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Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering methods for small, movable sources in reverberant fields —

Part 2: Methods for special reverberation test rooms

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit à partir de la pression acoustique — Méthodes d'expertise en champ réverbéré applicables aux petites sources transportables —

Partie 2: Méthodes en salle d'essai réverbérante spéciale

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Foreword

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

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

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

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

For an explanation on 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.

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

This second edition cancels and replaces the first edition (ISO 3743-2:1994), of which it constitutes a minor revision. The main changes are the following:

— Table 0.1 in the Introduction deleted;

— restructuring of the content of Clause 1;

— references updated;

— clause on measurement uncertainty revised to be in-line with the other standards of the ISO 3740 series (now Clause 11);

— new Annexes D, E, and F added;

— new entries in Bibliography added.

A list of all the parts in the ISO 3743 series can be found on the ISO website.

Introduction

ISO 3743 is one standard of the series ISO 3741 to ISO 3747 series, which specifies various methods for determining the sound power levels of machines, equipment and sub-assemblies. These basic standards specify the acoustical requirements for measurements appropriate for different test environments. When selecting one of the methods of the series ISO 3741 to ISO 3747, it is necessary to select the most appropriate for the conditions and purposes of the noise test. General guidelines to assist in the selection are provided in ISO 3740. The series ISO 3741 to ISO 3747 gives only general principles regarding the operating and mounting conditions of the machine or equipment under test. Reference should be made to the noise test code for a specific type of machine or equipment, if available, for specifications on mounting and operating conditions.

The method given in this document enables measurement of sound pressure levels with A-weighting and in octave bands at pre-scribed fixed microphone positions or along prescribed paths. It allows determination of A-weighted sound power levels or sound power levels with other weighting and octave-band sound power levels. Quantities which cannot be determined are the directivity characteristics of the source and the temporal pattern of noise radiated by sources emitting non-steady noise.

ISO 3743-1 and this document specify engineering methods for determining the A-weighted and octave-band sound power levels of small noise sources. The methods are applicable to small machines, devices, components and sub-assemblies which can be installed in a special reverberation test room or in a hard-walled test room with prescribed acoustical characteristics. The methods are particularly suitable for small items of portable equipment; they are not intended for larger pieces of stationary equipment which, due to their manner of operation or installation, cannot readily be moved into the test room and operated as in normal usage. The procedures are intended to be used when an engineering grade of accuracy is desired without requiring the use of laboratory facilities.

In ISO 3743-1, a comparison method is used to determine the octave-band sound power levels of the source. The spatial average (octave-band) sound pressure levels produced by the source under test are compared to the spatial average (octave-band) sound pressure levels produced by a reference sound source of known sound power output. The difference in sound pressure levels is equal to the difference in sound power levels if conditions are the same for both sets of measurements. The A-weighted sound power level is then calculated from the octave-band sound power levels.

The requirements to be fulfilled by the special reverberation test room for measurements in accordance with this document are significantly more restrictive than those placed on the hard-walled test room by the comparison method of ISO 3743-1.

Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering methods for small, movable sources in reverberant fields —

Part 2: **Methods for special reverberation test rooms**

1 Scope

This document specifies a relatively simple engineering method for determining the sound power levels of small, movable noise sources. The methods specified in this document are suitable for measurements of all types of noise within a specified frequency range, except impulsive noise consisting of isolated bursts of sound energy which are covered by ISO 3744 and ISO 3745.

NOTE A classification of different types of noise is given in ISO 12001.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 3741, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms*

ISO 3743-1, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for small movable sources in reverberant fields — Part 1: Comparison method for a hard-walled test room*

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

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

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

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

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61260 (all parts), *Electroacoustics — Octave-band and fractional-octave-band filters*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3743-1 and the following apply.

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

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

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

3.1
special reverberation test room
room which meets the requirements of Clause 6 of ISO ISO 3743-2

Note 1 to entry: The requirements for a test room according to this document are significantly more restrictive than those placed on the hard-walled test room by the comparison method of ISO 3743-1.

4 Principle

The measurements are carried out when the source is installed in a specially designed room having a specified reverberation time over the frequency range of interest. The A-weighted sound power level of the source under test is determined from a single A-weighted sound pressure level measurement at each microphone position, rather than from a summation of octave-band levels. This direct method eliminates the need for a reference sound source, but requires the use of a special reverberation test room. The direct method is based on the premise that the sound pressure level, averaged in space and time in the test room, can be used to determine the sound power level emitted by the source. The properties of the special reverberation test room are chosen so that the room's influence on the sound power output of the equipment under test is small. The number of microphone positions and source locations required in the test room are specified. Guidelines for the design of special reverberation rooms are given in Annex B.

In addition to the direct method, a comparison method is also described (see 10.3). However, since the requirements on the test room for the comparison method of ISO 3743-1 are considerably less restrictive, it is recommended that the comparison method of ISO 3743-1 be used if a special reverberation test room is not available.

NOTE Precision methods for the determination of the sound power levels of small noise sources are specified in ISO 3741 and ISO 3745.

5 Noise source

The noise source may be a device, machine, component or sub-assembly.

The maximum size of the source under test and the lower limit of the frequency range for which the methods are applicable depend upon the size of the room used for the acoustical measurements. The volume of the noise sources should not exceed 1 % of the volume of the special reverberation test room. For the minimum test room volume of 70 m^3, the recommended maximum size of the source is 0,7 m^3. Measurements on sources emitting discrete-frequency components below 200 Hz are frequently difficult to make in such small rooms.

6 Requirements for special reverberation test room

6.1 General

Guidelines for the design of a suitable test room and an example of the determination of the nominal reverberation time of the room are given in Annex B. Methods of measurement of reverberation time are given in ISO 354.

6.2 Volume of test room

The volume of the test room shall be at least 70 m^3 and preferably greater if the 125 Hz octave band is within the frequency range of interest. If the 4 kHz and 8 kHz octave bands are within the frequency range of interest, the volume shall not exceed 300 m^3.

NOTE When using the comparison method, the use of larger room volumes is acceptable.

6.3 Reverberation time of test room

The calculation of sound power levels from measured values of the sound pressure levels requires a compensation for the frequency-dependent concentration of sound energy near the walls of the test room. To facilitate this compensation, the reverberation time should be slightly higher at low frequencies. The reverberation time of the test room shall fall within the limiting curves defined by $T = 0{,}9\ RT_{\text{nom}}$ and $1{,}1\ RT_{\text{nom}}$ where the reverberation parameter, R, is given by

$$R = 1 + \frac{257}{fV^{1/3}} \tag{1}$$

where

f is the frequency, in hertz;

V is the volume, in cubic metres.

NOTE The following is a more robust formula for R and is not limited to rooms that are nearly cubical:

$$R = 1 + \frac{c \cdot S}{f \cdot 8V}$$

where

c is the sound velocity, in metres per second;

S is the surface area of the test room, in square metres.

For frequencies above 6,3 kHz, constants 0,9 and 1,1 shall be replaced by 0,8 and 1,2 respectively. The nominal reverberation time of the room, T_{nom} is determined by centring the measured values of T (normalized to the reverberation time at 1 000 Hz) within the limiting curves specified above, and shall be between 0,5 s and 1,0 s (see Annex B for an example). For a room volume V of 70 m^3, the value of R is determined from Figure 1.

