INTERNATIONAL STANDARD

ISO 1680

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Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machines

Acoustique — Code d'essai pour le mesurage du bruit aérien émis par les machines électriques tournantes

Reference number
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Contents

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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.

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 1680 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This first edition of ISO 1680 cancels and replaces ISO 1680-1:1986 and ISO 1680-2:1986, which have been combined and technically revised.

Annexes A and B of this International Standard are for information only.

Introduction

This International Standard is a noise test code giving methods for determining the airborne sound radiation of rotating electrical machines operating under steady-state conditions.

To characterize the airborne sound radiation, procedures are given to determine sound power levels and additionally emission sound pressure levels, if required. Furthermore, requirements are given for the declaration and verification of noise emission values.

Basic standards giving methods for determining sound power levels are as follows:

a) using sound pressure:

- grade 1 (precision): ISO 3741 and ISO 3745;
- grade 2 (engineering): ISO 3743-1, ISO 3743-2, ISO 3744, ISO 3747;
- grade 3 (survey): ISO 3746;

b) using sound intensity:

- all grades: ISO 9614-1;
- grades 2 and 3: ISO 9614-2.

The emission sound pressure level is determined on the basis of ISO 11203. Declaration and verification of noise emission values follow ISO 4871.

This International Standard has been drafted in accordance with ISO 12001.

Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machines

1 Scope

This International Standard specifies all the information necessary to carry out efficiently and under standardized conditions the determination, declaration and verification of the noise emission characteristics of rotating electrical machines. It specifies noise measurement methods that can be used, and specifies the operating and mounting conditions that shall be used for the test.

Noise emission characteristics include the sound power level and emission sound pressure level. The determination of these quantities is necessary

— for comparing the noise emitted by machines,

— to enable manufacturers to declare the noise emitted, and

— for the purposes of noise control.

The use of this International Standard as a noise test code ensures the reproducibility of the determination of the noise emission characteristics within specified limits determined by the grade of accuracy of the basic noise measurement method used. Noise measurement methods allowed by this International Standard are laboratory methods (grade 1), engineering methods (grade 2) and survey methods (grade 3). Methods of engineering grade (grade 2) are to be preferred.

This International Standard is applicable to rotating electrical machines of any length, width or height.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard 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.

ISO 3741, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms.*[1)]

ISO 3743-1, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for small, movable sources in reverberant fields — Part 1: Comparison method for hard-walled test rooms.*

ISO 3743-2, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering methods for small, movable sources in reverberant fields — Part 2: Methods for special reverberation test rooms.*

1) Revision of ISO 3741:1988 and ISO 3742:1988.

ISO 3744, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free-field over a reflecting plane.*

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

ISO 3746, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane.*

ISO 3747, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Comparison method for use in situ.*

ISO 4871, *Acoustics — Declaration and verification of noise emission values of machinery and equipment.*

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 7574-4, *Acoustics — Statistical methods for determining and verifying stated noise emission values of machinery and equipment — Part 4: Methods for stated values for batches of machines.*

ISO 7779:1999, *Acoustics — Measurement of airborne noise emitted by information technology and telecommunications equipment.*

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

ISO 9614-2, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning.*

ISO 11203, *Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions from the sound power level.*

IEC 60034-1, *Rotating electrical machines — Part 1: Rating and performance.*

IEC 60651, *Sound level meters.*

3 Terms and definitions

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

3.1
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the time-averaged square of the sound pressure radiated by the sound source under test to the square of the reference sound pressure

NOTE 1 Sound pressure levels are expressed in decibels.

NOTE 2 The frequency weighting or the width of the frequency band used, and time weighting (S, F or I, see IEC 60651), should be indicated. The reference sound pressure is 20 μPa (2×10^{-5} Pa).

EXAMPLE The A-weighted sound pressure level with time weighting S is L_{pAS}.

3.2
measurement surface
hypothetical surface of area S, enveloping the source on which the measurement points are located

NOTE The measurement surface terminates on one or more reflecting planes.

