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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Acoustics — Measurement of airborne noise emitted by computer and business equipment

Acoustique — Mesurage du bruit aérien émis par les équipements informatiques et de bureau

Reference number
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Foreword

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

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 7779 was prepared by Technical Committee ISO/TC 43, *Acoustics.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Acoustics — Measurement of airborne noise emitted by computer and business equipment

0 Introduction

This International Standard specifies methods for the measurement of airborne noise emitted by computer and business equipment. Hitherto, a wide variety of methods has 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 declaration of the noise emission level of computer and business equipment.

In order to ensure accuracy, validity and acceptability, this International Standard is based on the basic International Standards for determining the sound power level (ISO 3741, ISO 3742, ISO 3744 and ISO 3745) and the sound pressure level at the operator position(s) (ISO 6081). Furthermore, implementation is simplified by conformance to these International Standards.

In many cases, free-field conditions over a reflecting plane are obtained by semi-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 declaration purposes.

The method for measuring the sound pressure level at the operator or bystander positions (see ISO 6081) is specified in a separate clause, as this level is not considered to be primary declaration information. The measurements can, however, be carried out at the same time as 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. It is intended to extend annex C to other categories in a future revision.

1 Scope and field of application

1.1 Scope

This International Standard specifies procedures for measuring and reporting the noise emitted by computer and business equipment. It is based on the measurement procedures specified in ISO 3740, ISO 3741, ISO 3742, ISO 3744 and ISO 3745. 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.

The A-weighted sound power level is supplemented by the A-weighted sound pressure level measured at the operator position(s) or the bystander positions. This sound pressure level is not a measurement of total occupational noise exposure of workers (noise immission).

Two methods for determining the sound power levels are specified in this International Standard in order to avoid undue restriction on existing facilities and experience. The first method is based on reverberant room measurements (see ISO 3741 and ISO 3742); the second is based on measurements in an essentially free field over a reflecting plane (see ISO 3744 and ISO 3745). Either method may be used in accordance with this International Standard. They are comparable in accuracy and yield the same A-weighted sound power level within the tolerance range of the methods specified in this International Standard.

1.2 Field of application

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

The method specified in clause 5 provides a comparison procedure for determining sound power levels in a reverberation room. The method specified in clause 6 provides a direct procedure for determining sound power levels using essentially free-field conditions over a reflecting plane. The method specified in clause 7 provides a procedure for measuring noise at the operator or bystander positions. The procedures in this International Standard may be applied to equipment which radiates broad-band noise, narrow-band noise, noise which contains discrete-frequency components or impulsive noise.

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

The sound power levels and sound pressure levels are used for noise emission declaration and comparison purposes. They are not to be considered as installation noise levels; however they may be used for installation planning.

If sound power levels obtained are determined for several units of the same production series, the result can be used to determine a statistical value for that production series.

2 Conformance

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

a) The measurement procedure, the installation and the operating conditions specified by this International Standard are fully taken into account.

b) For the determination of sound power levels, the method specified in clause 5 or the method specified in clause 6 is used.

c) For the measurement of sound pressure level at the operator or bystander positions, the method specified in clause 7 is used.

3 References

ISO 266, *Acoustics — Preferred frequencies for measurements.*

ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards and for the preparation of noise test codes.*

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

ISO 3742, *Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete-frequency and narrow-band sources in reverberation rooms.*

ISO 3743, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for special reverberation test rooms.*

ISO 3744, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane.*

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

ISO 6081, *Acoustics — Noise emitted by machinery and equipment — Guidelines for the preparation of test codes of engineering grade requiring noise measurements at the operator's or bystander's position.*

ISO 6926, *Acoustics — Determination of sound power levels of noise sources — Characterization and calibration of reference sound sources.* [1)]

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.*

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

IEC Publication 651, *Sound level meters.*

IEC Publication 804, *Integrating-averaging sound level meters.*

4 Definitions

For the purposes of this International Standard, the following definitions apply.

4.1 level of background noise: The sound pressure level at specified locations when the equipment being tested is neither operating nor idling.

