

INTERNATIONAL STANDARD

**ISO
7779**

First edition
1988-06-15



INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
ORGANISATION INTERNATIONALE DE NORMALISATION
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

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Reference number
ISO 7779:1988 (E)

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 inmission).

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 μ Pa.

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, $\overline{L_{pt}}$, 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 m³. 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 $\pm 0,5$ 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:

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

where

L_i is the time-average sound pressure level at the i th 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

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

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
$s < 1,5$	Broad-band procedure adequate	$N_m = 3$ or l computed from equation (2) for a continuous path	$N_s = 1$
$1,5 < s < 3$	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 $1,5 < s \leq 3$ 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

$$d \geq 0,8 \times 10^{0,05(L_{wr} - L_{pr})} \quad \dots (3)$$

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:

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

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:

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

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:

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

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 i th 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

$$L_W = L_p + (L_{Wr} - L_{pr}) \quad \dots (7)$$

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:

$$L_{WA} = 10 \lg \sum_{j=1}^{j_{\max}} 10^{0,1(L_{Wj} + A_j)} \quad \dots (8)$$

where L_{Wj} is the band power level in the j th 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 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;
- 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;
- a complete description of the installation and mounting conditions;
- the location and functions of an operator, if present;
- nominal power line frequency, in hertz (e.g. 50 Hz, 60 Hz, 400 Hz), and measured power line voltage, in volts.

5.11.2 Acoustical environment

The following information shall be recorded:

- a description of the test room, including dimensions, shape, surface treatment of the walls, ceiling and floor;
- a description of diffusers, or rotating vanes, if any;
- results of qualification of the reverberation room in accordance with ISO 3741, annex A, or ISO 3742;
- the air temperature, in degrees Celsius, relative humidity, as a percentage, and barometric pressure, in kilopascals.

5.11.3 Instrumentation

The following information shall be recorded:

- equipment used for the measurements, including name, type, serial number and manufacturer;
- bandwidth of frequency analyser;
- frequency response of the instrumentation system;
- method used for checking the calibration of the microphone and other system components: the date and place of calibration shall be given;
- method used for determining the space/time-average sound pressure level;
- type and calibration of reference sound source.

5.11.4 Acoustical data

The following information shall be recorded:

- location and orientation of the microphone traverse (path) or array;
- 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 pass-band, background noise, etc;
- the values for the difference ($L_{Wf} - L_{pf}$), in decibels, as a function of frequency;
- the band sound pressure level readings, in decibels, to at least the nearest 0,5 dB, required for the calculations in 5.9;
- the sound power levels, in decibels (reference: 1 pW), in octave and/or one-third octave bands, tabulated or plotted to the nearest half decibel;
- the A-weighted sound power level, in decibels (reference: 1 pW), rounded to the nearest decibel;
- the date, time and place where the measurements were carried out, and the name of the person who carried out the measurements.

5.12 Test report

The test report shall contain the statement that the sound power levels have been obtained in full conformity with the procedures specified in clause 5 of this International Standard. The test report shall state that these sound power levels are given in decibels (reference: 1 pW).

NOTE — For the determination of declared noise emission values for computer and business equipment in accordance with ISO 9296, the numerical value of the sound power level, divided by ten, given to one decimal place, is used.

The test report shall contain at least the following information:

- the name(s) and model number(s) of the equipment being tested;
- the A-weighted sound power level, L_{WA} , in decibels (reference: 1 pW), for the idling mode and the operating mode(s);
- the sound power levels, L_W , in decibels (reference: 1 pW), in octave or one-third octave bands, if required, for the idling mode and the operating mode(s) — the bandwidth used shall be stated;
- a detailed description of the operating conditions of the equipment being tested with reference to annex C, if applicable.

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

6.1 General

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

The measurements shall be carried out in a qualified environment.

6.2 Measurement uncertainty

Measurements carried out in accordance with this method yield standard deviations which are equal to, or less than, those given in table 7.

Table 7 — Uncertainty in determining sound power levels in a free field over a reflecting plane

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

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 7 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 7 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 7, provided that the measurements are carried out in the same environment with the same shape of measurement surface.

6.3 Test environment

6.3.1 General

The test environment shall provide a free field or preferably a free field over a reflecting plane. Suitable test environments are defined in ISO 3744 and ISO 3745. These environments include

- a) a semi-anechoic or an anechoic room qualified in accordance with ISO 3745;
- b) a flat outdoor area that meets the requirements of 6.3.2;
- c) a room in which the contribution of the reverberant field to the sound pressure levels on the measurement surface are small compared with those of the direct field of the equipment.

NOTES

1 Conditions described in c) above are met in very large rooms as well as in smaller rooms with sufficient sound-absorptive materials on their walls and ceiling and a reflecting (hard) floor.

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

6.3.2 Adequacy of the test environment

The test environment should be free from reflecting objects other than a reflecting plane so that the equipment radiates into a free field over a reflecting plane.

The procedure in annex A of ISO 3744 shall be used to determine the magnitude of the environmental corrections to take account of departures (if any) of the test environment from the ideal condition. The correction shall not exceed 2 dB.

6.3.3 Level of background noise

At the microphone positions, the levels of the background noise shall be at least 6 dB, and preferably more than 10 dB, below either the sound pressure level to be measured in each

frequency band within the frequency range of interest or the A-weighted sound pressure level.

6.3.4 Temperature and relative humidity

The following conditions are recommended:

- barometric pressure: 86 to 106 kPa
- temperature: 15 to 30 °C
- relative humidity: 40 % to 70 %

For equipment the sound pressure level of which varies with temperature, the test temperature shall be 23 ± 2 °C.

6.4 Instrumentation

6.4.1 General

The instrumentation shall be designed to measure the space/time-average sound pressure level; the space/time-average sound pressure level is the level of the squared sound pressure averaged over time and the measurement surface. Surface averaging is performed over a fixed number of microphone positions (see 6.6) and by computing the average value in accordance with 6.9.1, except as described in clause B.3.

The instruments used may perform the required time and space-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 time average and it places restrictions on the settling time and observation time.

6.4.2 Microphone and its associated cable

The microphone used shall comply with the requirements regarding the accuracy, stability and frequency response for a type 1 instrument as specified either in IEC Publication 651 or in IEC Publication 804 for the angle of incidence specified by the manufacturer.

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 wind, gears, flexing cables or sliding contacts) that could interfere with the measurements.

6.4.3 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.

6.4.4 Weighting network and filter characteristics

An A-weighting network complying with the tolerances specified either in IEC Publication 651 or in IEC Publication 804 for type 1 instruments and 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 frequency bands shall correspond to those specified in ISO 266.

6.4.5 Calibration

During each series of measurements, an acoustical calibrator with an accuracy of $\pm 0,5$ 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. If a reference sound source is used, it shall be checked annually to verify that its output sound level has not changed.

6.5 Installation and operation of equipment — General requirements

6.5.1 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.

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 given in note 2 to 6.3.1. The plane(s) shall not contribute to the sound radiation due to their own vibrations.

- a) 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.

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. 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 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). In any case the measurement surface defined in 6.6 terminates on the floor.

- d) Wall-mounted equipment shall be mounted on a reflecting (hard) wall at least 1,5 m away from any other reflecting plane, unless otherwise specified. Alternatively, if operation permits, the equipment may be laid on its side and attached to the reflecting floor at a sufficient distance from the walls (more than 2 m, if possible).

- 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.

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 being tested shall be located outside the test room and the test room shall be cleared of all objects which may interfere with the measurements.

6.5.2 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 %.

6.5.3 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 Standard.

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.

6.6 Measurement surface and microphone positions

6.6.1 General

In order to facilitate the location of the microphone positions, a hypothetical reference surface is defined. This reference surface is the smallest possible rectangular box, i.e. rectangular parallelepiped, that just encloses the equipment and terminates on the reflecting plane. 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.

For computer and business equipment, the preferred measurement surface is the parallelepiped the sides of which are parallel to those of the reference box at the preferred measurement distance d , where $d = 1$ m.

In some cases, mainly for small equipment, a hemisphere or a quarter-sphere of radius r may be chosen as the measurement surface, provided that the condition $r > 2 d_0$ is met, where d_0 is the distance to the corners of the reference box from the origin of the coordinates. The coordinates for those measurement surfaces are given in annex B.

The location of the equipment being tested, the measurement surface and the microphone positions are defined by a co-ordinate system with the 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 box. The x -axis points towards the front of the equipment. The position of the origin for the coordinates of the microphone positions is given as follows:

- 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 with extension tables: on the extended table-top plane in the centre of the base plane of the reference box;
- c) for table-top equipment on a table without extension tables or on the floor: same conditions as for floor-standing equipment described above in a);
- d) for wall-mounted equipment: in the centre of that plane of the reference box which is coplanar with the mounting surface;
- e) for rack-mounted equipment: same conditions as for floor-standing equipment described above in a);
- f) for hand-held equipment: same conditions as for floor-standing equipment described above in a);
- g) for sub-assemblies: same conditions as for floor-standing equipment described above in a).