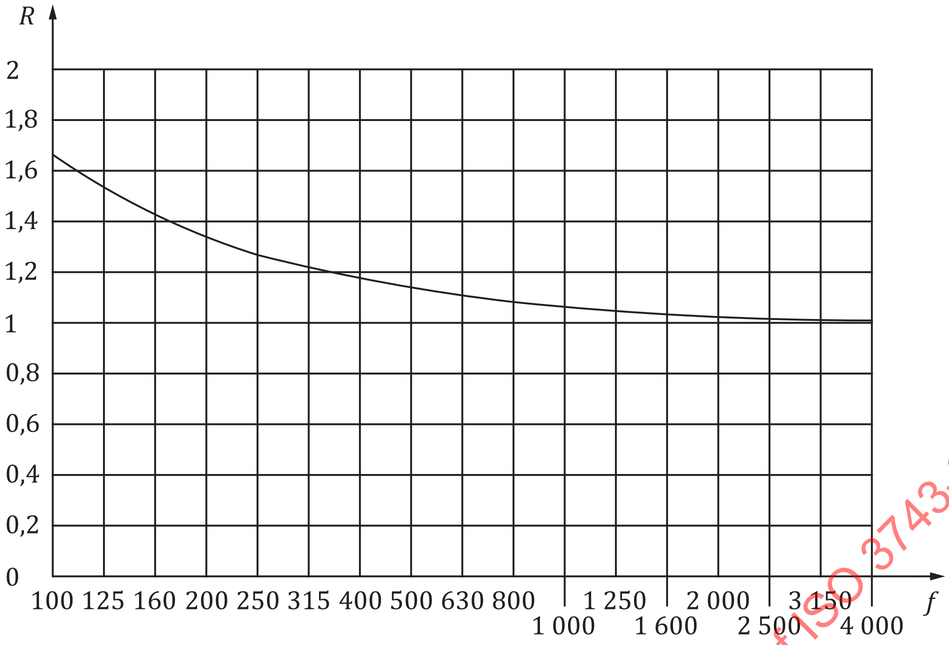
If, during the acoustical measurements, sound-absorptive structures support the source or if the source has absorptive surfaces, the reverberation time T shall be measured with these items present.

6.4 Surface treatment

The floor of the test room shall be reflective with an absorption coefficient less than 0,06. Except for the floor, none of the surfaces shall have absorptive properties significantly deviating from each other. For each octave band within the frequency range of interest, the mean value of the absorption coefficient of each wall and of the ceiling shall be within 0,5 and 1,5 times the mean value of the absorption coefficient of the walls and ceiling.

6.5 Criterion for background noise

At each microphone position, the sound pressure levels due to background noise shall be at least 4 dB and preferably more than 10 dB below the A-weighted sound pressure level or the band pressure levels produced by the source.



Key

f one-third-octave-band centre frequency, in hertz

R reverberation parameter

Figure 1 — Values of *R* at the one-third-octave-band centre frequencies for $V = 70\ m^3$

6.6 Criteria for temperature and humidity

The air absorption in the reverberation room varies with temperature and humidity, particularly at frequencies above 1 000 Hz. The temperature θ, in degrees Celsius, and the relative humidity (H), expressed as a percentage, shall be controlled during the sound pressure level measurements. The product

$$H \cdot (\theta + 5\,°C) \tag{2}$$

shall not differ by more than ±10 % from the value of the product which prevailed during the measurement of the reverberation time of the test room.

NOTE To keep the reverberation time within the specified limits at the highest frequencies, a reduction of the air absorption is sometimes necessary. An increase in the humidity (for example by using a small humidifier) may be beneficial.

6.7 Evaluation of suitability of test room

Before a test room is used for sound power level determinations, its suitability shall be evaluated using the following procedure.

a) Step 1

Obtain a small broad-band reference sound source which has been calibrated in accordance with ISO 3741, or by following the procedures specified in ISO 6926 and ISO 3745.

b) Step 2

In the special reverberation test room, determine the octave-band power levels of the same reference sound source under identical operating conditions in accordance with the procedure given in this document.

c) Step 3

For each octave band within the frequency range of interest, calculate the difference between the sound power levels obtained in this way.

d) Step 4

Compare these differences with the values given in Table 1.

If the differences in octave-band power levels do not exceed those specified in Table 1, the room is suitable for sound power determinations of broad-band noise sources in accordance with the procedures of this document.

Table 1 — Maximum permitted differences between octave-band power levels of broad-band noise sources measured in accordance with 6.7 a)

Octave-band centre frequency Hz	Difference in band power levels dB
125	±5
250 to 4 000	±3
8 000	±4

7 Instrumentation

7.1 General

The basic instrumentation consists of a microphone, an amplifier with A-weighting network, a squaring and averaging circuit and an indicating device. A set of octave-band filters is also required. These elements may be separate instruments or they may be integrated into a complete unit, for example, a suitable sound level meter. For requirements on sound level meters, see IEC 61672-1.

The microphone shall, whenever possible, be physically separated from the rest of the instrumentation with which it is connected by means of a cable. Examples of suitable instrumentation systems are given in Annex C.

7.2 Microphone and its associated cable

The microphone shall have a flat frequency response for randomly incident sound over the frequency range of interest, as determined by the procedure given in 7.6.

NOTE 1 This requirement is not normally met by the microphone of a sound level meter which is calibrated for free field measurements.

NOTE 2 If several microphones are used, it is desirable to avoid the axis of each microphone being oriented in the same direction in space.

The frequency response and stability of the microphone system shall not be adversely affected by the cable connecting the microphone to the rest of the instrumentation system. If the microphone is moved, care shall be exercised to avoid introducing acoustical or electrical noise that could interfere with the measurements.

7.3 Amplifier and weighting network

The properties of the amplifier and the A-weighting network shall comply with the requirements of IEC 61672-1.

7.4 Octave-band filters

The octave-band filters shall comply with the requirements of IEC 61260 (all parts).

7.5 Squaring and averaging circuits and indicating device

Squaring and averaging the microphone output voltage may be performed by analogue or digital equipment as described in Annex C. In analogue systems, continuous averaging is generally performed by an RC-smoothing network with a time constant τ_A. For these systems, the time constant shall be at least 0,5 s and such that the indicated fluctuations are less than ±5 dB.

In digital systems and in some analogue systems, true integration over a fixed time/interval (integration time τ_D) is employed. The integration time shall be at least 1 s. The indication of the squaring and averaging (integrating) circuits and indicating device shall be within 3 % of the values.

7.6 Frequency response of the instrumentation system

The frequency response of the instrumentation calibrated for randomly incident sound shall be determined in accordance with the procedure in IEC 61672 with the acceptance limits given in Table 2.

Table 2 — Acceptance limits for the instrumentation system

Frequency Hz	Acceptance limits dB
100 to 4 000	±1
5 000	±1,5
6 300	+1,5 −2
8 000	+1,5 −3
10 000	+2 −4
NOTE Adapted from IEC 61672-1.	

7.7 Calibration

During each series of measurements, a sound calibrator with an accuracy of ±0,3 dB (class 1 as specified in IEC 60942) shall be applied to the microphone to verify the calibration of the entire measuring system at one or more frequencies over the frequency range of interest.

The calibrator shall be checked annually to verify that its output has not changed. In addition, an electrical calibration of the instrumentation system over the entire frequency range of interest shall be carried out periodically, at intervals not exceeding 2 years.

8 Installation and operation of source under test

8.1 General

The acoustical properties of the special reverberation test room and the manner in which the source is operated may have a significant influence on the sound power emitted by the source.

8.2 Source location

Install the source in the test room in one or more locations as if it were being installed for normal usage. If no such location(s) can be defined, place the source on the floor of the test room with a minimum distance of 1 m between any surface of the source and the nearest wall.

The location(s) of the source in the test room shall be described in the test report.

NOTE The influence of the acoustical properties of the room on the sound power emitted by the source depends to some extent on the position of the source within the room. The requirements on the test room (see Clause 6) tend to decrease this influence. However, in some cases it may be necessary or desirable to determine the sound power level of a source in several locations in the test room (see 9.4).

8.3 Source mounting

In many cases, the sound power emitted will depend upon the support or mounting conditions of the source under test. Whenever a typical condition of mounting exists for the equipment under test, that condition shall be used or simulated, if feasible.

If a typical condition of mounting does not exist or cannot be utilized for the test, take care to avoid changes in the sound output of the source caused by the mounting system employed for the test. Take steps to reduce any sound radiation from the structure on which the equipment may be mounted.

Sources normally mounted through a window, wall or ceiling shall be mounted through a wall or the ceiling of the test room.

The mounting conditions of the source and its associated equipment shall be described in the test report.

NOTE The use of resilient mounts or vibration-damping material on large surfaces used to support the equipment under test may be appropriate.

8.4 Auxiliary equipment

Take care 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 room. If practicable, locate all auxiliary equipment necessary for the operation of the source under test outside the test room and clear the test room of all objects which may interfere with the measurements.

