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EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

STANDARD ECMA-160

DETERMINATION OF SOUND POWER LEVELS OF COMPUTER AND BUSINESS EQUIPMENT USING SOUND INTENSITY MEASUREMENTS; SCANNING METHOD IN CONTROLLED ROOMS

2nd Edition - December 1992

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Brief History

This ECMA Standard specifies methods for the measurement of sound power levels of the airborne noise emitted by computer and business equipment using sound intensity techniques, scanning methods.

The sound power radiated by equipment under test is given by the integral over a surface enclosing the equipment of the normally directed component of sound intensity. The previous standards for the determination of sound power levels of computer and business equipment are based on measurements of sound pressure under specific measurement conditions, mainly as described in ECMA-74 (ISO 7779) which is based on ISO 3741, ISO 3742, ISO 3744 and ISO 3745. This ECMA Standard provides methods for the determination with engineering grade accuracy of sound power levels of computers and business equipment by using scanning techniques to measure sound intensity.

The relationship between sound intensity level and sound pressure level at any point in space depends on the characteristics of the equipment, the characteristic of the measurement environment and the disposition of the measurement positions with respect to the noise source. Therefore the previous standards necessarily specify the source characteristics, the test environment characteristics and qualification procedures, and the measurement methods which are expected to restrict the uncertainty of the sound power level determination to within acceptable limits. However, the previous methods are not applicable when the equipment is to be measured in rooms other than reverberation rooms (ISO 3741 or ISO 3742) or essentially free field over reflecting planes (ISO 3744 or ISO 3745). The purpose of this ECMA Standard is to obtain a practical and sufficiently precise method of sound power determination of computer and business equipment by using sound intensity measurement technique. Thus the sound power level of computer and business equipment can be determined with engineering grade accuracy in rooms other than those required by ECMA-74, clauses 5 and 6.

The scanning method has been selected for use in this ECMA Standard instead of the fixed-point method because of its ease of use in measuring computer and business equipment and its potential for increased accuracy.

The bases for the first edition were:

Draft Danish Standard DS F 88/146: "Acoustics - Determination of Sound Power levels of Noise Sources using Sound Intensity Measurements. Scanning Method for use in situ" (April 1988) and ISO/DIS 9614-1. This second edition has been revised to ensure compatibility with ISO/DIS 9614-2.

Adopted as 2nd Edition of Standard ECMA-160 by the General Assembly of December 1992.

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1 General

1.1 Scope

This ECMA Standard specifies a procedure for the determination of sound power levels of computers and business equipment under its normal operating conditions (see ECMA-74), by using sound intensity measurements in rooms other than dedicated acoustical laboratories. The sound intensity distribution is measured on a surface enclosing the equipment under test.

The measurement procedure is based on a scanning technique, i.e. continuously moving the intensity probe across the measurement surface following a pre-defined pattern while the instrument is integrating. The measurements give the total radiated airborne sound power from a noise source.

The basic emission quantity for computer and business equipment is the A-weighted sound power level (sound power levels may also be determined in one-third octave or octave bands). The sound power levels may be used for declaration and comparison purposes (see ECMA-109) for equipment of the same type but from different manufacturers, or of different types. They are not to be considered as installation noise immission levels; however they may be used for installation planning (see ECMA TR/27).

The purpose of this measurement procedure is to obtain sound power levels in "controlled" environments using sound intensity procedures with an engineering grade accuracy that is comparable to that of the methods of clauses 5 and 6 of ECMA-74. The measurements performed using this Standard are made in less restrictive environments than special acoustical rooms; however, if the source is closer to a wall than specified in ECMA-74, the sound power emitted from the source may be different from that emitted in a reverberation room or in an hemi anechoic room, although this difference is not expected to be significant.

The scanning sound intensity technique in this Standard to determine sound power levels is an alternative to the two procedures in ECMA-74; however, ECMA-74, clause 7 must be used to determine the A-weighted sound pressure level at the bystander or operator position.

This scanning method can be used for checking whether the declared noise emission values reported in specification sheets, for example, according to ISO/IEC 11159 and ISO 11160 are, indeed, met by installed equipment. The advantage of this method is that this check can be made in ordinary rooms, which reduces the time and cost involved considerably.

This measurement procedure is not intended for the identification of noise sources within the equipment under test.

This standard gives requirements for the acoustical environment, extraneous noise, measurement surface, and scanning technique for the intensity measurement. The procedure for calculating sound power from sound intensity is given. The noise of the equipment under test has to be stationary so that proper time and spatial integration is obtained while scanning over the measurement surface. The measurement of isolated bursts of sound energy is thus not covered by the method, unless the isolated bursts are repeatable and special precautions are utilized during the scanning.

Surface integration of the intensity component normal to the measurement surface is approximated by subdividing the measurement surface into contiguous segments, and scanning the probe over each segment along a continuous path which covers the extent of the segment. The measurement instrument continuously time-integrates the normal intensity component and squared sound pressure over the duration of each scan. The scanning operation may be performed either manually or by means of a mechanical system.

The one octave, one-third octave or band-limited weighted sound power level is calculated from the measured values. The method is applicable to any computer and business equipment for which a physically stationary measurement surface can be defined, and on which the noise generated by the source is stationery in time, as defined in 4.12.

This Standard specifies certain ancillary procedures, described in annex B, to be followed in conjunction with the sound power determination. The results are used to indicate the quality of the determination, and hence the grade of accuracy. If the indicated quality of the determination does not meet the requirements of the Standard, the test procedure must be modified in the manner indicated in this Standard.

1.2 Field of Application

This Standard is suitable for type tests of computer and business equipment and provides methods for manufacturers and testing laboratories to obtain comparable results.

The methods specified in this Standard allow the determination of noise emission levels (sound power levels) for a unit tested individually.

The sound power and the sound pressure levels obtained may serve noise emission declaration and comparison purposes (see ECMA-109). They are not to be considered as installation noise immission levels; however they may be used for installation planning (see ECMA TR/27).

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

1.3 Character of noise radiated by the source

The noise radiated by the source shall be stationary in time, as defined in 4.12. If a source operates according to a duty cycle, within which there are distinct continuous periods of steady operation, for the purposes of application of this Standard an individual sound power level is determined and reported for each distinct period. Action shall be taken to avoid measurement during times of operation of non-stationary extraneous noise sources of which the occurences are predictable (see table B.3)

1.4 Measurement uncertainty

For the purpose of application of this Standard engineering grades of accuracy are defined in table 1. The stated uncertainties account for random errors associated with the measurement procedure, together with the maximum measurement bias error which is limited by the selection of the bias error factor K appropriate to the required grade of accuracy (see table 2). They do not account for tolerances in nominal instrument performance which are specified in IEC 1043. Nor do they account for the effects of variation in source installation, mounting and operating conditions.

