INTERNATIONAL STANDARD

ISO 10494

Second edition
2018-04

Turbines and turbine sets — Measurement of emitted airborne noise — Engineering/survey method

Turbines et groupes de turbines — Mesurage du bruit aérien émis — Méthode d'expertise/de contrôle

Reference number
ISO 10494:2018(E)

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Published in Switzerland

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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.

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 192, *Gas Turbines*, in collaboration with Technical Committee IEC/TC 5, *Steam Turbines*.

This second edition cancels and replaces the first edition (ISO 10494:1993), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the measurement of airborne noise from steam turbines and steam turbine sets has been added;

— the content has been aligned with ISO 3744:2010 and ISO 3746:2010;

— the title has been updated.

Introduction

0.1 Background

Control of noise from machines or equipment requires effective exchange of acoustical information among the several parties concerned. These include the manufacturer, specifier, 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 document 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.

Sound power level data are useful for the following:

a) calculating the approximate sound pressure level at a given distance from a machine operating in a specified environment;

b) comparing the noise radiated by machines of the same type and size;

c) comparing the noise radiated by machines of different types and sizes;

d) determining whether a machine complies with a specified upper limit of noise emission;

e) planning in order to determine the amount of transmission loss or noise control required under certain circumstances;

f) engineering work to assist in developing quiet machinery and equipment.

This document gives requirements for the measurement of the noise emission of turbines and turbine sets. It has been prepared in accordance with ISO 3740:2000 on the basis of ISO 3744:2010. Due to the special conditions concerning turbines and turbine sets, it is necessary to define different noise sources and to use measurement surfaces differing from those specified in ISO 3744:2010.

For some environmental conditions, it can be necessary to use the survey methods based on ISO 3746:2010 resulting in a lower grade of accuracy. Frequency information is still recorded and reported.

0.2 Aims

The methods defined in this document apply to the measurement of the noise emission of a turbine or turbine set under steady-state operating conditions. The results are expressed as sound pressure levels, and sound power levels in A-weighted and in octave bands.

The aim of this document 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 4 dB but is less than 7 dB, then a grade 3 (survey) result is obtained (see Table 2).

Measurements made in conformity with this document 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 measured sound power levels which are higher than the real sound power levels.

NOTE 1 If the methods specified in this document 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 are performed in the same environment with the same shape of measurement surface.

NOTE 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 can be caused, for example, by changes in the mounting or operating conditions of the source. The reproducibility and repeatability of the test result can be considerably better (i.e. smaller standard deviations) than the uncertainties given in Table 3 would indicate.

Table 1 — International Standards specifying various methods for determining the sound power levels of machines and equipment

International Standard	Classification of method	Test environment	Volume of source	Character of noise	Sound power levels obtainable
Normative					
ISO 3744	Grade 2 (engineering)	Outdoors or in large rooms	No restrictions; limited only by available test environment	Any	A-weighted and in octave bands or one-third octave bands
ISO 3746	Grade 3 (survey)	No special test environment	No restrictions; limited only by available test environment	Any	A-weighted
Informative					
ISO 3741	Grade 1 (precision)	Reverberation room meeting specified requirements	Less than 2 % of test room volume	Steady, non-steady, fluctuating, isolated bursts of sound energy, broad-band, discrete frequency	A-weighted and in octave bands or one-third octave bands
ISO 3743-1	Grade 2 (engineering)	Hard-walled test room	Less than 2,5 % of test room volume	Steady, non-steady, fluctuating, isolated bursts of sound energy	A-weighted and in octave bands
ISO 3743-2	Grade 2 (engineering)	Special reverberation test room	Preferably less than 1 % of test room volume	Steady, non-steady, fluctuating, broad-band, narrow-band, discrete frequency	A-weighted and in octave bands
ISO 3745	Grade 1 (precision)	Anechoic- or hemi-anechoic room	Preferably less than 0,5 % of test room volume	Any	A-weighted and in one-third octave bands
ISO 3747	Grade 2 and 3 (engineering and survey)	No special test environment, but sufficiently reverberant; source under test non-movable	No restrictions; limited only by available test environment	Steady, non-steady, fluctuating, isolated bursts of sound energy, primarily broad-band	A-weighted and in octave bands
ISO 9614-1	Grade 1, 2 and 3 (precision, engineering and survey)	No special test environment	No restrictions[b]	Any, but stationary in time	A-weighted and in octave bands or one-third octave

[a] Method to determine the sound power of airborne noise caused by machinery surface vibration specifically.