4.2 bystander: An individual who is not the operator of the equipment, but whose position lies within the sound field produced by the equipment, either occasionally or continuously.

4.3 bystander position: A measurement position at a typical location occupied by a bystander.

4.4 computer and business equipment: Equipment and components thereof which are primarily used in offices or office-like environments and in computer installations.

4.5 floor-standing equipment: A functional unit that has its own stand and is intended to be installed on the floor.

4.6 frequency range of interest: This range normally extends from the 100 Hz one-third octave band to the 10 000 Hz one-third octave band. The 16 kHz octave band shall be included if a preliminary investigation indicates that it may affect the A-weighted sound pressure or sound power levels. The range and centre frequencies of the octave bands are specified in ISO 266.

NOTES

1 If the 16 kHz octave band is included in the measurements, the procedures of this International Standard may yield measurement uncertainties greater than those stated.

2 For equipment which emits sound only in the 16 kHz octave band, the procedures specified in ISO 9295 should be used.

4.7 functional unit: An entity of physical equipment, which has been allocated an identification number, capable of accomplishing a specified task. A functional unit may be supported by a frame or frames and may be self-enclosed or designed to be attached to another device.

4.8 idling mode: A condition in which the equipment being tested, after any necessary warm-up period, is energized but is not operating.

4.9 measurement surface: A hypothetical surface of area S enveloping the equipment being tested on which the measuring points are located.

4.10 operating mode: A condition in which the equipment being tested is performing its intended function(s).

4.11 operator: An individual who operates a piece of equipment from a position in the immediate vicinity of the equipment.

1) At present at the stage of draft.

4.12 operator position: Measurement position at the assigned work-station of the operator.

4.13 rack-mounted equipment: One or more sub-assemblies installed in an end-use enclosure.

4.14 reference box: A hypothetical reference surface which is the smallest rectangular parallelepiped that just encloses the equipment being tested and terminates on the reflecting plane.

4.15 reference sound source: A device which is intended for use as a stable source of sound which has a known, calibrated broad-band sound power spectrum over the frequency range of interest and which conforms to ISO 6926.

4.16 sound power level, L_W, **in decibels:** Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. The weighting network (A-weighting) or the width of the frequency band used shall be indicated. The reference sound power is 1 pW.

NOTE — For the purposes of this International Standard, the sound power is the time-average value of the sound power during the measurement duration.

4.17 sound pressure level, L_p, **in decibels:** Ten times the logarithm to the base 10 of the time-mean-square sound pressure to the square of the reference sound pressure. The weighting network (A-weighting) or the width of the frequency band used shall be indicated. The reference sound pressure is 20 µPa.

NOTE — For the purposes of this International Standard, the sound pressure is the square root of the time average of the squared sound pressure during the measurement duration.

4.18 standard test table: A rigid table having a top surface of at least 0,5 m² (length of the top plane > 700 mm). A suitable design for the standard test table is shown in annex A.

4.19 sub-assembly: A functional unit intended to be installed in another unit or assembled with other units in a single enclosure. The unit may or may not have its own enclosure and identification number.

4.20 surface-average sound pressure level, $\overline{L_{pf}}$, **in decibels:** Space/time-average sound pressure level averaged over a measurement surface, corrected for the environment.

4.21 table-top equipment: A functional unit that has a complete enclosure and is intended to be installed or used on a table, desk or separate stand.

4.22 time-average sound pressure level, L_{pT}, **in decibels; equivalent continuous sound pressure level during time** T, **in decibels:** Ten times the logarithm to the base 10 of the ratio of a time-mean-square value of instantaneous band-limited sound pressure, during a stated time interval, to the square of the standard reference sound pressure.

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

5 Method for determining sound power levels of equipment in reverberation rooms

5.1 General

The method specified in this clause provides a comparison procedure for determining the sound power levels produced by computer and business equipment using a reverberation room. It applies to equipment which radiates broad-band noise, narrow-band noise, or noise which contains discrete-frequency components or impulsive noise.

The measurements shall be carried out in a qualified reverberation room. The volume of the equipment being tested should preferably be not greater than 1 % of the volume of the reverberation room.