NOTE 1

For the purpose of this Standard, the normal range for A-weighted data is covered by the one octave bands from 125 Hz to 4 kHz, and the one-third octave bands from 100 Hz to 6,3 kHz. The A-weighted value which is computed from one octave band levels in the range 125 Hz to 4 kHz, and one-third octave band levels in the range 100 Hz to 6,3 kHz is correct if there are no significantly high levels in the band from 8 kHz to 10 kHz. For the purpose of this assessment, significant levels are band levels which after A-weighting are no more than 6 dB below the A-weighted value computed. If A-weighted measurements and associated sound power level determinations are made in a more restricted frequency range, this range must be stated in accordance with 10.6 c).

The uncertainty of determination of the sound power level of a noise source is related to the nature of the sound field of the source, to the nature of the extraneous sound field, to the absorption of the source under test, and to the form of intensity field sampling and measurement procedure employed. For this reason this Standard specifies initial procedures for the evaluation of indicators of the nature of the sound field which exists in the region of the proposed measurement surface (see annex A). The results of this initial test are used to select an appropriate course of action according to table B.2.

If only an A-weighted determination is required any single-A-weighted band level of 10 dB or more below the highest A-weighted band level shall be neglected. If more than one band level appear insignificant, they may be neglected if the level of the sum of the A-weighted sound powers in these bands is 10 dB or more below the highest A-weighted band level. If only a frequency-weighted overall sound power level is required, the uncertainty of determination of the sound power level in any band in which it is 10 dB or more below the overall weighted level, is irrelevant.

Table 1 - Uncertainty of determination of sound power level

Octave band centre frequencies Hz	One third octave band centre frequencies Hz	Standard deviations (s*) Engineering (grade 2) dB
125	50 to 160	3
250 to 500	200 to 630	2
1 000 to 4 000	800 to 5 000	1,5
	6 300	2,5
A-weighted (125 Hz - 4 kHz or 100 Hz - 6,3 kHz)		1,5

*) The true value of the sound power level is to be expected with a certainty of 95% in the range of ± 2 s about the measured value.

NOTE 2

The stated uncertainty of the A-weighted estimate does not apply if the total A-weighted power in the one-third octave bands outside the range 800 Hz to 5 000 Hz exceeds the total within this range: individual band uncertainties apply.

2 Conformance

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

- The measurement procedure, the installation, and the operating conditions specified by this Standard are fully taken into account.
- The engineering accuracy requirements are met as specified in 1.4.

It is recommended that personnel performing sound intensity measurements according to this Standard are trained and experienced in performing acoustical and sound intensity measurements.

NOTE 3

To insure the quality of measurements performed to this Standard, it is recommended that the person responsible for performing measurements for the purpose of determining or verifying declared values be accredited to perform such measurements by a national accreditation body certified to ISO 9000.

3 References

ECMA-74	Measurement of Airborne Noise Emitted by Computer and Business Equipment (1992)
ECMA-109	Declared Noise Emission Values of Computer and Business Equipment (1992)
ECMA TR/27	Method for the Prediction of Installation Noise Levels (1985)
ISO 2204:1979	Acoustics - Guide to International Standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings
ISO 6926:1990	Characterization and calibration of reference sound sources
ISO 7779:1988	Acoustics - Measurement of airborne noise emitted by computer and business equipment
ISO 9296:1988	Acoustics - Declared noise emission values of computer and business equipment
ISO/DIS 9614-1:*	Acoustics - Determination of sound power levels of noise sources using sound intensity - Measurement at discrete points
ISO/DIS 9614-2:*	Acoustics - Determination of sound power levels of noise sources using sound intensity - Part 2: Measurement by scanning

ISO/IEC 11159:1992	Information technology - Office equipment - Minimum information to be included in specification sheets - Copying machines
ISO 11160:1993	Information technology - Minimum information to be included in specification sheets - Printing machines
IEC 942:1988	Sound calibrators
IEC 1043:*	Instruments for the measurement of sound intensity

* : under development

4 Definitions

For the purpose of this Standard the definitions in ECMA-74 and the following additional definitions apply.

4.1 Dynamic capability index, L_d

$$L_d = \delta_{pI_0} - K = \delta_{pI_0} - 7 \tag{1}$$

The value of K is selected according to the grade of accuracy required (see table 2).

Table 2 - Bias error factor K

Grade of accuracy		Bias error factor K dB
Engineering	(grade 2)	10

4.2 Field indicators $F_{+/-}$ and F_{pI}

Field indicators are defined in annex A.

4.3 Measurement distance

The shortest distance between the physical surface of the equipment under test and the measurement surface.

4.4 Measurement surface

A hypothetical surface on which intensity measurements are made, and which either completely encloses the noise source under test, or, in conjunction with an acoustically rigid, continuous surface, encloses the noise source under test. In cases where the hypothetical surface is penetrated by bodies possessing solid surfaces, the measurement surface terminates at the lines of intersection between the bodies and the surface.

4.5 Measurement segment

For the purpose of this Standard a measurement surface is subdivided into a set of smaller areas known as segments.

4.6 Probe

That part of the intensity measurement system which incorporates the sensors.

4.7 Pressure-residual intensity index, δ_{pI_0}

The difference between indicated L_p and indicated L_{I_n} when the intensity probe is placed and oriented in a sound field such that the sound intensity is zero. Details for determining δ_{pI_0} are given in IEC 1043. In this case only, the subscript n indicates the direction of the probe axis.

$$\delta_{pI_0} = \left(L_p - L_{I_n}\right) \qquad (2)$$

4.8 Scan

A continuous movement of an intensity probe along a path prescribed on a segment of a measurement surface.

4.9 Sound intensity

4.9.1 Instantaneous sound intensity, *I*(*t*)

The instantaneous rate of flow of sound energy per unit of surface are in the direction of the local instantaneous acoustic particle velocity. This is a vectorial quantity which is equal to the product of the instantaneous sound pressure at a point and the associated particle velocity:

$$\boldsymbol{I}(t) = p(t) \cdot \boldsymbol{u}(t) \qquad (3)$$

where:

- $p(t)$ is the instantaneous sound pressure at a point;
- $\boldsymbol{u}(t)$ is the associated instantaneous particle velocity at the same point;
- t is time.

4.9.2 Sound intensity, *I*

The time-average value of $\boldsymbol{I}(t)$ in a temporally stationary sound field:

$$\boldsymbol{I} = \lim_{T \to \infty} \frac{1}{T}\int_0^T \boldsymbol{I}(t)\,dt \qquad (4)$$

where:

- T is the integration period.

also:

- I is the signed magnitude of $\boldsymbol{I}$: the sign is an indication of directional sense, and is dictated by the choice of positive direction of energy flow;
- $|I|$ is the unsigned magnitude of $\boldsymbol{I}$.

4.9.3 Normal sound intensity, I_n

The component of sound intensity in the direction normal to a measurement surface defined by unit normal vector $\boldsymbol{n}$.

$$I_n = \boldsymbol{I} \cdot \boldsymbol{n} \qquad (5)$$

where:

- $\boldsymbol{n}$ is the unit normal directed out of the volume enclosed by the measurement surface.

4.9.4 Normal sound intensity level, L_{I_n}

The logarithmic measure of the unsigned value of the normal sound intensity $|I_n|$, given by:

$$L_{I_n} = 10 \lg \frac{|I_n|}{I_0} \mathrm{dB} \qquad (6)$$

where:

I_0 is the reference sound intensity 10^{-12} Wm^{-2}.