8.5 Operation of source during the test

During the measurements, use the operating conditions specified in the test code, if any exists for the particular type of machinery or equipment under test. If there is no test code, operate the source, if possible, in a manner which is typical of normal use. In such a case, one or more of the following operating conditions shall be selected:

a) device under specified load and operating conditions;

b) device under full load [if different from a) above];

c) device under no load (idling);

d) device under operating conditions corresponding to maximum sound generation representative of normal use.

The method given in this document is applicable for determining the sound power level of the source under any desired set of operating conditions (i.e. temperature, humidity, device speed, etc.). These test conditions shall be selected beforehand and shall be held constant during the test. The source shall be in the desired operating condition before any acoustical measurements are made.

The operating conditions of the source during the acoustical measurements shall be described in the test report.

9 Measurements in test room

9.1 General

The calculation of the approximate sound power level of the source is based on measured mean-square values of the sound pressure averaged in time over an appropriate number of positions within the test room.

Use a single microphone moved from position to position, an array of fixed microphones, or a microphone moving continuously over an appropriate path in the test room.

9.2 Period of observation

The period of observation shall be at least ten times the time constant τ_A. Average the results over this period and record the mean value as the result of the measurement.

For instrumentation with RC-smoothing, do not start any observation after any filter switching or disturbance of the sound field (including transfer of the microphone to a new fixed position) until a "settling" time of at least five times the time constant of the instrumentation has elapsed.

If integration over a fixed time interval, τ_D, is used, the measurement at each fixed microphone position shall be of at least 5 s duration (for example, if τ_D = 1 s, five readings shall be averaged on a mean-square basis; if τ_D = 5 s, the reading at the end of the interval of 5 s shall be taken). If the microphone is moved over a path, the total period of observation shall be at least 30 s for frequency bands centred on 160 Hz and below (and for A-weighting), and at least 10 s for frequency bands centred on 200 Hz or above.

9.3 Microphone positions

No microphone position shall be closer to the surface of the room than $\lambda/4$, where λ, is the wavelength of sound corresponding to the centre frequency of the lowest octave band in which measurements are made. The minimum distance, d_{min}, in metres, between any microphone position and the surface of the source under test shall be

$$d_{min} = 0{,}3 V^{1/3} \tag{3}$$

where V is the volume of the test room, in cubic metres.

The distance between any two microphone positions shall be at least $\lambda/2$, where λ is the wavelength of the sound wave corresponding to the centre frequency of the lowest octave band in which measurements are made.

For measurements with A-weighting, assume λ = 3,5 m.

9.4 Number of microphones and source positions

The number of microphone positions and source locations necessary to obtain a specified precision of the sound power levels depend on the properties of the source and the test room. For each source, the minimum number of positions necessary to obtain standard deviations which are equal to or less than the values given in Table 5 shall be determined by the following procedure which shall be followed for each octave band of interest and for A-weighting.

a) Step 1

For a particular source location, measure the sound pressure levels at six microphone positions.

b) Step 2

Calculate the estimated standard deviation, s_M, in decibels, of the measured sound pressure levels from Formula (4):

$$s_M = (n-1)^{-1/2}\left[\sum_{i=1}^{n}\left(L_{pi}-\overline{L_p}\right)^2\right]^{1/2} \quad (4)$$

where

L_{pi} is the sound pressure level, in decibels at the i^{th} measurement position (reference: 20 µPa);

$\overline{L_p}$ is the mean value of L_{p1}, L_{p2}, ..., L_{p6}, in decibels (reference: 20 µPa);

n is the number of microphone positions (n = 6).

If the range of values of L_{p1}, L_{p2}, ..., L_{p6} is not greater than 5 dB, a simple arithmetic average may be used for $\overline{L_p}$. If the range is greater than 5 dB, $\overline{L_p}$ shall be calculated using Formula (5):

$$\overline{L_p} = 10\lg\left[1/6\left(10^{0{,}1L_{p1}} + 10^{0{,}1L_{p2}} + ... + 10^{0{,}1L_{p6}}\right)\right]\text{dB} \quad (5)$$

NOTE The magnitude of s_M will depend on the properties of the sound field in the test room. These properties are influenced by the characteristics of the test room and the source (i.e. its directivity and the spectrum of the emitted sound).

c) Step 3

Enter in Table 3 the value of s_M, in decibels, determined from step 2 and select from the table a suitable combination of the minimum number of microphone positions, N_M, and source locations, N_S, for each octave band and for A-weighting. These minimum numbers of positions shall be used in order to obtain the accuracy specified in Table 5.

As s_M has been determined from six measurements in each octave band and for A-weighting, the minimum value of N_M will generally be 6. If several samples of the same type of sound source are measured one after another in the same test room, smaller values of N_M may be chosen for all but the first sample when appropriate. In these circumstances, the sources shall, however, be identical not only in geometry but also as far as the spectrum of the emitted sound is concerned.

Table 3 — Minimum number of source locations, N_S, for given numbers of microphone positions, N_M, values of estimated standard deviations, s_M, and octave-band centre frequencies

s_M	Octave-band centre frequency	Number of microphone positions, N_M		
		3	6	12
dB	Hz	Minimum number of source locations, N_S		
s_M < 2,3	125 to 8 000 and A-weighting	1	1	1
2,3 ≤ s_M ≤ 4	125	1	1	1
	250, 500 and A-weighting	2	2	1
	1 000 to 8 000	2	1	1
s_M > 4	125	3	2	2
	250 and A-weighting	4	3	2
	500	4	2	2
	1 000 to 8 000	3	2	1
NOTE For each source position, the mean-square pressure should be determined.				

9.5 Criteria for the presence of spectral irregularities

The presence of irregularities in the spectrum of the emitted sound can be determined from the values of s_M. Because s_M is only an estimate of the true standard deviation σ, three broad ranges have been selected to define the presence of discrete frequencies or narrow bands of noise:

a) if $s_M > 4$ dB, a discrete tone may be present in the band in question;

b) if 2,3 dB $\leq s_M \leq$ 4 dB, narrow-band noise components may be present in the frequency band in question;

c) if $s_M <$ 2,3 dB, the spectrum is probably broadband in character.

The suspected presence of any narrow-band components or discrete frequencies in the spectrum of the emitted sound shall be reported.

9.6 Averaging technique with moving microphones

9.6.1 General

The use of a moving microphone traversing a path in the test room at constant speed will often be more convenient than the use of a number of fixed microphone positions. The path may be a line, an arc, a circle or some other geometric figure.

9.6.2 Path length for continuous averaging

For continuous averaging, the minimum path length, l, may be determined from the formula

$$l = \frac{\lambda}{2} N_M \tag{6}$$

if the path is a line or arc.

If the averaging is made over a rectangular or circular area, the minimum area, A, may be determined from the formula

$$A = \left(\frac{\lambda}{2}\right)^2 N_M \tag{7}$$

In these formulae, λ, is the wavelength of the sound corresponding to the centre frequency of the octave band in which the measurement is made.

The values of s_M in Table 3 may be determined by measuring the mean-square pressure at six points spaced at least $\lambda/2$ apart along the path.

For measurements with A-weighting, assume $\lambda = 3{,}5\,\text{m}$.

9.6.3 Location of path within test room

The path shall contain only microphone positions that meet the requirements of 9.3.

If the path or a portion of the path can be included within a plane, this plane shall not lie within 10° of a parallel to any room surface.

9.6.4 Speed of traverse

The path shall be traversed by the microphone at a constant speed. The repetition rate of the microphone traverse (or the scanning rate for an array of fixed microphones) shall be related to the integrating time or time constant of the instrumentation system. For RC-smoothing, the traverse or scanning period shall be less than twice the time constant. If an integrator is used, a single period of the microphone traverse (or the period of scanning the entire microphone array) shall be equal to the integrating time. The total period of observation is specified in 9.2.

9.7 Array of fixed microphones

If an array of fixed microphones is used for the measurements, all microphones and cables shall comply with the requirements of 7.2.

The number of microphones to be used shall be determined as specified in 9.4 and the microphone positions shall be located as specified in 9.3.

If the array or a portion of the array can be included within a plane, this plane shall not lie within 10° of a parallel to any room surface.

During the sampling of the output of the microphones, the precautions given in 9.2 shall be observed.

