INTERNATIONAL
STANDARD

ISO
9614-1

First edition
1993-06-01

Acoustics — Determination of sound power levels of noise sources using sound intensity —

Part 1:
Measurement at discrete points

Acoustique — Détermination par intensimétrie des niveaux de puissance acoustique émis par les sources de bruit —
Partie 1: Mesurages par points

Reference number
ISO 9614-1:1993(E)

Contents

Annexes

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9614-1 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Sub-Committee SC 1, *Noise*.

ISO 9614 consists of the following parts, under the general title *Acoustics — Determination of sound power levels of noise sources using sound intensity*:

— *Part 1: Measurement at discrete points*

— *Part 2: Measurement by scanning*

Annexes A and B form an integral part of this part of ISO 9614. Annexes C, D and E are for information only.

Introduction

0.1 The sound power radiated by a source is equal in value to the integral of the scalar product of the sound intensity vector and the associated elemental area vector over any surface totally enclosing the source. Previous International Standards which describe methods of determination of sound power levels of noise sources, principally ISO 3740 to ISO 3747, without exception specify sound pressure level as the primary acoustic quantity to be measured. The relationship between sound intensity level and sound pressure level at any point depends on the characteristics of the source, the characteristics of the measurement environment, and the disposition of the measurement positions with respect to the source. Therefore ISO 3740 to ISO 3747 necessarily specify the source characteristics, the test environment characteristics and qualification procedures, together with measurement methods which are expected to restrict the uncertainty of the sound power level determination to within acceptable limits.

The procedures specified in ISO 3740 to ISO 3747 are not always appropriate, for the following reasons.

a) Costly facilities are necessary if high precision is required. It is frequently not possible to install and operate large pieces of equipment in such facilities.

b) They cannot be used in the presence of high levels of extraneous noise generated by sources other than that under investigation.

The purpose of ISO 9614 is to specify methods whereby the sound power levels of sources may be determined, within specific ranges of uncertainty, under test conditions which are less restricted than those required by the series ISO 3740 to ISO 3747. The sound power is the *in situ* sound power as determined by the procedure of this part of ISO 9614; it is physically a function of the environment, and may in some cases differ from the sound power of the same source determined under other conditions.

0.2 This part of ISO 9614 complements the series ISO 3740 to ISO 3747 which specify various methods for the determination of sound power levels of machines and equipment. It differs from these International Standards principally in three aspects.

a) Measurements are made of sound intensity as well as of sound pressure.

b) The uncertainty of the sound power level determined by the method specified in this part of ISO 9614 is classified according to the results of specified ancillary tests and calculations performed in association with the test measurements.

c) Current limitations of intensity measurement equipment restrict measurements to the one-third-octave range 50 Hz to 6,3 kHz. Band-limited A-weighted values are determined from the constituent one-octave or one-third-octave band values and not by direct A-weighted measurements.

0.3 This part of ISO 9614 gives a method for determining the sound power level of a source of stationary noise from measurements of sound intensity on a surface enclosing the source. In principle, the integral over any surface totally enclosing the source of the scalar product of the sound intensity vector and the associated elemental area vector provides a measure of the sound power radiated directly into the air by all sources located within the enclosing surface, and excludes sound radiated by sources located outside this surface. In the presence of sound sources operating outside the measurement surface, any system lying within the surface may absorb a proportion of energy incident upon it. The total sound power absorbed within the measurement surface will appear as a negative contribution to source power, and may produce an error in the sound power determination; in order to minimize the associated error, it is therefore necessary to remove any sound-absorbing material lying within the measurement surface which is not normally present during the operation of the source under test.

This part of ISO 9614 is based on discrete-point sampling of the intensity field normal to the measurement surface. The resulting sampling error is a function of the spatial variation of the normal intensity component over the measurement surface, which depends on the directivity of the source, the chosen sampling surface, the distribution of sample positions, and the proximity of extraneous sources outside the measurement surface.

The precision of measurement of the normal component of sound intensity at a position is sensitive to the difference between the local sound pressure level and the local normal sound intensity level. A large difference may occur when the intensity vector at a measurement position is directed at a large angle (approaching 90°) to the local normal to the measurement surface. Alternatively, the local sound pressure level may contain strong contributions from sources outside the measurement surface, but may be associated with little net sound energy flow, as in a reverberant field in an enclosure; or the field may be strongly reactive because of the presence of the near-field and/or standing waves.

Acoustics — Determination of sound power levels of noise sources using sound intensity —

Part 1:
Measurement at discrete points

1 Scope

1.1 This part of ISO 9614 specifies a method for measuring the component of sound intensity normal to a measurement surface which is chosen so as to enclose the noise source(s) of which the sound power level is to be determined. 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 source for which a physically stationary measurement surface can be defined, and on which the noise generated by the source is stationary in time (as defined in 3.13). The source is defined by the choice of measurement surface. The method is applicable *in situ*, or in special purpose test environments.

1.2 This part of ISO 9614 is applicable to sources situated in any environment which is neither so variable in time as to reduce the accuracy of the measurement of sound intensity to an unacceptable degree, nor subjects the intensity measurement probe to gas flows of unacceptable speed or unsteadiness (see 5.3 and 5.4).

In some cases, it will be found that the test conditions are too adverse to allow the requirements of this part of ISO 9614 to be met. In particular, extraneous noise levels may vary to an excessive degree during the test. In such cases, the method given in this part of ISO 9614 is not suitable for the determination of the sound power level of the source.

NOTE 1 Other methods, e.g. determination of sound power levels from surface vibration levels as described in ISO/TR 7849, may be more suitable.