Where I_n is negative, the level is expressed as (–) xx dB, except when used in the evaluation of δ_{pI_0} (see 4.7).

4.9.5 **Extraneous intensity**

The contribution to the sound intensity which arises from the operation of sources external to the measurement surface (source mechanisms operating outside the volume enclosed by the measurement surface).

4.10 **Sound power**

4.10.1 **Partial sound power, W_i**

The time-averaged rate of flow of sound energy through an element (segment) of a measurement surface, given by:

$$W_i = <I_i> \cdot S_i = <I_{ni}> S_i \qquad (7)$$

where:

$<I_{ni}>$ is the signed magnitude of the estimated spatial average normal sound intensity component measured on the segment i of the measurement surface;

S_i is the area of the segment i

and

$|W_i|$ is the magnitude of W_i.

4.10.2 **Sound power, W_I**

The total sound power generated by a source as determined by this Standard, given by:

$$W_I = \sum_{i=1}^{N} W_i, \text{and} \qquad (8)$$

$$|W_I| = \left|\sum_{i=1}^{N} W_i\right| \qquad (9)$$

where:

N is the total number of segments of the measurement surface.

NOTE 4

During a scan, an intensity measurement instrument performs a temporal average which is made equivalent to a spatial average by the movement of the probe along the path of the scan.

4.10.3 **Partial sound power level, $L_{W_{I_i}}$**

The logarithmic measure of the sound power passing through segment i of the measurement surface:

$$L_{W_{I_i}} = 10 \lg \frac{|W_i|}{W_0} \text{dB} \qquad (10)$$

4.10.4 Sound power level, L_{W_I}

The logarithmic measure of the sound power generated by a source, as determined using this Standard, given by:

$$L_{W_I} = 10\lg\frac{|W_I|}{W_0}\,\mathrm{dB} \qquad (11)$$

$|W_I|$ is the magnitude of the sound power of the source;

W_0 is the reference sound power, 10^{-12} Watts.

Where W_I is negative, the level is expressed as (–) xx dB for record purposes only.

This Standard does not apply if W_I of the source is measured to be negative.

4.10.5 Pseudo-sound power level, L_{Wp}

$$L_{Wp} = 10\lg\sum_{i=1}^{N}\left(S_i 10^{0,1L_{pi}}\right) \qquad (12)$$

where:

L_{p_i} average sound pressure level on segment i;

S_i area of segment i;

N number of segments.

4.11 Sound pressure

4.11.1 Sound pressure level, L_p, in decibels

Ten times the logarithm to the base 10 of the ratio of the mean-square sound pressure to the square of the reference sound pressure. The reference sound pressure is 20 µPa.

4.11.2 Segment-average sound pressure level, L_{p_i}, in decibels

Ten times the logarithm to the base 10 of the ratio of the ratio of the spatial average mean-square pressure on segment i to the square of the reference sound pressure.

4.12 Stationary signal

For the purpose of this Standard, a signal is considered to be stationary in time if its time-average properties during a measurement on one segment of the measurement surface are equal to those obtained on the same segment when the averaging period is extended over the total time taken to measure on all segments. Cyclic, or periodic, signals are, by this definition, stationary, if on each segment the measurement period extends over at least three cycles.

5 Acoustical environment

5.1 Criterion for adequacy of the test environment

The test environment shall be such that the principle upon which sound intensity is measured by the particular instrument employed as given in IEC Publication 1043 is not invalidated. In addition, it must satisfy the requirements stated in 4.2 to 4.4.

5.2 Extraneous intensity

5.2.1 Level of extraneous intensity

Make every effort to minimize the level of extraneous intensity which shall not be such as to unacceptably reduce measurement accuracy (see annex B and A.2.2 of annex A).

NOTE 5

If substantial quantities of absorbing material are part of the source under test, high levels of extraneous intensity may lead to an underestimate of the sound power. Annex D gives indications of how to evaluate the resulting error in the special case where the source under test can be switched off.

5.2.2 Variability of extraneous noise

Ensure that the variability of the extraneous noise intensity during the measurement period is minimised by appropriate actions prior to the test (e.g. disabling automatically switched sources of extraneous noise which are not essential to source operation) and by the selection of appropriate periods of measurement.

5.3 Wind, gas flows, vibration and temperature

Do not make measurements when air flow conditions in the vicinity of the intensity probe contravene the limits for satisfactory performance of the measurement system as specified by the manufacturer. In the absence of such information, do not make measurements if the mean air speed exceeds 2 ms^{-1} (see annex C). (Refer to IEC Publication 1043 for guidance on use of a probe windscreen). Do not place the probe in, or very close to, any stream of flowing gas of which the mean speed exceeds 2 ms^{-1}, and mount it so as not to be subject to significant vibration.

NOTE 6

Because the wind speed fluctuates about the mean, the sound power level determined may be an overestimate in cases where the mean wind speed is close to the maximum allowed.

NOTE 7

The probe shall not be placed closer than 20 mm to bodies having a temperature significantly different from that of the ambient air. Use of a probe in temperatures much higher than ambient, especially if there is a high temperature gradient across the probe, should be avoided.

NOTE 8

Air pressure and temperature affect air density and speed of sound. Effects of these quantities on instrument calibration should be ascertained and appropriate corrections shall be made to indicate intensities (see IEC Publication 1043).

NOTE 9

For equipment the sound pressure of which varies with temperature, the room temperature during the measurement shall be 23 °C ± 2 °C.

5.4 Configuration of the surroundings

The configuration of the test surroundings shall, as far as possible, remain unchanged during the performance of a test; this is particularly important if the source emits sound of a tonal nature. Record cases where variation in the test surroundings during a test is unavoidable. Ensure, as far as is possible, that the operator does not stand in a position on, or close to, the axis of the probe during the period of measurement at any position. If practicable, remove any extraneous objects from the vicinity of the source.

6 Instrumentation

6.1 General

A sound intensity measurement instrument and probe that meet the requirements of the IEC Publication 1043 shall be used. Class 1 instruments shall be used. Adjust the intensity measurement instrument to allow for ambient air pressure and temperature in accordance with IEC 1043. Record the pressure-residual intensity index of the instrument used for measurements according to this Standard for each frequency band of measurement.

6.2 Calibration and field check

The instrument, including the probe, shall comply with IEC Publication 1043. Verify compliance with IEC Publication 1043 at least once a year in a laboratory making traceable calibrations. Record the results in accordance with 10.4.

To check the instrumentation for proper operation prior to each series of measurements, apply the field check procedure specified by the manufacturer.

If no field check is specified, carry out the following procedure to indicate anomalies within the measuring system that may have occurred during transportation, etc.:

a) Sound pressure level

Check each pressure microphone of the intensity probe for sound pressure level using a class 0L or 1L calibrator in accordance with IEC Publication 942.

b) Intensity

Place the intensity probe on the measurement surface, with the axis oriented normal to the surface, at a position of higher than surface average intensity. Measure the normal sound intensity level. Rotate the intensity probe through 180° about an axis normal to the measurement axis and place it with its acoustic centre in the same position as the first measurement. Measure the intensity again. Mount the intensity probe on a stand to retain the same position while rotating the probe. For the maximum band level measured in one octave or one-third octave bands, the two values of I_n must have opposite signs and the difference between the two sound intensity levels shall be less than 1,5 dB for the measuring equipment to be acceptable.