9.8 Correction for background sound pressure levels

Correct the measured band pressure levels or the influence of background noise in accordance with Table 4. If the background sound pressure level is less than 4 dB below the sound pressure level with either the reference sound source or the equipment operating, the accuracy of the measurements will be reduced and no data shall be reported unless it is clearly stated that the background noise requirements of this document have not been fulfilled.

Table 4 — Corrections for background sound pressure levels

Difference between sound pressure level measured with sound source operating and background sound pressure level alone dB	Correction to be subtracted from sound pressure level measured with noise source operating to obtain sound pressure level due to noise source alone dB
4	2
5	2
6	1
7	1
8	1
9	0,5
10	0,5
>10	0

10 Calculation of sound power levels

10.1 Calculation of mean band pressure levels

From the measured band pressure levels for each octave band of interest and from the measured Aweighted sound pressure levels, calculate the mean octave-band level and the A-weighted sound pressure level, $\overline{L_p}$, in decibels, according to Formula (8):

$$\overline{L_p} = 10 \lg \left[\frac{1}{n} \left(10^{0,1 L_{p1}} + 10^{0,1 L_{p2}} + ... + 10^{0,1 L_{pn}} \right) \right] \tag{8}$$

where

L_{p1} is the octave-band level or A-weighted level for the first measurement, in decibels;

L_{pn} is the octave-band level or A-weighted level for the n^{th} measurement, in decibels;

n is the total number of measurements for a particular octave band or with the A-weighting network inserted.

10.2 Direct method for determining sound power levels

The approximate band power levels or A-weighted sound power level of the source, L_W, in decibels (reference: 1 pW), shall be calculated from Formula (9):

$$L_W = \overline{L_p} - 10\lg\frac{T_{nom}}{T_0} + 10\lg\frac{V}{V_0} - 13\text{dB} \quad (9)$$

where

$\overline{L_p}$ is the mean octave-band sound pressure level or mean A-weighted sound pressure level;

T_{nom} is the nominal reverberation time of the test room, in seconds (see 6.3);

T_0 = 1 s;

V is the volume of the test room, in cubic metres;

V_0 = 1 m^3.

NOTE The constant 13 dB instead of 14 dB (which appears in other International Standards) and the variation of the reverberation time with frequency account approximately for the increase in sound energy density near the surfaces of the special reverberation test room and near the source.

Reduced atmospheric pressure creates a bias in the sound power level. At altitudes greater than 500 m, sound power levels, $L_{W\text{ref,atm}}$, corresponding to the reference barometric pressure of 101,325 kPa and reference atmospheric temperature 23,0 °C shall be calculated according to Annex E.

10.3 Comparison method for determining band power levels

Place a reference source meeting the requirements laid down in Annex A on the floor of the test room at least 1,5 m from any wall. The minimum distance between the source and any microphones shall fulfil the requirements of 9.3.

Determine the mean sound pressure level of the reference source in each octave band, L_{pr}, using no fewer than six microphone positions, background noise corrections (if necessary) and the calculation procedure of 10.1.

Then calculate the sound power level produced by the source, L_{We}, in decibels (reference: 1 pW), in each octave band within the frequency range of interest as follows:

a) subtract the band pressure level produced by the reference sound source, L_{pr}, (after corrections for background noise in accordance with 9.8) from the known sound power level produced by the reference sound source;

b) add the difference to the band pressure level of the source under test, L_{pe} (after corrections for background noise in accordance with 9.8), i.e.

$$L_{We} = L_{pe} + \left(L_{Wr} - L_{pr}\right) \quad (10)$$

where

L_{pe} is the mean band pressure level of the source under test, in decibels (reference: 20 µPa);

L_{Wr} is the band power level of the reference sound source, in decibels (reference: 1 pW);

L_{pr} is the mean band pressure level of the reference sound source, in decibels (reference: 20 µPa).

Reduced atmospheric pressure creates a bias in the sound power level. At altitudes greater than 500 m, sound power levels, $L_{W\text{ref,atm}}$, corresponding to the reference barometric pressure of 101,325 kPa and reference atmospheric temperature 23,0 °C shall be calculated in accordance with Annex E.

10.4 A-weighted sound power levels determined by the comparison method

Calculation of the A-weighted sound power level of the noise source under test from the measurements made in octave bands according to 10.3 shall be performed using the procedure given in Annex F.

11 Measurement uncertainty

11.1 Methodology

The uncertainties of sound power levels, $u(L_W)$, in decibels, determined in accordance with this document are estimated by the total standard deviation, σ_{tot}, in decibels:

$$u(L_W) \approx \sigma_{\text{tot}} \tag{11}$$

This total standard deviation is obtained using the modelling approach specified in ISO/IEC Guide 98-3. This requires a mathematical model which in case of lack of knowledge can be substituted with 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, σ_{R0}, in decibels, and the standard deviation, σ_{omc}, in decibels, describing the uncertainty due to the variations of the operating and mounting conditions of the source under test according to:

$$\sigma_{\text{tot}} = \sqrt{\sigma_{R0}^2 + \sigma_{\text{omc}}^2} \tag{12}$$

Formula (12) 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 (see 11.5 and D.3).

NOTE If different measurement procedures offered by the series ISO 3741 to ISO 3747 are used, systematic numerical deviations (biases) may additionally occur.

Derived from σ_{tot}, the expanded measurement uncertainty U, in decibels, shall be calculated from

$$U = k\sigma_{\text{tot}} \tag{13}$$

The expanded uncertainty depends on the degree of confidence that is desired. For a normal distribution of measured values, there is a 95 % confidence 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 might 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.

11.2 Determination of σ_{omc}

The standard deviation σ_{omc} [see Formula (D.1)] which describes the uncertainty associated with the variations 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 σ_{omc} repeated sound pressure levels are measured either at the microphone position associated with the highest sound pressure level, or measured and averaged over the entire measurement surface. Measured levels are then corrected for background noise. For each of these repeated measurements, the mounting of the machine and its operating conditions are to be readjusted. For the individual sound 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 that are within the scope of the noise test code.

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} may be applicable. In other cases, for example, a large influence of the material flow in and out of the machine or material flow that might vary in an unforeseeable manner, a value of 2 dB may be 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 can result.

11.3 Determination of σ_{R0}

11.3.1 General

The standard deviation, σ_{R0}, includes uncertainty due to all conditions and situations allowed by this document (different radiation characteristics of the source under test, different instrumentation, different realizations of the measurement procedure), except the influence due to variations of the sound power of the source under test. The latter is considered separately by σ_{omc}.

The values of σ_{R0} given in Table 5 reflect the knowledge at the time of publication of this document. They are typical upper bounds taking into consideration the great variety of machines and equipment covered by this document. Machinery-specific values may be derived from round robin tests (see 11.3.2) or by using the mathematical modelling approach (see 11.3.3). They should be given in noise test codes specific to machinery families (see 11.2 and Annex D).

11.3.2 Round robin test

The round robin test for determining σ_{R0} shall be carried out in accordance with ISO 5725 (all parts), where the sound power 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 σ'_{tot} relevant for 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 σ'_{tot}, in decibels, of all results obtained with a round robin test includes the standard deviation σ'_{omc} and allows σ'_{R0} to be determined using Formula (14):

$$\sigma'_{R0} = \sqrt{{\sigma'_{tot}}^2 + {\sigma'_{omc}}^2} \tag{14}$$

If σ'_{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 document to this particular family and used as σ_{R0}. Whenever available, such value should be given in the noise test code specific to the machine family concerned (together with σ_{omc}) and used in particular for the purpose of declaring noise emission values.

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

For certain applications the effort for the round robin test can be reduced by omitting measurements for different locations, e.g. if machines under test usually are installed under conditions with a small background noise correction K_1, 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 $\sigma_{R0,\mathrm{DL}}$, and this designation should also be used for tests on large machines being not movable in space.

Values for $\sigma_{R0,\mathrm{DL}}$ can be expected to be lower than those given in Table 5.

The determination of σ_{R0} using Formula (14) is imprecise if σ_{tot} is only slightly higher than σ_{omc}. In this case, Formula (14) provides a small value of σ_{R0} but with a low accuracy. To limit this inaccuracy, σ_{omc} should not exceed $\sigma_{\mathrm{tot}} / \sqrt{2}$.

