INTERNATIONAL STANDARD

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Reciprocating internal combustion engines — Measurement of emitted airborne noise — Engineering method and survey method

Moteurs alternatifs à combustion interne — Mesurage du bruit aérien émis — Méthode d'expertise et méthode de contrôle

INTERNATIONAL ISO

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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.

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 6798 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*, Subcommittee SC 5, *Special requirements*.

Annex A forms an integral part of this International Standard. Annex B is for information only.

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Introduction

Control of noise from machines or equipment requires effective exchange of acoustical information among the several parties concerned. These include the manufacturer, the party who fixes specifications, installer and user of the machine or equipment. This acoustical information is obtained from measurements. These measurements are useful only if they are carried out under specified conditions to obtain defined acoustical quantities using standardized instruments.

The sound power level data determined according to this International Standard is essentially independent of the environment in which the data are obtained. This is one of the reasons for using sound power level to characterize the sound emitted by various types of machine equipment.

This International Standard gives requirements for the measurement of the noise emission of reciprocating internal combustion engines. It has been prepared in accordance with ISO 3740 on the basis of ISO 3744 (engineering method) and ISO 3746 (survey method). Due to the special conditions concerning reciprocating internal combustion engines, it is necessary to define different noise sources and to use measurement surfaces differing from those specified in ISO 3744 and ISO 3746.

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1 Scope

1.1 This International Standard specifies methods for measuring the sound pressure levels on a measurement surface enveloping a source, and for calculating the sound power level produced by the source. It gives requirements for the test environment and instrumentation, as well as techniques for obtaining the surface sound pressure level from which the A-weighted sound power level of the source and octave or one-third octave band sound power levels are calculated. This method may be used to perform acceptance tests.

1.2 The aim of this International Standard is a grade 2 (engineering) result (see table 1). When the correction for background noise exceeds the limit of 1,3 dB but is less than 3 dB, and/or the correction for environment exceeds the limits of 2 dB but is less than 7 dB, then a grade 3 (survey) result is obtained (see table 2).

The same rectangular parallelepiped measurement surface and microphone positions are used for both engineering method (designated "ISO 6798 - Engineering") and the survey method (designated "ISO 6798 - Survey").

1.3 This test code applies to all reciprocating internal combustion engines falling within the field of application of ISO 3046-1 and for other applications, if no suitable International Standard exists.

1.4 The methods defined in this International Standard apply to the measurement of the noise emission of a reciprocating internal combustion engine under steady-state operating conditions.

In annex A special requirements for measuring noise levels emitted from exhaust outlets or combustion air inlets of reciprocating internal combustion engines are laid down.

1.5 Measurements made in accordance with this International Standard should result in standard deviations which are equal to or less than those given in table 3. The uncertainties in table 3 depend not only on the accuracies with which sound pressure levels and measurement surface areas are determined, but also on the "near-field error" which increases for smaller measurement distances and lower frequencies (i.e. those below 250 Hz). The near-field error always leads to sound power levels which are higher than the real sound power levels.

NOTES

1 If the methods specified in this International Standard are used to compare the sound power levels of similar machines that are omnidirectional and radiate broad-band noise, the uncertainty in this comparison tends to result in standard deviations which are less than those given in table 3, provided that the measurements be performed in the same environment with the same shape of measurement surface.

2 The standard deviations given in table 3 reflect the cumulative effects of all causes of measurement uncertainty, excluding variations in the sound power levels from test to test which may be caused, for example, by changes in the mounting or operating conditions of the source. The reproducibility and repeatability of the test result may be considerably better (i.e. smaller standard deviations) than the uncertainties given in table 3 would indicate.

Table 1 — International Standards used as a basis for determining the sound power level of a reciprocating internal combustion engine

International Standard	Classification of method[1)]	Test environment	Volume of source	Character of noise	Sound power levels obtainable	Optional information available
ISO 3744	Engineering (grade 2)	Outdoors or in large room	Greatest dimension less than 15 m	Any	A-weighted and in one-third octave or octave bands	Directivity information; sound pressure levels as a function of time; other weighted sound power levels
ISO 3746	Survey (grade 3)	No special test environment	No restrictions: limited only by available test environment	Any	A-weighted	Sound pressure levels as a function of time; other weighted sound power levels

1) See ISO 2204.