7 Installation and operation of equipment under test

7.1 General

There is no restriction on the size of the equipment under test. The equipment has to be practically non-absorbing on its external surfaces.

The character of noise radiated by the equipment shall be stationary so that proper time and spatial integration is obtained. The frequency distribution can be broad-band, discrete frequency or narrow-band.

7.2 Installation of equipment

The equipment under test shall be mounted according to ECMA-74. The equipment should be mounted so that none of the sides of the measurement surface are parallel to the walls of the room except for equipment mounted on or near a wall (see 6.5.1 of ECMA-74). The floor underneath the equipment under test and the projection of the measurement surface shall be a hard reflecting plane.

7.3 Equipment operation

The equipment under test shall be operated according to 6.5.3 and annex C both of ECMA-74. If an operator is required for the equipment under test the operator shall be present at the same location during all measurements.

8 Measurement of normal sound intensity component levels

8.1 The scan

The intensity probe is moved continuously (scanned) along prescribed paths on each segment of the selected measurement surface. The measuring instrumentation is set to time-average the sound intensity and sound pressure over the total duration T of a scan on one segment. The scanning operation should be performed in such a manner that the prescribed scan path is accurately followed, that the axis of the probe is maintained perpendicular to the measurement surface at all times, and that the speed of movement of the probe is uniform.

Scanning may be performed either manually or mechanically. In order to restrict the error to an acceptable limit, scanning shall not be performed at a speed exceeding 0,3 m/s or less than 0,1 m/s.

In the case of mechanised scanning, it is technically possible to satisfy these conditions closely on any form of measurement surface. Care shall be taken to minimise probe vibration and mechanism noise.

In the case of manual scanning, it is virtually impossible to satisfy these conditions exactly. Consequently, simple, regular surface forms are preferred (see annex E).

The basic element of a scan is a single straight line. The scan path consists of a set of parallel straight lines which covers an individual segment. The distances between adjacent lines shall be equal and shall not exceed half the average distance of the segment from the source surface. The adjacent lines either shall be joined by semi-circular paths between their extremities (see figure 1(a)), or by signal acquisition may be temporally suspended while the probe is moved between adjacent lines (figure 1(b)).

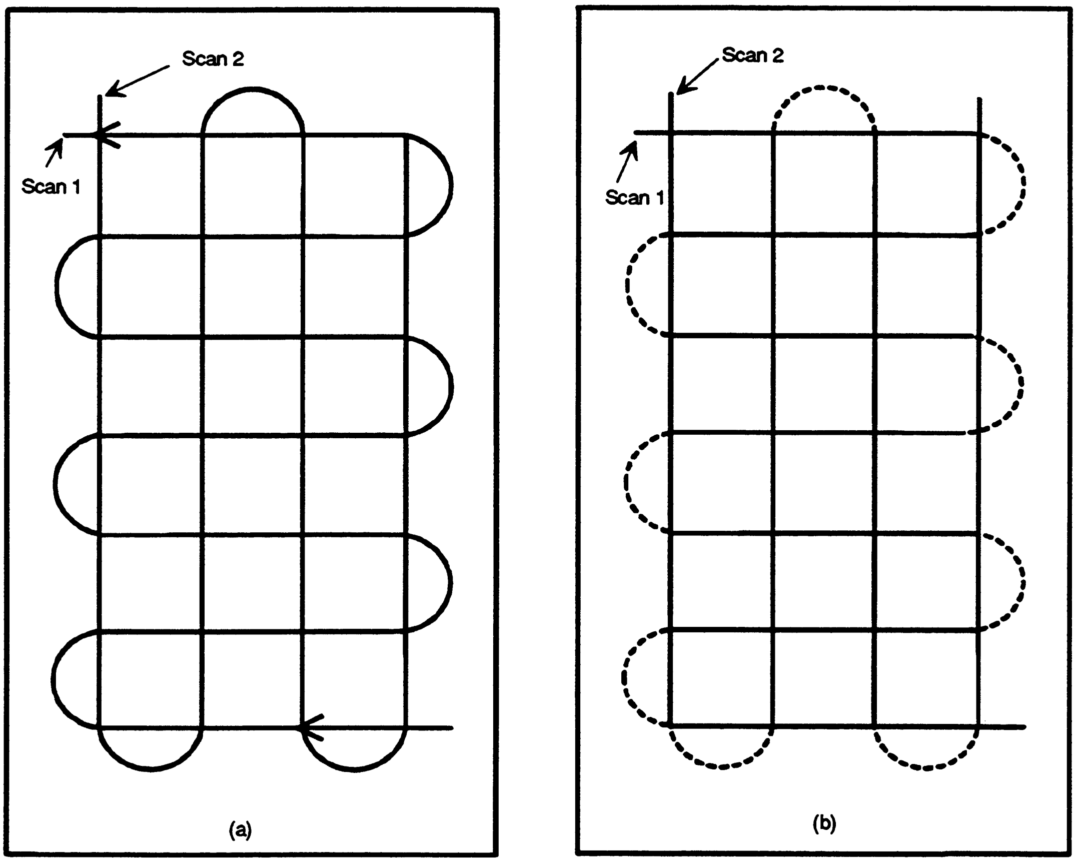

Figure 1 - Scanning pattern

The duration of any one scan over an individual segment must be not less than 20 seconds. Time averaging shall be initiated at the beginning of the scan over any one segment and terminated upon the completion of the scan over that segment (see annex E). Time averaging may be temporarily suspended while the probe leaves a segment, or must negotiate obstacles in the scan path, or while the probe is moved from the end of one scan line to beginning of the next.

During manual scanning, the operator shall not stand facing the segment being scanned but shall stand to the side so that his or her body does not impede the radiation of sound from the source. In the case of mechanised scanning, the scattering cross sections of the components of the scanning mechanism shall be minimized in order to reduce the interference effects created by the presence of the scanning mechanism.

8.2 The initial measurement surface

Define an initial measurement surface around the source under test. The chosen surface may incorporate areas of non-absorbent (diffuse field absorption coefficient less than 0,06) surface, such as a concrete floor or masonry wall, where convenient. Intensity measurements shall not be made on such surfaces, and the areas of such surfaces shall not be included in the evaluation of source sound power according to equation (8).

In the case of manual scanning, planar segments are recommended. Examples of suitable planar segments are shown in figure E.1 in annex E. The average distance between each segment of the measurement surface and the surface of the source under test shall not be less than 0,2 m, unless the segment covers a component which can be shown, by test, to radiate an insignificant proportion of the sound power of the source under test.

The geometric form of each segment shall be such that it is possible to scan the probe along the predetermined path while maintaining the axis of the probe normal to the chosen surface and to able to accurately determine the surface area.

