INTERNATIONAL STANDARD

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Reciprocating internal combustion engine driven alternating current generating sets —

Part 10:
Measurement of airborne noise

Groupes électrogènes à courant alternatif entraînés par moteurs alternatifs à combustion interne —

Partie 10: Mesurage du bruit aérien

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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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*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 270, *Internal combustion engines*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 8528-10:1998), which has been technically revised.

The main changes are as follows:

— the normative references have been updated;

— the latest requirements of ISO 3744:2010 and ISO 3746:2010 have been included, respecting ISO 12001:1996 requirements;

— the measurement surfaces have been updated;

— the definition of the reference box in special cases has been added;

— the guaranteed sound power level has been added;

— requirements concerning variable speed engine gensets, fans and lighting towers have been added;

— the requirements for welding generators have been updated;

— the determination of the emission sound pressure level at workstation has been updated.

A list of all parts in the ISO 8528 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

This document specifies noise test codes for determining the basic noise emission descriptors.

For many manufacturers of generating sets, the control of noise is a major issue that requires effective exchange of acoustical information, in particular on noise emission. The basic noise emission descriptors are the sound power level of the generating set itself and the emission sound pressure level at the workstation.

In this context, the main flow of information goes from the manufacturer to the purchaser. However, installers and users of the generating sets also desire comprehensive information about the generating sets' ability to generate airborne sound.

Thus, measuring the basic noise emission descriptors allows the generating set manufacturer to determine, declare and verify the noise emission values.

Therefore, the sound power level, as the major parameter to characterize machines as sound sources, is determined by measurements. The sound power level is a major parameter because it represents an intrinsic characteristic of generating sets as noise sources. It is useful, for example, in noise-abatement programmes or when designing a building where the generating set is intended to be used.

The emission sound pressure level at the workstation is also measured. This enables an assessment of the risk of exposure to the airborne sound of the operators. This assessment is essential for health and safety reasons.

In this document, the generating sets are considered as steady noise sources as per ISO 12001:1996. The generating sets concerned and the extent to which noise is covered are indicated in this document. This document allows measurements to be made in many different test environments. Clause 5 can be used as a general guideline to assist in the selection of the right noise test code. The selection mainly depends on the test environment and the desired grade of accuracy.

This document contains two methodologies for determining the measurement uncertainty. In Clause 12, the uncertainty U is determined by considering measurements on a single generating set. In Clause 13, the uncertainty K is determined by considering a batch of generating sets, which can be useful for control of production purpose.

This document is a C-type standard as stated in ISO 12001:1996. When provisions of this C-type standard are different from those stated in A or B standards, the provisions of this C-type standard take precedence.

Reciprocating internal combustion engine driven alternating current generating sets —

Part 10:
Measurement of airborne noise

1 Scope

This document specifies noise test codes for determining the sound power level and the emission sound pressure level at the workstation of reciprocating internal combustion engine driven electrical power generating sets.

This document applies to constant and variable-speed reciprocating internal combustion (RIC) engine driven alternating current (AC) and direct current (DC) generating sets for fixed and mobile applications with rigid or flexible mountings. It is applicable for land and marine use, excluding generating sets used on aircraft or to propel land vehicles and locomotives.

NOTE 1   For some specific applications (e.g. essential hospital supplies, high-rise buildings) supplementary requirements can be necessary. The provisions of this document can be regarded as a basis.

NOTE 2   This document is referenced with regard to noise in ISO 8528-13:2016, which contains requirements concerning the design of generating sets, verification of noise levels and information related to noise in the operating and maintenance instructions.

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 3046-1:2002, *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 3744:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane*

ISO 3746:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

ISO 8528-1:2018, *Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance*

ISO 8528-2:2018, *Reciprocating internal combustion engine driven alternating current generating sets — Part 2: Engines*

ISO 15619:2013, *Reciprocating internal combustion engines — Measurement method for exhaust silencers — Sound power level of exhaust noise and insertion loss using sound pressure and power loss ratio*

IEC 60942:2017, *Electroacoustics - Sound calibrators*

IEC 60974-1:2021, *Arc welding equipment - Part 1: Welding power sources*

IEC 61260-1:2014, *Electroacoustics - Octave-band and fractional-octave-band filters - Part 1: Specifications*

IEC 61672-1:2013, *Electroacoustics – Sound level meters – Part 1: specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3046-1:2002, ISO 8528-1:2018 and ISO 8528-2:2018 and the following apply.

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

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

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

3.1
emission
<acoustics> airborne sound radiated by the generating set under test

3.2
emission sound pressure
p_e
sound pressure, at a workstation or another 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

Note 1 to entry: Emission sound pressure is expressed in pascals.

3.3
emission sound pressure level
L_{pe}
ten times the logarithm to the base 10 of the ratio of the square of the emission sound pressure, p_e, to the square of a reference value, p_0, expressed in decibels by Formula (1):

$$L_{pe} = 10\ lg\frac{p_e^2}{p_0^2}$$ (1)

where the reference value, p_0, is 20 μPa

3.4
time-averaged emission sound pressure level
$L_{pe,T}$
ten times the logarithm to the base 10 of the ratio of the time average of the square of the emission sound pressure, p_e, 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, expressed in decibels by Formula (2):

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

where the reference value, p_0, is 20 μPa

Note 1 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 2 to entry: L_{peA} denotes the A-weighted emission sound pressure level.

3.5
workstation
operator's position
position in the vicinity of the generating set under test which is intended for the operator

Note 1 to entry: This position is defined as the location in the vicinity of the device(s) mounted to the generating set for work tasks.

Note 2 to entry: Such devices can be a control panel, an emergency stop button or the most likely device on the equipment that an operator would interact with.

Note 3 to entry: A generating set can have more than one workstation.

3.6
operator
individual whose workstation is in the vicinity of a machine and who is performing a work task associated with that machine

4 Symbols

$\cos\varphi$	power factor
d	measurement distance, in metres
D_{Ii}^{*}	apparent directivity index, in decibels
i	subscript denoting a particular measuring point
K	expanded measurement uncertainty of the sound power level, or of the emission sound pressure level at the workstation, for a batch of generating sets, in decibels
$K_{1\mathrm{A}}$	A-weighted background noise correction, in decibels
$K_{2\mathrm{A}}$	A-weighted environmental correction, in decibels
L_{p}	sound pressure level, in decibels
$\overline{L_{\mathrm{p}}}$	surface time-averaged sound pressure level, in decibels
L_{pe}	emission sound pressure level, in decibels
L_{peA}	A-weighted emission sound pressure level, in decibels
$L_{\mathrm{pe,T}}$	time-averaged emission sound pressure level, in decibels
$L_{\mathrm{p}i,\mathrm{T}}$	time-averaged sound pressure level, for the ith microphone position on the measurement surface, in decibels
$L_{\mathrm{p,T}}$	time-averaged sound pressure level, in decibels
L_{W}	sound power level, in decibels
L_{WA}	A-weighted sound power level, in decibels
ΔL_{p}	difference between the time-averaged sound pressure level of the background noise measured and averaged over the microphone positions, and corresponding time-averaged sound pressure level of the noise source under test when measured in the presence of this background noise, in decibels
p	sound pressure, in pascals

r	measurement radius, in metres
S	measurement surface, in square metres
T	measurement time interval, in seconds
U	expanded measurement uncertainty of the sound power level, or of the emission sound pressure level at the workstation, for a single generating set, in decibels
V_I^*	apparent surface sound pressure level non-uniformity index, in decibels

5 Selection of the most appropriate method

5.1 General

Table 1 provides a detailed overview of the technical characteristics of the measurements methods in this document. Table 1 describes noise test codes with two levels of accuracy (grades 2 and 3). It can help in the selection of the appropriate noise test code.

Table 1 — Technical characteristics of this document

Parameters	Measurement methods		
	Sound power level measurement ISO 8528-10 grade 2	Sound power level measurement ISO 8528-10 grade 3	Emission sound pressure level at the workstation measurement ISO 8528-10 grade 2
Basic standards referenced	ISO 3744:2010	ISO 3746:2010	ISO 11201:2010
Accuracy	Grade 2 engineering	Grade 3 survey	Grade 2 engineering
Test environment	Indoor or outdoor	Indoor or outdoor	Indoor or outdoor
Type of environment	Dedicated to tests	In situ	Dedicated to tests
Characteristics of environment	Hemi-anechoic rooms, large rooms or unobstructed outdoor area	Not especially designed for acoustic tests	Hemi-anechoic rooms, large rooms or unobstructed outdoor area
Acoustic field	Essentially free field over a reflecting plane	Unspecified field with one or multiple reflecting plane(s)	Essentially free field over a reflecting plane
Generating set volume	Unlimited	Unlimited	Unlimited
Applications as per ISO 12001:1996	Noise declaration engineering study for noise reduction	Comparative tests	Noise declaration engineering study for noise reduction
Obtainable quantities	A-weighted sound power level	A-weighted sound power level	A-weighted sound pressure level
	Frequency bands (octave) sound power level		Frequency bands (octave) sound pressure level
	Frequency bands (one-third octave) sound power level		Frequency bands (one-third octave) sound pressure level
Criterion for background noise	$\Delta L_p \geq 6$ dB	$\Delta L_p \geq 3$ dB	$\Delta L_p \geq 6$ dB
	$K_{1A} \leq 1,3$ dB	$K_{1A} \leq 3$ dB	$K_{1A} \leq 1,3$ dB
a For indoor measurements only.			
b Specific studies carried out on generating sets can lead to lower values.			

Table 1 *(continued)*

Parameters	Measurement methods		
	Sound power level measurement ISO 8528-10 grade 2	Sound power level measurement ISO 8528-10 grade 3	Emission sound pressure level at the workstation measurement ISO 8528-10 grade 2
Criterion for acoustic adequacy of test environment	$K_{2A} \leq 4$ dB	$K_{2A} \leq 7$ dB	$K_{2A} \leq 4$ dB[a]
Instrumentation	Class 1	Class 2	Class 1
Typical upper bound values of the standard deviation of reproducibility[b]	1,5 dB	4 dB	1,5 dB

[a] For indoor measurements only.

[b] Specific studies carried out on generating sets can lead to lower values.

5.2 Sound power level measurements accuracy grades

5.2.1 General

For sound power level measurements:

— Grade 2 provides more accurate results than grade 3 but involves greater measurement efforts.