1.3 This part of ISO 9614 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 this part of ISO 9614, the test procedure should be modified in the manner indicated.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9614. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9614 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 5725:1986, *Precision of test methods — Determination of repeatability and reproducibility for a standard test method by inter-laboratory tests.*

IEC 942:1988, *Sound calibrators.*

IEC 1043:—,[1] *Instruments for the measurement of sound intensity.*

3 Definitions

For the purposes of this part of ISO 9614, the following definitions apply.

3.1 sound pressure level, L_p: 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.

Sound pressure level is measured in decibels.

---

[1] To be published.

3.2 instantaneous sound intensity, $\vec{I}(t)$: Instantaneous rate of flow of sound energy per unit of surface area 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:

$$\vec{I}(t) = p(t) \cdot \vec{u}(t) \qquad \ldots (1)$$

where

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

3.3 sound intensity, $\vec{I}$: Time-averaged value of $\vec{I}(t)$ in a temporally stationary sound field:

$$\vec{I} = \lim_{T \to \infty} \frac{1}{T} \int_0^T \vec{I}(t)\,\mathrm{d}t \qquad \ldots (2)$$

where T is the integration period.

Also

I	is the signed magnitude of $\vec{I}$; the sign is an indication of directional sense, and is dictated by the choice of positive direction of energy flow;
$\lvert I \rvert$	is the unsigned magnitude of $\vec{I}$.

3.4 normal sound intensity, I_n: Component of the sound intensity in the direction normal to a measurement surface defined by the unit normal vector $\vec{n}$.

$$I_\mathrm{n} = \vec{I} \cdot \vec{n} \qquad \ldots (3)$$

where $\vec{n}$ is the unit normal vector directed out of the volume enclosed by the measurement surface.

3.5 normal sound intensity level, L_{I_n}: Logarithmic measure of the unsigned value of the normal sound intensity $\lvert I_\mathrm{n} \rvert$, given by:

$$L_{I_\mathrm{n}} = 10 \lg[\lvert I_\mathrm{n} \rvert / I_0] \text{ dB} \qquad \ldots (4)$$

where I_0 is the reference sound intensity ($= 10^{-12}$ W/m^2).

It is expressed in decibels.

When I_n is negative, the level is expressed as (–) XX dB, except when used in the evaluation of δ_{pI_0} (see 3.11).

3.6 sound power

3.6.1 partial sound power, P_i: Time-averaged rate of flow of sound energy through an element (segment) of a measurement surface, given by:

$$P_i = \vec{I}_i \cdot \vec{S}_i = I_{\mathrm{n}i} \cdot S_i \qquad \ldots (5)$$

where

$I_{\mathrm{n}i}$	is the signed magnitude of the normal sound intensity component measured at position i on the measurement surface;
S_i	is the area of the segment of surface associated with point i.

3.6.2 sound power, P: Total sound power generated by a source as determined using the method given in this part of ISO 9614, given by:

$$P = \sum_{i=1}^{N} P_i \qquad \ldots (6)$$

and

$$\lvert P \rvert = \left\lvert \sum_{i=1}^{N} P_i \right\rvert \qquad \ldots (7)$$

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

3.6.3 sound power level, L_W: Logarithmic measure of the sound power generated by a source, as determined using the method given in this part of ISO 9614, given by:

$$L_W = 10 \lg[\lvert P \rvert / P_0] \text{ dB} \qquad \ldots (8)$$

where

$\lvert P \rvert$	is the magnitude of the sound power of the source;
P_0	is the reference sound power ($= 10^{-12}$ W).

Sound power level is expressed in decibels.

When P is negative, the level is expressed as (–) XX dB for record purposes only.

NOTE 2 This part of ISO 9614 is not applicable if the value of P of the source is found to be negative.

3.7 measurement surface: 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.

3.8 segment: Portion of the measurement surface associated with one measurement position.

3.9 extraneous intensity: 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).

3.10 probe: That part of the intensity measurement system which incorporates the sensors.

3.11 pressure-residual intensity index, δ_{pI_0}: The difference between the indicated L_p and the indicated L_{I_n} when the intensity probe is placed and oriented in a sound field such that the sound intensity is zero. It is expressed in decibels.

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.

$$\delta_{pI_0} = (L_p - L_{I_n}) \qquad \dots (9)$$

3.12 dynamic capability index, L_d: Given by:

$$L_d = \delta_{pI_0} - K \qquad \dots (10)$$

It is expressed in decibels.

The value of K is selected according to the grade of accuracy required (see table 1).

Table 1 — Bias error factor, K

Grade of accuracy	Bias error factor dB
Precision (grade 1)	10
Engineering (grade 2)	10
Survey (grade 3)	7

3.13 stationary signal: For the purposes of this part of ISO 9614, a signal is considered stationary in time if, for each measurement position, its time-averaged properties during each individual measurement period are equal to those obtained at the same position when the averaging period is extended over the total time taken to measure at all positions on the measurement surface. Cyclic, or periodic, signals are, by this definition, stationary if at each individual position the measurement period extends over at least ten cycles.

3.14 field indicators, F_1 to F_4: See annex A.

4 General requirements

4.1 Size of noise source

The size of the noise source is unrestricted. The extent of the source is defined by the choice of the measurement surface.

4.2 Character of noise radiated by the source

The signal shall be stationary in time, as defined in 3.13. If a source operates according to a duty cycle, within which there are distinct continuous periods of steady operation, for the purposes of this part of ISO 9614, 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 occurrences are predictable (see table B.3 in annex B).

4.3 Measurement uncertainty

For the purposes of this part of ISO 9614, three grades of accuracy are defined in table 2. 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 1). 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.