NOTE — Measurements on equipment which has a volume of less than 1 m³ and emits broad-band noise may be carried out in a special reverberation test room (see ISO 3743).

5.2 Measurement uncertainty

Measurements carried out in accordance with this method yield standard deviations which are equal to, or less than, those given in table 1.

Table 1 — Uncertainty in determining sound power levels in a reverberation room

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

NOTES

1 For most computer and business equipment, the A-weighted sound power level is determined by the sound power levels in the 250 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 may result when the sound power levels in other bands determine the A-weighted level.

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 may 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 may be considerably better (i.e. smaller standard deviations) than the uncertainties given in table 1 would indicate.

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.

5.3 Test environment

5.3.1 General

Guidelines specified in ISO 3741 and ISO 3742 for the design of the reverberation room shall be used. Criteria for room absorption and the procedure for room qualifications given in these same International Standards shall be used.

5.3.2 Test room volume

The minimum test room volume shall be as stated in table 2. If frequencies above 3 000 Hz are included in the frequency range of interest, the volume of the test room shall not exceed 300 m^3. The ratio of the maximum dimension of the test room to its minimum dimension shall not exceed 3:1.

Table 2 — Minimum room volume as a function of the lowest frequency band of interest

Lowest frequency band of interest Hz	Minimum room volume m^3
125 (octave) or 100 (one-third octave)	200
125 (one-third octave)	150
160 (one-third octave)	100
250 (octave) or 200 (one-third octave) or higher	70

5.3.3 Level of background noise

The level of the background noise, including any noise due to motion of the microphone and/or rotating diffusers, shall be at least 6 dB, and preferably more than 10 dB, below the sound pressure level to be measured in each frequency band within the frequency range of interest.

5.3.4 Temperature and relative humidity

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

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

shall not vary by more than ± 10 % during the measurements specified in 5.6, 5.7 and 5.8. For equipment the sound pressure level of which varies with temperature, the test temperature shall be 23 ± 2 °C.

The following conditions are recommended:

— barometric pressure: 86 to 106 kPa

— temperature: 15 to 30 °C

— relative humidity: 40 % to 70 %

5.4 Instrumentation

5.4.1 General

The instrumentation shall be designed to measure the space/time-average sound pressure level in octave and/or one-third octave bands; the space/time-average sound pressure level is the level of the squared sound pressure averaged over time and space. Alternatively, the space/time-average may be calculated in accordance with 5.9.

The instruments used may perform the required averaging in one of two different ways:

a) By integrating the square of the signal over a fixed time interval and dividing by the time interval. This integration may be performed by either digital or analogue means; digital integration is the preferred method (see IEC Publication 804).

b) By continuous averaging of the square of the signal using RC-smoothing with a time constant of at least 1 s ("slow" meter characteristic). Such continuous averaging provides only an approximation of the true average and it places restrictions on the settling time and observation time (see note to 5.7.2).

5.4.2 Microphone and its associated cable

The microphone used shall comply with the requirements regarding accuracy, stability and frequency response for a type 1 instrument specified either in IEC Publication 651 or in IEC Publication 804 and shall have been calibrated for its random incidence response.

The microphone and its associated cable shall be chosen so that their sensitivity does not change by more than 0,2 dB over the temperature range encountered during measurement. 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.

5.4.3 Frequency response of the instrumentation system

The frequency response of the entire instrumentation system shall be flat over the frequency range of interest within the tolerances given either in IEC Publication 651 or, preferably, in IEC Publication 804, for type 1 instruments.

5.4.4 Reference sound source

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

5.4.5 Filter characteristics

An octave-band or one-third octave-band filter set complying with the requirements specified in IEC Publication 225 shall be used. The centre frequencies of the bands shall correspond to those specified in ISO 266.

5.4.6 Calibration

During each series of measurements, an acoustical calibrator with an accuracy of ± 0,5 dB shall be applied to the microphone to check the calibration of the entire measuring system at one or more frequencies over the frequency range of interest. The calibrator shall be checked at least once a year to verify that its output has not changed. In addition, an acoustical and an electrical calibration of the instrumentation system over the entire frequency range shall be carried out at least every two years. The reference sound source shall be checked annually to verify that its output sound level has not changed.

