lower than those given in Table 1.

The determination of  $\sigma_{R0}$  using Equation (12) is imprecise if  $\sigma_{tot}$  is only slightly higher than  $\sigma_{omc}$ . In this case, Equation (12) provides a small value of  $\sigma_{R0}$  but with a low accuracy. To limit this inaccuracy,  $\sigma_{omc}$  should not exceed  $\sigma_{tot}/\sqrt{2}$ .

### 11.3.3 Modelling approach for $\sigma_{R0}$

Generally,  $\sigma_{R0}$ , in decibels, is dependent upon several partial uncertainty components,  $c_i u_i$ , associated with the different measurement parameters such as uncertainties of instruments, environmental corrections, and microphone positions. If these contributions are assumed to be uncorrelated,  $\sigma_{R0}$  can be described by the modelling approach presented in ISO/IEC Guide 98-3, as follows:

$$\sigma_{R0} \approx \sqrt{(c_1 u_1)^2 + (c_2 u_2)^2 + \dots + (c_n u_n)^2} \quad (13)$$

In Equation (13), the uncertainty components due to the instability of the sound emission of the source are not included. These components are covered by  $\sigma_{omc}$ . Annex C discusses each component of the uncertainty,  $\sigma_{R0}$ , according to knowledge at the time of publication.

**NOTE** If the uncertainty components in the modelling approach are correlated, Equation (13) is not valid. Furthermore, the modelling approach requires detailed knowledge for determining the individual terms in Equation (13).

By contrast, the estimation of  $\sigma_{R0}$  based on a round robin test does not require assumptions about possible correlations between the individual terms of Equation (13). Round robin test-based estimation is, at the time of publication, more realistic than the evaluation of possible correlations between the single terms of Equation (13) and their interdependencies with all other relevant parameters using the modelling approach. However, round robin tests are not always possible and are often replaced by experience from earlier measurements.

### 11.4 Typical upper bound values of $\sigma_{R0}$

Table 1 shows typical upper bound values of the standard deviation,  $\sigma_{R0}$ , for accuracy grades 1 and 2 that may cover most of the applications of this International Standard. In special cases or if certain requirements of this International Standard are not met for a machine family or if it is anticipated that actual values of  $\sigma_{R0}$  for a given family of machines are smaller than those given in Table 1, a round robin test is recommended to obtain machine-specific values of  $\sigma_{R0}$ .

**Table 1 — Typical upper bound values of the standard deviation of reproducibility of the method,  $\sigma_{R0}$ , for the A-weighted emission sound pressure levels determined in accordance with this International Standard**

| Grade of accuracy | Standard deviation of reproducibility, $\sigma_{R0}$<br>dB |
|-------------------|--|
| 1                 | 0,5  |
| 2                 | 1,5  |

### 11.5 Total standard deviation, $\sigma_{tot}$ and expanded uncertainty, $U$

The total standard deviation and the expanded uncertainty shall be determined using Equation (10) and Equation (11) respectively.

**EXAMPLE** Accuracy grade 2;  $\sigma_{omc} = 2,0$  dB; coverage factor,  $k = 1,6$ ; measured  $L_{pA} = 82$  dB. Machine-specific determinations of  $\sigma_{R0}$  have not been undertaken thus the value is taken from Table 1 ( $\sigma_{R0} = 1,5$  dB). Using Equations (11) and (10) it follows that

$$U = 1,6 \times \sqrt{1,5^2 + 2^2} \text{ dB} = 4 \text{ dB}$$

The best estimate of the sound power level does not exceed 86 dB with a probability of 95 % assuming normal distribution of the fluctuating quantities (see C.5 and C.6).

Additional examples of calculated values for  $\sigma_{tot}$  are given in C.3.

**NOTE** The expanded uncertainty as described in this International Standard does not include the standard deviation of production which is used in ISO 4871<sup>[8]</sup> for the purpose of making a noise declaration for batches of machines.

