MACHINES:
DETERMINATION OF EMISSION SOUND PRESSURE LEVELS
USING SOUND INTENSITY

Key words: Machines, sound, pressure level, emission level intensity

1 SCOPE AND FIELD OF APPLICATION

1.1 General

This NORDTEST method specifies how to determine the emission sound pressure level at the work station or at other specified positions of machines using sound intensity. The method supplements ISO 11201 and it applies to all kinds of test environments as long as the requirements on background noise and field indicator are fulfilled and as long as the environmental indicator, $K_{5A}$, as defined in ISO 11201 is larger than 2 dB.

Note 1 If the method is applied on 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 and two reflecting panels respectively.

Note 2 $K_{5A} < 2$ dB has been excluded because in this case ISO 11201 is valid and there is no need for this Nordtest method.

The method is applicable to equipment operating under steady state conditions and emitting broad-band noise with or without discrete-frequency or narrow-band components. The method yields results comparable with those of ISO 11201 and 11204.

1.2 Measurement uncertainty

The uncertainty of this Nordtest method is not known (see note 3).

There is no strict correlation between the measurement uncertainty and the field indicator. However, when the field indicator $F_{Pl}$ exceeds 5 dB the emission sound pressure level will normally tend to be overestimated. When $F_{Pl}$ exceeds 12 dB the measurement uncertainty will tend to be outside the normal range of this method.

Note 3 Comparison measurements carried out between 3 Nordic laboratories indicate that this Nordtest method will on average, with a standard deviation of 1 dB, yield values equivalent to those of ISO 11201 (with $K_4 = 0$) within 1 dB in A-weighted emission sound pressure level. For individual frequency bands the uncertainty may be twice as large.

2 NORMATIVE REFERENCES

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

ISO 9614-1:1993, Acoustics - Determination of sound power levels of noise sources using sound intensity - Measurement at discrete points.


ISO 11200:1995, Noise emitted by machinery and equipment - Guidelines for the use of basic standards for the determination of emission sound pressure levels at the work station and at other specified positions.

ISO 11201:1995, Noise emitted by machinery and equipment - Engineering method for the measurement of emission sound pressure level at the work station and at other specified positions.

ISO 11202:1995, Noise emitted by machinery and equipment - Survey method for the measurement of emission sound pressure levels at the work station and at other specified positions.

ISO 11203:1995, Noise emitted by machinery and equipment - Determination of emission sound pressure levels at the work station and at other specified positions from the sound power level.

ISO 11204:1995, Noise emitted by machinery and equipment - Determination of emission sound pressure levels at the work station and at other specified positions in situ.


IEC 1043: 1993, Instruments for the measurement of sound intensity.
3 DEFINITIONS

3.1 sound intensity, I:
Time averaged rate of flow of sound energy per unit of surface area oriented in the direction of the local particle velocity. This is a vectorial quantity which is equal to

\[ \tilde{I} = \frac{1}{T} \int_0^T p(t) \tilde{u}(t) dt \text{ W/m}^2 \] (1)

where
- \( p(t) \) is the instantaneous sound pressure at a point, in pascals;
- \( u(t) \) is the instantaneous particle velocity at the same point, m/s;
- \( T \) is the averaging time, in seconds;

3.2 normal sound intensity, \( I_n \):
Component of the sound intensity in the direction normal to a measurement surface defined by the unit normal vector \( \tilde{n} \):

\[ I_n = I \cdot \tilde{n} \] (2)

where \( \tilde{n} \) is the unit normal vector directed out of the volume enclosed by the measurement surface.

3.3 normal sound intensity level, \( L_{in} \):
Ten times the common logarithm of the ratio of the unsigned value of the normal sound intensity to the reference intensity \( I_0 \) as given by:

\[ L_{in} = 10 \log \left( \frac{I_n}{I_0} \right) \text{ dB} \] (3)

where \( I_0 = 10^{-12} \text{ W/m}^2 \).

3.4 sound field pressure-intensity indicator or field indicator, \( F_{pl} \):
The difference between time and surface averaged sound pressure level, \( L_p \), and the normal sound intensity level, \( L_{in} \), on the measurement surface given by:

\[ F_{pl} = L_p - L_{in} \text{ dB} \] (4)

Note 4 In ISO 9614-1 the notation \( F_2 \) is used.

3.5 residual pressure-intensity index, \( \delta_{pln} \):
The difference, in decibels, between indicated sound pressure level and sound intensity level when the probe is placed in a sound field in such an orientation that the particle velocity in the direction of the probe measurement axis is zero (e.g. in an acoustic coupler or transverse to the direction of propagation of a plane sound wave).

3.6 emission sound pressure level, \( L_p \):
The sound pressure level, in decibels, at a specified position near a noise source, when the source 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.

3.7 specified position:
A position defined in relation to a machine, including, but not limited to, an operator's position. 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.

3.8 environmental indicator, \( K_e \):
A term, in decibels, to describe the influence of reflected or absorbed sound on the surface sound pressure level; \( K_2 \) is frequency dependent, and, in the case of A-weighting, is denoted \( K_{2A} \) (see ISO 11201, 11202, 3744 or 3746).

