BRITISH STANDARD

BS EN ISO 3743-2:2009

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 (ISO 3743-2:1994)

ICS 17.140.01

British Standards

National foreword

This British Standard is the UK implementation of EN ISO 3743-2:2009. It is identical to ISO 3743-2:1994. It supersedes BS EN ISO 3743-2:1997 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EH/1/4, Machinery noise.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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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 (ISO 3743-2:1994)

Akustik - Bestimmung der Schalleistungspegel von Geräuschquellen aus Schalldruckmessungen - Verfahren der Genauigkeitsklasse 2 für kleine, transportable Quellen in Hallfeldern - Teil 2: Verfahren für Sonder-Hallräume (ISO 3743-2:1994)

This European Standard was approved by CEN on 13 July 2009.

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Foreword

The text of ISO 3743-2:1994 has been prepared by Technical Committee ISO/TC 43 "Acoustics" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 3743-2:2009 by Technical Committee CEN/TC 211 "Acoustics" the secretariat of which is held by DS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2010, and conflicting national standards shall be withdrawn at the latest by January 2010.

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This document supersedes EN ISO 3743-2:1996.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EC Directives.

For relationship with EC Directives, see informative Annexes ZA and ZB, which are integral parts of this document.

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Endorsement notice

The text of ISO 3743-2:1994 has been approved by CEN as a EN ISO 3743-2:2009 without any modification.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 98/37/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 98/37/EC, amended by 98/79/EC on machinery.

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this standard confers, within the limits of the scope of this standard, a presumption of conformity with the relevant Essential Requirements of that Directive and associated EFTA regulations.

WARNING - Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Annex ZB
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2006/42/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 2006/42/EC on machinery.

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this standard confers, within the limits of the scope of this standard, a presumption of conformity with the relevant Essential Requirements of that Directive and associated EFTA regulations.

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Introduction

0.1 ISO 3743 is one of the ISO 3740 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 as shown in table 0.1. When selecting one of the methods of the ISO 3740 series, 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 ISO 3740 series 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.

0.2 The method given in this part of ISO 3743 enables measurement of sound pressure levels with A-weighting and in octave bands at prescribed 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.

0.3 Parts 1 and 2 of ISO 3743 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.

0.4 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 part of ISO 3743 are significantly more restrictive than those placed on the hard-walled test room by the comparison method of ISO 3743-1.

Table 0.1 — International Standards specifying various methods for determining the sound power levels of machines and equipment

International Standard	Classification of method[1)]	Test environment	Volume of source	Character of noise	Sound power levels obtainable	Optional information available
3741	Precision (grade 1)	Reverberation room meeting specified requirements	Preferably less than 1 % of test room volume	Steady, broad-band	In one-third-octave or octave bands	A-weighted sound power level
3742				Steady, discrete frequency or narrow-band		
3743-1	Engineering (grade 2)	Hard-walled test room		Steady, broad-band, narrow-band, or discrete frequency	A-weighted and in octave bands	Other weighted sound power levels
3743-2		Special reverberation test room				
3744	Engineering (grade 2)	Outdoors or in large room	Greatest dimension less than 15 m	Any	A-weighted and in one-third-octave or octave bands	Directivity information and sound pressure levels as a function of time; other weighted sound power levels
3745	Precision (grade 1)	Anechoic or semi-anechoic room	Preferably less than 0,5 % of test room volume	Any		
3746	Survey (grade 3)	No special test environment	No restrictions: limited only by available test environment	Any	A-weighted	Sound pressure levels as a function of time; other weighted sound power levels
3747	Survey (grade 3)	No special test environment; source under test not movable	No restrictions	Steady, broad-band, narrow-band, or discrete frequency	A-weighted	Sound power levels in octave bands

1) See ISO 2204.

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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

1 Scope

1.1 General

This part of ISO 3743 specifies a relatively simple engineering method for determining the sound power levels of small, movable noise sources. 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 8.3). 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 1 Precision methods for the determination of the sound power levels of small noise sources are specified in ISO 3741 and ISO 3745.

1.2 Types of noise

The methods specified in this part of ISO 3743 are suitable for measurements of all types of noise within a specified frequency range, except impulsive noise consisting of isolated bursts of sound energy.