The number and location of the microphone positions is as specified in 6.6.2 and in annex B.

NOTE — Either a single microphone may be moved from one position to the next sequentially or a number of fixed microphones may be used and their outputs sampled sequentially (see note to 6.7.2).

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

The microphone 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 will be an orientation towards the approximate geometric centre of the equipment.

6.6.2 Microphone positions on the measurement surface

6.6.2.1 Arrangement 1: Measurement surface for floor-standing equipment

If this arrangement is applied to wall-mounted equipment, the origin of the coordinate axes shall be positioned accordingly.

The key microphone positions are given in figure 1 and table 8. The area S of the measurement surface is given by the formula:

$S = 4 (ab + bc + ca)$

where

$a = 0,5 l_1 + d$

$b = 0,5 l_2 + d$

$c = l_3 + d$

where

l_1, l_2 and l_3 are the length, width and height of the reference box,

d is the measurement distance, normally 1 m.

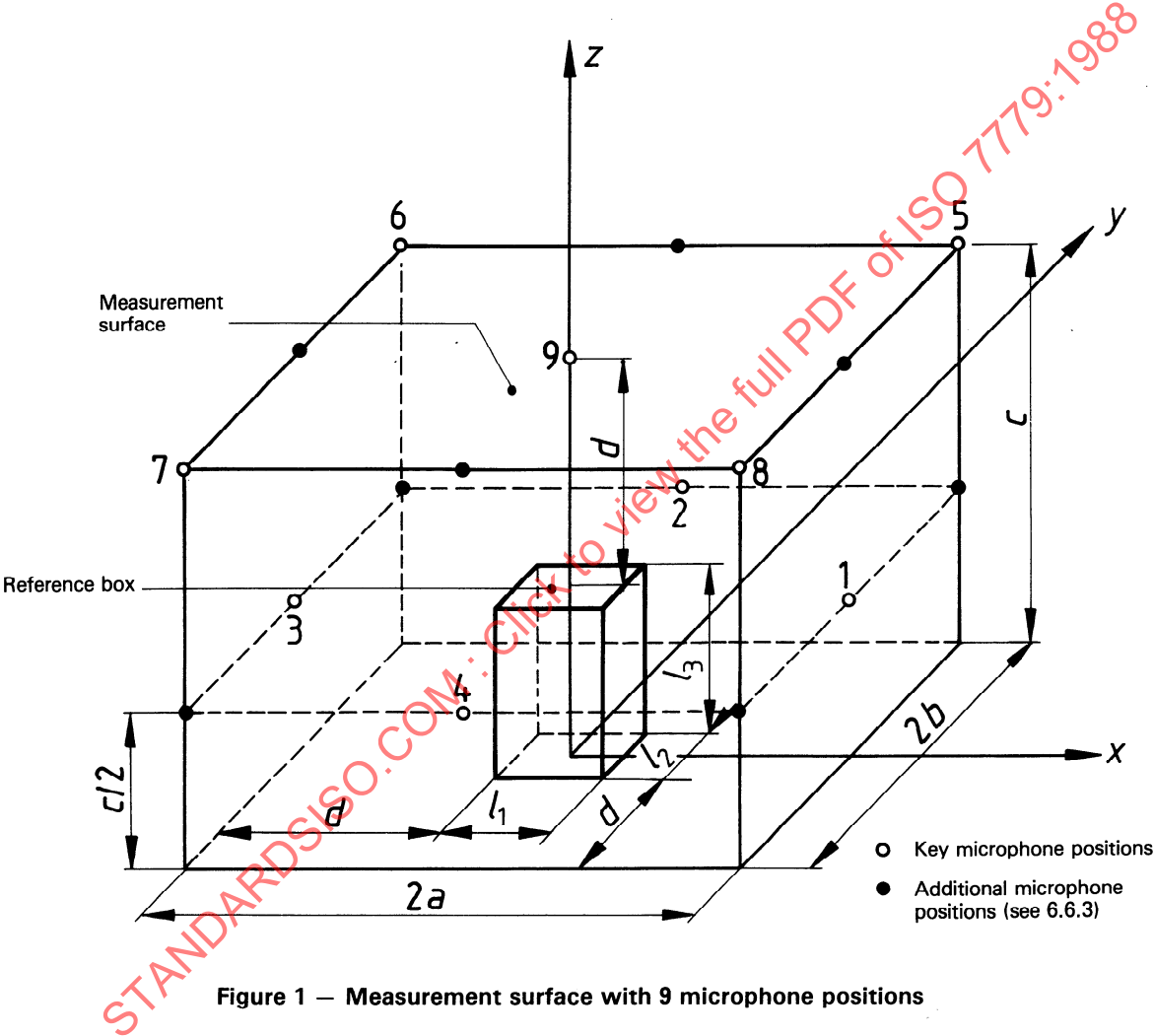


Table 8 — Coordinates of key microphone positions for arrangement 1

Position No.	Coordinates		
	x	y	z
1	a	0	c/2
2	0	b	c/2
3	-a	0	c/2
4	0	-b	c/2
5	a	b	c
6	-a	b	c
7	-a	-b	c
8	a	-b	c
9	0	0	c

6.6.2.2 Arrangement 2: Measurement surface for floor-standing equipment in front of a wall

The key microphone positions are given in figure 2 and table 9.
The area S of the measurement surface is given by the formula:

$$S = 2 (2ab + 2ac + bc)$$

where

$$a = 0,5 (l_1 + d)$$

$$b = 0,5 l_2 + d$$

$$c = l_3 + d$$

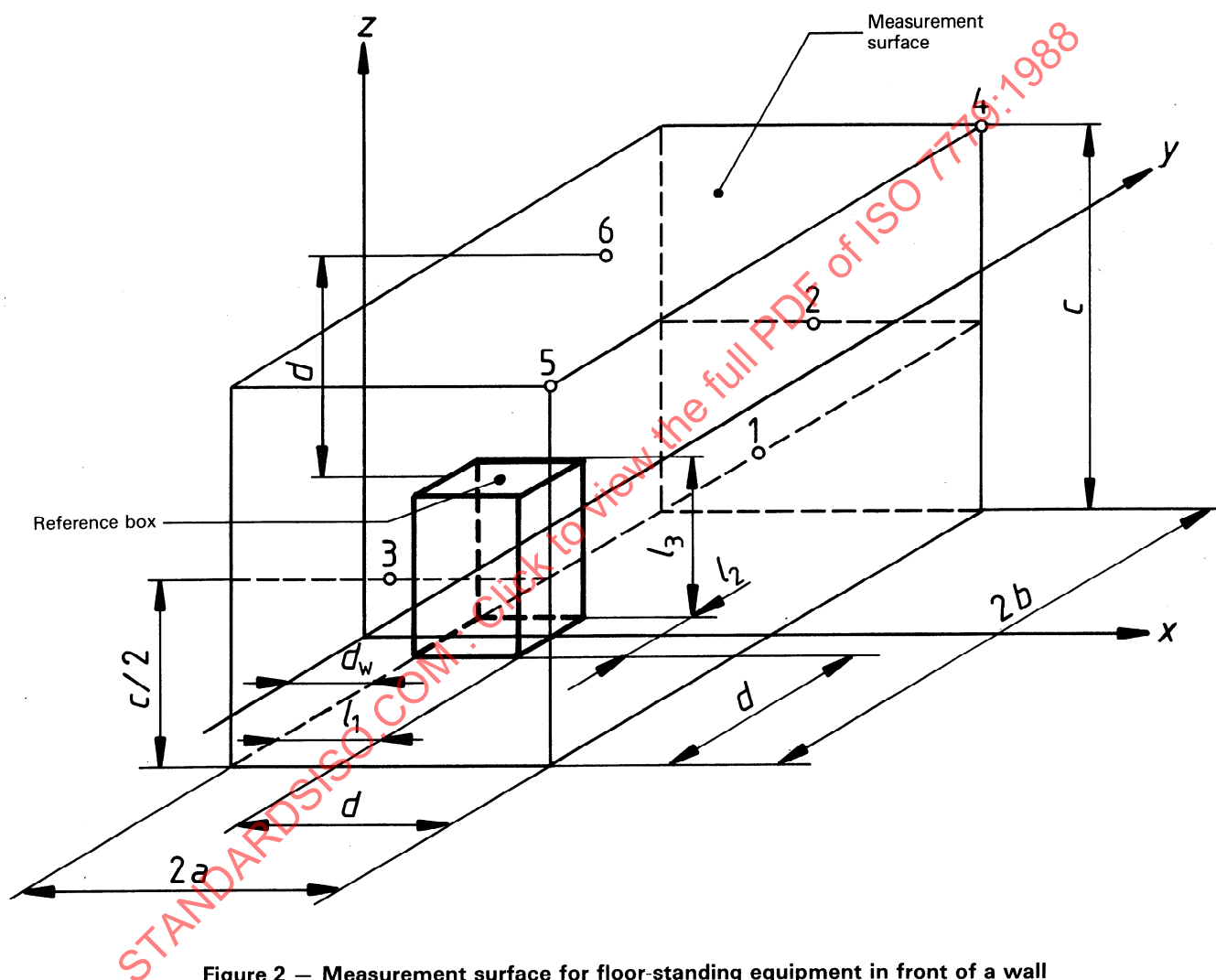


Figure 2 — Measurement surface for floor-standing equipment in front of a wall

Table 9 — Coordinates of key microphone positions for arrangement 2

Position No.	Coordinates		
	x	y	z
1	$2a$	0	$c/2$
2	a	b	$c/2$
3	a	$-b$	$c/2$
4	$2a$	b	c
5	$2a$	$-b$	c
6	a	0	c

NOTES

1 If large equipment is to be measured in small rooms providing free-field conditions over a reflecting plane, 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.