Segments shall be selected, as far as possible, so as to be associated with individual components of the source, or parts thereof, as defined by geometric features, material type, joints, apertures, etc. Where it is evident that a large portion of the total sound power is radiated by a particular region, or regions of the source, segments shall be defined, as far as possible, to separate regions of above- and below-average sound power. The maximum dimension of any segment shall be such that it is possible to scan the probe along the prescribed path at constant speed with a constant line density and with the probe axis maintained normal to the surface.

8.3 Initial test

Make measurements of spatial average normal sound intensity levels and sound pressure levels on each segment in those frequency bands in which the sound power determination is to be made.

8.3.1 Partial power repeatability

Make two separate scans on each segment of the measurement surface, and separately record the space average pressure levels $L_{p_i}^{(1)}$ and $L_{p_i}^{(2)}$ and partial sound power levels $L_{W_{I_i}}^{(1)}$ and $L_{W_{I_i}}^{(2)}$ for all frequency bands of measurement, according to 4.11.2 and 4.10.3: the two individual scan paths shall be orthogonal wherever possible (see figure 1). Introduce the difference between partial sound power levels into equation (B.3) of B.1.3. In cases where criterion 3 is not satisfied, attempt to identify the cause of the difference and suppress it where practicable. If such action is not effective or practicable, take action according to B.2. In frequency bands where criterion 3 is still not satisfied, a determination of source sound power level according to this Standard is not possible, and a statement shall be made in the report according to the effect that the uncertainty of the sound power level determination in these bands exceeds that stated in table 1.

8.3.2 Evaluation of instrument capability and environment

Evaluate indicator F_{pI} for all frequency bands of measurement according to equation (A.1) and introduce the values into the formula given for qualification procedure B.1.1.

8.3.3 Evaluation of negative partial power

Evaluate indicator $F_{+/-}$ for all frequency bands of measurement according to equation (A.2) and introduce the values into the formula given for qualification procedure of B.1.2.

8.3.4 Further action

Where criteria 1, 2 and 3 of annex B are satisfied in each frequency band, the initial sound power determination is qualified as a final result. If criteria 1 or 2 of B.1 indicates that the initial choice of measurement surface does not meet the desired grade of accuracy, take appropriate action according to B.2. Measure the normal sound intensity component levels and associated sound pressure levels using the modified measurement surface. Recalculate field indicators F_{pI} and $F_{+/-}$ and assess according to B.1. Take action according to B.2. Repeat this procedure until the criteria of B.1 are attained. In cases where repeated action fails to satisfy the specified criteria, record a null test result, and state the associated reasons; alternatively record the test results and indicate nonconformance with this Standard and state the associated reasons.

8.3.5 Direct determination of A-weighted sound intensity levels

The A-weighted sound intensity levels of each segment may be determined directly for additional sources after measurement of one source using band levels if the following conditions are met:

- The criteria of annex B is met for all bands meeting the significance criteria of 1.4.
- The environmental conditions are not changed during measurements, i.e., extraneous noise source are constant.

– The contributions to the A-weighted sound power level outside the frequency range of the probe and instrument system are insignificant.

NOTE 10

The above conditions for measuring A-weighted sound intensity levels will usually be met when the "apparent" background sound power level caused by other noise sources is more than 10 dB lower than the sound power level of the equipment under test. Such conditions are more easily obtained when testing is performed in controlled type environments such as a conference room and when the noise emissions from the equipment under test are significantly greater than extraneous noise.

When A-weighted levels are measured directly, the procedures of 8.1-8.4 shall be followed, with A-weighted field indicators and criterion evaluated instead of band levels. If the measurements are overall A-weighted sound intensity and pressure, the measurement duration of any one scan over an individual segment shall be at least 16 seconds.

9 Calculation of sound power levels

9.1 Calculation of partial sound powers for each segment of the measurement surface

Calculate a partial sound power in each frequency band for each segment of the measurement surface from the equation:

$$W_i = < I_{ni} > S_i \tag{13}$$

where:

W_i is the partial sound power for segment i;

$<I_{ni}>=[<I_{ni}^{(1)}> + <I_{ni}^{(2)}>]/2$ is the signed magnitude of the spatial average normal sound intensity component measured on the segment i of the measurement surface;

S_i is the area of segment i;

and

$<I_{ni}^{(1)}>$ and $<I_{ni}^{(2)}>$ are the values of $<I_{ni}>$ obtained from two separate scans of segment i.

If more than two values are validly determined, then $<I_{ni}>$ is the arithmetic average of the valid determinations.

Where the normal sound intensity level $L_{I_{ni}}$ for segment i is expressed as xx dB the value of I_{ni} shall be calculated from the equation $I_{ni} = I_0(10^{xx/10})$; where the normal sound intensity level $L_{I_{ni}}$ for segment i is expressed as (–) xx dB the value of I_{ni} shall be calculated from the equation $I_{ni} = (I_0(10^{xx/10})$.
In these equations $I_0 = 10^{-12}\mathrm{Wm}^{-2}$.

NOTE 11

Where $<I_{ni}^{(1)}>$ and $<I_{ni}^{(2)}>$ are expressed in logarithmic terms, an arithmetic mean of these levels may be used. The preferred method is to use equation F.2.

9.2 Calculation of sound power level of the equipment under test

Calculate a sound power level of the equipment under test in each frequency band from the equation:

$$L_{W_I} = 10\lg\left|\sum_{i=1}^{N} W_i / W_0\right| \text{ dB} \tag{14}$$

where:

L_{W_I} is the sound power level of the equipment under test;

N is the total number of measurement positions and segments;

W_i is the partial sound power for segment i, calculated from equation (13);

W_0 is the reference sound power, 10^{-12}W.

If $\sum_{i=1}^{N} W_i$ is negative in any frequency band, this Standard does not apply to that band.

An alternative method of obtaining L_{W_I} from $L_{W_{I_i}}$ is presented in annex F.

9.3 Calculation of A-weighted sound power level of equipment under test

The A-weighted sound power level (L_{WA}) in dB, shall be calculated from the following equation; if not determined directly per 8.3.5.

$$L_{WA} = 10\log \sum_{j=1}^{j_{max}} 10^{0,1\left[\left(L_{W_I}\right)_j + A_j\right]} \tag{15}$$

where:

$(L_{W_I})_j$ = the level in the j-th octave or third-octave band.

For computations with octave-band data, j_{max} = 6 and A_j is given in table 3.

Table 3 - Values of A-weighting, A_j

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

For computations with third-octave band data, j_{max} = 19 and A_j is given in table 4.

Table 4 - Values of A-weighting, A_j

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	0,0
12	1 250	0,6
13	1 600	1,0
14	2 000	1,2
15	2 500	1,3
16	3 150	1,2
17	4 000	1,0
18	5 000	0,5
19	6 300	- 0,1

10 Information to be recorded

The following information, where applicable, shall be recorded for all measurements made in accordance with the requirements of this Standard.

10.1 General

The date, time and place where the measurements were performed, and the name of the person having performed the measurements.

10.2 Equipment under test

a) Description of the equipment under test (including name, model, serial number, principal dimensions and location of sub-assemblies, where applicable).

b) Operating conditions, including supply frequency and voltage.

c) Installation conditions.

d) Location of the equipment in the test environment.

e) Description of each individual operating mode for which measurements have been performed.

f) Location and function of any operator required for operation of equipment under test.

