
**Acoustics — Noise emitted by machinery
and equipment — Engineering method
for the determination of emission sound
pressure levels *in situ* at the work station
and at other specified positions using
sound intensity**

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*Acoustique — Bruits émis par les machines et les équipements —
Méthode d'expertise pour la détermination par intensimétrie des
niveaux de pression acoustique d'émission *in situ* au poste de travail et
en d'autres positions spécifiées*

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Contents

Page

Foreword.....	iv
1 Scope.....	1
2 Normative references	1
3 Terms and definitions.....	1
4 Measurement uncertainty.....	3
5 Principle	4
6 Instrumentation	4
6.1 General	4
6.2 Calibration.....	4
7 Installation and operation of the source.....	5
7.1 General	5
7.2 Location of the machine.....	5
7.3 Mounting of the machine.....	5
7.4 Auxiliary equipment.....	6
7.5 Operation of the machine under test.....	6
8 Test procedure	7
8.1 Applicability	7
8.2 Measurement time interval.....	7
8.3 Measurements	8
8.4 Wind and gas flows.....	9
8.5 Criteria for qualification of the measurement	9
8.6 Criterion for background noise	9
8.7 Frequency range of measurements	9
8.8 Evaluation of the measurement result.....	9
9 Information to be recorded	10
9.1 General	10
9.2 Machine under test	10
9.3 Test conditions.....	10
9.4 Acoustic environment	10
9.5 Instrumentation	10
9.6 Location of specified positions	11
9.7 Noise data	11
10 Information to be reported	11
Annex A (normative) Criterion for the adequacy of the direction of the sound intensity vector.....	12
Annex B (normative) Procedure for frequencies higher than 5 000 Hz	14
Annex C (normative) Procedure in case the measurement fails to qualify	15
Annex D (informative) Example of a test table	16
Bibliography	17

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.

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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.

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Acoustics — Noise emitted by machinery and equipment — Engineering method for the determination of emission sound pressure levels *in situ* at the work station and at other specified positions using sound intensity

1 Scope

This International Standard specifies an engineering method (grade 2 accuracy) to determine the emission sound pressure level of machines *in situ*, at the work station or at other specified positions, using sound intensity. It is an alternative to ISO 11201, ISO 11202 and ISO 11204 for *in situ* measurements. It is applicable to all kinds of test environments provided that the requirements on background noise and field indicators are fulfilled.

This International Standard is applicable to equipment emitting stationary broadband noise. The noise can differ between operational cycles and can be with or without discrete frequency or narrow band components.

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2 Normative references (standards.iteh.ai)

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7574-1, *Acoustics — Statistical methods for determining and verifying stated noise emission values of machinery and equipment — Part 1: General considerations and definitions*

ISO 12001, *Acoustics — Noise emitted by machinery and equipment — Rules for the drafting and presentation of a noise test code*

IEC 60942:2003, *Electroacoustics — Sound calibrators*

IEC 61043:2003, *Electroacoustics — Instruments for the measurement of sound intensity — Measurements with pairs of pressure sensing microphones*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

sound intensity

\bar{I}

time-averaged instantaneous flow of sound energy per unit of area and per unit time in the direction of the local instantaneous acoustic particle velocity in a temporally stationary sound field

$$\bar{I} = \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T p(t) \vec{u}(t) dt$$

where

$p(t)$ is the instantaneous sound pressure at a point, in pascals;

$\vec{u}(t)$ is the associated instantaneous particle velocity at the same point, in metres per second;

T is the integration period, in seconds;

NOTE The sound intensity is a vectorial quantity. It is expressed in watts per square metre.

**3.2
sound intensity vector**

$$\vec{I}_{xyz}$$

vector sum of three measured orthogonal intensity components

NOTE It is expressed in watts per square metre.

**3.3
level of the sound intensity vector**

$$L_{Ixyz}$$

ten times the logarithm to the base 10 of the ratio of the modulus of the sound intensity vector to the reference intensity I_0 , in decibels, as given by

$$L_{Ixyz} = 10 \lg \left(\frac{|\vec{I}_{xyz}|}{I_0} \right) \text{ dB}$$

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NOTE The reference sound intensity is $I_0 = 10^{-12} \text{ W/m}^2$.

**3.4
sound field pressure-intensity indicator or field indicator**

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$$F_{pIxyz}$$

difference, in decibels, between the time-averaged measured sound pressure level, L'_p , and the level of the sound intensity vector, L_{Ixyz} , given by

$$F_{pIxyz} = L'_p - L_{Ixyz}$$

NOTE 1 When the indicator is determined for each of the Cartesian coordinates x , y and z , it is denoted F_{pIx} , F_{pIy} and F_{pIz} respectively.