11.3.3 Modelling approach for σ_{R0}

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

$$\sigma_{R0} \approx \sqrt{(c_1 u_1)^2 + (c_2 u_2)^2 + \ldots + (c_n u_n)^2} \qquad (15)$$

In Formula (15), the uncertainty components due to the variations of the noise emission of the source are not included. These components are covered by σ_{omc}. Annex D discusses each component of the uncertainty σ_{R0} according to existing knowledge.

NOTE If the uncertainty components in the modelling approach are correlated, Formula (15) does not apply. Furthermore, the modelling approach requires detailed knowledge to determine the individual terms in Formula (15).

By contrast, the estimation of σ_{R0} based on round robin tests does not require assumptions about possible correlations between the individual terms of Formula (15). Therefore, at the time of publication of this document, estimation by round robin testing is more realistic than a modelling approach when possible correlations between terms and their dependency from all other influencing parameters are not well understood. However, round robin tests are not always possible and are often replaced by experience from earlier measurements.

11.4 Typical upper bound values of σ_{R0}

Table 5 shows typical upper bound values of the standard deviation σ_{R0} for accuracy grade 2 that may cover most of the applications of this document (see References [15] and [16]). In special cases or if certain requirements of this document are not met for a machine family or if it is anticipated that actual values of σ_{R0} for a given family of machines are smaller than those given in Table 5, a round robin test is recommended to obtain machine-specific values of σ_{R0}.

Table 5 — Typical upper bound values of the standard deviation of reproducibility of the method, σ_{R0}, for octave band and A-weighted sound power levels determined in accordance with this document

Frequency band-width	Octave mid-band frequency Hz	Standard deviation of reproducibility, σ_{R0} dB
Octave	125	5,0
	250	3,0
	500 to 4 000	2,0
	8 000	3,0
A-weighted		2,0 [a]
[a] Applicable to noise sources which emit sound with a relatively “flat” spectrum in the frequency range from 125 Hz to 8 000 Hz.		

11.5 Total standard deviation σ_{tot} and expanded uncertainty U

The total standard deviation and the expanded uncertainty shall be determined using Formula (12) and Formula (13) respectively.

EXAMPLE Accuracy grade 2; σ_{omc} = 2,0 dB; coverage factor k = 2; measured L_{WA} = 82 dB. Machine-specific determinations of σ_{R0} have not been undertaken thus the value is taken from Table 5 (σ_{R0} = 2,0 dB). Using Formulae (13) and (12) it follows:

$$U = 2 \cdot \sqrt{2^2 + 2^2}\ \text{dB} = 5{,}7\ \text{dB} \tag{16}$$

Additional examples of calculated values for σ_{tot} are given in D.3.

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

12 Information to be recorded

12.1 General

The information specified in 12.2 to 12.5, when applicable, shall be compiled and recorded for all measurements made in accordance with the requirements of this document.

12.2 Sound source under test

a) Description of the sound source under test, including its

- type,
- technical data,
- dimensions,
- manufacturer,
- serial number, and
- year of manufacture.

b) Operating conditions.

c) Mounting conditions.

d) Location(s) of noise source in test room.

e) If the test object has multiple noise sources, description of source(s) in operation during measurements.

12.3 Acoustical environment

a) Description of test room, including dimensions, treatment of walls, ceiling and floor.

b) Sketch of the test room showing the location of the source and room contents.

c) Acoustical qualification of the test room (see 6.7).

d) Air temperature in degrees Celsius, relative humidity as a percentage, and barometric pressure in pascals.

12.4 Instrumentation

a) Equipment used for the acoustical measurements, including the name, type, serial number and manufacturer.

b) Bandwidth of the frequency analyser.

c) Frequency response of the instrumentation system.

d) Method used to calibrate the microphone(s), and the date and place of calibration.

e) Calibration of the reference sound source (see 6.7).

12.5 Acoustical data

a) The position and orientation of the microphone path or array (a sketch should be included if necessary).

b) The corrections, in decibels, if any, applied in each frequency band for the frequency response of the microphone, frequency response of the filter in the pass band, background noise, etc.

c) The sound power levels, in decibels (reference: 1 pW), calculated f or all frequency bands used, and the A-weighted sound power level, in decibels (reference: 1 pW).

d) The corrected sound power levels, tabulated or plotted to the nearest one-half decibel.

e) The date and time when the measurements were performed.

f) Remarks on subjective impression of noise (audible discrete tones, impulsive character, spectral content, temporal characteristics, etc.).

13 Information to be reported

Only those recorded data (see Clause 12) are to be reported which are required for the purposes of the measurements. The report shall state whether or not the reported sound power levels have been obtained in full conformity with the requirements of this document. The report shall state that these sound power levels are given in decibels (reference: 1 pW).

Annex A
(normative)

Characteristics and calibration of reference sound source

A.1 Characteristics of reference sound source

A.1.1 The reference sound source shall have the characteristics specified in A.1.2 to A.1.6.

A.1.2 The sound radiated shall be broad-band in character without discrete-tone components; i.e. the sound pressure level in any one-tenth-octave band shall be at least 5 dB below the corresponding octave band level.

A.1.3 The reference sound source shall be suitably mounted to prevent transmission of vibration to the structure on which it rests.

A.1.4 The directivity index of the source, in any one-third-octave band, shall not exceed 6 dB relative to uniform hemispherical radiation over the frequency range from 100 Hz to 10 000 Hz.

A.1.5 The reference sound source shall be physically small (maximum dimension preferably less than 0,5 m).

A.1.6 The power level in each frequency band shall remain constant, within the tolerances of Table A.1, during the useful life of the source.

A.2 Calibration of reference sound source

The sound power produced by the reference sound source shall be determined in octave and one-third-octave bands with an accuracy as specified in Table A.1. During calibration, the source shall be operated on the floor in the same manner as during its intended use.

Table A.1 — Calibration accuracy for reference sound source

One-third-octave-band centre frequencies Hz	Tolerance dB
100 to 160	±1
200 to 4 000	±0,5
5 000 to 10 000	±1

NOTE The tolerances specified can only be obtained by more elaborate measurement procedures than those described in this document (see ISO 3745 and ISO 6926).

Annex B
(informative)

Guidelines for the design of special reverberation test rooms

B.1 General

For the measurements specified in this document, the noise source (machine, device or component) should be operated in a test room which has the required acoustical properties specified in Clause 6. These characteristics may be obtained in different ways, some of which are described in this annex.

B.2 Size and shape of test room

The minimum volume of the test room should be 70 m^3. The test room should provide an adequate reverberant sound field for all frequency bands within the frequency range of interest. This requires that the frequencies of the normal modes of the room be well distributed within the frequency range of interest. Some recommended ratios of dimensions for rectangular rooms are given in Table B.1. Other ratios may be used, but ratios equal to or closely approximating integers or simple fractions should be avoided.

Table B.1 — Recommended room dimension ratios for rectangular rooms

l_y/l_x	l_z/l_x
0,83	0,47
0,83	0,65
0,79	0,63
NOTE The symbols l_x, l_y and l_z are the room dimensions.	

If the dimension ratios approximate those of Table B.1, rooms with volumes larger than 70 m^3 will generally give an improved accuracy for measurements at low frequencies.

B.3 Absorption of test room

In many cases it is necessary to adapt a room with hard surfaces (e.g. concrete walls) as a test room. The reverberation time of such a room is usually high at low and middle frequencies, but approximates the specified value at the upper limit of the frequency range of interest. The reverberation time of the room at low and middle frequencies can be reduced to the recommended values by installing sound-absorptive materials on the walls and ceiling.

To correct the middle and high frequencies, perforated panels with mineral wool interiors will often be suitable. Information concerning the absorptive properties of such materials is generally available from manufacturers and test laboratories.