2 For comparison of equipment of the same kind and size, e.g. for quality control tests during series production, a reduced number of representative microphone positions may be adequate (see 6.6.4).

6.6.3 Additional microphone positions on the measurement surface

Sound pressure measurements are required at additional microphone positions if one or more of the following conditions exist:

- a) the range of sound pressure values measured at the microphone positions (i.e. the difference, in decibels, between the highest and the lowest sound pressure levels) exceeds the number of measurement positions;
- b) any of the dimensions of the reference parallelepiped is larger than $2d$;
- c) the equipment radiates noise with a high directivity;
- d) the noise from large equipment is radiated only from a small portion of the equipment, for example, the openings of an otherwise enclosed machine.

If conditions a) or b) exist, additional microphone positions as shown in figure 1 shall be used.

If conditions c) or d) exist, a detailed investigation is necessary of the sound pressure levels over a restricted portion of the measurement surface. The purpose of this detailed investigation is to determine the highest and lowest values of the sound pressure level in the frequency bands of interest. The additional microphone positions will usually not be associated with equal areas on the measurement surface. In this case, the calculation procedure specified in ISO 3745 sub-clause 7.7.1.2 (unequal areas), for the determination of L_{Wp} shall be used.

6.6.4 Reduction in the number of microphone positions

When testing a series of units which are of the same type and which produce a symmetrical radiation pattern, it may be permissible to use a reduced number of microphone positions. The first unit shall be tested using both the full number of microphone positions defined over the entire measurement surface and a reduced number of microphone positions defined over only a portion of the measurement surface. If the surface sound pressure levels for the two cases, determined in accordance with the calculation procedures specified in 6.9, do not differ by more than 0,5 dB, the reduced number of positions may be used for subsequent units in the series.

6.7 Measurement of sound pressure levels

6.7.1 General

Measurements of the sound pressure level shall be carried out at the microphone positions specified in 6.6 with A-weighting

and for each frequency band within the frequency range of interest, if required. The following data shall be obtained:

- a) the A-weighted sound pressure levels and band sound pressure levels, if required, for the specified modes of operation of the equipment;
- b) the A-weighted sound pressure levels and band sound pressure levels, if required, of the background noise (including noise from support equipment).

NOTES

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

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

3 If equipment noise emissions include short-duration high-amplitude (i.e. impulsive) sounds, a sound level meter that has a 1 000 ms (or "slow") exponential time average may be overloaded and may not provide an accurate measurement of the time-average sound pressure level. If such sounds are noted to be present, measurements should be made with instruments conforming to the requirements of IEC Publication 804 for type 1 integrating-averaging sound level meters.

6.7.2 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 8 s for each measurement position.

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.

NOTE — When the measurement duration over the total sequence of operation cycles exceeds 40 s, time and spatial averaging may be performed in combination by sampling all microphones in sequence at least ten times and dwelling at each microphone each time for at least 4 s. This may be accomplished, for example, with nine microphones, a multiplexer and an integrating analyser or integrating-averaging sound level meter. Sampling for a period longer than 4 s should be carried out, as required, to ensure that 4 s of data at that microphone position are actually acquired and that any settling period (due to exponential averaging, for example) is excluded. Dwell duration and number of samples should be the same for all microphones.

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.

6.7.3 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:

$$B = L_c - 10 \lg (10^{0,1L_c} - 10^{0,1L_b}) \quad \dots (9)$$

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.

6.8 Corrections for unwanted reflections

If a room as defined in 6.3.1c) is used, the A-weighted sound pressure levels and band sound pressure levels shall be corrected for unwanted reflections present in the test environment. The environmental correction factor, K , accounts for the influence of a non-ideal environment.

Annex A of ISO 3744 gives the detailed procedures to be followed for determining the magnitude of the environmental correction K , in decibels [the absolute comparison test (clause A.3) shall be used]. The maximum allowable range for K is from 0 to 2 dB. It shall be subtracted from the measured sound pressure levels [see equation (11)]. For laboratory-quality semi-anechoic rooms, the qualification procedure of ISO 3745 may be used.

NOTE — If the environmental correction varies from microphone position to microphone position within the maximum allowable range, a mean value should be determined and subtracted from the measured sound pressure level.

6.9 Calculation of surface-average sound pressure level

6.9.1 Calculation of sound pressure level averaged over the measurement surface

If automatic microphone scanning is used together with analogue or digital integration, the sound pressure levels measured in accordance with 6.7 (corrected in accordance with 6.7.3, if applicable) constitute the A-weighted sound pressure

levels and band sound pressure levels averaged over time and over the measurement surface. 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:

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

where

$\overline{L_p}$ is the band sound pressure level averaged over the measurement surface, in decibels;

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

N is the total number of measurements.

NOTE — For A-weighted sound pressure levels, the symbols L_{pi} and $\overline{L_p}$ should be replaced by L_{pAf} and $\overline{L_{pAf}}$.

6.9.2 Calculation of surface-average sound pressure level

The band surface-average sound pressure levels, $\overline{L_{pft}}$, are obtained by correcting the values of $\overline{L_p}$ for reflected sound to approximate the sound pressure level which could be obtained under ideal free-field conditions (or free-field conditions over a reflecting plane) by the equation:

$$\overline{L_{pft}} = \overline{L_p} - K \quad \dots (11)$$

where K is the mean value, in decibels, of the environmental correction over the measurement surface to account for the influence of unwanted reflections (see 6.8).

NOTE — For A-weighted levels, the symbols $\overline{L_{pft}}$ and $\overline{L_p}$ are replaced by $\overline{L_{pAft}}$ and $\overline{L_{pAf}}$.

6.10 Calculation of sound power level

The sound power level of the equipment shall be calculated from the following equations:

$$L_{WA} = \overline{L_{pAft}} + 10 \lg \frac{S}{S_0} \quad \dots (12)$$

$$L_W = \overline{L_{pft}} + 10 \lg \frac{S}{S_0} \quad \dots (13)$$

where

L_{WA} is the A-weighted sound power level of the equipment, in decibels;

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

$\overline{L_{pAft}}$ is the A-weighted surface-average sound pressure level in decibels, determined in accordance with 6.9.2;

$\overline{L}_{pfr}$ is the band surface-average sound pressure level, in decibels, determined in accordance with 6.9.2;

S is the area of the measurement surface, in square metres;

$$S_0 = 1 \text{ m}^2.$$

NOTE — The effect of variations in temperature and barometric pressure is not included in the calculation of equations (12) and (13) because of the relatively large uncertainty in the sound power using this method. If the effect is of interest, a precision method of measurement should be used.

6.11 Information to be recorded

The information (when applicable) specified in 6.11.1 to 6.11.4 shall be recorded.

6.11.1 Equipment being tested

The following information shall be recorded:

- a) a description of the equipment being tested (including main dimensions);
- b) operating conditions;
- c) installation conditions;
- d) the location of equipment in the test environment;
- e) if the equipment has multiple operating modes, a description of each individual mode for which measurements have been carried out.

6.11.2 Acoustical environment

The following information shall be recorded:

- a) a description of the acoustical environment — if indoors, the size and acoustical characteristics of the room, including absorptive properties of the walls, ceiling and floor;
- b) environmental correction resulting from the acoustical qualification of test environment in accordance with ISO 3744, annex A;
- c) the air temperature, in degrees Celsius, relative humidity, as a percentage, and barometric pressure, in kilopascals.

6.11.3 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;
- c) frequency response of the instrumentation system;
- d) method used for checking the calibration of the microphones and other system components: the date and place of calibration shall be given;

e) method used for determining the space-time average sound pressure level;

f) type and calibration of reference sound source.

6.11.4 Acoustical data

The following information shall be recorded;

- a) the shape of the measurement surface, the measurement distance, the location and orientation of microphone positions or paths;
- b) the area, S , of the measurement surface;
- c) the corrections, if any, in decibels, applied in each frequency band for the frequency response of the microphone, and frequency response of the filter in the pass-band;
- d) the corrections, if any, for background noise;
- e) the corrections, if any, for unwanted reflections;
- f) the A-weighted surface-average sound pressure level, $\overline{L}_{pAf}$, and the band surface-average sound pressure level, $\overline{L}_{pfr}$, for each frequency band of interest, rounded to at least the nearest 0,5 dB;
- g) the A-weighted sound power level, L_{WA} , and the band sound power level, L_W , for each frequency band of interest, rounded to at least the nearest decibel;
- h) the date, time and place where the measurements were carried out, and the name of the person who carried out the measurements.

