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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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Foreword

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

~~Attention is drawn~~ISO draws attention to the possibility that ~~some of~~ the ~~elements~~implementation of this document may ~~be~~involve the ~~subject~~use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights~~.~~ in respect thereof. As of the date of publication of this document, ISO had received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights. ~~Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).~~

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

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).

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

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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.

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 test code based on one of these measurement standards.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

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

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)~~(3.3)

3.5
reproducibility condition

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

3.6
standard deviation of reproducibility of the method

~~σ_{R0}~~

σ_{R0}

standard deviation of measured values obtained under *reproducibility conditions* ~~(3.5)~~(3.5) 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.

3.7
standard deviation for the operating and mounting conditions

~~σ_{omc}~~

σ_{omc}

standard deviation of measured values caused by variations of operating and mounting conditions

3.8
total standard deviation

~~σ_{tot}~~

σ_{tot}

standard deviation of measured values obtained under *reproducibility conditions* ~~(3.5)~~(3.5)

3.9
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

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

The uncertainties of sound power levels, ~~$U(L_W)$,~~$U(L_W)$, 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):~~Formula (1):

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

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

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

~~Formula (2)~~ $$\sigma_{\text{tot}} = \sqrt{\sigma_{R0}^2 + \sigma_{\text{omc}}^2} \qquad (2)$$

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

Values for the standard deviation ~~σ_{R0}~~ σ_{R0} may be derived from dedicated round robin tests (see ~~Clause 6)~~ Clause 6) or by using the mathematical modelling approach (see ~~Clause 7).~~ 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},~~ σ_{tot}, the expanded measurement uncertainty, ~~$U(L_W)$,~~ $U(L_W)$, in decibels, shall be calculated from ~~Formula (3):~~ Formula (3):

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

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 ~~$(L_W + U)$~~ $(L_W + U)$ to ~~$(L_W - U)$.~~ $(L_W - U)$. This corresponds to a coverage factor of ~~$k = 2$.~~ $k = 2$. 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 ~~$k = 1{,}6$~~ $k = 1{,}6$ 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]~~[18] for the purpose of making a noise declaration for batches of machines.

5 Determination of ~~σ_{omc}~~ σ_{omc}

The standard deviation for the operating and mounting conditions ~~σ_{omc}~~ σ_{omc} which describes 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 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},~~ 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 ~~hemifree~~ 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 sound source under test, ~~σ_{omc}~~ σ_{omc} is designated as ~~σ'_{omc}.~~ σ'_{omc}. It is possible

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that a noise test code provides a value of ~~σ_{omc}~~ 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}~~ σ_{omc} is calculated by ~~Formula (4):~~ Formula (4):

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

$$\sigma'_{\mathrm{omc}} = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}(L_{p,j}-L_{\mathrm{pav}})^2}\mathrm{dB} \qquad (4)$$

where

~~$L_{p,j}$~~ $L_{p,j}$	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}~~ 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}~~ 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}~~ 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.

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

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

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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}~~ 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}~~ σ_{R0} by round robin tests

The standard deviation ~~σ_{R0}~~ 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}~~ σ_{omc}.

Typical values of ~~σ_{R0}~~ σ_{R0} are given in ~~Table 1.~~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]).~~[2], [3], [7], [8]). In special cases or if certain requirements of the standards are not met for a machine family or if it is anticipated that actual values of ~~σ_{R0}~~ 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}~~ σ_{R0}.

Table 1 — Typical values for the standard deviation of reproducibility ~~σ_{R0}~~ 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}~~ 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}~~ 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}~~ σ_{R0} dB		5,0	3,0	2,0	3,0	2,0
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