5.5 Installation and operation of equipment — General requirements

5.5.1 Equipment installation

The equipment shall be installed according to its intended use. If the normal installation is unknown or if several possibilities exist, the same conditions for a group of similar machines shall be chosen and reported. Installation conditions for many different categories of equipment are specified in annex C; these shall be followed when labelling information is to be obtained.

a) 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 room.

If the equipment being tested consists of several frames bolted together in an installation and 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 levels of one are significantly influenced by the other, the equipment being tested shall, where practicable, include all units coupled together in this way.

b) Floor-standing equipment which is to be installed in front of a wall shall be placed on a hard floor in front of a hard wall (see note 2 in 6.3.1). 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.

c) Table-top equipment 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 according to 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).

d) Wall-mounted equipment shall be mounted on a wall of the reverberation room at least 1,5 m from any other reflecting surface, unless otherwise specified. Alternatively, if operation permits, the equipment may be laid on its side and installed with its mounting surface attached to the floor at least 1,5 m from any wall of the room.

e) Rack-mounted equipment shall be placed in an enclosure which complies with the installation specifications for the equipment. The location of all units within the enclosure shall be described. The enclosure shall be tested as floor-standing or table-top equipment. Rack-mounted equipment which does not include, but requires the use of, air-moving equipment (i.e. cooling-fan assemblies) when in operation shall be tested with such equipment, as supplied or recommended by the manufacturer.

f) 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.

g) Hand-held equipment shall be supported 0,1 m above the reflecting plane by vibration-isolating elements. The supports shall not interfere with the propagation of airborne sound.

h) A sub-assembly shall be supported 0,25 m above the reflecting plane by vibration-isolating elements. The supports shall not interfere with the propagation of airborne sound.

NOTE — If the equipment is mounted near one or more reflecting planes, the sound power radiated by the equipment may depend strongly upon its position and orientation. It may be of interest to determine the radiated sound power either for one particular equipment position and orientation or from the average value for several positions and orientations.

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 cleared of all objects which may interfere with the measurements.

5.5.2 Input voltage and frequency

The equipment shall be operated within 5 % of either

a) the rated voltage (if any is stated), or

b) the average voltage of a stated voltage range (i.e. operating at 120 V for a stated range from 110 to 130 V), at the rated power line frequency.

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

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 different categories of equipment.

The noise shall be measured with the equipment in both the idling and the operating modes. If several operating modes exist, e.g. reading and punching, the noise of each individual mode shall be determined and recorded. For equipment which, in normal functional operation, has several operating modes, the mode producing the highest A-weighted sound power level shall be determined, unless otherwise specified in annex C.

In the case of rack-mounted equipment in which the operation of several functional units is possible, the unit producing the highest A-weighted sound power level shall be operated together with those other units required for its operation. All other units shall be in the idling mode.

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 idling. The operating mode measurements shall not include these idling 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 should be inoperative.

NOTE — For certain applications, e.g. in ergonomics, such signals as well as the maximum response of feedback signals of keyboards may be of interest. In such cases, special measurements may be made which are not part of this International Standards.

The equipment shall be operated for a sufficient period of time before proceeding with the acoustical test to allow the temperature to stabilize. If this time is unknown, the equipment shall be operated at least 30 min before the acoustical test.

5.6 Microphone and source positions

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

The procedure specified in 5.6.1 shall be followed to ascertain whether any significant discrete-frequency components or narrow bands of noise are present in the sound emitted by the source. It is strongly recommended that the room be qualified in accordance with ISO 3742 because the number of microphone and equipment positions calculated in accordance with the following procedure is usually large.

5.6.1 Identification of discrete-frequency components and narrow bands of noise

The presence of a significant discrete-frequency component can often be detected by a simple listening test. If such a component is audible, omit the measurements described in this clause. In this case, either the provisions of the bottom line in table 3 shall be applied or, alternatively, the reverberation room shall be qualified as described in ISO 3742, annex A.