## 12 Information to be recorded

### 12.1 General

The following information, when applicable, shall be compiled and recorded for all measurements made in accordance with this International Standard. Rounding to the first place of decimals of computed data values shall occur only after performing the final computational step before recording.

### 12.2 Source under test

Description of the source under test, including its

- a) type;
- b) technical data;
- c) dimensions;
- d) manufacturer;
- e) serial number;
- f) year of manufacture.

### 12.3 Test conditions

Description of the test conditions, including:

- a) precise quantitative description of operating conditions if not specified in a machine-specific noise test code, if one exists, and, if relevant, operational periods and cycle;
- b) mounting conditions;
- c) location of the source under test in the test environment;
- d) if the source under test has multiple sources of noise, a description of the sources in operation.

### 12.4 Acoustic environment

Description of the test environment:

- a) if indoors, description of physical treatment of wall, ceiling and floor; sketch showing the location of the source under test and room contents; acoustical qualification of room in accordance with 5.2; air temperature in degrees Celsius, ambient pressure in pascals, and relative humidity as a percentage;
- b) if outdoors, sketch showing the location of the source under test with respect to surrounding terrain, including
  - 1) physical description of test environment,
  - 2) air temperature in degrees Celsius, ambient pressure in pascals, and relative humidity as a percentage,
  - 3) wind speed, in metres per second.

## 12.5 Instrumentation

Description of the instrumentation:

- a) equipment used for measurements, including name, type, serial number and manufacturer;
- b) method used for verifying the calibration of the measuring system; the date, place and result of calibration;
- c) characteristics of windscreen (if any).

## 12.6 Location of work station(s)

A precise quantitative description shall be recorded of all positions where sound pressure levels have been measured.

## 12.7 Noise data

Description of the noise data:

- a) all measured sound pressure level data;
- b) A-weighted emission sound pressure level(s) at work station(s) and, if required, the same quantity with other frequency weightings and/or in frequency bands;
- c) if required, C-weighted peak emission sound pressure level(s) at work station(s) and/or levels in frequency bands, and/or other time characteristics of noise emission at work station(s);
- d) expanded measurement uncertainty of the results, in decibels, together with the associated coverage factor and coverage probability;
- e) A-weighted background noise levels and background noise correction,  $K_{1A}$ , at each work station, plus, if required, background noise levels and correction,  $K_1$ , in frequency bands;
- f) A-weighted environmental correction,  $K_{2A}$  (if used in case of accuracy grade 2 measurement);
- g) place, date when the measurements were performed, and person responsible for the test;
- h) optional information such as the highest emission sound pressure level measured on a measurement path or any other data.

## 13 Test report

Only those data recorded in accordance with 12.2, 12.3 a) and b), 12.6, 12.7 b), c), d) and f) shall be reported. If a standardized noise test code exists for the source under test, report the data in accordance with the specifications of the code.

The test report shall include at least the following information:

- a) whether the reported emission sound pressure levels at the work station(s) have been obtained in full conformity with the requirements of this International Standard (ISO 11201:2010);
- b) the date on which the emission sound pressure levels were measured;
- c) the name of the person responsible for the tests;
- d) an explicit statement of the grade of accuracy achieved [accuracy grade 1 (precision) or accuracy grade 2 (engineering)] — information may be given on the basis of Annex C;
- e) emission sound pressure levels, in decibels, at the work station(s) and the associated expanded measurement uncertainties, in decibels, resulting from the grade of accuracy, reported to the nearest first place of decimals.

## Annex A (normative)

### Allocation of the accuracy grade (1 or 2)

#### A.1 Accuracy grade 1 (precision)

The determination of emission sound pressure levels in accordance with this International Standard is related to accuracy grade 1 if the following are fulfilled:

- a) the criteria for the adequacy of the test environment in accordance with 5.2.1;
- b) the criteria for background noise related to grade 1 measurements in accordance with 5.4.1;
- c) the results are related to meteorological reference conditions with the correction in accordance with 5.5.2.