Suitable absorbers of low-frequency sound can be constructed as membrane absorbers, for example, a wooden frame covered with hardboard and filled with mineral wool. For such an absorber, the approximate value of the frequency, f, in hertz, at which maximum absorption is obtained, is given by the formula

$$f \approx 60\left(l \cdot \rho_{\mathrm{A}}\right)^{-1/2} \tag{B.1}$$

where

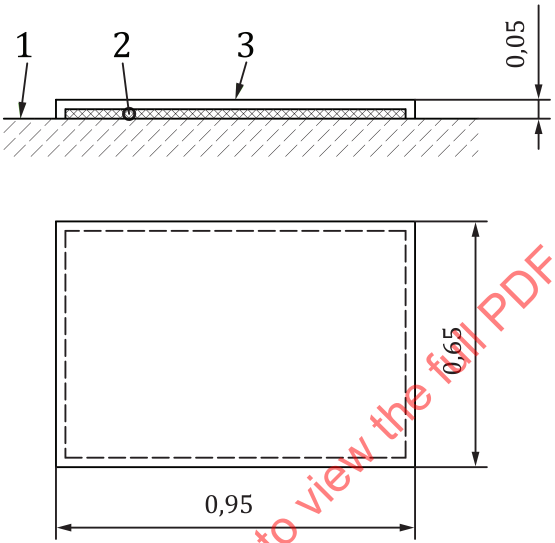
l is the distance of the hardboard from the wall, in metres;

ρ_A is the surface density of the hardboard, in kilograms per square metre.

EXAMPLE An absorber consisting of a wooden frame 0,95 m × 0,65 m × 0,05 m covered with a 4 mm thick hardboard, with a nominal surface density equal to 3,5 kg/m^2, as shown in Figure B.1, has a sound absorption characteristic as shown in Figure B.2.

The samples of sound-absorptive material should be randomly distributed over the entire surfaces of the walls and ceiling of the test room. The materials should be applied in patches not larger than 1,5 m^2 in area and the requirements of 6.4 should be satisfied. In this way, the desired smooth decay curve may be obtained when the reverberation time is measured.

Dimensions in metres



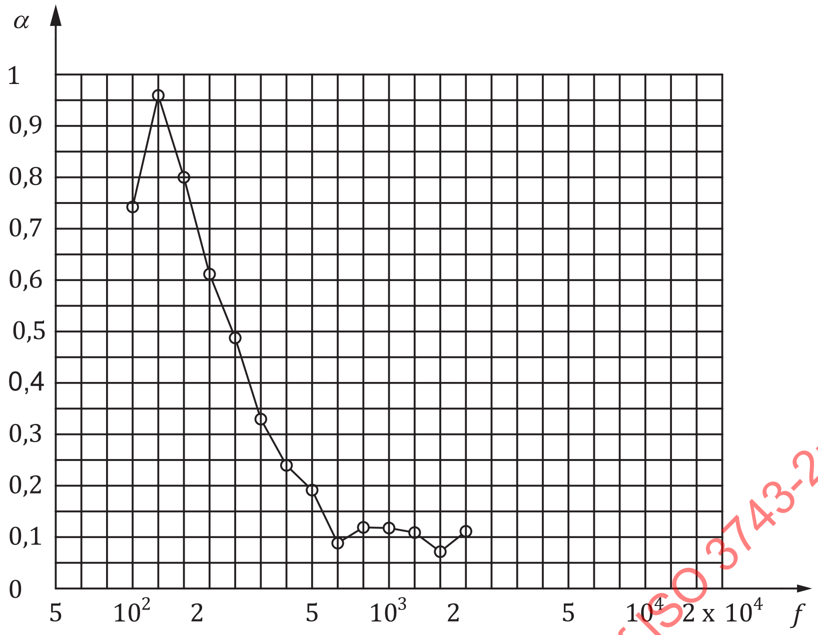
Key

1 wall

2 mineral wool

3 hardboard membrane

Figure B.1 — Hardboard membrane absorber



Key

f frequency of membrane absorber, in hertz

α sound absorption coefficient

Figure B.2 — Sound absorption coefficient *α* for the membrane absorber measured in a 200 m³ reverberation room

The floor of the test room should be reflecting over the entire frequency range of interest. A floor of painted poured concrete will usually meet the requirements of 6.4.

B.4 Sound insulation

The insulation of the test room for airborne and structure-borne sound should be such that the requirements of 6.5 are fulfilled for the sources under test. Rooms which have windows are generally unsuitable for use as test rooms because of the small values of transmission loss provided by the windows.

For some types of noise source, the sound power levels of which are small (e.g. domestic refrigerators), special installations incorporating double walls and ceilings may be required. In such cases, the location of the test room with respect to nearby exterior noise sources should be carefully considered.

B.5 Example of determination of the nominal reverberation time of a room

A formula for the ratio T/T_{nom}, together with expressions for the limiting curves of T/T_{nom}, are given in 6.3. For a 70 m³ room, these curves are shown in Figure B.3 for the one-third-octave-band centre frequencies. If the specified curve is exactly obtained, then

$$T_{nom} = \frac{T_{1\,000}}{1,06} \tag{B.2}$$

where 1,06 is the value of R at 1 000 Hz.

In practice, T_{nom} is determined by centring the measured values of T (normalized to the reverberation time at 1 000 Hz) within the limiting curves.

EXAMPLE The reverberation time T is assumed to be 0,8 s at 1 000 Hz ($T_{1\,000}$ = 0,8) and the ratio $T/T_{1\,000}$ is given in Figure B.4 for the other one-third-octave-band centre frequencies. When the data of Figure B.4 are centred within the limiting curves of Figure B.3, it is found that, at 1 000 Hz, the ratio $T/T_{1\,000}$ = 1 corresponds to T/T_{nom} = 1,09.

Thus

$$\frac{T/T_{1\,000}}{T/T_{nom}} = \frac{1}{1{,}09}$$

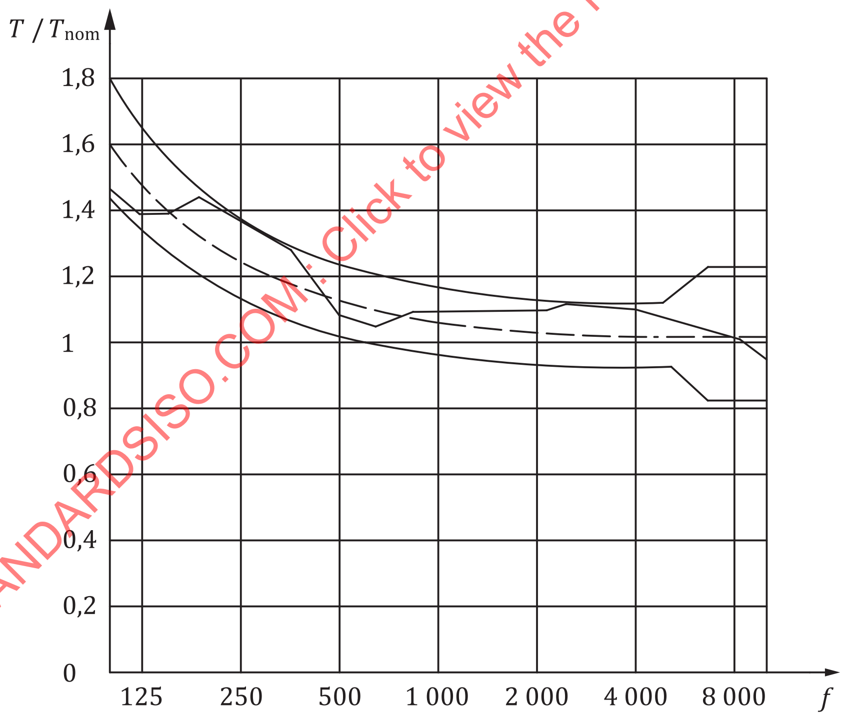
or

$$\frac{T}{T_{nom}} = 1{,}09\frac{T}{T_{1\,000}}$$

or

$$T_{nom} = \frac{T_{1\,000}}{1{,}09} = \frac{0{,}8}{1{,}09} = 0{,}73\,\text{s}$$

If the measured values $T/T_{1\,000}$ cannot be centred within the limiting curves, the reverberation time of the test room should be adjusted.