NOTES

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

3 For sources of impulsive noise consisting of short-duration noise bursts, the free-field methods specified in ISO 3744 and ISO 3745 should be used.

1.3 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.

1.4 Measurement uncertainty

Determinations made in accordance with this part of ISO 3743 result, with few exceptions, in standard deviations of reproducibility equal to or less than 2,0 dB from 500 Hz to 4 000 Hz, 3,0 dB for 250 Hz and 8 000 Hz, and 5,0 dB for 125 Hz (see table 1).

A single value of the sound power level of a noise source determined according to the procedures of this part of ISO 3743 is likely to differ from the true value by an amount within the range of the measurement uncertainty. The uncertainty in determinations of the sound power level arises from several factors which affect the results, some associated with environmental conditions in the measurement laboratory and others with experimental techniques.

If a particular noise source were to be transported to each of a number of different laboratories, and if, at each laboratory, the sound power level of that source were to be determined in accordance with this part of ISO 3743, the results would show a scatter. The standard deviation of the measured levels could be calculated (see examples in ISO 7574-4:1985, annex B) and would vary with frequency. With few exceptions, these standard deviations would not exceed those listed in table 1. The values given in table 1 are standard deviations of reproducibility, σ_R, as defined in ISO 7574-1. The values of table 1 take into account the cumulative effects of measurement uncertainty in applying the procedures of this part of ISO 3743, but exclude variations in the sound power output caused by changes in operating conditions (e.g. rotational speed, line voltage) or mounting conditions.

The measurement uncertainty depends on the standard deviation of reproducibility tabulated in table 1 and on the degree of confidence that is desired. As examples, for a normal distribution of sound power levels, there is a 90 % confidence that the true value of the sound power level of a source lies within the range $\pm$ 1,645σ_R of the measured value and a 95 % confidence that it lies within the range $\pm$ 1,96σ_R of the measured value. For further examples, reference may be made to the ISO 9296 and ISO 7574 series.

NOTES

4 The standard deviations listed in table 1 are associated with the test conditions and procedures defined in this part of ISO 3743, and not with the noise source itself. They arise partly from variations between measurement laboratories in the geometry of the test room, the acoustical properties of the test room boundaries, background noise, the type and calibration of instrumentation, and the reference sound source. They are also due to variations in experimental measurement techniques, including microphone placement and spatial averaging, location of source under test, integration times, and measurement of reverberation time.

5 If several laboratories use similar facilities and instrumentation, the results of sound power determinations on a given source in those laboratories may be in better agreement than would be implied by the standard deviations given in table 1.

6 For a particular family of sound sources, of similar size with similar sound power spectra and similar operating conditions, the standard deviations of reproducibility may be smaller than the values given in table 1. Hence, a noise test code for a particular type of machinery or equipment making reference to this part of ISO 3743 may state standard deviations smaller than those listed in table 1 if substantiation is available from the results of suitable interlaboratory tests.

7 The standard deviations of reproducibility, as tabulated in table 1, include the uncertainty associated with repeated measurements on the same noise source under the same conditions (for standard deviation of repeatability, see ISO 7574-1). This uncertainty is usually much smaller than the uncertainty associated with interlaboratory variability. However, if it is difficult to maintain stable operating or mounting conditions for a particular source, the standard deviation of repeatability may not be small compared with the values given in table 1. In such cases, the fact that it was difficult to obtain repeatable sound power level data on the source should be recorded and stated in the test report.

8 The procedures of this part of ISO 3743 and the standard deviations given in table 1 are applicable to measurements on an individual machine. Characterization of the sound power levels of batches of machines of the same family or type involves the use of random sampling techniques in which confidence intervals are specified, and the results are expressed in terms of statistical upper limits. In applying these techniques, the total standard deviation must be known or estimated, including the standard deviation of production, as defined in ISO 7574-1, which is a measure of the variation in sound power output between individual machines within the batch. Statistical methods for the characterization of batches of machines are described in ISO 7574-4.

