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BSI Standards Publication

Acoustics — Measurement of airborne noise emitted by information technology and telecommunications equipment (ISO 7779:2010)

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National foreword

This British Standard is the UK implementation of EN ISO 7779:2010. It supersedes BS EN ISO 7779:2001 which is withdrawn.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.

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Acoustics - Measurement of airborne noise emitted by information technology and telecommunications equipment (ISO 7779:2010)

Acoustique - Mesurage du bruit aérien émis par les équipements liés aux technologies de l'information et aux télécommunications (ISO 7779:2010)

Akustik - Geräuschemissionsmessung an Geräten der Informations- und Telekommunikationstechnik (ISO 7779:2010)

This European Standard was approved by CEN on 26 July 2010.

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Foreword

This document (EN ISO 7779:2010) has been prepared by Technical Committee ISO/TC 43 "Acoustics" in collaboration with 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of an identical text or by endorsement, at the latest by February 2010, and conflicting national standards shall be withdrawn at the latest by February 2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN ISO 7779:2001.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of ISO 7779:2010 has been approved by CEN as a EN ISO 7779:2010 without any modification.

Introduction

This International Standard specifies methods for the measurement of airborne noise emitted by information technology and telecommunications (ITT) equipment. Hitherto, a wide variety of methods have been applied by individual manufacturers and users to satisfy particular equipment or application needs. These diverse practices have, in many cases, made comparison of noise emission difficult. This International Standard simplifies such comparisons and is the basis for the declaration of the noise emission levels of ITT equipment.

In order to ensure accuracy, validity and acceptability, this International Standard is based on the basic International Standards for determination of the sound power level and for determination of the emission sound pressure level at the operator position(s) and bystander position(s). Furthermore, implementation is simplified by conformity with these International Standards.

In many cases, free-field conditions over a reflecting plane are realised by hemi-anechoic rooms. These rooms may be particularly useful during product design to locate and to improve individual contributing noise sources. Reverberation rooms may be more economical for production control and for obtaining sound power levels for noise emission declaration purposes.

The method for measuring the emission sound pressure level at the operator or bystander positions (based on ISO 11201) is specified in a separate clause, as this level is not considered to be primary noise emission declaration information. The measurements can, however, be carried out in conjunction with those for sound power determination in a free field over a reflecting plane.

For comparison of similar equipment, it is essential that the installation conditions and mode of operation be the same. In Annex C these parameters are standardized for many categories of equipment.

This International Standard is based on ECMA-74.

Acoustics — Measurement of airborne noise emitted by information technology and telecommunications equipment

1 Scope

This International Standard specifies procedures for measuring and reporting the noise emission of information technology and telecommunications equipment.

NOTE 1 This International Standard is considered part of a noise test code (see 3.1.2) for this type of equipment, and is based on basic noise emission standards (see 3.1.1) ISO 3741, ISO 3744, ISO 3745 and ISO 11201.

The basic emission quantity is the A-weighted sound power level which may be used for comparing equipment of the same type but from different manufacturers, or for comparing different equipment.

Three basic noise emission standards for determination of the sound power levels are specified in this International Standard in order to avoid undue restriction on existing facilities and experience. ISO 3741 specifies comparison measurements in a reverberation test room; ISO 3744 and ISO 3745 specify measurements in an essentially free field over a reflecting plane. Any one of these three basic noise emission standards can be selected and used exclusively in accordance with this International Standard when determining sound power levels of a machine.

The A-weighted sound power level is supplemented by the A-weighted emission sound pressure level determined at the operator position(s) or the bystander positions, based on basic noise emission standard ISO 11201. This sound pressure level is not a worker's immission rating level, but it can assist in identifying any potential problems that could cause annoyance, activity interference, or hearing damage to operators and bystanders.

Methods for determination of whether the noise emission includes prominent discrete tones or is impulsive in character are specified in Annexes D and E, respectively.

This International Standard is suitable for type tests and provides methods for manufacturers and testing laboratories to obtain comparable results.

The methods specified in this International Standard allow the determination of noise emission levels for a functional unit (see 3.1.4) tested individually.

The procedures apply to equipment which emits broad-band noise, narrow-band noise and noise which contains discrete-frequency components, or impulsive noise.

The sound power and emission sound pressure levels obtained can serve noise emission declaration and comparison purposes (see ISO 9296).

NOTE 2 The sound power and emission sound pressure levels obtained are not to be considered as installation noise immission levels; however, they can be used for installation planning (see ECMA TR/27[4]).

If sound power levels obtained are determined for a number of functional units of the same production series, they can be used to determine a statistical value for that production series (see ISO 9296).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 266, *Acoustics — Preferred frequencies*

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 3744, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane*

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

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

ISO 9295, *Acoustics — Measurement of high-frequency noise emitted by computer and business equipment*

ISO 9296, *Acoustics — Declared noise emission values of computer and business equipment*

ISO 11201, *Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions in an essentially free field over a reflecting plane with negligible environmental corrections*

ISO 11203, *Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions from the sound power level*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*

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

ECMA-74, *Measurement of airborne noise emitted by information technology and telecommunications equipment*[1)]

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3744, ISO 11201, and the following apply.

3.1 General definitions

3.1.1
basic noise emission standard
B-type standard
standard which specifies the procedure for determining the noise emission of machinery and equipment in such a way as to obtain reliable, reproducible results with a specified degree of accuracy

[ISO 12001:1996[2], 3.1]

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1) Available [viewed 2010-07-13] at: http://www.ecma-international.org/publications/files/ECMA-ST/ECMA-74.pdf

3.1.2
noise test code
C-type standard
standard that is applicable to a particular class, family or type of machinery or equipment, which specifies all the information necessary to carry out efficiently the determination, declaration and verification of the noise emission characteristics under standardized conditions

[ISO 12001:1996[2], 3.2]

NOTE This International Standard, together with ISO 9295 and ISO 9296, comprise the noise test code for ITT equipment.

3.1.3
information technology and telecommunications equipment
ITT equipment
equipment for information processing, and components thereof, used in homes, offices, server installations, telecommunications installations or similar environments

3.1.4
functional unit
unit of information technology and telecommunications equipment, either with or without its own end-use enclosure, that is tested or intended to be tested in accordance with the procedures of this International Standard

NOTE 1 A functional unit can comprise more than one unit of ITT equipment when such units are to be tested together in accordance with the methods of this International Standard. A functional unit can also comprise one or more units of ITT equipment coupled to one or more units of non-ITT equipment, such as power modules, water pumps, or refrigeration units, when such equipment is necessary for the normal operation of the ITT equipment.

NOTE 2 Functional units of ITT equipment can take on a wide range of forms, including commercially available products, prototype units under development or sub-assemblies and components thereof.

3.1.5
work station
operator position
position in the vicinity of the equipment under test which is intended for the operator

NOTE 1 Adapted from ISO 11201:2010, 3.11.

NOTE 2 This term does not refer to a computer “workstation”, which denotes a high-performance, single-user computer.

3.1.6
operating mode
condition in which the equipment under test is performing its intended function(s)

3.1.7
idle mode
one or more steady-state conditions in which the equipment being tested is energized but is not operating

3.1.8
floor-standing equipment
functional unit which is intended to be installed on the floor

3.1.9
table-top equipment
functional unit which has a complete enclosure and which is intended to be installed or used on a table, desk or separate stand

3.1.10
wall-mounted equipment
functional unit which is normally mounted against or in a wall and which does not have a stand of its own

3.1.11
sub-assembly
functional unit, generally without its own end-use enclosure, intended to be installed in another unit of ITT equipment or assembled together with other sub-assemblies or units of ITT equipment into a single end-use enclosure

3.1.12
rack-mountable unit
functional unit that is designed to be installed in an end-use enclosure, in the form of a rack, frame, or cabinet, which can be fully enclosed, partially enclosed, or open frame

3.1.13
rack-enclosed system
functional unit in the form of a rack, frame, or cabinet containing one or more rack-mountable units

NOTE Rack-enclosed systems represent a wide variety of ITT equipment, depending on the particular configuration of the rack-mountable units in the rack or enclosure. These may be server systems, storage systems, I/O systems, networking systems or "integrated" systems of these or other types of rack-mountable units.

3.1.14
hand-held equipment
functional unit, generally small and lightweight, intended to be supported by the hand(s) during normal use

3.1.15
standard test table
rigid table having a top surface of at least 0,5 m^2 and length of the top plane not less than 700 mm

NOTE The design for the standard test table is shown in Annex A.

3.2 Acoustical definitions

3.2.1
emission
noise emission
airborne sound radiated by a well-defined noise source (e.g. the equipment under test)

NOTE Noise emission descriptors can be incorporated into a product declaration and/or product specification. The basic noise emission descriptors are the sound power level of the source itself and the emission sound pressure levels at an operator position or at bystander positions (if no operator position is defined) in the vicinity of the source.

3.2.2
sound pressure
p
difference between instantaneous total pressure and static pressure

NOTE 1 Sound pressure is expressed in pascals.

NOTE 2 The symbol p is often used without modification to represent a root mean square (r.m.s.) sound pressure.

[ISO 80000-8:2007[3], 9.2]

3.2.3
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, p, to the square of a reference value, p0, expressed in decibels

$$L_p = 10 \lg \frac{p^2}{p_0^2} \text{ dB}$$

where the reference value, p_0, is 20 µPa

NOTE This definition is technically in accordance with ISO 80000-8:2007[3], 8.22.

[ISO/TR 25417:2007[22], 2.2]

3.2.4
time-averaged sound pressure level
L_{pT}
sound pressure level of a continuous steady sound that, within a measurement time interval, T, has the same mean-square sound pressure as a sound under consideration which varies with time

3.2.5
emission sound pressure level
L_p
sound pressure level measured at a specified position near a noise source, when the source is in operation under specified operating and mounting conditions on a reflecting plane surface, but excluding the effects of background noise

NOTE 1 The emission sound pressure level is expressed in decibels.

NOTE 2 Clause 8 specifies the method for determination of emission sound pressure level.

3.2.6
time-averaged emission sound pressure level
$L_{p\text{eq}T}$
emission sound pressure level of a continuous steady sound that, within a measurement time interval, T, has the same mean-square sound pressure as a sound under consideration which varies with time

$$L_{p\text{eq}T} = 10 \lg \left[\frac{\frac{1}{T}\int_0^T p^2(t)\,\text{d}t}{p_0^2} \right] \text{dB}$$

NOTE 1 The time-averaged emission sound pressure level is expressed in decibels.

NOTE 2 The emission sound pressure level is determined at the specified position(s) required by the noise test code (i.e. this International Standard, for specific families of ITT equipment).

NOTE 3 In general, the subscripts “eq” and “T” are omitted since time-averaged emission sound pressure levels are necessarily determined over a certain measurement time interval.

3.2.7
A-weighted impulse sound pressure level
$L_{p\text{AI}}$
A-weighted sound pressure level determined with a sound level meter set for the I time-weighting characteristic (impulse)

NOTE The A-weighted impulse sound pressure level is expressed in decibels.

3.2.8
C-weighted peak sound pressure level
$L_{p\mathrm{Cpeak}}$
highest instantaneous value of the C-weighted sound pressure level determined over an operational cycle

NOTE The C-weighted peak sound pressure level is expressed in decibels.

3.2.9
sound power
P
rate per time at which airborne sound energy is radiated by a source

NOTE 1 Sound power is expressed in watts.

NOTE 2 In this International Standard, it is the time-averaged value of the sound power during the measurement duration.

3.2.10
reference sound source
device which is intended for use as a stable source of sound, which has a known broad-band sound power spectrum calibrated in accordance with ISO 6926 over the frequency range of interest

3.2.11
frequency range of interest
one-third-octave bands with centre frequencies specified in ISO 266 from 100 Hz to 10 000 Hz inclusive

NOTE For equipment which emits discrete tone(s) in the 16 kHz octave band, the procedures specified in ISO 9295 are used; see Table 4.

4 Conformity requirements

Measurements are in conformity with this International Standard if they meet the following requirements:

a) the measurement procedures, the installation and the operating conditions specified in this International Standard are fully taken into account;

b) for the determination of sound power levels, one (and only one) of the methods specified in Clause 6 or 7 is used;

c) for determination of emission sound pressure level at the operator or bystander positions, the method specified in Clause 8 is used.

5 Installation and operating conditions

5.1 Equipment installation

5.1.1 General

The equipment shall be installed according to its intended use. Installation conditions for many different categories of ITT equipment are specified in Annex C; these shall be followed when noise emission declaration information is to be obtained. If the normal installation is unknown or if several possibilities exist, a representative condition shall be chosen and reported.

Care shall be taken to ensure that any electrical conduits, piping, air ducts or other auxiliary equipment connected to the equipment being tested do not radiate significant amounts of sound energy into the test room. If practicable, all auxiliary equipment necessary for the operation of the equipment shall be located outside the test room and the test room shall be free from all objects which may interfere with the measurements.

NOTE If the equipment is mounted near one or more reflecting planes, the sound power radiated by the equipment can depend upon its position and orientation. It is possible that the determination of the radiated sound power is of interest either for one particular equipment position and orientation or from the average value for several positions and orientations.

5.1.2 Floor-standing equipment

5.1.2.1 Requirements for reverberation test rooms

Floor-standing equipment shall be located at least 1,5 m from any wall of the room and no major surfaces shall be parallel to a wall of the reverberation test room.

5.1.2.2 Requirements for hemi-anechoic rooms

Floor-standing equipment shall be installed on the reflecting (hard) floor at a sufficient distance (more than 2 m, if possible) from the walls, unless otherwise specified in Annex C.

The equipment shall be installed in a way which allows access to all sides except the reflecting plane(s). The dimensions of the reflecting plane(s) shall extend beyond the test object by at least the measurement distance. The requirements for reflection are specified in the Note to 7.3.1. The plane(s) shall not contribute to the sound radiation due to their own vibrations.

5.1.2.3 Common requirements

If the equipment being tested consists of several frames bolted together in an installation or is too large for testing purposes, the frames may be measured separately. In such circumstances, additional covers may be required for the frames during the acoustical evaluation. These additional covers shall be acoustically comparable with the other covers on the equipment. If a unit is mechanically or acoustically coupled to another unit so that the noise emission levels of one are significantly influenced by the other, the equipment being tested shall, where practicable, include all units coupled together in this way.

Floor-standing equipment which is to be installed only in front of a wall shall be placed on a hard floor in front of a hard wall (see the Note to 7.3.1). The distance from the wall shall be in accordance with the manufacturer's instructions or as specified in Annex C. If such information is not available, the distance shall be 0,1 m.

5.1.3 Table-top equipment

5.1.3.1 Requirements for reverberation test rooms

Table-top equipment (see 3.1.9) shall be placed on the floor at least 1,5 m from any wall of the room unless a table or stand is required for operation in accordance with Annex C (e.g. printers which take paper from or stack paper on the floor). Such equipment shall be placed in the centre of the top plane of the standard test table (see Annex A).

5.1.3.2 Requirements for hemi-anechoic rooms

Table-top equipment (see 3.1.9) shall be placed on the floor, unless a table or stand is required for operation in accordance with Annex C (e.g. printers which take paper from or stack paper on the floor). Such equipment shall be placed in the centre of the top plane of the standard test table (see Annex A). In any case, the measurement surface defined in 7.6 terminates on the floor.

5.1.4 Wall-mounted equipment

Wall-mounted equipment (see 3.1.10) shall be affixed to a wall of the reverberation test room at least 1,5 m from any other reflecting surface, unless otherwise specified. Alternatively, if operation permits, the equipment may be laid with its mounting surface on the floor at least 1,5 m (more than 2 m, if possible, in hemi-anechoic rooms) from any wall of the room.

If the equipment is usually installed by being recessed into a wall or other structure, a representative structure shall be used for mounting during the measurements and described in the test report.

5.1.5 Rack-mounted equipment

Rack-mounted equipment includes both individual rack-mountable units (see 3.1.12) and rack-enclosed systems (see 3.1.13). Rack-mountable units shall either be tested outside of the rack or installed in a rack enclosure in accordance with the requirements of ECMA-74. Rack-enclosed systems shall be tested either as floor-standing equipment (see 5.1.2) or as table-top equipment (see 5.1.3) according to the type and size of system. The specific installation and operation requirements of ECMA-74 shall be followed.

For rack-enclosed systems that are available in more than one configuration of rack-mountable units, the particular configuration to be measured is usually governed by the purposes of the test and is thus not specified in this International Standard (see ECMA-74 for more information).

5.1.6 Hand-held equipment

Hand-held equipment (see 3.1.14) shall be supported 0,25 m ± 0,03 m above the reflecting plane by a vibration-isolating stand or fixture, or by appropriate vibration-isolating elements. If a hemispherical measurement surface is used with any radius less than 1 m (see B.1), the hand-held equipment support height shall be reduced to 0,125 m ± 0,015 m. The method of supporting the hand-held equipment shall not interfere with the propagation of airborne sound from the equipment or generate any additional sound radiation.

5.1.7 Sub-assemblies

A sub-assembly (see 3.1.11) shall be supported 0,25 m ± 0,03 m above the reflecting plane by a vibration-isolating stand or fixture, or by appropriate vibration-isolating elements. If a hemispherical measurement surface is used with a radius less than 1 m (see B.1), the sub-assembly support height shall be reduced to 0,125 m ± 0,015 m. The method of supporting the sub-assembly shall not interfere with the propagation of airborne sound from the sub-assembly or generate any additional sound radiation.

If the above-specified support height is not adequate to allow the manufacturer's recommended air flow at the sub-assembly's intake port, the height may be adjusted accordingly, but shall not exceed 0,5 m. The new height shall be documented in the test report.

5.2 Input voltage and frequency

The equipment shall be operated at its nominal rated voltage and the rated power line frequency.

Phase-to-phase voltage variations shall not exceed 5 %.

5.3 Equipment operation

During the acoustical measurements, the equipment shall be operated in a manner typical of normal use.

Annex C specifies such conditions for many categories of equipment and shall be followed. However, if the specified conditions are clearly contrary to the objective of providing uniform conditions closely corresponding to the intended use of the product, then an additional mode or modes closely related to the intended use shall be defined, tested and documented. Any subsequent declaration shall either:

— declare both values, indicating that one is based on Annex C, and indicating that the other is declared by the manufacturer to be typical use for the intended application; or

— declare only the latter, indicating that it is not based on Annex C, but is declared by the manufacturer to be typical use for the intended application.

When there are multiple operating modes specified in Annex C, at a minimum, the most typical operating mode shall be tested and reported.

The equipment shall be operated for a sufficient period of time before proceeding with the acoustical test to allow temperature and other pertinent conditions to stabilize.

The noise shall be measured with the equipment in both the idle and operating modes. If the equipment is designed to perform different functions, such as manual typing and automatic printing of stored information or for printing in different print qualities, unless otherwise specified in Annex C, the noise of each individual mode shall be determined and recorded. For equipment which, in normal functional operation, performs several operating modes, such as document insertion, reading, encoding, printing and document eject, and for which a typical operation cycle has not been defined in Annex C, such a typical cycle shall be defined for the measurements and described in the test report.

For rack-mounted equipment in which the operation of several functional units is possible, the units intended to operate together shall do so during the test; all other units shall be in idle mode. In the absence of operational specifications provided by Annex C or by the manufacturer, an operating mode that represents the most typical usage shall be tested. This mode shall be clearly described in the test report.

Some equipment does not operate continuously because of its mechanical design or its mode of operation under program control. Long periods may occur during which the equipment is idle. The operating mode measurements shall not include these idle periods. If it is not possible to operate the equipment continuously during the acoustical evaluation, the time interval during which measurements have to be made shall be described in the test plan, equipment specifications or other documentation.

Some equipment has operational cycles that are too short to allow reliable determination of the noise emissions. In such cases, a typical cycle shall be repeated several times.

If the equipment being tested produces attention signals, such as tones or bells, such intermittent sound shall not be included in an operating mode. During the acoustical evaluation in the operating mode(s), such attention signals shall be inoperative or, if this is not possible, they shall be set to a minimum.

NOTE For certain applications, such signals as well as the maximum response of feedback signals of keyboards can be of interest. Such measurements can be made, but they are not part of the methods specified in this International Standard.

6 Method for determination of sound power levels of equipment in reverberation test rooms

6.1 General

The method specified in this clause provides a comparison procedure for determination of the sound power levels produced by ITT equipment in a reverberation test room, in accordance with the comparison method specified in ISO 3741. It applies to equipment which radiates broad-band noise, narrow-band noise, noise which contains discrete-frequency components or impulsive noise.

It is strongly recommended that the room be qualified for discrete-frequency components in accordance with the relevant procedure specified in ISO 3741. This avoids the need to determine the number of microphone positions and equipment locations each time equipment is measured.

6.2 Measurement uncertainty

Measurements carried out in accordance with this method yield standard deviations of reproducibility for the frequency range of interest of this International Standard which are equal to, or less than, those given in Table 1.

Table 1 — Uncertainty in determining sound power levels in a reverberation test room in accordance with Clause 6

Octave band centre frequencies Hz	**One-third-octave-band centre frequencies** Hz	**Standard deviation** dB
125	100 to 160	3,0
250	200 to 315	2,0
500 to 4 000	400 to 5 000	1,5
8 000	6 300 to 10 000	3,0

NOTE 1 For most ITT equipment, the A-weighted sound power level is determined by the sound power levels in the 250 Hz to 4 000 Hz octave bands. The A-weighted sound power level is determined with a standard deviation of approximately 1,5 dB. A larger standard deviation can result when the sound power levels in other bands determine the A-weighted sound power level.

