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Reciprocating internal combustion engines — Measurement of sound power level using sound pressure —

Part 1: Engineering method

Moteurs alternatifs à combustion interne — Mesurage du niveau de puissance acoustique à partir de la pression acoustique — Partie 1: Méthode d'expertise

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*.

This first edition of ISO 6798-1, together with ISO 6798-2, cancels and replaces ISO 6798:1995, which has been technically revised. The main changes compared to the previous edition are as follows:

- the requirements of the test environment and the measurement uncertainty have been changed;
- the accuracy of measurement results has been changed from 1 dB to 0,1 dB;
- the calculation of background noise correction has been changed from table method to formula method;
- the requirements of installation of engine and auxiliaries have been specified clearly;
- the specification for measurement units has been added;
- the criterion for position adequacy of microphone has been added;
- the criterion for acoustic adequacy of test environment has been improved.

A list of all parts in the ISO 6798 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 6798 series can be used to calculate the sound power level by using the sound pressure level on a measurement surface enveloping a noise source.

The measurement result of sound power level has nothing to do with the test environment and the installation conditions of the noise source, which is one of the important reasons for using sound power level to characterize the noise radiation of different types of machinery and equipment.

Sound power level has the following applications:

— indication of noise radiated from machinery under the specified condition;

— validation of the indicated value of a noise;

— radiation noise comparison of different types and sizes of machinery;

— comparison of the noise limit value specified in the purchase contract or specification;

— making engineering measures to reduce radiation noise of machinery (generally, the frequency band sound power level is also needed);

— prediction of the sound pressure level of noise in the specified position.

Table 1 gives the measurement methods for determining the sound power level of two types of accuracy grade, these measurement methods apply to the measurement on the enveloping surface in the ISO 6798 series. The measurement result of the sound power level is rounded to the nearest 0,1 dB. The method given in this document allows the determination of the A-weighted and frequency-band sound power level, the accuracy of the measurement result is grade 2. The A-weighted sound power level can also be calculated from frequency band sound power levels, but the calculated result from frequency band data can differ from what is determined from the measured A-weighted sound pressure levels.

Table 2 gives the measurement uncertainty of the sound power level (upper bound values of the standard deviation of reproducibility). The standard deviations listed in Table 2 are the comprehensive effect of the measurement uncertainty, but do not include variations of the sound power level caused by installation and operation conditions of the noise source.

In the noise control of a reciprocating internal combustion engine, the relevant members (the manufacturers, installers, and users) should conduct effective communication of acoustic information which is obtained from measurement. The measurement result is valid when in the specified measurement conditions by using the instrumentation and measurement method as specified in this document to obtain a clear acoustic value. The ISO 6798 series can be used according to the purpose of noise measurement and measurement conditions.

Table 1 — How the ISO 6798 series determines the sound power level using sound pressure

Parameters	ISO 6798-1 Engineering method Accuracy grade 2	ISO 6798-2 Survey method Accuracy grade 3
International Standards referenced	ISO 3744	ISO 3746
Test environment	An essentially free field over a reflecting plane	An acoustic field over a reflecting plane
Noise source volume	Unlimited, depending on the test environment	
Criterion for background noise[a]	$\Delta L_{pA} \geq 6{,}0$ dB $K_{1A} \leq 1{,}3$ dB	$\Delta L_{pA} \geq 3{,}0$ dB $K_{1A} \leq 3{,}0$ dB
Criterion for acoustic adequacy of test environment[b]	$K_{2A} \leq 4{,}0$ dB	$K_{2A} \leq 7{,}0$ dB

Table 1 *(continued)*

Parameters	ISO 6798-1 Engineering method Accuracy grade 2	ISO 6798-2 Survey method Accuracy grade 3
Criterion for position adequacy of microphone[c]	$s(L'_{pAm}) \leq 1{,}0$ dB	$s\left(L'_{pAm}\right) \leq \sqrt{2}$dB
Instrumentation[d] sound level meter/filter/sound calibrator	Class 1/class 1/class 1	Class 2/class 2/class 1
Sound power level acquired	A-weighted or frequency bands	A-weighted
Application	Acceptance test of sound power level; making engineering measures	Comparative test of sound power level

[a] For the difference of sound pressure level, ΔL_{pA}, and the background noise correction, K_{1A}, see 8.3.2.