3.3
surface sound pressure level
$\overline{L_{pf}}$
energy average of the time-averaged sound pressure levels at all the microphone positions on the measurement surface, with the background noise correction K_1 and the environmental correction K_2 applied

NOTE It is expressed in decibels.

3.4
sound intensity
$\vec{I}$
time-averaged value of the product of the instantaneous sound pressure and the associated sound velocity at a point in a temporally stationary sound field

3.5
normal sound intensity level
L_{In}
ten times the logarithm to the base 10 of the ratio of the unsigned value of the normal component of the sound intensity (which is radiated by the sound source under test and determined in a direction perpendicular to the measurement surface) to the reference sound intensity

NOTE 1 It is expressed in decibels.

NOTE 2 The reference sound intensity is 10^{-12} Wm^{-2}.

3.6
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the sound power radiated by the sound source under test to the reference sound power

NOTE 1 It is expressed in decibels.

NOTE 2 The frequency weighting or the width of the frequency band used should be indicated. The reference sound power is 1 pW (10^{-12} W).

EXAMPLE The A-weighted sound power level is denoted L_{WA}.

3.7
emission sound pressure
p
time-averaged sound pressure, 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 effects of reflections from room surfaces other than the plane or planes permitted for the purpose of the test

NOTE It is expressed in pascals.

3.8
emission sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the emission sound pressure, $p^2(t)$, to the square of the reference sound pressure, ${p_0}^2$, measured with a particular time weighting and a particular frequency weighting, selected from those defined in IEC 60651

NOTE It is expressed in decibels. The reference sound pressure is 20 µPa.

EXAMPLES The A-weighted emission sound pressure level with time weighting F is denoted L_{pAF}. The C-weighted peak emission sound pressure level is denoted $L_{pC,peak}$.

3.9
noise emission declaration
information on the noise emitted by the machine, given by the manufacturer or supplier in technical documents or other literature concerning noise emission values

NOTE The noise emission declaration may take the form of either the declared single-number noise emission value or the declared dual-number noise emission value.

3.10
measured noise emission value
L
A-weighted sound power level, or the A-weighted time-averaged emission sound pressure level, or the C-weighted peak emission sound pressure level, as determined from measurements

NOTE Measured values may be determined either from a single machine or from the average of a number of machines, and are not rounded.

3.11
declared single-number noise emission value
L_d
sum of the measured noise emission value, L, and the associated uncertainty, K, rounded to the nearest decibel:

$$L_d = L + K$$

3.12
declared dual-number noise emission value
L and K
measured noise emission value L, and its associated uncertainty K, rounded to the nearest decibel

4 Description of machinery family

This International Standard is applicable to self-standing rotating electrical machines, i.e. motors and generators (d.c. and a.c machines), without any limitation on the output or voltage, and with any linear dimensions.

Families of devices covered by this International Standard include rotating electrical machines to be fed by the following possibilities:

— a network (sinusoidal supply) whenever specially designed for that purpose;

— an associated converter.

In the case of supply by an converter, the noise radiated by the converter is excluded from the scope of this International Standard; only the effect of non-sinusoidal voltage and current within the machine is to be taken into account.

Auxiliary components required for the operation of the machine (e.g. oil pumps or cooling ventilators) should be included when integrated with the machine. When these components are separately mounted, they shall not be included as part of the machine under test.

5 Sound power determination

5.1 General

The sound power radiated by rotating electrical machines shall be determined on the basis of one of the following basic standards:

— accuracy grade 1: ISO 3741, ISO 3745, ISO 9614-1;

— accuracy grade 2: ISO 3743-1, ISO 3743-2, ISO 3744, ISO 3747, ISO 9614-1, ISO 9614-2.

Methods of engineering grade (grade 2) are to be preferred.

Furthermore, survey methods may also be used if it has been proved that no method with better accuracy is practical:

— accuracy grade 3: ISO 3746, ISO 9614-1, ISO 9614-2.