NOTE 2 The standard deviations given in Table 1 reflect the cumulative effects of all causes of measurement uncertainty, including variations from laboratory to laboratory, but excluding variations in the sound power level from equipment to equipment or from test to test which can be caused, for example, by changes in the installation or operating conditions of the equipment. The reproducibility and repeatability of the test results for the same piece of equipment and the same measurement conditions can be considerably better (i.e. smaller standard deviations) than the uncertainties given in Table 1 indicate.

NOTE 3 If the method specified in this clause is used to compare the sound power levels of similar equipment that are omnidirectional and radiate broad-band noise, the uncertainty in this comparison yields a standard deviation which is less than that given in Table 1, provided that the measurements are carried out in the same environment.

6.3 Test environment

6.3.1 General

Guidelines specified in ISO 3741 for the design of the reverberation test room, as applicable, shall be used. Criteria for room absorption and the procedure for room qualifications, specified in ISO 3741, shall be used.

ISO 3741 shall be followed with regard to the following:

a) test room volume;

b) level of background noise.

6.3.2 Meteorological conditions

The requirements of ISO 3741 shall be followed.

The following conditions are recommended:

a) ambient pressure: 86 kPa to 106 kPa;

b) temperature: within the range defined by the manufacturer for the equipment, if a range is defined; if no range is defined by the manufacturer, the recommended range is 15 °C to 30 °C;

c) relative humidity: within the range defined by the manufacturer for the equipment, if a range is defined; for processing of paper and card media only, if no range is defined by the manufacturer, the recommended range is 40 % to 70 %.

For equipment whose noise emissions vary with ambient temperature in a prescribed manner (e.g. by varying the speeds of air-moving devices), the room temperature during the measurement shall be 23 °C ± 2 °C.

For equipment whose noise emissions vary with altitude in a prescribed manner (e.g. by varying the speeds of air-moving devices), the altitude of the test room shall either be less than or equal to 500 m or the equipment shall be tested under conditions simulating its operation at an altitude less than or equal to 500 m.

NOTE This variation of speed of air-moving devices does not refer to the changing speed that is already accounted for in the correction for ambient pressure described in the Note to 6.10.1.

6.4 Instrumentation

6.4.1 General

The requirements of this subclause (6.4), as well as the instrumentation requirements of ISO 3741, shall be followed.

Digital integration is the preferred method of averaging.

6.4.2 The microphone and its associated cable

The instrumentation system, including the microphone and its associated cable, shall meet the requirements of ISO 3741. If the microphone is moved, care shall be exercised to avoid introducing acoustical or electrical noise (e.g. from gears, flexing cables, or sliding contacts) that could interfere with the measurements.

6.4.3 Frequency response of the instrumentation system

The requirements of ISO 3741 shall be followed.

6.4.4 Reference sound source

The reference sound source shall meet the requirements specified in ISO 6926 over the frequency range of interest.

6.4.5 Filter characteristics

The requirements for an instrument specified in accordance with IEC 61260, class 1 shall be followed.

6.4.6 Calibration

During each series of measurements, a sound calibrator as specified in IEC 60942, class 1, 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 compliance of the calibrator with the requirements of IEC 60942 shall be verified once a year, and the compliance of the instrumentation system with the requirements of IEC 61672-1 at least every 2 years in a laboratory that makes calibrations traceable to appropriate standards.

The reference sound source shall be fully calibrated every 2 years in accordance with ISO 6926.

The reference sound source shall be checked annually in accordance with the procedure in ISO 6926 to determine whether recalibration of the reference sound source is necessary prior to the 2 year calibration period. If changes in any one-third-octave-band sound pressure level exceed values for recalibration specified in ISO 6926, then the reference sound source shall be fully calibrated in accordance with ISO 6926 before further use.

The date of the last verification of the compliance with the relevant International Standards shall be recorded.

6.5 Installation and operation of equipment: General requirements

See Clause 5.

6.6 Microphone positions and source locations

6.6.1 General

The major cause of uncertainty in determining sound power level in a reverberation test room is the spatial irregularity of the sound field. The extent of this irregularity and, hence, the effort required to determine the time-average sound pressure level accurately is greater for discrete-frequency sound than for broad-band sound.

It is strongly recommended that the room be qualified for the measurement of discrete-frequency components in accordance with the relevant procedures of ISO 3741. This avoids the need to determine the number of microphone positions and equipment locations each time equipment is measured.

If the room has not been qualified for the measurement of discrete-frequency components, the procedures specified in ISO 3741 shall be used to determine the minimum number of microphone positions and to evaluate the need for additional noise source locations prior to each measurement. The results of these procedures depend on the presence or absence of significant discrete-frequency components or narrow bands of noise in the sound emitted by the source. When these are present, the number of microphone positions and equipment locations may be large.

6.6.2 Number of microphone positions, reference sound source locations and equipment locations

The requirements of ISO 3741 shall be followed.

6.6.3 Microphone arrangement

The requirements of ISO 3741 shall be followed.

6.7 Measurement of sound pressure level

6.7.1 General

The requirements of ISO 3741 shall be followed, as applicable.

6.7.2 Measurement duration

The requirements below, in addition to those of ISO 3741, shall be followed, as applicable.

For equipment which performs repetitive operation cycles (e.g. enveloping machines), the measurement duration shall include at least three operation cycles. For equipment which performs a sequence of varying operation cycles, the measurement duration shall include the total sequence. Annex C specifies additional requirements for many categories of equipment.

6.7.3 Corrections for background noise

The requirements of ISO 3741 shall be followed, as applicable.

NOTE When the levels of the background noise in the test room are extremely low and very controlled, it is possible that the environment satisfies the absolute and/or relative criteria for background noise in accordance with ISO 3741.

6.8 Measurement of the sound pressure level of the reference sound source

The requirements below, in addition to those of ISO 3741, shall be followed.

For the purposes of determining the sound power level of the equipment by means of reverberation test rooms, this International Standard uses exclusively the comparison method specified in ISO 3741. This method has the advantage that it is not necessary to measure the reverberation time of the test room. The comparison method requires the use of a reference sound source with characteristics and calibration in accordance with ISO 6926. The reference sound source shall be operated, as described in its calibration chart, in the presence of the equipment being tested and in the presence of the operator, if required to operate the equipment.

6.9 Calculation of mean time-averaged band sound pressure level

The requirements of ISO 3741 shall be followed.

6.10 Determination of sound power level

6.10.1 Calculation of band sound power levels

The sound power level, under reference meteorological conditions, of the equipment in each one-third-octave band within the frequency range of interest (see 3.2.11) is obtained by using the comparison method of ISO 3741.

NOTE The procedures in ISO 3741 are used to determine the sound power level under reference meteorological conditions (ambient pressure 1,013 25 × 10⁵ Pa, temperature 23 °C, relative humidity 50 %).

The sound power level in the kth octave band, $L_{W\text{oct},\,k}$ in decibels, if needed, shall be based on one-third-octave-band data, and calculated from:

$$L_{W\text{oct},\,k} = 10\lg \sum_{j=3k-2}^{3k} 10^{0,1 L_{W1/3,\,j}} \text{ dB} \qquad (1)$$

where

k is an identification number of octave band within the frequency range of interest (see Table 2);

$L_{W1/3,\,j}$ is the sound power level in the jth one-third-octave band, in decibels (see Table 3);

j is an identification number lying within the range of $(3k - 2)$ and $3k$, which identifies the three one-third-octave bands which make up the kth octave band.

6.10.2 Calculation of A-weighted sound power level

The A-weighted sound power level, L_{WA}, in decibels, shall be based on the frequency range of interest, and calculated from:

$$L_{WA} = 10\lg \sum_{j=1}^{21} 10^{0,1(L_{W1/3,\,j} + A_j)} \text{ dB} \qquad (2)$$

where

$L_{W1/3,\,j}$ is the sound power level, in decibels, in the jth one-third-octave band;

A_j is the A-weighting value corresponding to the jth one-third-octave band (see Table 3);

j is an identification number of a one-third-octave band within the frequency range of interest (see Table 3).

NOTE Equations (1) and (2), as well as Tables 2 and 3, are intended for common use for not only Clause 6, but also Clause 7.

Table 2 — Identification number k for octave bands

k	Octave-band centre frequency Hz
1	125
2	250
3	500
4	1 000
5	2 000
6	4 000
7	8 000

Table 3 — Values of A-weighting, A_j, for one-third-octave bands

j	One-third-octave-band centre frequency Hz	A-weighting A_j dB
1	100	–19,1
2	125	–16,1
3	160	–13,4
4	200	–10,9
5	250	–8,6
6	315	–6,6
7	400	–4,8
8	500	–3,2
9	630	–1,9
10	800	–0,8
11	1 000	0,0
12	1 250	0,6
13	1 600	1,0
14	2 000	1,2
15	2 500	1,3
16	3 150	1,2
17	4 000	1,0
18	5 000	0,5
19	6 300	–0,1
20	8 000	–1,1
21	10 000	–2,5

Some ITT equipment emits high-frequency noise in the 16 kHz octave band. Depending upon the nature of noise emissions, Table 4 shows how to handle each situation.

For the determination of A-weighted sound power levels from band levels, this International Standard does not extend the frequency range of interest to include the 16 kHz octave band.

For equipment which emits discrete tone(s) in the 16 kHz octave band, each frequency and level of the tone(s) that is (are) within 10 dB of the highest tone level in the band shall be determined in accordance with the procedures specified in ISO 9295 (see Table 4). The derived levels are not frequency weighted.

CAUTION — The 16 kHz octave-band contribution is not included in the determination of the A-weighted level.

Table 4 — Type of noise and determination of sound power levels

Type of noise in the frequency range of the octave bands centred at		**Sound power level to be determined**
125 Hz to 8 kHz	16 kHz	
Broad-band or narrow-band noise[a]	No significant noise	A-weighted level (consisting of contribution from 125 Hz to 8 kHz octave bands) in accordance with this International Standard
	Broad-band noise	A-weighted level (consisting of contribution from 125 Hz to 8 kHz octave bands) in accordance with this International Standard, and one-third-octave-band levels in 16 kHz octave band in accordance with the procedure of ISO 9295
	Discrete tone	A-weighted level (consisting of contribution from 125 Hz to 8 kHz octave bands) in accordance with this International Standard and the level and frequency of the discrete tone in accordance with ISO 9295
	Multiple tones	A-weighted level (consisting of contribution from 125 Hz to 8 kHz octave bands) in accordance with this International Standard and the levels and frequencies of all tones in the 16 kHz octave band that are within 10 dB of the highest tone level in the band in accordance with ISO 9295
No significant noise[b]	Discrete tone	Level and frequency of the discrete tone in the 16 kHz octave band in accordance with ISO 9295
	Multiple tones	Levels and frequencies of all tones in the 16 kHz octave band that are within 10 dB of the highest tone level in the band in accordance with ISO 9295

[a] For noise in the 125 Hz to 8 kHz octave bands, sound power level in one-third-octave bands and in octave bands may also be reported.

[b] A significant noise contribution not within the 125 Hz to 8 kHz octave band lies outside the scope of this International Standard; in that case only ISO 9295 is applicable.

7 Method for determination of sound power levels of equipment under essentially free-field conditions over a reflecting plane

7.1 General

The method specified in this clause provides a direct procedure for determination of the sound power levels produced by ITT equipment using essentially free-field conditions over a reflecting plane as specified in ISO 3744 or ISO 3745. It applies to equipment which radiates broad-band noise, narrow-band noise, noise which contains discrete-frequency components or impulsive noise.

The measurement shall be carried out in an environment qualified in accordance with ISO 3744 or ISO 3745.

7.2 Measurement uncertainty

Measurements carried out in accordance with this method yield standard deviations of reproducibility for the frequency range of interest of this International Standard which are less than or equal to those given in Table 5.

Table 5 — Uncertainty in determining sound power levels in an essentially free field over a reflecting plane in accordance with Clause 7

Octave band centre frequencies Hz	One-third-octave-band centre frequencies Hz	Standard deviation dB
125	100 to 160	3,0
250 to 500	200 to 630	2,0
1 000 to 4 000	800 to 5 000	1,5
8 000	6 300 to 10 000	2,5

NOTE 1 For most ITT equipment, the A-weighted sound power level is determined by the sound power levels in the 250 Hz to 4 000 Hz octave bands. The A-weighted sound power level is determined with a standard deviation of approximately 1,5 dB. A larger standard deviation can result when the sound power levels in other bands determine the A-weighted sound power level.

NOTE 2 The standard deviations given in Table 5 reflect the cumulative effects of all causes of measurement uncertainty, including variations from laboratory to laboratory, but excluding variations in the sound power level from equipment to equipment or from test to test which can be caused, for example, by changes in the installation or operating conditions of the equipment. The reproducibility and repeatability of the test results for the same piece of equipment and the same measurement conditions can be considerably better (i.e. smaller standard deviations) than the uncertainties given in Table 5 indicate.

NOTE 3 If the method specified in this clause is used to compare the sound power levels of similar equipment that are omnidirectional and radiate broad-band noise, the uncertainty in this comparison yields a standard deviation which is less than that given in Table 5, provided that the measurements are carried out in the same environment.

7.3 Test environment

7.3.1 General

The test environment shall provide an essentially free field over a reflecting plane. Criteria for suitable test environments are defined in ISO 3744 and ISO 3745 with the exception that the environmental correction, K_2, in accordance with ISO 3744, shall be equal to or less than 2 dB.

NOTE A plane (floor, wall) is considered to be reflecting (hard) if its absorption coefficient, α, is less than 0,06 over the frequency range of interest (e.g. concrete floor: $\alpha < 0{,}01$, plastered wall: $\alpha \approx 0{,}04$, tiled wall: $\alpha \approx 0{,}01$).

7.3.2 Meteorological conditions

The requirements of ISO 3744 shall be followed, as applicable.

The following conditions are recommended:

a) ambient pressure: 86 kPa to 106 kPa;

b) temperature: within the range defined by the manufacturer for the equipment if a range is defined — if no range is defined by the manufacturer, the recommended range is 15 °C to 30 °C;

c) relative humidity: within the range defined by the manufacturer for the equipment, for processing of paper and card media only or, if there is no such range 40 % to 70 %.

For equipment whose noise emissions vary with ambient temperature in a prescribed manner (e.g. by varying the speeds of air-moving devices), the room temperature during the measurement shall be 23 °C ± 2 °C.

For equipment whose noise emissions vary with altitude in a prescribed manner (e.g. by varying the speeds of air-moving devices), the altitude of the test room shall either be less than or equal to 500 m or the equipment shall be tested under conditions simulating its operation at an altitude less than or equal to 500 m.

NOTE This variation of speed of air-moving devices does not refer to the changing speed that is already accounted for in the correction for ambient pressure specified in 7.9.1.

7.4 Instrumentation

7.4.1 General

The requirements of this subclause (7.4), as well as the instrumentation requirements of ISO 3744 or ISO 3745, shall be followed.

Digital integration is the preferred method of averaging.

7.4.2 The microphone and its associated cable

The instrumentation system, including the microphone and its associated cable, shall meet the requirements of ISO 3744 or ISO 3745, as applicable. If the microphone is moved, care shall be exercised to avoid introducing acoustical or electrical noise (e.g. from wind, gears, flexing cables or sliding contacts) that could interfere with the measurements.

7.4.3 Frequency response of the instrumentation system

The requirements of ISO 3744 or ISO 3745, as applicable, shall be followed.

7.4.4 Reference sound source

The reference sound source shall meet the requirements specified in ISO 6926 over the frequency range of interest.

7.4.5 Filter characteristics

The requirements for an instrument specified in accordance with IEC 61260, class 1 shall be followed.

7.4.6 Calibration

During each series of measurements, a sound calibrator as specified in IEC 60942, class 1, 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 compliance of the calibrator with the requirements of IEC 60942 shall be verified once a year, and the compliance of the instrumentation system with the requirements of IEC 61672-1 at least every 2 years in a laboratory that makes calibrations traceable to appropriate standards.

The reference sound source, if used for determination of environmental correction, K_2, shall be fully calibrated every 2 years in accordance with ISO 6926.

The reference sound source shall be checked annually in accordance with ISO 6926 to determine whether recalibration of the reference sound source is necessary prior to the 2 year calibration period. If changes in any one-third-octave-band sound pressure level exceed the limits specified in ISO 6926, then the reference sound source shall be fully calibrated in accordance with ISO 6926 before further use.

The date of the last verification of the compliance with the relevant International Standards shall be recorded.

7.5 Installation and operation of equipment: General requirements

See Clause 5.

7.6 Measurement surface and microphone positions

7.6.1 General

Except as specified in Annex B, the requirements of ISO 3744 or ISO 3745 shall be followed, as applicable. For most ITT equipment, the preferred measurement surface is hemispherical. If a hemispherical surface is used, then one of the following shall be applied:

a) B.1;

b) relevant annex of ISO 3745;

c) relevant annex of ISO 3744 (but, with a minimum of five different microphone heights).

However, for equipment with tall aspect ratios, such as equipment racks, frames or cabinets, the cylindrical measurement surface specified in B.2 may be preferred. For sources which have a relatively large footprint, the parallelepiped measurement surface may be more practical. The conditions of Clause 5 shall, however, be followed. The number and location of the microphone positions shall be as specified in ISO 3744 or ISO 3745, as applicable, except as specified in Annex B.

In some cases, e.g. when small equipment emits very low-level noise, it may be helpful to use a hemispherical measurement surface with a smaller radius. For such situations, B.1 defines measurement conditions with a hemisphere radius less than 1 m, but at least 0,5 m.

In order to facilitate the location of the microphone positions, a hypothetical reference surface is defined. This reference surface, or “reference box”, is the smallest possible rectangular box (i.e. a right parallelepiped) that just encloses the equipment and terminates on the reflecting plane(s). It has length l_1, width l_2 and height l_3. Elements protruding from the equipment being tested which are unlikely to contribute to the noise emission may be disregarded. The microphone positions lie on the measurement surface, a hypothetical surface of area, S, which envelops the equipment as well as the reference box and terminates on the reflecting plane.

The location of the equipment being tested, the measurement surface and the microphone positions are defined by a co-ordinate system with horizontal axes x and y in the ground plane parallel to the length and width of the reference box and with the vertical axis z passing through the geometric centre of the reference box. The x-axis points towards the front of the equipment. The position of the origin for the co-ordinates of the microphone positions is:

a) for floor-standing equipment: on the floor in the centre of the plane of the reference box which is coplanar with the room floor;

b) for table-top equipment on a table or on the floor: as for a);

c) for wall-mounted equipment: in the centre of that plane of the reference box which is coplanar with the mounting surface;

d) for rack-mounted equipment: as for a);

e) for hand-held equipment: as for a);

f) for sub-assemblies: as for a).

NOTE For fixed microphone arrays, either a single microphone can be moved from one position to the next sequentially or a number of fixed microphones can be used and their outputs sampled sequentially or simultaneously. Alternatively, a continuous microphone traverse can be used, as specified in ISO 3744.

Near air exhausts, the microphone position shall be selected in such a way that the microphone is not exposed to the air stream; otherwise, a windscreen shall be used.

The microphones shall be oriented in such a way that the angle of sound incidence is the same as the angle for which the microphone has the most uniform frequency response, as specified by the manufacturer. For most practical cases, this is an orientation towards the origin of the co-ordinate system on the floor.

7.6.2 Microphone positions on the measurement surface

Except as stated in the next paragraph, microphone positions shall meet the requirements of ISO 3744 or ISO 3745, as applicable, including the requirements for additional microphone positions and for reduction in the number of microphone positions, where applicable.

If large equipment is to be measured in small rooms providing free-field conditions over a reflecting plane in accordance with ISO 3745, it may be easier to place the equipment not in the centre of the room but closer to a corner and to arrange the microphone positions in the free field of the room. The equipment should be turned around so that noise radiation from the different sides of the machine can be determined sequentially.

7.7 Measurement of sound pressure levels

7.7.1 General

Measurements of the sound pressure levels shall be carried out in accordance with ISO 3744 or ISO 3745 and with the following requirements.

Measurements of the sound pressure level shall be carried out at the microphone positions specified in 7.6 with A-weighting and/or for each frequency band within the frequency range of interest, if required. Record:

— the A-weighted sound pressure levels and/or the one-third-octave-band sound pressure levels, for the specified modes of operation of the equipment;

— the A-weighted sound pressure levels and/or the one-third-octave-band sound pressure levels of the background noise (including noise from support equipment).

When using a sound level meter, the person reading the meter shall not disturb the sound field at the microphone.

7.7.2 Measurement duration

The requirements below, in addition to those of ISO 3744, shall be followed, as applicable.

For equipment which performs repetitive operation cycles (e.g. enveloping machines), the measurement duration shall include at least three cycles. For equipment which performs a sequence of varying cycles, the measurement duration shall include the total sequence. Annex C specifies additional requirements for many types of equipment.

7.7.3 Corrections for background noise

The requirements of ISO 3744 shall be followed, as applicable.

NOTE When the levels of the background noise in the test room are extremely low and very controlled, it is possible that the environment satisfies the absolute and/or relative criteria for background noise in accordance with ISO 3744.

7.8 Calculation of surface sound pressure level

Calculation of surface sound pressure level over the measurement surface shall be in accordance with the relevant procedure of ISO 3744. This includes corrections for background noise, K_1, and test environment, K_2. For hemi-anechoic rooms meeting the qualification requirements of ISO 3745, no K_2 correction is applied.

7.9 Determination of sound power levels

7.9.1 Calculation of band sound power levels

When band data are required, the sound power level, under reference meteorological conditions, of the equipment in each one-third-octave band within the frequency range of interest shall be based on the surface sound pressure level and determined in accordance with the procedure of ISO 3744.

NOTE The procedure in ISO 3744 is used to determine the sound power level under reference meteorological conditions (ambient pressure $1{,}013\,25 \times 10^5$ Pa, temperature 23 °C, relative humidity 50 %).