NOTE 2 In ISO 9614-1 the notation F_2 is used.

**3.5
pressure-residual intensity index**

$$\delta_{pI0}$$

difference, in decibels, between the indicated sound pressure level and the sound intensity level when the intensity probe is placed and oriented in a sound field such that the sound intensity is zero

EXAMPLE This can be achieved in an acoustic coupler, or other suitable unit that has been designed for the probe so that the microphones are transverse to the direction of propagation of plane sound waves.

**3.6
emission sound pressure level**

$$L_p$$

sound pressure level at a specified position near a machine, when the machine is in operation under specified operating and mounting conditions on a reflecting plane surface, excluding the effects of background noise as well as the effect of reflections other than those from the plane or planes permitted for the purpose of the test

NOTE It is expressed in decibels.

3.7**specified position**

position defined in relation to a machine, including, but not limited to, an operator's position

NOTE The position can be a single, fixed point, or a combination of points along a path or on a surface located at a specified distance from the machine, as described in the relevant test code, if any. Positions located in the vicinity of a work station, or in the vicinity of an unattended machine, may be identified as "bystander positions".

3.8**dynamic capability index**

L_d

difference, in decibels, between the pressure-residual intensity index and the bias error factor, K

$$L_d = \delta_{pI0} - K$$

NOTE The value of K is 10 dB in this International Standard.

3.9**hemi-free field intensity correction**

K_5

correction to account for the fact that the sound intensity level is slightly smaller than the sound pressure level in a hemi-free field

NOTE 1 In this International Standard, $K_5 = 1$ dB.

NOTE 2 By introducing this correction, the risk of a small systematic underestimate of the emission sound pressure level is minimized, see references [9] to [16] in the Bibliography. K_5 is frequency independent and thus also valid for A-weighted sound pressure levels with the notation K_{5A} .

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4 Measurement uncertainty

A single value of an emission sound pressure level of a noise source determined according to the procedures of this International Standard is likely to differ from the true value at a fixed position by an amount within the range of the measurement uncertainty. The uncertainty in measurements of emission sound pressure levels arises from several factors which affect the results, some associated with environmental conditions in the measurement room and others with experimental techniques. A method for the determination of the measurement uncertainty from information on the various influence parameters is specified in the GUM.

Until more specific knowledge is available, the estimation of the measurement uncertainty might be based on existing information on the standard deviations of reproducibility and repeatability according to ISO 7574-1. Extensive measurement data are necessary in order to establish standard deviations of reproducibility and repeatability of emission sound pressure levels at individual positions; in any case, these standard deviations are likely to vary considerably between the many types of different machinery and equipment to which this International Standard is applied. It is therefore not possible to provide information that is universally applicable, and reference can only be made to noise test codes for relevant data on individual types of machines.

A typical value for the standard deviation of reproducibility is given in Table 1. From this, and with additional information on the standard deviation of repeatability, the total standard deviation and an estimate of the expanded measurement uncertainty for a coverage probability of approximately 95 % corresponding to a coverage factor of two, may be derived, as indicated.

Table 1 — Measurement uncertainty of the A-weighted emission sound pressure level

Reproducibility ^a standard deviation, σ_{RA} , for a stable source dB	Repeatability ^b standard deviation, σ_{rA} , for an unstable source dB	Total standard deviation dB	Expanded uncertainty ^d dB
1,5 ^c	σ_{rA}	$\sqrt{\sigma_{RA}^2 + \sigma_{rA}^2}$	$2\sqrt{\sigma_{RA}^2 + \sigma_{rA}^2}$
<p>^a Found by different operators using different equipment measuring the same machine in different environments. This value includes a small repeatability standard deviation ($\sigma_r \approx 0,5$ dB).</p> <p>^b Found by the same operator measuring the same machine in the same environment using the same equipment (only to be used if $\sigma_r > 0,5$ dB).</p> <p>^c If frequencies above 5 000 Hz dominate the A-weighted level, σ_{RA} may be greater, see Annex B.</p> <p>^d 95 % confidence under the assumption of a Gaussian distribution.</p>			

NOTE The value of the measurement uncertainty has been taken from References [11], [12], [15], [16] and [17] in the Bibliography.

5 Principle

The basic principle of the test method is that the sound intensity in a diffuse sound field is small (theoretically it should be zero) and that the sound pressure level equals the sound intensity level in a free progressive wave. The test method assumes that sound which has been reflected will add up to a diffuse sound field. The direct sound from the machine under test will not be part of the diffuse sound field but constitute the free progressive wave.