Table 2 — Limits for correction

Values in decibels

Grade of accuracy	Background noise correction	Environment correction
Grade 2	⩽ 1,3	⩽ 2
Grade 3	> 1,3 but ⩽ 3	> 2 but ⩽ 7
Special case[1)]	> 3	> 7

1) For higher values of background noise and/or environmental corrections, the real sound power level cannot be determined with acceptable uncertainty, but the results can be useful to estimate an upper limit of the noise emission of the reciprocating internal combustion engine to be tested.

Table 3 — Uncertainty in determining sound power levels, expressed as the largest value of the standard deviation

Values in decibels

Grade of accuracy	Octave band centre frequency					A-weighted
	31,5 Hz to 63 Hz [1)]	125 Hz	250 Hz to 500 Hz	1 000 Hz to 4 000 Hz	8 000 Hz	
Grade 2	5	3	2	1,5	2,5	2
Grade 3	For a source which produces sounds that contain prominent discrete tones.					5
	For a source which produces sounds that are uniformly distributed in frequency over the frequency range of interest.					4

1) If measurement is outdoors.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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 3046-1:1995, *Reciprocating internal combustion engines — Performance — Part 1: Standard reference conditions, declarations of power, fuel and lubricating oil consumptions, and test methods.*

ISO 3046-3:1989, *Reciprocating internal combustion engines — Performance — Part 3: Test measurements.*

ISO 3744:1994, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane.*

ISO 3745:1977, *Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms.*

ISO 3746:1995, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane.*

IEC 225:1966, *Octave, half octave and third octave band filters intended for the analysis of sounds and vibrations.*

IEC 651:1979, *Sound level meters.*

IEC 804:1985, *Integrating-averaging sound level meters.*

3 Definitions

For the purposes of this International Standard the definitions of ISO 3744 and ISO 3746 apply with the following additions.

3.1 airborne noise: At the microphone positions on the measurement surface, the sound pressure levels of the noise which is generated by the engine under test, including the following sources:

— surface of the engine;

— combustion air inlet;

— exhaust outlet;

— essential dependant auxiliaries (e.g. fuel pump, coolant pump, air charging equipment, heat exchanger, cooling systems).

NOTES

3 The following sources are excluded: gearbox (unless it forms an integral part of the engine); driven machinery or loading system.

4 Where the installation is such that combustion air inlet and/or exhaust outlet noise cannot be included, this International Standard requires this to be stated in the test report.

5 Where any of the essential dependent auxiliaries are located outside the measurement surface, this International Standard requires that the noise be measured either in accordance with a suitable application standard or the relevant general standard (ISO 3744 or ISO 3746).

3.2 background noise: At the microphone positions on the measurement surface, the sound pressure levels of the noise which is not generated by the engine under test.

4 Acoustic environment

4.1 Criteria for adequacy of the test environment

No reflecting objects that are not part of the source under test shall be located inside the measurement surface other than the reflecting plane (ground).

4.1.1 Engineering method

Test environments that are suitable for measurements according to the engineering method include a flat outdoor area or a room which meets the qualification requirements of annex A of ISO 3744:1994. If indoors, the test environment shall be adequately isolated from extraneous noise (see 4.2). Annex A of ISO 3744:1994 specifies a procedure for determining whether or not a test environment is adequate for measurements made according to the engineering method.

4.1.2 Survey method

The adequacy of the test environment for the survey measurements shall be evaluated according to annex A of ISO 3746:1995.

4.2 Criteria for background noise

4.2.1 Engineering method

At the microphone positions, the sound pressure levels of the background noise including influence of wind shall be at least 6 dB and preferably more than 10 dB below the sound pressure level to be measured in each frequency band within the frequency range as shown in table 3.

NOTE 6 If levels of background noise are less than 6 dB below the sound pressure level to be measured in a maximum of 2 of the frequency bands then the results for these bands may be reported in brackets. If more than 2 frequency bands are so affected then the level of the background noise is too high for measurements according to this engineering method and the survey method should be considered.

4.2.2 Survey method

At the microphone positions, the A-weighted sound pressure level due to the background noise including influence of wind shall be at least 3 dB below the A-weighted sound pressure level with the source operating.

NOTE 7 Background noise levels which are less than 3 dB below the sound level of the source to be measured are too high for the purposes of this International Standard. Under such circumstances, it is not possible to determine the A-weighted sound power level of the source within the accuracy limits prescribed in table 3. However, the result determined with higher background noise levels may be useful as an indication of the upper limit of the sound power level of the source.

4.3 Wind

Where recommended by the manufacturer, microphones shall be fitted with windscreens. Appropriate corrections shall be made in accordance with the manufacturer's instructions.