5.2 Guidelines for the selection of the most appropriate basic standard

The usable basic standards are mainly distinguished by the following:

— different environmental conditions;

— different requirements with respect to the background noise levels related to the noise level of the machine under test;

— different grades of accuracy;

— different quantities to be measured: sound pressure or sound intensity.

NOTE Detailed guidelines for the selection of the most appropriate basic standards are given in ISO 3740.

The sound intensity measurement method has the following advantages as compared to the sound pressure measurement method.

a) Determination of the correct sound power will be possible regardless of whether the measurement surface lies within or outside the near field.

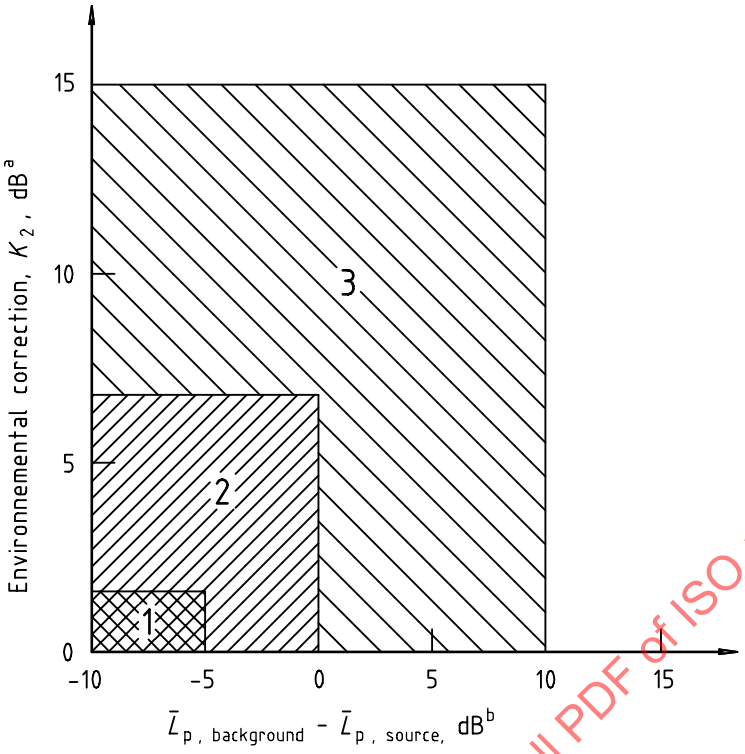
b) Determination of the correct sound power will be possible in the presence of noise fields where the sound pressure method gives results which are so wrong that they would be no longer conform to sound pressure measurement standards.

c) It allows a better grade of accuracy for the sound power determination especially under the worst environmental conditions (and therefore allows determination of the sound power level of machines in the presence of noisy loading machines).

A description of the fields of application of the main basic standards is given in Table 1, supplemented by Figure 1. A more precise distinction of these standards is shown in annex A.

Table 1 — Sound power determination procedures and relations to their fields of application

International Standard	Environment	Background noise levels	Grade of accuracy	Quantity to be measured
ISO 3741	Special measurement room, "reverberant room"	Very low background noise levels	grade 1	Sound pressure
ISO 3743-1	High reverberant ordinary room	Low background noise level	grade 2	Sound pressure
ISO 3743-2	Special measurement room	Low background noise level	grade 2	Sound pressure
ISO 3744	*In situ*, but with limited environmental reflections	Low background noise levels	grade 2	Sound pressure
ISO 3745	Special measurement room, "anechoic, semi-anechoic room"	Very low back-ground noise levels	grade 1	Sound pressure
ISO 3746	*In situ*, less limited environmental reflections	Less limited back-ground noise levels	grade 3	Sound pressure
ISO 3747	*In situ*, approximately reverberant conditions	Low background noise levels	grade 2	Sound pressure
ISO 9614-1	*In situ*, practically no limitations	Practically no limitation for stationary background noise levels	grades 1, 2 and 3	Normal component of sound intensity
ISO 9614-2	*In situ*, practically no limitations	Practically no limitation for stationary background noise levels	grades 2 and 3	Normal component of sound intensity



Key

1 p^2-method, grade 2
2 p^2-method, grade 3
3 Intensity method, grade 2

a See e.g. ISO 3744.
b Background noise level related to source level (sound pressure averaged over measurement surface).