— The grade 2 method is based on ISO 3744:2010. The requirements listed in Annex A shall be followed.

— Terms and definitions of ISO 3744:2010 applicable to generating sets are indicated in Table A.1.

— The grade 3 method is based on ISO 3746:2010. The requirements listed in Annex B shall be followed.

— Terms and definitions of ISO 3746:2010 applicable to generating sets are indicated in Table B.1.

— In this document, when the accuracy grade is not specified the requirements apply for grade 2 and grade 3. The grade 3 method has many requirements in common with the grade 2 method.

5.2.2 Engineering grade (grade 2)

In this accuracy grade, the acoustic environment is analysed to determine its effect upon the measurements. The environmental correction K_{2A} shall be less than or equal to 4 dB. The background noise level is analysed too. Background noise correction K_{1A} shall be less than or equal to 1,3 dB. The measuring points are selected according to the characteristics of the generating set. The engineering method is the preferred method for noise declaration purposes. This method usually provides information that is sufficient for taking engineering action in many situations, for example, in connection with noise-abatement programmes.

5.2.3 Survey grade (grade 3)

This accuracy grade needs less time and equipment than grade 2. It may be used for comparison between generating sets with similar characteristics. The measurements are made in situ with little effort expended to control the acoustic environment in which the generating set operates. The environmental correction K_{2A} shall be less than or equal to 7 dB. The background noise correction K_{1A} shall be less than or equal to 3 dB. The survey method is generally of limited value if corrective measures to reduce the noise are to be evaluated.

NOTE   True comparisons can only be made between generating sets when the measurements are classified in the same accuracy grade.

6 Measuring equipment

6.1 General

ISO 3744:2010, 5.1 and ISO 3746:2010, 5.1 are replaced by subclause A.2.1.

6.2 Calibration

ISO 3744:2010, 5.2 and ISO 3746:2010, 5.2 are replaced by subclause A.2.2.

7 Measuring environment

7.1 General

For accuracy grade 2, ISO 3744:2010, 1.3, and 4.1 apply.

For accuracy grade 3, ISO 3746:2010, 1.3, and 4.1 apply.

7.2 Verification of acoustic adequacy of test environment

For accuracy grade 2, the test environment shall meet the requirements of ISO 3744:2010, 4.3. In addition, the following considerations shall be taken into account:

— Where it is decided to make measurements in frequency bands, the relevant environmental correction K_2 shall be determined in each band over the frequency range of interest in accordance with A.6.

— In many cases, due to the reality of the acoustic properties of the measuring area and the test bench conditions (this occurs predominantly with larger generating sets), sound power level grade 2 might not be obtainable using the method described in this document. In special cases with the agreement of the customer or the accepting company or authority, the accuracy may be improved with the use of special measuring methods (e.g. sound intensity method in accordance with ISO 9614-1:1993 and ISO 9614-2:1996, see Annex C).

For accuracy grade 3, the test environment shall meet the requirements of ISO 3746:2010, 8.1 and 4.3.

7.3 Criteria for background noise

For accuracy grade 2, the background noise shall meet the requirements of ISO 3744:2010, 4.2.

For accuracy grade 3, the background noise shall meet the requirements of ISO 3746:2010, 4.2.

In both cases, the following additional considerations shall be taken into account:

— Noise generated by air movement at the microphone itself is classified as background noise.

— For measuring out of doors, a microphone wind cover in accordance with the microphone manufacturer's specifications shall be used.

— When measurements are done outside, the maximum speed of the wind shall not exceed 6 m/s.

8 Definition of noise source and operating conditions of the generating set

8.1 Definition of noise source under test

The noise of a generating set is defined as the total noise emitted by that generating set. This includes the surface noise of the engine and the AC or DC alternator, the air intake and discharge noise, exhaust

noise (including the genset muffler, rain cap and tail pipe exhaust outlet), the noise emitted from the cooling system of the power generator set, the radiator and other fans of the power generator, and the noise which is emitted, for example, from the joining sections and the base frame, chassis and fuel tank.

In the case of totally or partially encapsulated generating sets, the surface noise is the noise emitted from the enclosure.

If, as in special cases, one of the above-mentioned noise emissions is not in the measurement results, then this shall be recorded in the measuring report. Such special cases include:

— in situ: when the exhaust and cooling systems are ducted to a remote site.

— in a test room: when the exhaust of the generating set is ducted out of the test room.

8.2 Location, installation of the generating set

For accuracy grade 2, the generalities in ISO 3744:2010, 6.1 apply.

For accuracy grade 3, the generalities in ISO 3746:2010, 6.1 apply.

For accuracy grade 2, ISO 3744:2010, 6.3, concerning noise source location, shall apply.

For accuracy grade 3, ISO 3746:2010, 6.3, concerning noise source location, shall apply.

In addition, the following considerations shall be taken into account:

— The generating set shall be prepared in accordance with the instructions given by the manufacturer.

— If simulated loading conditions are used, they shall be chosen such that the sound power levels of the source under test are representative of normal use.

8.3 Mounting of the generating set

For accuracy grade 2, ISO 3744:2010, 6.4.1, concerning generalities about mounting of the noise source, shall apply.

For accuracy grade 3, ISO 3746:2010, 6.4.1, concerning generalities about mounting of the noise source, shall apply.

For accuracy grade 2, ISO 3744:2010, 6.4.3, concerning base-mounted, wall-mounted and tabletop machinery and equipment, shall apply.

For accuracy grade 3, ISO 3746:2010, 6.4.3, concerning base-mounted, wall-mounted and tabletop machinery and equipment, shall apply.

In addition, the following considerations shall be taken into account:

— For accuracy grade 2, the generating set shall be installed on a typical noise-reflecting ground plane of concrete or non-porous asphalt, in an essentially free-field environment. Refer to the free-field environment definition from ISO 3744:2010.

— For accuracy grade 2 and grade 3, the generating set shall be installed according to the manufacturer's recommendation, representative of a typical operational installation. This shall consider the location of any discrete items (e.g. cooling, aftertreatment, exhaust) and mounting (e.g. trailer with stabilizing jacks, skid).

8.4 Operation of the generating set during test

ISO 3744:2010, 6.6 and ISO 3746:2010, 6.5 are replaced by subclause A.3.

9 Reference box and measurement surface

9.1 Reference box

ISO 3744:2010, 7.1 and ISO 3746:2010, 7.1 are replaced by subclause A.4.

9.2 Determination of the reference box in special cases

9.2.1 Elevated generating set on a trailer or trolley kit

In cases where the generating set is elevated (e.g. on a trailer or a trolley kit) in normal customer use, the reference box shall be delineated as per 9.1. An example is given in Figure 1.
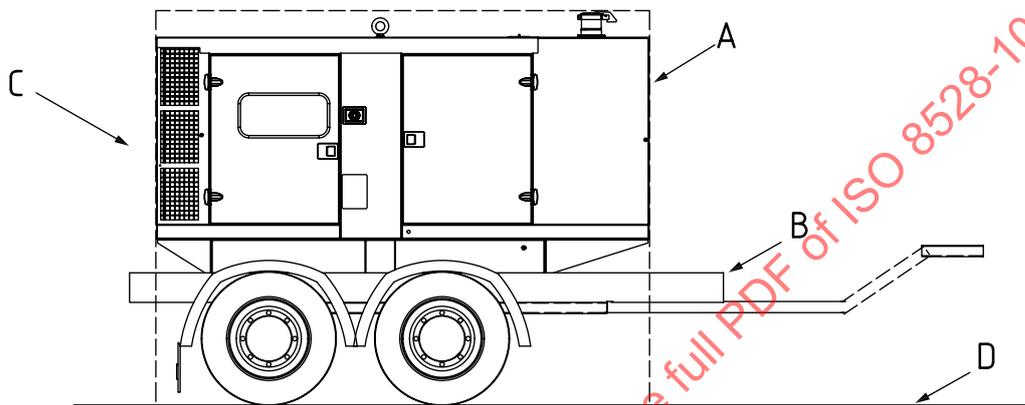
Key

A   generating set
B   trailer
C   reference box
D   ground (reflecting plane)

Figure 1 — Example of a reference box for a generating set on a trailer

9.2.2 Generating set with extended exhaust device

In cases where the generating set is installed outdoors, with a vertical extended exhaust device, the reference box shall be delineated depending on the value of m in the following cases. m is the distance between the exhaust outlet of the generating set and the uppermost noise-emitting devices' top surface.

Case 1:   If $m > 2$ metres then a reduced reference box shall be used, including the uppermost noise emitting devices' top surface, but excluding the exhaust outlet. An example is given in Figure 2 a).

Case 2:   If 1 metre ≤ m ≤ 2 metres, then the exhaust outlet shall be temporarily extended to have $m > 2$ metres. Then a reduced reference box shall be used, including the uppermost noise emitting devices' top surface, but excluding the exhaust outlet. An example is given in Figure 2 a).

   This extension is for measurement purposes only.

Case 3:   If $m < 1$ metre then regular reference box shall be used, including the exhaust outlet. An example is given in Figure 2 b).