Table 1 — Estimated values of the standard deviation of reproducibility of sound power levels determined according to this part of ISO 3743

Octave-band centre frequency Hz	**Standard deviation of reproducibility,** σ_R dB
125	5,0
250	3,0
500 to 4 000	2,0
8 000	3,0
A-weighted	2,0 1)

1) Applicable to a source which emits noise with a relatively "flat" spectrum in the frequency range 100 Hz to 10 000 Hz.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 3743. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 3743 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3741:1988, *Acoustics — Determination of sound power levels of noise sources — Precision methods for broad-band sources in reverberation rooms.*

ISO 3743-1:1994, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for small, movable sources in reverberant fields — Part 1: Comparison method for hard-walled test rooms.*

ISO 3745:1977, *Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms.*

ISO 6926:1990, *Acoustics — Determination of sound power levels of noise sources — Requirements for the performance and calibration of reference sound sources.*

ISO 7574-1:1985, *Acoustics — Statistical methods for determining and verifying stated noise emission values of machinery and equipment — Part 1: General considerations and definitions.*

ISO 7574-4:1985, *Acoustics — Statistical methods for determining and verifying stated noise emission values of machinery and equipment — Part 4: Methods for stated values for batches of machines.*

IEC 225:1966, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

IEC 651:1979, *Sound level meters.*

IEC 804:1985, *Integrating-averaging sound level meters.*

IEC 942:1988, *Sound calibrators.*

3 Definitions

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

3.1 special reverberation test room: A test room meeting the requirements of this part of ISO 3743.

4 Requirements for special reverberation test room

4.1 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.

4.2 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 9 When using the comparison method, the use of larger room volumes is acceptable.

4.3 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 T of the test room shall fall within the limiting curves defined by $T = 0{,}9\,R\,T_{nom}$ and $1{,}1\,R\,T_{nom}$, where the reverberation parameter, R, is given by

$$R = 1 + 257/\left(f\,V^{1/3}\right)$$

where

f is the frequency, in hertz;

V is the volume, in cubic 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.

4.4 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.

4.5 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.