[b] For measurements in anechoic or hemi-anechoic rooms limited by the size of the test room.

Table 1 *(continued)*

International Standard	Classification of method	Test environment	Volume of source	Character of noise	Sound power levels obtainable
ISO 9614-2	Grade 2 and 3 (engineering and survey)	No special test environment	No restrictions[b]	Any, but stationary in time	A-weighted and in octave bands or one-third octave bands
ISO 9614-3	Grade 1 (precision)	No special test environment	No restrictions[b]	Any, but stationary in time	A-weighted and in octave bands or one-third octave bands
ISO/TS 7849-1[a]	Grade 3 (survey)	No special test environment	No restrictions	Any	A-weighted
ISO/TS 7849-2[a]	Grade 2 (engineering)	No special test environment	No restrictions	Any	A-weighted and in octave bands or one-third octave bands

[a] Method to determine the sound power of airborne noise caused by machinery surface vibration specifically.

[b] For measurements in anechoic or hemi-anechoic rooms limited by the size of the test room.

Table 2 — Limits for correction

Grade of accuracy	Background noise correction dB	Environment correction dB
Grade 2	≤1,3	≤4
Grade 3	≤3	≤7
Special case[a]	>3	>7

[a] 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 turbine or the turbine set to be tested.

Table 3 — Uncertainty in determining sound power levels and sound pressure levels, expressed as the standard deviation

Grade of accuracy	Octave band centre frequency dB					A-weighted dB
	31,5 Hz to 63 Hz	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						3

NOTE 1 Grade 3 uncertainty is related to stable conditions.

NOTE 2 The value of the standard deviation for air intake and gas exhaust outlet of gas turbines can be higher.

Turbines and turbine sets — Measurement of emitted airborne noise — Engineering/survey method

1 Scope

This document specifies methods for measuring the noise emission of a turbine or turbine set under steady-state operating conditions. It 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. These methods can be used to conduct performance tests even if the purpose of the test is simply to determine the sound pressure level around the machine.

This document is applicable to turbines and turbine sets:

— for power plant and industrial applications (e.g. stationary);

— for installation on board ships, or offshore installations, road and railway vehicles.

It does not apply to gas turbines in aircraft applications.

This document is applicable to only the part of the turbine set (turbine, driven equipment and attached components) located above the floor and inside a continuous enveloping measurement surface bounded by this floor.

It is applicable to steady-state operation and excludes transients such as start-up and shut-down, when the noise emission can be higher for short times. Under these conditions, this document does not apply.

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.

IEC 60942, *Electroacoustics — Sound calibrators*

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

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

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

3 Terms and definitions

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

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

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

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

3.1
sound pressure
p
difference between instantaneous pressure and static pressure

Note 1 to entry: Adapted from ISO 80000-8:2007, 8-9.2.

Note 2 to entry: Sound pressure is expressed in pascals.

[SOURCE: ISO 3744:2010, 3.1]

3.2
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the *sound pressure* (3.1), *p*, to the square of a reference value, p_0, expressed in decibels

$$L_p = 10 \lg \frac{p^2}{p_0^2} \text{ dB}$$

where the reference value, p_0, is 20 µPa

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

Note 2 to entry: This definition is technically in accordance with ISO 80000-8:2007, 8-22.

[SOURCE: ISO 3744:2010, 3.2]

3.3
time averaged sound pressure level
$L_{p,T}$
ten times the logarithm to the base 10 of the ratio of the time average of the square of the *sound pressure* (3.1), *p*, during a stated time interval of duration, *T* (starting at t_1 and ending at t_2), to the square of a reference value, p_0, expressed in decibels

$$L_{p,T} = 10 \lg \left[\frac{\frac{1}{T}\int_{t_1}^{t_2} p^2(t)\,\mathrm{d}t}{p_0^2} \right] \text{dB}$$

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

Note 3 to entry: Adapted from ISO/TR 25417:2007, 2.3.