With respect to cases 1 and 2, two components of sound power level (L_{WA}) shall be determined. The first component, L_{WA1}, shall be determined by taking into consideration the reduced reference box, where sound power level emitted by the genset excluding the exhaust system is determined. The second

component, L_{WA2}, is the sound power level of the exhaust outlet. L_{WA2} shall be determined by using the ISO 15619:2013 accuracy grade 2 method. Then Formula (3) shall be used.

$$L_{WA} = 10 \ \lg\left[\left(10^{(L_{WA1}/10)}\right) + \left(10^{(L_{WA2}/10)}\right)\right] \tag{3}$$

In cases where the generating set is installed outdoors, with a remote exhaust device on the side, the same requirements as detailed above shall apply.
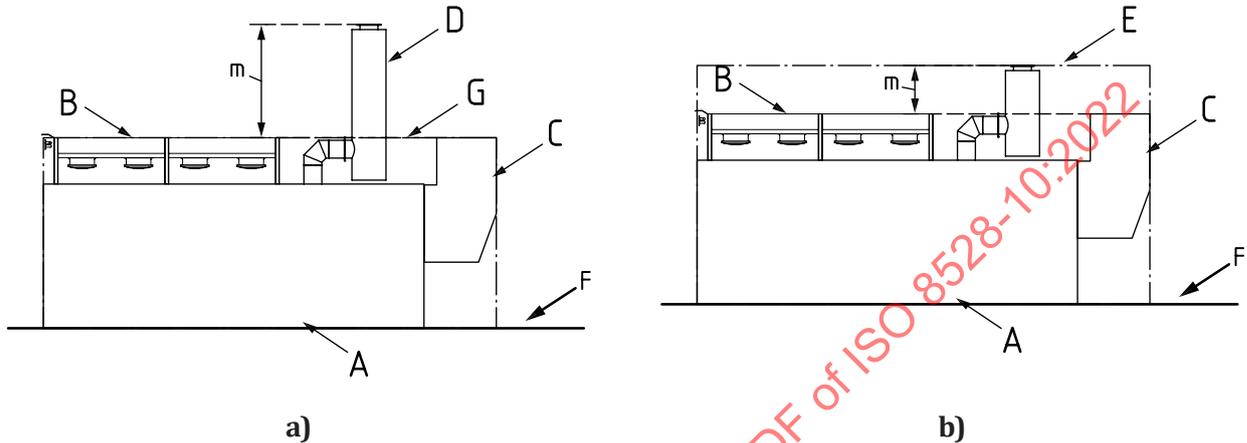
Key

A	generating set	E	reference box
B	cooling system	F	ground (reflecting plane)
C	air intake	G	reduced reference box
D	vertical extended exhaust device		

Figure 2 — Example of reference boxes for generating sets with a vertical extended exhaust device

9.2.3 Generating set with auxiliary equipment

In cases with auxiliary equipment that is necessary for the operation of the generating set but not part of it (e.g. load banks), ISO 3744:2010, 6.2 or ISO 3746:2010, 6.2 shall apply.

In cases where there are auxiliary equipment that are necessary for the operation of the generating set that are parts of it, ISO 3744:2010, 6.2, or ISO 3746:2010, 6.2 shall apply.

9.3 Measurement surface

9.3.1 General

ISO 3744:2010, 7.2.1 and ISO 3746:2010, 7.2.1 are replaced by subclause A.5.1.

9.3.2 Microphone orientation

For accuracy grade 2, ISO 3744:2010, 7.2.2 shall apply.

For accuracy grade 3, ISO 3746:2010, 7.2.2 shall apply.

In addition, the following considerations shall be taken into account:

— In an effort to reduce the influence on measured results due to people involved in the measuring process, the microphone shall preferably be mounted statically.

— The measuring personnel shall remain at least 1,5 m from the microphone.

9.3.3 Hemispherical measurement surface

ISO 3744:2010, 7.2.3, 8.1.1, Annex B and Annex F and ISO 3746:2010, 7.2.3, 8.2.1, Annex B are replaced by subclause A.5.2.

For accuracy grade 2, ISO 3744:2010, 8.4, concerning apparent directivity index and concentrated microphone positions, can be used as an opportunity to reduce the measured sound power level.

9.3.4 Parallelepiped measurement surface

ISO 3744:2010, 7.2.4, 8.1.2 and Annex C and ISO 3746:2010, 7.2.4, 8.2.2 and Annex C are replaced by subclause A.5.3.

For accuracy grade 2, ISO 3744:2010, 8.4, concerning apparent directivity index and concentrated microphone positions, can be used as an opportunity to reduce the measured sound power level.

9.3.5 Reduction in the number of microphone positions

For accuracy grade 3 only, ISO 3746:2010, 8.2.3 is replaced by subclause B.2.

10 Measurement of sound pressure levels

For accuracy grade 2, ISO 3744:2010, 8.2.1, concerning measurement of sound pressure levels of the generating set and of the background noise, applies.

For accuracy grade 3, ISO 3746:2010, 8.3.1, concerning measurement of sound pressure levels of the generating set and of the background noise, applies.

In addition, the following considerations shall be taken into account for accuracy grades 2 and 3:

— The measurement time interval should be 20 s or longer but shall be at least 15 s for all frequency bands or for A-weighting.

— The definition of the frequency range of interest, in ISO 3744:2010, 3.9 and ISO 3746:2010, 3.7, is replaced by subclause A.6.

11 Determination of the A-weighted sound power level

11.1 Calculation of mean-time-averaged sound pressure levels

For accuracy grade 2, ISO 3744:2010, 8.2.2.1 shall apply.

For accuracy grade 3, ISO 3746:2010, 8.3.2 shall apply.

11.2 Corrections for background noise

For accuracy grade 2, ISO 3744:2010, 8.2.3 shall apply.

For accuracy grade 3, ISO 3746:2010, 8.3.3 shall apply.

11.3 Calculation of the surface time-averaged sound pressure levels

For accuracy grade 2, ISO 3744:2010, 8.2.4 shall apply.

For accuracy grade 3, ISO 3746:2010, 8.3.4 shall apply.

11.4 Calculation of sound power levels

For accuracy grade 2, ISO 3744:2010, 8.2.5 and Annex G shall apply.

For accuracy grade 3, ISO 3746:2010, 8.3.5 shall apply.

11.5 Calculation of apparent surface sound pressure level non-uniformity index

For accuracy grade 2, ISO 3744:2010, 8.5 shall apply.

11.6 A-weighted sound power level

For accuracy grade 2, ISO 3744:2010, 8.6 and Annex E are replaced by subclause A.7.

12 Measurement uncertainty

For accuracy grade 2:

— ISO 3744:2010, Clause 9 is replaced by subclause A.8.

— ISO 3744:2010, 1.4 and Annex H apply.

For accuracy grade 3:

— ISO 3746:2010, Clause 9 is replaced by subclause A.8.

— ISO 3746:2010, 1.4 and Annex D apply.

13 Guaranteed sound power level

13.1 General

This clause makes it possible to determine the guaranteed sound power level, which includes measurement uncertainty, by considering measurements on several generating sets. The guaranteed sound power level can be used in a control of production process as it includes (among others) the standard deviation of production. The purpose of determining the guaranteed sound power level is to compare it with a limit value.

The guaranteed sound power level, L_{WAd}, in decibels, is given by Formula (4):

$$L_{\mathrm{WAd}} = L_{\mathrm{WAm}} + K \tag{4}$$

where

L_{WAm} is the arithmetic mean of sound power levels, in decibels, which are measured on a sample of N generating sets, in accordance with the requirements of the sound power level measurement ISO 8528-10 grade 2 method laid down in this document;

K is the expanded measurement uncertainty, in decibels.

13.2 Arithmetic mean of sound power levels

L_{WAm}, in decibels, is given by Formula (5):

$$L_{\mathrm{WAm}} = \frac{\sum_{i=1}^{N} L_{\mathrm{WA},i}}{N} \tag{5}$$

where

$L_{\text{WA},i}$ is the sound power level, in decibels, measured on the ith generating set, in accordance with the requirements of the sound power level measurement ISO 8528-10 grade 2 method laid down in this document;

N is the sample size (i.e. the number of generating sets under test).

The sample size, N, shall be equal to or greater than two for the first control of production session. This sample size can grow over years as per the control of production-cycle-based measurement. The arithmetic mean of sound power levels can be updated by using each additional sample's measured results. The relevance of the control of production can be expected to increase as the sample size grows. Thus, it is advisable to reach the number of five measured generating sets as soon as possible. The arithmetic mean of sound power levels shall be based on the set of all the samples from the first sample to the current sample.

13.3 Expanded measurement uncertainty

The expanded measurement uncertainty, K, in decibels, is given by Formula (6):

$$K = k_2 \times \sqrt{\sigma_{R0}^2 + \sigma_{\text{omc}}^2 + \sigma_{\text{p}}^2} \tag{6}$$

where

k_2 is the coverage factor;

σ_{R0} is the standard deviation of reproducibility of the method, in decibels;

σ_{omc} is the standard deviation describing the uncertainty due to the instability of the operating and mounting conditions of the generating sets, in decibels;

σ_{p} is the standard deviation of production, in decibels.

13.4 Coverage factor

As the purpose of determining the guaranteed sound power level is to compare the result with a limit value, the coverage factor for a one-sided normal distribution shall be considered. Then k_2 shall be equal to 1,6. This coverage factor corresponds to a 95 % confidence level.

13.5 Determination of σ_{R0}

A.8.4 shall apply for determination of σ_{R0}, considering exclusively accuracy grade 2.

13.6 Determination of σ_{omc}

A.8.3 shall apply for determination of σ_{omc}.

13.7 Determination of σ_p

The standard deviation of production of a sample of N generating sets is given by Formula (7):

$$\sigma_p = \sqrt{\frac{\sum_{i=1}^{N}\left(L_{WA,i} - L_{WAm}\right)^2}{N-1}} \tag{7}$$

As with the arithmetic mean of sound power levels, the standard deviation of production can be updated by using each additional sample's measured results. The standard deviation of production shall be based on the set of all the samples from the first sample to the current sample.

13.8 Calculation of the guaranteed sound power level

Formula (4) shall apply to calculate the guaranteed sound power level.

The result shall be rounded up or down to the nearest integer number (less than 0,5, use the lower number; greater than or equal to 0,5, use the higher number).

EXAMPLE   Generating set determination of σ_{R0} has not been undertaken, thus the value is taken from Table A.2 (σ_{R0} = 1,5 dB); measured σ_{omc} = 0,4 dB; measured $L_{WA,1}$ = 86,2 dB; measured $L_{WA,2}$ = 87,1 dB; measured $L_{WA,3}$ = 86,5 dB; measured $L_{WA,4}$ = 86,9 dB; measured $L_{WA,5}$ = 85,9 dB; determined L_{WAm} = 86,5 dB; determined σ_p = 0,5 dB;

Using Formula (6), it follows that:

$$K = 1,6 \times \sqrt{1,5^2 + 0,4^2 + 0,5^2} = 2,6 \text{ dB}$$

Then using Formula (4), it follows that:

L_{WAd} = L_{WAm} + K = 86,5 + 2,6 = 89,1 dB

Finally, the guaranteed sound power level, L_{WAd}, is 89 dB.

14 Test report

ISO 3744:2010, Clauses 10 and 11 and ISO 3746:2010, Clauses 10 and 11 are replaced by subclause A.9.