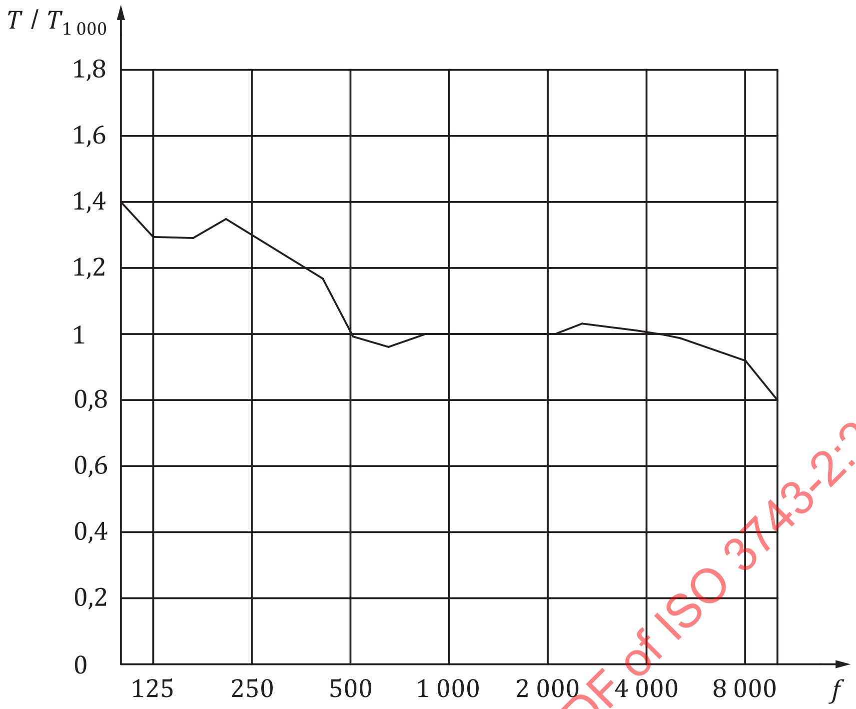
Key

f frequency, in hertz

T/T_{nom} normalized reverberation time

NOTE The dotted curve shows the ideal ratio. The data of Figure B.4 are centred within the limiting curves.

Figure B.3 — Limiting curves for the ratio of the reverberation time T to the nominal reverberation time T_{nom} for a 70 m³ room



Key

f frequency, in hertz

$T/T_{1\,000}$ reverberation time, normalized to $T_{1\,000}$

Figure B.4 — Plot of an experimentally determined reverberation time (normalized to $T_{1\,000}$) as a function of one-third-octave-band centre frequency

Annex C
(informative)

Examples of suitable instrumentation systems

C.1 General

Basically, the instrumentation system consists of a microphone, an amplifier with filters, a squaring and averaging circuit, and an indicating device. There are several methods of processing or conditioning the filter outputs that may be used to obtain an estimate of the mean-square value of the output; these include use of detection equivalent to RC-smoothing, integration of the squared value of the filter outputs and digital methods. Some general aspects are described in C.2 to C.4.

C.2 RC-smoothing, sound level meter

Many analogue devices, including the sound level meter conforming to IEC 61672-1, use RC-smoothing.

For the sound level meter set on time-weighting characteristic S, the time constant of the indicating meter plus the RC-smoothing network is 1 s. The average value of the meter deflection approximates the mean-square sound pressure level if the fluctuations are less than 5 dB.

The microphone usually supplied with the sound level meter should be replaced by a microphone having flat response for randomly incident sound. A condenser microphone with a diameter of 13 mm will be suitable for this purpose. The microphone and its associated pre-amplifier (if any) should be placed in the test room and connected with the sound level meter by a cable that complies with the requirements of 7.2. The system should be calibrated with the cable inserted between pre-amplifier and sound level meter.

The sound level meter and the observer should be located in a room adjacent to the test room; the meter should be set on time-weighting characteristic S.

Other analogue devices can provide smoothing with longer time constants and should be used if the fluctuations exceed 5 dB.

C.3 Analogue integrators

Another approach to r.m.s. detection is the "true" analogue integrator that computes (approximately) the integral

$$e_{\mathrm{rms}} = \left[\frac{1}{T} \int_0^T e_0^2(t)\,\mathrm{d}t \right]^{1/2} \tag{C.1}$$

where $e_0(t)$ is the filter output.

The square and square roots are usually accomplished by non-linear analogue elements. The integral may be computed either by conversion of $e_0(t)$ to a current and accumulation of charge on a capacitor, or by counting the number of cycles in a signal whose frequency is proportional to $e_0^2(t)$.

C.4 Digital systems

The r.m.s. value of the filter outputs may be determined by sampling, conversion to digital values, squaring and accumulating the results. The sampling rate can be either

a) high, compared with the highest frequency present in the filter output, or

b) relatively low, compared with the highest frequency present so that the resulting samples are (approximately) statistically independent.

In either case, the output of the detector after a specified time interval should be within 3 % of the true r.m.s. value of the time function for all frequencies within the frequency range of interest.

C.5 Level recorders

A level recorder may be used either as a squaring, averaging and indicating device, or exclusively as an indicating device.

In the first case, the time constant of the instrumentation system is determined by the writing speed of the level recorder. Since the level recorder is a complicated electromechanical system, a simple rule for the determination of the resulting time constant cannot be given. It is advisable to consult the manufacturer in this matter.

If the level recorder is used for indication only, the recorder will normally be set for recording of the d.c. output of a preceding squaring and averaging device, the time constant of which will determine the resulting time constant of the instrumentation system.

In both cases, the average value obtained will only be an acceptable approximation to the r.m.s. value if the pen fluctuations are less than 5 dB. Larger fluctuations can easily be obtained if narrow-band noises are measured with a traversing microphone.

Annex D
(informative)

Guidance on the development of information on measurement uncertainty

D.1 General

The accepted format for the expression of uncertainties generally associated with methods of measurement is that given in the ISO/IEC Guide 98-3. This format incorporates a budget of uncertainty components, in which all 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:

— those that are intrinsic to the measurement procedure;

— those that result from the variations of the noise emission of the machine.

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

This annex complements Clause 11.

D.2 Considerations on the total standard deviation σ_{tot}

The measurement uncertainty used in this document is determined by the expanded measurement uncertainty, U, which is derived directly from the total standard deviation σ_{tot} [see Formula (13)] with σ_{tot} being the approximation of the relevant $u(L_W)$ as defined in the ISO/IEC Guide 98-3.

This total standard deviation, σ_{tot}, results from the two components σ_{R0} and σ_{omc} [see Formula (12)], which are significantly different in nature.

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

The machinery specific standard deviation, σ_{omc}, cannot be calculated and has to be determined by repeated measurements as described in D.3, see Table D.1. Information on the standard deviation σ_{R0} is given in D.4.

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

D.3 Considerations on σ_{omc}

The standard deviation σ_{omc}, described in 11.2, is calculated by:

$$\sigma_{omc} = \sqrt{\frac{1}{N-1}\sum_{j=i}^{N}\left(L_{p,j} - L_{pav}\right)^2} \text{ dB} \tag{D.1}$$

where

$L_{p,j}$ is the sound pressure level measured at a prescribed position and corrected for background noise for the j^{th} repetition of the prescribed operating and mounting conditions;

L_{pav} is its arithmetic mean level calculated for all these repetitions;

N is the number of repetitions of the prescribed operating and mounting conditions.

These measurements are carried out at the microphone position associated with the highest sound pressure level on the measurement surface. When measurements are averaged over the measurement surface $L_{p,j}$ and L_{pav} are replaced in Formula (D.1) by $\overline{L_{p,j}}$ and $\overline{L_{pav}}$, respectively.

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 σ_{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 are exclusively standing on soft springs or on heavy concrete floors will 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 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.

In 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 (12)]. This is because σ_{omc} may be significantly larger in practice than e.g. σ_{R0} = 2 dB for accuracy grade 2 measurements as given in Table 5.

If $\sigma_{omc} > \sigma_{R0}$, 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.

Table D.1 — Examples of calculated total A-weighted standard deviations σ_{tot} for three different cases

Standard deviation of reproducibility of the method, σ_{R0}, dB	**Operating and mounting conditions**		
	stable	unstable	very unstable
	Standard deviation, σ_{omc}, dB		
	0,5	2,0	4,0
	Total standard deviation, σ_{tot}, dB		
0,5 (Accuracy grade 1)	0,7	2,1	4,0
2 (Accuracy grade 2)	2,1	2,8	4,5
3 (Accuracy grade 3)	3,0	3,6	5,0

These examples show that it might 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 $\sigma_{\text{omc}} > \sigma_{R0}$ might create substantial misunderstandings with respect to the true relevant total standard deviation, σ_{tot}, because the different grades of accuracy are, at the time of publication, defined by the value of σ_{R0} only.