[SOURCE: ISO 3744:2010, 3.3]

3.4
acoustic free field
sound field in a homogeneous, isotropic medium free of boundaries

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

[SOURCE: ISO 3744:2010, 3.6]

3.5
acoustic free field over a reflecting plane
acoustic free field (3.4) in the half-space above an infinite reflecting plane in the absence of any other obstacles

[SOURCE: ISO 3744:2010, 3.7]

3.6
reflecting plane
sound-reflecting planar surface on which the noise source under test is located

[SOURCE: ISO 3744:2010, 3.6]

3.7
frequency range of interest
for general purposes, the frequency range of octave bands with nominal mid-band frequencies from 31,5 Hz to 8 000 Hz (including one-third octave bands with mid-band frequencies from 25 Hz to 10 000 Hz)

Note 1 to entry: Any band may be excluded in which the level is more than 50 dB below the highest band pressure level.

Note 2 to entry: For special purposes, the frequency range can be extended or reduced, provided that the test environment and instrument specifications are satisfactory for use over the modified frequency range. For sources which radiate predominantly high (or low) frequency sound, the frequency range of interest may be limited in order to optimize the test facility and procedures. Changes to the frequency range of interest are included in the test report.

Note 3 to entry: Adapted from ISO 3744:2010, 3.9.

3.8
reference box
hypothetical right parallelepiped terminating on the *reflecting plane(s)* (3.6) on which the noise source under test is located, that just encloses the source including all the significant sound radiating components and any test table on which the source is mounted

Note 1 to entry: If required, the smallest possible test table can be used for compatibility with emission sound pressure measurements at bystander positions in accordance with, for example, ISO 11201:2010.

[SOURCE: ISO 3744:2010, 3.10]

3.9
measurement distance
d
distance from the *reference box* (3.8) to a parallelepiped *measurement surface* (3.10)

Note 1 to entry: Measurement distances are expressed in metres.

[SOURCE: ISO 3744:2010, 3.12]

3.10
measurement surface
hypothetical surface of area, *S*, on which the microphone positions are located at which the *sound pressure levels* (3.2) are measured, enveloping the noise source under test and terminating on the *reflecting plane(s)* (3.6) on which the source is located

[SOURCE: ISO 3744:2010, 3.14]

3.11
background noise
noise from all sources other than the noise source under test

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

[SOURCE: ISO 3744:2010, 3.15]

3.12
background noise correction
K_1
correction applied to the mean (energy average) of the *time-averaged sound pressure levels* (3.3) over all the microphone positions on the *measurement surface* (3.10), to account for the influence of *background noise* (3.11)

Note 1 to entry: Background noise correction is expressed in decibels.

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

[SOURCE: ISO 3744:2010, 3.16]

3.13
environmental correction
K_2
correction applied to the mean (energy average) of the *time-averaged sound pressure levels* (3.3) over all the microphone positions on the *measurement surface* (3.10), to account for the influence of reflected or absorbed sound

Note 1 to entry: Environmental correction is expressed in decibels.

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

Note 3 to entry: In general, the environmental correction depends on the area of the measurement surface and usually K_2 increases with S.

[SOURCE: ISO 3744:2010, 3.17]

3.14
surface time-averaged sound pressure level
$\overline{L_p}$
mean (energy average) of the *time-averaged sound pressure levels* (3.3) over all the microphone positions, or traverses, on the *measurement surface* (3.10), with the *background noise correction* (3.12), K_1, and the *environmental correction* (3.13), K_2, applied

Note 1 to entry: Surface time-averaged sound pressure levels is expressed in decibels.

[SOURCE: ISO 3744:2010, 3.18]

3.15
sound power
P
through a surface, product of the *sound pressure*, *p*, (3.1) and the component of the particle velocity, u_n, at a point on the surface in the direction normal to the surface, integrated over that surface

Note 1 to entry: Sound power is expressed in watts.

