INTERNATIONAL STANDARD

ISO 9614-3

First edition
2002-11-01

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

Part 3:
Precision method for measurement by scanning

Acoustique — Détermination par intensimétrie des niveaux de puissance acoustique émis par les sources de bruit —

Partie 3: Méthode de précision pour mesurage par balayage

Reference number
ISO 9614-3:2002(E)

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this part of ISO 9614 may be the subject of patent rights other than those identified above. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 9614-3 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee 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*

— *Part 3: Precision method for measurement by scanning*

Annexes B and C form a normative part of this part of ISO 9614. Annexes A, D, E, F, G, H and I 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. Other International Standards which describe methods of determination of the 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.

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

a) Specific 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.

0.2 This part of ISO 9614 specifies methods of determining the sound power levels of sources, within specific ranges of uncertainty, under test conditions which are less restricted than those required by ISO 3740 to ISO 3747.

It is recommended that personnel performing sound intensity measurements according to this part of ISO 9614 are appropriately trained and experienced.

0.3 This part of ISO 9614 complements ISO 9614-1, ISO 9614-2 and the ISO 3740 to ISO 3747 series, which specify various methods for the determination of sound power levels of machines and equipment. It differs from the ISO 3740 to ISO 3747 series 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 which conforms to IEC 61043 restrict measurements to the one-third octave range 50 Hz to 6,3 kHz. Octave band and band-limited A-weighted values are determined from the constituent one-third-octave band values.

0.4 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 practice, this exclusion is effective only if the source under test and other sources of extraneous intensity on the measurement surface are stationary over time. In the presence of sound sources operating outside the measurement surface, any system lying within the surface can 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 can 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 method is based on sampling of the intensity normal to the measurement surface by moving an intensity probe continuously along specified paths. 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 measurement surface, the pattern and speed of the probe scanning, and the proximity of extraneous sources outside the measurement surface.

The accuracy 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 can 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 can contain strong contributions from sources outside the measurement surface, but can be associated with little net sound energy flow, as in a reverberant field in an enclosure; or the field can be strongly reactive because of the presence of the near field and/or standing waves.

The accuracy of determination of sound power level is adversely affected by a flow of sound energy into the volume enclosed by the measurement surface through a portion of that surface, even though it is, in principle, compensated by increased flow of the volume out through the remaining portion of the surface. This condition is caused by the presence of a strong extraneous source outside the measurement surface. This part of ISO 9614 limits such situations by giving relevant criteria.

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

Part 3: Precision method for measurement by scanning

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 sound source(s) of which the sound power level is to be determined.

Surface integration of the intensity component normal to the measurement surface is approximated by subdividing the measurement surface into contiguous partial surfaces, and scanning the intensity probe over each partial surface along a continuous path which covers the extent of the partial surface. The measurement instrument determines the averaged normal intensity component and averaged squared sound pressure over the duration of each scan. The scanning operation can be performed either manually or by means of a mechanical system.

The octave band or band-limited weighted sound power level is calculated from the measured one-third-octave-band values. The method is applicable to any source for which a physically stationary measurement surface can be defined, and on which the sound generated by the source under test and by other significant extraneous sources are stationary in time. The source is defined by the choice of measurement surface. The method is applicable in specific test environments fulfilling all relevant requirements of this part of ISO 9614.

This part of ISO 9614 specifies certain ancillary procedures, described in annex C, 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 quality of the determination does not meet the requirements of this part of ISO 9614, the test procedure shall be modified in the manner indicated.

This part of ISO 9614 is not applicable to any frequency band in which the sound power of the source is found to be negative on measurement.

1.2 This part of ISO 9614 is applicable to sources situated in any environment which is neither so variable over 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 5.2.2, 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. For example, extraneous noise levels can exceed the dynamic capability of the measuring instrument or can 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.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 9614. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 9614 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60651, *Sound level meters*

IEC 60942:1998, *Electroacoustics — Sound calibrators*

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

IEC 61043:1993, *Electroacoustics — Instruments for the measurement of sound intensity — Measurements with pairs of pressure sensing microphones*

GUM:1993, *Guide to the expression of uncertainty in measurement.* BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML.

3 Terms and definitions

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

NOTE Symbols used in this part of ISO 9614 are listed in annex A. Definitions of field indicators are given in annex B.

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

NOTE 1 The reference sound pressure is 20 μPa.

NOTE 2 Sound pressure level is expressed in decibels.

3.2
instantaneous sound intensity

$\vec{I}(t)$
instantaneous flow of sound energy per unit of area and per unit time in the direction of the local instantaneous acoustic particle velocity

NOTE This is a vectorial quantity which is equal to the product of the instantaneous sound pressure at a point and the associated particle velocity

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

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 time.

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

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

where

T is the integration period

NOTE Also

I is the signed magnitude of $\vec{I}$; in this part of ISO 9614, the sign is chosen so that the energy flow going out of the sound source through the measurement surface is measured positive;

$|I|$ is the unsigned magnitude of $\vec{I}$.

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

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

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, $|I_\mathrm{n}|$, given by

$$L_{I_\mathrm{n}} = 10\lg\frac{|I_\mathrm{n}|}{I_0}\ \mathrm{dB} \quad (4)$$

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

NOTE 1 It is expressed in decibels.

NOTE 2 When I_n is negative, the level is expressed as (–) XX dB, except when used in the evaluation of δ_{pI_0} (see 3.10).

3.6 Sound powers

3.6.1
partial sound power
P_i
time-averaged flow of sound energy per unit of time through a partial surface of a measurement surface, given by

$$P_i = \overline{I_{\mathrm{n}i}} \cdot S_i \quad (5)$$

where

$\overline{I_{\mathrm{n}i}}$ is the signed magnitude of the partial surface average normal sound intensity measured on the partial surface i of the measurement surface;

S_i is the area of the partial surface i.

NOTE 1 When the averaged normal sound intensity level $\overline{L}_{I_n}$ for a partial surface i is expressed as XX dB, the value of $\overline{I_{ni}}$ is calculated from the equation.

$$\overline{I_{ni}} = I_0 10^{XX/10} \quad (6)$$

NOTE 2 When the averaged normal sound intensity level $\overline{L}_{I_n}$ for a partial surface i is expressed as (–) XX dB, the value of $\overline{I_{ni}}$ is calculated from the equation.

$$\overline{I_{ni}} = -I_0 10^{XX/10} \quad (7)$$

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

$$P = \sum_{i=1}^{N} P_i \quad (8)$$

where N is the total number of partial surfaces 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 this part of ISO 9614, given by

$$L_W = 10 \lg \frac{|P|}{P_0} \text{ dB} \quad (9)$$

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

NOTE 1 It is expressed in decibels.

NOTE 2 When P is negative, the level is expressed as (–) XX dB for record purposes only.

3.6.4
normalized sound power level
L_{W0}
sound power level under the reference meteorological condition (temperature θ_0 = 23 °C, barometric pressure B_0 = 101 325 Pa), given by

$$L_{W0} = L_W - 15 \lg\left[\frac{B}{101\,325} \times \frac{296{,}15}{273{,}15 + \theta}\right] \text{dB} \quad (10)$$

where

θ is the air temperature, in degrees Celsius, during the actual measurement;

B is the barometric pressure, in pascals, during the actual measurement.

NOTE See annex H.