Below 50 Hz there are insufficient data on which to base uncertainty values. For the purposes of this part of ISO 9614, the normal range for A-weighted data is covered by the one-octave bands from 63 Hz to 4 kHz, and the one-third-octave bands from 50 Hz to 6,3 kHz. The A-weighted value which is computed from one-octave band levels in the range 63 Hz to 4 kHz, and one-third-octave band levels in the range 50 Hz to 6,3 kHz is correct if there are no significantly high levels in the bands below 50 Hz and above 6,3 kHz. For the purposes 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 shall be stated in accordance with 10.5 b).

Table 2 — Uncertainty in the determination of sound power levels

Octave band centre frequencies Hz	One-third-octave band centre frequencies Hz	Standard deviations, s 1)		
		Precision (grade 1) dB	**Engineering** (grade 2) dB	**Survey** (grade 3) dB
63 to 125	50 to 160	2	3	
250 to 500	200 to 630	1,5	2	
1 000 to 4 000	800 to 5 000	1	1,5	
	6 300	2	2,5	
A-weighted2)				43)

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

2) 63 Hz to 4 kHz or 50 Hz to 6,3 kHz.

3) In view of the wide variation of equipment for which the standards may be applied, the value given is only tentative.

The uncertainty in the 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 type of intensity-field sampling and measurement procedure employed. For this reason this part of ISO 9614 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 tables B.2 and B.3 (see annex B).

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 levels 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 its weighted value is 10 dB or more below the overall weighted level, is irrelevant.

5 Acoustic 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 1043, is not invalidated. In addition, it shall satisfy the requirements stated in 5.2 to 5.4.

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 reduce unacceptably the measurement accuracy (see annex B and A.2.2 of annex A).

NOTE 3 If substantial quantities of absorbing material are part of the source under test, high levels of extraneous intensity may lead to an erroneous estimate 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 is not such that the specified limit on the sound field temporal variability indicator, F_1, is exceeded. See table B.3.

5.3 Wind, gas flow, 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 m/s (see annex C). Always use a probe windscreen during outdoor measurements (refer to IEC 1043 for guidance). Do not place the probe in, or very close to, any stream of flowing gas of which the mean speed exceeds 2 m/s, and mount it so that it is not subject to significant vibration.

NOTES

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

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

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

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. Examine the repeatability of the results (as defined in ISO 5725) and 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 IEC 1043 shall be used. Class 1 instruments shall be used for grade 1 and grade 2 determinations. Adjust the intensity measurement instrument to allow for ambient air pressure and temperature according to IEC 1043. Record the pressure-residual intensity index of the instrument used for measurements according to this part of ISO 9614 for each frequency band of measurement.

6.2 Calibration and field check

The instrument, including the probe, shall comply with IEC 1043. Verify compliance with IEC 1043 at least once a year in a laboratory making calibrations in accordance with national standards. Record the results in accordance with 10.3.

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 procedures given in 6.2.1 and 6.2.2 to indicate anomalies within the measuring system that may have occurred during transportation, etc.

6.2.1 Sound pressure level

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

6.2.2 Intensity

Place the intensity probe on the measurement surface, with the axis oriented normal to the surface, at a position with intensity higher than the surface average intensity. Measure the normal sound intensity level (see 3.5). 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 shall have opposite signs and the difference between the two sound intensity levels shall be less than 1,5 dB in order for the measuring equipment to be acceptable.

7 Installation and operation of the source

7.1 General

Mount the source or place it in a proper way representative of normal use or the way stated in a special test code for the particular type of machinery or equipment.

7.2 Operating and mounting conditions of the source under test

Use the operating and mounting conditions specified in a test code, if any, for the particular type of machinery or equipment. If there is no test code, operate the source heavily loaded in a steady condition representative of normal use.

The following operational conditions may be appropriate:

a) under the load of maximum sound generation representative of normal use (probability of such use being more than 10 %);

b) under full load;

c) under no load (idling);

d) under simulated load (the load is not representative of normal use but simulating it, preferably being the load of maximum sound generation);

e) under other specified load and operating conditions.

One of the alternatives a) or b) is recommended in this order to be applied as the main operating condition. One or more of the others can be chosen as additional operating conditions.

8 Measurement of normal sound intensity component levels

8.1 Averaging time

For a 95 % confidence level of a maximum error of 5 % in measured intensity, the averaging time requirement for instruments using filters for white noise with Gaussian distribution is given by

$$BT \geqslant 400$$

where

B is the filter bandwidth;

T is the averaging time.

For instruments which synthesize one- or one-third-octave bands from narrow-band analyses, reference shall be made to IEC 1043 for guidance on the equivalent averaging time/number of averages. Special care shall be taken in cases of cyclic signals.

8.2 Initial test

Make measurements of normal sound intensity on an initial measurement surface. If this initial surface proves to be unsatisfactory, modify it according to the actions specified in annex B.

The initial measurement surface shall be defined around the source under test.

NOTE 7 This should preferably take one of the geometrically simple and quantifiable forms indicated in figure 1.

The average distance between the measurement surface and the surface of the source under test shall be greater than 0,5 m, unless that position is on a component which can be shown, by test, to radiate an insignificant proportion of the sound power of the source under test. The chosen surface may incorporate areas which are non-absorbent (diffuse-field absorption coefficient less than 0,06), 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 (6) (see 3.6.2).

Choose a "typical" measurement position on the initial measurement surface for the assessment of whether the sound field is stationary. Calculate indicator F_1 for all frequency bands of measurement according to A.2.1 of annex A. If the temporal variability of the sound field exceeds that specified in table B.3 in annex B, take appropriate action according to table B.3 to reduce this variability.