5 Instrumentation

The instrumentation for measuring sound pressure levels shall be as specified in ISO 3744 (for the sound level meters IEC 651, type 1, or IEC 804, class 1). For the survey method type 2 instruments according to IEC 225 may also be used.

6 Installation and operating conditions

6.1 Installation conditions

Engine driven cooling fans and other dependent auxiliaries (see ISO 3046-1) fitted to the engine under test shall be stated in the test report. Where any of the essential dependent auxiliaries are located outside the measurement surface, the noise shall be measured either in accordance with a suitable applications standard or the relevant general standard (ISO 3744 or ISO 3746), as agreed by the manufacturer and customer. The combustion air inlet shall be fitted with the specified air filter as noise from the air inlet is regarded as part of the airborne noise which is to be measured (see 3.1).

The silencer shall also be fitted to the engine as noise from the exhaust outlet and silencer surface is normally defined as part of the airborne noise which is to be measured (see 3.1). If noise from the combustion air inlet or from the exhaust cannot be included in the measurement, then this shall be clearly stated in the test report.

A gearbox or any driven machinery which is used to load the engine under test should be stated in the test report. Noise radiated from any such gearbox or driven machinery shall be regarded as extraneous noise, except in the case of engines where the gearbox forms an integral part of the engine (e.g. two-wheelers).

Appropriate steps shall be taken to reduce extraneous noise. This can be done by shielding or wrapping the driven noise source with a heavy material that has low transmission capabilities for the frequency range of the noise from the driven source.

The engine will normally be resiliently mounted but if this is not the case then any sound found to be radiating from the foundation as a result of structure-borne vibration shall be treated as extraneous noise and its effect minimized.

6.2 Operating conditions

For the determination of the sound power level of the reciprocating internal combustion engine the engine shall be operated at a power and speed as defined in ISO 3046-1 under the ambient conditions prevailing during the test. The ambient and intake temperature shall not be higher than 45 °C. For the particular case of an engine operating at its ISO standard power under ISO standard reference conditions the determined sound power level may be referred to as the ISO

sound power level engineering or ISO sound power level survey.

In all cases the ambient conditions, power and speed shall be recorded [see 9.1 e), 9.1 f) and 9.1 g)]. In addition the type of fuel used and especially its ignition characteristics, as defined by its octane or cetane number or index as appropriate, shall be recorded.

All measurements of engine power shall be determined in accordance with ISO 3046-1 and ISO 3046-3. For the torque a tolerance of ± 10 % is acceptable.

7 Measurement of weighted and octave band or one-third octave band sound pressure levels

7.1 Reference box

To facilitate the location of the microphone positions, a hypothetical reference box is defined. This reference box is the smallest possible rectangular parallelepiped that just encloses the engine and terminates on the reflecting plane (see figure 1). When defining the dimensions of the reference box, elements protruding from the engine which are not significant radiators of sound energy should be disregarded. For safety reasons, the reference parallelepiped may be made sufficiently large to include danger areas, for example, moving parts of an otherwise stationary machine.

7.2 Measurement surface

The microphone positions lie on the measurement surface, S_1, a hypothetical rectangular parallelepiped of area S (enveloping the engine) whose sides are parallel to the sides of the reference box and spaced out at a distance d (measurement distance) from the reference box.

7.3 Measurement distance

The measurement distance, d, between the reference box and the measurement surface shall be 1,0 m, except in the following circumstances.

Distances 0,5 m $\leqslant d \leqslant$ 1,0 m may be used for the survey method.

Distances $d >$ 1,0 m may be used where the acoustic environment complies with annex A of ISO 3744:1994 for the engineering method, or annex A of ISO 3746:1995 for the survey method.

7.4 Microphone positions

7.4.1 General

The number of microphone positions and their locations on the measurement surface depend on the dimensions of the reference box (that is, on the size of the engine) and the spatial uniformity of the noise radiated. Requirements for the number of microphone positions and their locations, depending on the dimensions of the reciprocating internal combustion engine, are given in table 4.

7.4.1.1 For the engineering method

If an engine radiates noise with a high directivity, for example, substantially from a small portion of the engine only, then a detailed investigation of the sound pressure levels over a restricted portion of the measurement surface will also be required. An indication for high directivity could be a difference of sound pressure levels higher than 5 dB, between adjacent measurement points. The purpose of this de-

Table 4 — Engine dimensions and microphone positions

Length l_1 m	Width l_2 m	Height l_3 m	Number of microphones	Figure showing the positions
$\leqslant$ 2	$\leqslant$ 2	$\leqslant$ 2,5	9 (5)	1
2 to 4	1)	$\leqslant$ 2,5	12	2
> 4		$\leqslant$ 2,5	15	3
1)		> 2,5	19	4

1) For this engine dimension any value is acceptable with only one exception: for the engineering method this dimension must be less than or equal to 15 m.

tailed investigation is to determine the highest and lowest sound pressure levels in the frequency bands of interest with a view to choosing further additional microphone positions. These further additional microphone positions will usually not be associated with equal areas on the measurement surface. In this case, the calculation in ISO 3745:1977, 7.7.1.2 (unequal areas) for the determination of L_W shall be used.