For the purpose of this International Standard, the character of the noise of the equipment being tested is defined by an estimate of the standard deviation of the sound pressure level variations in the reverberation room. The procedure given in 5.6.1.1 to 5.6.1.3 shall be used.

5.6.1.1 Select an array of six fixed microphones (or six microphone positions) spaced at least $\lambda/2$ apart, where λ is the wavelength of the sound corresponding to the centre frequency of the lowest frequency band of interest. Locate the equipment at a single position in the test room.

5.6.1.2 Obtain the time-average sound pressure level at each microphone position in accordance with the techniques described in 5.7. Instead of a fixed array, a single microphone may be sequentially moved to six positions equally spaced along a path the length, l, of which is calculated from equation (2) with $N_m = 6$.

5.6.1.3 For each one-third octave or octave band within the frequency range of interest, calculate the standard deviation, s, from the following equation:

$$s = (n - 1)^{-1/2} \left[\sum_{i=1}^{n} (L_i - L_m)^2 \right]^{1/2} \quad \text{... (1)}$$

where

L_i is the time-average sound pressure level at the ith microphone position, in decibels;

L_m is the arithmetic mean value of the sound pressure levels L_1 to L_6, in decibels;

$n = 6$.

The value of s calculated according to equation (1) is used with tables 3 and 4 to determine the number of microphone positions and the number of source locations.

5.6.2 Number of microphone positions

For broad-band noise, the minimum number of microphone positions is $N_m = 3$ (see table 3, first line). For narrow-band noise and discrete-frequency noise, the number of microphone positions is determined from table 4. If a continuous microphone traverse is used, the length of the traverse, l, should be at least

$$l = N_m \frac{\lambda}{2} \quad \text{... (2)}$$

where N_m is the number of microphone positions.

Table 3 — Procedures to be followed for measuring discrete-frequency components or narrow bands of noise

Standard deviation, s dB	Procedure	Number of microphone positions, N_m (or microphone path length, l)	Number of equipment locations, N_s
$s \leqslant 1{,}5$	Broad-band procedure adequate	$N_m = 3$ or l computed from equation (2) for a continuous path	$N_s = 1$
$1{,}5 < s \leqslant 3$	Assume that a narrow band of noise is present	N_m determined from table 4 or l computed from equation (2) for a continuous path	Use half the number of equipment locations computed from equation (4)
$s > 3$	Assume that a discrete tone is present	N_m determined from table 4 or l computed from equation (2) for a continuous path	Compute N_s from equation (4)

Table 4 — Number of microphone positions required and constant k for determining the number of equipment locations

Octave-band (and one-third octave-band) centre frequency	Number of microphone positions (N_m), if $1{,}5 < s \leqslant 3$ dB	Number of microphone positions (N_m), if $s > 3$ dB	Constant k for determining the number of equipment locations
125 (100, 125, 160)	3	6	5
250 (200, 250, 315)	6	12	10
500 (400, 500, 630)	12	24	20
1 000 (800, 1 000, 1 250) and above	15	30	25

5.6.3 Microphone arrangement

The microphone traverse or array shall not lie in any plane within 10° of a major room surface. No position on the traverse or array shall be closer than $\lambda/2$ or 1 m, whichever is smaller, to any major room surface. No point on the traverse or array shall be closer than $\lambda/4$ or 0,5 m, whichever is smaller, to the path of a moving diffuser.

The minimum distance, d, in metres, between the nearest microphone position and the equipment being tested shall be

$$d > 0{,}8 \times 10^{0{,}05(L_{Wr} - L_{pr})} \quad \ldots (3)$$

where

L_{Wr} is the calibrated sound power level, in decibels, of the reference source;

L_{pr} is the space/time-average sound pressure level, in decibels, produced in the room by the reference sound source.

NOTES

1 It is highly desirable that, whenever possible, all microphone positions be more than the minimum distance, d, from the equipment so as to minimize contributions from the direct sound field.