6.12 Test report

The test report shall contain the statement that the sound power levels have been obtained in full conformity with the procedures specified in clause 6 of this International Standard. The test report shall state that these sound power levels are given in decibels (reference: 1 pW).

NOTE — For the determination of declared noise emission values for computer and business equipment in accordance with ISO 9296, the numerical value of the sound power level, divided by ten, given to one decimal place, is used.

The test report shall contain at least the following information:

- a) the name(s) and model number(s) of the equipment being tested;
- b) the A-weighted sound power level, L_{WA} , in decibels (reference: 1 pW), for the idling mode and the operating mode(s);
- c) the sound power levels, L_W , in decibels (reference 1 pW), in octave or one-third octave bands, if required, for the idling mode and the operating mode(s) — the bandwidth used shall be stated;
- d) a detailed description of the operating conditions of the equipment being tested with reference to annex C, if applicable.

7 Method for measuring sound pressure levels at the operator and bystander positions

7.1 General

The method specified in this clause lays down the conditions of measurement of noise at the operator and bystander positions. The method applies to equipment which radiates broad-band noise, narrow-band noise, noise which contains discrete-frequency components or impulsive noise. This method of measurement does not apply to sub-assemblies.

NOTE — Methods for determining whether the noise at the operator position or at the bystander positions is impulsive in character or includes prominent discrete tones are given in annex D.

The measurements shall be carried out in a free field over a reflecting plane. For convenience, the measurements may be carried out in conjunction with those performed in accordance with clause 6.

7.2 Measurement uncertainty

Measurements carried out in accordance with this method yield standard deviations which are equal to, or less than, those given in table 10.

Table 10 — Uncertainty in determining time-average sound pressure level at the operator position over a reflecting plane

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

NOTES

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

2 In free-field conditions over a reflecting plane, the standard deviations given in table 10 reflect the cumulative effects of all causes of measurement uncertainty, including variations from laboratory to laboratory, but excluding variations in the sound pressure 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.

7.3 Test environment

7.3.1 General

These measurements shall be carried out in a free field over a reflecting plane. Suitable environments are specified in 6.3.1.

7.3.2 Adequacy of the test environment

The test environment should be free from reflecting objects other than a reflecting plane so that the equipment radiates into a free field over a reflecting plane.

NOTE — Any deviations from these conditions may result in an increased sound pressure level and, therefore, in standard deviations greater than those given in table 10.

Standard deviations greater than those given in table 10 shall be reported. No environmental correction shall be made to compensate for an unfavourable test environment.

7.3.3 Level of background noise

At the microphone positions, the levels of the background noise shall be at least 6 dB, and preferably more than 10 dB, below either the sound pressure level to be measured in each frequency band within the frequency range of interest or the A-weighted sound pressure level.

7.3.4 Temperature and relative humidity

The environmental conditions shall be as specified in 6.3.4.

7.4 Instrumentation

Instrumentation shall be designed in accordance with either 5.4 or 6.4 with the following provisos:

- The microphone shall meet the requirement of 6.4.2.
- There is no requirement for spatial averaging of sound pressure level.
- The microphone shall be stationary during the measurement except when standing waves or interference requires otherwise (see note 2 to 7.7.1).

7.5 Installation and operation of equipment

Equipment shall be installed and operated in accordance with the requirements of 6.5 except that table-top equipment shall always be installed on a standard test table without extension tables.

7.6 Microphone positions

7.6.1 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 $1,5 \text{ m} \pm 0,03 \text{ m}$ above the floor (see figure 3).

For equipment which is operated from a seated position, the microphone shall be located $1,2 \text{ m} \pm 0,03 \text{ m}$ above the floor.

The horizontal distance from the reference box shall be $0,25 \text{ m} \pm 0,03 \text{ m}$ (see figure 3), unless this distance is not representative of the operator position: in which case the representative operator position shall be described and shall be used.

NOTE — During this measurement, the operator should be absent, if possible, or move aside so that (s)he can still operate the equipment but not significantly disturb the sound field around the microphone.

7.6.2 At the bystander position(s)

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 $1\text{ m} \pm 0,03\text{ m}$ away from the projection of the reference box on the horizontal plane and $1,5\text{ m} \pm 0,03\text{ m}$ above the floor. The four preferred bystander positions are centred at the front, rear, right and left sides of the equipment. If the length of any side of the reference box

exceeds 2 m, additional bystander positions at 1 m intervals should be used.

7.6.3 Microphone orientation

The microphone 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, the primary sound source is assumed to be 30° below horizontal (see figure 3).

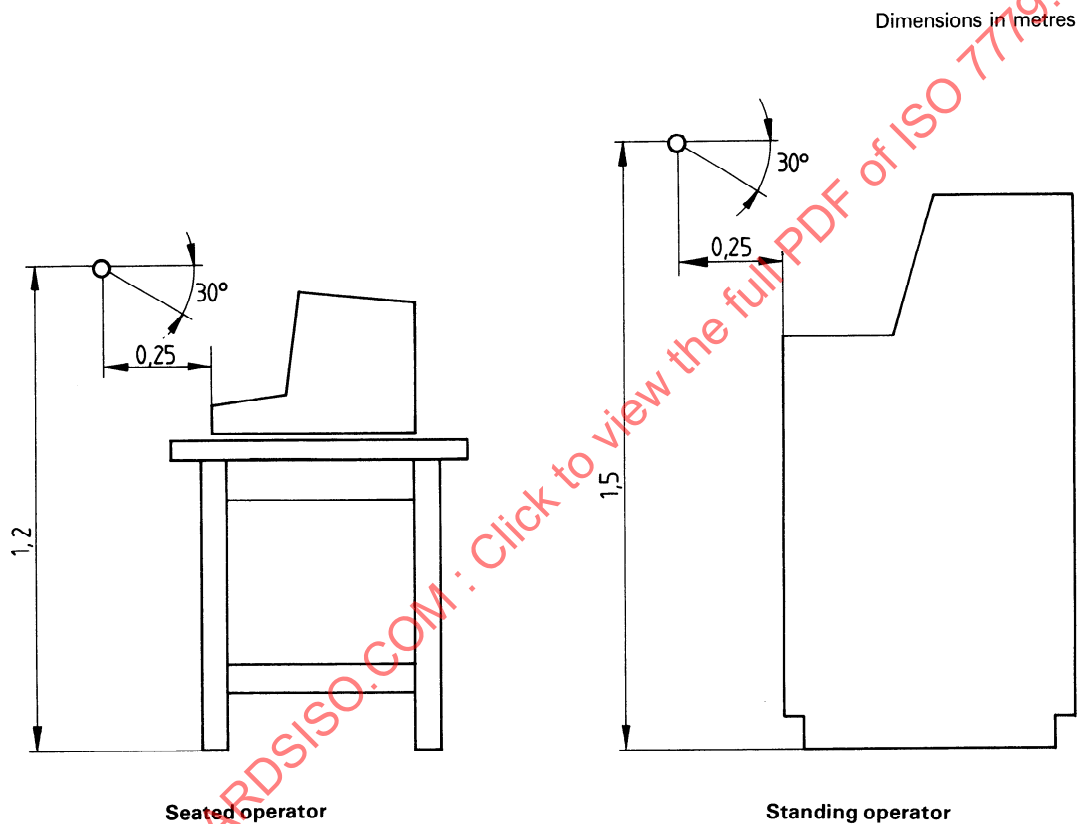


Figure 3 — Examples of microphone positions for standing and seated operators

7.7 Measurement of sound pressure levels

7.7.1 General

Measurements of the sound pressure level required by this clause shall be carried out at the microphone positions specified in 7.6 with A-weighting and for each frequency band within the frequency range of interest, if required. The following data shall be obtained:

- the A-weighted sound pressure levels and band sound pressure levels, if required, for the specified modes of operation of the equipment;
- the A-weighted sound pressure levels and band sound pressure levels, if required, of the background noise (including noise from support equipment).

NOTES

- When using a sound level meter, the person reading the meter should 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 mean value of the sound pressure level be recorded.
- Measurements of impulsive sound pressure levels and discrete tones, if required, should be carried out in accordance with annex D.

7.7.2 Measurement duration

The measurement duration shall be as specified in 6.7.2.

7.7.3 Corrections for background noise

If the level of 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:

$$B = L_c - 10 \lg (10^{0,1L_c} - 10^{0,1L_b}) \quad \dots (14)$$

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.

7.7.4 Corrections for unwanted reflections

No corrections are permitted.

7.8 Calculation of the mean sound pressure level at the bystander position

If bystander positions are defined, the mean A-weighted sound pressure level, $\overline{L_{pA}}$, and the mean band pressure levels, $\overline{L_p}$, if required, at the four (or more) bystander positions defined in 7.6.2, shall be calculated as specified in 6.9.1.