If it is possible to turn off the source under test, extraneous noise is insignificant if A-weighted sound pressure levels measured at five positions (distributed reasonably uniformly over the measurement surface) fall by at least 10 dB when the source is turned off.

NOTE 8 This condition does not apply in cases where the source under test drives sources of significant extraneous noise external to the measurement surface.

Make measurements of normal sound intensity levels and sound pressure levels in those frequency bands in which the sound power determination is to be made, at a minimum of one position per square metre, and a minimum of 10 positions distributed as uniformly as possible (according to segment area) over the measurement surface. In cases where the extraneous noise is not insignificant, and where this would require more than 50 measurement positions, a reduction to one position per 2 m^2 is permissible, provided that the total number is not less than 50. In cases where the extraneous noise is insignificant, and for measurement surface areas greater than 50 m^2, distribute 50 positions as uniformly as possible (according to segment area) over the entire measurement surface.

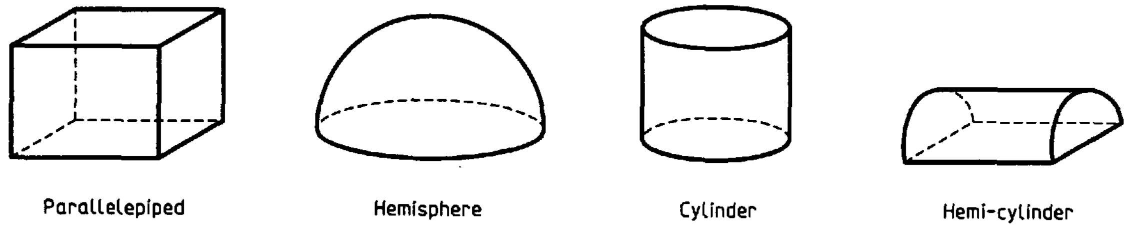


Figure 1 — Preferred initial measurement surfaces

Calculate the field indicators F_2, F_3 and F_4 for all frequency bands of measurement according to annex A, and introduce them into the formulae given for the qualification procedure of B.1.1 of annex B. If this check is fulfilled for each frequency band, the initial sound power determination is qualified as a final result within the range of uncertainty given by table 2.

If criterion 1 of B.1.1 is not satisfied for all frequency bands of measurement, then take one of the following alternative courses of action:

a) make a statement in the report according to 10.5 to the effect that the uncertainty of the sound power level determination in these frequency bands exceeds that stated in table 2 for the desired grade of accuracy; or

b) take action according to table B.3, to increase the accuracy of the determination.

If criterion 2 of B.1.2 is not satisfied in all frequency bands of measurement, take alternative action in accordance with either 8.3 or 8.4.

8.3 Optional procedure designed to minimize the number of additional measurement positions on an initial measurement surface

8.3.1 Identification of concentrations of partial sound power

If the check given in B.1.2 (criterion 2) indicates that, for any frequency band (or bands), the normalized standard deviation of the measured values of normal sound intensity indicated by F_4 on the initial measurement surface exceeds that necessary to ensure a sampling error within the range corresponding to the desired class of accuracy, it may be possible to minimize the additional measurement effort required to qualify the *initial* measurement surface by selectively modifying the array of measurement positions in a manner which optimizes the normal sound intensity sampling process. The possibility of such optimization may be checked by implementing the procedure given in 8.3.2.

8.3.2 Positive partial sound power concentration

This procedure determines whether or not it is possible to optimize the normal sound intensity sampling process by selectively modifying the array of measurement positions. If criterion 1 of B.1.1 is satisfied but criterion 2 of B.1.2 is not satisfied, and if $F_3 - F_2 \leqslant 1$ dB (in some or all of the frequency bands of measurement), it is possible that a major part of the source sound power in those bands passes through a subset of measurement segments of which the total area is less than half the total area of the measurement surface. Selective increase of the number of measurement positions in such segments will normally improve the accuracy of determination of sound power. The possibility is assessed according to the calculation procedure given in B.1.3.

If confirmation of the existence of partial sound power concentrations is obtained, evaluate the necessary number of additional positions on the subset of segments passing the major part of the sound power according to the calculation procedure specified in B.1.3, and distribute the number uniformly (according to segment area) over that subset. Measure normal sound intensity levels only at the new measurement positions. Calculate the partial sound powers and source sound power level from equations (11) and (12), and qualify the sound power determination as a final result within the range of uncertainty given by table 2.

If this selective modification procedure cannot be implemented, take alternative appropriate action according to B.2 and table B.3.

8.4 Further tests

If the checks given in B.1 indicate that neither the initial choice of measurement array nor, if the procedure in 8.3.2 is implemented, the modified measurement array meets 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 and/or array. Recalculate the field indicators F_2, F_3 and F_4 and assess them according to B.1. Take action according to B.2.

Repeat this procedure until the required grade of accuracy, as indicated by B.1, is attained. In cases where repeated action fails to satisfy the specified criteria, record a null test result and state the associated reasons.

9 Calculation of sound power level

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

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

$$P_i = I_{ni} S_i \qquad \ldots (11)$$

where

P_i is the partial sound power for segment i;

I_{ni} is the signed magnitude of the normal sound intensity component measured at position i on the measurement surface;

S_i is the area of segment i.

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

$$I_{ni} = I_0 \times 10^{XX/10}$$

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

$$I_{ni} = -I_0 \times 10^{XX/10}$$

In these equations $I_0 = 10^{-12}$ W/m^2.

9.2 Calculation of the sound power level of the noise source

Calculate the sound power level of the noise source in each frequency band from the equation:

$$L_W = 10 \lg \sum_{i=1}^{N} P_i/P_0 \text{ dB} \qquad \ldots (12)$$

where

P_i is the partial sound power for segment i, calculated from equation (11);

P_0 is the reference sound power ($= 10^{-12}$ W);

N is the total number of measurement positions and segments.