The sound power level in the kth octave band, $L_{W\text{oct},\,k}$, in decibels, if needed, shall be based on one-third-octave-band data, $L_{W1/3,\,j}$, and calculated from Equation (1).

7.9.2 Calculation of A-weighted sound power level

For the purposes of this International Standard, the A-weighted sound power level, L_{WA}, in decibels, under reference meteorological conditions, can be derived either directly from A-weighted sound pressure levels, or by calculation from one-third-octave-band data using the A-weighting values for each band in accordance with the procedures of ISO 3744.

NOTE The procedures in ISO 3744 are used to determine the sound power level under reference meteorological conditions (ambient pressure $1{,}013\,25 \times 10^5$ Pa, temperature 23 °C, relative humidity 50 %).

In the latter case, the A-weighted sound power level, L_{WA}, in decibels, shall be based on the frequency range of interest, or calculated from Equation (2).

Some ITT equipment emits high-frequency noise in the 16 kHz octave band. Depending upon the nature of noise emissions, Table 4 shows how to handle each situation.

For the determination of A-weighted sound power levels from band levels, this International Standard does not extend the frequency range of interest to include the 16 kHz octave band.

For equipment which emits discrete tone(s) in the 16 kHz octave band, each frequency and level of the tone(s) that is (are) within 10 dB of the highest tone level in the band shall be determined in accordance with the procedures specified in ISO 9295 (see Table 4). The derived levels are not frequency weighted.

CAUTION — The 16 kHz octave band contribution is not included in the determination of the A-weighted level.

8 Method for determination of emission sound pressure levels at defined operator and bystander positions

8.1 General

The method specified in this clause defines the conditions for determination of the emission sound pressure levels of ITT equipment at the work station (operator position) and, if there is no operator position, at the bystander position(s) in an essentially free field over a reflecting plane in accordance with ISO 11201, accuracy grade 2 (engineering method). It applies to equipment which radiates broad-band noise, narrow-band noise, noise which contains discrete-frequency components, or impulsive noise.

NOTE The determination specified in this clause is historically based on an engineering method.

This determination does not apply to sub-assemblies. However, where desired for sub-assemblies, determine an emission sound pressure level from a previously obtained sound power level using $Q = Q_1 = 8$ dB in accordance with ISO 11203. This value of Q corresponds to a radial distance of 1 m from a small sub-assembly radiating hemispherically; for uniformity, this value of Q is applicable to all sub-assemblies. Optionally, actual emission sound pressure levels may be determined at operator or bystander positions, as described in the following.

Determinations of whether the noise at the operator position or at the bystander positions contains prominent discrete tones and/or is impulsive in character are specified in Annex D and Annex E, respectively. These methods are applicable to equipment and sub-assemblies.

8.2 Measurement uncertainty

Measurements carried out in accordance with this method yield standard deviations of reproducibility for the frequency range of interest of this International Standard which are equal to, or less than, those given in Table 6.

Table 6 — Uncertainty in determining emission sound pressure levels at the operator and bystander positions in an essentially free field over a reflecting plane in accordance with Clause 8

Octave-band centre frequencies Hz	One-third-octave-band centre frequencies Hz	Standard deviation dB
125	100 to 160	3,0
250 to 500	200 to 630	2,0
1 000 to 4 000	800 to 5 000	1,5
8 000	6 300 to 10 000	2,5

NOTE 1 For most ITT equipment, the A-weighted emission sound pressure level is determined by the emission sound pressure levels in the 250 Hz to 4 000 Hz octave bands. The A-weighted emission sound pressure level is determined with a standard deviation of approximately 1,5 dB. A larger standard deviation can result when the emission sound pressure levels in other bands determine the A-weighted emission sound pressure level.

NOTE 2 In free-field conditions over a reflecting plane, the standard deviations given in Table 6 reflect the cumulative effects of all causes of measurement uncertainty, including variations from laboratory to laboratory, but excluding variations in the emission sound pressure level from equipment to equipment or from test to test which can be caused, for example, by changes in the installation or operating conditions of the equipment. The reproducibility and repeatability of the test results for the same piece of equipment and the same measurement conditions can be considerably better (i.e. smaller standard deviations) than the uncertainties given in Table 6 indicate.

NOTE 3 If the method specified in this clause is used to compare the emission sound pressure levels of similar equipment that are omnidirectional and radiate broad-band noise, the uncertainty in this comparison yields a standard deviation which is less than that given in Table 6, provided that the measurements are carried out in the same environment.

8.3 Test environment

8.3.1 General

The measurements shall be carried out in a qualified environment in accordance with ISO 11201, accuracy grade 2 (engineering method). For convenience, the measurements may be carried out in conjunction with those performed in accordance with Clause 7.

CAUTION — Installation conditions are not always identical between Clause 7 and Clause 8.

8.3.2 Meteorological conditions

The requirements of ISO 11201, accuracy grade 2 (engineering method), shall be followed.

The following conditions are recommended:

a) ambient pressure: 86 kPa to 106 kPa;

b) temperature: within the range defined by the manufacturer for the equipment, if a range is defined; if no range is defined by the manufacturer, the recommended range is 15 °C to 30 °C;

c) relative humidity: within the range defined by the manufacturer for the equipment, if a range is defined; for processing of paper and card media only, if no range is defined by the manufacturer, the recommended range is 40 % to 70 %.

In addition, for equipment whose sound pressure level varies with temperature, the room temperature during the measurement shall be 23 °C ± 2 °C.

For equipment whose noise emissions vary with altitude in a prescribed manner (e.g. by varying the speeds of air-moving devices), the altitude of the test room shall either be less than or equal to 500 m or the equipment shall be tested under conditions simulating its operation at an altitude less than or equal to 500 m.

NOTE This variation of speed of air-moving devices does not refer to the changing speed that is already accounted for in the correction for ambient pressure described in the Note to 8.8.1.

8.4 Instrumentation

Instrumentation shall meet the requirements of ISO 11201, accuracy grade 2 (engineering method) and the additional requirements of 7.4.

8.5 Installation and operation of equipment

Equipment shall be installed and operated in accordance with the requirements of Clause 5, except for hand-held and table-top equipment.

Hand-held equipment shall be installed so that the equipment is flat on a standard test table, with the front edge of the device aligned with the front edge of the table. Hand-held equipment may be optionally isolated from the surface by a small number of elastomeric feet, approximately 12 mm high.

Table-top equipment shall be installed centred on a standard test table, unless otherwise specified in Annex C. Any table-top equipment combination which includes a keyboard shall be installed such that the smallest rectangle in the plane of the table and encompassing the keyboard and other units is centred on the top of the standard test table or as specified in Annex C. Any table-top equipment combination which normally is operated with a detachable keyboard but which is tested without the keyboard shall be centred on the test table as in the preceding sentence and as if the keyboard were present, unless otherwise specified in Annex C.

For optional measurement of sub-assemblies intended for use in table-top products, install the sub-assembly in the centre of a standard test table, isolated from the surface by a small number of elastomeric feet, approximately 12 mm high. For optional measurement of sub-assemblies intended for use in other enclosures or racks, install the sub-assembly as specified in 5.1.7.

8.6 Microphone positions

NOTE These requirements are in accordance with, but more specific than, those of ISO 11201, accuracy grade 2 (engineering method).

8.6.1 At the operator position(s)

One or more operator positions shall be specified for equipment which requires operator attention while in the operating mode.

For equipment which is operated from a standing position, the microphone shall be located 1,50 m ± 0,03 m above the floor [see Figure 1 a), position P1].

For equipment which is operated from a seated position, the microphone shall be located 1,20 m ± 0,03 m above the floor [see Figure 1 b) or c), position P2 or P3].

The horizontal distance from the reference box shall be 0,25 m ± 0,03 m, unless this distance is not representative of the operator position; in the latter case the representative operator position shall be described and shall be used.

For desktop equipment which normally has a detachable keyboard and which is tested without the keyboard (e.g. a desktop personal computer or a video display unit that is tested without a keyboard), the distance from the front end of the reference box, for the purposes of determining the operator position, shall be 0,50 m ± 0,03 m [see Figure 1 d), position P4].

For optional measurement of sub-assemblies intended for use in equipment with a defined operator position, the above position shall be used for the sub-assembly measurement (i.e. 0,25 m ± 0,03 m if table-top equipment does not have a detachable keyboard, and 0,50 m ± 0,03 m otherwise from front of reference box, and 1,20 m above the reflecting plane).

During this measurement the operator should be absent, if possible, or move aside, so that he/she can still operate the equipment but does not significantly disturb the sound field around the microphone.

For hand-held equipment, the microphone shall be located 1,0 m ± 0,03 m above the floor, and the horizontal distance from the reference box shall be 0,125 m ± 0,01 m [see Figure 1 e), position P5].

NOTE If the sound pressure level at the operator position is measured on operator-attended equipment, then measurement of sound pressure level at a bystander position is not required.

8.6.2 At the bystander positions

For equipment which does not require operator attention while in the operating mode, an operator position need not be specified. In this case, at least four bystander positions shall be selected and specified.

The bystander positions shall be at a horizontal distance of 1,00 m ± 0,03 m from the sides of the reference box and at a vertical distance of 1,50 m ± 0,03 m above the floor. The four preferred bystander positions are centred horizontally at the front, rear, right, and left sides of the reference box. If the length of any side of the reference box exceeds 2,0 m, additional bystander positions at 1,0 m intervals should be used. For wall-mounted equipment or for equipment placed against the wall, the three preferred bystander positions are centred at the front, right, and left sides of the reference box.

For optional measurement of sub-assemblies intended for use in equipment which does not require operator attention while in the operating mode, install the sub-assembly in accordance with 5.1.7, define the reference box and apply the provisions of the preceding two paragraphs to define the bystander positions.

8.6.3 Microphone orientation

The microphones shall be oriented in such a way that the angle of sound incidence is the same as the angle for which the microphone has the most uniform frequency response. For most practical cases, the primary sound source is assumed to be either 30° or 45° below horizontal (see Figure 1).

8.7 Measurement of sound pressure levels

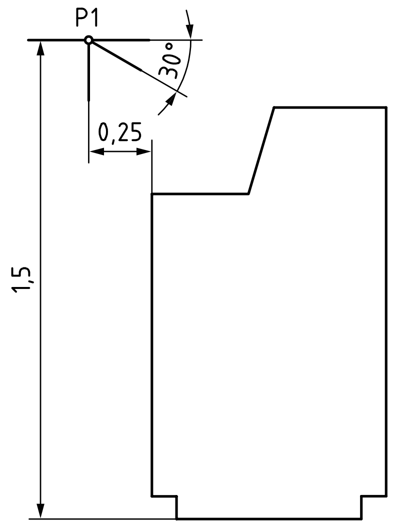
8.7.1 General

Measurements of the sound pressure level required by this clause shall be carried out at the microphone positions specified in 8.6 with A-weighting and/or for each frequency band within the frequency range of interest. Record:

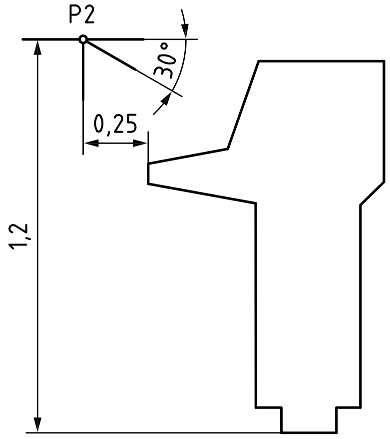
a) the A-weighted sound pressure levels and/or the one-third-octave-band sound pressure levels, for the specified modes of operation of the equipment;

b) the A-weighted sound pressure levels and/or the one-third-octave-band sound pressure levels of the background noise (including noise from support equipment).

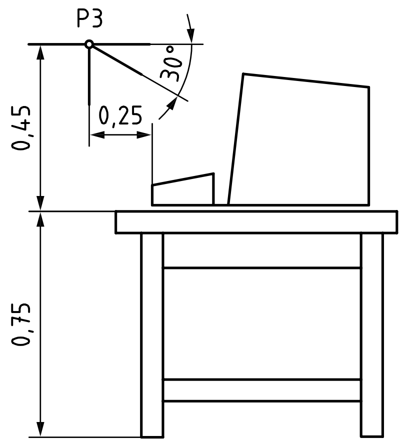
Dimensions in metres



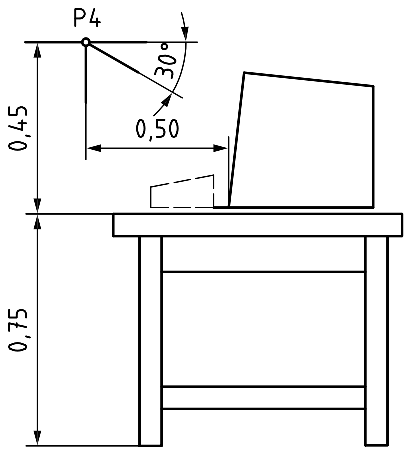
a) Standing operator



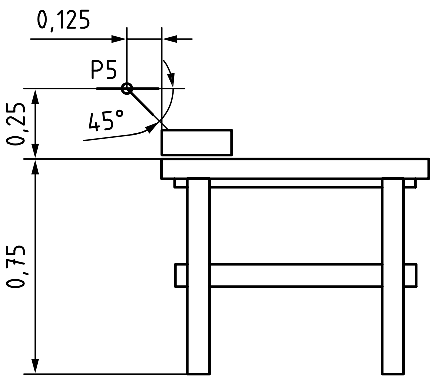
b) Seated operator for floor-standing equipment



c) Seated operator for table-top equipment (case 1: with keyboard)



d) Seated operator for table-top equipment (case 2: without keyboard)



e) Operator for hand-held equipment

Figure 1 — Examples of microphone positions for standing and seated operators

When using a sound level meter, the person reading the meter shall not disturb the sound field at the microphone.

Should spatial fluctuations occur, due to interferences or standing waves, it is recommended that the microphone be moved by approximately 0,1 m in a vertical plane around the nominal measurement position, and the average sound pressure level recorded.

In order to obtain the emission sound pressure level at a specified position, only background noise corrections, K_1 (K_{1A} for A-weighted sound pressure level), shall be applied to the measured sound pressure level, in accordance with the procedure of ISO 11201, accuracy grade 2 (engineering method) (see 8.7.3.); environmental corrections, K_2 (K_{2A} for A-weighted sound pressure level), shall not be applied.

NOTE 1 Determinations of whether the noise emission at the operator position or at the bystander positions contains prominent discrete tones and/or is impulsive in character are specified in Annex D and Annex E, respectively.

Measurements of the C-weighted peak sound pressure level, $L_{p\text{Cpeak}}$, shall be carried out at the microphone positions specified in 8.6 if any of the C-weighted peak sound pressure levels at the specified positions exceed 120 dB.

NOTE 2 Some regulations require declaration of C-weighted peak sound pressure levels greater than 130 dB. Contemporary ITT equipment is unlikely to emit C-weighted peak sound pressure levels, $L_{p\text{Cpeak}}$, greater than 120 dB, which is set in this International Standard as a conservative threshold above which measurement and reporting are required.

8.7.2 Measurement duration

The measurement duration shall be as specified in 7.7.2.

8.7.3 Corrections for background noise

The requirements of ISO 11201, accuracy grade 2 (engineering method), shall be followed.

NOTE When the levels of the background noise in the test room are extremely low and very controlled, it is possible that the environment satisfies the absolute and/or relative criteria for background noise in accordance with ISO 11201, accuracy grade 2 (engineering method).

8.8 Determination of emission sound pressure levels

8.8.1 Calculation of band emission sound pressure levels

The emission sound pressure level, under reference meteorological conditions, of the equipment in each one-third-octave band within the frequency range of interest (see 3.2.11) is obtained by using the procedure of ISO 11201, accuracy grade 2 (engineering method).

NOTE The procedures in ISO 11201 are used to determine the emission sound pressure level under reference meteorological conditions (ambient pressure 1,013 25 × 10^5 Pa, temperature 23 °C, relative humidity 50 %).

The emission sound pressure level in the kth octave band, $L_{p\text{oct},\,k}$, in decibels, if needed, shall be based on one-third-octave-band data, and calculated from:

$$L_{p\text{oct},\,k} = 10\lg \sum_{j=3k-2}^{3k} 10^{0{,}1 L_{p1/3,\,j}} \text{ dB} \tag{3}$$

where

- k is an identification number of an octave band within the frequency range of interest (see Table 2);
- $L_{p1/3,\,j}$ is the emission sound pressure level, in decibels, in the jth one-third-octave band (see Table 3);
- j is an identification number lying within the range of $(3k - 2)$ and $3k$, and which identifies the three one-third-octave bands which make up the kth octave band.

8.8.2 Calculation of A-weighted emission sound pressure levels from band levels

For the purposes of this International Standard, A-weighted emission sound pressure levels, L_{pA}, in decibels, can be derived either directly from A-weighted sound pressure levels, or by calculation from one-third-octave-band data using the A-weighting values for each band in accordance with the procedures of ISO 11201, accuracy grade 2 (engineering method).

NOTE The procedures in ISO 11201 are used to determine the emission sound pressure level under reference meteorological conditions (ambient pressure 1,013 25 × 10^5 Pa, temperature 23 °C, relative humidity 50 %).

In the latter case, the A-weighted emission sound pressure level, L_{pA}, in decibels, shall be based on the frequency range of interest, and calculated from:

$$L_{pA} = 10 \lg \sum_{j=1}^{21} 10^{0,1(L_{p1/3,\, j} + A_j)} \text{ dB} \qquad (4)$$

where

$L_{p1/3,\, j}$ is the emission sound pressure level, in decibels, in the jth one-third-octave band;

A_j is the A-weighting value corresponding to the jth one-third-octave band from Table 3;

j is an identification number of one-third-octave band within the frequency range of interest.

Some ITT equipment emits high-frequency noise in the 16 kHz octave band. Depending upon the nature of noise emissions, Table 4 shows how to handle each situation. For the purposes of Clause 8, “sound power level” or “level” in Table 4 shall be replaced by “emission sound pressure level”. The derived levels are not frequency weighted.

For the determination of A-weighted emission sound pressure levels from band levels, this International Standard does not extend the frequency range of interest.

For equipment which emits discrete tone(s) in the 16 kHz octave band, each frequency and level of the tone(s) that is (are) within 10 dB of the highest tone level in the band shall be determined in accordance with the procedures specified in ISO 9295 (see Table 4).

CAUTION — The 16 kHz octave-band contribution is not included in the determination of the A-weighted level.

8.8.3 Calculation of the mean emission sound pressure level at the bystander positions

If bystander positions are defined, the mean A-weighted emission sound pressure level, L_{pA}, and the mean band emission sound pressure levels, L_p, in decibels (reference: 20 µPa), if required, at the bystander positions defined in 8.6.2, shall be calculated as specified in Equation (5):

$$L_p = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L_{pi}} \right] \text{dB} \qquad (5)$$

where

L_{pi} is the band emission sound pressure level, in decibels (reference: 20 µPa), resulting from measurement at the ith bystander position;

N is the number of bystander positions.

For the A-weighted emission sound pressure level, the symbols L_p and L_{pi} are replaced by L_{pA} and L_{pAi}.

9 Information to be recorded and reported

9.1 Information to be recorded

9.1.1 General

The information specified in 9.1.2 to 9.1.5 shall be recorded, when applicable. In addition, any deviation from any requirement in this noise test code or from the basic noise emission standards upon which it is based shall be recorded together with the technical justification for such deviation.

All requirements for recording and reporting specified in the basic noise emission standards are also requirements of this International Standard. That is, the requirements below are necessary but not sufficient.

9.1.2 Equipment under test

The following information shall be recorded:

a) a description of the equipment under test (including main dimensions; name, model and serial number of each unit; name, model and serial number of noise-producing components and sub-assemblies in the equipment under test);

b) a complete description of the idle and operating modes, including operating speed, data medium used and the test programme in terms that are meaningful for the type of equipment being tested;

c) a complete description of the installation and mounting conditions;

d) the location of the equipment in the test environment;

e) the location and functions of an operator, if present;

f) the nominal power line frequency, in hertz (e.g. 50 Hz), and the measured power line voltage, in volts;

g) a sample of typical hardcopy output of the product being tested, which, when applicable, should be filed as part of the recorded data;

h) a statement as to whether the noise emission depends on room temperature, if known.

The following information is recommended for recording on tape or digitally.

For each operating mode, for the operator position (if defined), otherwise for the bystander position (if defined) with the highest A-weighted sound pressure level, a high-quality magnetic tape recording may be made, of at least 1 min duration, annotated by voice on the second track with the name of the product, the test mode, the microphone position, and the A-weighted sound pressure level of the signal. Dolby[2)] or other magnetic tape or digital noise reduction features shall not be used. This International Standard does not require that a calibration signal be recorded. The bias used in recording shall be noted on the cassette.

9.1.3 Acoustical environment

The following information shall be recorded.

a) If the sound power level is determined in accordance with Clause 6 (ISO 3741):

   1) a description of the test room, including dimensions, shape, surface treatment of the walls, ceiling and floor; a sketch showing location of source and room contents;

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2) Dolby is an example of a suitable product available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product.

2) a description of diffusers, or rotating vanes, if any;

3) qualification of reverberation test room in accordance with ISO 3741;

4) the air temperature, in degrees Celsius, relative humidity, as a percentage, and ambient pressure, in kilopascals.

b) If the sound power level is determined in accordance with Clause 7 (ISO 3744 or ISO 3745):

1) a description of the acoustical environment, if indoors, the size and acoustic characteristics of the room, including absorptive properties of the walls, ceiling and floor; a sketch showing the location of the equipment under test;

2) environmental correction, K_2, resulting from the acoustical qualification of the test environment in accordance with the relevant procedure of ISO 3744, unless the environment has been qualified in accordance with ISO 3745 — in the case of compliance with ISO 3745, this fact should be stated;

3) the air temperature, in degrees Celsius, relative humidity, as a percentage, and ambient pressure, in kilopascals.

c) For emission sound pressure levels at the operator and bystander positions in accordance with Clause 8 [ISO 11201, accuracy grade 2 (engineering method)]:

NOTE 1 The type of information below is the same as for sound power determination, just described, but the values can differ from those recorded for sound power. If the information recorded for sound power determination in accordance with the preceding paragraph is applicable here, it is sufficient to so note in the test file.