2 The microphone traverse or array should avoid areas of air discharge (if any) or sound beaming from the equipment being tested.

The repetition rate of the microphone traverse (or the scanning rate for an array of fixed microphones) shall satisfy the following requirements:

a) there shall be a whole number of microphone traverses or array scans during the observation period (see 5.7.2);

b) if integration over a fixed time interval is used, there shall be a whole number of complete microphone traverses or array scans during the integrating time of the indicating device;

c) if continuous averaging is used, the traverse or scanning period shall be less than twice the time constant of the indicating device.

5.6.4 Number of equipment locations

The required number of locations at which the equipment being tested shall be placed successively depends on the room absorption and on the frequency. If discrete-frequency tones are present, the required number of equipment locations, N_s, shall be computed from the following formula:

$$N_s \geqslant k \left[0{,}032 \times 10^{0{,}1(L_{pr} - L_{Wr})} \times \left(\frac{1000}{f}\right)^2 + \frac{1}{N_m} \right] \quad \ldots (4)$$

where

L_{pr} is the space/time-average sound pressure level, in decibels, produced in the room by the reference sound source;

L_{Wr} is the calibrated sound power level, in decibels, of the reference source;

f is the frequency, in hertz, of the discrete tone or the centre frequency of the band in which a discrete-frequency or narrow-band noise component is found;

k is a constant given in table 4;

N_m is the number of microphone positions for the narrow-band or discrete-frequency tone (see table 4).

The value of N_s shall be rounded to the nearest higher integer.

The minimum distance between any two equipment locations shall be $r_{min} = \lambda/2$. The source positions should not be symmetrical with respect to the axes of the test room.

5.7 Measurement of sound pressure levels

5.7.1 General

Measurements of the sound pressure level along the microphone path (or at the individual microphone positions) shall be carried out for each frequency band within the frequency range of interest. The following data shall be obtained:

a) the band sound pressure levels for the specified modes of operation of the equipment;

b) the band sound pressure levels of the background noise (including noise from support equipment);

c) the band sound pressure levels during operation of the reference sound source (see 5.8).

The microphone traverse or array shall be the same for each set of readings and shall meet the requirements of 5.6. The sound diffuser(s), if any, shall be operated in exactly the same way for each set of readings. No observers or operators shall be present in the test room during the measurements unless necessary for operating the equipment being tested. If their presence is necessary, they should also be present during the reference sound source measurements.

5.7.2 Measurement duration

The measurement duration shall be adjusted to the operation of the equipment. For all idling or operating modes the measurement duration shall be at least

— 30 s for the frequency bands centred on or below 160 Hz;

— 10 s for the frequency bands centred on or above 200 Hz.

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 types of equipment.

If the measuring instruments use continuous time-averaging (RC-smoothing), no observation shall be made after any microphone or filter switching (including transfer of the microphone to a new position) until a settling time of five times the time constant of the instrumentation has elapsed. The observation time shall have at least the same duration as the settling time.

5.7.3 Corrections for background noise

If the level of the background noise is at least 15 dB below the sound pressure level at each measurement point and in each frequency band, no corrections for background noise are required. If the level of the background noise is less than 15 dB but more than 6 dB below the sound pressure level at each measurement point and in each frequency band, the measured sound pressure levels shall be corrected for the influence of background noise using the following formula:

$$B = L_c - 10 \lg (10^{0,1L_c} - 10^{0,1L_b}) \qquad \dots (5)$$

where

B is the correction, in decibels, to be subtracted from the sound pressure level measured with the sound source operating to obtain the sound pressure level due to the sound source alone;

L_c is the measured sound pressure level, in decibels, with the sound source operating;

L_b is the level of background noise alone, in decibels.

If the level of the background noise is less than 6 dB below the sound pressure level at each measurement point and in a given frequency band, the accuracy of the measurements is reduced and no corrections shall be applied for that band. The results may, however, be reported and may be useful in determining an upper limit to the sound power level of the equipment being tested. If such data are reported, it shall be clearly stated that the background noise requirements of this International Standard have not been satisfied for that frequency band.