Figure 1 — Fields of application for sound power determination methods using an enveloping measurement surface

5.3 Additional requirements

Each of the basic standards gives detailed and precise requirements for all acoustical aspects of the relevant measurement procedure such as definition of the measurement surface, if any, microphone array, environmental adequacy, determination of environmental and background noise corrections, if relevant, together with requirements for instrumentation, etc. These standards leave open precise definitions of mounting and operating conditions which shall be stated in the machinery-specific noise test code. These requirements are given in clause 6.

When applying ISO 3744 or ISO 3746 which use sound pressure measurements under more or less free-field conditions, a parallelepiped measurement surface shall be used to facilitate the location of the microphone positions.

Supplementing the general rules for rotating electrical machines, the following simplifications may be used.

a) The arrangement of the measurement positions may, especially for large machines, be simplified if, for a specific type of machine, it can be shown, with the help of preliminary investigations on machines of that specific type, that the sound field is adequately uniform and that measurements lead to values of sound power level deviating by no more than 0,5 dB for grade 2 methods and 1 dB (A-weighted) for grade 3 methods from those determined with a complete arrangement of measurement positions.

b) For sources that produce a symmetrical radiation pattern, it may be sufficient to distribute the measurement positions over only a portion of the measurement surface. This is acceptable only if, for a specific type of machine, it can be shown, with the help of preliminary investigations on machines of that specific type, that the measurements lead to values of sound power level deviating by no more than 0,5 dB for grade 2 methods and

1 dB (A-weighted) for grade 3 methods from those determined with a complete arrangement of measurement positions.

6 Installation and mounting conditions

6.1 Mounting of the machine

6.1.1 General

If practicable, the machine shall be mounted in the same way as for normal usage. Care shall be taken to minimize the transmission and the radiation of structure-borne noise from all mounting elements including the foundation. This minimizing may be achieved by resilient mounting for smaller machines. Larger machines can usually only be tested under rigid mounting conditions. A detailed description of the mounting conditions used shall be given [see 11 a)].

Machines tested under loaded conditions shall have rigid mounting. It is likely that the higher load ratings may be available only *in situ*. In this respect precautions shall be taken according to 6.2 in order to discriminate between the supplementary noise due to the loading (to be measured) and the noise emitted by the load itself (for a motor) or by the driving machine itself (for a generator) which is not to be measured.

In all cases measurements shall be processed in accordance with clauses 5 and 10, if relevant.

The installation and mounting conditions shall be identical for the determination of both sound power levels and emission sound pressure levels at specified positions, if relevant, and/or declaration purposes.

6.1.2 Resilient mounting

The highest natural frequency of the system consisting of the support device and the machine under test shall be lower than a quarter of the frequency corresponding to the lowest rotational speed of the machine.

The effective mass of the resilient support shall not be greater than 1/10 of that of the machine under test.

6.1.3 Rigid mounting

The machines shall be rigidly mounted to a surface with dimensions adequate for the machine type (for example by foot or flange fixed in accordance with the manufacturer's instructions). The machine shall not be subject to additional mounting stresses from incorrect shimming.

The mass of the support shall be at least twice that of the machine under test.

6.2 Auxiliary equipment and loaded machines

All auxiliary equipment (loading machines, gears, transformer, converters, external cooling systems) and coupled machines which are necessary for the operation of the machine under test, but which do not form an integral part of the machine, shall not significantly affect the noise measurement. If they do, they should be shielded acoustically, located outside the test environment or the test should be carried out in accordance with the ISO 9614 series.