1) a description of the acoustical environment, if indoors, the size and acoustic characteristics of the room, including absorptive properties of the walls, ceiling and floor; a sketch showing the location of the equipment under test;

2) environmental correction, K_2, resulting from the acoustical qualification of the test environment in accordance with the relevant procedure of ISO 3744, unless the environment has been qualified in accordance with ISO 3745 — in the case of compliance with ISO 3745, this fact should be stated;

NOTE 2 Environmental correction, K_2, is not to be used to modify the measured values, but is included as part of the test record as an indication of the quality of the measurement.

3) the air temperature, in degrees Celsius, relative humidity, as a percentage, and ambient pressure, in kilopascals.

9.1.4 Instrumentation

The following information shall be recorded:

a) equipment used for the measurements, including name, type, serial number and manufacturer;

b) bandwidth of frequency analyser [including a digital fast Fourier transform (FFT) analyser, if used in Annex D];

c) frequency response of the instrumentation system;

d) method used for daily checking of the calibration of the microphones and other system components;

e) the date and place of any required periodic calibrations;

f) the test method used for determination of:

1) the mean time-averaged sound pressure level in accordance with ISO 3741 or the surface time-averaged sound pressure level in accordance with ISO 3744,

2) the mean value of the emission sound pressure level at the operator or bystander positions in accordance with ISO 11201;

g) the impulsive parameter, ΔL_{I}, in decibels, in accordance with Annex E, if measured.

9.1.5 Acoustical data

The following information shall be recorded.

a) If the sound power is determined in accordance with Clause 6 (ISO 3741):

1) location and orientation of the microphone traverse (path) or array (a sketch should be included if necessary);

2) the corrections, if any, in decibels, applied in each frequency band for the frequency response of the microphone, frequency response of the filter in the passband, background noise, etc.;

3) the values of the difference between the sound power and sound pressure levels produced by the reference sound source ($L_{W\mathrm{r}} - L_{p\mathrm{r}}$), in decibels, as a function of frequency;

4) the band sound pressure level readings, in decibels, to at least the nearest 0,1 dB (preferred), or 0,5 dB (required) for the calculations in accordance with ISO 3741;

5) the sound power levels in decibels (reference: 1 pW) in octave and/or one-third-octave bands, tabulated or plotted to the nearest 0,1 dB (preferred), or 0,5 dB (required);

6) the sound power level in decibels (reference: 1 pW), under reference meteorological conditions, in octave and/or one-third-octave bands, tabulated or plotted to the nearest 0,1 dB (preferred), or 0,5 dB (required);

7) the A-weighted sound power level in decibels (reference: 1 pW) to the nearest 0,1 dB (preferred), or 0,5 dB (required);

8) the A-weighted sound power level in decibels (reference: 1 pW), under reference meteorological conditions, to the nearest 0,1 dB (preferred), or 0,5 dB (required);

9) the date, time and place that the measurements were carried out, and the name of the person who carried out the measurements.

b) If the sound power level is determined in accordance with Clause 7 (ISO 3744):

1) the shape of the measurement surface, the measurement distance, the location and orientation of microphone positions (including both key microphone positions and additional ones, if required) or paths used plus, if traversing microphones were used, the maximum traversing speed along a path and microphone orientation;

2) the area, S, in square metres, of the measurement surface;

3) the corrections, if any, in decibels, applied to each frequency band for the frequency response of the microphone, and the frequency response of the filter in the passband;

4) the background noise correction, K_1 (A-weighted or in frequency bands), for the surface time-averaged sound pressure levels;

5) the background noise level measured at each point and the average background sound pressure levels;

6) the environmental corrections, K_2 (A-weighted or in frequency bands), and the method by which it was determined in accordance with one of the procedures of ISO 3744;

7) the A-weighted surface time-averaged sound pressure level and the band surface time-averaged sound pressure level, $\overline{L_p}$, for each frequency band of interest, rounded to at least the nearest 0,1 dB (preferred), or 0,5 dB (required);

8) the sound pressure levels, L_{pi} (A-weighted or in frequency bands), at each measuring point, i;

9) the A-weighted sound power level, L_{WA}, and the band sound power level, L_W, for each frequency band of interest, rounded to the nearest 0,1 dB (preferred), or 0,5 dB (required);

10) the A-weighted sound power level, L_{WA}, and the band sound power level, L_W, under reference meteorological conditions, for each frequency band of interest, rounded to the nearest 0,1 dB (preferred), or 0,5 dB (required);

11) the date, time, and place that the measurements were carried out, and the name of the person who carried out the measurements.

c) For emission sound pressure levels at the operator and bystander positions in accordance with Clause 8 [ISO 11201, accuracy grade 2 (engineering method)]:

1) the measurement positions and microphone orientations (preferably including a sketch);

2) if an operator position is defined in accordance with 8.6.1, the A-weighted emission sound pressure level, L_{pA}, the band emission sound pressure levels, if required, and the C-weighted peak emission sound pressure level, $L_{p\text{Cpeak}}$, if greater than 120 dB, measured at the operator position(s), for both the idle and operating modes, in decibels, rounded to the nearest 0,1 dB (preferred), or 0,5 dB (required);

3) if bystander positions are defined in accordance with 8.6.2, the A-weighted emission sound pressure levels at the bystander positions, the mean A-weighted emission sound pressure level, L_{pA}, and the mean band emission sound pressure levels, if required, calculated in accordance with 8.8.3, and the C-weighted peak emission sound pressure level, $L_{p\text{Cpeak}}$, if greater than 120 dB (see Note 2 to 8.7.1) at the bystander position with the highest A-weighted emission sound pressure level, for both the idle and operating modes, in decibels, rounded to the nearest 0,1 dB (preferred), or (0,5 dB required);

4) all emission sound pressure levels, in decibels, under reference meteorological conditions;

5) optionally, the frequency, in hertz, of any prominent discrete tones identified in accordance with the procedures of Annex D and the tone-to-noise ratio, ΔL_T, and/or prominence ratio, ΔL_P, as applicable, in decibels, associated with that prominent discrete tone;

6) optionally, the impulsive parameter, ΔL_I, in decibels, if $\Delta L_\text{I} > 3$ dB, in accordance with the procedure outlined in Annex E;

7) A-weighted background noise levels and background noise correction, K_{1A}, at each specified position, and as required, background noise levels and correction, K_1, in frequency bands;

8) the date, time, and place where the measurements were carried out, and the name of the person who carried out the measurements.

9.2 Test report

The test report shall contain at least the following information.

a) A statement of whether the sound power levels and emission sound pressure levels at operator or bystander positions have been obtained in full conformity with the procedures specified in this International Standard and ISO 3741, ISO 3744 or ISO 3745, as applicable, and ISO 11201. Any deviation from any requirement of these International Standards shall be reported, together with the technical justification for such deviation.

b) A statement that these sound power levels are expressed in decibels (reference: 1 pW) to the nearest 0,1 dB (preferred), or 0,5 dB (required) and that these emission sound pressure levels are expressed in decibels (reference: 20 µPa) rounded to the nearest 0,1 dB (preferred), or 0,5 dB (required).

c) A statement that "Measured values in this report are for use in planning or in determining declared values. They are not to be confused with the declared values".

d) The name(s) and model number(s) of the equipment under test.

e) The A-weighted sound power level, $L_{W\mathrm{A}}$, under reference meteorological conditions, in decibels, for the idle mode and the operating mode(s) (reference: 1 pW).

f) The sound power levels, L_W, under reference meteorological conditions, in decibels, in octave or one-third-octave bands, if required, for the idle mode and the operating mode(s); the bandwidth used shall be stated (reference: 1 pW).

g) If an operator position is defined in accordance with 8.6.1, the A-weighted emission sound pressure level, $L_{p\mathrm{A}}$, and if required, the band emission sound pressure levels, under reference meteorological conditions, in decibels (reference: 20 µPa), at the operator position(s) for the idle and operating modes.

h) If bystander positions are defined in accordance with 8.6.2, the mean A-weighted emission sound pressure level, $L_{p\mathrm{A}}$, and, if required, the mean band emission sound pressure levels in decibels (reference: 20 µPa), under reference meteorological conditions, at the positions specified in 8.6.2 around the equipment for the idle and operating modes.

i) A detailed description of operating and installation conditions of the equipment being tested with reference to a specific subclause of ECMA-74, if applicable.

NOTE 1 To avoid confusion between emission sound pressure level in decibels (reference: 20 µPa) and sound power levels in decibels (reference: 1 pW), sound power level can be expressed in bels, using the identity 1 bel = 10 decibels.

NOTE 2 For the determination of declared noise emission values for ITT equipment in accordance with ISO 9296, a positive number is added to the average measured value in decibels of the sound power level based on statistical considerations to account for both random measurement errors and production variations; the sum is divided by 10 and expressed in bels.

Information in a) to i) may be supplemented by one of the following statements, which describe the character of the noise as determined in accordance with Annexes D and E:

1) no prominent discrete tones, no impulsive noise;

2) impulsive noise, no prominent discrete tones;

3) prominent discrete tones, no impulsive noise;

4) prominent discrete tones and impulsive noise.

Items 1) to 4) shall be supplemented with a statement of the method used to identify prominent discrete tones.

NOTE 3 Some regulations require the reporting of the C-weighted peak emission sound pressure level if greater than 130 dB.

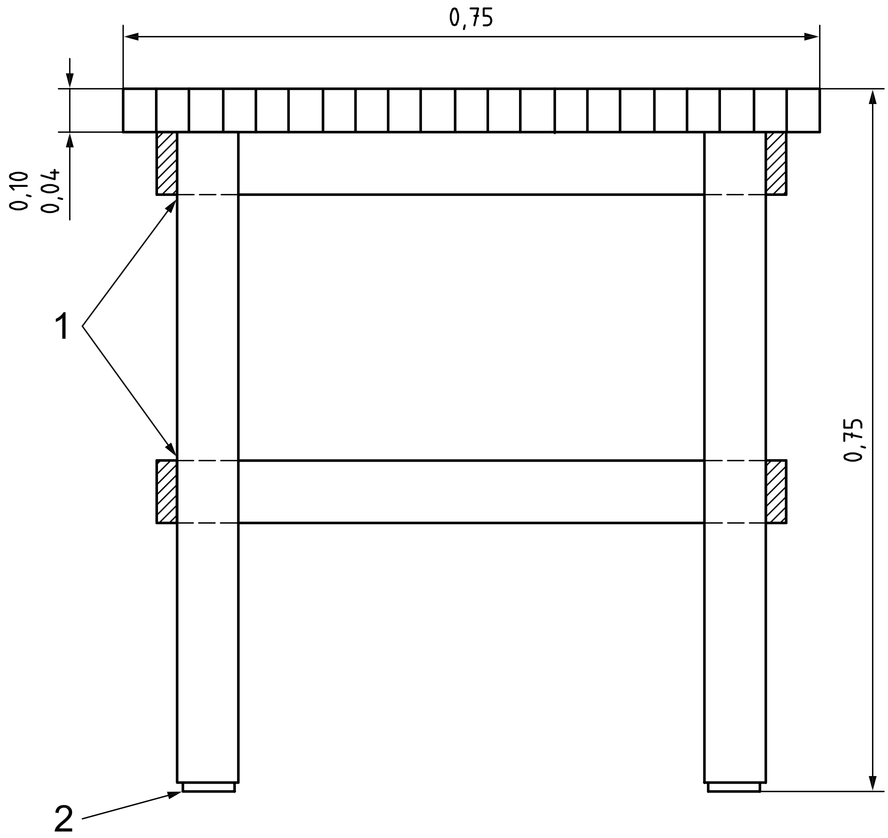
Annex A
(normative)

Test accessories

A.1 Standard test table

The design for the standard test table is shown in Figure A.1. The top of the table shall be of bonded laminated wood, 0,04 m to 0,10 m thick, having a minimum area of 0,5 m^2 and lateral dimensions between 0,70 m and 0,75 m. The height of the table shall be 0,75 m ± 0,03 m. The table may have a slot in its top plate to allow paper to be inserted for printers which feed the paper from underneath their bottom cover. A slot 0,015 m by 0,400 m in lateral dimensions has been found practical for most printer paper.

Dimensions in metres



Key

1 legs and braces: screwed and bonded

2 isolating pads

Figure A.1 — Standard test table

A.2 Typing robot

The typing robot shall be designed to operate a keyboard in the manner specified in this International Standard. The robot here described uses eight solenoids, each being individually adjustable to operate one of the selected keyboard keys.

The requirements for this robot are:

a) the noise of the robot shall meet the requirements for background noise of this International Standard;

b) the stroke of each solenoid plunger shall fully release the key in its upper position and push it completely down to its stop; a total stroke of 6 mm to 7 mm should be sufficient for most types of keyboards, including typewriters;

c) the electrical input signal shall be a rectangular pulse of 50 ms duration, and of adjustable amplitude;

d) the solenoid characteristics shall provide an increasing force during key-down motion, as shown in Figure A.2 — a suitable design is shown in Figure A.3;

e) the plunger mass shall be 20 g ± 1 g; its end shall be soft (e.g. closed-cell foam, 40 Shore A).

A complete operation of a single key includes the following three steps, which are shown in Figure A.4:

a) Home position

The plunger rests under its own weight with its soft end on the key.

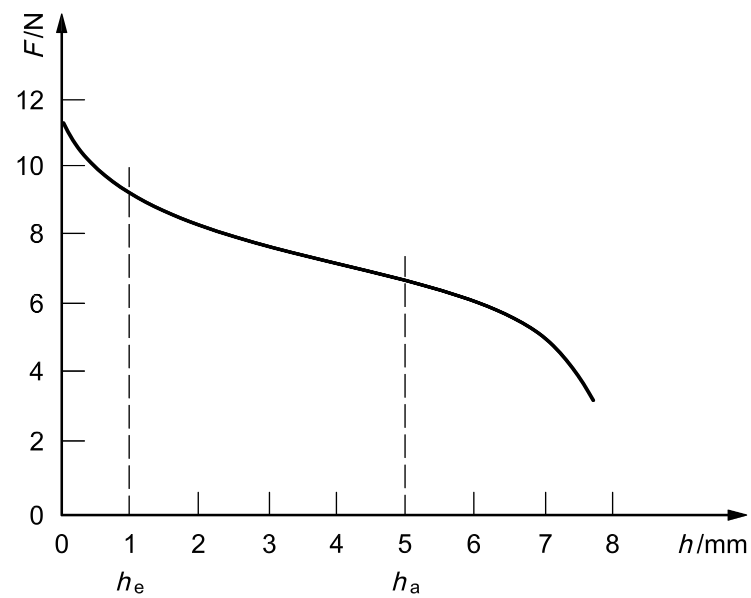
b) Key operation

When excited by the solenoid, the plunger pushes the key down until it has reached its stop position. The adjustment of the solenoid should give a plunger clearance of 1 mm; an appropriate mark at the upper plunger end facilitates this adjustment.

c) Key return

The plunger is returned only by the key spring. The plunger return stop shall be soft and allow a maximum overshoot of 0,5 mm; the plunger returns to its home position, resting on the key.

NOTE The specification is based on the design of the robot described in Reference [7].



Key

F magnetic force

h stroke height

h_a home position

h_e stop position

Figure A.2 — Solenoid characteristics for a plunger stroke of 4 mm

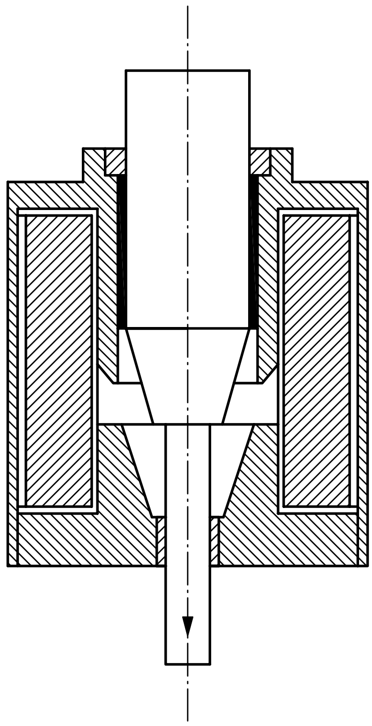
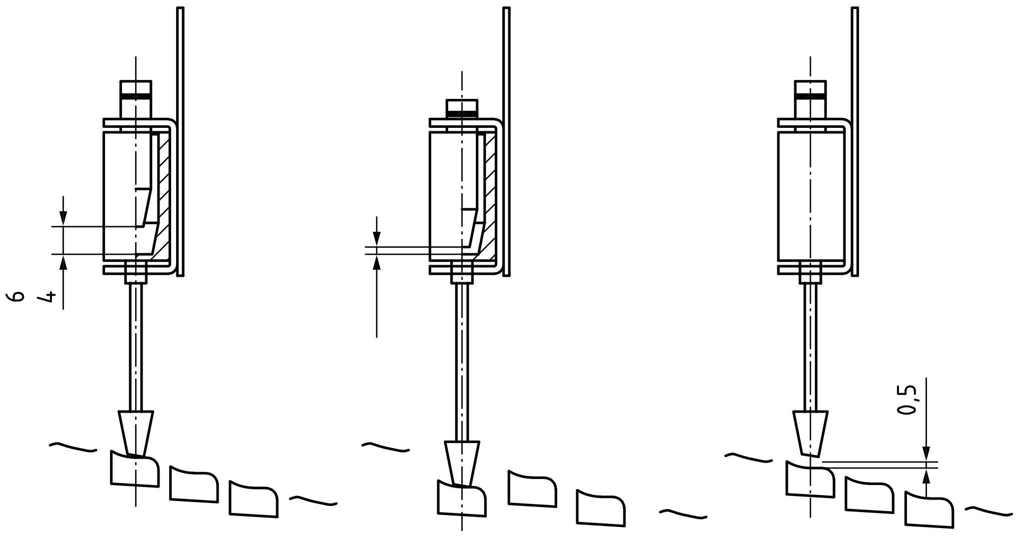


Figure A.3 — Solenoid cross-section

Dimensions in millimetres



a) **Step 1 — home position** b) **Step 2 — key operation** c) **Step 3 — key return**

Figure A.4 — Individual steps of the solenoid operation

Annex B
(normative)

Measurement surfaces

B.1 Hemispherical measurement surface

Refer to ISO 3744 for the requirements for microphone locations and geometry of the hemispherical measurement surface and microphone array, supplemented by the following additional conditions.

a) When using fixed microphone positions, the microphone positions given in ISO 3744 for sources emitting discrete tones shall be used for all sources. The co-ordinates for this array are reproduced in Table B.1.

b) When using the coaxial circular paths arrangement specified in ISO 3744, it is recommended that a minimum of 10 heights be used.

Other acceptable alternatives are described in the relevant annexes of ISO 3745.

Table B.1 — Co-ordinates of microphone positions for equipment emitting discrete tones

Position	x/r	y/r	z/r
1	0,16	−0,96	0,22
2	0,78	−0,60	0,20
3	0,78	0,55	0,31
4	0,16	0,90	0,41
5	−0,83	0,32	0,45
6	−0,83	−0,40	0,38
7	−0,26	−0,65	0,71
8	0,74	−0,07	0,67
9	−0,26	0,50	0,83
10	0,10	−0,10	0,99

For the purposes of this International Standard, for small equipment which emits very low level noise, a hemispherical measurement surface with a radius less than 1 m, but at least 0,5 m, may be used, provided that the reduced radius is greater than or equal to twice the characteristic source dimension (specified in ISO 3744). If the radius is reduced below 1 m, the lower end of the frequency range of interest becomes higher. To minimize the near-field effects, the 0,5 m radius would have a corresponding lower frequency limit of approximately 172 Hz (based on a requirement of one-quarter of the wavelength of sound at the lowest frequency of interest). Additional information is given in References [8][9][10].

B.2 Cylindrical measurement surface

B.2.1 General

Figure B.1 illustrates the cylindrical measurement surface, having microphones located along the side and top of the cylinder. The cylinder shall be centred around the reference box with the centre of the cylinder's base corresponding to the centre of the reference box base. The dimensions of the reference box, l_1, l_2, and l_3, and the reference distances to the cylinder, d_1, d_2, and d_3, are as shown. For the purposes of this annex, the dimensional labels shall be assigned so that $l_1 \geqslant l_2$.

B.2.2 Selection of size of cylindrical measurement surface

The microphone positions lie on the measurement surface, a hypothetical cylindrical surface enveloping the source and having a total area, S, equal to the sum of the area of the top circular surface, S_{top}, given by

$$S_{top} = \pi R^2 \qquad (B.1)$$

and the area of the side vertical surface, S_{side}, given by

$$S_{side} = 2\pi Rh \qquad (B.2)$$

where

R is the radius of the cylinder, given by

$$R = \frac{l_1}{2} + d_1 = \frac{l_2}{2} + d_2 \qquad (B.3)$$

h is the height of the cylinder, given by

$$h = l_3 + d_3 \qquad (B.4)$$

Due to the fact that the microphones are associated with unequal sub-areas, both d_3 and d_1 may be selected arbitrarily based on the size of the equipment under test or other considerations. It is recommended that both of these be set to the same value, preferably 1 m, but neither shall be less than 0,5 m. Furthermore, none of the distances d_1, d_2, or d_3 shall be greater than 1,5 times either of the others (e.g. this condition is met for d_1 and d_2 provided $d_1 \geqslant l_1 - l_2$). With d_3 and d_1 selected, h and R are defined and d_2 defaults to

$$d_2 = R - \frac{l_2}{2} \qquad (B.5)$$

In certain cases, such as for large machines where l_1 and l_2 are of the same magnitude, the side microphones can pass too close to the machine during their traverse even when the above constraints are met. In view of this, the radius, R, shall be large enough such that the side microphones remain more than 0,25 m from any corner of the reference box.