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

For the purposes of calculating the sound power level of the equipment, this International Standard uses the comparison method of 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.

The reference sound source shall be mounted on the floor of the reverberation room at least 1,5 m away from any other sound-reflecting surface, such as a wall or the equipment being tested. The distance from the source to the microphone traverse or array shall be in accordance with 5.6.3. The number of microphone positions or the equivalent path length shall be the same as specified for the sound pressure level measurements on the equipment. One source position for the reference sound source will suffice.

The sound pressure levels in each octave band or one-third octave band within the frequency range of interest shall be measured in accordance with 5.7.

5.9 Calculation of space/time-average band sound pressure levels

If a continuous path or automatic microphone scanning is used together with analogue or digital integration, the sound pressure levels measured in accordance with 5.7 (corrected in accordance with 5.7.3, if applicable) in each frequency band of interest constitute the space/time-average band sound pressure levels. If individual microphone positions are used or if the sound pressure levels fluctuate during the period of observation, the averaging shall be performed by using the following equation:

$$L_p = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1L_{pi}} \right] \qquad \dots (6)$$

where

L_p is the space/time-average band sound pressure level, in decibels;

L_{pi} is the band sound pressure level resulting from the ith measurement, in decibels;

N is the total number of measurements in the band.

5.10 Calculation of sound power levels

5.10.1 Calculation of band sound power levels

The sound power level of the equipment in each octave band or one-third octave band within the frequency range of interest is obtained as follows. The space/time-average band sound pressure level produced by the reference sound source (corrected for background noise in accordance with 5.7.3) is subtracted from the known sound power level of the reference sound source. The difference is added to the band sound pressure level of the equipment being tested (corrected for background noise in accordance with 5.7.3). Hence

$$L_W = L_p + (L_{Wr} - L_{pr}) \qquad \ldots (7)$$

where

L_W is the band sound power level, in decibels, of the equipment being tested;

L_p is the space/time-average band sound pressure level, in decibels, of the equipment being tested;

L_{Wr} is the calibrated band power level, in decibels, of the reference sound source;

L_{pr} is the space/time-average band sound pressure level, in decibels, of the reference sound source.

5.10.2 Calculation of A-weighted sound power level

The A-weighted sound power level, L_{WA}, in decibels, shall be calculated from the following equation:

$$L_{WA} = 10 \lg \sum_{j=1}^{j_{max}} 10^{0,1[L_{Wj} + A_j]} \qquad \ldots (8)$$

where L_{Wj} is the band power level in the jth octave or one-third octave band.

For computations with octave-band data, the values of the A-weighting A_j are given in table 5.

Table 5 — Values of the A-weighting, A_j, for j = 1 to j_{max} = 7

j	Octave-band centre frequency Hz	A_j dB
1	125	– 16,1
2	250	– 8,6
3	500	– 3,2
4	1 000	0
5	2 000	1,2
6	4 000	1
7	8 000	– 1,1

For computations with one-third octave band data, the values of the A-weighting, A_j, are given in table 6.

Table 6 — Values of the A-weighting, A_j, for j = 1 to j_{max} = 21

j	One-third octave-band centre frequency Hz	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
12	1 250	0,6
13	1 600	1
14	2 000	1,2
15	2 500	1,3
16	3 150	1,2
17	4 000	1
18	5 000	0,5
19	6 300	– 0,1
20	8 000	– 1,1
21	10 000	– 2,5

5.11 Information to be recorded

The information (when applicable) specified in 5.11.1 to 5.11.4, shall be recorded.

5.11.1 Equipment being tested

The following information shall be recorded:

a) a complete description of the equipment under test, including the name, model and serial number of each unit: the complexities of the equipment and the variety of the available options are such that a detailed description of the equipment under test is required; the equipment under test will normally consist of a single unit, and may have its own type or model number or the same type or model number of other units with which it operates;

b) a complete description of the idling 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 and functions of an operator, if present;

e) nominal power line frequency, in hertz (e.g. 50 Hz, 60 Hz, 400 Hz), and measured power line voltage, in volts.