7 Operating conditions

7.1 General

The machine shall operate at rated voltage(s) and speed(s), and with the corresponding excitation(s) (see IEC 60034-1).

For a.c. machines, the sinusoidality of the supply voltage and the degree of unbalance of the supply voltage system shall comply with the same limits that are specified in IEC 60034-1. For converter-fed machines, the harmonics of voltage or current are given by the properties of the relevant converter.

Synchronous machines shall be run with the field current which permits the rated voltage.

Other conditions may be agreed between the manufacturer and the customer.

The operating conditions used shall be recorded and reported in detail [see 11 a) and clause 12].

The operating conditions shall be identical for the determination of both sound power level and emission sound pressure level at the specified position, if relevant.

7.2 Load

The testing shall be performed under no-load conditions.

NOTE 1 Rated load conditions are very useful in practice although not mandatory according to this noise test code because of the variety of possible loads. Noise emission values under specified load conditions may be established by agreement between the manufacturer and the customer.

NOTE 2 In some cases the difference in noise levels between load and no-load conditions may be required. The use of the ISO 9614 series or ISO/TR 7849 is recommended.

7.3 Variable speed devices

The machine under test shall be monitored over the whole range of operating speeds to determine the speed(s) generating the maximum noise level. To find this level a low speed variation shall be applied. This condition shall be used for the noise test and the speed reported in the results.

NOTE 1 The variation in noise levels results mainly from the following two causes which cannot be accurately predicted in general:

a) frequency coincidence between the rotation speed, respectively its harmonics, and a natural frequency of the equipment;

b) the possible existence of higher harmonic components in the supply producing structure mechanical excitations and noise emission.

NOTE 2 The purpose of the test will be to determine

a) the noise characteristics at full speed conditions;

b) the noise characteristics at the worst noise conditions over the whole specified speed range.

8 Measurement uncertainty

A single value of the sound power level of a noise source determined according to the procedures of this International Standard is likely to differ from the true value by an amount within the range of the measurement uncertainty. The uncertainty in determinations of the sound power level arises from several factors which affect the result, some associated with environmental conditions in the measurement laboratory and others with experimental technique.

If, at different laboratories, the sound power level of one certain source were to be determined in accordance with the provisions of this International Standard, the results would show a scatter. The standard deviation of the measured levels could be calculated and would vary with midband frequency (see note in Table 2). With few exceptions, these standard deviations would not exceed those listed in Table 2. The values given in the table are standard deviations of reproducibility, σ_R, as defined in ISO 7574-1. The values take into account the cumulative effects of measurement uncertainty in applying the procedures of this International Standard, but exclude variations in the sound power output caused, for example, by adjusting the operating conditions (e.g. rotation speed, line voltage) or mounting or atmospheric conditions.[2)]

The measurement uncertainty depends on the standard deviation of reproducibility tabulated in Table 2 and on the degree of confidence that is desired. As examples, for a normal distribution of sound power levels, there is a 90 % confidence that the true value of the sound power level of a source lies within the range $\pm$ 1,645 σ_R of the measured value and a 95 % confidence that it lies within the range $\pm$ 1,96 σ_R of the measured value.

2) In the standards specifying grade 1 methods, atmospheric conditions have already been taken into consideration.

Table 2 — Estimated values of the standard deviations of reproducibility of A-weighted sound power levels for different grades of accuracy determined in accordance with this International Standard

Grade of accuracy	Standard deviation of reproducibility, σ_R dB
Grade 1	1
Grade 2	1,5
Grade 3	3

NOTE 1 Information on values of σ_R for octave or one-third-octave-band sound power levels are to be found in the relevant basic standards.

NOTE 2 Information on the correlation between σ_R and the uncertainty K (see clause 13) is given in ISO 4871.

9 Determination of the emission sound pressure level

9.1 General

The determination of emission sound pressure levels is not a requirement of this International Standard. If requested, they shall be determined according to this International Standard.

9.2 Selection of the relevant work station

For rotating electrical machines, this International Standard defines the work station as the enveloping measurement surface at a distance of 1 m from the reference box.