B.2.3 Selection of microphone positions on the cylindrical measurement surface

The microphones on the cylindrical measurement surface are associated with unequal sub-areas, as described in the following. It is strongly recommended that continuous paths (circular traverses) be used for the microphones. However, if fixed microphone positions are used to sample over the circular traverses, at least 12 equally spaced angular positions (i.e. at 30° spacing or less) shall be used. The traverses may be implemented by either rotating the microphones, keeping the source stationary, or rotating the source, keeping the microphones stationary.

The following requirements govern the number of side microphones, N_{side}, and the number of top microphones, N_{top}, and the associated sub-areas:

a) $N_{side} \geqslant h/h_0$ (where h_0 is set to 0,5 m to achieve adequate vertical sampling by limiting spacing to 0,5 m or less);

b) as a minimum, $N_{side} \geqslant 4$;

c) $N_{top} \geqslant R/R_0$ (where R_0 is set to 0,5 m to achieve adequate radial sampling by limiting spacing to 0,5 m or less);

d) as a minimum, $N_{top} \geqslant 2$.

The vertical side microphones are associated with equal sub-areas, S_i, where $S_i = S_{side}/N_{side}$, and positioned such that the ith microphone is at a height, from the floor, h_i, given by

$$h_i = \frac{(i - 1/2)h}{N_{side}} \tag{B.6}$$

The mean time-averaged sound pressure level over the side surface, $\overline{L_{p,\text{ side}}}$ is:

$$\overline{L_{p,\text{ side}}} = 10 \lg \left(\frac{1}{N_{side}} \sum_{i=1}^{N_{side}} 10^{0,1 L_{p,\text{ side},\, i}} \right) \text{dB} \tag{B.7}$$

where $L_{p,\text{ side},\, i}$ is the frequency-band time-averaged sound pressure level, in decibels, measured along the ith microphone traverse or at the ith microphone position on the side surface.

The top microphones are associated with unequal sub-areas, S_j, and are spaced equally along the radius of the top surface. The outer radius of the jth sub-area is $R_j = jR/N_{top}$, and the position of each top microphone is

$$r_j = R_{j-1} + \frac{R_j - R_{j-1}}{2} \tag{B.8}$$

for $j > 1$, and $r_1 = R_1/2$. The mean time-averaged sound pressure level over the top surface is:

$$\overline{L_{p,\text{ top}}} = 10 \lg \left[\frac{1}{S_{top}} \sum_{j=1}^{N_{top}} S_j 10^{0,1 L_{p,\text{ top},\, j}} \right] \text{dB} \tag{B.9}$$

where

$L_{p,\text{ top},\, j}$ is the frequency-band time-averaged sound pressure level, in decibels, measured along the jth microphone traverse or at the jth microphone position on the top surface;

$$S_j = \pi \left(R_j^2 - R_{j-1}^2 \right) \quad \text{for } j > 1 \tag{B.10A}$$

$$S_1 = \pi R_1^2 \tag{B.10B}$$

Figure B.2 illustrates an example of the cylindrical microphone array for five vertical side microphones and four top microphones.

B.2.4 Calculation of the mean time-averaged sound pressure level over the cylindrical measurement surface

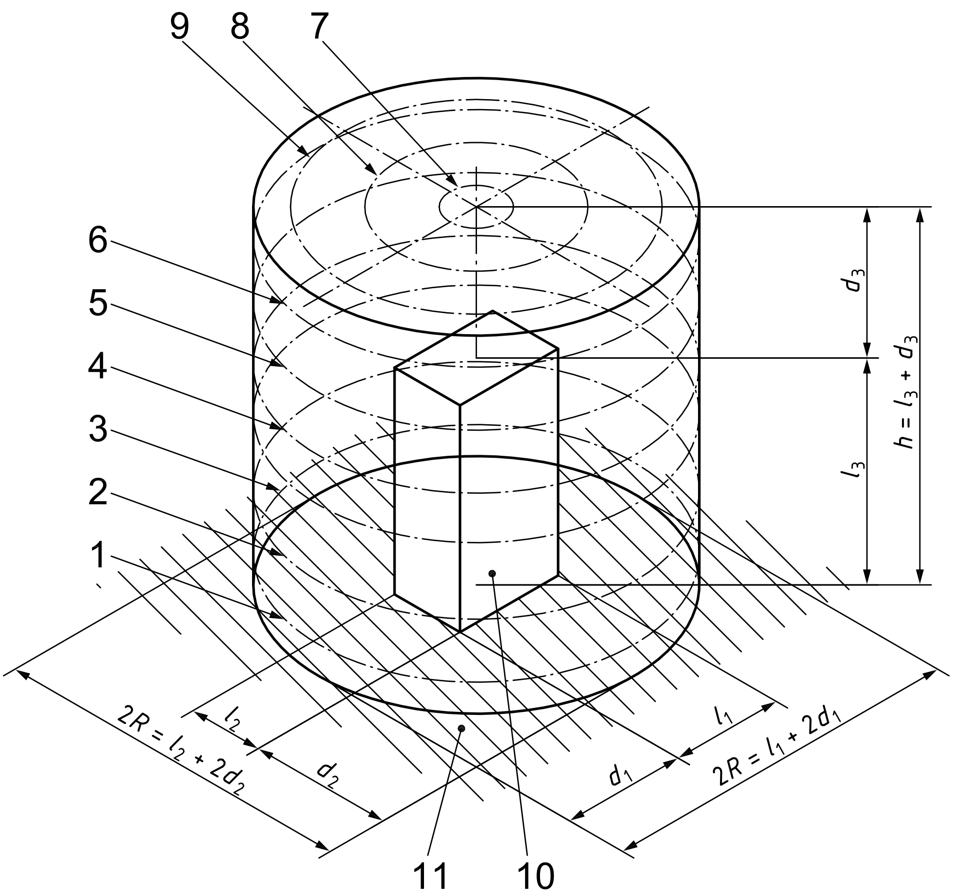
The mean time-averaged sound pressure level from the array of microphones over the cylindrical measurement surface, for the chosen mode of operation of the equipment under test, is given by:

$$\overline{L_p} = 10\lg\frac{1}{S}\left[S_{\text{top}}10^{0,1\overline{L_{p,\text{top}}}} + S_{\text{side}}10^{0,1\overline{L_{p,\text{side}}}}\right]\text{dB} \tag{B.11}$$

where $S = S_{\text{top}} + S_{\text{side}}$ and $\overline{L_{p,\text{top}}}$ and $\overline{L_{p,\text{side}}}$ are given by Equations (B.9) and (B.7), respectively.

NOTE 1 The quantity $\overline{L_p}$ above is equivalent to the quantity $\overline{L'_{p(\text{ST})}}$ in ISO 3744; i.e. the quantity that is subsequently corrected for background noise and the test environment before computing the surface time-averaged sound pressure level.

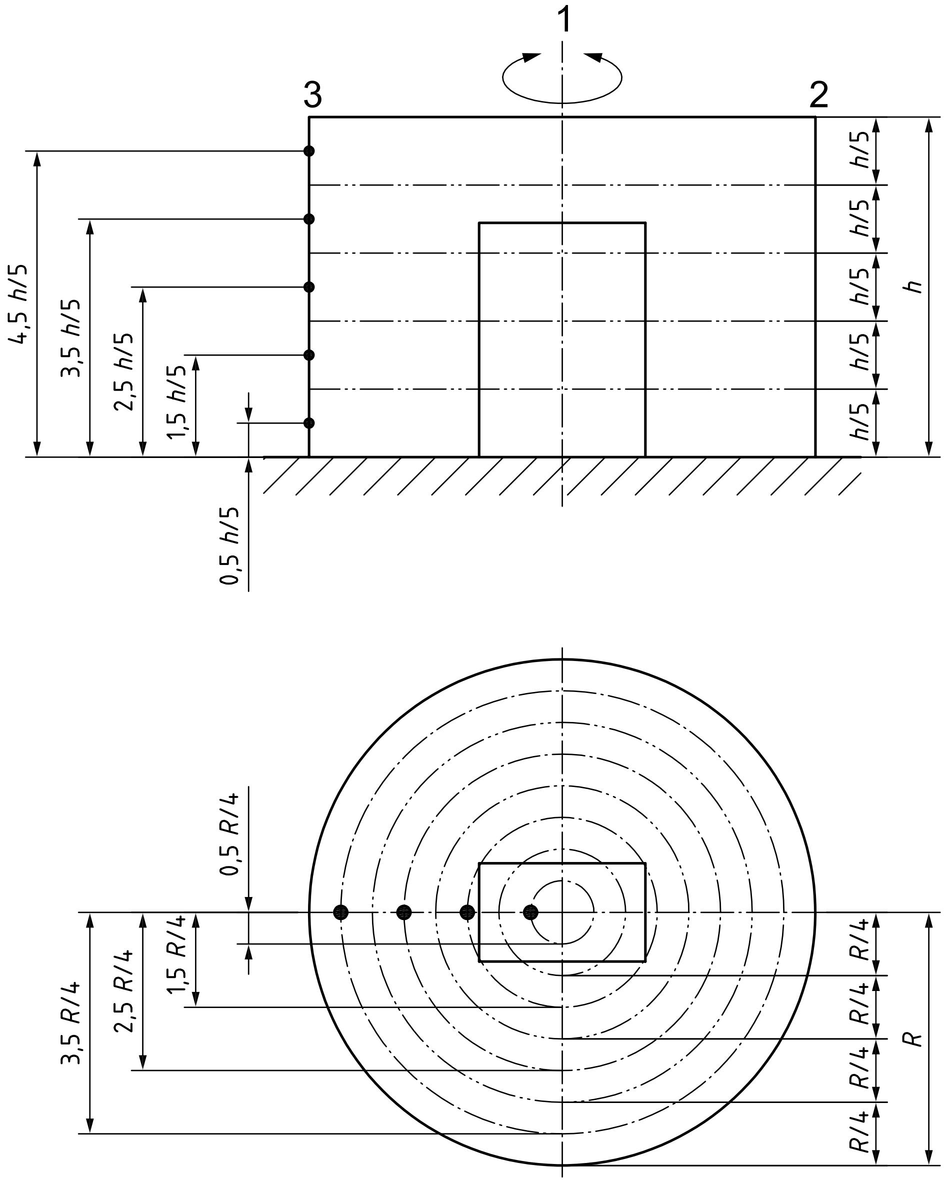
NOTE 2 Additional details about the cylindrical measurement surface can be found in References [11] [12] [13].



Key

1 to 6	side microphone paths
7 to 9	top microphone paths
10	reference box
11	reflecting plane
d_1, d_2, d_3	reference distances to the cylinder
h	cylinder height
l_1, l_2, l_3	reference box dimensions
R	cylinder radius

Figure B.1 — Example 1: illustration of the cylindrical measurement surface and cylindrical microphone array showing the arrangement using six side microphones and three top microphones



Key

1 axis of rotation of microphone traversing mechanism

2 dimensions of corresponding areas of cylinder

3 locations of microphone traverses

h cylinder height

R cylinder radius

Figure B.2 — Example 2: illustration of the cylindrical measurement surface and microphone array showing an arrangement using five side microphones and four top microphones

Annex C
(normative)

Installation and operating conditions for specific equipment categories

This annex specifies installation and operating conditions for many specific categories of equipment by reference to ECMA-74, which gives such details.

During testing of such equipment, the conditions shall be satisfied in order to comply with this International Standard. When possible, the conditions specified in ECMA-74 are considered to be typical of average end use. They are specified with a view to facilitating the operation of the equipment and enhancing the reliability of the acoustical measurements.

For the purposes of conformity with this International Standard, all the requirements specified in ECMA-74 mentioned above are also mandatory. However, any reference to ECMA-108[5] and ECMA-109[6] in ECMA-74 shall be replaced by reference to ISO 9295 and ISO 9296, respectively.

For categories of equipment not covered in ECMA-74, the actual test conditions used shall be described and justified in the test report. If test modes and product operation are in accordance with ECMA-74, both the date and edition of ECMA-74 shall be included in the test report.

Annex D
(informative)

Identification and evaluation of prominent discrete tones

D.1 Scope

This annex describes two procedures for determination of whether noise emissions contain prominent discrete tones: the tone-to-noise ratio method and the prominence ratio method.

Discrete tones occurring at any frequency within the one-third-octave bands having centre frequencies from 100 Hz to 10 000 Hz can be evaluated by the procedures in this annex (i.e. discrete tones between 89,1 Hz and 11 220 Hz inclusive).

All requirements of the test environment (8.3) apply. However, for the purposes of this annex, corrections neither for background noise, K_1, nor for test environment, K_2, apply.

NOTE 1 Since some ITT equipment emits discrete tones in the 16 kHz octave band, the tone-to-noise ratio or the prominence ratio can be computed for these tones in accordance with the procedures in this annex in an attempt to quantify their relative levels. However, the prominence criteria in either D.9.5 or D.10.6 cannot be applied, since there is no supporting psychoacoustical data on such high-frequency discrete tones.

Declaration of product noise emissions in accordance with ISO 9296 offers the option of stating whether there are prominent discrete tones in the noise emissions of a product, as determined by this annex. Other standards, or other test codes relating to products besides ITT equipment, can also refer to this annex for the declaration of prominent discrete tones. For the purposes of such declarations, either the tone-to-noise ratio method or the prominence ratio method can be used, unless otherwise specified in the standard or test code.

NOTE 2 The tone-to-noise ratio method can prove to be more accurate for multiple tones in adjacent critical bands, e.g. when strong harmonics exist. The prominence ratio method can be more effective for multiple tones within the same critical band, and is more readily automated to handle such cases.

D.2 Annex status

Although this annex is informative, it contains requirements for fulfilment when its procedures are referenced normatively by another standard or test code. These requirements are generally identified through the use of the prescriptive word “shall”.

D.3 Psychoacoustical background

A discrete tone which occurs together with broad-band noise is partially masked by that part of the noise contained in a relatively narrow frequency band, called the critical band, that is centred at the frequency of the discrete tone. Noise at frequencies outside the critical band does not contribute significantly to the masking effect. The width of a critical band is analytically expressed as a function of frequency (see D.8). In general, a discrete tone is just audible in the presence of noise when the sound pressure level of the tone is about 4 dB {2 dB to 6 dB, depending on frequency (Reference [14])} below the sound pressure level of the masking noise contained in the critical band centred around the tone. This is sometimes referred to as the threshold of detectability. For the purposes of this annex, a discrete tone is classified as *prominent* when using the tone-to-noise ratio method if the sound pressure level of the tone exceeds the sound pressure level of the masking noise in the critical band by 8 dB for tone frequencies of 1 000 Hz and higher, and by a greater amount for tones at lower frequencies. This corresponds, in general, to a discrete tone being prominent when it is more than 10 dB to 14 dB above the threshold of detectability. When using the prominence ratio method, a discrete tone is classified as *prominent* if the difference between the level of the critical band centred on the tone and the average level of the adjacent critical bands is equal to or greater than 9 dB for tone frequencies of 1 000 Hz and higher, and by a greater amount for tones at lower frequencies. Reference [15] provides the basis for these criterion values.

D.4 Microphone position(s)

If the equipment has an operator position, the measurements shall be performed at the operator position defined in 8.6.1. If there is more than one operator position, the measurements described in the following shall be performed at the operator position with the highest A-weighted sound pressure level.

If the equipment has no operator position, the measurements to determine the tone-to-noise ratios or prominence ratios shall be performed at the bystander position defined in 8.6.2 with the highest A-weighted sound pressure level and at all other bystander positions having A-weighted sound pressure levels within 0,5 dB of the highest.

When the methods of this annex are to be applied to sub-assemblies, the conditions in the next two paragraphs shall be used.

For sub-assemblies intended for use in equipment with a defined operator position, the measurement shall be performed at the operator position (8.6.1).

For sub-assemblies intended for use in equipment which does not require operator attention while in the operating mode, the measurement shall be performed at the bystander position (8.6.2) with the highest A-weighted sound pressure level and at all other bystander positions having A-weighted sound pressure levels within 0,5 dB of the highest. For small, low-noise sub-assemblies needing a hemispherical measurement surface with a radius equal to or less than 1 m (see 5.1.7 and B.1), the signal-to-noise ratio may not be sufficient at the bystander position(s). In such cases, the measurements may be performed at selected microphone positions from Table B.1 on the hemispherical measurement surface itself (even if the sound power determination is done without fixed positions). In such cases, the radius of the hemisphere, the co-ordinates of the microphone positions from Table B.1, and enough information to uniquely identify the equipment orientation relative to the microphone positions shall be reported.

If multiple microphone positions are used to perform the measurements described in this annex, the highest values computed for tone-to-noise ratio (D.9.4) and prominence ratio (D.10.5), and the corresponding microphone position for each, shall be reported.

D.5 Instrumentation

A digital fast Fourier transform (FFT) analyser capable of measuring the power spectral density of the microphone signal shall be used for the measurements described in this annex.

The analyser shall have r.m.s. averaging (linear averaging, rather than exponential averaging) capabilities, a Hanning time window function, an upper frequency limit high enough to allow computing the quantities required herein for the particular discrete tone under investigation, and an FFT resolution less than 1 % of the frequency of the tone.

NOTE For the tone-to-noise ratio procedure (see D.9), experience has shown that an FFT resolution of 1 % of the frequency of the discrete tone under investigation is occasionally insufficient to properly resolve the tone. Therefore, for application to the tone-to-noise ratio procedure, an FFT resolution of 0, 25 % or better is recommended (see Reference [16]).

The microphone output signal fed to an FFT analyser shall meet the requirements for sound level meters specified in accordance with IEC 61672-1, class 1. Because the procedures of this annex include the option of working directly in terms of sound pressure levels, the FFT analyser (or, alternatively, the software used for post-processing of the FFT data) should allow calibration directly in terms of sound pressure levels in decibels (reference: 20 µPa).

No frequency weighting function (e.g. A-weighting) shall be applied to the analyser input signal.

The FFT analysis shall use a sufficient number of averages to provide an analysis time satisfying the requirements of 8.7.2.

D.6 Initial screening tests

D.6.1 General

Before proceeding with either the tone-to-noise ratio method (D.9) or the prominence ratio method (D.10), one of the tests specified in D.6.2 and D.6.3 shall be conducted, as applicable.

D.6.2 Screening test for audibility of discrete tone(s) in noise generally well above the threshold of hearing

Discrete tones should only be classified as *prominent* if they are, in fact, *audible* in the noise emissions of the equipment under test. For the purposes of the screening test, it is assumed that the level of the noise being measured is well above the threshold of hearing. Discrete tones or tonal components that might be present in the noise emissions may not be audible due to masking by the noise itself or due to some other reason (e.g. the tones may be harmonics of a lower fundamental tone and not individually audible). Therefore, an initial aural examination of the noise emitted from the equipment under test shall be made at the specified microphone position, with the following cases applied.

a) If one or more discrete tones are audible, then the measurement procedures of this annex for either the tone-to-noise ratio or prominence ratio, or both, shall be carried out for each audible tone.

b) If no discrete tones are audible in the noise emissions, and there is a high degree of confidence in this conclusion, the procedures of this annex need not be carried out and a statement such as “no audible discrete tones” or “no prominent discrete tones” may be included in the test report.

c) If there is doubt as to whether a discrete tone is audible in the noise emissions (e.g. if the test engineer has a hearing loss or is not a trained or experienced listener), then other, more objective evidence should be sought. For this purpose, a preliminary FFT analysis shall be taken of the noise emissions at the specified microphone position(s). If the spectrum indicates the presence of potentially audible discrete tones or tonal components (i.e. if the spectrum shows one or more sharp spikes), then the measurement procedures of this annex for either the tone-to-noise ratio or prominence ratio, or both, shall be carried out for each potentially audible tone.

NOTE The aural examination in cases a) and b) can be bypassed, and the preliminary FFT analysis of case c) used directly as this screening test for the audibility of discrete tones.

Any discrete tone that is determined to be prominent in accordance with either the tone-to-noise ratio method or the prominence ratio method shall also meet the audibility requirements of D.9.8 or D.10.8, respectively.

D.6.3 Screening test for audibility of discrete tone(s) in noise near the threshold of hearing

If the noise emissions to be analysed for the presence of prominent discrete tones are extremely low in level such that either the noise itself or any discrete tone occurring in the noise is near or below the threshold of hearing, the following screening test shall be applied. An FFT spectrum of the noise emissions at the specified microphone position(s) shall be acquired in accordance with either D.9.1 or D.10.1, as applicable. The FFT spectrum shall be calibrated in terms of sound pressure level in decibels (reference: 20 µPa) following the manufacturer's instructions for the particular FFT analyser in use. The following cases apply.

a) If the sound pressure level, L_t (see D.9.2, and if applicable, D.9.6), of a discrete tone or tonal component to be evaluated for prominence falls below the lower threshold of hearing (LTH), $P_1(f)$, as defined in D.7.1 and calculated at the frequency of the tone by Equation (D.1), it is assumed to be *inaudible*, and the procedures of this annex need not be carried out. A statement such as “no audible discrete tones” or “no prominent discrete tones” may be included in the test report.

b) If the sound pressure level, L_t (see D.9.2, and if applicable, D.9.6), of a discrete tone or tonal component to be evaluated for prominence is less than or equal to $P_1(f) + 10$ dB, as calculated at the frequency of the tone by Equation (D.1), it is assumed to be not prominent, and the procedures of this annex need not be carried out. A statement such as "no audible discrete tones" or "no prominent discrete tones" may be included in the test report. Figure D.1 shows both the $P_1(f)$ and $P_1(f) + 10$ dB curves.