7.4.1.2 For the survey method

If preliminary investigations show that the sound pressure levels determined at the positions vertically above the top of the engine do not influence the sound power level determined using the full microphone array by more than 1 dB, then these positions can be omitted. This shall be mentioned in the test report.

7.4.1.3 For the engineering method and the survey method

If measurements at any position are not permissible due to machine obstructions (e.g. driving shaft, driven machinery, etc.) or for safety reasons, or are being adversely affected by cooling air flow, then another position as close as is practicable to the prescribed position shall be selected. Any such revised microphone position shall be recorded [see 9.4 b)].

NOTE 8 In relation to figures 2 to 4 the number of microphone positions specified is fewer than that specified in ISO 3744 and ISO 3746. Preliminary investigations have shown that in all cases for the types of engine concerned, the surface sound pressure levels from these reduced arrays differ by less than 0,5 dB(A) by comparison with the full arrays.

7.4.2 Reciprocating internal combustion engines with reference box dimensions: l_1 and $l_2 \leqslant 2$ m; $l_3 \leqslant 2{,}5$ m

For all such engines, the number of microphone positions is represented by the nine measurement positions shown in figure 1 and numbered 1 to 9. Measurement positions 1 to 4 are on a horizontal rectangular path at a height $(l_3 + d)/2$ above the reflecting plane whilst positions 5 to 9 are at a height $(l_3 + d)$ above the reflecting plane.

For certain types of engine it will suffice to take measurements only at the five microphone positions 1 to 4 and 9. Preliminary investigations have shown that for this case the A-weighted sound power level determined as a result of the measurement at only 5 measuring points (measuring points 1, 2, 3, 4 and 9 in figure 1) is normally higher than with the arrangement at nine measuring points by a level difference ΔL_{WA}[1].

In this case ΔL_{WA} has to be subtracted from the sound power level determined with five microphone positions.

For a given type of engine, preliminary investigations must be made to determine ΔL_{WA}.

Furthermore, measurements shall be made to show that the different ΔL_{WA} values obtained do not differ by more than 0,5 dB(A).

7.4.3 Reciprocating internal combustion engines with reference box dimesions: $2 \leqslant l_1 \leqslant 4$ m; $l_3 \leqslant 2{,}5$ m

For all such engines, the number of microphone positions is represented by the twelve measurement positions shown in figure 2 and numbered 1 to 12. Compared with the arrangement in figure 1, there are more microphone positions due to the greater length of the engine. The height of the microphone positions is as described in 7.4.2.

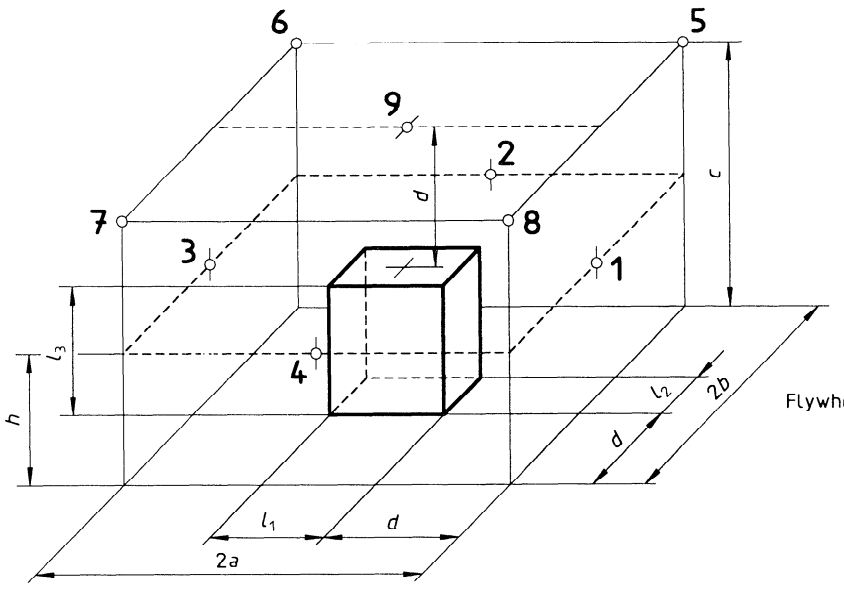
7.4.4 Reciprocating internal combustion engines with reference box dimensions: $l_1 > 4$ m; $l_3 \leqslant 2{,}5$ m

For all such engines, the number of microphone positions is increased to 15 due to the greater length of the engine. The microphone positions are numbered 1 to 15 and are shown in figure 3. The height of the microphone positions is as described in 7.4.2.