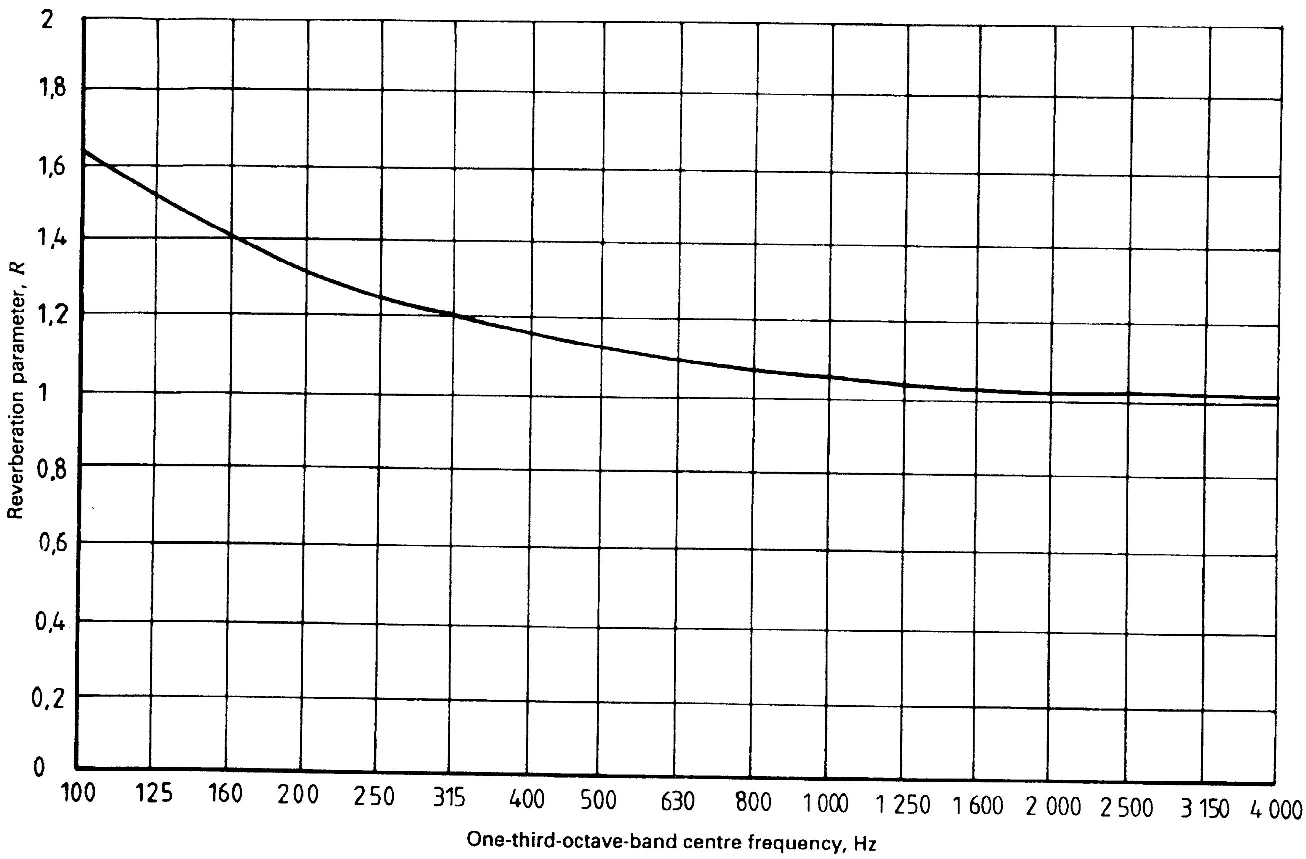


Figure 1 — Values of R at the one-third-octave-band centre frequencies for $V = 70$ m^3

4.6 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 (r.h.), expressed as a percentage, shall be controlled during the sound pressure level measurements. The product

$$\text{r.h.} \times (\theta + 5\ °\text{C})$$

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 10 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.

4.7 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 described 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 part of ISO 3743.

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 2.

If the differences in octave-band power levels do not exceed those specified in table 2, the room is suitable for sound power determinations of broad-band noise sources in accordance with the procedures of this part of ISO 3743.

Table 2 — Maximum permitted differences between octave-band power levels of broad-band noise sources measured in accordance with 4.7 a)

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

5 Instrumentation

5.1 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 651 and IEC 804.

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.

5.2 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 5.6.

NOTES

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

12 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.

5.3 Amplifier and weighting network

The properties of the amplifier and the A-weighting network shall comply with the requirements of IEC 651.

5.4 Octave-band filters

The octave-band filters shall comply with the requirements of IEC 225.

5.5 Squaring and averaging circuits, and indicating device

Squaring and averaging the microphone output voltage may be performed by analog or digital equipment as described in annex C. In analog 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 analog 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.

5.6 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 651 with the tolerances given in table 3.

Table 3 — Relative tolerances for the instrumentation system

Frequency Hz	Tolerance 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 651.	

5.7 Calibration

During each series of measurements, a sound calibrator with an accuracy of ± 0,3 dB (class 1 as specified in IEC 942) 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.

6 Installation and operation of source under test

6.1 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.

6.2 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 13 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 4) 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 7.4).

6.3 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 14 The use of resilient mounts or vibration-damping material on large surfaces used to support the equipment under test may be appropriate.

6.4 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.

6.5 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 part of ISO 3743 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.

7 Measurements in test room

7.1 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.

7.2 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 $\tau_D = 1$ s, five readings shall be averaged on a mean-square basis; if $\tau_D = 5$ 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.

7.3 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

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

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 $\lambda = 3{,}5$ m.

7.4 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 1 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 the following equation:

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

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 the following equation:

$$\overline{L_p} =$$

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

NOTE 15 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 4 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 1.

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 4 — 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
		Minimum number of source locations, N_s		
dB	Hz			
$s_M < 2{,}3$	125 to 8 000 and A-weighting	1	1	1
$2{,}3 \leqslant s_M \leqslant 4$	125 250, 500 and A-weighting 1 000 to 8 000	1 2 2	1 2 1	1 1 1
$s_M > 4$	125 250 and A-weighting 500 1 000 to 8 000	3 4 4 3	2 3 2 2	2 2 2 1

NOTE — For each source position, the mean-square pressure should be determined.

7.5 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 $\leqslant s_M \leqslant$ 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.

7.6 Averaging technique with moving microphone

7.6.1 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.

7.6.2 Path length for continuous averaging

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

$$l = \frac{\lambda}{2} N_m$$

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

$$A = \left(\frac{\lambda}{2}\right)^2 N_m$$

If 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 4 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 $\lambda = 3,5$ m.