7.9 Information to be recorded

The information (when applicable) specified in 7.9.1 to 7.9.4 shall be recorded for all sound pressure level measurements at operator or bystander positions.

7.9.1 Equipment being tested

The following information shall be recorded:

- a description of the equipment being tested (including main dimensions);
- operating conditions;
- installation conditions;
- the location of equipment in the test environment;
- if the equipment has multiple operating modes, a description of each individual mode for which measurements have been carried out.

7.9.2 Acoustical environment

The following information shall be recorded:

- a description of the acoustical environment — if indoors, the size and acoustical characteristics of the room, including absorptive properties of the walls, ceiling and floor;
- environmental correction resulting from the acoustical qualification of test environment in accordance with ISO 3744, annex A;
- the air temperature, in degrees Celsius, relative humidity, as a percentage, and barometric pressure, in kilopascals.

7.9.3 Instrumentation

The following information shall be recorded:

- equipment used for the measurements, including name, type, serial number and manufacturer;
- bandwidth of frequency analyser;
- frequency response of the instrumentation system;

- d) method used for checking the calibration of the microphones and other system components: the date and place of calibration shall be given;
- e) method used for determining the mean value of the sound pressure level and the impulse sound pressure level.

7.9.4 Acoustical data

The following information shall be recorded:

- a) the measurement positions and microphone orientations (preferably including a sketch);
- b) if an operator position is defined according to 7.6.1, the A-weighted sound pressure level, L_{pA} , in decibels, rounded to the nearest decibel measured at the operator position(s) for both the idling and operating modes;
- c) if bystander positions are defined according to 7.6.2, the mean A-weighted sound pressure level, L_{pA} , in decibels, rounded to the nearest decibel, calculated according to 7.8, for both the idling and operating modes;
- d) the impulsive parameter, ΔL_I , in decibels, if $\Delta L_I \geq 3$ dB, in accordance with the procedure outlined in annex D;
- e) optionally, the frequency, in hertz, of any prominent tones identified in accordance with the procedure of annex D and the quantity $(L_t - L_n)$, in decibels, associated with that prominent tone;

- f) the corrections, if any, for background noise;
- g) the date, time and place where the measurements were carried out, and the name of the person who carried out the measurements.

7.10 Test report

The test report shall contain the statement that the sound pressure levels have been obtained in full conformity with the procedures specified in clause 7 of this International Standard. The test report shall state that these sound pressure levels are given in decibels (reference: 20 μ Pa). The test report shall contain the following information:

- a) the name(s) and model number(s) of the equipment being tested;
- b) if an operator position is defined according to 7.6.1, the A-weighted sound pressure level, in decibels, at the operator position(s) for the idling and operating modes;
- c) if bystander positions are defined according to 7.6.2, the mean A-weighted sound pressure level, in decibels, at the four (or more) positions around the equipment for the idling and operating modes;
- d) detailed description of the operating conditions of the equipment being tested with reference to annex C, if applicable.

Annex A

Standard test table

(This annex forms an integral part of the standard.)

A suitable design for a standard test table is shown in figure 4 below. The table shall be made of laminated wood, 0,04 to 0,1 m thick, having a minimum area of 0,5 m² and a minimum lateral dimension of 0,7 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 through their bottom cover.

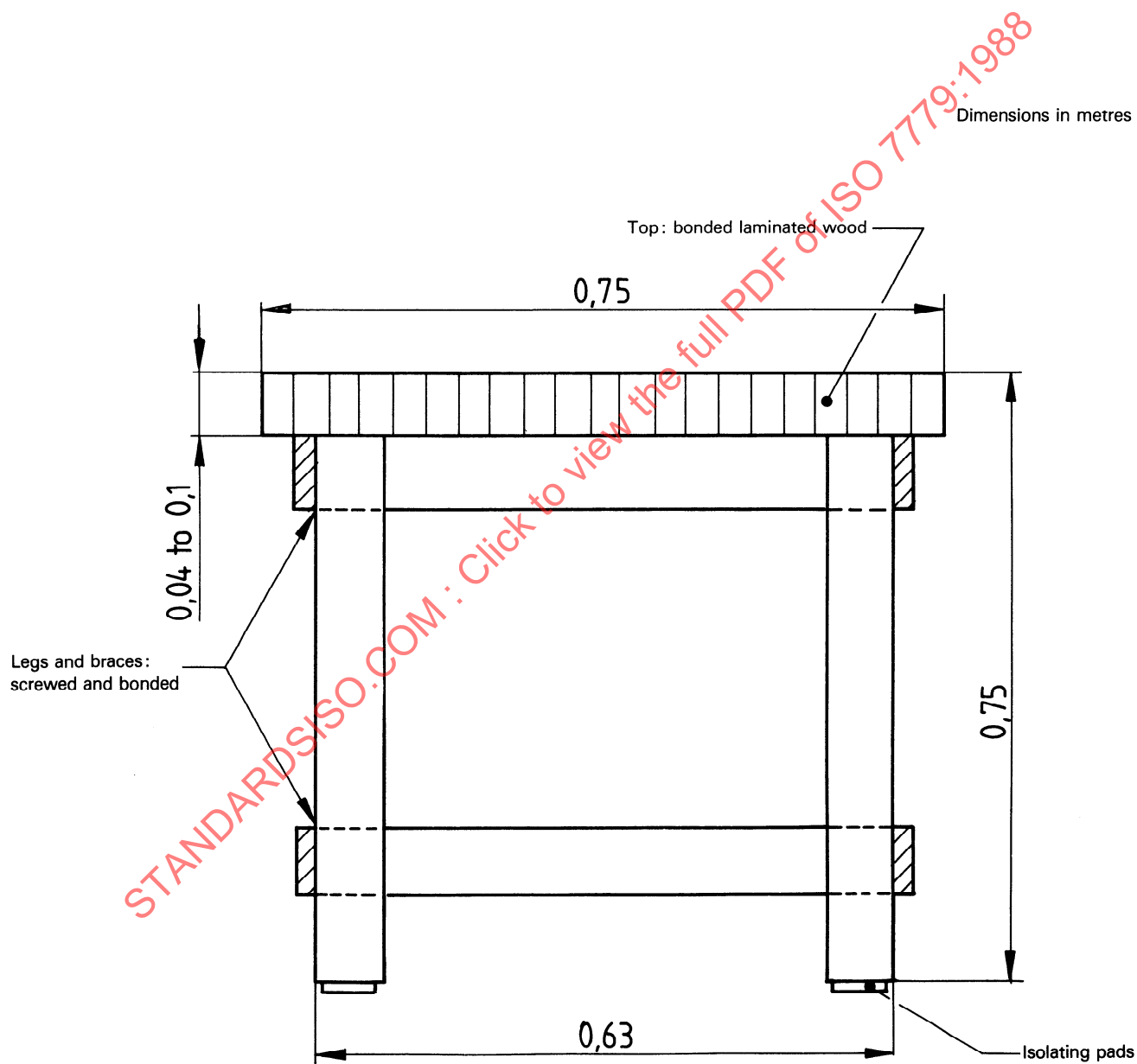


Figure 4 — Example of a standard test table

Annex B

Alternative measurement surfaces for sound power measurements
in accordance with clause 6

(This annex forms an integral part of the standard.)

In some cases a spherical measurement surface (sphere, hemisphere or quarter-sphere) may be used instead of the parallelepiped which is preferred for computers and business equipment. This is mainly recommended for small equipment for which the reference box is small, e.g. not exceeding 0,4 m in length and 0,2 m in height and for which the measuring distance is equal to 1 m. In this case, the spherical measurement surface shall have a radius of at least 1 m; see ISO 3745 for measurement positions.

B.1 Arrangement 3: Hemispherical measurement surface — 10 measurement positions (see table 11 and figure 5)

Table 11 — Hemispherical measurement surface — 10 measurement positions

Position No.	$\frac{x}{r}$	$\frac{y}{r}$	$\frac{z}{r}$
1	− 0,99	0	0,15
2	0,5	− 0,86	0,15
3	0,5	0,86	0,15
4	− 0,45	0,77	0,45
5	− 0,45	− 0,77	0,45
6	0,89	0	0,45
7	0,33	0,57	0,75
8	− 0,66	0	0,75
9	0,33	− 0,57	0,75
10	0	0	1

B.2 Arrangement 4: Hemispherical measurement surface — 10 measurement positions (see table 12)

If the equipment emits prominent tones, strong interference effects may occur if several microphone positions are placed at the same height above the reflecting plane. In such cases the use of a microphone array with the coordinates given in table 12 is recommended.