15 Determination of the emission sound pressure level at the workstation

15.1 General

This clause specifies a method for determining the emission sound pressure level at the workstation of the generating set. This method is based on the ISO 11201:2010 accuracy grade 2 method. All the requirements of the sound power level measurement ISO 8528-10 grade 2 method shall apply with the modifications and specificities detailed in the following subclauses.

15.2 Determination of location of the workstation(s)

The location(s) of the workstation(s) of the generating set shall be determined first. For the purpose of this subclause, the considered work tasks are operation (e.g. start, stop) and monitoring of the generating set with the device(s) supplied by the manufacturer as an integral part of the generating set.

Appropriate positions where measurements may be made include the following:

a)   workstation located in the vicinity of the generating set;

b)   workstation within a partial or total enclosure (or behind a screen) supplied by the manufacturer as an integral part of the generating set under test (e.g. walk-in enclosure);

c)   other specified positions, if there is no clearly identifiable workstation.

15.3 Criteria for the adequacy of the test environment

For indoor measurements, the environmental correction, K_{2A}, shall be determined in accordance with 7.2, but the correction shall not be applied.

For outdoor measurements, the distance between a reflecting object and the generating set under test or the microphone position is not smaller than the distance between the microphone position and the most remote point of the generating set under test.

15.4 Corrections for background noise

The corrections for background noise, K_{1A}, shall be determined in accordance with 7.3 for each workstation and shall apply in accordance with 15.8.

15.5 Measured quantity

The basic quantity to be measured at each workstation is the A-weighted emission sound pressure level, L'_{peA} (the prime indicates measured values).

Sound pressure levels in octave or one-third-octave frequency bands may also be measured as required, for example for the design of low-noise machines.

15.6 Calculation of A-weighted emission sound pressure level

In cases where the A-weighted emission sound pressure level is not measured directly but is calculated from measurements in frequency bands, only one-third octave bands shall be used. Calculation of the A-weighted emission sound pressure level, L'_{peA}, from measurements made in frequency bands shall be performed using Formula (8):

$$L'_{peA} = 10 \lg \sum_{k=k_{min}}^{k_{max}} 10^{0,1\left(L'_{pek} + C_k\right)} \text{dB} \tag{8}$$

where

L'_{pek} is the measured emission sound pressure level in the kth one-third octave band, in decibels;

k, C_k are given in Table A.4 for calculations with frequency band data covering the range of mid-band frequencies 50 Hz to 10 kHz for one-third octave bands;

k_{min}, k_{max} are values of k corresponding, respectively, to the lowest and highest frequency bands of measurement.

15.7 Normalizing to reference meteorological conditions

At altitudes greater than 500 m above sea level or temperatures outside the range −20 °C to 40 °C, the measured emission sound pressure level shall be normalized to the reference meteorological conditions:

$p_{amb,0}$ = 1,013 25 × 10⁵ Pa

Θ_0 = 296 K

by using Formula (9) to obtain the emission sound pressure level for the reference meteorological conditions, $L'_{\mathrm{pe,0A}}$, in decibels:

$$L'_{\mathrm{pe,0A}} = L'_{\mathrm{peA}} - 20\lg\frac{p_{\mathrm{amb}}}{p_{\mathrm{amb,\,0}}} + 20\lg\frac{\Theta}{\Theta_0} \tag{9}$$

where

p_{amb} is the ambient pressure, in pascals, at the time and place of the test;

Θ is the air temperature, in kelvins, at the time and place of the test.

At altitudes less than or equal to 500 m above sea level and in the temperature range −20 °C to 40 °C, no normalization to reference meteorological conditions is required. If these cases, Formula (10) applies:

$$L'_{\mathrm{pe,0A}} = L'_{\mathrm{peA}} \tag{10}$$

15.8 Quantities to be determined

The quantity to be determined at each workstation is the A-weighted emission sound pressure level, L_{peA}. Additionally, emission sound pressure levels in frequency bands may be determined.

To obtain emission sound pressure levels at the workstation(s), only background noise corrections, K_{1A}, shall apply to measured emission sound pressure levels, as shown in Formula (11).

$$L_{\mathrm{peA}} = L'_{\mathrm{pe,0A}} - K_{1A} \tag{11}$$

In the case of multiple workstation locations, the value of the highest emission sound pressure level shall be recorded and reported as the emission sound pressure level at the workstation of the generating set. The position where this value is measured shall be recorded and reported.

15.9 Operation of the generating set

If an opening system must be opened to interact with the generating set, the measurements shall be made with the opening system open, to be representative of an actual use of the generating set by an operator.

15.10 Microphone positions

15.10.1 General

The measurement positions shall be chosen from the alternatives specified in 15.10.2, 15.10.3 and 15.10.4.

The emission sound pressure level shall be measured without the operator at the location of the workstation and with the microphone reference direction oriented towards the dominant sound source.

If the measured sound pressure level is strongly position-dependent, it is recommended that the space average be taken on a small measuring surface (e.g. 0,5 m × 0,5 m) parallel to the reference box and centred at the workstation.

15.10.2 Microphone position for a standing operator

The microphone position shall be at a distance of 1 m from the device or control panel the operator has to interact with during work tasks, and at a height of 1,6 m from the ground plane, floor or access platform on which the operator normally stands.

15.10.3 Microphone position for a bending, crouching or kneeling operator

The microphone position shall be at a distance of 1 m from the device or control panel the operator has to interact with during work tasks, and at a height of 0,8 m from the ground plane, floor or access platform on which the operator is normally located.

15.10.4 Microphone positions if there is no clearly identifiable operator position or for machines without operator

If no operator's position can be identified, the microphone shall be placed on a path around the generating set, at a distance of 1 m from the reference box and at a height of 1,6 m from the ground plane, floor or access platform. The number of emission sound pressure level measurements along this path shall be equal to or greater than four. The value of the highest emission sound pressure level shall be recorded and reported as the emission sound pressure level of the generating set. The position where this value is measured shall be recorded and reported.

15.11 Measurement uncertainty

Subclause A.8, concerning measurement uncertainties, applies even if it considers sound power levels and not sound pressure levels.

15.12 Test report

The test report shall be in accordance with subclause A.9.

Annex A
(normative)

Application of ISO 3744:2010 for generating sets

A.1 General

This annex specifies and completes the general requirements of ISO 3744:2010 which are applicable to the generating sets.

Table A.1 indicates the following:

— A: the articles or subclauses of ISO 3744:2010 applicable to generating sets;

— R: the articles or subclauses of ISO 3744:2010 for which a replacement or additional requirements are necessary so that these apply to generating sets and are indicated by the clause or subclauses numbers;

— N/A: the articles or subclauses of ISO 3744:2010 that do not apply.

Whenever an article, clause or subclause is referenced, check in Table A.1 if it is "A", "R" or "N/A".   The replacements of these clauses or subclauses are given in the rest of this annex. The necessary additional requirements are given elsewhere in this document.

Table A.1 — Application of ISO 3744:2010 for generating sets

ISO 3744:2010			Application for generating sets		
Clause	Subclause	Title	A	R	N/A
1		Scope			
	1.1	General			X
	1.2	Types of noise and noise sources			X
	1.3	Test environment	X		
	1.4	Measurement uncertainty	X		
2		Normative references	X		
3		Terms and definitions			
	3.1	sound pressure	X		
	3.2	sound pressure level	X		
	3.3	time-averaged sound pressure level	X		
	3.4	single event time-integrated sound pressure level			X
	3.5	measurement time interval	X		
	3.6	acoustic free field	X		
	3.7	acoustic free field over a reflecting plate	X		
	3.8	reflecting plate	X		
	3.9	frequency range of interest		A.6	
Key					
A applicable					
R replacement					
N/A not applicable					

Table A.1 *(continued)*

ISO 3744:2010			Application for generating sets		
Clause	Subclause	Title	A	R	N/A
	3.10	reference box	X		
	3.11	characteristic source reference	X		
	3.12	measurement distance	X		
	3.13	measurement radius	X		
	3.14	measurement surface	X		
	3.15	background noise	X		
	3.16	background noise correction	X		
	3.17	environmental correction	X		
	3.18	surface time-averaged sound pressure level	X		
	3.19	surface single event time-integrated sound pressure level			X
	3.20	sound power	X		
	3.21	sound power level	X		
	3.22	sound energy			X
	3.23	sound energy level			X
	3.24	apparent directivity index	X		
	3.25	apparent surface sound pressure level non-uniformity index	X		
4		Test environment			
	4.1	General	X		
	4.2	Criteria for background noise		7.3	
	4.3	Criterion for acoustic adequacy of test environment		7.2	
5		Instrumentation			
	5.1	General		A.2.1	
	5.2	Calibration		A.2.2	
6		Definition, location, installation, and operation of noise source under test			
	6.1	General	X		
	6.2	Auxiliary equipment		9.2.3	
	6.3	Noise source location		8.2	
	6.4	Mounting of the noise source			
	6.4.1	General	X		
	6.4.2	Hand-held machinery and equipment			X
	6.4.3	Base-mounted, wall-mounted, and tabletop machinery and equipment		8.3	
	6.5	Installation and mounting conditions for moving noise sources			X
	6.6	Operation of source during test		A.3	
7		Reference box and measurement surface			

Key

A   applicable

R   replacement

N/A   not applicable

Table A.1 *(continued)*

ISO 3744:2010			Application for generating sets		
Clause	Subclause	Title	A	R	N/A
	7.1	Reference box		A.4	
	7.2	Measurement surface			
	7.2.1	General		A.5.1	
	7.2.2	Microphone orientation		9.3.2	
	7.2.3	Hemispherical measurement surface		A.5.2	
	7.2.4	Parallelepiped measurement surface		A.5.3	
	7.2.5	Cylindrical measurement surface			X
	7.2.6	Combination measurement surface			X
8		Determination of sound power levels and sound energy levels			
	8.1	Microphone positions on the measurement surface			
	8.1.1	Hemispherical measurement surface		A.5.2	
	8.1.2	Parallelepiped measurement surface		A.5.3	
	8.1.3	Cylindrical measurement surface			X
	8.1.4	Combination measurement surface			X
	8.2	Determination of sound power levels			
	8.2.1	Measurement of sound pressure levels		10	
	8.2.2	Calculation of mean time-averaged sound pressure levels			
	8.2.2.1	Measurement surface with microphone positions or traverses uniformly distributed	X		
	8.2.2.2	Measurement surface with segments having unequal areas	X		
	8.2.3	Corrections for background noise	X		
	8.2.4	Calculation of surface time-averaged sound pressure levels	X		
	8.2.5	Calculation of sound power levels	X		
	8.3	Determination of sound energy levels			X
	8.4	Calculation of apparent directivity indices	X		
	8.5	Calculation of apparent surface sound pressure level non-uniformity index	X		
	8.6	A-weighted sound power level and sound energy level		A.7	
9		Measurement uncertainty		A.8	
10		Information to be recorded		A.9	
11		Test report		A.9	
Annex A (normative)		Qualifications procedures for the acoustic environment			
	A.1	General	X		
Key					
A applicable					
R replacement					
N/A not applicable					