7.6.3 Location of path within test room

The path shall contain only microphone positions that meet the requirements of 7.3.

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.

7.6.4 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 7.2.

7.7 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 5.2.

The number of microphones to be used shall be determined as specified in 7.4 and the microphone positions shall be located as specified in 7.3.

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 7.2 shall be observed.

7.8 Correction for background sound pressure levels

Correct the measured band pressure levels for the influence of background noise in accordance with table 5. 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 part of ISO 3743 have not been fulfilled.

Table 5 — 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

8 Calculation of sound power levels

8.1 Calculation of mean band pressure levels

From the measured band pressure levels for each octave band of interest and from the measured A-weighted sound pressure levels, calculate the mean octave-band level and the A-weighted sound pressure level, $\overline{L_p}$, in decibels, from the following expression:

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

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.

8.2 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 the following expression:

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

where

T_{nom} is the nominal reverberation time of the test room (see 4.3);

$T_0 = 1$ s;

V is the volume of the test room;

$V_0 = 1$ m^3.

NOTE 16 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.

8.3 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 7.3.

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 8.1.

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 7.8) 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 7.8), i.e.

$$L_{We} = L_{pe} + (L_{Wr} - L_{pr})$$

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).

9 Information to be recorded

The information specified in 9.1 to 9.4, when applicable, shall be compiled and recorded for all measurements made in accordance with the requirements of this part of ISO 3743.

9.1 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.

9.2 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 4.7).

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

9.3 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 4.7).

9.4 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 for 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.).

10 Information to be reported

Only those recorded data (see clause 9) 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 part of ISO 3743. 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

The reference sound source shall have the characteristics specified in A.1.1 to A.1.5.

A.1.1 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.1.2 The reference sound source shall be suitably mounted to prevent transmission of vibration to the structure on which it rests.

A.1.3 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.1.4 The reference sound source shall be physically small (maximum dimension preferably less than 0,5 m).

A.1.5 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 part of ISO 3743 (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 part of ISO 3743, the noise source (machine, device or component) should be operated in a test room which has the required acoustical properties specified in clause 4. 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

$$f \approx 60\ (l\varrho_A)^{-1/2}$$

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 4.4 should be satisfied. In this way, the desired smooth decay curve may be obtained when the reverberation time is measured.

Dimensions in metres

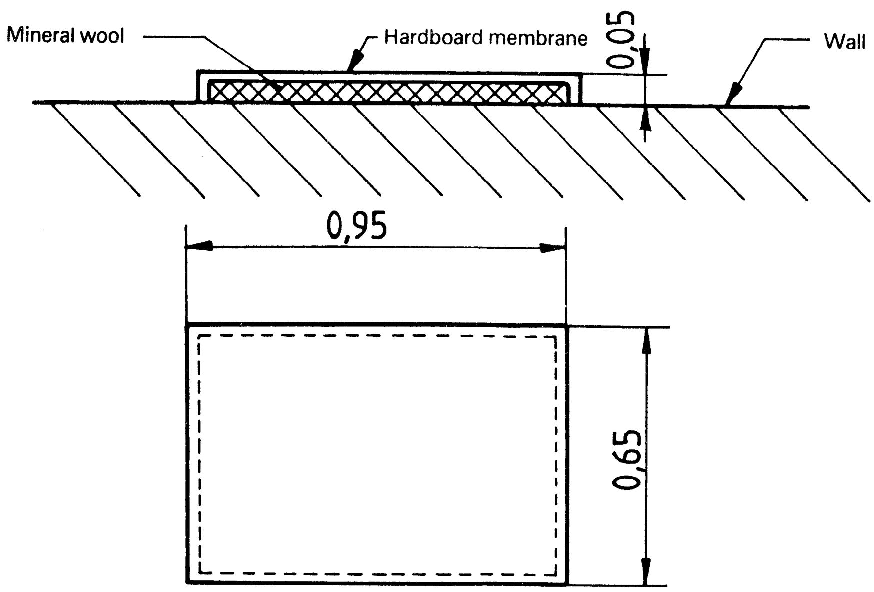


Figure B.1 — Hardboard membrane absorber

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 4.4.