NOTE For most ITT equipment that contain cooling fans, even for small, relatively quiet products, the noise levels are well above the threshold of hearing. However, for certain components evaluated separately from their end-use product, such as small disk drives, the levels can, in fact, be below the threshold of hearing and the above screening procedure is applicable.

D.7 Discrete tones and noise emissions near the threshold of hearing

D.7.1 Lower threshold of hearing

Studies of normal hearing thresholds have shown that the measured thresholds vary about a mean level in approximately a normal distribution. The 50-percentile distribution values have been standardized in ISO 389-7[1], as a function of frequency and termed the "reference threshold of hearing".

For the purposes of this annex, the threshold of hearing that corresponds to the 1-percentile distribution (essentially, the "lower limit" of the hearing threshold) is more suitable. This may be termed the lower threshold of hearing (LTH). The sound pressure level at frequency f corresponding to this LTH is calculated from Equation (D.1).

$$P_1(f) = \left(a_1 f'^4 + a_2 f'^3 + a_3 f'^2 + a_4 f'^1 + a_5\right) \text{ dB} \tag{D.1}$$

where

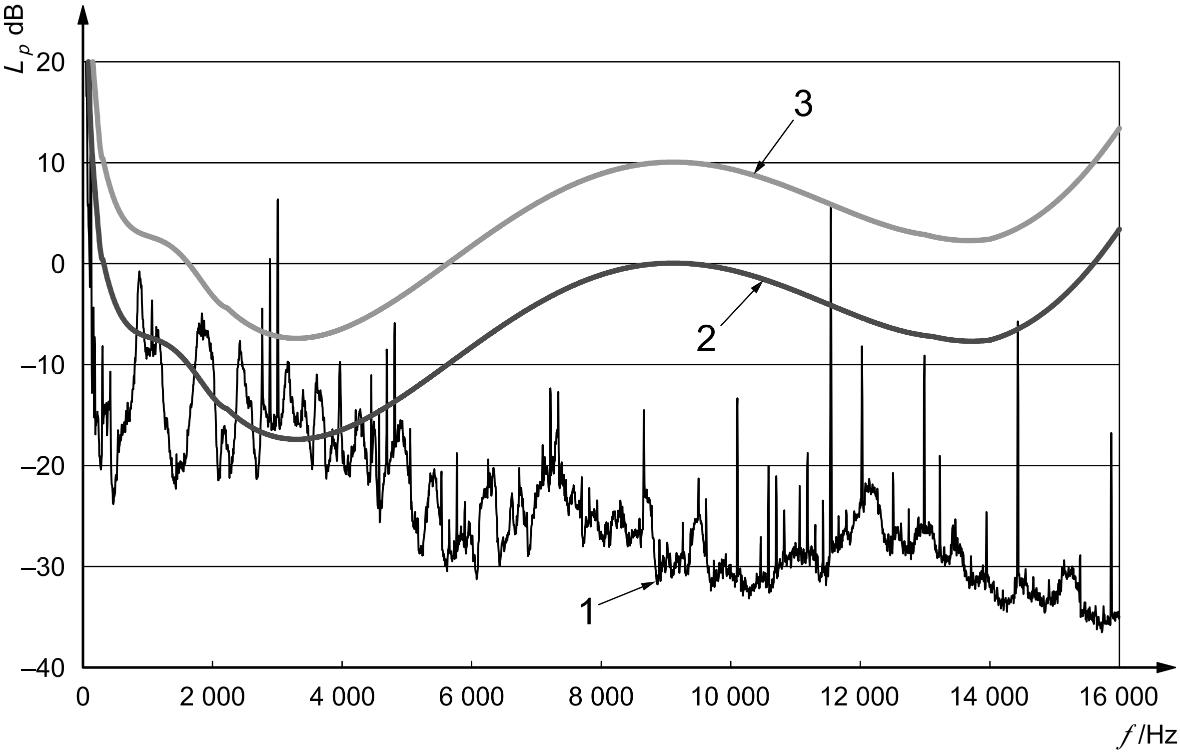
$f' = \dfrac{f - f_{\text{mean}}}{f_{\text{std}}}$ is the non-dimensional parameter calculated from the values in Table D.1;

a_1 to a_5 are the polynomial coefficients given in Table D.1.

Table D.1 — Parameters for calculation of $P_1(f)$

f	f_{mean} Hz	f_{std} Hz	a_1	a_2	a_3	a_4	a_5
$20 \leqslant f < 305$	167,5	87,321 2	1,415 532	–2,451 068	1,498 869	–6,983 224	8,621 226
$305 \leqslant f < 2\,230$	1 157,5	488,582	0,397 994	–0,891 839	–0,815 138	–1,221 319	–7,600 754
$2\,230 \leqslant f < 14\,000$	7 250,0	3 033,25	1,584 978	–2,766 599	–6,906 192	10,138 553	–3,149 339
$14\,000 \leqslant f < 22\,050$	16 990,0	4 049,0	–5,775 593	–9,200 034	26,591 15	52,167 12	15,615 520 48

NOTE The sound pressure level $P_1(f)$ defined in Equation (D.1) represents the threshold of hearing that only 1 % of individuals having normal hearing would be expected to hear. Equation (D.1) represents a 4th order polynomial fit to data collected and tabulated in References [17][18] to estimate the LTH at a given frequency for the purposes of this annex. To improve the fit over a wide frequency range, four different polynomials are used to cover the range of frequencies between 20 Hz to 22 kHz (Reference [19]).



Key

1 FFT spectrum

2 LTH, $P_1(f)$

3 LTH, $P_1(f) + 10$ dB

f frequency

L_p sound pressure level (reference value: 20 µPa)

Figure D.1 — The lower threshold of hearing curve, $P_1(f)$ and the $P_1(f) + 10$ dB curves illustrated for the analysis of low-level discrete tones

D.7.2 Normalization of noise near threshold of hearing

For low-level sound, the sound pressure level of one or more data points in the FFT spectrum may fall below the LTH, as defined by Equation (D.1). If calculations are performed using the as-measured sound pressure levels, very high values of tone-to-noise ratio or prominence ratio can be obtained, which may not correspond to subjective impressions of the sound. If, however, the sound pressure level at each data point is adjusted to be equal to the value of the LTH, the total sound pressure level in each critical band can be overstated, leading to unrealistically low values of tone-to-noise ratio or prominence ratio. For such low-level sounds, a normalization of the FFT spectrum is required so that the masking noise level (for tone-to-noise ratio) or the total levels in the lower, middle, and upper critical bands (for prominence ratio) reflects the correct psychoacoustic value. The threshold of hearing based on one-third-octave bands of white or pink noise may be more appropriate for this normalization, rather than the LTH defined above, which is based on pure discrete tones. Such a normalization procedure is yet to be defined for the purposes of this annex.

D.8 Critical bandwidths

The width of the critical band Δf_c, centred at any frequency f_0, in hertz, can be calculated from Equation (D.2):

$$\Delta f_c = 25,0 + 75,0 \times \left[1,0 + 1,4 \times \left(\frac{f_0}{1\,000} \right)^2 \right]^{0,69} \qquad \text{(D.2)}$$

EXAMPLE Δf_c = 162,2 Hz for f_0 = 1 000 Hz and Δf_c = 117,3 Hz for f_0 = 500 Hz. See Reference [20].

For the purposes of this annex, the critical band is modelled as an ideal rectangular filter with centre frequency f_0, lower band-edge frequency f_1, and upper band-edge frequency f_2, where

$$f_2 - f_1 = \Delta f_c \qquad \text{(D.3)}$$

For $f_0 \leqslant 500$ Hz, the critical band approximates a constant-bandwidth filter, and the band-edge frequencies are computed as follows:

$$f_1 = f_0 - \frac{\Delta f_c}{2} \qquad \text{(D.4)}$$

and

$$f_2 = f_0 + \frac{\Delta f_c}{2} \qquad \text{(D.5)}$$

For 500 Hz $< f_0$, the critical band approximates a constant-percentage bandwidth filter, where

$$f_0 = \sqrt{f_1 \, f_2} \qquad \text{(D.6)}$$

and the band-edge frequencies, in hertz, are computed from Equations (D.3) and (D.6) as follows:

$$f_1 = -\frac{\Delta f_c}{2} + \frac{\sqrt{(\Delta f_c)^2 + 4 f_0^2}}{2} \qquad \text{(D.7)}$$

and

$$f_2 = f_0 + \frac{\Delta f_c}{2} \qquad \text{(D.8)}$$

NOTE Although Equation (D.2) for the width of the critical band is well-known and widely used, equations for the corresponding band-edge frequencies have not been formally derived. Given the behaviour of the critical band below and above 500 Hz, however, the assignment of the band-edge frequencies in accordance with Equations (D.7) and (D.8) seems to be logical. That is, for constant-bandwidth filters, the lower and upper band-edge frequencies are arithmetically related to the centre frequency, whereas for constant-percentage bandwidth filters, they are geometrically related.

D.9 Tone-to-noise ratio method

D.9.1 Measurement using FFT analyser

The operating procedures for the FFT analyser shall be followed to acquire the power spectral density (or sound pressure level) of the signal at the measurement position (see D.4), for the same mode(s) of operation and measurement conditions as used for the measurements in 8.7, employing the Hanning time window and r.m.s. averaging (linear averaging). No frequency weighting, such as A-weighting, shall be applied to the signal fed to the FFT analyser. The FFT analysis shall use a sufficient number of averages to provide an analysis time satisfying 8.7.2. Zoom analysis should be used, with the centre frequency of the zoom band corresponding, approximately, to the frequency of the discrete tone, and the width of the zoom band at least equal to, and preferably slightly greater than, the width of the critical band.

NOTE The power spectral density of a signal is usually calculated and displayed as a mean-square value per cycle of some quantity (e.g. a mean-square voltage per cycle, in volts squared per hertz, or a mean-square sound pressure per cycle, in pascals squared per hertz, versus frequency). For the purposes of determining the tone-to-noise ratio, ΔL_T, the units of the measured power spectral density are not important, and absolute calibration of the analyser to some reference value (such as 1 V or 20 µPa) is unnecessary. However, calibration of the instrument in units of pascals squared enables sound pressure level quantities to be readily obtained. The procedures in this annex assume this calibration and the text is written in terms of the "mean-square sound pressure", but to indicate that any quantity can be used, the symbol chosen is X.

D.9.2 Determination of discrete tone level

The mean-square sound pressure of the discrete tone, X_t, (or the sound pressure level of the discrete tone, L_t) is determined from the FFT spectrum measured as in D.9.1 by computing the mean-square sound pressure in the narrow band that "defines" the tone. The width of this frequency band, Δf_t, in hertz, is equal to the number of discrete data points ("the number of lines") included in the band, times the resolution bandwidth ("line spacing"). If the width of the frequency band selected for the purpose of computing X_t (or L_t) is greater than 15 % of the width of the critical band centred at the frequency of the discrete tone, the FFT analysis should be repeated with a smaller resolution bandwidth. A discrete tone bandwidth that remains greater than 15 % of the critical band through repeated FFT analyses with smaller resolution bandwidths may indicate that the tone is not steady in frequency, or some other phenomenon. In this case, the following procedure may proceed with the discrete tone bandwidth greater than 15 % of the critical band.

For the determination of the mean-square sound pressure of the discrete tone (or sound pressure level of the discrete tone) for multiple tones in a single critical band, see D.9.6.

CAUTION — Too narrow a bandwidth selected for Δf_t to delineate the discrete tone, especially when automated procedures are being used, may result in underestimation of the mean-square sound pressure of the tone (or the sound pressure level of the discrete tone) and overestimation of the mean-square sound pressure of the noise (see D.9.3). If the band is too wide, masking noise or secondary tones may be erroneously included with the tone computations and omitted from the noise computation.

D.9.3 Determination of masking noise level

For the purposes of this annex, the mean-square sound pressure of the masking noise, X_n, (or the sound pressure level of the masking noise, L_n) is taken as the value determined using the following two-step procedure.

The first step is to compute the total mean-square sound pressure (or the total sound pressure level) in the critical band. The width of the critical band is determined from Equation (D.2) with f_0 set equal to the frequency of the discrete tone under investigation, f_t, and with lower band-edge frequency f_1 and upper band-edge frequency f_2 as given in either Equation (D.4) and Equation (D.5), or Equation (D.7) and Equation (D.8).

From the FFT spectrum, the total mean-square sound pressure of the critical band, X_{tot} (or the total sound pressure level of the critical band, L_{tot}), is computed. Depending on the particular instrumentation used, this may be performed on the FFT analyser itself using band cursors, on an external computer using appropriate software, or by some other means. In any event, the width of the frequency band used to compute this value, Δf_{tot}, in hertz, is equal to the number of discrete FFT data points included in the band times the resolution bandwidth.

The second step is to calculate the masking noise mean-square sound pressure, X_n (or the sound pressure level of the masking noise, L_n), from one of the following equations:

$$X_n = (X_{tot} - X_t)\frac{\Delta f_c}{\Delta f_{tot} - \Delta f_t} \tag{D.9A}$$

or, when working with sound pressure levels, Equation (D.9A) becomes:

$$L_n = 10\lg\left(10^{0,1L_{tot}} - 10^{0,1L_t}\right)\text{ dB} + 10\lg\left(\frac{\Delta f_c}{\Delta f_{tot} - \Delta f_t}\right)\text{ dB} \qquad \text{(D.9B)}$$

For the determination of the mean-square sound pressure of the masking noise (or the sound pressure level of the masking noise) for multiple tones in a critical band, see D.9.6.

NOTE Equation (D.9A) [or Equation (D.9B)] accounts for both the fact that the FFT analyser bandwidth, Δf_{tot}, used to compute X_{tot} (or L_{tot}), may not be exactly equal to the critical bandwidth, Δf_c, and the fact that the calculated mean-square sound pressure ($X_{tot} - X_t$), [or the calculated sound pressure level, $10\lg\left(10^{0,1L_{tot}} - 10^{0,1L_t}\right)$ dB] does not include the noise contained in the narrow band, Δf_t.

D.9.4 Determination of the tone-to-noise ratio

The tone-to-noise ratio, ΔL_T, in decibels, is calculated from one of the following equations:

$$\Delta L_T = 10\lg\frac{X_t}{X_n}\text{ dB} \qquad \text{(D.10A)}$$

or, when working with sound pressure levels, Equation (D.10A) becomes:

$$\Delta L_T = L_t - L_n \qquad \text{(D.10B)}$$

For the determination of the tone-to-noise ratio for multiple tones in a critical band, see D.9.6.

D.9.5 Prominent discrete tone criteria for tone-to-noise ratio method

A discrete tone is classified as prominent in accordance with the tone-to-noise ratio method if one of the following conditions is met:

$$\Delta L_T \geqslant 8{,}0\text{ dB} + 8{,}33 \times \lg\left(\frac{1000}{f_t}\right)\text{ dB} \quad \text{for } 89{,}1\text{ Hz} \leqslant f_t < 1\,000\text{ Hz} \qquad \text{(D.11A)}$$

$$\Delta L_T \geqslant 8{,}0\text{ dB} \quad \text{for } f_t \geqslant 1\,000\text{ Hz} \qquad \text{(D.11B)}$$

and the discrete tone meets the audibility requirement of D.9.8. The criteria in Equation (D.11A) and Equation (D.11B) are illustrated graphically in Figure D.4.

D.9.6 Multiple tones in a critical band

The noise emitted by a machine may contain multiple tones, and several of these may fall within a single critical band. If one or more discrete tones are audible, the procedure is followed for each tone, with the following differences. The discrete tone with the highest amplitude in the critical band is identified as the primary tone, and its frequency is denoted as f_p. For the critical band centred on this primary tone, the tone with the second highest level is identified as the secondary tone and its frequency denoted as f_s.

If the secondary tone is sufficiently close in frequency to the primary tone, then the two are considered to be perceived as a single discrete tone and the prominence is determined by combining their mean-square sound pressures (or sound pressure levels). Two discrete tones may be considered sufficiently close or "proximate" if their spacing $\Delta f_{s,\,p} = |f_s - f_p|$ is less than the proximity spacing, Δf_{prox}, in hertz, defined by Equation (D.12):

$$\Delta f_{prox} = 21 \times 10^{1,2 \times [\,|\lg(f_p/212)|\,]^{1,8}} \quad \text{for } 89{,}1\text{ Hz} \leqslant f_p < 1\,000\text{ Hz} \qquad \text{(D.12)}$$

EXAMPLE $\Delta f_{prox} = 23{,}0$ Hz for $f_p = 150$ Hz; $\Delta f_{prox} = 63{,}8$ Hz for $f_p = 850$ Hz.

If the proximity criterion $\Delta f_{\text{s, p}} < \Delta f_{\text{prox}}$ is met, then the mean-square sound pressure of the secondary tone, $X_{\text{t, s}}$, is added to the mean-square sound pressure of the primary tone, $X_{\text{t, p}}$, when calculating the mean-square sound pressure of the tone, X_{t}, and subtracted from the total mean-square sound pressure, X_{tot}, before calculating the tone-to-noise ratio ΔL_{T}. When working with sound pressure levels for this case, the sound pressure level of the secondary tone, $L_{\text{t, s}}$, is combined on an energy basis with the sound pressure level of the primary tone, $L_{\text{t, p}}$, and subtracted on an energy basis from the total sound pressure level of the noise, L_{tot}. For discrete tone frequencies equal to or higher than 1 000 Hz, the proximity spacing, Δf_{prox}, exceeds half the width of the critical band, so the criterion is always met. See Reference [21]. Thus, in equation form:

$$X_{\text{t}} = X_{\text{t, p}} + X_{\text{t, s}} \qquad \text{(D.13A)}$$

or, when working with sound pressure levels, Equation (D.13A) becomes:

$$L_{\text{t}} = 10\,\text{lg}\left(10^{0{,}1L_{\text{t, p}}} + 10^{0{,}1L_{\text{t, s}}}\right)\text{ dB} \qquad \text{(D.13B)}$$

and

$$X_{\text{n}} = \left[X_{\text{tot}} - \left(X_{\text{t, p}} + X_{\text{t, s}}\right)\right] \times \left[\frac{\Delta f_{\text{c}}}{\Delta f_{\text{tot}} - \left(\Delta f_{\text{t, p}} + \Delta f_{\text{t, s}}\right)}\right] \qquad \text{(D.14A)}$$

or, when working with sound pressure levels, Equation (D.14A) becomes:

$$L_{\text{n}} = 10\,\text{lg}\left[10^{0{,}1L_{\text{tot}}} - \left(10^{0{,}1L_{\text{t, p}}} + 10^{0{,}1L_{\text{t, s}}}\right)\right]\text{ dB} + 10\,\text{lg}\frac{\Delta f_{\text{c}}}{\Delta f_{\text{tot}} - \left(\Delta f_{\text{t, p}} + \Delta f_{\text{t, s}}\right)}\text{ dB} \qquad \text{(D.14B)}$$

With the above values for X_{n} and X_{t}, (or L_{n} and L_{t}), Equation (D.10A) is used to compute the tone-to-noise ratio.

If the proximity criterion is not met, then the discrete tones are considered to be perceived as separate tones and are treated individually. In this case, the mean-square sound pressure of the secondary tone is still removed from the mean-square sound pressure of the masking noise (but otherwise ignored, i.e. not added to the mean-square value of the primary tone) before calculating the tone-to-noise ratio of the primary tone. In this case, Equation (D.14A) is again used for X_{n}, but Equation (D.13A) simply becomes $X_{\text{t}} = X_{\text{t, p}}$. These values of X_{n} and X_{t} are then used in Equation (D.10A) to compute the tone-to-noise ratio for the primary tone.

When working with sound pressure levels for this case, the sound pressure level of the secondary tone is still subtracted on an energy basis from the sound pressure level of the noise, but it is not added to the sound pressure level of the primary tone, before calculating the tone-to-noise ratio of the primary tone. In this case, Equation (D14.B) is again used for L_{n}, but Equation (D.13B) simply becomes $L_{\text{t}} = 10\text{lg}(10^{0{,}1L_{\text{t, p}}})$ dB. These values of L_{n} and L_{t} are then used in Equation (D.10B) to compute the tone-to-noise ratio for the primary tone.

When the proximity criterion is not met and it is desired to compute the tone-to-noise ratio for the secondary tone individually, then the above procedure may be repeated with the secondary tone considered as the primary tone. The critical band is then centred on this discrete tone, with all quantities being recomputed.

D.9.7 Complex tones containing harmonic components (tone-to-noise ratio method)

Although laboratory-generated discrete tones may be pure sinusoids, most of the discrete tones that occur in the noise emissions from real machinery and equipment are not. As such, the FFT spectrum generally shows a series of tonal components (called harmonics or partials) at integral multiples of some fundamental frequency. Usually, the fundamental is the strongest component, but this is not always the case. For the purposes of this annex, each tonal component in the harmonic series shall be screened for audibility in accordance with D.6 and, depending on the outcome, evaluated independently in accordance with the procedures of this annex. Alternatively, since presumably the presence of harmonics has already been determined from inspecting an FFT spectrum of the noise emissions, the procedures of this annex may be applied to each tonal component without the initial audibility screening. In this case, any tonal component that meets the prominence criteria of D.9.5 shall also meet the audibility requirements of D.9.8 before it can be classified as prominent.