4 INSTRUMENTATION

4.1 General
The intensity measuring instrumentation shall be able to measure intensity levels re 10^{-12} \text{ W/m}^2 in one-third octave bands. The instrument, including the probe, shall comply with a class 1 instrument in accordance with IEC 1043. A probe wind screen shall always be employed. The residual pressure-intensity index \( \delta_{pln} \) of microphone probe and analyser shall be higher than \( F_{pl} + 10 \text{ dB} \) in each third octave band.

4.2 Calibration
The instrument and the probe shall be calibrated at least at one frequency in the range from 200 to 1000 Hz in accordance with the calibration procedure and at intervals specified by the manufacturer.

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 or better in accordance with IEC 942.

c) Intensity: Calibrate using an intensity calibrator. If such a calibrator is not available or if the probe build up does not allow it make a check as follows:

Place the intensity probe at the specified position, oriented towards the most important source of sound emission, at a position where the noise from the source is characteristic for that source. The intensity probe should be mounted on a stand to retain the same position while carrying out the measurement check. Measure the intensity. Rotate the intensity probe through 180° about a normal to its measurement axis in the same position as the first measurement. 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.

Note 5 This test may not be completely appropriate for pressure-velocity probes for which the manufacturer's instruction should apply.
5 INSTALLATION AND OPERATION OF THE SOURCE
See ISO 11201.

6 TEST PROCEDURE

6.1 Principle
The basic principle of the test method is to eliminate diffuse sound reflections by approximating the emission sound pressure level by the sound intensity level. In a diffuse sound field the sound intensity is very small. A lack of diffusivity is one source of error in this test method. Sound first reflected from surfaces very close to the machine will not be part of the diffuse sound field at a specified position close to the machine unless the test environment is extremely reverberant. Thus the sound intensity level will normally be determined by a combination of sound arriving directly from the sound source and sound reflected from surfaces close to the machine. Adding sound from different directions will affect the sound pressure and the sound intensity differently. This difference is another source of error.

A lack of diffusivity will tend to yield an overestimate of the emission sound pressure level and strong reflections from several different directions will tend to an underestimate of the emission sound pressure level.

6.2 The specified position
Mount the intensity probe at the specified position of the object under test. Direct it towards the most important source of sound emission. Try some different orientations and select the one giving the highest sound intensity level. No reflecting objects, other than the machine under test, are allowed within 0.5 m of the intensity probe. If there are such objects they shall be covered with sound absorbing material.

Note 6 In many cases reflections from the floor or from a table will contribute to the sound intensity level. These reflections will also affect the optimum probe direction. In such cases the most important source of sound emission will move towards the reflecting surface.

Note 7 If the machine under test is located in front of a wall the wall must be covered with sound absorbing material if it is the intention to simulate hemi-anechoic measurement results according to ISO 11201. 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. However, if the normal location of the machine is in front of a wall and it is desirable to include the wall reflection, the method is applicable without any additional measures.

Measure the sound intensity level and the sound pressure level in the frequency bands in which the emission sound pressure level is to be determined. The averaging time shall be at least 30 s in each probe position. If possible, measure the time integrated sound pressure level $L_p$ simultaneously. If this is not possible, measure the sound pressure level afterwards at the same point or along the same path as during the intensity measurements. Calculate the sound field pressure-intensity indicator, $F_{pl}$.

6.3 Wind and gas flows
Intensity probes are more sensitive to wind and gas flows than normal microphones. Use a wind screen when there is a detectable flow. If the wind/gas flow exceeds 4 m/s the measurement is not valid unless it can be shown that the flow has had a negligible influence on the frequencies of interest. Some further guidelines on measurements in flow are given in ISO 9614-2.

6.4 Criterion for the adequacy of the test environment
For this Nordtest method, the environmental indicator $K_{2A}$, see ISO 11201, for a measurement surface enveloping the measurement position(s) shall not be less than 2 dB. The field indicator $F_{pl}$ shall be less than 12 dB.

6.5 Criterion for background noise
At the probe position(s), the background sound pressure level and the background sound intensity level measured as a weighted level or in each of the frequency bands of interest shall be at least 10 dB below the level due to the machine under test. No corrections shall be made.

6.6 Frequency range of measurements
The sound pressure level and the sound intensity level shall be measured using octave band filters having the following mid band frequencies in hertz:

\[
63 \quad 125 \quad 250 \quad 500 \quad 1000 \quad 2000 \quad 4000
\]

Optionally the measurements can be made in third octave bands with mid band frequencies of at least from 50 to 5000 Hz.

Note 8 Frequency bands without influence on the A-weighted emission sound pressure level may be excluded.

6.7 Evaluation of the measurement result
The emission sound pressure level $L_p$, is given by

\[
L_p = L_i \quad (5)
\]

For each frequency band for which the sound intensity flow is towards the source ($L_i < 0$) the measurement is not valid.

7 INFORMATION TO BE REPORTED
In addition to the relevant requirements of ISO 11201 the following shall be reported:

a) The value of the emission sound pressure level together with the field indicator $F_{pl}$ for each frequency band of interest.

b) Description of the measurement probe and its calibration.