9.3 Selection of basic standard to be used

In this International Standard the emission sound pressure level L_p is determined in accordance with ISO 11203.

No additional measurements are necessary for the determination. As defined by ISO 11203, L_p is calculated directly from the sound power level L_W determined according to clauses 5 and 6 of this International Standard:

$$L_p = L_W - 10 \lg \left(\frac{S}{S_0} \right) \text{ dB} \qquad (1)$$

where

S is the area, in square metres, of the surface enveloping the machine with respect to the reference box at 1 m distance; this means L_p is the surface sound pressure level at 1 m distance;

$S_0 = 1 \text{ m}^2$.

9.4 Measurement uncertainty

Based on equation (1), the emission sound pressure level is determined with the same accuracy as L_W (see clause 8).

10 Indication of noise emission quantities determined according to this International Standard

Noise emission quantities determined according to the requirements of this International Standard shall be indicated by a double number describing both the basic standard used and this International Standard establishing all machinery-specific parameters applied for the emission measurement.

EXAMPLE 1 ISO 1680/ISO 3744

(rotating electrical machines)/(grade 2 determination of sound power levels; sound pressure enveloping surface method)

EXAMPLE 2 If it is requested to determine the emission sound pressure level, see:

ISO 1680/ISO 9614-2/ISO 11203

(rotating electrical machines)/(grade 2 determination of sound power levels; sound intensity method)/(determination of emission sound pressure levels from the sound power level)

11 Information to be recorded

The following information shall be compiled and recorded for all measurements carried out in accordance with the requirements of this International Standard. Any deviations from the requirements of this International Standard shall be indicated.

a) Machine under test:

- description of the machine under test (i.e. type, size and auxiliary equipment, if any);
- operating conditions (especially voltage; type of converter, if any; load);
- mounting conditions.

b) Acoustic environment

- see relevant clause of the appropriate basic standard used.

c) Instrumentation

- see relevant clause of the appropriate basic standard used.

d) Acoustical data

- see relevant clause of the appropriate basic standard used.

12 Information to be reported

The test report shall contain the statement that the sound power levels have been obtained in full conformity with the procedures of this International Standard. If not, any deviations shall be indicated.

The following information shall be reported:

a) a description of the machine under test;

b) the operating conditions;

c) the A-weighted sound power level, L_{WA}, in decibels, and, if requested, unweighted sound power levels in frequency bands; reference: 1 pW;

d) the A-weighted emission sound pressure level, L_{pA}, in decibels, if requested; reference: 20 µPa;

e) if relevant, information on the presence of discrete tones (e.g. determined by listening or using annex D of ISO 7779:1999);

f) the date when the measurements were carried out.

NOTE According to ISO 7779 a discrete tone is regarded as prominent if the sound pressure level of the tone exceeds the sound pressure level of the masking noise in the critical band by 6 dB.

13 Declaration and verification of noise emission values (if required)

Declaration and verification of the noise emission values determined in accordance with this International Standard shall follow the procedures of ISO 4871 using the dual-number presentation (measured noise emission value L and uncertainty K).

In applying this International Standard it is recommended to use the following values for the uncertainty K for single machines: 1,5 dB (grade 1); 2,5 dB (grade 2); 4,5 dB (grade 3) (confidence: 95 %). For the determination of K for batches, see ISO 4871 or ISO 7574-4.

NOTE According to ISO 4871, the sum of L and K includes a greater part of the measurement uncertainty and, if relevant, also includes a certain portion of the spread caused by deviations in production, if using the same declaration for a whole batch.

The declaration shall give at least the following information:

— an indication of the measurement method used (see clause 10);

— whether the declaration is related to one single machine or to a well-defined batch of machines; and

— the operating conditions used.

An example of a noise emission declaration is given in annex B.

For the verification it is recommended to apply a procedure of the same or a higher grade of accuracy as compared to the method used for determining the declared values.