D.9.8 Audibility requirements

A discrete tone should not be classified as *prominent* if it is not, in fact, *audible*. Therefore, for each discrete tone identified as prominent in D.9.5, an aural examination of the noise emitted from the equipment under test shall be made at the microphone position, or positions, used for the analysis. If the discrete tone is audible in the noise emissions, then it shall be reported as prominent, as determined. If the discrete tone is clearly not audible in the noise emissions, and there is a high degree of confidence in this conclusion, then it need not be reported as prominent. If there is any doubt as to whether a discrete tone is audible in the noise emissions (e.g. if the test engineer has a hearing loss or is not a trained or experienced listener), then the following listening test shall be conducted to help determine whether the tone is audible.

A sinusoidal signal corresponding to the frequency of the discrete tone in question shall be reproduced audibly, and compared by the listener to the noise from the product, noting whether a tone at the same frequency is audible in the product noise emissions. If the discrete tone is now audible in the noise emissions, then it shall be reported as prominent, as determined. If the discrete tone is not audible in the noise emissions even with the help of the comparison tone, then it need not be reported as prominent.

D.9.9 Example (tone-to-noise ratio method)

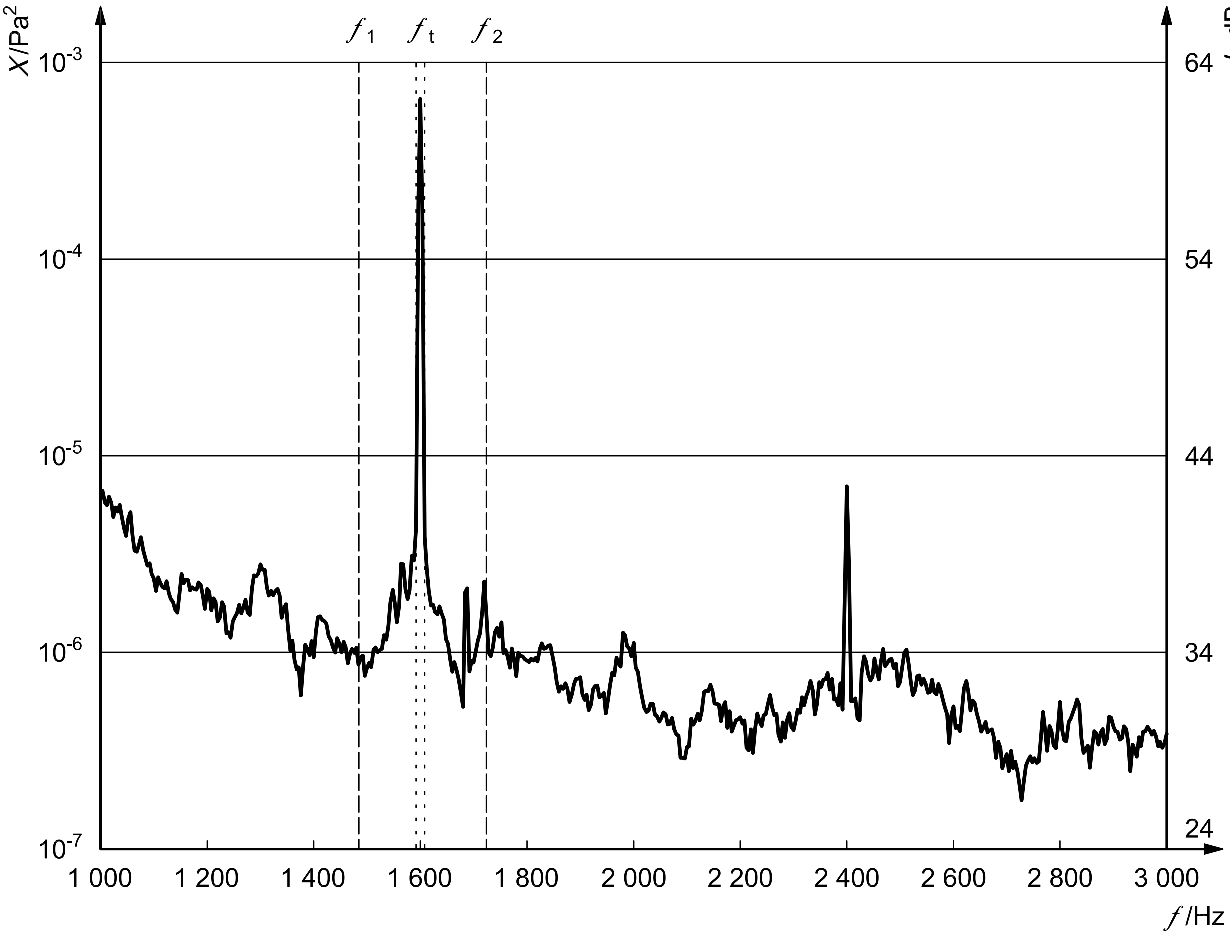
Figure D.2 shows how a single discrete tone in a critical band is analysed using the tone-to-noise ratio method. Figure D.3 shows how the tone-to-noise ratio method is used when multiple tones exist in a critical band.

D.10 Prominence ratio method

D.10.1 Measurement using FFT analyser

The operating procedures for the FFT analyser shall be followed to acquire the power spectral density (or sound pressure level) of the signal at the measurement position (see D.4), for the same mode(s) of operation and measurement conditions as used for the measurements in 8.7, employing the Hanning time window and r.m.s. averaging (linear averaging). No frequency weighting, such as A-weighting, shall be applied to the signal fed to the FFT analyser. The FFT analysis shall use a sufficient number of averages to provide an analysis time satisfying the requirements of 8.7.2. Zoom analysis should be used with the centre frequency of the zoom band corresponding, approximately, to the frequency of the discrete tone, and the width of the zoom band equal to about four times the width of the critical band.

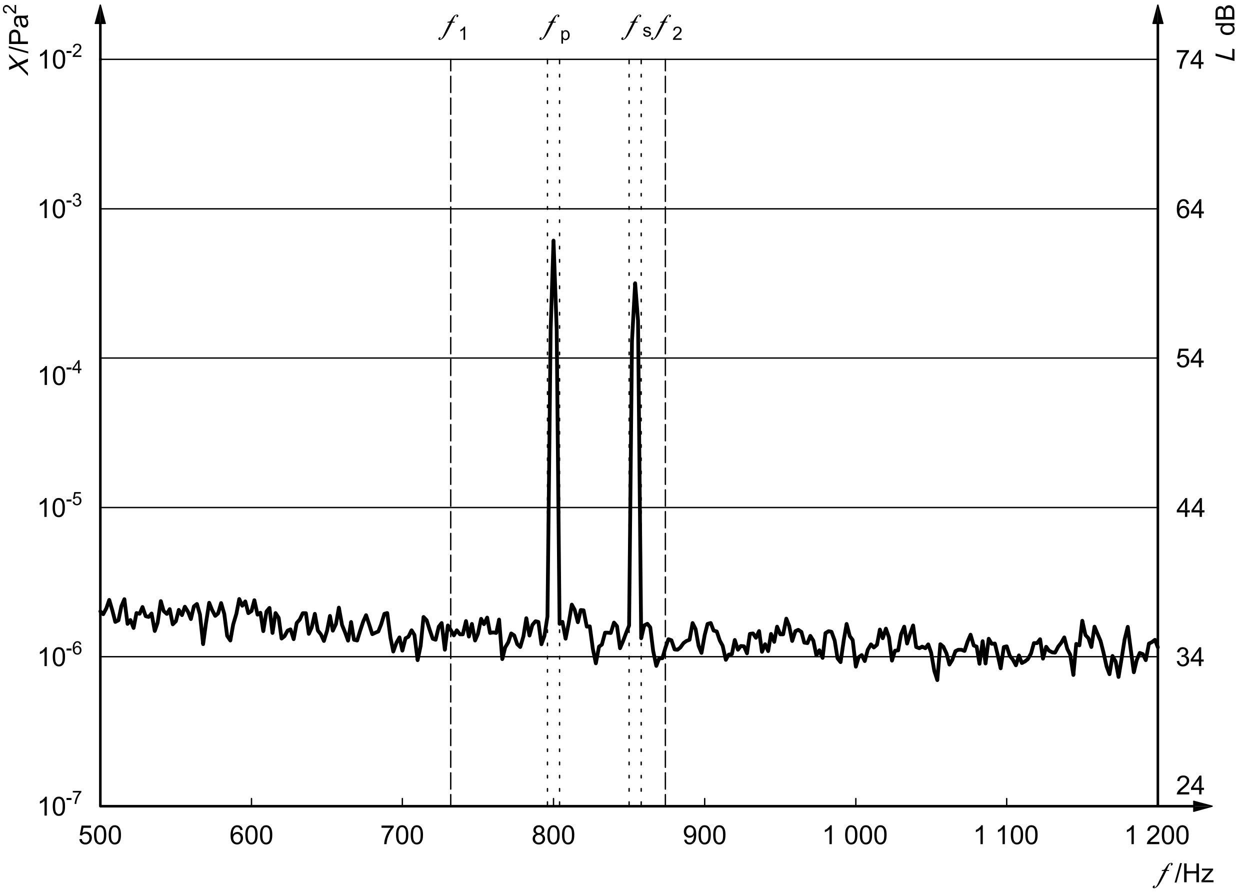
NOTE The power spectral density of a signal is usually calculated and displayed as a mean-square value per cycle of some quantity (e.g. a mean-square voltage per cycle, in volts squared per hertz, or a mean-square sound pressure per cycle, in pascals squared per hertz, versus frequency). For the purposes of determining the prominence ratio, ΔL_P, the units of the measured power spectral density are not important, and absolute calibration of the analyser to some reference value (such as 1 V or 20 μPa) is unnecessary. However, calibration of the instrument in units of pascals squared enables sound pressure level quantities to be readily obtained. The procedures in this annex assume this calibration and the text is written in terms of the “mean-square sound pressure”, but to indicate that any quantity may be used, the symbol chosen is X.



Key

X	mean-square sound pressure	
L	sound pressure level (reference value: 20 µPa)	
f	frequency (FFT resolution is 1,0 Hz)	
f_1	lower band-edge frequency	1 485 Hz
f_2	upper band-edge frequency	1 724 Hz
f_t	frequency of discrete tone under investigation	1 600 Hz
L_n	sound pressure level of masking noise	51,6 dB
L_t	sound pressure level of discrete tone under investigation	62,3 dB
L_{tot}	total sound pressure level of critical band	62,6 dB
X_n	mean-square sound pressure of masking noise	$5{,}76 \times 10^{-5}$ Pa²
X_t	mean-square sound pressure of discrete tone under investigation	$6{,}77 \times 10^{-4}$ Pa²
X_{tot}	total mean-square sound pressure of critical band	$7{,}31 \times 10^{-4}$ Pa²
Δf_c	critical bandwidth	239,45 Hz
Δf_t	width of frequency band	20 Hz
Δf_{tot}	total width of frequency band	240 Hz
		Prominent discrete tone
ΔL_T	tone-to-noise ratio	10,7 dB

Figure D.2 — Tone-to-noise ratio method applied to a single tone in a critical band



Key

X	mean-square sound pressure	
L	sound pressure level (reference value: 20 μPa)	
f	frequency (FFT resolution is 0,5 Hz)	
		Primary tone
f_1	lower band-edge frequency	732,0 Hz
f_2	upper band-edge frequency	874 Hz
f_p	frequency of primary tone	800 Hz
$X_{t,\,p}$	mean-square sound pressure of primary tone	$6{,}17 \times 10^{-4}$ Pa^2
Δf_c	critical bandwidth	141,62 Hz
Δf_{prox}	proximity spacing	59 Hz
$\Delta f_{s,\,p}$	secondary-to-primary spacing	54 Hz
$\Delta f_{t,\,p}$	frequency bandwidth of primary tone	10 Hz
		Proximate tones
X_n	mean-square sound pressure of masking noise	$6{,}92 \times 10^{-5}$ Pa^2
X_t	mean-square sound pressure of discrete tone	$1{,}04 \times 10^{-3}$ Pa^2
X_{tot}	total mean-square sound pressure of critical band	$1{,}10 \times 10^{-3}$ Pa^2
		Secondary tone
f_s	frequency of secondary tone	854 Hz
$X_{t,\,s}$	mean-square sound pressure of secondary tone	$4{,}19 \times 10^{-4}$ Pa^2
$\Delta f_{t,\,s}$	frequency bandwidth of secondary tone	10 Hz
L_n	sound pressure level of masking noise	52,4 dB
L_t	sound pressure level of discrete tone (reference value: 20 μPa)	64,1 dB
L_{tot}	total sound pressure level of critical band	64,4 dB
$L_{t,\,p}$	sound pressure level of primary tone	61,9 dB
$L_{t,\,s}$	sound pressure level of secondary tone	60,2 dB
		Prominent discrete tone
ΔL_T	tone-to-noise ratio	11,8 dB

Figure D.3 — Tone-to-noise ratio method applied to multiple tones in a critical band

D.10.2 Determination of the level of the middle critical band

The mean-square sound pressure of the middle critical band, X_M, is defined as the total mean-square sound pressure contained in the critical band centred on the discrete tone under investigation. (When working with sound pressure levels, this quantity becomes the sound pressure level of the middle critical band, L_M.) The width of the middle critical band, Δf_M, as well as the lower and upper band-edge frequencies, $f_{1,\,M}$ and $f_{2,\,M}$, are determined from the relationships in D.8 with f_0 set equal to the frequency of the discrete tone under investigation, f_t. The band-edge frequencies then become:

For $f_t \leqslant 500$ Hz:

$$f_{1,\,M} = f_t - \frac{\Delta f_M}{2} \tag{D.15}$$

and

$$f_{2,\,M} = f_t + \frac{\Delta f_M}{2} \tag{D.16}$$

For $f_t > 500$ Hz:

$$f_{1,\,M} = -\frac{\Delta f_M}{2} + \frac{\sqrt{(\Delta f_M)^2 + 4 f_t^{\,2}}}{2} \tag{D.17}$$

and

$$f_{2,\,M} = f_{1,\,M} + \Delta f_M \tag{D.18}$$

EXAMPLE $f_{1,\,M}$ = 922,2 Hz and $f_{2,\,M}$ = 1 084,4 Hz when f_t = 1 000 Hz.

The value of X_M (or L_M) is determined from the FFT spectrum by bracketing the data points lying between $f_{1,\,M}$ and $f_{2,\,M}$ and computing the mean-square sound pressure of the middle critical band (or the sound pressure level of the middle critical band). Depending on the particular instrumentation used, this may be performed on the FFT analyser itself using band cursors, on an external computer using appropriate software, or by some other means.

D.10.3 Determination of the level of the lower critical band

The mean-square sound pressure of the lower critical band, X_L, is defined as the total mean-square sound pressure contained in the critical band immediately below, and contiguous with, the middle critical band defined in D.10.2. (When working with sound pressure levels, this quantity becomes the sound pressure level of the lower critical band, L_L.) The relationships in D.8 govern this lower critical band, with centre frequency $f_{0,\,L}$, bandwidth Δf_L, and lower and upper band-edge frequencies $f_{1,\,L}$ and $f_{2,\,L}$, respectively. Since this lower critical band must be contiguous with the middle critical band, it follows that $f_{2,\,L} = f_{1,\,M}$. However, because $f_{0,\,L}$ is not known *a priori*, Equations (D.2) to (D.8) cannot be used directly to determine the value of $f_{1,\,L}$, and an iterative method of solution would ordinarily have to be used. For the purposes of this annex, the value of $f_{1,\,L}$ shall be computed from Equation (D.19), which has been derived from an iterative solution through the use of curve fitting.

$$f_{1,\,L} = C_{L,\,0} + C_{L,\,1}\, f_t + C_{L,\,2}\, f_t^2 \tag{D.19}$$

where

f_t	is the frequency of the discrete tone under investigation;
$C_{L,\,0}$, $C_{L,\,1}$, $C_{L,\,2}$	are constants given in Table D.2.

Table D.2 — Parameters for calculation of $f_{1,\,L}$

Frequency range Hz	$C_{L,\,0}$ Hz	$C_{L,\,1}$	$C_{L,\,2}$ Hz^{-1}
$89{,}1 \leqslant f_t \leqslant 171{,}4$	20,0	0,0	0,0
$171{,}4 < f_t \leqslant 1\,600$	–149,5	1,001	$-6{,}90 \times 10^{-5}$
$f_t > 1\,600$	6,8	0,806	$-8{,}20 \times 10^{-6}$

For discrete tone frequencies less than or equal to 171,4 Hz, the lower band-edge frequency for the lower critical band would compute to less than 20 Hz, the accepted lower limit of human hearing. For such cases, the lower band-edge frequency shall be set equal to 20 Hz (so that the band used for the determination of X_L extends from 20 Hz up to $f_{2,\,L}$). The width of this lower band, Δf_L, is now less than the width of the true critical band, and the determination of the prominence ratio takes this into account (see D.10.5).

The value of X_L (or L_L) is determined from the FFT spectrum by bracketing the data points lying between $f_{1,\,L}$ and $f_{2,\,L}$ and computing the mean-square sound pressure (or the sound pressure level) of the lower critical band. Depending on the particular instrumentation used, this may be performed on the FFT analyser itself using band cursors, on an external computer using appropriate software, or by some other means. Care should be taken to ensure that the lower critical band and the middle critical band do not overlap computationally, i.e. that the FFT data points closest to the common band edge are assigned uniquely to one band or the other, and not to both.

D.10.4 Determination of the level of the upper critical band

The mean-square sound pressure of the upper critical band, X_U, is defined as the total mean-square sound pressure contained in the critical band immediately above, and contiguous with, the middle critical band defined in D.10.2. (When working with sound pressure levels, this quantity becomes the sound pressure level of the upper critical band, L_U.) The relationships in D.8 govern this upper critical band, with centre frequency $f_{0,\,U}$, bandwidth Δf_U, and lower and upper band-edge frequencies $f_{1,\,U}$ and $f_{2,\,U}$, respectively. Since this upper critical band must be contiguous with the middle critical band, it follows that $f_{1,\,U} = f_{2,\,M}$. However, because $f_{0,\,U}$ is not known *a priori*, Equations (D.2) to (D.8) cannot be used directly to determine the value of $f_{2,\,U}$, and an iterative method of solution would ordinarily have to be used. For the purposes of this annex, the value of $f_{2,\,U}$ shall be computed from Equation (D.20), which has been derived from an iterative solution through the use of curve fitting.

$$f_{2,U} = C_{U,0} + C_{U,1}\, f_t + C_{U,2}\, f_t^2 \tag{D.20}$$

where

f_t is the frequency of the discrete tone under investigation;

$C_{U,\,0}$, $C_{U,\,1}$, $C_{U,\,2}$ are constants given in Table D.3.

Table D.3 — Parameters for calculation of $f_{2,\,U}$

Frequency range Hz	$C_{U,\,0}$ Hz	$C_{U,\,1}$	$C_{U,\,2}$ Hz^{-1}
$89{,}1 \leqslant f_t \leqslant 1\,600$	149,5	1,035	$7{,}70 \times 10^{-5}$
$f_t > 1\,600$	3,3	1,215	$2{,}16 \times 10^{-5}$

The value of X_U (or L_U) is determined from the FFT spectrum by bracketing the data points lying between $f_{1,\,U}$ and $f_{2,\,U}$ and computing the mean-square sound pressure (or the sound pressure level) of the upper critical band. Depending on the particular instrumentation used, this may be performed on the FFT analyser itself using band cursors, on an external computer using appropriate software, or by some other means. Care should be taken to ensure that the upper critical band and the middle critical band do not overlap computationally, i.e. that the FFT data point(s) closest to the common band edge is (are) assigned uniquely to one band or the other, and not to both.