Note 2 to entry: The quantity relates to the rate per time at which airborne sound energy is radiated by a source.

[SOURCE: ISO 3744:2010, 3.20]

3.16
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the *sound power* (3.15) of a source, *P*, to a reference value, P_0, expressed in decibels

$$L_W = 10 \lg \frac{P}{P_0} \text{dB}$$

where the reference value, P_0, is 1 pW

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

Note 2 to entry: This definition is technically in accordance with ISO 80000-8:2007, 8-23.

[SOURCE: ISO 3744:2010, 3.21]

3.17
anechoic room
test room in which a free sound field is obtained

[SOURCE: ISO 3745:2012, 3.7]

3.18
hemi-anechoic room
test room in which a free sound field over a *reflecting plane* (3.6) is obtained

[SOURCE: ISO 3745:2012, 3.10]

4 Acoustic environment

4.1 Criteria of adequacy of the test environment

Ideally, the test environment should be free from reflecting objects other than a reflecting plane so that the source radiates into a free-field over a reflecting plane. Annex A describes procedures for determining the magnitude of the environmental correction (if any) to account for departures of the test environment from the ideal condition. Test environments which are suitable for engineering measurements permit the sound power level to be determined with an uncertainty that does not exceed the values given in Table 3.

NOTE If it is necessary to make measurements in spaces which do not meet the criteria of Annex A, standard deviations of the test results can be greater than those given in Table 3. In those cases, the sound power level determined according to this document can be useful for obtaining a valid upper limit for the sound power level of the turbine or the turbine set.

4.2 Criteria for background noise

At the microphone positions used, the sound pressure levels of the background noise shall be at least 6 dB and preferably more than 10 dB (grade 2 result) or at least 3 dB (grade 3 result) below the corresponding uncorrected time-averaged sound pressure level of the noise source under test when measured in the presence of this background noise.

For measurements in frequency bands the above requirements shall be met in each frequency band within the frequency range of interest.

When the sound pressure level of the primary source is less than 3 dB above the background sound pressure level, a valid measurement of the machine under test cannot be made. If the delta of the sound pressure level is smaller than 3 dB, the accuracy of the result is reduced and the value of K_1 to be applied in this case is 3 dB. In this case, it shall be clearly stated in the text of the report, as well as in graphs and tables of results, that the data from the test represent an upper boundary to the sound power level of the noise source under test.

4.3 Wind

Care shall be taken to minimize the effects of wind which can increase the apparent background noise. A windscreen should be used for wind speeds above 1 m/s and the wind speed should be less than 5 m/s.

The appropriate instructions provided by the microphone manufacturer shall be followed.

4.4 Special measurement methods

In cases where the corrections for background noise and for the influence of the environment exceed the limits mentioned in 4.1 and 4.2, additional complex measurement methods, which are not part of this document (e.g. sound intensity analysing devices or other methods in Table 1) can be used to get an estimate for the noise emission.

If one of these methods is used for performance tests, the details should be agreed by the supplier and the customer.

5 Instrumentation

The instrumentation used shall meet the requirements for Class 1 of IEC 61672-1 for sound level meters. The octave band filters shall meet the requirements of IEC 61260-1.

6 Installation and operation of turbine set

6.1 General

The object under test is the turbine or the turbine set. Components included in the test are to be defined clearly and agreed to by the parties involved. Usually, they comprise the basic equipment necessary for the proper operation of the turbine or the turbine set at its final location.

Turbine sets are of all sizes without limitation of output when fitted with their normal auxiliaries. The applicable part of the turbine set (turbine, driven equipment and attached components) is that which is located above the floor and inside a continuous enveloping measurement surface bounded by this floor. An extensive and continuous turbine operating floor of a reflecting nature above the turbine foundation floor level shall be considered as the reflecting plane.

In the case of large turbine sets, the turbine operating floor is often located below and near the horizontal centreline of the turbine. If this floor is continuous and free from openings which would otherwise allow noise radiated below the turbine operating floor to influence the noise measured at microphone locations, a valid measure of the turbine set noise emission can be obtained by use of this document.