These assumptions will not be fulfilled if sound intensities from different parts of the machine with similar magnitude will meet at the probe and, to some extent, cancel each other. In such cases, the sound intensity will become smaller and, assuming uncorrelated summation, the sound pressure will become greater. In such cases, the level of the sound intensity vector will underestimate the emission sound pressure level. By adding K_5 to deal with the underestimate of the floor reflection and, for large machines, by requiring that the sound field pressure-intensity indicator meets the criterion specified in 8.5 the underestimate will be negligible.

6 Instrumentation

6.1 General

The intensity-measuring instrumentation shall be able to measure intensity levels re 10^{-12} W/m² in decibels in octave or one-third-octave bands. The instrument, including the probe, shall comply with a Class 1 instrument in accordance with IEC 61043:2003. If the probe does not have a flat frequency response above 5 000 Hz, see Annex B.

The residual pressure-intensity index δ_{pI0} of the microphone probe and analyser shall be higher than $F_{pI} + 10$ dB in each octave or one-third-octave band.

6.2 Calibration

The compliance of the instrumentation system with the requirements of IEC 61043 shall be verified periodically in a manner that is traceable to appropriate standards.

During each series of measurements, the instrument and the probe shall be calibrated at least at one frequency in the range from 200 Hz to 1 000 Hz in accordance with the calibration procedure.

The following field checks to test the instrument shall be made before each series of measurements.

- a) Carry out a field check according to the instrument manufacturer's specifications.

If no field check is specified by the instrument manufacturer, check the instrumentation according to b) and c):

- b) Sound pressure level: Check each pressure microphone of the intensity probe for sound pressure level using a Class 1 calibrator in accordance with IEC 60942:2003.
- c) Intensity: Calibrate using an intensity calibrator. If such a calibrator is not available or if the probe construction does not allow it, make a check as follows. Place the intensity probe, oriented towards the most important source of sound emission, at a position where the noise from the machine is characteristic for that machine. The intensity probe should be mounted on a stand to retain the same position while carrying out the measurement check. Measure the intensity. Reverse the direction of the intensity probe 180° in the same position as the first measurement and measure the intensity again. For the maximum sound intensity level measured in one-third-octave or octave bands, the unsigned difference between the two sound intensity levels shall be less than 1,5 dB for the measurement instrumentation to be acceptable.

7 Installation and operation of the source

7.1 General

The manner in which the machine under test is installed and operated may have a significant influence on the emission sound pressure levels at the specified positions. This clause specifies conditions that are intended to minimize variations in the noise emission due to the installation and operating conditions of the machine under test. Relevant instructions to a noise test code, if any exists for the family of machinery or equipment to which the machine under test belongs, shall be followed. The same installation and operating conditions of the machine under test shall be used for the determination of emission sound pressure levels and sound power levels. The noise test code for the machinery concerned describes the installation, mounting and operating conditions in detail.

NOTE The noise test code might make an exception to this requirement on identical installation, mounting and operating conditions for equipment that is used on tables. Such equipment may be mounted on the floor during sound power determinations.

Particularly for large machines, it is necessary to make a decision as to which components, sub-assemblies, auxiliary equipment, power sources, etc., belong to the machine under test.

7.2 Location of the machine

The machine under test shall be installed in one or more locations with respect to the reflecting plane as if it were being installed for normal usage. Where possible, unless the typical installation is against a wall, ceiling or reflecting object, the machine under test shall be located at a position remote from such reflecting surfaces.

NOTE Typical installation conditions for some machines involve two or more reflecting surfaces (e.g. an appliance installed against a wall), or free space (e.g. a hoist), or an opening in an otherwise reflecting plane (so that radiation can occur on both sides of the reflecting plane). Detailed information on installation conditions should be based on the general requirements of this International Standard and on the relevant noise test code, if one exists. Procedures for testing when the machine is close to reflecting surfaces are outlined in subsequent clauses of this International Standard.

7.3 Mounting of the machine

7.3.1 General

In many cases, the noise emission at the specified positions of the machine under test will depend upon the support or mounting conditions of the machine. Whenever a typical mounting condition exists for a machine, that condition shall be used or simulated, if practicable.

If a typical mounting condition does not exist or cannot be utilized for the test, care shall be taken to avoid changes in the sound emission of the machine caused by the mounting system used for the test. Steps shall be taken to reduce any sound radiation from the structure on which the machine is mounted.

Resilient mounts shall be used only if the machine under test is resiliently mounted in typical field installations. Many small machines, although themselves poor radiators of low-frequency sound, may, as a result of the method of mounting, radiate more low-frequency sound when their vibrational energy is transmitted to surfaces large enough to be efficient radiators. If this is so, then resilient mounting shall be interposed, if possible, between the machine to be tested and the supporting surfaces so that the transmission of vibration to the support and the reaction of the source are both minimized. In this case, the mounting base should be rigid (i.e. have a sufficiently high mechanical impedance) to prevent it from vibrating excessively and radiating sound.