B.4 Sound insulation

The insulation of the test room for airborne and structure-borne sound should be such that the requirements of 4.5 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

An equation for the ratio T/T_{nom}, together with expressions for the limiting curves of T/T_{nom}, are given in 4.3. For a 70 m^3 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

$$T_{nom} = \frac{T_{1\,000}}{1{,}06}$$

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

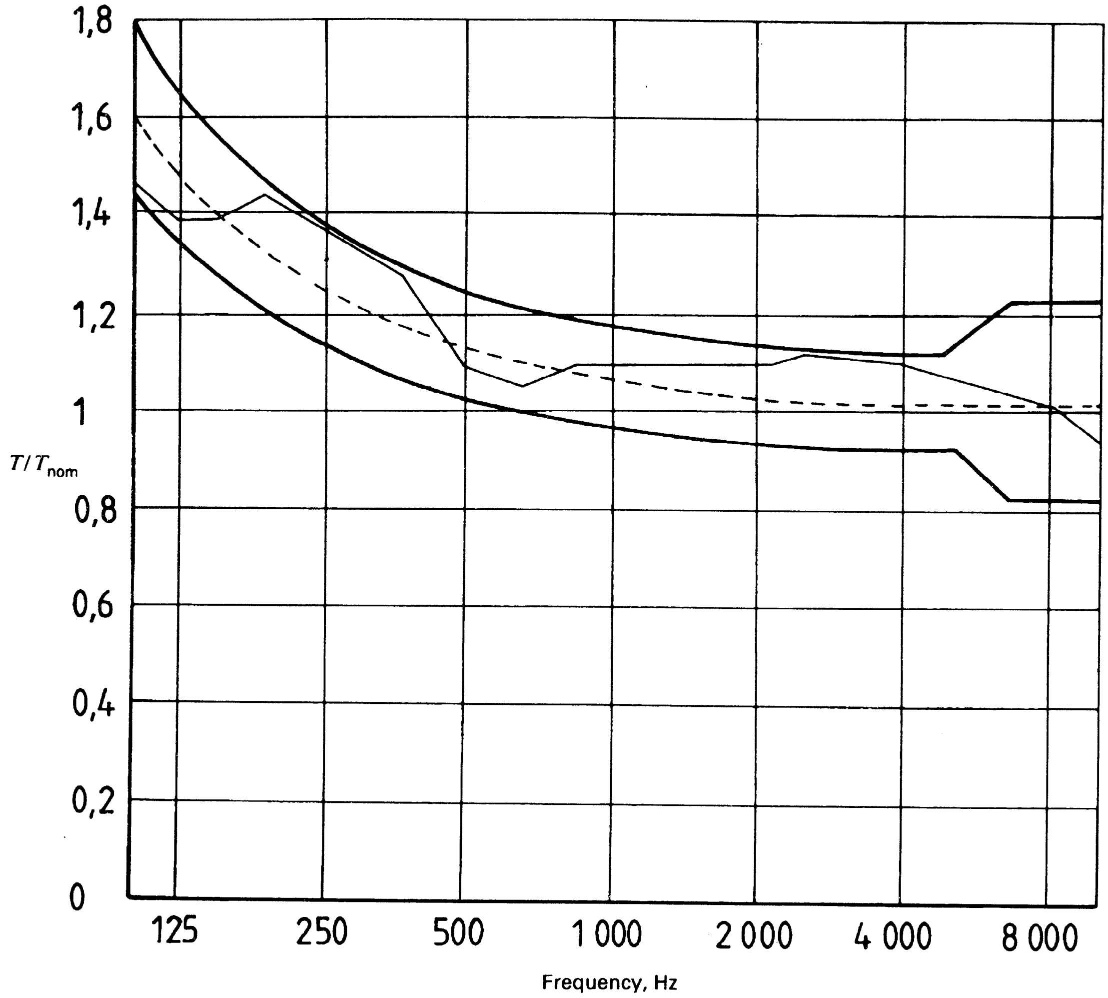
$$\frac{T}{T_{nom}} = 1{,}09 \frac{T}{T_{1\,000}}$$

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.