In the case where the turbine operating floor is located below and near the horizontal centreline of the turbine set, but consists of:

a) an open grating construction;

b) a solid floor with openings near to the boundary of the turbine set; or

c) walkways typically 1 m to 2 m wide of either solid or grated construction,

the turbine operating floor cannot be considered as a reflecting plane. In this case, the reflecting plane is the turbine set foundation floor.

In the case of the continuous enveloping measurement surface being bounded by either the turbine operating floor or the turbine foundation floor, a large contribution from the noise of ancillary and auxiliary plant located below the turbine operating floor can be expected at the microphone measuring positions. In this case, the use of this document for the determination of sound power levels is not valid.

When openings in the floor are suitably blocked during the test with appropriate panels (upper side of panels should have same reflective characteristics as the turbine operating floor), valid measurements are permitted. In the case of turbine sets mounted on, or partially submerged in, the foundation floor, which can also be defined as the turbine operating floor, a valid measure of the turbine set noise emission can be obtained by use of this document.

The noise sources for gas turbines and gas turbine sets are different than the noise sources for steam turbines and steam turbine sets. Measurements that are specific to gas turbines and gas turbine sets shall be conducted in accordance with Annex B. Measurements that are specific to steam turbines and steam turbine sets shall be conducted in accordance with Annex C.

6.2 Mounting of turbine set

Normally, measurements are performed on site, at the completely mounted turbine set fitted with all insulations and lagging.

6.3 Operation of turbine set during test

The test shall be performed under steady-state operating conditions of the turbine or the turbine set with the rated values of power, speed, temperatures, pressures, etc., as agreed to by the parties involved. If not otherwise specified, base load operation shall be applied. Relevant operating conditions and atmospheric conditions (temperature, pressure, humidity, snow, frost) shall be recorded in the test report.

The operating conditions should not be changed during the measurements.

6.4 Auxiliary equipment and coupled machines

All auxiliary equipment which is necessary for the operation of the turbine set under test, but not part of it, shall not significantly influence the noise measurement.

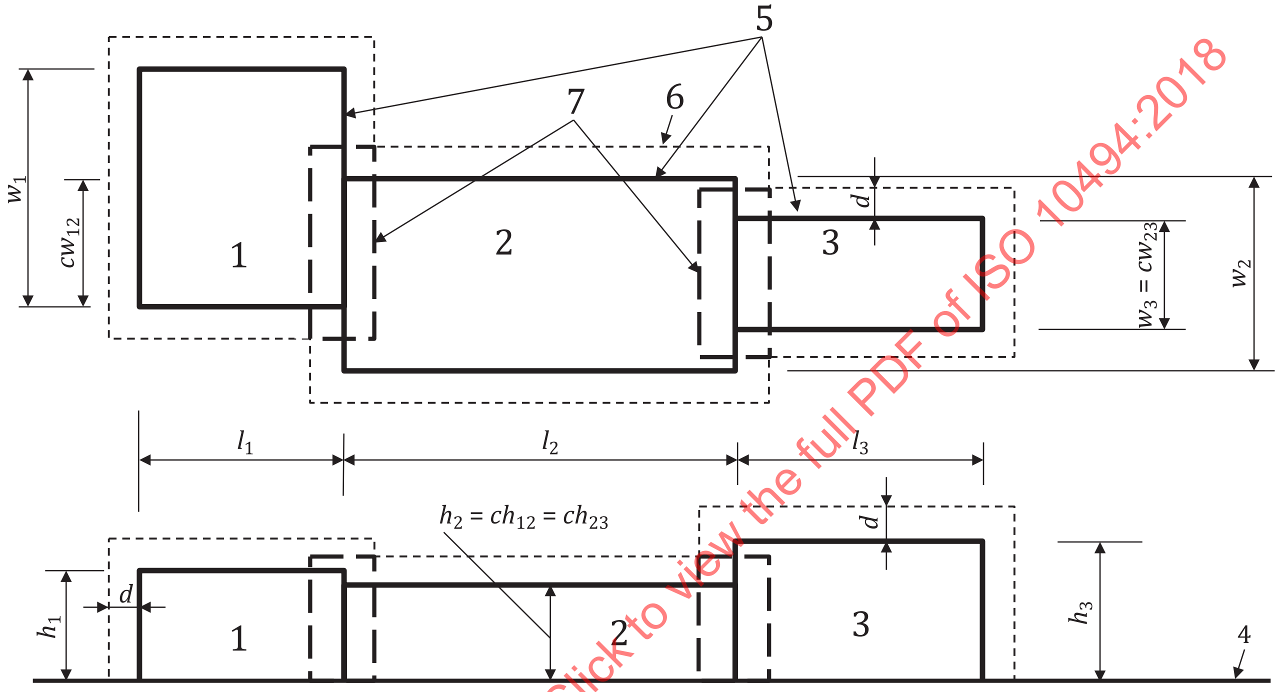
7 Sound pressure levels on the measurement surface

