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

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.

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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:

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

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:

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

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;

$|I|$ 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 $\vec{n}$.

$$I_n = \vec{I} \cdot \vec{n} \quad \ldots (3)$$

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 $|I_n|$, given by:

$$L_{I_n} = 10 \lg[|I_n|/I_0] \text{ dB} \quad \ldots (4)$$

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:

$$P_i = \vec{I}_i \cdot \vec{S}_i = I_{ni} \cdot S_i \quad \ldots (5)$$

where

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 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:

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

and

$$|P| = \left| \sum_{i=1}^{N} P_i \right| \quad \ldots (7)$$

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:

$$L_W = 10 \lg[|P|/P_0] \text{ dB} \quad \ldots (8)$$

where

$|P|$ 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.

$$\delta_{pI_0} = (L_p - L_{I_n}) \quad \text{. . . (9)}$$

3.12 dynamic capability index, L_d: Given by:

$$L_d = \delta_{pI_0} - K \quad \text{. . . (10)}$$

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-weighted[2)]				4[3)]

1) The true value of the sound power level is to be expected with a certainty of 95 % in the range of $\pm 2s$ 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);