10.3 Acoustical environment

a) Description of the test environment, including a sketch showing the location of the equipment, configurations and positions of nearby objects. Dimensions of rooms and material of room surfaces.

b) Environmental data during the test (air temperature in °C, barometric pressure in kPa and relative humidity in %).

c) Description of character of noise from sources other than that under test, including variability, occurrence of cycles, tonal quality.

d) Description of any devices/procedures to minimize the effects of extraneous noise.

e) Qualitative description of any gas/air flows and unsteadiness.

10.4 Instrumentation

a) Equipment used for the measurements, including names, types, serial numbers and manufacturers. Type(s) of probe(s) or probe configurations. If more than one probe configuration is used, the frequency range of each probe used for determining the total sound power shall be reported.

b) Bandwidth of frequency analyser.

c) Method(s) used to calibrate and perform field checks on the instrumentation.

d) The pressure-residual intensity index of the intensity measurement system in each frequency and of measurement, and for every probe configuration employed.

e) Date and place of calibration of the intensity measurement device.

10.5 Measurement procedure

a) Description of each step in the measurement procedure.

b) Description of the mounting, or support system, of the scanning mechanism, and of the intensity probe.

c) Quantitative description of the measurement surface(s) and its segments; each segment shall be allocated a number and an area, and a drawing shall be presented.

d) Dimensioned sketch of the scanning pattern(s).

e) Averaging time on each segment.

f) Scan speed.

10.6 Acoustical data

a) L_{WI_i} and L_{p_i} for each sub-area, if applicable, for all frequency bands used.

b) Tabulation of the field indicators F_{pI} and $F_{+/-}$ calculated from each set of measurements on each measurement surface used.

c) Tabular of graphical presentation of the calculated value of sound power level of the source in all frequency bands used. Where an A-weighted sound power level determination is to be made, the contribution of frequency bands in which criterion 1 and/or criterion 2 is not satisfied shall be omitted from the determination and a statement to this effect shall be made unless their contributions may be neglected according to 1.4.

d) Presentation of the results of the probe reversal field checks specified in 6.2 b), if appropriate.

10.7 Conformance to this Standard

In the special case that the engineering grade of accuracy can only be met for a sound power level over a restricted frequency range, a statement to this effect shall be made according to 10.6 c).

11 Information to be reported

The report shall contain the statement that the sound power levels have been obtained in full conformance with the procedures of this Standard. The report shall state that these sound power levels are given in dB, reference 1 pW.

The report shall contain at least the following information considered to be most characteristic for computer and business equipment:

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

– The A-weighted sound power level, L_{WA} in dB, for the idle mode and operating mode(s), reference 1 pW.

– The band sound power levels, L_W in dB, for the idle mode and operating mode(s), if required, reference 1 pW.

– The field indicator F_I for the A-weighted sound power level.

- Detailed description of the operating conditions of the equipment under test with reference to annex C of ECMA-74, if applicable.

NOTE 12

For the determination of declared noise emission values, the procedures of ECMA-109 shall be used. According to ECMA-109 the declared A-weighted sound power level, L_{WAd}, *of computer and business equipment is expressed in bels using the identity*

$$1\,B = 10\,dB$$

Annex A

(normative)

Calculation of field indicators

A.1 General

Field indicators F_{pI} and $F_{+/-}$ shall be evaluated according to the equations given in A.2 for each measurements surface and segment array used, in each frequency band used for the determination of sound power levels.

A.2 Determination of field indicators

A.2.1 Negative partial power indicator

$$F_{+/-} = 10\lg\left[\frac{\sum|W_i|}{\sum W_i}\right] \tag{A.1}$$

where:

W_i and $|W_i|$ are given in 4.10.1.

A.2.2 Sound field pressure-intensity indicator

Calculate the sound field pressure-intensity indicator F_{pI} from the equation

$$F_{pI} = L_{Wp} - L_{W_I} \text{ dB} \tag{A.2}$$

where:

L_{W_I} is given be equation (14) and L_{Wp} is given by equation 12.

Annex B

(normative)

Procedure for achieving desired grade of accuracy

B.1 Qualification requirements

In the application of this Standard the sound field conditions on the initial measurement surface at measurement positions may vary widely. In order to guarantee upper limits for uncertainties of the sound power levels determined, it is necessary to check the adequacy of the instrumentation and of the chose measurement parameters (e.g. measurement surface, distance, scan) in relation to the sound field/environment condition particular to the specific measurement.

B.1.1 Adequacy of the measurement equipment

For a measurement surface to qualify as suitable for the determination of sound power level of a noise source according to this Standard the dynamic capability index L_d of the measurement instrumentation shall be greater than the indicator F_{pI} determined in accordance with annex A in each frequency band of measurement:

$$L_d > F_{pI} \qquad \textbf{criterion 1} \qquad \text{(B.1)}$$

If a chosen measurement surface does not satisfy criterion 1, take action according to table B.3.

B.1.2 Limit on negative partial power

The following check should be made on the suitability of the measurement conditions:

$$F_{+/-} \leq 3 \qquad \textbf{criterion 2} \qquad \text{(B.2)}$$

NOTE B.1

When measurements are performed in a conference room or other controlled room with low levels of background noise relative to the equipment under test, criterion 3 should be met.

B.1.3 Partial power repeatability check

$$\left| L_{W_{I_i}}{}^{(1)} - L_{W_{I_i}}{}^{(2)} \right| \leq s \qquad \textbf{criterion 3} \qquad \text{(B.3)}$$

where s is given in table B.1.

Alternatively, if more than two valid partial power measurements are performed, the criterion becomes:

$$T_{n-1}\left(L_{W_{I_i}}\right) \leq s \qquad \textbf{criterion 3.a} \qquad \text{(B.4)}$$

where $T_{n-1}(L_{W_{I_i}})$ is the standard deviation of the partial power $L_{W_{I_i}}$.

B.2 Action to be taken to increase the grade of accuracy of determination

Table B.1 specifies the actions to be taken in cases where the chosen measurement surface and/or array does not qualify according to B.1.