7.1 Reference surface and measurement surface

The relevant reference surface is composed of several separate reference boxes placed in juxtaposition so that they enclose only the different parts of the turbine set, including its lagging and any noise control screen and enclosures. The surface terminates on the reflecting plane. When defining the dimensions of these reference boxes, elements protruding from the source which are not significant radiators of sound energy may be disregarded. These protruding elements should be identified for different types of equipment.

The microphone positions lie on the measurement surface, a hypothetical surface of area, *S*, which envelops the source as well as the reference box(es) and terminates on the reflecting plane.

For turbine sets, regardless of their size, the measurement surface shape is composed of rectangular parallelepipeds (see Figure 1), whose sides are parallel to the sides of the reference boxes spaced out at a distance, *d*, (measurement distance) from the reference boxes. For turbine sets with multiple unconnected reference boxes spaced less than 3,5 m apart, the measurement surface shape shall encompass the reference boxes without re-entrants. In this sense, a re-entrant is defined as the extension of the measurement surface into the area between reference boxes. The typical measurement distance, *d*, is 1 m but larger distances can be used if necessary.



Key

1, 2, 3	components of turbine set	4	reflecting surface
h_1, h_2, h_3	heights of components reference surfaces	5	reference surfaces / reference boxes
w_1, w_2, w_3	widths of components reference surfaces	6	measurement surface
l_1, l_2, l_3	lengths of components reference surfaces	7	penetrations of component measurement surfaces
cw_{12}, cw_{23}	common widths between components		
ch_{12}, ch_{23}	common heights between components		
d	measurement distance		

Figure 1 — Calculation of measurement surface

According to Figure 1, the area S of the measurement surface can be calculated for this example from Formula (1):

$$\begin{aligned} S = & 2(h_1+d)(w_1+l_1+4d)+(l_1+2d)(w_1+2d) \\ & +2(h_2+d)(w_2+l_2+4d)+(l_2+2d)(w_2+2d) \\ & +2(h_3+d)(w_3+l_3+4d)+(l_3+2d)(w_3+2d) \\ & -\left[2(ch_{12}+d)(cw_{12}+4d)+2d(cw_{12}+2d)\right] \\ & -\left[2(ch_{23}+d)(cw_{23}+4d)+2d(cw_{23}+2d)\right] \end{aligned} \quad (1)$$

Or more generally (for arrangements in one line), Formula (2) may be used:

$$\begin{aligned} S = & \sum_{i=1}^{n} 2\left(h_i+d\right)\left(w_i+l_i+4d\right)+\left(w_i+2d\right)\left(l_i+2d\right) \\ & -\sum_{i=1}^{n-1} 2\left(ch_{ii+1}+d\right)\left(cw_{ii+1}+4d\right)+2d\left(cw_{ii+1}+2d\right) \end{aligned} \quad (2)$$

where

S is the total measurement surface;

n is the number of components.

In general (for all arrangements above one reflecting surface), the measurement surface can be calculated from Formula (3):

$$\begin{aligned} & S = \sum_{i=1}^{n} S_i - \sum_{i=1}^{m} P_j \\ & S_i = 2\left(h_i+d\right)\left(w_i+l_i+4d\right)+\left(l_i+2d\right)\left(w_i+2d\right) \\ & P_j = 2(ch_{xy}+d)(cw_{xy}+cl_{xy}+4d)+(cl_{xy}+2d)(cw_{xy}+2d) \end{aligned} \quad (3)$$

where

S is the total measurement surface;

S_i is the partial measurement surface of component I;

n is the number of components;

P_j is the penetration between partial measurement surfaces of components x and y;

m is the number of penetrations.