If $\sum_{i=1}^{N} P_i$ is negative in any frequency band, the method given in this part of ISO 9614 is not applicable to that band.

10 Information to be reported

The following information, if applicable, shall be compiled and recorded for measurements that are made according to this part of ISO 9614.

10.1 Source under test

a) Description of the source under test (including its dimensions and surface texture).

b) Character of the noise source under test (variability, occurrence of cycles, tonal quality, etc.).

c) Operating conditions.

d) Mounting conditions.

10.2 Acoustic environment

a) Description of the test environment, including a sketch showing the location of the source, configuration and positions of nearby objects, nature of local terrain and/or ground plane.

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

c) Air temperature and static pressure.

d) Mean wind speed and direction.

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

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

10.3 Instrumentation

a) Equipment used for the measurements, including names, types, serial numbers and manufacturers, and probe configuration.

b) Method(s) used to calibrate and perform field checks on the instrumentation, including dates of calibration.

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

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

10.4 Measurement procedure

a) Description of each step in the measurement procedure.

b) Description of the mounting, or support system, of the intensity probe during measurements.

c) Quantitative description of the measurement surface(s) and segments; a diagram should be presented.

d) Description of the measurement array; each position should be allocated a number and coordinates.

e) Averaging time at each position.

10.5 Acoustical data

a) Tabulation of the field indicators F_1 to F_4 calculated from each set of measurements on each measurement surface used.

b) Tabular or graphical presentation of the calculated value of the 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 of annex B 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 4.3.

c) A statement of the predicted uncertainty in the sound power level determined for each frequency band, in which criterion 2 of annex B is not satisfied, according to equation (B.3).

d) Presentation of the results of the probe-reversal field checks specified in 6.2.2, if appropriate.

e) The date when the measurements were performed (year/month/day).

10.6 Grade of accuracy of the sound power level determination

The grade of accuracy attained in the final test, according to table 2, shall be stated. In the special case where the grade of accuracy can only be met for a sound power level over a restricted frequency range, the 95 % confidence limits in the frequency bands where this accuracy cannot be assured according to annex B shall be reported.

Annex A
(normative)

Calculation of field indicators

A.1 General

Evaluate field indicators according to equations (A.1) to (A.9) for each measurement surface and array used, in each frequency band used for the determination of sound power level.

A.2 Definitions of field indicators

A.2.1 Temporal variability indicator of the sound field

Evaluate a typical value of the temporal variability indicator, F_1, of the sound field at an appropriate position selected on the measurement surface and calculated from equation (A.1):

$$F_1 = \frac{1}{\overline{I_n}}\sqrt{\frac{1}{M-1}\sum_{k=1}^{M}\left(I_{nk}-\overline{I_n}\right)^2} \qquad \ldots (A.1)$$

where

$\overline{I_n}$ is the mean value of I_n for M short-time-average samples I_{nk} calculated from equation (A.2):

$$\overline{I_n} = \frac{1}{M}\sum_{k=1}^{M} I_{nk} \qquad \ldots (A.2)$$

NOTE 9 M will normally take a value of 10. A recommended short averaging time is between 8 s and 12 s, or any integer number of cycles for periodic signals.

A.2.2 Surface pressure-intensity indicator

Calculate the surface pressure-intensity indicator, F_2, from equation (A.3):

$$F_2 = \overline{L_p} - \overline{L_{|I_n|}} \qquad \ldots (A.3)$$

where

$\overline{L_p}$ is the surface sound pressure level, in decibels, calculated from equation (A.4):

$$\overline{L_p} = 10\lg\left(\frac{1}{N}\sum_{i=1}^{N}10^{0,1L_{pi}}\right)\ \text{dB} \qquad \ldots (A.4)$$

and

$\overline{L_{|I_n|}}$ is the surface normal unsigned sound intensity level, in decibels, calculated from equation (A.5):

$$\overline{L_{|I_n|}} = 10\lg\left(\frac{1}{N}\sum_{i=1}^{N}|I_{ni}|/I_0\right)\ \text{dB} \qquad \ldots (A.5)$$

where $|I_{ni}|$ is the unsigned normal sound intensity at measurement position i.

A.2.3 Negative partial power indicator

Calculate the negative partial power indicator, F_3, from equation (A.6):

$$F_3 = \overline{L_p} - \overline{L_{I_n}} \qquad \ldots (A.6)$$

where

$\overline{L_p}$ is the surface sound pressure level, in decibels, calculated from equation (A.4);

$\overline{L_{I_n}}$ is the surface normal signed intensity level, in decibels, calculated from equation (A.7):

$$\overline{L_{I_n}} = 10\lg\left|\frac{1}{N}\sum_{i=1}^{N}I_{ni}/I_0\right|\ \text{dB} \qquad \ldots (A.7)$$

and

I_{ni} is the signed magnitude of the normal sound intensity component measured at position i on the measurement surface;

I_0 is the reference sound intensity ($= 10^{-12}$ W/m^2).

If the normal sound intensity component level $L_{I_{ni}}$ at position i is expressed as XX dB, calculate the value of I_{ni} from the equation

$$I_{ni} = I_0 \times 10^{XX/10}$$

If the normal sound intensity component level $L_{I_{ni}}$ at position i is expressed as (–) XX dB, calculate the value of I_{ni} from the equation

$$I_{ni} = -I_0 \times 10^{XX/10}$$

If $\sum I_{ni}/I_0$ is negative in any frequency band, the test conditions do not satisfy the requirements of this part of ISO 9614 in that frequency band.