D.4 Considerations on σ_{R0}

D.4.1 General

Upper bound values of σ_{R0} are given in Table 5. Additionally in 11.3 it is recommended to investigate values of σ_{R0} that are relevant to individual machines or machine families in order to achieve more realistic values. These investigations are to be carried out either by measurements under reproducibility conditions as defined in ISO 5725 (all parts) or by calculations using the so-called modelling approach based on Formula (15) which requires more detailed information.

If certain uncertainty components are not relevant for specific applications or are difficult to investigate delimited definitions of σ_{R0} should be given by noise test codes both for round robin tests (see fifth paragraph in 11.3.2) and for the modelling approach analogously.

The budget approach however implies both, statistically independent components c_i, u_i and especially the existence of formulae which allow assessment of these uncertainty components by considering measurement parameters and environmental conditions or by at least reasonable experience. Relevant well-founded data for this document were not available at the time when it was prepared. However, the following information may give a rough impression of the relevant quantities without final reliability.

D.4.2 Contributions to the uncertainty σ_{R0}

D.4.2.1 General

Preliminary estimations show that when corrected for meteorological conditions, the sound power level, $L_{W\text{ref,atm}}$, determined by the direct method is a function of a number of parameters, indicated by Formula (D.2):

$$L_{W\,\text{ref,atm}} = \delta_{\text{method}} + \delta_{\text{omc}} + \overline{L_p} - 10\lg\left(\frac{T_{\text{nom}}}{T_0}\right) + 10\lg\left(\frac{V}{V_0}\right) + C_2 + \delta_{\text{slm}} + \delta_{\text{mic}} + \delta_{\theta} + \delta_H - 13\,\text{dB} \quad \text{(D.2)}$$

where

δ_{method} is an input quantity to allow for any uncertainty due to the applied measurement method including the derivation of results and associated uncertainties;

δ_{omc} is an input quantity to allow for any uncertainty due to operating and mounting conditions. This quantity is not included in the calculation of σ_{R0} [see 11.1, Formula (12)];

$\overline{L_p}$ is the mean time-averaged sound pressure level of the noise source under test (and is corrected for background noise); $\overline{L_p} = \overline{L'_p} - K_1$;

$\overline{L'_p}$ is the measured mean time-averaged sound pressure level of the noise source under test before background corrections are applied;

K_1 is the background noise correction, in decibels;

T_{nom} is the nominal reverberation time of the test room, in seconds;

T_0 = 1 s;

V is the volume in cubic meters of the test room;

V_0 = 1 m^3;

C_2 is a meteorological correction to account for changes in sound power with temperature and pressure, in decibels;

δ_{slm} is an input quantity to allow for any uncertainty in the measuring instrumentation;

δ_{mic} is an input quantity to allow for any uncertainty due to the finite number of microphone and source positions;

δ_θ is an input quantity to allow for any uncertainty due to fluctuations in air temperature in the reverberation test room;

δ_H is an input quantity to allow for any uncertainty due to fluctuations in the relative humidity in the reverberation test room.

NOTE 1 Similar expressions to that of Formula (D.2) apply with respect to sound power levels determined in frequency bands and with A-weighting applied.

NOTE 2 The input quantities included in Formula (D.2) to allow for uncertainties are those thought to be applicable in the state of knowledge at the time of publication of this document, but further research could reveal that there are others.

The contributions to uncertainty for sound power levels determined by the comparison method of ISO 3743-2 are the same as those presented in ISO 3743-1:2010, Annex C.

A probability distribution (normal, rectangular, Student-*t*, etc.) is associated with each of the input quantities. Its expectation (mean value) is the best estimate for the value of the input quantity and its standard deviation is a measure of the dispersion of values, termed uncertainty.

The uncertainty components related to mounting and operating conditions are already covered by σ_{omc} whereas σ_{R0} includes the rest of the uncertainty components.

Table D.2 provides some information about expectations at the time of publication of this document concerning the values for the components, c_i, u_i, that are necessary for calculating $\sigma_{R0} = \sqrt{\sum_i (c_i u_i)^2}$ dB according to the direct method.

Table D.2 — Uncertainty budget for determinations of σ_{R0} for sound power level using the direct method, valid for A-weighted measurements of a source with a relatively flat frequency spectrum

Quantity	Estimate dB	Standard uncertainty, u_i dB	Probability distribution	Sensitivity coefficient, c_i
δ_{method} method	0	0,3	Normal	1
$\overline{L_p}$ mean time-averaged sound pressure level	$\overline{L'_p}$	$\frac{u'_{L_{pi,j}}}{\sqrt{N_M N_S}}$	Normal	$1 + \frac{1}{10^{0,1\Delta L_p} - 1}$
K_1 background noise correction	K_1	$s_{L_{p(B)}}$	Normal	$\frac{1}{10^{0,1\Delta L_p} - 1}$
C_2 meteorological correction	C_2	0,2	Triangular	1

Table D.2 *(continued)*

Quantity		Estimate dB	Standard uncertainty, u_i dB	Probability distribution	Sensitivity coefficient, c_i
δ_{slm}	sound level meter	0	0,5	Normal	1,0
δ_{mic}	sampling	0	$\frac{s_M}{\sqrt{N_M N_S}}$	Normal	1,0
δ_θ	temperature	0	$\Delta\theta / \sqrt{3}$	Rectangular	$\frac{6,5}{273+\theta} + \frac{-0,57+0,25\lg(2,6f)}{1+0,0011H+0,0070\theta}$
δ_H	relative humidity	0	$\Delta H / \sqrt{3}$	Rectangular	$\frac{-2,6+1,6\lg(0,7f)}{1+0,5H}$
V	room volume	0	u_V	Normal	$c_V = 4,3 / V$
T_{nom}	reverberation time	0	$\sqrt{\frac{2,42\,T}{f} + \frac{s_T^2}{N_{decay}}}$	Normal	$\frac{-4,3}{T_{nom}} - \frac{240 \cdot V}{T_{nom}^2 \cdot S \cdot c}$

The calculation of σ_{R0} assumes that the individual uncertainty contributions are not correlated.

The standard uncertainties from some contributions remain to be established by research.

Explanation and numerical example for the uncertainty parameters in Table D.2 are given in D.4.2.2 to D.4.2.11. Formulae to calculate uncertainties are given with examples to show the expected range of measurement uncertainties.

D.4.2.2 Measurement method, δ_{method}

The uncertainty due to the measurement method applied, u_{method}, includes the derivation of results and associated uncertainties. Assuming known biases are accounted for, this uncertainty can only be derived from practical experience or round robin testing. This uncertainty will approach zero as the modelling approach becomes more sophisticated. If however, there is a lack of knowledge, or if it is difficult, or if it is impractical to model certain uncertainty components this component of uncertainty could become the sole determinant of measurement reproducibility, σ_{R0}. An example of this latter case is the implementation of standards by inexperienced users.

Assuming the full modelling approach as implemented in this example is complete and correct, for frequencies above 100 Hz, the assumed value of this parameter is u_{method} = 0,3 dB. Below 100 Hz the wavelength reduces both the effective number of possible microphone positions and the number of room modes. This increases this parameter to u_{method} = 3 dB below 100 Hz.

Uncertainties related to the method directly affect results, so that c_{method} = 1. In this example for A-weighted measurements the uncertainty contribution, $u_{method} \cdot c_{method}$, is typically 0,3 dB.

D.4.2.3 Sound pressure level repeatability, $\overline{L'_p}$

The uncertainty due to the repeatability, $u_{L'_p}$, of measurements of the sound pressure level, $\overline{L'_p}$, is the closeness of agreement between results of successive measurements carried out under the same conditions; it may be obtained from the standard deviation of repeatability, $s_{L'_p}\big|_{rep}$, using six measurements of the decibel sound pressure levels at a single microphone position.