Table B.1 - Actions to be taken to increase grade of accuracy of determination

Criteria	Action Code	Action
$F_{+/-} > 3$ and $F_{pI} > L_d$	a	Reduce the average distance of the measurement surface from source to not less than a minimum average value of 0,1 m and double the scan line density.
	or	
$F_{pI} > L_d$ and $F_{+/-} > 3$	b	Shield the measurement surface from strong extraneous noise sources in the vicinity of the measurement surface.
$F_{pI} > L_d$ and $F_{+/-} \leq 3$	a	Reduce the average distance of the measurement surface from source to not less than a minimum average value of 0,1 m and double the scan line density.
$\left\| L_{W_{I_i}}^{(1)} - L_{W_{I_i}}^{(2)} \right\| > s$	c	Double the scan line density on the same segment and repeat double scan at the original scan speed or Repeat the measurement

Annex C

(informative)

The effects of airflow on measurement of sound intensity

Sound intensity probes are sometimes exposed to airflow during the process of measurement, for example in windy outdoor conditions, or near flows generated by cooling fans. In principle the theoretical basis of intensity measurement by pressure-pressure (p-p) probes is invalid in the presence of steady fluid flow; however, the errors are negligible in low Mach number flow (M < 0,05), except in high reactive fields. More serious errors are likely to be caused by the effects of unsteady airflow (turbulence)

Turbulence may exist in the flow impinging on a probe, and it may also be caused by the presence of the probe itself. The fluid momentum fluctuations inherent to turbulence are associated with fluctuating pressures; these are non-acoustic and are normally correlated with the pressure fluctuations due to any sound field present. They are, however, registered by any pressure-sensitive transducer exposed to the flow, and the resulting signals cannot be distinguished from those caused by acoustic pressures. Turbulence is convected at a speed close to that of the mean (time-average) flow, and contains eddies (regions of correlated motion), which are generally much smaller than typical audio-frequency wavelengths, with the result that spatial pressure gradients in turbulence can greatly exceed those in sound waves; hence the associated particle velocities can considerably exceed those in typical audio-frequency wavelengths, with the result that spatial pressure gradients in turbulence can greatly exceed those in sound waves; hence the associated particle velocities can considerably exceed those in typical sound fields. The result is that strong pseudo-intensity signals can be generated.

The function of the probe windscreen is to divert the flow from the immediate vicinity of the pressure transducers. Because of the low convection speed of the turbulence, the turbulent pressure and velocity fluctuations acting on the outer surface of the windscreen cannot effectively propagate to the central region of a windscreen where the pressure transducers are situated, while sound waves are much less attenuated. This is the principle of discrimination effected by a windscreen.

It must be realized, however, that there is a limit to the effectiveness of this discrimination. Very intense turbulent fluctuations will not be completely excluded, and low frequency, large scale turbulence is less well attenuated than small scale, high frequency turbulence. Since the frequency spectrum of wind and fan-generated turbulence tends to fall rapidly with frequency, it is the low frequency (typically < 200 Hz) intensity measurements which are likely to be the most affected.

Turbulence scale and frequency content depend very much on the nature of the generation process, and therefore it is impossible to legislate specifically for every unsteady/flow situation which may be encountered during the application of intensity measurement in field situations. Since the rms value of turbulent pressure fluctuations increases as the square of mean flow speed a conservative "blanket" limitation is placed on mean flow speed.

As a general guide, it should be noted that a tendency for one octave or one-third octave intensity and/or particle velocity levels to remain high or even to rise at low frequencies (< 100 Hz), is a danger sign, unless there is evidence that sound pressure levels do likewise, and that the measured source can be subjectively judged to radiate strongly in the low frequency range. Another qualitative indication of the contamination of sound intensity is a high degree of unsteadiness in the indicated intensity and particle velocity levels. Inter-microphone coherence is not necessarily a good indicator of contamination by turbulence, because low frequency, large scale turbulent pressure fluctuations can be highly correlated over distances typical of intensity microphone separations. A major adverse effect of turbulence contamination is a reduction of useful dynamic range for the measurement of sound intensity signals, especially where auto-ranging instrumentation is employed.

Annex D

(normative)

The effect of sound absorption within the measurement surface

If the source shows obvious significant sound absorption (e.g. relevant material for sound absorbers), and if the measurement of the indicator F_{pI} yields a value of more than 8 dB, the influence of the absorbed sound power W_{Iabs} (with $W_{Iabs} < 0$) on the total sound power measured W_I should be checked.

This is possible if the source under test can be switched off. Then, if the remaining extraneous noise is unchanged, the absorbed sound power W_{Iabs} can be directly determined from the measurements of the sound intensity on the surface enclosing the switched off source under test. If the extraneous noise cannot be maintained when switching off the source under test, a rough estimated of the absorbed sound power can be determined by help of a suitable artificial extraneous sound source producing similar levels on the measurement surface as the original extraneous sound source.

The effects of absorption may be neglected if the following condition is satisfied:

$$L_{W_I} - L_{WIabs} \geq K = 10\,\mathrm{dB} \tag{D.1}$$

where:

L_{W_I} is the level of the total sound power level (according to equation (14))

L_{WIabs} is the level of the absorbed sound power

($L_{WIabs} = 10 \lg (|W_{Iabs}| / W_0)$);

K is given by table 2, and = 10 dB.

Otherwise actions have to be taken in order to reduce the level of the extraneous intensity or to shield the measurement surface from the extraneous noise sources.

Annex E

(informative)

Measurement surface and scanning procedure

The basic principle of sound power determination using the intensity measurement technique is to measure the intensity component normal to the measurement surface which totally encloses the source under test. The main uncertainties in the results obtained by this technique are associated with instrumentation and signal analysis errors and with a non-ideal field sampling (scanning) process. This annex presents guidelines for performing the field sampling procedure. By following these guidelines and using the scanning parameters specified in this Standard, the uncertainties may be minimized, and the engineering grade of accuracy stated in table 1 may be achieved.

The measurement surface should be so defined that it is easily scanned, and should be of such a form that the effects of extraneous intensity and the source near filed are minimised. The scanning of a singly-curved measurement surface, for example around a circular cylindrical duct, should be performed by moving the probe parallel to the axis of the duct, as shown in figure E.1. The scan lines are thus kept straight, and the orientation of the probe remains unchanged during each straight line section of the path. The use of scan lines which are curved in planes normal to the measurement surface should be avoided whenever practicable, because the probe orientation has to be continuously varied during the scan.

The measurement surface, the segments and the scan pattern should be selected to suit the source geometry and its environment, within the limits specified by clause 8. An approximation to a conformal surface (all points at the same distance from the source surface) should be constructed from planar segments as illustrated by figure E.1.