D.10.5 Determination of prominence ratio

The prominence ratio, ΔL_P in decibels, is calculated as follows (for discrete tone frequencies greater than 171,4 Hz):

$$\Delta L_P = 10\lg\left[\frac{X_M}{(X_L + X_U)\times 0,5}\right]\text{dB} \qquad \text{for } f_t > 171,4\text{ Hz} \qquad \text{(D.21A)}$$

When working with sound pressure levels, Equation (D.21A) becomes:

$$\Delta L_P = 10\lg\left(10^{0,1L_M}\right)\text{dB} - 10\lg\left[\left(10^{0,1L_L} + 10^{0,1L_U}\right)\times 0,5\right]\text{dB} \qquad \text{for } f_t > 171,4\text{ Hz} \qquad \text{(D.21B)}$$

For discrete tone frequencies less than or equal to 171,4 Hz, the lower critical band becomes truncated (see D.10.3) so that its width is less than what would be calculated from Equation (D.2). Therefore, for the purposes of computing the prominence ratio for discrete tone frequencies less than or equal to 171,4 Hz, the level in the lower band is normalized to a bandwidth of 100 Hz (the width of a full critical band at these frequencies), so that the above equations are modified as follows.

$$\Delta L_P = 10\lg\left\{\frac{X_M}{\left[X_L\left(100/\Delta f_L\right) + X_U\right]\times 0,5}\right\}\text{dB} \qquad \text{for } f_t \leqslant 171,4\text{ Hz} \qquad \text{(D.22A)}$$

or, when working with sound pressure levels, Equation (D.22A) becomes:

$$\Delta L_P = 10\lg\left(10^{0,1L_M}\right)\text{dB} - 10\lg\left[\left(\frac{100}{\Delta f_L}\times 10^{0,1L_L} + 10^{0,1L_U}\right)\times 0,5\right]\text{dB} \qquad \text{for } f_t \leqslant 171,4\text{ Hz} \qquad \text{(D.22B)}$$

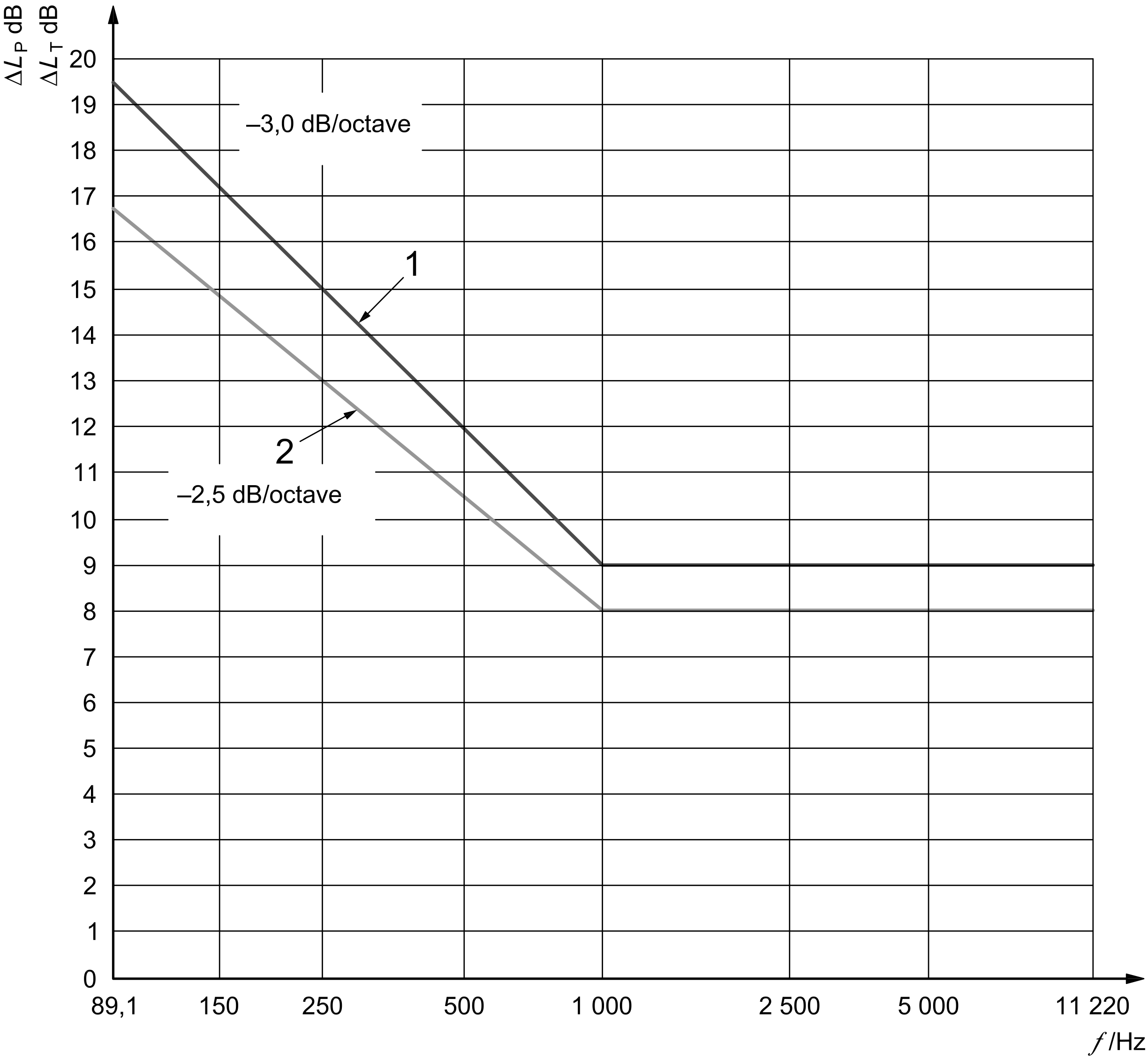
D.10.6 Prominent discrete tone criterion for prominence ratio method

A discrete tone is classified as prominent in accordance with the prominence ratio method if:

$$\Delta L_P \geqslant 9,0\text{ dB} + 10\lg\left(\frac{1000}{f_t}\right)\text{dB} \qquad \text{for } f_t \geqslant 1\,000\text{ Hz} \qquad \text{(D.23A)}$$

$$\Delta L_P \geqslant 9,0\text{ dB} \qquad \text{for } 89,1\text{ Hz} \leqslant f_t < 1\,000\text{ Hz} \qquad \text{(D.23B)}$$

and the discrete tone meets the audibility requirement of D.9.8. The criteria in Equations (D.23A) and (D.23B) are illustrated graphically in Figure D.4.



Key

1 prominence ratio criterion

2 tone-to-noise ratio criterion

f frequency

ΔL_P prominence ratio level

ΔL_T tone-to-noise ratio level

A discrete tone is prominent when either ΔL_T or ΔL_P is above the relevant criterion curve.

Figure D.4 — Criteria for prominence for both tone-to-noise ratio (D.9.5) and prominence ratio (D.10.6) as a function of frequency

D.10.7 Complex tones containing harmonic components (prominence ratio method)

Although laboratory-generated discrete tones may be pure sinusoids, most of the discrete tones that occur in the noise emissions from real machinery and equipment are not. As such, the FFT spectrum generally shows a series of tonal components (called harmonics, or partials) at integral multiples of some fundamental frequency. Usually, the fundamental is the strongest component, but this is not always the case. For the purposes of this annex, each tonal component in the harmonic series shall be screened for audibility in accordance with D.6.1 and, depending on the outcome, evaluated independently in accordance with the procedures of this annex. Alternatively, since presumably the presence of harmonics has already been determined from inspecting an FFT spectrum of the noise emissions, the procedures of this annex may be applied to each tonal component without the initial audibility screening. In this case, any tonal component that meets the prominence criteria of D.10.6 shall also meet the audibility requirements of D.10.8 before it can be classified as prominent.

D.10.8 Audibility requirements

A discrete tone should not be classified as prominent if it is not, in fact, audible. Therefore, for each discrete tone identified as prominent in D.10.6, an aural examination of the noise emitted from the equipment under test shall be made at the microphone position, or positions, used for the analysis (see D.4). If the discrete tone is audible in the noise emissions, then it shall be reported as prominent, as determined. If the discrete tone is clearly not audible in the noise emissions, and there is a high degree of confidence in this conclusion, then it need not be reported as prominent. If there is any doubt as to whether a discrete tone is audible in the noise emissions (e.g. if the test engineer has a hearing loss or is not a trained or experienced listener), then the following listening test shall be conducted to help determine whether the tone is audible.

A sinusoidal signal corresponding to the frequency of the discrete tone in question shall be reproduced audibly, and compared by the listener to the noise from the product, noting whether a tone at the same frequency is audible in the product noise emissions. If the discrete tone is now audible in the noise emissions, then it shall be reported as prominent, as determined. If the discrete tone is not audible in the noise emissions even with the help of the comparison tone, then it need not be reported as prominent.

D.10.9 Example (prominence ratio method)

The prominence ratio method is illustrated graphically in Figure D.5. The prominence ratio was calculated in accordance with D.10.5 and was found to be $\Delta L_P = 12{,}1$ dB for the 1 600 Hz discrete tone. Because the result is more than 9,0 dB, which is the prominence ratio criterion at 1 600 Hz, the discrete tone is classified as prominent.

D.11 Information to be recorded for prominent discrete tones

For each discrete tone that has been identified as prominent in accordance with this annex, the following information shall be recorded:

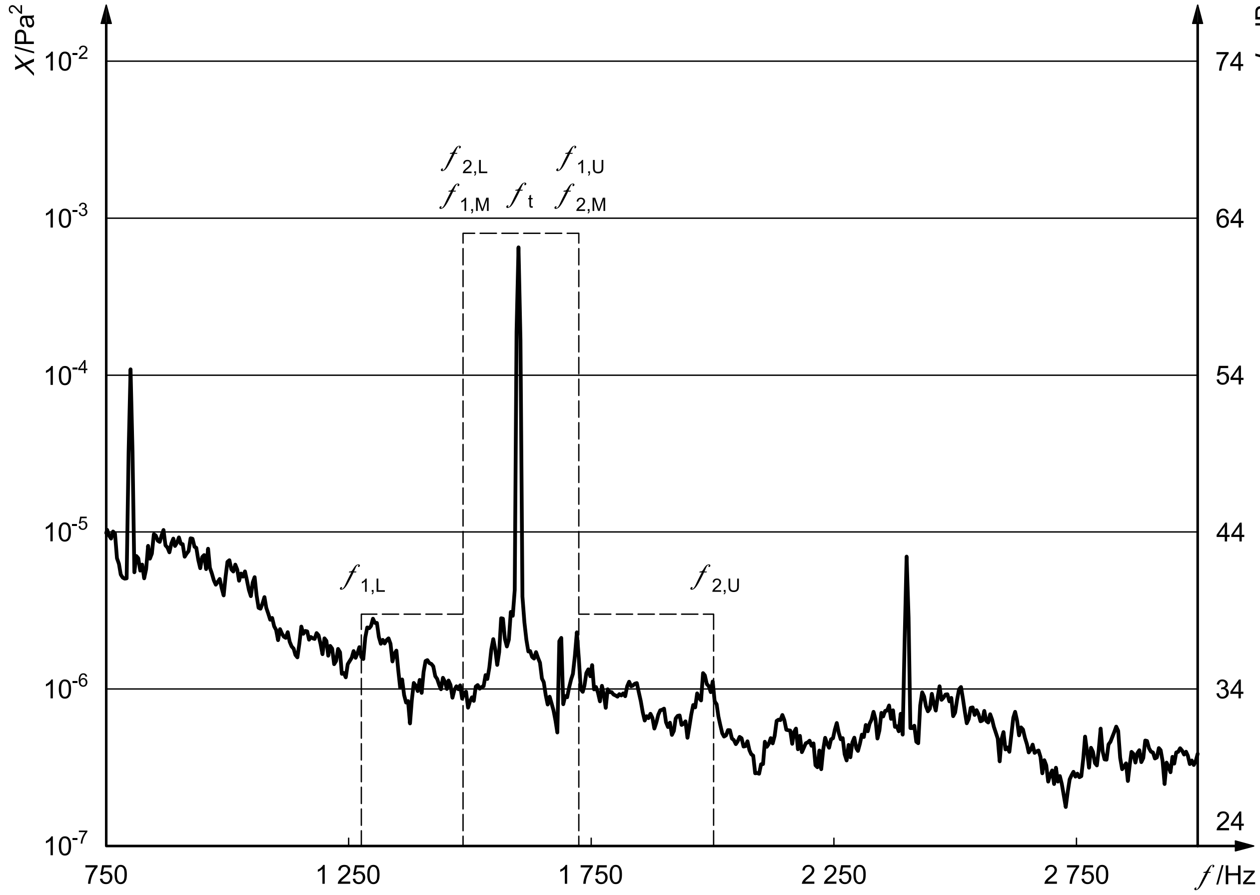
a) the frequency, f_t, in hertz, of the discrete tone;

b) details of the method used to evaluate the discrete tone (see D.9 tone-to-noise ratio method or D.10 prominence ratio method), together with a reference to this International Standard (ISO 7779:2010);

c) if the tone-to-noise ratio method was used, the discrete tone-to-noise ratio, ΔL_T, in decibels or if the prominence ratio procedure was used, the prominence ratio, ΔL_P, in decibels;

d) if the noise emissions under investigation include more than one identified prominent discrete tone, the frequency of each tone, and either ΔL_T or ΔL_P for each tone.

NOTE It can be useful to record the A-weighted sound pressure level of the prominent discrete tone.



Key

X	mean-square sound pressure	
L	sound pressure level (reference value: 20 µPa)	
f	frequency (FFT resolution is 1,0 Hz)	
		Middle critical band
f_t	frequency of discrete tone under investigation	1 600 Hz
$f_{1,\,M}$	lower band-edge frequency of the middle critical band	1 485 Hz
$f_{2,\,M}$	upper band-edge frequency of the middle critical band	1 724 Hz
L_M	sound pressure level of the middle critical band	62,6 dB
X_M	mean-square sound pressure of the middle critical band	$7{,}31 \times 10^{-4}$ Pa²
		Upper critical band
$f_{1,\,U}$	lower band-edge frequency of the upper critical band	1 724 Hz
$f_{2,\,U}$	upper band-edge frequency of the upper critical band	2 002 Hz
L_U	sound pressure level of the upper critical band	50,0 dB
X_U	mean-square sound pressure of the upper critical band	$4{,}03 \times 10^{-5}$ Pa²
		Lower critical band
$f_{1,\,L}$	lower band-edge frequency of the lower critical band	1 276 Hz
$f_{2,\,L}$	upper band-edge frequency of the lower critical band	1 485 Hz
L_L	sound pressure level of the lower critical band	51,0 dB
X_L	mean-square sound pressure of the lower critical band	$5{,}07 \times 10^{-5}$ Pa²
		Prominent discrete tone
ΔL_P	prominence ratio	12,1 dB

Figure D.5 — Illustration of the prominence ratio method for prominent discrete-tone identification

Annex E
(informative)

Detection of impulsive noise

E.1 General

This annex provides an objective test method for determination of whether the noise emissions are impulsive in character, i.e. are of short duration and relatively high amplitude.

This method is primarily applicable to operator-attended equipment with non-steady noise emissions.

NOTE This method is based on ISO 11201:1995[23], Annex A, paragraph 1, with modifications for consistency with other parts of this International Standard.

E.2 Annex status

Although this annex is informative, it contains requirements that must be met when its procedures are referenced normatively by another standard or test code. These requirements are generally identified through the use of the prescriptive word “shall”.

E.3 Instruments

The instruments shall meet the requirements of 8.4. The sound level meter shall be equipped with the time weighting I in accordance with IEC 61672-1:2002, Annex C.

For historical reasons, time-weighting I is used in this annex. For the applicability of time weighting I, IEC 61672-1:2002, C.1.1 states, “Various investigations have concluded that time-weighting I is not suitable for rating impulsive sounds with respect to their loudness. Time-weighting I is also not suitable for assessing the risk of hearing impairment, nor for determination of the ‘impulsiveness’ of a sound. Because of the possibility of obtaining misleading results, time-weighting I is not recommended for the purposes described above”.

E.4 Microphone position

If the equipment has an operator position, the measurements shall be performed at the operator position. If there is more than one operator position, the measurements described in the following shall be performed at the operator position with the highest A-weighted sound pressure level.

If the equipment has no operator position, the measurements shall be performed at the bystander position with the highest A-weighted sound pressure level and at all other bystander positions having A-weighted sound pressure levels within 0,5 dB of it to determine the impulsive parameter ΔL_{I} identified in the following.

For sub-assemblies for installation in table-top products, the sub-assembly shall be installed in the centre of a standard test table and isolated from the surface by a small number of elastomeric feet, approximately 12 mm high. For sub-assemblies for installation in other enclosures or racks, the sub-assembly shall be installed as in 5.1.7. For sub-assemblies for installation in equipment with a defined operator position, this operator position shall be used for the sub-assembly measurement; otherwise, the bystander position having the highest A-weighted sound pressure level shall be used.

E.5 Measurement procedure

Aural examination of the noise emitted by the equipment under test shall be made at the microphone position described earlier by a person with no hearing loss. If the noise emissions are perceived to include impulsive sound, the following test shall be performed.

The time-averaged A-weighted impulse sound pressure level, $L_{p\mathrm{AI}}$, and A-weighted sound pressure level, $L_{p\mathrm{A}}$, shall be measured for the same mode(s) of operation, measurement conditions, time duration and time averaging as used for the measurements in 8.7. The difference in decibels between the time-averaged A-weighted impulse sound pressure level, $L_{p\mathrm{AI}}$, and the A-weighted sound pressure level, $L_{p\mathrm{A}}$, shall be obtained. The difference ($L_{p\mathrm{AI}} - L_{p\mathrm{A}}$) is the impulsive parameter, ΔL_I. If $\Delta L_\mathrm{I} \geqslant 3$ dB the noise is considered to be impulsive.

The time-averaged A-weighted impulse sound pressure level, $L_{p\mathrm{AI}}$, is used only to determine whether the noise emissions are impulsive. The impulsive parameter, ΔL_I, is zero for steady, non-impulsive noises, and increases in value with increasing impulsiveness of the noise.

If the impulse sound level is recorded, the d.c. level output of the impulse sound level meter shall be used. The dynamic response of the level recorder shall be such that it responds to at least 90 % of full scale for a rectangular pulse, the duration of which is 0,2 s.

E.6 Test record for impulsive noise

If no impulsive noise was identified, record this fact. If impulsive noise is identified, record that fact and the value of the impulsive parameter, ΔL_I, in the test record.

Bibliography

[1] ISO 389-7, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions*

[2] ISO 12001:1996, *Acoustics — Noise emitted by machinery and equipment — Rules for the drafting and presentation of a noise test code*

[3] ISO 80000-8:2007, *Quantities and units — Part 8: Acoustics*

[4] ECMA TR/27, *Method for the prediction of installation noise levels.* Available (2010-07-14) at: http://www.ecma-international.org/publications/files/ECMA-TR/TR-027.pdf

[5] ECMA-108, *Measurement of high-frequency noise emitted by information technology and telecommunications equipment*. Available (2010-07-14) at: http://www.ecma-international.org/publications/files/ECMA-ST/Ecma-108.pdf

[6] ECMA-109, *Declared noise emission values of information technology and telecommunications equipment*. Available (2010-07-14) at: http://www.ecma-international.org/publications/files/ECMA-ST/Ecma-109.pdf

[7] FEIERFEIL, P.-J., SCHAFFERT, E. Geräuschemission von Geräten der Büro- und Informationstechnik [Noise emission by office and information technology equipment]. Wirtschaftsverlag NW, Verlag für neue Wissenschaft, Bremerhaven. (*Schriftenreihe der Bundesanstalt für Arbeitsschutz* [Federal Institute for Industrial Safety publications series], Report 481, Vol. 1.)

[8] DUNENS, E.K. Measurement of the sound power emitted by small sound sources with a reduced radius hemispherical surface. In: *Proceedings of Inter-Noise 2002* [CD-ROM], Dearborn, MI, 2002-08-19/21, N374. International Institute of Noise Control Engineering, Notre Dame, IN, 2002

[9] XU, Y., LIU, Y., OLIVER, D., PARKER, J. Evaluation of smaller hemispheric measurement surface for sound power measurement of very quiet hard disk drives. In: *Proceedings of Inter-Noise 2002* [CD-ROM], Dearborn, MI, 2002-08-19/21, N278. International Institute of Noise Control Engineering, Notre Dame, IN, 2002

[10] BAUGH, E., GREEN, K. Numerical and experimental investigations for hard disk drive sound power level measurements in hemianechoic rooms. In: *Proceedings of Inter-Noise 2002* [CD-ROM], Dearborn, MI, 2002-08-19/21, N422. International Institute of Noise Control Engineering, Notre Dame, IN, 2002

[11] NOBILE, M.A., SHAW, J.A. The cylindrical microphone array for measuring sound power levels of noise sources. In: *Proceedings of Inter-Noise 99: The 1999 International Congress on noise control engineering*, Fort Lauderdale, FL, 1999-12, pp. 1535-1540. Institute of Noise Control Engineering of the USA, Indianapolis, IN, 1999

[12] NOBILE, M.A., DONALD, B., SHAW, J.A. The cylindrical microphone array: A proposal for use in international standards for sound power level measurements. In: *Proceedings of Noise-Con 2000* [CD-ROM], Newport Beach, CA, 2000-12, 1PNSc2. Institute of Noise Control Engineering of the USA, Indianapolis, IN, 2000

[13] NOBILE, M.A., SHAW, J.A., BOYES, R.A. The cylindrical microphone array for the measurement of sound power level: Number and arrangement of microphones. In: *Proceedings of Inter-Noise 2002* [CD-ROM], Dearborn, MI, 2002-08-19/21, N318. International Institute of Noise Control Engineering, Notre Dame, IN, 2002

[14] ZWICKER, E., FASTL, H. 6.3 Critical-band level and excitation level. In: *Psychoacoustics: Facts and models*, pp. 165-173. Springer, Berlin, 1990. (*Springer series in information sciences*; 22)

[15] HELLWEG, R.D., NOBILE, M.A. Modification to procedures for determining prominent discrete tones. In: *Proceedings of Inter-Noise 2002* [CD-ROM], Dearborn, MI, 2002-08-19/21, N473. International Institute of Noise Control Engineering, Notre Dame, IN, 2002

[16] UPTON, R. Possibility for errors in tone-to-noise ratio calculation arising from insufficient FFT resolution. In: *Proceedings of the 22nd National Conference on Noise Control Engineering* (Noise-Con 2007) [CD-ROM], Reno, NV, 2007-10-22/24, NC07_110. Curran, Red Hook, NY, 2007

[17] KURAKATA, K., MIZUNAMI, T., MATSUSHITA, K., ASHIHARA, K. Statistical distribution of normal hearing thresholds under free-field listening conditions. *Acoust. Sci. Technol*. 2005, **26**, pp. 440-446

[18] KURAKATA, K., MIZUNAMI, T., MATSUSHITA, K. Percentiles of normal hearing-threshold distribution under free-field listening conditions in numerical form. *Acoust. Sci. Technol*. 2005, **26**, pp. 447-449

[19] ASHIHARA, K. Hearing thresholds for pure tones above 16 kHz. *J. Acoust. Soc. Am.* 2007, **122**, pp. EL52-EL57

[20] ZWICKER, E., TERHARDT, E. Analytical expression for critical-band rate and critical bandwidth as a function of frequency. *J. Acoust. Soc. Am*. 1980, **68**, pp. 1523-1525

[21] PLOMP, R. The ear as a frequency analyzer. *J. Acoust. Soc. Am*. 1964, **36**, pp. 1628-1636

[22] ISO/TR 25417, *Acoustics — Definitions of basic quantities and terms*

[23] ISO 11201:1995, *Acoustics — Noise emitted by machinery and equipment — Measurement of emission sound pressure levels at a work station and at other specified positions — Engineering method in an essentially free field over a reflecting plane*

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