International Standard

ISO 5114-1

Acoustics — Determination of uncertainties associated with sound emission measures —

Part 1: Sound power levels determined from sound pressure measurements

Acoustique — Détermination des incertitudes associées aux mesurages de l'émission sonore —

Partie 1: Niveaux de puissance acoustique déterminés à partir des mesurages de pression acoustique

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This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 211, *Acoustics,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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Introduction

An assessment of uncertainties that is comprehensible and close to reality is indispensable for reporting and using measured sound power levels. Uncertainties are determined following the principles of ISO/IEC Guide 98-3. This Guide specifies a detailed procedure for uncertainty evaluation that is based upon a mathematical model of the measurement. The detailedness of the model can vary from the mere analysis of the statistical spread of measured sound power levels up to an exhaustive characterisation of all relevant physical phenomena. Different such models are described by this document.

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Acoustics — Determination of uncertainties associated with sound emission measures —

Part 1: Sound power levels determined from sound pressure measurements

1 Scope

This document gives guidance on the determination of measurement uncertainties of sound power levels determined according to ISO 3741, ISO 3743-1, ISO 3743-2, ISO 3744, ISO 3745, ISO 3746, ISO 3747 or according to a noise test code based on one of these measurement standards.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

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

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3.1
measurement result
value attributed to a particular quantity, obtained by following the complete set of instructions given in a measurement procedure (the measured value), together with measurement uncertainty

Note 1 to entry: The measurement result can be expressed in terms of a sound power level in octave bands, one-third octave bands or an A-weighted sound power level.

3.2
measurement uncertainty
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that can reasonably be attributed to the particular quantity subject to measurement

3.3
expanded uncertainty
U
quantity defining an interval about the result of a measurement that is expected to encompass a large fraction of the distribution of values that can reasonably be attributed to the particular quantity subject to measurement

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3.4
coverage factor
k
numerical factor used as a multiplier of the measurement uncertainty in order to obtain an *expanded uncertainty* (3.3)

3.5
repeatability condition
condition of measurement that includes same measurement procedure; same observer; same measuring instrument; same location; and repetition over a short period of time

3.6
reproducibility condition
condition of measurement that includes different laboratories, operators, measuring systems, and replicate measurements on the same or similar objects

3.7
standard deviation of reproducibility of the method
σ_{R0}
standard deviation of measured values obtained under *reproducibility conditions* (3.6) using a specified method

Note 1 to entry: In statistics, it is usually distinguished between the standard deviation of the basic population σ and the empirical standard deviation derived from a sample s. Despite this, the symbol σ is used for all standard deviations in this document to be in line with other standards on sound emission.

3.8
standard deviation for the operating and mounting conditions
σ_{omc}
standard deviation of measured values caused by variations of operating and mounting conditions

3.9
total standard deviation
σ_{tot}
standard deviation of measured values obtained under *reproducibility conditions* (3.6)

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4 General concept to describe the uncertainty of measured sound power levels

The uncertainties of sound power levels, $u(L_W)$, in decibels, determined in accordance with the International Standard used (ISO 3741, ISO 3743-1, ISO 3743-2, ISO 3744, ISO 3745, ISO 3746 or ISO 3747) are estimated by the total standard deviation, in decibels, given by Formula (1):

$$u(L_W) = \sigma_{\text{tot}} \tag{1}$$

This standard deviation is expressed by the standard deviation of reproducibility of the method, σ_{R0}, in decibels, and the standard deviation for the operating and mounting conditions, σ_{omc}, in decibels, describing the uncertainty due to the instability of the operating and mounting conditions of the noise source under test in accordance with Formula (2):

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

Formula (2) shows that variations of operating and mounting conditions expressed by σ_{omc} should be taken into account before a measurement procedure with a certain grade of accuracy (characterized by σ_{R0}) is selected for a specific machine family. The standard deviation σ_{R0} includes all uncertainty due to conditions and situations allowed by the International Standard used (different radiation characteristics of the noise source under test, different instrumentation, different implementations of the measurement procedure),

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except that due to instability of the sound power of the noise source under test. The latter is considered separately by σ_{omc}.

Values for the standard deviation σ_{R0} may be derived from dedicated round robin tests (see Clause 6) or by using the mathematical modelling approach (see Clause 7). They should be given in noise test codes specific to machinery families.

NOTE 1 If different measurement procedures offered by ISO 3741, ISO 3743-1, ISO 3743-2, ISO 3744, ISO 3745, ISO 3746 or ISO 3747 are used, systematic numerical deviations (biases) can additionally occur.

Derived from σ_{tot}, the expanded measurement uncertainty, $U(L_W)$, in decibels, shall be calculated from Formula (3):

$$U(L_W) = k\sigma_{\text{tot}} \tag{3}$$

The expanded measurement uncertainty depends on the confidence level that is desired. For a normal distribution of measured values, there is a 95 % confidence level that the true value lies within the range $(L_W + U)$ to $(L_W - U)$. This corresponds to a coverage factor of $k = 2$. If the purpose of determining the sound power level is to compare the result with a limit value, it can 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 95 % confidence level.

NOTE 2 The expanded uncertainty, as described in this document, does not include the standard deviation of production which is used in ISO 4871[18] for the purpose of making a noise declaration for batches of machines.