[b] For the environmental correction, K_{2A}, see 8.3.3.

[c] For the standard deviation, $s(L'_{pAm})$, see 7.7.

[d] For the requirements of instrumentation, see Clause 5.

Table 2 — Measurement uncertainty of the sound power level (upper bound values of the standard deviation of reproducibility)

Mid-band frequency Hz		ISO 6798-1 standard deviation of reproducibility dB	ISO 6798-2 standard deviation of reproducibility dB
Octave bands	One-third-octave bands		
63	50 to 80	5,0	—
125	100 to 160	3,0	
250	200 to 315	2,0	
500	400 to 630	1,5	
1 000 to 4 000	800 to 5 000	1,5	
8 000	6 300 to 10 000	2,5	
A-weighted		1,5	3,0

Reciprocating internal combustion engines — Measurement of sound power level using sound pressure —

Part 1: Engineering method

1 Scope

This document specifies the engineering method, which is the measurement method of the sound power level for reciprocating internal combustion engines.

This document applies to all reciprocating internal combustion engines falling within the field of application of ISO 3046-1 and other internal combustion engines where no suitable International Standard exists.

NOTE In this document, reciprocating internal combustion engines are referred to as engines unless otherwise explained.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 3046-1, *Reciprocating internal combustion engines — Performance — Part 1: Declarations of power, fuel and lubricating oil consumptions, and test methods — Additional requirements for engines for general use*

ISO 3046-3, *Reciprocating internal combustion engines — Performance — Part 3: Test measurements*

ISO 6926, *Acoustics — Requirements for the performance and calibration of reference sound sources used for the determination of sound power levels*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61260-1, *Electroacoustics — Octave-band and fractional-octave-band filters —Part 1: Specifications*

IEC 61672-1, *Electroacoustics — Sound level meters —Part 1: Specifications*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3046-1, ISO 6926, IEC 61260-1, IEC 61672-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
sound pressure
p
difference between the instantaneous pressure and the static pressure

Note 1 to entry: It is expressed in pascals (Pa).

[SOURCE: ISO 80000-8:2007, 8-9.2, modified — Note1 to entry has been added.]

3.1.2
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the *sound pressure* (3.1.1), p, to the square of a reference value, p_0

Note 1 to entry: Sound pressure level is calculated using Formula (1):

$$L_p = 10 \times \lg\left(\frac{p^2}{p_0^2}\right) \tag{1}$$

where

p is the sound pressure;
p_0 is the reference value, which equals 20 µPa.

Note 2 to entry: If specific frequency and time weightings, as specified in IEC 61672-1, and/or specific frequency bands are applied, this is indicated by appropriate subscripts, e.g. L_{pA} denotes the A-weighted sound pressure level.

Note 3 to entry: It is expressed in decibels (dB).

[SOURCE: ISO 3744:2010, 3.2, modified — Editorial modifications have been made.]

3.1.3
time-averaged sound pressure level
$L_{p,T}$
ten times the logarithm to the base 10 of the ratio of the time average of the square of the *sound pressure* (3.1.1), p, during a stated time interval of duration, T (starting at t_1 and ending at t_2), to the square of a reference value, p_0

Note 1 to entry: the time-averaged sound pressure level is calculated using Formula (2):

$$L_{p,T} = 10 \times \lg\left[\frac{\frac{1}{T}\int_{t_1}^{t_2} p^2(t)\,dt}{p_0^2}\right] \tag{2}$$

where

p is the sound pressure;
p_0 is the reference value, which equals 20 µPa;
T is a stated time interval of duration.

Note 2 to entry: In general, the subscript "T" is omitted since time-averaged sound pressure levels are necessarily determined over a certain measurement time interval.

Note 3 to entry: Time-averaged sound pressure levels are often A-weighted, in which case they are denoted by $L_{pA,T}$, which is usually abbreviated to L_{pA}.

Note 4 to entry: It is expressed in decibels (dB).

[SOURCE: ISO 3744:2010, 3.3, modified — Editorial modifications have been made.]

3.1.4
surface time-averaged sound pressure level
$\overline{L_p}$
mean (energy average) of the *time-averaged sound pressure levels* (3.1.3) over all the microphone positions, or traverses, on the measurement surface, with the background noise correction, K_1, and the environmental correction, K_2, applied

Note 1 to entry: It is expressed in decibels (dB).