Table A.1 *(continued)*

ISO 3744:2010			Application for generating sets		
Clause	Subclause	Title	A	R	N/A
	A.2	Absolute comparison test	X		
	A.3	Determination of the environmental correction based on room absorption	X		
Annex B (normative)		Microphone arrays on a hemispherical measurement surface		A.5.2	
Annex C (normative)		Microphone arrays on a parallelepiped measurement surface		A.5.3	
Annex D (informative)		Microphone arrays on a cylindrical measurement surface			X
Annex E (normative)		Calculation of A-weighted sound power levels and A-weighted sound energy levels from frequency band levels		A.7	
Annex F (normative)		Alternative microphone array on a hemispherical measurement surface for direct measurements of A-weighted sound pressure level		A.5.2	
Annex G (normative)		Sound power level and sound energy level under reference meteorological conditions	X		
Annex H (informative)		Guidelines on the development of information on measurement uncertainty	X		
Key					
A applicable					
R replacement					
N/A not applicable					

A.2 Measuring equipment

A.2.1 General

ISO 3744:2010, 5.1 and ISO 3746:2010, 5.1 are replaced as follows:

If the measurement equipment is a hand-held sound level meter it shall be an integrating sound level meter.

The whole measurement chain, including the analyser, the cable(s), the microphone(s) and the software shall meet the requirements of IEC 61672-1:2013, class 1 for accuracy grade 2 and class 2 for accuracy grade 3, and the filters shall meet the requirements of IEC 61260-1:2014, class 1 (for accuracy grade 2 only). The manufacturer's certificate of conformity proves that these standards have been met.

Otherwise, a type test shall be performed according to the following procedure:

The type test is intended to establish technical capabilities of a measurement chain to conform with class 1 or class 2 requirements. The following principles shall apply:

— The type test shall be done just after purchasing the measuring equipment.

— The type test shall prove that the association of an acquisition module (brand, model) with a cable (brand, model), a microphone (brand, model) and software (brand, model) meets the requirements of IEC 61672-1:2013, class 1 for accuracy grade 2 and class 2 for accuracy grade 3, and that the filters meet the requirements of IEC 61260-1:2014 class 1 (for accuracy grade 2 only).

— Implications:

  — If the measuring equipment consists of more than one type of acquisition module, a type test shall be done for each type of acquisition module.

  — If the measuring equipment consists of several acquisition modules with the same brand and model, only one acquisition module shall be tested.

  — If an acquisition module is used in association with more than one microphone, with the same brand and model, only one microphone shall be tested.

— If an acquisition module has more than one measuring input, only one measuring input shall be tested.

The sound calibrators shall meet the requirements of IEC 60942:2017, class 1.

A.2.2 Calibration

ISO 3744:2010, 5.2 and ISO 3746:2010, 5.2 are replaced as follows:

The following conformities shall be verified at intervals in a laboratory making calibrations traceable to appropriate standards:

— Conformity of the hand-held sound level meters with the requirements of IEC 61672-1:2013 for accuracy grade 2 and grade 3 and IEC 61260-1:2014 for accuracy grade 2 only.

— Conformity of all the parts of the data loggers (all acquisition modules, all microphones) with the instrumentation manufacturer's maximum permissible error.

— Conformity of the sound calibrators with the requirements of IEC 60942:2017.

Unless national regulations dictate otherwise, these verifications shall be done at intervals not exceeding:

— 2 years for the hand-held sound level meters, the data loggers and the microphones;

— 1 year for the sound calibrators.

Before and after each series of measurements, a sound calibrator meeting the requirements of IEC 60942:2017 class 1 shall be applied to each microphone to verify the calibration of the entire measuring system at one or more frequencies within the frequency range of interest. Without any adjustment, the difference between the readings made before and after each series of measurements shall be less than or equal to 0,5 dB. If this value is exceeded, the results of the series of measurements shall be discarded.

A.3 Operating conditions during test

ISO 3744:2010, 6.6 and ISO 3746:2010, 6.5 are replaced as follows:

A.3.1 General

The generating set shall be stabilized in the desired operating condition, with any power source or transmission system running at a stable temperature, prior to the start of measurements for sound power level determination. The load, speed and operating conditions shall be held constant during the test.

When the measurements are taken, the ambient and air inlet temperatures shall be not higher than 320 K.

A.3.2 Generating set electrical power during noise measurements

The generating set shall operate at a steady power output at 75 % of its rated power in kilowatts as per ISO 8528-1:2018.

The given output, i.e. the useful output calculated on the basis of the given output in kilovoltamperes under the application of the power factor (cos φ), shall be reported.

A.3.3 Variable speed engine gensets

In the case of variable speed engine gensets, where engine and other noise-producing component speeds vary with respect to the load applied, the following conditions are required while conducting the noise measurements according to this document:

a) variable speed engine genset engines shall operate at the higher of the following speeds:

— no less than 70 % of the maximum permissive speed set by the manufacturer;

— the speed at which genset delivers power as per A.3.2;

b) variable speed engine gensets with directly mounted components that produce noise shall operate at appropriate speeds to satisfy the requirements detailed in a);

c) variable speed engine genset components that produce noise and are not directly mounted on the engine shall operate at no less than 70 % of the maximum speed set by the manufacturer

A.3.4 Fan(s)

A.3.4.1 General

If the engine of the equipment or its hydraulic system is fitted with (a) fan(s) it (they) must operate during the test. The fan speed is, in accordance with one of the following conditions, stated and set by the manufacturer of the equipment. This speed shall be used in further measurements.

A.3.4.2 Fan drive directly connected to the engine

If the fan drive is directly connected to the engine and/or hydraulic equipment (e.g. by belt drive) it must operate during the test.

A.3.4.3 Fan drive with several distinct speeds

If the fan can work at several distinct speeds the test shall be carried out either:

a) at its maximum working speed; or

b) in a first test with the fan set at zero speed and in a second test the fan set at maximum speed. The resulting surface time-averaged sound pressure level $\overline{L_p}$ shall then be calculated by combining both test results using Formula (A.1):

$$\overline{L_p} = 10\lg\left(0{,}3 \times 10^{0{,}1 \times \overline{L_{p,0\%}}} + 0{,}7 \times 10^{0{,}1 \times \overline{L_{p,100\%}}} \right) \tag{A.1}$$

where

$\overline{L_{p,0\%}}$ is the sound pressure level determined with the fan set at zero speed, in decibels;

$\overline{L_{p,100\%}}$ is the sound pressure level determined with the fan set at maximum speed, in decibels.

If the lowest of the distinct speeds is different from zero then this speed shall be substituted to the $L_{p,0\,\%}$ condition.

A.3.4.4   Fan drive with continuous variable speed

If the fan can work at continuous variable speed, the test shall be carried out either according to A.3.4.3 b) or with the fan speed set by the manufacturer at no less than 70 % of the speed range.

A.3.5   Welding generator current during noise measurements

The welding generator (AC or DC) shall operate at a steady output current. The current shall be 40 % of the current associated to a 60 % duty cycle as defined in IEC 60974-1:2021. A resistive load bank shall be used. The load voltage during the noise measurements shall be reported.

A.3.6   Lighting towers electrical power during noise measurements

All the spotlights shall be switched on at their maximum intensity. The electrical power during the noise measurement shall be written in the test report.

The light tower shall be deployed to the minimum height allowed by the manufacturer, with lights on.

A.4   Reference box

ISO 3744:2010, 7.1, and ISO 3746:2010, 7.1 are replaced as follows:

In order to facilitate the selection of the shape and dimensions of the measurement surface, the reference box shall first be delineated. The reference box is a hypothetical surface defined by the smallest right parallelepiped that just encloses the generating set. When defining the dimensions of the reference box, elements protruding from the generating set which are known not to be significant radiators of sound may be disregarded. For the gensets with and without enclosure, canopy or housing, the reference box shall envelope any protruding devices outside of the enclosure, canopy or housing, or remotely mounted, which are essential for the function or operation of the genset. For safety reasons, the reference box may be enlarged to remove measuring points from the dangerous areas, for example hot surfaces and moving parts.

The locations of the reference box, the measurement surface and the microphone positions for measurements are defined with respect to a coordinate system with origin O in the ground plane, shown in Figure A.1. The point O is the middle point of the face of the reference box that lies on the ground. The horizontal X- and Y-axes of the coordinate system also lie in the ground plane, parallel to the length and width of the reference box.
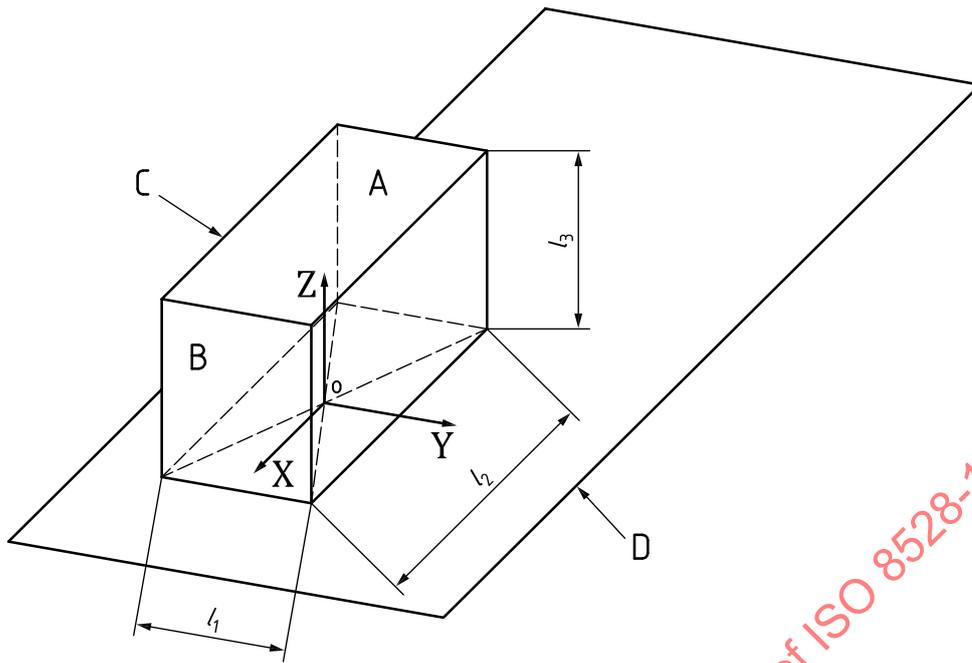
Key

A   engine side

B   generator side

C   reference box

D   ground (reflecting plane)

l_1 reference box width

l_2 reference box length

l_3 reference box height

O   origin

Figure A.1 — Reference box and coordinate system

A.5   Measurement surface

A.5.1   General

ISO 3744:2010, 7.2.1 and ISO 3746:2010, 7.2.1 are replaced as follows:

This document gives specifications relating to the shape of the measurement surface.