Table 12 — Hemispherical measurement surface — 10 measurement positions

Position No.	$\frac{x}{r}$	$\frac{y}{r}$	$\frac{z}{r}$
1	0,16	− 0,96	0,22
2	0,78	− 0,6	0,2
3	0,78	0,55	0,31
4	0,16	0,9	0,41
5	− 0,83	0,32	0,45
6	− 0,83	− 0,4	0,38
7	− 0,26	− 0,65	0,71
8	0,74	− 0,07	0,67
9	− 0,26	0,5	0,83
10	0,1	− 0,1	0,99

Measurement surface area $S = 2 \pi r^2$

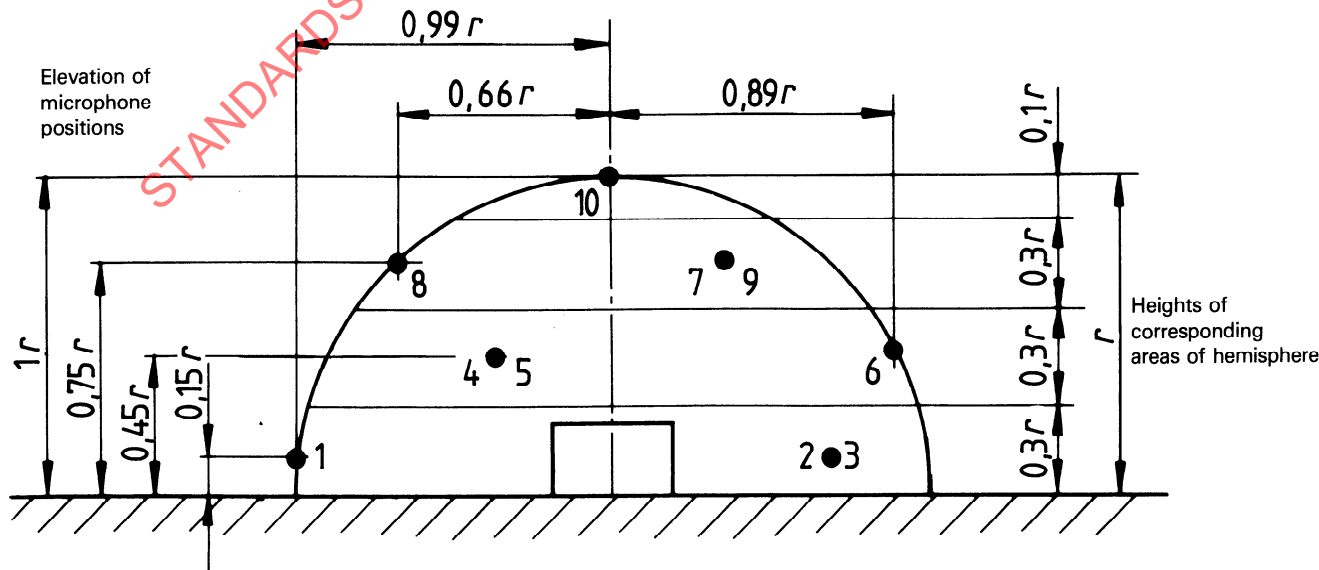


Figure 5 — Hemispherical surface — 10 measurement positions

B.3 Arrangement 5: Coaxial circular paths in parallel planes for microphone traverses in a free field over a reflecting plane (see figure 6)

The paths are selected so that each path is associated with a zone of equal area.

B.4 Arrangement 6: Quarter-sphere measurement surface — 5 measurement positions

The measurement positions are those numbered 2, 3, 6, 7 and 9 in arrangement 3.

Measurement surface area $S = \pi r^2$

This arrangement should only be used where small equipment is to be placed against two perpendicular reflecting planes.

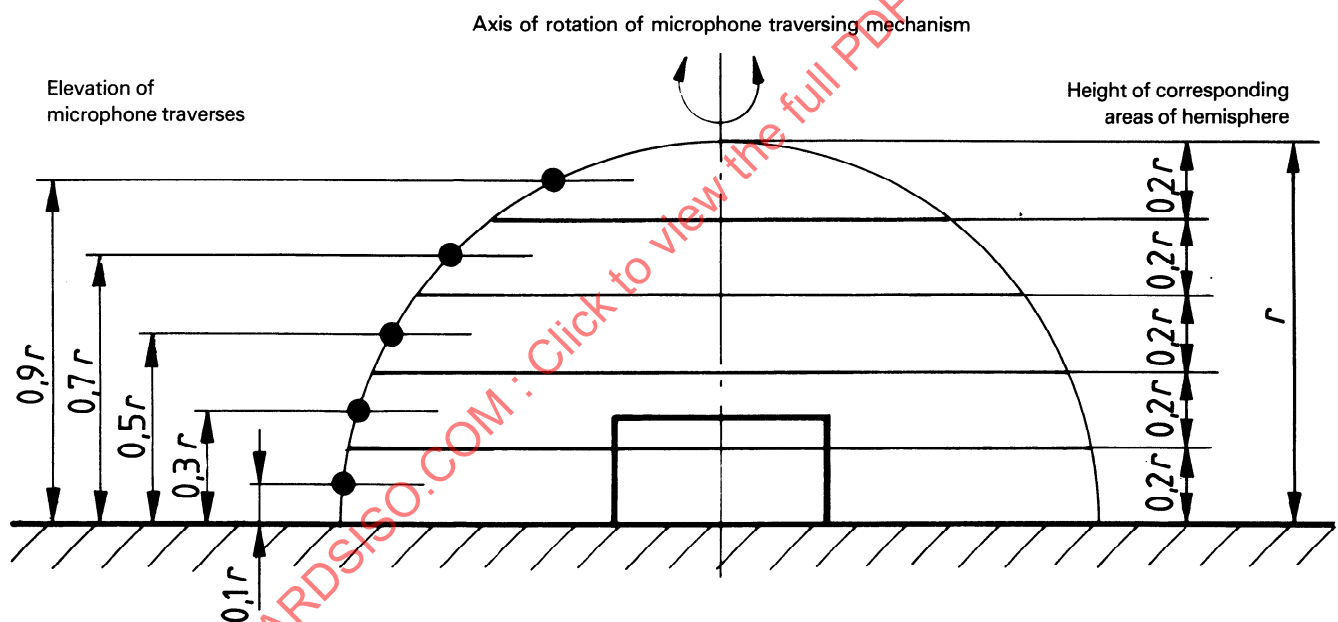


Figure 6 — Hemispherical measurement surface — Circular paths for microphone traverses

Annex C

Installation and operating conditions for specific equipment categories

(This annex forms an integral part of the standard.)

C.1 General

This annex specifies installation and operating conditions for many specific categories of equipment. When testing such equipment, the conditions shall be satisfied in order to comply with this International Standard. For categories of equipment not covered in this annex, the actual test conditions used shall be described and justified in the test report.

The conditions specified in this annex are considered to be typical of average end use. Where end use is too difficult to simulate, equivalent conditions are specified with a view to facilitating the operation of the equipment and to enhancing the reliability of the acoustic measurements.

C.2 Equipment category: Typewriters

C.2.1 Description

typewriters: Equipment which prints information on paper, normally equipped with a keyboard for manual information entry. The information is either keyed-in and immediately printed on paper character-by-character (manual typing), or keyed-in and stored for word or line editing (interactive operation). Typewriters which are equipped with a full-page storage are considered as typewriters during manual typing and as printers (see clause C.3) during automatic print-out on a full page.

C.2.2 Installation

Equipment shall be installed in accordance with the relevant clauses of this International Standard.

C.2.2.1 Type font

If the typewriter allows the use of different type fonts or different type elements, a fine line typestyle (e.g. pica, elite) shall be used with a pitch typical of normal use.

C.2.2.2 Paper

Single sheets of paper weighing approximately 75 g/m², in the ISO A4 or equivalent format shall be used, unless the typewriter is designed for special paper having a different weight; in this case, the special paper shall be used. Paper shall be inserted in vertical format with left-hand edge at zero; the leading edge of paper sheet shall be fed through to approximately 1/3 of the paper length (or 100 mm) lower than the trailing edge (see figure 7).

The paper shall have been stored unpacked and exposed to the environmental conditions specified in 5.3.4 or 6.3.4 for seven days immediately prior to the test.

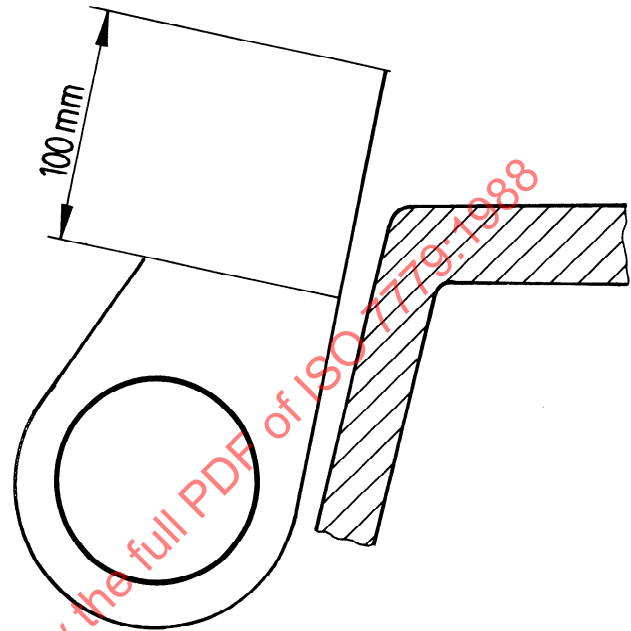


Figure 7 — Insertion of a single sheet of paper

C.2.3 Operation

C.2.3.1 Idling mode

Power shall be switched on; the equipment shall be ready for information entry and/or print-out. Paper shall be inserted in accordance with figure 7.