7.2 Location and number of microphone positions

7.2.1 General

The microphone positions shall be arranged on the measurement surface at equal distances from each other. The distances are such that there is at least one measurement position at each section of the turbine set. In the vicinity of local discharges, the microphone positions shall be such that the microphones and cables are not exposed to the flow. The number of microphone positions depends on the area of the reference box and the difference in the sound pressure levels at the microphone positions.

7.2.2 Additional microphone positions on measurement surface

The number of microphone positions shall be increased when:

a) the range of sound pressure level values measured at the microphone positions (i.e. the difference, in decibels, measured in octave bands or A-weighted, between the highest and lowest sound pressure levels) exceeds the number of measurement points; or

b) noise is emitted by only a small part of a large machine, e.g. from a small opening. Then the measurement surface shall be divided into different parts with different distances between the microphone positions at each part. For each part of the measurement surface, the partial sound power level shall be determined. The total sound power level of the machine is then calculated by summarizing the partial sound power levels.

For the individual partial measurement surfaces, the partial sound power level, L, in decibels, shall be calculated by using Formula (4).

$$L_{Wj} = \overline{L_{pj}} + 10\lg\left(\frac{S_j}{S_0}\right)\mathrm{dB} \tag{4}$$

where

$\overline{L_{pj}}$ is the surface sound pressure level of the j^{th} partial measurement surface;

S_j is the area of the j^{th} partial measurement surface;

S_0 1 m^2.

The n individual partial sound power levels can be combined using Formula (5) to give the total sound power level, in decibels, as follows:

$$L_{Wg} = 10\lg\left(\sum_{j=1}^{n} 10^{0,1L_{Wj}}\right)\mathrm{dB} \tag{5}$$

where

n is the total number of partial sound powers levels;

L_{Wj} is the partial sound power level, in decibels.

It is possible that microphone positions need to be deleted in cases where they cannot be reached, or where measurement at these positions is dangerous, or where results were falsified. e.g. by temperature, steam, humidity, strong electric or magnetic field.

Care should be taken when measurements are made less than 3,5 m from a façade, and in no circumstances should measurements be made at less than at 1 m from a façade. Where the conditions at any measurement location are different from the general environmental correction of the test site then an individual correction should be derived for each measurement location affected. Record the measurement location, height and the distance from any reflecting structure other than the ground.

If the purpose of the test is to determine the sound pressure level around the machine, it is sufficient to measure at a distance of 1 m and a height of 1,5 m above floor or equivalent.

If a turbine is mounted on a foundation high above ground, some of its parts can radiate noise into the room below the operating floor. At these locations, the noise often comes mainly from equipment which is not part of the turbine set. Because of this high background noise, no microphone positions for this area can be recommended. This area can be neglected for the determination of the sound power level of the turbine set as its radiating surface in this area is small compared with the total surface of the turbine.

7.2.3 Surface noise

Surface noise is the noise that emanates from the measurement surface of the turbine or the turbine set.

The surface of the turbine or of the turbine set is, according to the definition given above, the outer contour of the turbine or the turbine set ready for operation.

In some cases, (e.g. compact machines) the noise emitted by the openings and by the surface cannot be determined separately as the openings are situated within the measurement surface of the machine. In such cases, the total noise emission of the turbine set shall be determined at the microphone positions on a measurement surface enveloping the turbine or the turbine set including the openings for air intake and exhaust.

For some types of turbines an enclosure is included. Then the “surface noise” is the noise emitted by the enclosure including that from openings in the enclosure.

7.3 Conditions of measurement

7.3.1 General

Environmental conditions can have an adverse effect on the microphone used for the measurements. Such conditions (e.g. strong electric or magnetic fields, wind, impingement of air or steam discharged from the machine being tested, high or low temperatures) shall be avoided by proper selection of placement of the microphone.