A.2.4 Field non-uniformity indicator

Calculate the field non-uniformity indicator, F_4, from equation (A.8):

$$F_4 = \frac{1}{\overline{I_n}} \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (I_{ni} - \overline{I_n})^2} \qquad \ldots \text{(A.8)}$$

where $\overline{I_n}$ is the surface normal sound intensity calculated from equation (A.9):

$$\overline{I_n} = \frac{1}{N} \sum_{i=1}^{N} I_{ni} \qquad \ldots \text{(A.9)}$$

Annex B
(normative)

Procedure for achieving a desired grade of accuracy

B.1 Qualification requirements

In the application of this part of ISO 9614, the sound field conditions at measurement positions on the initial measurement surface 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 chosen measurement parameters (e.g. measurement surface, distance, microphone array) in relation to the sound field/environmental conditions particular to the specific measurement. The general procedure is summarized in figure B.1.

B.1.1 Check for the adequacy of the measurement equipment

For a measurement array to qualify as being suitable for the determination of sound power level of a noise source according to this part of ISO 9614, the dynamic capability index L_d of the measurement instrumentation shall be greater than the indicator F_2 determined in accordance with annex A in each frequency band of measurement:

criterion 1

$$L_d > F_2 \qquad \ldots (B.1)$$

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

NOTE 10 If the indicator F_3 is used instead of F_2, the test will be more conservative.

B.1.2 Check for the adequacy of the chosen array of measurement positions

The number N of probe positions uniformly distributed over a chosen measurement surface is regarded as sufficient if:

criterion 2

$$N > CF_4^2 \qquad \ldots (B.2)$$

where the indicator F_4 is determined according to annex A and factor C is given in table B.2. Where the same number of measurement positions is used for all frequency bands, use the maximum value of CF_4^2 in criterion 2.

If criterion 2 is not met in some frequency bands, and the levels in these bands are not significant (see 4.3), then these levels shall not be reported.

The results for individual one-third-octave or octave frequency bands have an estimated 95 % confidence interval given by

$$10 \lg\left(1 \pm 2F_4/\sqrt{N}\right) \text{ dB} \qquad \ldots (B.3)$$

where F_4 is computed for each band considered. If, in a certain frequency band, criterion 2 for the required grade of accuracy has not been met, the computed sound power level in that band may only be reported if accompanied by a statement of the corresponding estimated 95 % confidence interval.

In cases where the A-weighted sound power level is to be determined by the summation of weighted sound powers computed in a number of contiguous frequency bands, then F_4 shall be computed from equations (A.8) and (A.9) using values of I_{ni} and I_n computed as the sums of the weighted sound intensities in each included band. Criterion 2 shall then be applied using the highest value of C in the frequency band encompassed by this summation for the required grade of accuracy.

The weighted sound intensity in an individual frequency band is computed as follows. When the A-weighted normal sound intensity level L_{I_n} for segment i is expressed as XX dB, the weighted value of I_{ni} shall be calculated from the equation

$$I_{ni} = I_0 \times 10^{XX/10}$$

When the A-weighted sound intensity level L_{I_n} for segment i is expressed as (–) XX dB, the weighted value of I_{ni} shall be calculated from the equation

$$I_{ni} = -I_0 \times 10^{XX/10}$$

In these equations $I_0 = 10^{-12}$ W/m^2.

B.1.3 Check for concentrations of positive partial sound power and evaluation of the necessary modification of the measurement array (Optional procedure)

In each frequency band for which the conditions specified in 8.3.2 apply, arrange the *positive* partial sound powers passing through each measurement segment in descending order of magnitude, and select an upper subset of segments passing more than half the total sound power. Denote by α the selected fraction of total sound power ($\alpha > 0,5$). The number of segments N_α so identified shall be less than half the total number of segments N. Implement the procedure specified below for assessing the number of additional measurement positions on this segment subset.

If a segment subset which satisfies the above condition does not exist, take alternative appropriate actions to increase the accuracy of sound power determination according to table B.3.

Calculate indicator F_4 separately according to A.2.3

a) for the segment subset N_α having total area S_α, and

b) for the remaining segments.

These values of F_4 are denoted by $F_4(\alpha)$ and $F_4(1-\alpha)$, respectively.

Determine the total number of new measurement positions N^* required on the measurement surface S_α from equation (B.4):

$$N^* \geqslant 4[F_4(\alpha)/\Delta_\alpha]^2 \qquad \ldots (B.4)$$

where

$$\Delta_\alpha = \frac{1}{\alpha}\left[\Delta - (1-\alpha)\frac{2}{\sqrt{N_{1-\alpha}}}F_4(1-\alpha)\right]$$

and

$$N_{1-\alpha} = N - N_\alpha$$

and values of Δ are given in table B.1.

Distribute the N^* measurement positions as uniformly as possible (according to segment area) over area S_α.

NOTE 11 If the total contribution to the A-weighted sound power from the one-third-octave bands in the frequency range 800 Hz to 5 000 Hz is less than half the total power, then the values of C for the one-third-octave band 200 Hz to 630 Hz should be used.

B.1.4 Indication that the field is not stationary

Evaluate indicator F_1 immediately before and immediately after measurement on any one measurement surface. If F_1 exceeds the limit given in table B.3, take steps to reduce the temporal variability of the field.

B.1.5 Indication of the presence of strongly directional extraneous sources

If F_2 and F_3 are significantly different, it is probable that there exists strongly directional extraneous noise sources in the vicinity of the source under test.

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

Table B.3 specifies the actions to be taken in cases where the chosen measurement surface and/or array does not qualify according to the requirements given in B.1.