#### A.2 Accuracy grade 2 (engineering)

The determination of emission sound pressure levels in accordance with this International Standard is related to accuracy grade 2 if the following are fulfilled:

- a) the criteria for the adequacy of the test environment in accordance with 5.2.2;
- b) the criteria for background noise related to grade 2 measurements in accordance with 5.4.1;
- c) the results are related to meteorological reference conditions with the correction in accordance with 5.5.3, if relevant.

## Annex B (normative)

### Criteria for background noise for measurements in frequency bands

#### B.1 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 B.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 10 dB requirement for accuracy grade 1, or 6 dB requirement for accuracy grade 2 (see 5.4.1), 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 represent upper bounds to the emission sound pressure level in these bands.

#### B.2 Relative criteria for frequency band measurements

The requirements of 5.4.1 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 pressure level of the source under test is at least 15 dB below the highest A-weighted band sound pressure level may be excluded from the frequency range of interest for the purposes of determining compliance with the criterion for background noise of 5.4.1.

#### B.3 Relative criteria for A-weighted level determined from frequency band levels

If the A-weighted emission sound pressure level is to be determined from frequency band levels, the following steps shall be followed to determine whether this quantity meets the background noise criteria of this International Standard:

- the A-weighted emission sound pressure level is computed by analogy to the relevant procedures of ISO 3744 using the data from every frequency band within the frequency range of interest;
- the computation is repeated, but excluding those bands for which  $\Delta L_p$  is less than 10 dB for accuracy grade 1 or less than 6 dB for accuracy grade 2.

If the difference between these two levels is less than 0,2 dB for accuracy grade 1 or 0,5 dB for accuracy grade 2, the A-weighted emission sound pressure level determined from the data for all bands shall be considered as conforming to the background noise criteria of this International Standard.

#### B.4 Failure to meet relevant criteria

If the background noise criteria (one of 5.4.1, B.1 or B.2, and additionally B.3 if the A-weighted level is determined from frequency bands) are not satisfied, the report shall clearly state that the background noise requirements of this International Standard have not been met, and 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 conformity" with this International Standard.

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

| One-third-octave mid-band frequency<br>Hz | Maximum band sound pressure level<br>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                                      |

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## Annex C

(informative)

### Guidance on the development of information on measurement uncertainty

#### C.1 General

The accepted format for the expression of uncertainties generally associated with methods of measurement is that given in ISO/IEC Guide 98-3. This format incorporates a budget of uncertainty components, in which various sources of uncertainty are identified and from which the combined total measurement uncertainty can be obtained.

To determine the noise emission of machines and equipment, it is advisable to split up its total uncertainty into two different groups of uncertainty components:

- a) those that are intrinsic to the measurement procedure;
- b) those that result from the instability of the sound emission of the machine.

Based on knowledge at the time of publication, this annex provides additional explanations and information by which ISO/IEC Guide 98-3 can be applied in practice for this International Standard.

This annex complements Clause 11.

#### C.2 Considerations on the total standard deviation, $\sigma_{\text{tot}}$

The measurement uncertainty used in this International Standard is determined by the expanded measurement uncertainty,  $U$ , which is derived directly from the total standard deviation,  $\sigma_{\text{tot}}$  [Equation (11)], with  $\sigma_{\text{tot}}$  being the approximation of the relevant  $u(L_p)$  as defined in ISO/IEC Guide 98-3.

This total standard deviation,  $\sigma_{\text{tot}}$ , results from the two components,  $\sigma_{R0}$  and  $\sigma_{\text{omc}}$  [see Equation (10)], which are significantly different in nature.

Both quantities are assumed to be statistically independent and are determined separately.

The machinery-specific standard deviation,  $\sigma_{\text{omc}}$ , cannot be calculated and has to be determined by repeated measurements as described in C.3. Information on the standard deviation,  $\sigma_{R0}$ , is given in C.4.