The microphone positions at which the sound pressure levels are measured lie on the measurement surface, a hypothetical surface of area S which envelops the reference box and terminates on the reflecting plane. The measurement surface shall be a hemisphere of radius r, as described in A.5.2. The radius r of the hemisphere shall be equal to or greater than twice the largest dimension of the reference box (see Figure A.1). The radius of the hemisphere shall be rounded to the nearest higher of the following values: 4 m, 10 m, 16 m. If the largest dimension of the reference box is strictly greater than 8 m then the parallelepiped measurement surfaces described in A.5.3 shall be used.

For practical reasons, an alternative to the hemispherical measurement surfaces may be used under the following condition: if the largest dimension of the reference box is strictly greater than 2 m, and equal to or less than 8 m, then the parallelepiped measurement surfaces described in A.5.3 may be applied.

NOTE 1   The hemispherical surface requires lower background noise than the parallelepiped surface but is known to result in lower A-weighted sound power level than the parallelepiped measurement surface.

NOTE 2   The measuring environment requirements of this document apply to all the measurement surfaces.

A.5.2   Hemispherical measurement surface

ISO 3744:2010, 7.2.3, 8.1.1, Annex B and Annex F and ISO 3746:2010, 7.2.3, 8.2.1 and Annex B are replaced as follows:

The hemisphere shall be centred on the coordinate origin, O, see Figure A.1. A set of 12 microphones on the hemispherical measurement surface shall be used. The location of 12 microphone positions distributed on the surface of a hemisphere of radius r are listed in the form of Cartesian coordinates in Table A.2. The measurement surface is a full hemisphere and its area is $S = 2\pi r^2$ in square metres.

The number of measuring points shall be 12. Preliminary investigations have shown that for the appropriate generating sets the A-weighted sound power level determined as a result of the measurement at only six measuring points (measuring points 2, 4, 6, 8, 10 and 12 in Figure A.2) is normally lower than with the arrangement at 12 measuring points by a level difference ΔL_{WA}.

For determining ΔL_{WA}, each model of the genset shall be tested by using 12 measuring points first then sound power level shall be calculated by using only six measuring points. If the difference in sound power level (ΔL_{WA}) determined by using these two measuring schemes does not exceed 0,5 dB then the reduced microphone measuring scheme shall be used. Note that ΔL_{WA} needs to be established for every new genset model that is tested for the first time.

Table A.2 — Coordinates of the 12 microphone positions in the coordinate system

Position number	x/r	y/r	z/r	z
1	1,00a	0	–	1,5 m
2	0,707a	0,707a	–	1,5 m
3	0	1,00a	–	1,5 m
4	−0,707a	0,707a	–	1,5 m
5	−1,00a	0	–	1,5 m
6	−0,707a	−0,707a	–	1,5 m
7	0	−1,00a	–	1,5 m
8	0,707a	−0,707a	–	1,5 m
9	0,65	0,27	0,71	–
10	−0,27	0,65	0,71	–
11	−0,65	−0,27	0,71	–
12	0,27	−0,65	0,71	–
NOTE The constant "a" depends on the measurement radius and is taken from Table A.3.				

Table A.3 — Values of the constant "a"

r m	a
4	0,927
10	0,989
16	0,996
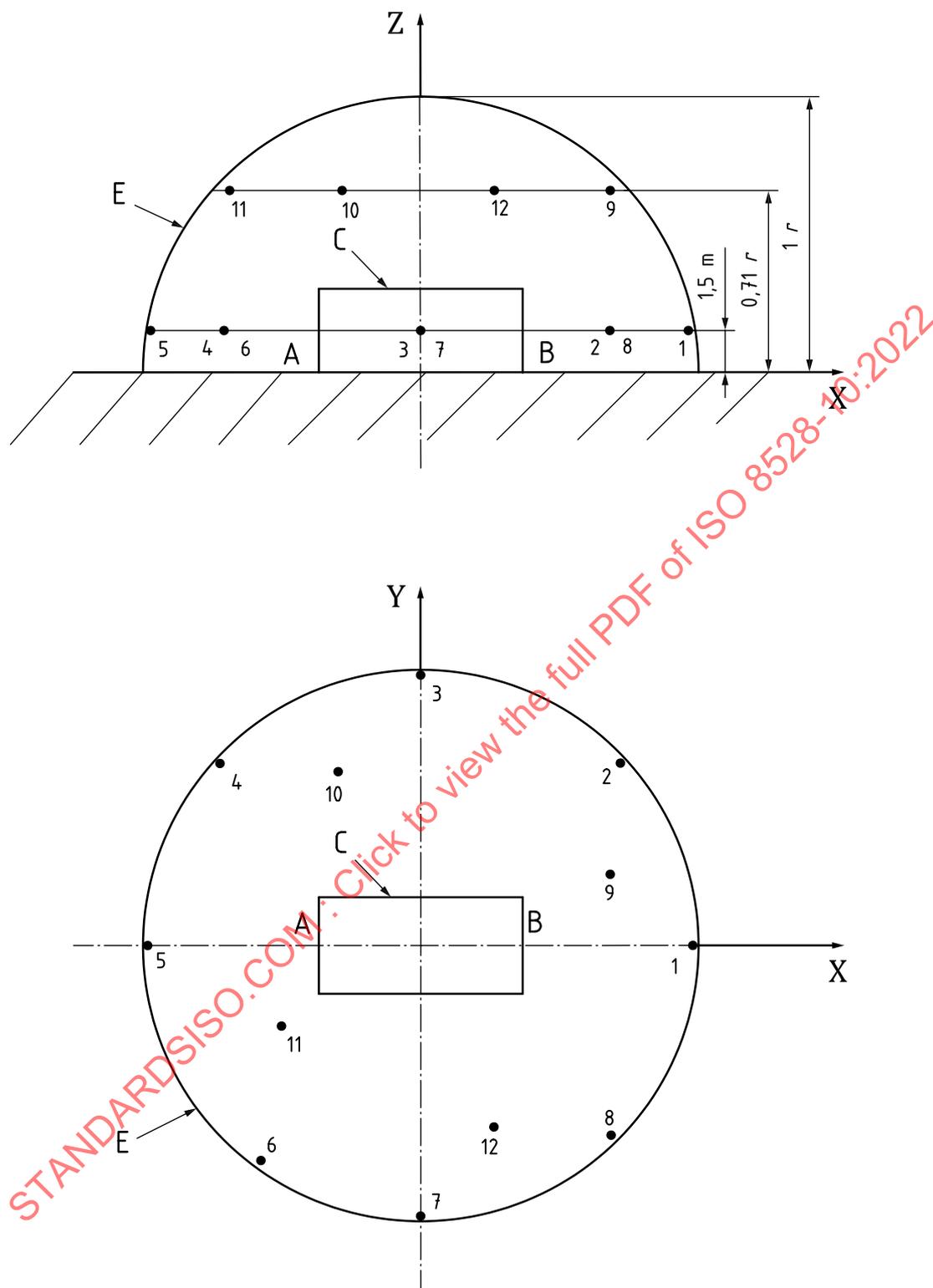
Key

•	microphone positions (1 to 12)	C	reference box
A	engine side	E	measurement surface
B	generator side	r	measurement surface radius

Figure A.2 — Hemispherical measurement surface and measuring points arrangement for generating sets

A.5.3 Parallelepiped measurement surface

ISO 3744:2010, 7.2.4, 8.1.2 and Annex C and ISO 3746:2010, 7.2.4, 8.2.2 and Annex C are replaced as follows:

The parallelepiped shall have the same orientation with respect to the coordinate origin, O, as the reference box, see Figure A.1. The measuring distance, d, between the reference box and the parallelepiped measurement surface is 1 m. The area, S, of the measurement surface is given by Formula (A.2):

$$S = 4(ab + bc + ca) \tag{A.2}$$

where

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

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

$$c = l_3 + d$$

In which l_1, l_2 and l_3 are the width, length and height, respectively, of the reference box.

The measuring points shall be arranged equidistantly along the measuring surface and completely enclose all relevant sources of noise. The number depends upon the size of the generating set. The arrangement and the number of the measuring points on the measuring surface depend on the measurements l_1, l_2 and l_3 of the reference box and are shown in Figures A.3 to A.5.

In relation to Figures A.3, A.4 and A.5, for the engineering method the number of microphone positions specified is less than that specified in ISO 3744:2010. Preliminary investigations[26] have shown that in all cases for the types of engines concerned, the A-weighted surface sound pressure levels from these reduced arrays differ by less than 0,5 dB from the full arrays.

If one of the measuring points shown in Figures A.3 to A.5 is not accessible due to lack of space or other reasons, the measuring point on the measuring place can be moved along its measurement surface, provided that the distance from the previous measuring position is as small as possible.

If one of the measuring points shown in Figures A.3 to A.5 is found in the area of the air intake and exhaust gas openings, the microphone shall be arranged so that it does not encounter air or gas movements greater than 6 m/s and temperatures greater than 320 K (46,9 °C or 116,3 °F).