5 Determination of σ_{omc}

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The standard deviation for the operating and mounting conditions σ_{omc} which describes the uncertainty associated with the instability of the operating and mounting conditions for the particular noise source under test shall be taken into account when determining the measurement uncertainty. It is determined 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 σ_{omc}, sound pressure level measurements are repeated either at the single microphone position associated with the highest sound pressure level, or at multiple microphone positions. These positions shall be distributed on an enveloping surface in approximated hemi-free fields or in a volume in approximated diffuse fields.

Measurements are then corrected for background noise. Background noise measurements should be taken at the same location, and as close as possible in time to the measurement when the machine is operating. Further, if background sound levels are within 10 dB of the total measured level, then the uncertainty associated with the variation in background sound level should be considered.

For each of these repeated measurements, the mounting of the machine and its operating conditions shall be readjusted. For the individual noise source under test, σ_{omc} is designated as σ'_{omc}. It is possible that a noise test code provides a value of σ_{omc} which is representative for the machine family concerned. This value should take into account all possible variations of operating and mounting conditions specified in the noise test code.

The standard deviation σ'_{omc} is calculated by Formula (4):

$$\sigma'_{\text{omc}} = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}\left(L_{p,j} - L_{\text{pav}}\right)^2} \tag{4}$$

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where

$L_{p,j}$	is the sound pressure level measured at a prescribed position or averaged over the surface or volume and corrected for background noise for the j^{th} repetition of the prescribed operating and mounting conditions, in decibels;
L_{pav}	is its arithmetic mean level calculated for all these repetitions, in decibels;
N	is the number of repeated measurements under variation of the prescribed operating and mounting conditions.

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 shall be defined precisely and described in the test report.

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

The test conditions shall represent normal usage and conform to manufacturers' and users' recommended practice. However, even in normal usage, variations within a specified operation mode, variations in material flow, and other conditions varying between different phases of operation can 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 can 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 σ_{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.

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

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

NOTE If the sound power has only a small variation with time and the measurement procedure is defined properly, a value of 0,5 dB for σ_{omc} can apply. In other cases, e.g. a large influence of the material flow into and out of the machine or material flow that varies in an unpredictable manner, a value of 2 dB is appropriate. However, in extreme cases such as strongly varying noise generated by the processed material (stone-breaking machines, metal-cutting machines and presses operating under load) a value of 4 dB results.

6 Determination of σ_{R0} by round robin tests

The standard deviation σ_{R0} includes uncertainty due to all conditions and situations allowed by ISO 3741, ISO 3743-1, ISO 3743-2, ISO 3744, ISO 3745, ISO 3746 and ISO 3747 (different radiation characteristics of the source under test, different instrumentation, different implementations of the measurement procedure) except that due to instability of the sound power of the source under test. The latter is considered separately by σ_{omc}.

Typical values of σ_{R0} are given in Table 1. They reflect the knowledge at the time of publication taking into consideration the great variety of machines and equipment covered by these standards (see References [2], [3], [7], [8]). In special cases or if certain requirements of the standards are not met for a machine family or

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if it is anticipated that actual values of σ_{R0} for a given family of machines are smaller than those given in the standards respectively, a round robin test is recommended to obtain machine-specific values of σ_{R0}.

Table 1 — Typical values for the standard deviation of reproducibility, σ_{R0}

ISO 3741						
Frequency bandwidth		**One-third-octave**				
One-third-octave mid-band frequency Hz		100 - 160	200 - 315	400 - 5 000	6 300 - 10 000	A-weighted
Standard deviation of reproducibility, σ_{R0} dB		3,0	2,0	1,5	3,0	0,5
ISO 3743-1						
Frequency bandwidth		**Octave**				
Octave mid-band frequency Hz		125	250	500 - 5 000	8 000	A-weighted
Standard deviation of reproducibility, σ_{R0} dB		3,0	2,0	1,5	2,5	1,5
ISO 3743-2						
Frequency bandwidth		**Octave**				
Octave mid-band frequency Hz		125	250	500 - 4 000	8 000	A-weighted
Standard deviation of reproducibility, σ_{R0} dB		5,0	3,0	2,0	3,0	2,0
ISO 3744						
Frequency bandwidth		**One-third-octave**				
One-third-octave mid-band frequency Hz		100 - 160	200 - 315	400 - 5 000	6 300 - 10 000	A-weighted
Standard deviation of reproducibility, σ_{R0} dB		3,0	2,0	1,5	2,5	1,5
ISO 3745						
Frequency bandwidth	**One-third-octave**					
One-third-octave mid-band frequency Hz	50- 80	100 - 630	800 - 5 000	6 300 - 10 000	12 500 - 20 000	A-weighted
	Hemi-anechoic room					
Standard deviation of reproducibility, σ_{R0} dB	2,0	1,5	1,0	1,5	2,0	0,5
	Anechoic room					
Standard deviation of reproducibility, σ_{R0} dB	2,0	1,0	0,5	1,0	2,0	0,5
ISO 3746						
						A-weighted
Standard deviation of reproducibility, σ_{R0} dB	For a noise source which emits sound without significant tones					3,0
	For a noise source which emits sound that contains predominant discrete tones					4,0
ISO 3747						
Grade of accuracy						A-weighted

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