Table B.1 — Error factor Δ

Frequency	Grade 1	Grade 2	Grade 3
All bands	0,20	0,29	
A-weighted			0,60

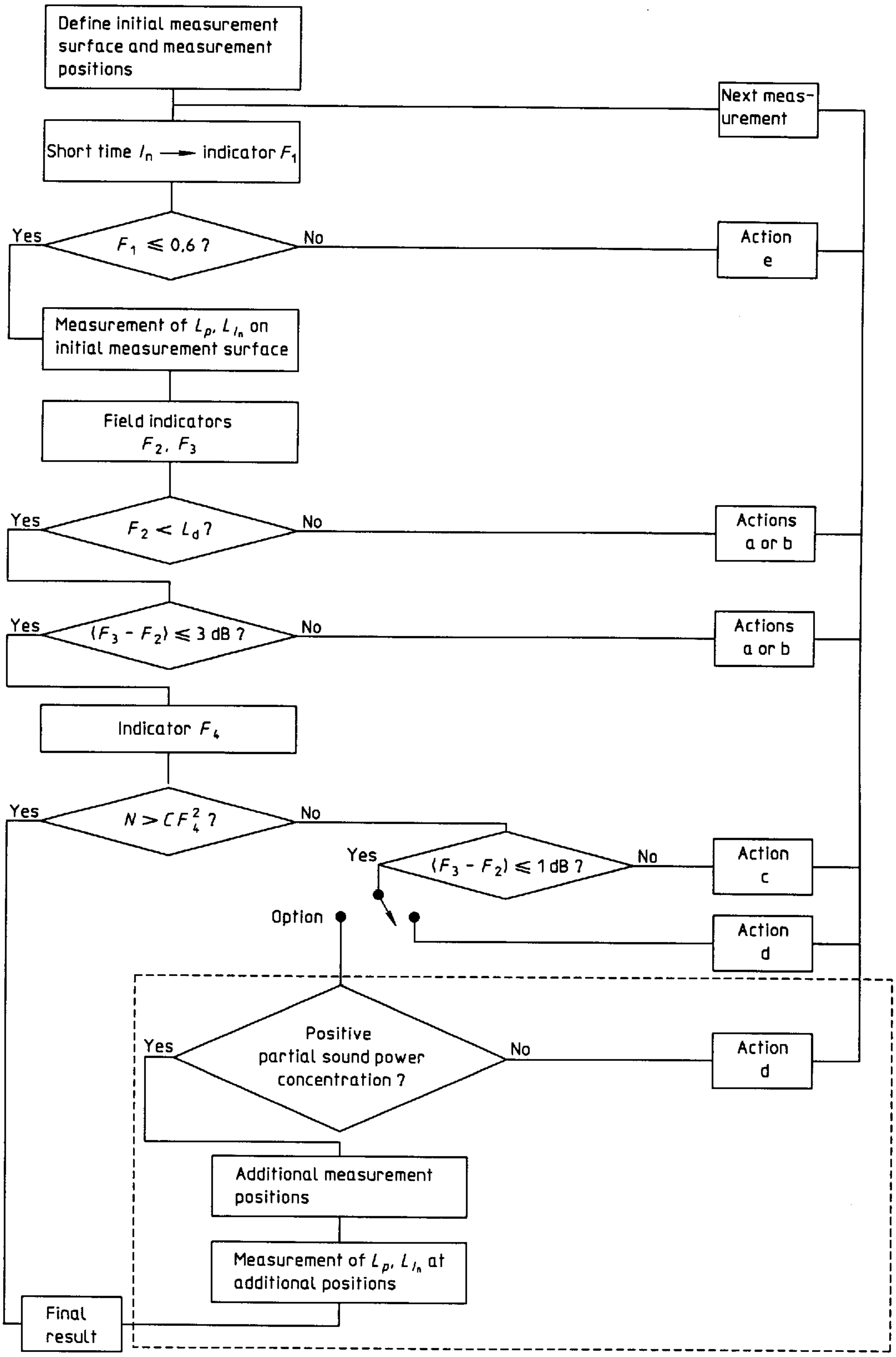
Table B.2 — Values for factor C

Octave band centre frequencies Hz	**One-third-octave band centre frequencies** Hz	C		
		Precision (grade 1)	**Engineering** (grade 2)	**Survey** (grade 3)
63 to 125	50 to 160	19	11	
250 to 500	200 to 630	29	19	
1 000 to 4 000	800 to 5 000	57	29	
	6 300	19	14	
A-weighted[1]				8

[1] 63 Hz to 4 kHz or 50 Hz to 6,3 kHz.

Table B.3 — Actions to be taken to increase grade of accuracy of determination

Criterion	**Action code** (see figure B.1)	**Action**
$F_1 > 0{,}6$	e	Take action to reduce the temporal variability of extraneous intensity, or measure during periods of less variability, or increase the measurement period at each position (if appropriate).
$F_2 > L_d$ or $(F_3 - F_2) > 3$ dB	a or b	In the presence of significant extraneous noise and/or strong reverberation, reduce the average distance of the measured surface from the source to a minimum average value of 0,25 m. In the absence of significant extraneous noise and/or strong reverberation, increase the average measured distance to 1 m. Shield measurement surface from extraneous noise sources or take action to reduce sound reflections towards the source.
Criterion 2 not satisfied and $1 \text{ dB} \leqslant (F_3 - F_2) \leqslant 3$ dB	c	Increase the density of measurement positions uniformly in order to satisfy criterion 2.
Criterion 2 not satisfied and $(F_3 - F_2) \leqslant 1$ dB, and the procedure of 8.3.2 either fails or is not selected	d	Increase average distance of measurement surface from source using the same number of measurement positions, or increase the number of measurement positions on the same surface.