#### C.3 Considerations on $\sigma_{\text{omc}}$

The standard deviation,  $\sigma_{\text{omc}}$ , described in 11.2, is calculated by

$$\sigma_{\text{omc}} = \sqrt{\frac{1}{N-1} \sum_{j=1}^N \left( L'_{p,j} - \overline{L'_p} \right)^2} \text{ dB} \quad (\text{C.1})$$

where

- $L'_{p,j}$  is the sound pressure level measured at a prescribed position for the  $j$ th repetition of the prescribed operating and mounting conditions;
- $\overline{L'_p}$  is the mean sound pressure level calculated for all  $N$  repetitions.

These measurements are carried out under the actual *in situ* environmental conditions. Consequently  $L'_{p,j}$  and  $L'_p$  do not need any further correction.

In general, the mounting and operating conditions to be used for noise emission measurements are prescribed by machinery-specific noise test codes. Otherwise, these conditions have to be defined precisely and described in the test report.

Some recommendations for defining these conditions and consequences for the expected values of  $\sigma_{omc}$  are given hereafter.

The test conditions have to represent normal usage and to conform to manufacturers' and users' recommended practice. However, even in normal usage, slightly different modes of operation, variations in material flow and other conditions varying between different phases of operation may occur. This uncertainty covers both the uncertainty due to variation in long-term operating conditions (e.g. from day to day) and fluctuations of noise emission measurements repeated immediately after readjusting mounting and operating conditions.

Machines that stand exclusively on soft springs or on heavy concrete floors do not normally exhibit any effect of mounting. However, there can be large discrepancies between measurements on heavy concrete floors and those made *in situ*. The uncertainty due to mounting can be highest for machinery that is connected to auxiliary equipment. Hand-held machines may also cause problems. This parameter should be investigated if movement of the machine or mounts causes changes in noise. If there is a range of possible mounting conditions to be included in a single declaration, then  $\sigma_{omc}$  is estimated from the standard deviation of the sound levels for these mounting conditions. If there is any known effect due to mounting, recommended mounting conditions should be documented in the relevant noise test code or manufacturers' recommended practice.

With respect to the main uncertainty quantity,  $\sigma_{tot}$ , investigations on  $\sigma_{omc}$  have a higher priority compared to those on the other uncertainty components leading to  $\sigma_{R0}$  [see Equation (10)]. This is because  $\sigma_{omc}$  may be significantly larger in practice than, for example,  $\sigma_{R0} = 0,5$  dB for accuracy grade 1 or  $\sigma_{R0} = 1,5$  dB for accuracy grade 2 measurements as given in Table 1.

If  $\sigma_{omc} > \sigma_{R0}$ , the application of measurement procedures with a high accuracy, i.e. a low value of  $\sigma_{R0}$ , makes no sense economically because this is not going to result in a lower value of the total uncertainty.

**Table C.1 — Examples of calculated total standard deviations,  $\sigma_{tot}$ , for three different cases**

| Standard deviation of reproducibility of the method<br>$\sigma_{R0}$<br>dB | Operating and mounting conditions       |          |               |
|--|---|----------|---------------|
|  | stable                                  | unstable | very unstable |
|  | Standard deviation, $\sigma_{omc}$ , dB |          |               |
| 0,5<br>(Accuracy grade 1)  | 0,5                                     | 2        | 4             |
| Total standard deviation, $\sigma_{tot}$ , dB                              |   |          |               |
| 1,5<br>(Accuracy grade 2)  | 0,7                                     | 2,1      | 4,0           |
|  | 1,6                                     | 2,5      | 4,3           |

These examples show that it can be superfluous to extend the measuring effort to ensure a measurement of accuracy grade 1 if the uncertainty associated with the mounting and operating conditions is large.

Furthermore  $\sigma_{omc} > \sigma_{R0}$  may create substantial misunderstandings with respect to the true relevant total standard deviation,  $\sigma_{tot}$ , because the different grades of accuracy of this International Standard are currently defined by the value of  $\sigma_{R0}$  only.