[SOURCE: ISO 3744:2010, 3.18, modified — Editorial modifications have been made.]

3.1.5
measurement time interval
T
portion or a multiple of an operational period or operational cycle of the noise source under test for which the *time-averaged sound pressure level* (3.1.3) is determined

Note 1 to entry: It is expressed in seconds (s).

[SOURCE: ISO 3744:2010, 3.5, modified — Editorial modifications have been made to Note 1 to entry.]

3.1.6
acoustic free field
sound field in a homogeneous, isotropic medium free of boundaries

Note 1 to entry: In practice, an acoustic free field is a field in which the influence of reflections at the boundaries or other disturbing objects are negligible over the frequency range of interest.

[SOURCE: ISO 3744:2010, 3.6]

3.1.7
reflecting plane
sound- reflecting planar surface on which the noise source under test is located

[SOURCE: ISO 3744:2010, 3.8]

3.1.8
acoustic free field over a reflecting plane
acoustic free field (3.1.6) in the half-space above an infinite *reflecting plane* (3.1.7) in the absence of any other obstacles

[SOURCE: ISO 3744:2010, 3.7]

3.1.9
frequency range of interest
frequency range of octave bands with nominal mid-band frequencies from 63 Hz to 8 000 Hz (including one-third octave bands with mid-band frequencies from 50 Hz to 10 000 Hz)

Note 1 to entry: For special purposes, the frequency range can be extended or reduced, provided that the test environment and instrument specifications are satisfactory for use over the modified frequency range. Changes to the frequency range of interest are included in the test report.

[SOURCE: ISO 3744:2010, 3.9, modified — Frequencies have been changed.]

3.1.10
reference box
hypothetical right smallest parallelepiped terminating on one *reflecting plane* (3.1.7) on which the noise source under test is located, that just encloses the source including all the significant sound radiating components

[SOURCE: ISO 3744:2010, 3.10, modified — Test table has been deleted.]

3.1.11
measurement distance
d
distance from the *reference box* (3.1.10) to a parallelepiped measurement surface

[SOURCE: ISO 3744:2010, 3.12, modified — Note has been deleted.]

3.1.12
measurement surface
S
hypothetical parallelepiped surface of area on which the microphone positions are located at which the *sound pressure levels* (3.1.2) are measured, enveloping the noise source under test and terminating on the *reflecting plane* (3.1.7) on which the source is located

[SOURCE: ISO 3744:2010, 3.14]

3.1.13
background noise
noise from all sources other than the noise source under test

Note 1 to entry: Background noise includes contributions from airborne sound, noise from structure-borne vibration, and electrical noise in the instrumentation.

[SOURCE: ISO 3744:2010, 3.15]

3.1.14
background noise correction
K_1
correction applied to the mean (energy average) of the *time-averaged sound pressure levels* (3.1.3) over all the microphone positions on the *measurement surface* (3.1.12), to account for the influence of *background noise* (3.1.13)

Note 1 to entry: The background noise correction is frequency dependent; the correction in the case of a frequency band is denoted by K_{1f}, where f denotes the relevant mid-band frequency, and that in the case of A-weighting is denoted by K_{1A}.

Note 2 to entry: It is expressed in decibels (dB).

[SOURCE: ISO 3744:2010, 3.16]

3.1.15
environmental correction
K_2
correction applied to the mean (energy average) of the *time-averaged sound pressure levels* (3.1.3) over all the microphone positions on the *measurement surface* (3.1.12), to account for the influence of reflected sound

Note 1 to entry: The environmental correction is frequency dependent; the correction in the case of a frequency band is denoted by K_{2f}, where f denotes the relevant mid-band frequency, and that in the case of A-weighting is denoted by K_{2A}.

Note 2 to entry: It is expressed in decibels (dB).

[SOURCE: ISO 3744:2010, 3.17, modified — Note 3 has been deleted.]

3.1.16
sound power
W
through a surface, product of the *sound pressure* (3.1.1), p, and the component of the particle velocity, u_n, at a point on the surface in the direction normal to the surface, integrated over that surface

Note 1 to entry: The quantity relates to the rate per time at which airborne sound energy is radiated by a source.

Note 2 to entry: It is expressed in watts (W).

[SOURCE: ISO 3744:2010, 3.20, modified — Symbol has been changed.]