NOTE Coupling conditions (e.g. between prime movers and driven machines) can exert a considerable influence on the sound radiation of the machine under test.

7.3.2 Hand-held machinery and equipment

Such machinery and equipment shall be suspended or guided by hand so that no structure-borne sound is transmitted via any attachment that does not belong to the machine under test. If the machine under test requires a support for its operation, the support structure shall be small, considered to be a part of the machine under test, and as described in the relevant test code, if any exists.

7.3.3 Base-mounted and wall-mounted machinery and equipment

Such machinery and equipment shall be placed on a reflecting (acoustically hard) plane (floor or wall). Base-mounted machinery or equipment intended exclusively for mounting in front of a wall shall be installed on an acoustically hard surface in front of an acoustically hard wall. Table-top machinery or equipment shall be placed on a table or stand as required for operation according to the noise test code specific to the family of machinery or equipment to which the machine under test belongs. The table or stand shall be at least 1,5 m from any absorptive surface of the test room. Such machinery or equipment shall be placed at the centre of the top of the standard test table. A suitable design of a test table is shown in Annex D.

7.4 Auxiliary equipment

Care shall be taken to ensure that any electrical conduits, piping or air ducts connected to the machine under test do not radiate significant amounts of sound energy into the test environment.

If practicable, all auxiliary equipment necessary for the operation of the machine under test but which is not part of it (see 7.1) shall be located outside the test environment. If this is impracticable, the auxiliary equipment shall be included in the test configuration and its operating conditions described in the test report.

7.5 Operation of the machine under test

During the noise measurements, the operating conditions specified in the relevant noise test code shall be used, if any exists for the particular family of machinery or equipment to which the machine under test belongs. If there is no test code, the machine under test shall, if possible, be operated in a manner which is typical of normal use. In such cases, one or more of the following operating conditions shall be selected:

- a) machine under specified load and operating conditions;
- b) machine under full load (if different from the first condition above);
- c) machine under no load (idling);
- d) machine under operating conditions corresponding to maximum sound generation representative of normal use;

- e) machine with simulated load operating under carefully defined conditions;
- f) machine under operating conditions with characteristic operational cycle.

Emission sound pressure levels at specified positions shall be determined for any desired set of operating conditions (e.g. temperature, humidity, device speed). These test conditions shall be selected beforehand and shall be held constant during the test. The machine under test shall be in the desired operating condition before any noise measurements are made.

If the noise emission also depends on other operating parameters (e.g. type of material being processed or type of tool) then, out of the aggregate of possibilities, the ones to be defined shall be those which narrow down the variation possibilities as far as is practicable and which can be regarded as typical with regard to the noise emission.

For special purposes, it is appropriate to define one or more operating conditions in such a way that both a high reproducibility of noise emission of machinery or equipment of the same family is ensured and that the operating conditions which are most common and typical for the family of machinery or equipment are covered. These operating conditions shall be defined in specific noise test codes.

If simulated operating conditions are used, they shall be chosen to give emission sound pressure levels at specified positions which are representative of normal usage of the machine under test.

In special cases, the results for several operating conditions may be combined by energy averaging, possibly with different time components taken into account, thereby yielding the result for the main operating condition so defined.

The operating conditions of the machine under test during noise measurements shall be fully described in the test report.

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8 Test procedure

8.1 Applicability

The method of this International Standard is not applicable when the intensity vector is directed towards the machine under test, see Annex A.

If the method of this International Standard is applied to a machine located in front of a reflecting wall or in a corner, the result will be the emission sound pressure level corresponding to the one obtained in a hemi-anechoic room with the machine in front of one or two reflecting panels respectively, provided that the measurement position is not between the machine under test and one of the walls. If the measurement position is between the machine under test and the wall, the probe shall be at least 1 m from the wall. If the purpose is to simulate hemi-free field conditions and the machine is mounted in such a position, it is necessary to cover the wall with sound-absorbing material. The thickness of the sound-absorbing material required will depend on the frequency spectrum. Normally 10 cm of mineral wool or equivalent materials will be sufficient.

8.2 Measurement time interval

8.2.1 General

The measurement time interval shall be chosen in such a way that the emission sound pressure level and, as required, the time characteristics of sound emission at specified positions can be determined for the specified operating conditions.

For a given machine under test, the measurement time interval, T , may be composed of a number of sub-measurement time intervals, T_i , each of which corresponds to a specified operational period of the machine. In