7.4.5 Reciprocating internal combustion engines the reference box of which has a height exceeding 2,5 m

For all such engines, the number of microphone positions is represented by the 19 measurement positions shown in figure 4 and numbered 1 to 19. Measurement positions 1 to 8 are on a horizontal rectangular path at a height of $(l_3 + d)/4$ above the reflecting plane. Due to the greater height of the engine there is another horizontal rectangular path at a height of $3(l_3 + d)/4$ above the reflecting plane with the microphone positions 9 to 16. Positions 17 to 19 are at a height $(l_3 + d)$ above the reflecting plane.

1) Numerous investigations have shown that for different types of engine ΔL_{WA} has a value of ca. 0,7 dB to 1,8 dB.



$$a = \frac{l_1}{2} + d$$

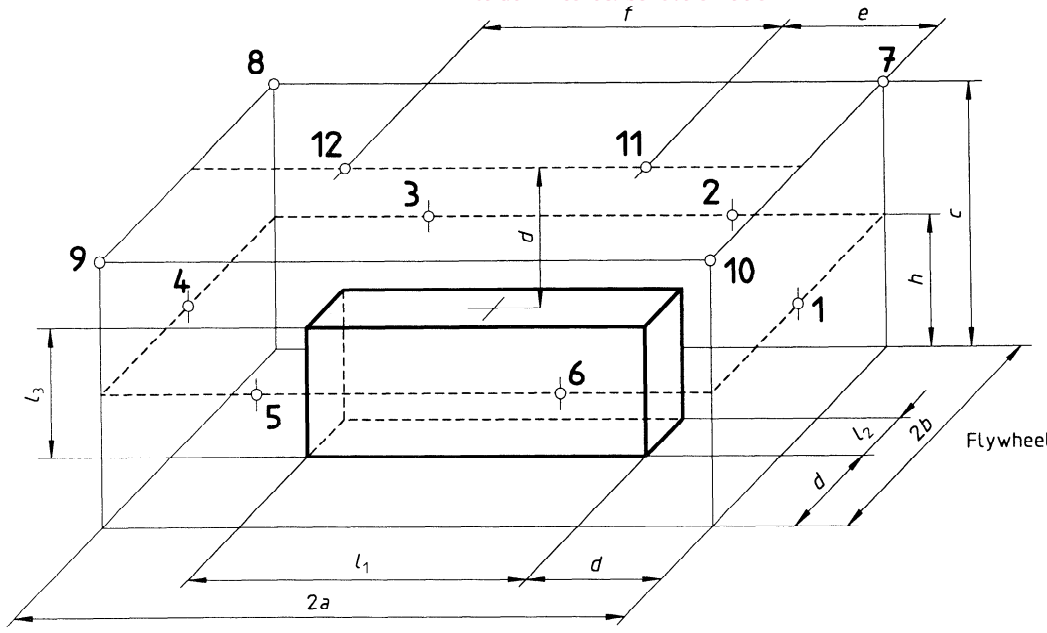
$$b = \frac{l_2}{2} + d$$

$$c = l_3 + d$$

$$h = \frac{c}{2}$$

NOTE — See 7.3 for specification of dimension *d*.

Figure 1 — Arrangement of nine (five) measurement points and measurement surface
(For engines with reference parallelepiped dimensions $l_1 \leqslant 2$ m, $l_2 \leqslant 2$ m, $l_3 \leqslant 2{,}5$ m.)



$$a = \frac{l_1}{2} + d$$

$$b = \frac{l_2}{2} + d$$

$$c = l_3 + d$$

$$h = \frac{c}{2}$$

$$e = \frac{a}{2}$$

$$f = 2e = a$$

NOTE — See 7.3 for specification of dimension *d*.

Figure 2 — Arrangement of twelve measurement points and measurement surface
(For engines with reference parallelepiped dimensions 2 m $\leqslant l_1 <$ 4 m, $l_3 \leqslant 2{,}5$ m.)