C.2.3.2 Typing mode

The typing mode consists of keying-in the specified character pattern and printing it on paper. The force necessary to depress the key completely shall be adjustable. Keying-in should preferably be performed with a suitable electromagnetic robot to simulate manual keystrokes. The noise level due to the operation of the robot alone should be at least 10 dB below the level of operation. The robot may consist of several electronically controlled electromagnets, fixed on a frame and positioned above the keyboard.

Typing shall be started in the second quarter of the paper length, as specified in figure 7, and shall continue down the paper length for not more than one-third of the total paper depth from the starting point. The following settings, when applicable, shall be used.

C.2.3.2.1 Impression control

As recommended for a single sheet of paper (usually "weak").

C.2.3.2.2 Multi-copy control

Set for a single sheet.

C.2.3.2.3 Line spacing

Double line spacing.

C.2.3.2.4 Margin

The margin shall be set at 25 mm from the edges. The end-of-line indicator (bell) shall be disconnected.

C.2.3.2.5 Paperbail rollers

The paperbail rollers shall be positioned 25 mm from the edges of the paper, with the others equally spaced between.

C.2.3.2.6 Character pattern

The test pattern characters shall be:

etnaiv etnaiv etnaiv etnaiv...

and so on until a full printline of approximately 60 characters has been completed. The space between each group of six characters is intentional. The carriage return after each line is part of the operation.

NOTES

1 A maximum of two characters may be replaced by other small letters if there is a need for alteration.

2 Should small letters not be available, capital letters may be used instead; equivalent conditions may be selected for typewriters with special character sets.

C.2.3.3 Operating speed

The operating speed shall be as follows:

- a) for non-interactive operation: the typing speed shall be 5 characters per second.

NOTE — A typing robot as described in C.2.3.2 should preferably be used to perform this operation; alternatively manual typing may be used.

- b) for interactive operation: the specified characters shall be keyed-in at a rate of 5 characters per second until the buffer is filled up; a maximum buffer capacity of one printline shall not be exceeded. Immediate printing of the stored information (maximum of one line) at rated printing speed is required.

C.2.4 Measurement duration

The time-average sound pressure level shall be measured, for at least the duration given in 5.7.2 or 6.7.2, during the following operations:

- a) for non-interactive operation: continuous typing for at least three full lines;
- b) for interactive operation: keying-in and print-out until at least three full lines have been printed.

C.3 Equipment category : Printers**C.3.1 Description**

printers: Electronically controlled equipment which prints stored information on paper and is not normally keyboard-

operated. The output may be obtained by means of printing (e.g. typebar-, train-, chain- or bandprinters, typewheel, type-element or matrix printers) or by non-impact printing (e.g. ink jet, electro-erosion, thermal or laser printers).

C.3.2 Installation

Printers which are placed on a normal office table or desk and which take paper from, or stack paper on, the floor shall, if possible, be placed in the centre of the top plane of the standard test table, using the floor to support the paper. For measurements in accordance with clause 6, the measurement surface terminates on the reflecting floor.

Floor-standing printers, printers with a special stand and table-top printers which do not use the floor for paper supply or exit stacking shall be installed in accordance with the relevant clauses of this International Standard.

C.3.2.1 Type font

If the printer allows the use of different type fonts or different type elements, a type font typical of normal use, with the exception of condensed or extended characters, shall be selected.

C.3.2.2 Paper

Either single sheets of paper, weighing approximately 75 g/m², or continuous, folded or rolled stationery, weighing approximately 55 g/m², shall be used, unless the printer is designed for special paper having a different weight; in this case, the special paper shall be used. The size of the paper shall be as close as possible to the maximum capacity of the printer. The form width shall be typical for the printer; if different widths can be used, the most common one shall be used and described in the report. For special applications (e.g. passbook or cheque processing) the material shall be typical for customer usage and shall be described in the test report.

The paper shall have been stored unpacked and exposed to the environmental conditions specified in 5.3.4 or 6.3.4 for seven days immediately prior to the test.

C.3.3 Operation**C.3.3.1 Idling mode**

Power shall be switched on; the equipment shall be ready for printing.

C.3.3.2 Paper position

Except when single sheets are being used, the paper shall be loaded and fed through for a length of at least ten times its width. If single sheets are being used, the paper should be inserted in such a way that it can be printed on at least 60 % of the page length with the printing area centred vertically.

C.3.3.3 Print mode

The print mode consists of printing a specified character pattern on paper. The following settings, when applicable, shall be used.

C.3.3.3.1 Impression control

As recommended for a single sheet of paper.

C.3.3.3.2 Multi-copy control

Set for a single sheet.

C.3.3.3.3 Line spacing

Double line spacing: skip 20 to 30 mm on each side of the paper fold.

C.3.3.3.4 Margin

The margin shall be set at 25 mm from the edges (excluding the perforation strip).

C.3.3.3.5 Character pattern

The full content of a 40-character test pattern is given below

J1YY7 2DA90 8S8=2 6AI8Q B31AJ 5FT0E PG1TK X6D-4

If the line comprises fewer characters, those characters on the left-hand side of the pattern shall be used. The character pattern shall be arranged in groups of five printed characters followed by five blank spaces. The position of the pattern should preferably be shifted by five characters each line using an end-around shift over the available line length.

NOTE — If some of the specified characters are not available, alternative characters accounting for up to 20 % of the characters in one line may be used. If a printer prints both capital and small letters, the first character of each 5-character group, if a letter, should be a capital letter. For printers which print only numerical information a random set of numbers should be selected and reported.

The number of characters to be printed in one line depends on the printer itself and is given in table 13.

Table 13 — Number of characters to be used

Available line length, in characters	Number of characters to be used
< 40	50 % of maximum line length
40 to 59	20 characters
60 to 110	30 characters
> 110	40 characters

NOTE — Examples of character patterns are given in figures 8 and 9.

C.3.3.3.6 Set of characters

If the printer can be used with different sets of characters, a set of characters shall be chosen which corresponds to normal use, with the exception of condensed or extended characters.

C.3.3.3.7 Density of characters or lines

If possible, the printer shall be set at 10 pitch (characters per inch) and 6 lines per inch (lpi). If this is not possible, an adjustment as close as possible to these values shall be chosen.

C.3.3.4 Operating speed

The rated speed for which the printer is designed shall be used; if several speeds are provided, the one which is typical of the majority of uses shall be employed and reported. Additional conditions may be specified for special applications.

C.3.4 Measurement duration

The time-average sound pressure level shall be measured, for at least the duration given in 5.7.2 and 6.7.2, during the following operations:

- single-page form: continuous printing for at least 60 % of the page length with the printing area centred vertically. If the printer has an automatic paper feed mechanism, the test shall be extended to three pages;
- folded stationery: continuous printing for at least three pages;
- rolled stationery: continuous printing for a length equal to at least the paper width;
- passbook: printing the middle pages for a complete operation cycle from insertion to ejection.

C.4 Equipment category: Teleprinters**C.4.1 Description**

teleprinters: Equipment operating as a send/receive machine basically comprising a keyboard, a printing unit, a mechanical or electronic send/receive unit (line control unit) and an integrated or optional memory unit (electronic, paper tape punch/reader, magnetic tape disk or cassette).

Two typical uses are:

- Keyboard operation (when in local or transmission mode): the information is keyed-in by manual typing and immediately printed on paper and/or stored in the memory. In this case, the teleprinter is considered to be a typewriter in accordance with clause C.2, with interactive operation, if available.
- Automatic operation (when in local or on-line mode): the machine prints automatically the information received from line network or from memory unit. In this case, the teleprinter is considered to be a printer in accordance with clause C.3.

If a teleprinter is fitted with an auxiliary unit which produces noise (paper tape punch/reader, magnetic tape disk or cassette), the machine shall be tested with and without the unit in operation.

In some cases, a teleprinter can be available in receive-only configuration (without keyboard). That machine is considered to be a printer in accordance with clause C.3.