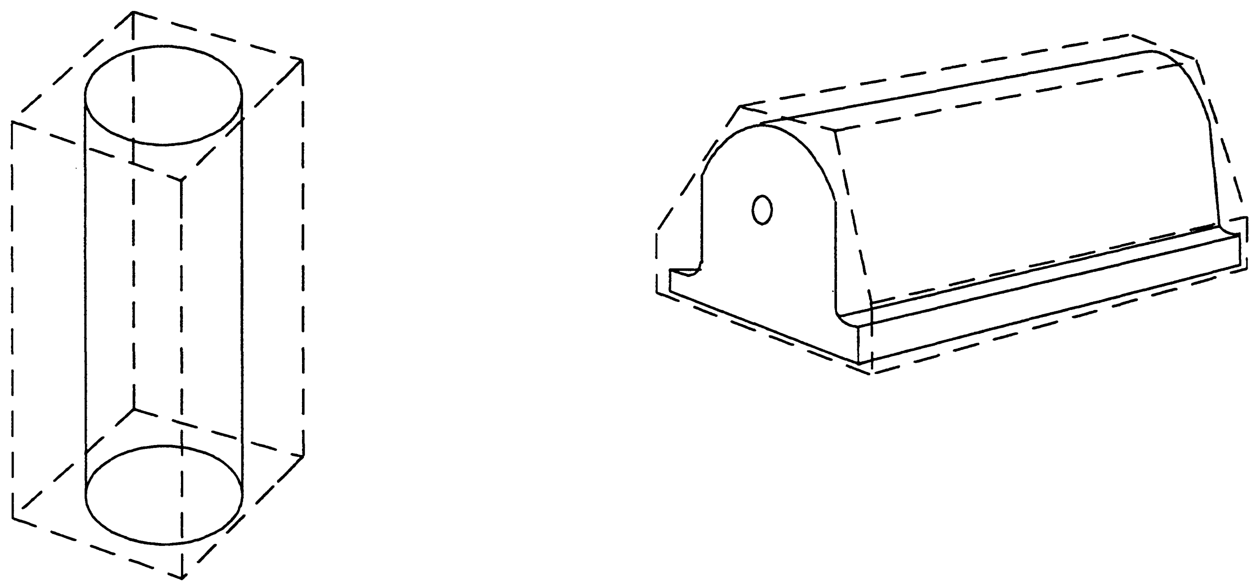

Figure E.1

Each segment should be so defined that it is easily and confortably scanned at constant speed with a uniform line density, while maintaining the axis of the probe perpendicular to the local surface. The turn at the end of a scanning line produces an error in the surface averaging process, overweighing the contribution from the edge. Every effort should be made to maintain constant scanning speed over the whole of the scan path.

In case when the processor integration time is predetermined in discrete steps, every effort should be made to minimize the interval between finishing the scan over any one segment and stopping the integration.

Equal attention should be paid to following the selected scan path and maintaining the uniformity of scanning speed, uniformity of line density and probe axis orientation. Excessive concentration on any one of these tasks may adversely affect the accuracy of the measurement.

Annex F

(informative)

Determination of sound power levels using $L_{W_{I_i}}$ and $L_{I_{n_i}}$

An alternative method to the method in 9.1 and 9.2 for determining L_{W_I} using sound power levels and sound intensity levels of each segment is presented below:

F.1 Calculation of radiated sound power levels for segments

The sound power level for the *i*-th segment is calculated from the intensity level by the equation:

$$L_{W_{I_i}} = L_{I_{n_i}} + 10\lg\frac{S_i}{S_0} \qquad \text{(F.1)}$$

where:

$L_{W_{I_i}}$ is the sound power level in decibels for segment *i*;

$L_{I_{n_i}}$ is the normal signed sound intensity level in decibels for segment *i*;

S_i is the area, in square metres, of segment *i*;

S_0 is the reference area, 1 m^2.

The sign of L_{W_I} is the same as that of $L_{I_{n_i}}$.

$L_{I_{n_i}}$ and $L_{W_{I_i}}$ are given either as one-third octave band levels or octave band levels or as A-weighted levels.

L_{I_i} shall be determined from the valid measurements of the segment sound intensity from the following:

$$L_{I_i} = 10\lg\left[\frac{1}{n}\sum\left(10^{L_{I_i}^{(1)}} + 10^{L_{I_i}^{(2)}} + \ldots 10^{L_{I_i}^{(n)}}\right)\right] \qquad \text{(F.2)}$$

where n is the number of valid determinations of L_{I_i} per 8.3.

F.2 Calculation of total sound power level

The sound power from each segment is summed to obtain the total sound power radiated from the equipment, given be the equations:

$$L_{W_I} = 10\lg\sum_{i=1}^{N}\frac{W_{I_i}}{W_0} \tag{F.3}$$

$$W_I - \sum_{i=1}^{N} W_{I_i} \tag{F.4}$$

where:

L_{W_I} is the total sound power level, in decibels;

N is the total number of segments;

W_{I_i} is the sound power, in watts, for segment i.

The values of W_{I_i} shall be calculated from the equation:

$$\frac{W_I}{W_0} = 10^{\left(L_{W_{I_i}}/10\right)} \tag{F.5}$$

When the sound power $L_{W_{I_i}}$ is expressed as negative, the value of W_{I_i} will also be negative.

NOTE F.1

An example of the summation of sound power levels of five segments of 53, 52, 52, 51 and (–) 50 dB is given below:

$$\sum_{i=1}^{N}\frac{W_{I_i}}{W_0} = 10^{53/10} + 10^{52/10} + 10^{52/10} + 10^{51/10} - 10^{50/10} = 5,42\times 10^5$$

$$L_{W_I} = 10\lg\left(5,42\times 10^5\right) = 57\text{dB}$$

L_{W_I} and $L_{W_{I_i}}$ are given as one-third octave or octave band levels or as A-weighted levels. If A-weighted levels are calculated from one third octave or octave band levels the procedure in 9.3 shall be used.

Annex G
(informative)
Main differences between the second and the first editions

G.1 Scope

This annex lists the main differences between the 2nd and the 1st edition of ECMA-160.

This Standard was rewritten to take into account:

- experience gained by the use of the 1st edition
- publication of draft ISO 9614-2.

G.2 Main differences

Much of the text has been rewritten for compatibility with ISO 9614-2, which is presently in preparation. When ISO 9614-2 is available, ECMA-160 will be modified to refer to portions of ISO 9614-2 instead of repeating large portions of text from ISO 9614-2.

References to ISO 9614-2 and IEC 1043 have been added.

The symbol of the field indicator F has been changed to F_{pI}.

A new field indicator $F_{+/-}$ has been included.

A new definition of dynamic capability index L_d has been added.

The instrument section has been modified to refer to IEC 1043.

The maximum m scanning speed has been reduced from 0,5 m/s to 0,3 m/s.

The minimum measurement distance d has been increased from 0,1 m to 0,2 m.

Annexes A - F have been added.

There are two permitted scanning patterns.

The distance between scanning lines has decreased from d to $d/2$.

The requirement to measure background sound pressure level and apparent background sound power level has been deleted.

Recommendations on training and qualifications for the person performing the measurement have been strengthened.

Annex H

(informative)

Main differences between ISO 9614-2 and ECMA-160

H.1 Scope

This annex list the main differences between the 2nd edition of ECMA-160 and ISO 9614-2.

H.2 Main differences included in ECMA-160

The type of noise source is limited to computer and business equipment, with installation and operating conditions prescribed by ECMA-74.

The frequency range of ECMA-160 does not include the 63 Hz octave band or the 50 – 80 Hz one-third octave bands since the frequency range for computer and business equipment has a lower bound of 125 Hz octave.

A-weighted measurements of sound intensity and pressure are permitted under limited conditions.

The number of cycles for stationary (4.12) has been reduced from 10 to 3 based on the experience with ECMA-160 and ECMA-74.

The symbol for sound power in ECMA-160 is W whereas in ISO 9614-2 it is P.

A new annex F has been added for an alternative method of determining sound power level from intensity levels instead of from intensity.

A section has been added to calculate A-weighted levels from band levels.

The data to be reported section of ISO 9614-2 has been replaced by a data to be recorded section, and reporting requirements for computer and business equipment have been added.

Grade of accuracy has been limited to engineering.

A measurement uncertainty for A-weighted levels is presented.

Permits more than two determinations of partial power, which will improve repeatability of sources with cyclic patterns and of manual scanning.