NOTE — The path enclosed in broken lines represents an optional procedure designed to minimize the number of additional measurement positions required on the initial measurement surface (8.3).

Figure B.1 — Scheme for the procedure for achieving the desired grade of accuracy

Annex C
(informative)

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 $p-p$ 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 highly reactive fields. More serious errors are likely to be caused by the effects of unsteady airflow (turbulence).

Turbulence may exist in 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 uncorrelated to 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 sound fields. The result is that strong pseudo-intensity signals can be generated.

The function of a 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.

The scale and frequency of turbulence 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 r.m.s. value of turbulent pressure fluctuations increases as the square of mean flow speed, a conservative "blanket" limitation is placed on the 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 values by turbulent pseudo-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
(informative)

Effect of sound absorption within the measurement surface

If the source shows obvious significant sound absorption (e.g. relevant material for heat insulation and/or sound absorbers), and if the measurement of the indicator F_3 yields a value of more than 6 dB, the influence of the absorbed sound power $P_{I,\text{abs}}$ (with $P_{I,\text{abs}} < 0$) on the total sound power measured, P_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 $P_{I,\text{abs}}$ 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 estimate of the absorbed sound power can be determined by means 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:

$$L_W - L_{W,\text{abs}} \geqslant K \text{ dB} \qquad \ldots \text{(D.1)}$$

where

L_W is the level of the total sound power, in decibels [according to equation (8)];

$L_{W,\text{abs}}$ is the level of the absorbed sound power, in decibels $[= 10 \lg(|P_{I,\text{abs}}|/P_0)]$;

K is given in table 1.

Otherwise, action should 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)

Bibliography

[1] ISO 2204:1979, *Acoustics — Guide to International Standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings.*

[2] ISO 3740:1980, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards and for the preparation of noise test codes.*

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

[4] ISO 3742:1988, *Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete-frequency and narrow-band sources in reverberation rooms.*

[5] ISO 3743:1988, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for special reverberation test rooms.*

[6] ISO 3744:1981, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane.*

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

[8] ISO 3746:1979, *Acoustics — Determination of sound power levels of noise sources — Survey method.*

[9] ISO 3747:1987, *Acoustics — Determination of sound power levels of noise sources — Survey method using a reference sound source.*

[10] ISO/TR 7849:1987, *Acoustics — Estimation of airborne noise emitted by machinery using vibration measurement.*

[11] BENOIT, R. et al. Analysis of sound power measurements via intensity for a spinning frame. *Inter-Noise 85* (Munich), 1985, pp. 1131-1134.

[12] BOCKHOFF, M. Sound power determination by intensity measurements in the near-field of a vibrating panel. *Inter-Noise 85* (Munich), 1985, pp. 1135-1138.

[13] BOCKHOFF, M. et al. Messungsicherheit bei der Schalleistungsbestimmung nach dem Intensitätsmessverfahren. *DAGA 87* (Aachen), 1987, pp. 789-792.

[14] BOCKHOFF, M. et al. Sound power determination of machines by intensity technique. *Inter-Noise 88* (Avignon), 1988, pp. 1125-1128.

[15] CROCKER, M.J. The use of existing and advanced intensity techniques to identify noise sources of a Diesel engine. *SAE 810694*, 1981.

[16] FAHY, F.J. *Sound Intensity*, Elsevier Applied Science, London, 1989.

[17] HÜBNER, G. Development of requirements for an intensity measurement code determining sound power level of machines under (worst) *in situ* conditions. *Inter-Noise 84* (Honolulu, USA), 1984, pp. 1093-1098.

[18] HÜBNER, G. Recent developments of sound power determination for machines using sound intensity measurements. A survey of procedure and accuracy aspects. *Inter-Noise 85* (Munich), 1985, pp. 57-68.

[19] HÜBNER, G. Recent developments of requirements for an intensity measurement code determining sound power levels of machines. 2e *Congrès international sur l'intensimétrie acoustique, Senlis, France,* September 1985, pp. 307-318.

[20] HÜBNER, G. Sound intensity method. Errors in determining the sound power levels of machines and its correlation with sound field indicators. *Inter-Noise 87* (Beijing, China), 1987, pp. 1227-1230.

[21] HÜBNER, G. Sound power determination of machines using sound intensity measurements. Reduction of number of measurement positions in cases of "hot areas". *Inter-Noise 88* (Avignon), 1988, pp. 1113-1116.

[22] HÜBNER, G. and RIEGER, W. *Schallintensitätsmessverfahren zur Schalleistungsbestimmung in der Praxis.* Forschungsbericht der Bundesanstalt für Arbeitsschutz, Fb Nr. 550, ISBN 3-88314-809.1. Wirtschaftsverlag NW, Verlag für die Neue Wissenschaft GmbH, Bremerhafen, Germany.

[23] LAMBERT, J.M. The application of a modern intensity meter to industrial problems: example of *in situ* sound power determination. *Inter-Noise 79* (Warszawa), 1979, pp. 227-231.

[24] PASCAL, J.C. Unbiased sound power determination. *Proceedings of the Institute of Acoustics Autumn Conference* (Bournemouth), 1982, pp. B2.1-B2.4.

[25] POPE, J. Intensity measurements for sound power determination over a reflecting plane. *Inter-Noise 86* (Boston), 1986, pp. 1115-1120.

[26] RASMUSSEN, P. Sound power measurements by different operators. *Inter-Noise 86* (Boston), 1986, pp. 1121-1124.

UDC 534.61

Descriptors: acoustics, sound sources, noise (sound), tests, acoustic tests, determination, sound power, acoustic measurements.

Price based on 19 pages