This microphone shall be moved along its measurement surface, provided that the distance from the previous measuring position is at most 1 m. If the altered microphone position still encounters air or gas movements greater than 6 m/s and temperatures greater than 320 K, then it can be moved 1 m away from the air opening boundary and into the plane perpendicular to the line of the air flow, and not necessarily along the parallelepipedal measurement surface.

In any case, the position of the altered measuring point shall be shown in the measurement report.
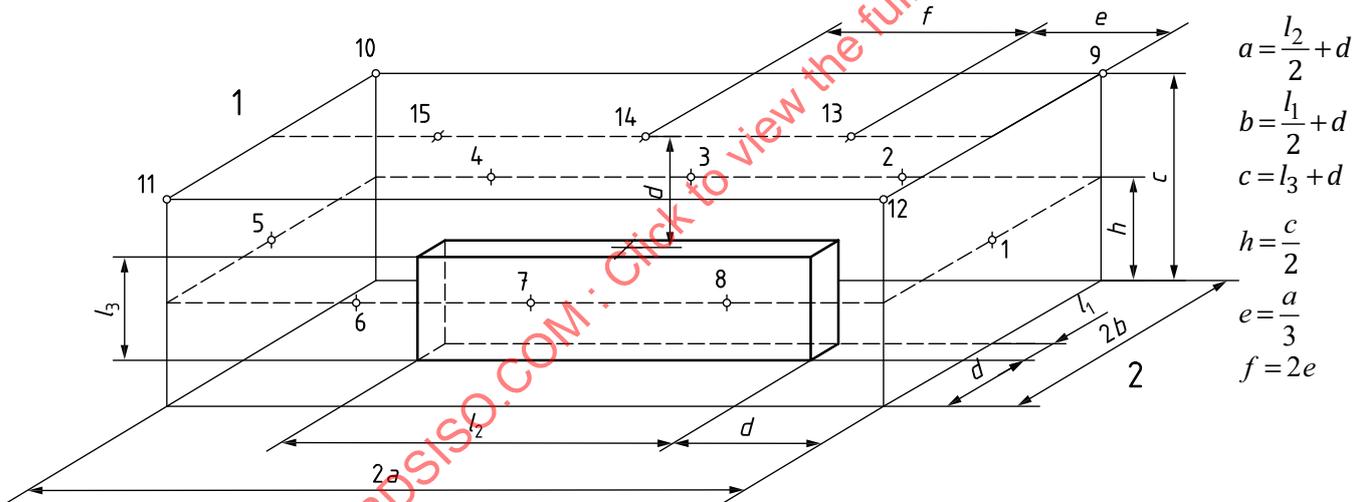
For all measuring points, Figures A.3 to A.5 apply.

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

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

$$c = l_3 + d$$

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

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

$$f = 2e = a$$

Key
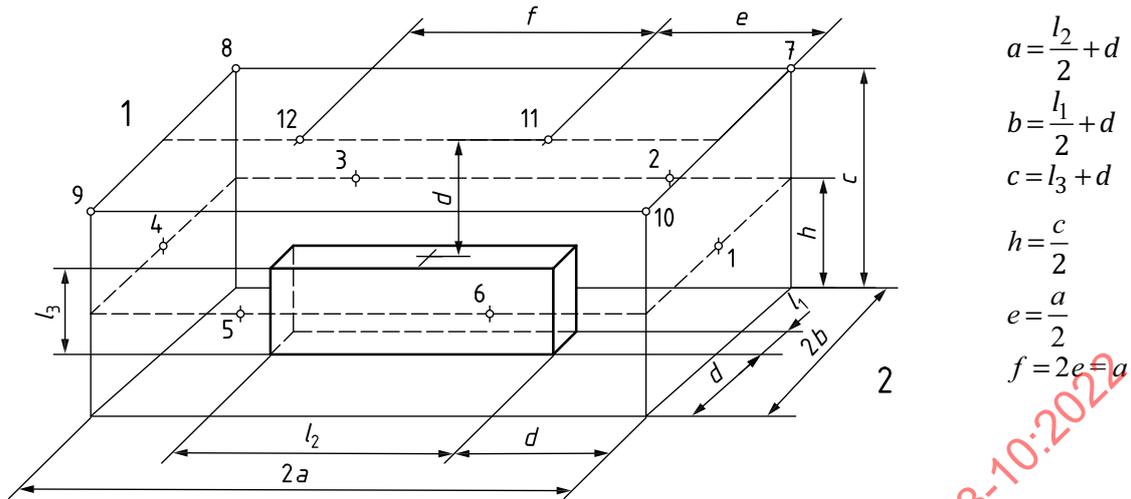
1   engine side   2   generator side

Figure A.3 — Measuring point arrangement (12 measuring points) and measuring plane for generating sets with the reference box measurements: 2 m < l_2 ≤ 4 m and l_3 ≤ 2,5 m

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

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

$$c = l_3 + d$$

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

$$e = \frac{a}{3}$$

$$f = 2e$$

Key

1   engine side   2   generator side

Figure A.4 — Measuring point arrangement (15 measuring points) and measuring plane for generating sets with the reference box measurements: l_2 > 4 m and l_3 ≤ 2,5 m

Key

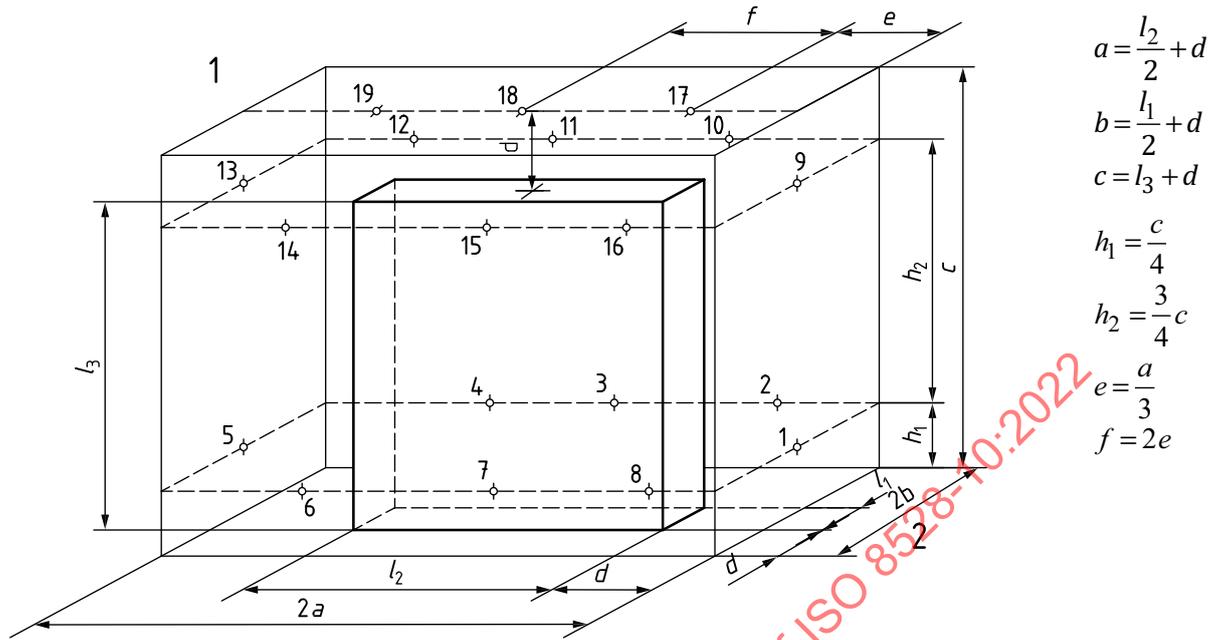1   engine side   2   generator side

Figure A.5 — Measuring point arrangement (19 measuring points) and measuring plane for generating sets with the reference box measurements: $l_2 > 4$ m and/or $l_3 > 2,5$ m

A.6   Frequency range of interest

The definitions of the frequency range of interest in ISO 3744:2010, 3.9 and ISO 3746:2010, 3.7 are replaced as follows:

The minimum frequency range shall include the octave bands with centre frequencies from 63 Hz to 8 000 Hz or one-third octave bands from 50 Hz to 10 000 Hz.

NOTE   In the case of indoor measurements, meeting the requirements for acoustic adequacy of the test environment can be a difficult challenge.

A.7   Calculation of A-weighted sound power level

ISO 3744:2010, 8.6 and Annex E are replaced as follows:

In cases where the A-weighted sound power level is not measured directly but is calculated from measurements in frequency bands, only one-third octave bands shall be used. Calculation of the A-weighted sound power level, L_{WA}, from measurements made in frequency bands shall be performed using Formula (A.3):

$$L_{WA} = 10 \lg \sum_{k=k_{\min}}^{k_{\max}} 10^{0,1(L_{Wk}+C_k)} \text{ dB} \tag{A.3}$$

where

    L_{Wk} is the sound power level in the kth one-third octave band, in decibels;

k, C_k are given in Table A.4 for calculations with frequency band data covering the range of mid-band frequencies 50 Hz to 10 kHz for one-third octave bands;

k_{min}, k_{max} are values of k corresponding, respectively, to the lowest and highest frequency bands of measurement.

Table A.4 — Values of k and C_k for mid-band frequencies of one-third octave bands

k	Mid-band frequency Hz	C_k dB
1	50	−30,2
2	63	−26,2
3	80	−22,5
4	100	−19,1
5	125	−16,1
6	160	−13,4
7	200	−10,9
8	250	−8,6
9	315	−6,6
10	400	−4,8
11	500	−3,2
12	630	−1,9
13	800	−0,8
14	1 000	0,0
15	1 250	0,6
16	1 600	1,0
17	2 000	1,2
18	2 500	1,3
19	3 150	1,2
20	4 000	1,0
21	5 000	0,5
22	6 300	−0,1
23	8 000	−1,1
24	10 000	−2,5

A.8 Measurement uncertainty

A.8.1 General

This clause makes it possible to present the sound power level with its measurement uncertainty, considering measurements on a single generating set.

NOTE The expanded measurement uncertainty as described in this clause does not include the standard deviation of production, which is covered in Clause 13.

A.8.2 Methodology

ISO 3744:2010, 9.1 is replaced as follows:

The uncertainties of sound power levels, $u(L_W)$, in decibels, determined in accordance with this document are estimated by the total standard deviation, σ_{tot}, in decibels, as per Formula (A.4):

$$u(L_W) \approx \sigma_{tot} \tag{A.4}$$

This total standard deviation is obtained using the modelling approach described in ISO/IEC Guide 98-3:2008. This requires a mathematical model which in the case of lack of knowledge can be replaced by results from measurements, including results from interlaboratory tests.