Margin of 25 mm

Available line length (65 characters)

20 to 30 mm skip

Margin of 25 mm

J1YY7	2DA90	BS8=2	6A18Q	B31AJ	5FTOE
J1YY7	2DA90	BS8=2	6A18Q	B31AJ	5FTOE
J1YY7	2DA90	BS8=2	6A18Q	B31AJ	5FTOE
5FTOE	J1YY7	2DA90	BS8=2	6A18Q	B31AJ
5FTOE	J1YY7	2DA90	BS8=2	6A18Q	B31AJ
B31AJ	5FTOE	J1YY7	2DA90	BS8=2	6A18Q
B31AJ	5FTOE	J1YY7	2DA90	BS8=2	6A18Q
6A18Q	B31AJ	5FTOE	J1YY7	2DA90	BS8=2
6A18Q	B31AJ	5FTOE	J1YY7	2DA90	BS8=2
BS8=2	6A18Q	B31AJ	5FTOE	J1YY7	2DA90
BS8=2	6A18Q	B31AJ	5FTOE	J1YY7	2DA90
2DA90	BS8=2	6A18Q	B31AJ	5FTOE	J1YY7
2DA90	BS8=2	6A18Q	B31AJ	5FTOE	J1YY7
J1YY7	2DA90	BS8=2	6A18Q	B31AJ	5FTOE
J1YY7	2DA90	BS8=2	6A18Q	B31AJ	5FTOE
J1YY7	2DA90	BS8=2	6A18Q	B31AJ	5FTOE
5FTOE	J1YY7	2DA90	BS8=2	6A18Q	B31AJ
5FTOE	J1YY7	2DA90	BS8=2	6A18Q	B31AJ
B31AJ	5FTOE	J1YY7	2DA90	BS8=2	6A18Q
B31AJ	5FTOE	J1YY7	2DA90	BS8=2	6A18Q
6A18Q	B31AJ	5FTOE	J1YY7	2DA90	BS8=2
6A18Q	B31AJ	5FTOE	J1YY7	2DA90	BS8=2
BS8=2	6A18Q	B31AJ	5FTOE	J1YY7	2DA90
BS8=2	6A18Q	B31AJ	5FTOE	J1YY7	2DA90
2DA90	BS8=2	6A18Q	B31AJ	5FTOE	J1YY7
2DA90	BS8=2	6A18Q	B31AJ	5FTOE	J1YY7
J1YY7	2DA90	BS8=2	6A18Q	B31AJ	5FTOE

20 to 30 mm skip

Figure 8 — Example of full print page: line length of 60 to 110 characters

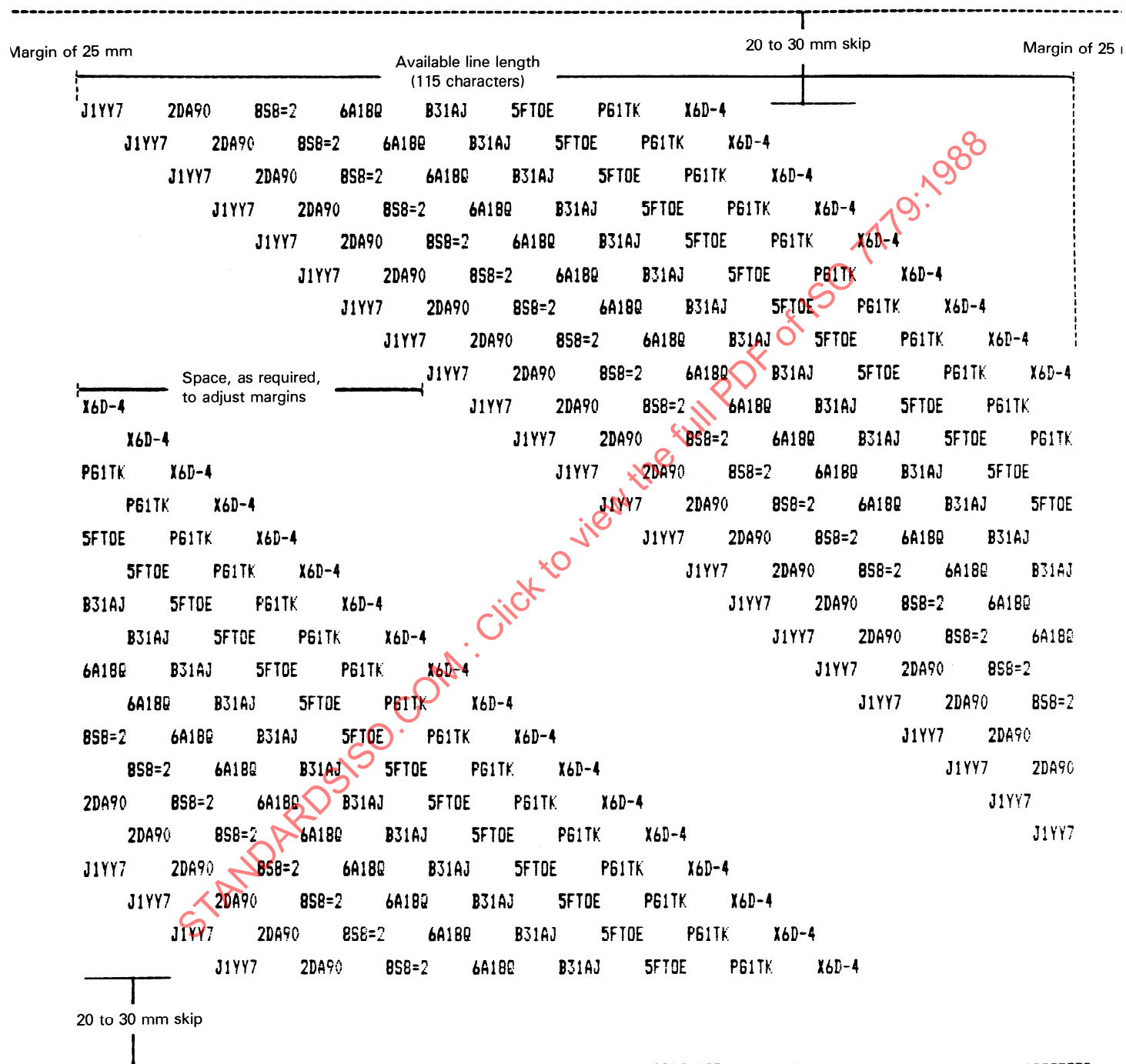


Figure 9 — Example of full print page: line length of more than 110 characters

C.4.2 Installation

C.4.2.1 General

For keyboard operation of the teleprinter, the general installation condition for typewriters (see C.2.2) apply.

For automatic operation of the teleprinter, the general installation conditions for printers (see C.3.2) apply.

C.4.2.2 Paper

Either single sheets of paper, weighing approximately 75 g/m², or continuous folded or rolled stationery, weighing approximately 55 g/m², shall be used. The form width shall be typical for the printer; if different widths can be used, the most common one shall be used and described in the report.

If in typical use, multi-part stationery is employed, an additional test with such stationery shall be carried out and reported.

The paper shall have been stored unpacked and exposed to the environmental conditions specified in 5.3.4 or 6.3.4 for seven days immediately prior to the test.

C.4.3 Operation

C.4.3.1 Idling mode

Power shall be switched on; the equipment shall be ready for printing.

C.4.3.2 Print mode

For keyboard operation of the teleprinter, the operating conditions specified for typewriters shall apply (see C.2.3).

For automatic operation of the teleprinter, the operating conditions specified for printers shall apply (see C.3.3).

C.4.3.3 Operating speed

For keyboard operation of the teleprinter, the operating speed shall be as specified for typewriters (see C.2.3.3).

For automatic operation of the teleprinter, the operation speed should, preferably, correspond to the rated speed typical of the majority of uses; transmission rates of 50, 300 and 1 200 baud are common. The transmission rate used shall be reported. In addition, the teleprinter shall be operated at its highest rated speed which shall also be reported.

C.4.4 Measurement duration

The time-average sound pressure level shall be measured for at least the duration given in 5.7.2 or 6.7.2.

For keyboard operation of the teleprinter, the requirements specified for typewriters shall apply (see C.2.4).

For automatic operation of the teleprinter, the requirements specified for printers shall apply (see C.3.4).

C.5 Equipment category: Keyboards

C.5.1 Description

keyboards: Equipment for manual data entry, fixed or connected via a cable to other units, e.g. visual display units, computer console, hand-held calculator, etc.

C.5.2 Installation

Equipment shall be installed in accordance with the relevant clauses of this International Standard.

C.5.3 Operation

C.5.3.1 Operating mode

Keying-in shall be performed at a rate of five characters per second. A suitable electromagnetic robot should be used to simulate manual keystrokes. The noise level due to the operation of the robot alone should be at least 10 dB below the level of operation. The force necessary to depress the key completely shall be adjustable.

For other requirements of the robot, see C.2.3.2.

If the keyboard has an acoustic feedback, the minimum volume setting shall be used for the test.

NOTE — If a typing robot is not available, manual keying-in may be used.

C.5.3.2 Test pattern

For alphanumeric keyboards, the test pattern shall be as specified for typewriters (C.2.3.2.6).

For numeric keyboards without alphanumeric keyboard, the test pattern shall be four digits plus function key.

C.6 Equipment category: Duplicators

C.6.1 Description

duplicators: Equipment which can produce one or more copies from a master. Such equipment can be linked up to a number of additional attachments, in particular with a sorter, with or without automatic stapling, a master loading device and a special paper feeder for continuous stationery or label printing.

C.6.2 Installation

Duplicators which are placed on a normal office table or desk and which take paper from, or stack paper on, the floor shall, if possible, be placed in the centre of the top plane of the standard test table, using the floor to support the paper. For measurements in accordance with clause 6, the measurement surface terminates on the reflecting floor.