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

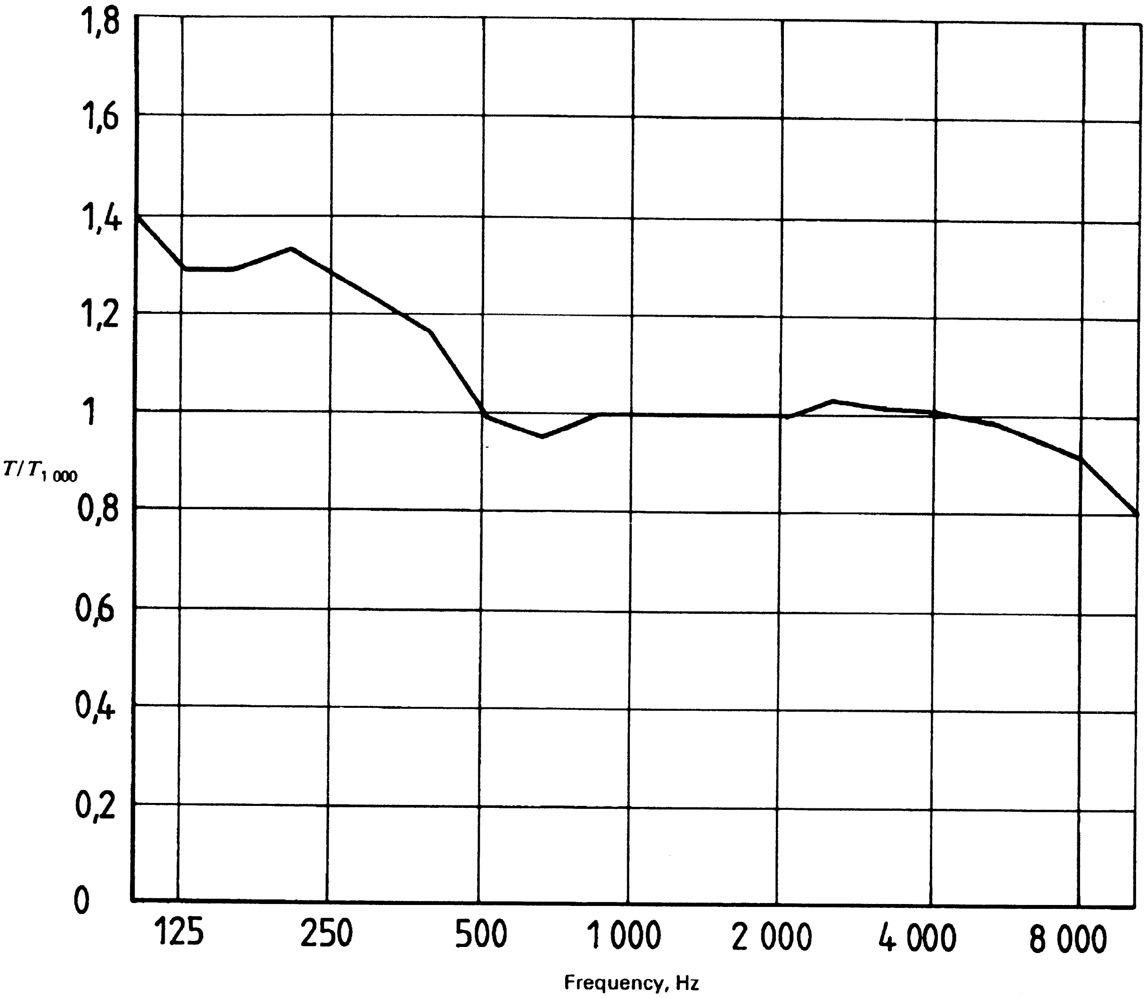


Figure B.4 — Plot of an experimentally determined reverberation time (normalized to $T_{1\,000}$) as a function of one-third-octave-band centre frequency

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.1.1 to C.1.3.

C.1.1 RC-smoothing, sound level meter

Many analog devices, including the sound level meter conforming to IEC 651, 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 5.2. 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 analog devices can provide smoothing with longer time constants and should be used if the fluctuations exceed 5 dB.

C.1.2 Analog integrators

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

$$e_{\text{rms}} = \left[\frac{1}{T} \int_0^T e_o^2(t)\ \mathrm{d}t \right]^{1/2}$$

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

The square and square roots are usually accomplished by non-linear analog elements. The integral may be computed either by conversion of $e_o(t)$ 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 $e_o^2(t)$.

C.1.3 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.2 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)

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