3.1.17
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the *sound power* (3.1.16) of a source, W, to a reference value, W_0

Note 1 to entry: the sound power level is calculated using Formula (3):

$$L_W = 10 \times \lg\left(\frac{W}{W_0}\right) \tag{3}$$

where

W is the sound power;

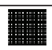
W_0 is the reference value, which equals 1 pW.

Note 2 to entry: If a specific frequency weighting, as specified in IEC 61672-1, and/or specific frequency bands are applied, this is indicated by appropriate subscripts, e.g. L_{WA} denotes the A-weighted sound power level.

Note 3 to entry: It is expressed in decibels (dB).

[SOURCE: ISO 3744:2010, 3.21, modified — Editorial modifications have been made.]

3.2 Symbols

Symbol	Description	Unit
$2a$	measurement surface length	m
$2b$	measurement surface width	m
c	measurement surface height	m
d	measurement distance	m
FS	flywheel side	—
l_1	reference box length	m
l_2	reference box width	m
l_3	reference box height	m
r_s	size ratio	—
•	key microphone positions	—
∘	additional microphone positions	—
	reflecting plane	—
	reference box	—

4 Test environment

4.1 General

The test environments that are applicable for measurements in accordance with this document are as follows:

a) a room or a flat outdoor area which is adequately isolated from background noise and which provides an acoustic free field over a reflecting plane, or;

b) a room or a flat outdoor area which is adequately isolated from background noise and in which an environmental correction can be applied to allow for a limited contribution from the reverberant field to the sound pressures on the measurement surface.

Environmental conditions having an adverse effect on the microphones used for the measurements (e.g. wind, impingement of air discharge, high or low temperatures) shall be avoided. The instructions of the manufacturer of the measuring instrumentation regarding adverse environmental conditions shall be followed. Particular care should be exercised to ensure that any plane does not radiate any appreciable sound due to vibrations.

4.2 Criterion for background noise

The time-averaged sound pressure level (abbreviated as sound pressure level in the following text) of the background noise measured and averaged over the microphone positions shall be at least 6,0 dB, and preferably more than 15,0 dB, below the corresponding uncorrected sound pressure level of the noise source under test when measured in the presence of this background noise.

For the measurements in frequency bands, the criteria for background noise may not be achievable in all frequency bands, even when the background noise levels in the test room are extremely low and well controlled. In this situation, for the measurements in frequency bands, the following steps shall be followed to determine whether the requirements of the background noise criteria are met.

a) Calculate the data from every frequency band within the frequency range of interest to A-weighted sound power level.

b) Delete those bands within the frequency range of interest in which the A-weighted sound power level of the noise source under test is at least 15,0 dB below the highest A-weighted sound power level and for which $\Delta L_{pA} < 6{,}0$ dB (see 8.3), then repeat the calculation of A-weighted sound power level.

c) If the calculation value difference between a) and b) is less than or equal to 0,5 dB, the A-weighted sound power level determined from the data for all bands may be considered as conforming to the background noise criteria of this document. If the calculation value difference between a) and b) is larger than 0,5 dB, the measurement is not valid.

4.3 Criterion for acoustic adequacy of test environment

Annex A specifies the procedures for determining the environmental correction, K_2.

As far as is practicable, the test environment shall be free from reflecting objects other than the reflecting plane (the ground). The reflecting plane shall extend at least 0,5 m beyond the projection of the measurement surface on the plane. The sound absorption coefficient of the reflecting plane shall be less than 0,1 in the frequency range of interest.

NOTE 1 Smooth concrete or smooth sealed asphalt surface(s) can meet the requirements.

Measurements in accordance with this document are only valid when $K_2 \leq 4{,}0$ dB.

NOTE 2 When $4{,}0 < K_2 \leq 7{,}0$, see ISO 6798-2. If necessary, ISO 9614 (all parts) can be used.

NOTE 3 The environmental correction, K_2, is assumed to be zero for measurements made in hemi-anechoic rooms which meet the requirements of ISO 3745.

The environmental correction, K_2, shall be first determined without reference to frequency band data, using one of the procedures in Annex A. Where it is decided to make measurements in frequency bands, the relevant environmental correction K_2 and the sound power level of the noise source L_W shall be determined in each band over the frequency range of interest in accordance with A.2 or A.3. L_{WA} of a noise source shall be calculated in accordance with Annex B.