In this context, this standard deviation is expressed by the standard deviation of reproducibility of the method, σ_{R0}, in decibels, and the standard deviation, σ_{omc}, in decibels, describing the uncertainty due to the instability of the operating and mounting conditions of the source under test in accordance with Formula (A.5):

$$\sigma_{tot} = \sqrt{\sigma_{R0}^2 + \sigma_{omc}^2} \tag{A.5}$$

Derived from σ_{tot}, the expanded measurement uncertainty U, in decibels, shall be calculated from Formula (A.6):

$$U = k_1\, \sigma_{tot} \tag{A.6}$$

For a normal distribution of measured values, there is 95 % confidence that the true value lies within the range $(L_W - U)$ to $(L_W + U)$. This corresponds to a coverage factor of $k_1 = 2$.

A.8.3 Determination of σ_{omc}

ISO 3744:2010, 9.2 is replaced as follows:

The standard deviation σ_{omc}, which describes the uncertainty associated with the instability of the operating and mounting conditions for the generating set under test, shall be taken into account when determining the measurement uncertainty.

σ_{omc}, in decibels, is given by Formula (A.7):

$$\sigma_{omc} = \sqrt{\frac{1}{N-1} \sum_{j=1}^{N} \left(\overline{L_{p,j}} - \overline{L_{pav}} \right)^2} \tag{A.7}$$

where

$\overline{L_{p,j}}$ is mean (energy average) of the time-averaged sound pressure levels over all the microphone positions on the measurement surface, with the background noise correction applied, for the jth repetition of the prescribed operating and mounting conditions;

$\overline{L_{pav}}$ is its arithmetic mean level calculated for all these repetitions.

σ_{omc} can be determined separately from repeated measurements carried out on the same generating set at the same location by the same persons, using the same measuring instruments and the same measurement positions. To determine σ_{omc}, repeated measurements are made with microphone arrays. For each of these repeated measurements, the mounting of the machine and its operating conditions shall be readjusted.

If σ_{omc} is not determined by making measurements, a typical value of 0,5 dB for σ_{omc} can be applied.

A.8.4 Determination of σ_{R0}

ISO 3744:2010, 9.3 is replaced as follows:

A.8.4.1 General

The standard deviation σ_{R0} includes all uncertainty due to conditions and situations allowed by this document (different radiation characteristics of the generating set under test, different instrumentation, different implementations of the measurement procedure), except that due to instability of the sound power of the generating set under test. The latter is considered separately by σ_{omc}.

A.8.4.2 Interlaboratory test

To determine σ_{R0}, an interlaboratory test can be carried out in accordance with ISO 5725-1:1994, ISO 5725-1:1994/Cor 1:1998, ISO 5725-2:2019, ISO 5725-3:1994, ISO 5725-4:2020, ISO 5725-5:1998, ISO 5725-5:1998/Cor 1:2005, ISO 5725-6:1994 and ISO 5725-6:1994/Cor 1:2001, where the sound power level of the source under test is determined under reproducibility conditions, i.e. different laboratories, different persons carrying out measurements at different testing locations with different measuring instruments.

Such a test provides the total standard deviation, σ'_{tot}, relevant for the individual generating set which has been used for the interlaboratory test. Participating laboratories in interlaboratory tests should cover all possible practical situations.

This total standard deviation σ'_{tot}, in decibels, of all results obtained with an interlaboratory test includes the standard deviation σ'_{omc} and allows σ'_{R0} to be determined by using Formula (A.8):

$$\sigma'_{R0} = \sqrt{\sigma'_{tot}{}^2 - \sigma'^2_{omc}} \tag{A.8}$$

A.8.4.3 Reproducibility tests

For generating sets, the effort involved in an interlaboratory test can be reduced by omitting measurements for different laboratories and different locations, for example if machines under test are usually installed under conditions with a small background noise correction K_1, and a small or similar environmental correction K_2, or if the noise emission of a machine is rechecked at the same location. Results of such delimited tests should be denoted by $\sigma_{R0,DL}$, and this designation should also be used for tests on large machines not movable in space. Reproducibility tests consist in making repetition of sound pressure measurements on the same generating set, without changing its mounting and operating conditions between two measurements, and changing the person and measurement device (if one exists). For each of these repeated measurements, the microphones positions shall be readjusted.

$\sigma_{R0,DL}$ in decibels is calculated by Formula (A.9):

$$\sigma_{R0,\,DL} = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}\left(\overline{L_{p,j}} - \overline{L_{pav}}\right)^2} \tag{A.9}$$

where

$\overline{L_{p,j}}$ is mean (energy average) of the time-averaged sound pressure levels over all the microphone positions on the measurement surface, with the background noise correction applied, for the jth repetition of measurement;

$\overline{L_{pav}}$ is its arithmetic mean level calculated for all these repetitions.

Values for $\sigma_{R0,DL}$ can be expected to be lower than those given in A.8.4.4 and A.8.4.5.

A.8.4.4 Typical upper bound values of σ_{R0} for accuracy grade 2

If no tests are carried out to determine σ_{R0}, typical values can be taken from Table A.5. Table A.5 reflects current knowledge and shows typical upper bound values of the standard deviation σ_{R0} for accuracy grade 2 that may cover most of the applications of this document.

Table A.5 — Typical upper bound values of the standard deviation of reproducibility of the method, σ_{R0}, for sound power levels determined in accordance with this document

Frequency bandwidth	One-third-octave mid-band frequency	Standard deviation of reproducibility, σ_{R0}
	Hz	dB
One-third octave	100 to 160	3,0
	200 to 315	2,0
	400 to 5 000	1,5
	6 300 to 10 000	2,5
A-weighted		1,5

A.8.4.5 Typical upper bound values of σ_{R0} for accuracy grade 3

If no tests are carried out to determine σ_{R0} a typical upper bound value of 4 dB can be taken for A-weighted sound power levels, accuracy grade 3, in accordance with this document.

A.8.5 Expanded measurement uncertainty U

ISO 3744:2010, 9.5 is replaced as follows:

The expanded measurement uncertainty, U, shall be determined using Formula (A.6).

The A-weighted sound power level presented with its measurement uncertainty shall be written as follows:

L_{WA} = x dB ± U dB (k = 2, level of confidence 95 %)

EXAMPLE   Accuracy grade 2; generating set determination of σ_{R0} has not been undertaken, thus the value is taken from Table A.5 (σ_{R0} = 1,5 dB); measured σ_{omc} = 0,4 dB; determined L_{WA} = 86,2 dB. Using Formulae (A.5) and (A.6) it follows that:

$$U = 2 \times \sqrt{1,5^2 + 0,4^2} \text{ dB} = 3,1 \text{ dB}$$

The A-weighted sound power level presented with its measurement uncertainty is:

L_{WA} = 86,2 dB ± 3,1 dB (k = 2, level of confidence 95 %).

A.9   Test report

ISO 3744:2010, Clauses 10 and 11 and ISO 3746:2010, Clauses 10 and 11 are replaced as follows:

A.9.1   General

The method of sound power level measurement according to this document, grade 2, is designated as follows:

Sound power level measurement ISO 8528-10 grade 2.

The method of sound power level measurement according to this document, grade 3, is designated as follows:

Sound power level measurement ISO 8528-10 grade 3.

The method of emission sound pressure level at the workstation measurement according to this document, grade 2, is designated as follows:

Emission sound pressure level at the workstation measurement ISO 8528-10 grade 2.

The test report carried out in accordance with this document shall contain a designation of the procedure(s), as specified above, and the data given in A.9.2 to A.9.5, because of their influence on the noise emission.

If the reported levels have been obtained in full conformity with the requirements of this document, the report shall state this fact. If the levels have not been obtained in full conformity, the report shall not state or imply that they have been. If one or a small number of identifiable discrepancies exist between the reported levels and the requirements of this document, then the report may state that the measurements have been conducted "in conformity with the requirements of this document, except for..." and the discrepancies clearly identified. In this case, the term "full conformity" shall not be stated or implied.

A.9.2   Data of the generating set being tested

The test report shall contain the following data:

— manufacturer;

— type;

— serial number;

— dimensions;

— model of enclosure, if applicable;

— rated power output of the generating set (kW);

— generating set rated speed (rounds per minute);

— mounting arrangement;

— manufacturer of the internal combustion engine;

— type of the internal combustion engine;

— internal combustion engine serial number;

— type and arrangement of the inlet system;

— type and arrangement of the exhaust system;

— type of generator cooling;

— type and arrangement of engine cooling;

— type of fuel and, where available, any international or national standard that the fuel used during the test is supplied according to (e.g. EN 590:2013+A1:2017);

— manufacturer of the generator;

— type of generator;

— generator serial number.

A.9.3   Details of measurement conditions

The test report shall contain the following data:

— place and date of the measurements;

— names of those responsible for carrying out the measurements;

— generating set average power output (kW);

— generating set average power output (kVA);

— generating set power factor (without units);

— generating set speed (rounds per minute);

— fan(s) speed (rounds per minute);

— generating set inlet temperature (K);

— ambient temperature (K);

— humidity (%);

— atmospheric pressure (kPa);

— wind speed (m/s) when measuring outside;

— arrangement of generating set in the test environment;

— description of the test environment:

— if indoors, the description shall include the nature of the building, the construction and any lining of the walls, floor and ceiling, and a sketch showing the location of the noise source under test and any other contents of the room;

— if outdoors, the description shall include the nature of the reflecting floor surface and the surrounding terrain, with a sketch showing the location of the noise source under test;

— whether indoors or outdoors, the description shall also include any object(s) near the generating set under test;

— description of the acoustical qualification of the test environment in accordance with 7.2.

A.9.4 Measuring equipment used

The test report shall contain the following data:

— manufacturer(s);

— type(s);

— serial number(s);

— calibration procedure used;

— place and date of calibration.

A.9.5 Acoustical data

A.9.5.1 Sound power level measurement ISO 8528-10 grades 2 and grade 3

The test report shall contain the following data:

— dimensions of the reference box (l_1, l_2, l_3);

— shape of the measurement surface;

— radius of measurement surface, r, or distance, d;

— measuring surface area, S;