NOTE For additional information, see IEC 60268-4 and IEC 61672-1.

At the measurement positions, the microphone shall be directed with its specified main axis of sound incidence toward the machine.

7.3.2 Calibration

During each series of measurements, a sound calibrator meeting the requirements of IEC 60942 Class 1 shall be applied to the microphone to verify the calibration of the complete instrumentation system at one or more frequencies within the frequency range of interest. The calibrator shall be calibrated annually to determine its acoustical output. In addition, an electrical calibration of the instrumentation system over the entire frequency range of interest shall have been carried out within the preceding 2 years.

7.3.3 Measurement of the A-weighted sound pressure level

Following selection of the appropriate microphone locations on the rectangular array, the A-weighted time averaged sound pressure levels are measured at each of the specified positions. After corrections are applied for background noise (see 8.1), this data are used for the calculation of the surface sound pressure level and sound power level according to 8.3 and 8.4.

7.3.4 Measurement of sound pressure spectrum

For the determination of spectra, the sound pressure level is measured in a way similar to that given in 7.3.3 and the measurement time shall be at least 10 s. For the frequency bands centreed on or below 160 Hz, the measurement time shall be at least 30 s.

If background sound pressure levels need to be taken into account, they shall be measured at a representative number of microphone positions, before the machine under test is put into operation or after it has been taken out of operation.

NOTE Background noise emitted by components which are not part of the turbine set but are necessary for its operation and which can operate only together with the turbine or the turbine set (e.g. pumps, valves, pipes), usually cannot be determined exactly. It is seldom possible to screen the test object sufficiently in order to determine its noise emission or to screen the background noise source for measurement of the structure-borne noise. In those cases, it can be more appropriate to use an alternative measurement method such as sound intensity per ISO 9614 or other methods in Table 1. If the background sound levels are excessive, it is not possible to measure the sound levels from the turbine per this document.

8 Calculation of surface sound pressure level and sound power level

8.1 Corrections for background noise

The background noise correction, K_1, shall be calculated using Formula (6):

$$K_1 = -10\lg(1 - 10^{-0,1\Delta L_p})\text{dB} \tag{6}$$

where

$$\Delta L_p = \overline{L'_{p(\mathrm{ST})}} - \overline{L_{p(\mathrm{B})}}$$

in which

$\overline{L'_{p(\mathrm{ST})}}$ is the mean frequency-band or A-weighted time-averaged sound pressure level from the array of microphone positions over the measurement surface, with the noise source under test in operation, in decibels;

$\overline{L_{p(\mathrm{B})}}$ is the mean frequency-band or A-weighted time-averaged sound pressure level of the background noise from the array of microphone positions over the measurement surface, in decibels.

During measurements at turbines and turbine sets, unavoidable background sound can be present. If a background noise correction, K_1, of up to 1,3 dB is required, then a grade 2 result is achieved. For corrections greater than 1,3 dB up to 3 dB, a grade 3 result is achieved. If the background noise correction is greater than 3 dB, then the accuracy of the result falls outside the requirements of this document.

Sometimes high background levels are present only at some of the microphone positions. When it is known from other measurements or the design of the machine that its noise emission is symmetrical, useful results can be obtained by deleting the microphone positions at the site of high background sound pressure levels.

On-site measurements can result in impulse or occasional noise which is not due to the turbine installation itself. Measurements made under such conditions are invalid.

8.2 Calculation of sound pressure level averaged over the measurement surface

For the A-weighted sound pressure level and the level in each frequency band of interest, calculate an average sound pressure level over the measurement surface, from the measured sound pressure levels $\overline{L'_{p(\mathrm{ST})}}$ by using Formula (7).

$$\overline{L'_{p(\mathrm{ST})}} = 10\lg\left[\frac{1}{N_{\mathrm{M}}}\sum_{i=1}^{N_{\mathrm{M}}} 10^{0,1 L'_{pi(\mathrm{ST})}}\right] \mathrm{dB} \tag{7}$$

where

$L'_{p(\mathrm{ST})}$ is the A-weighted or band pressure level resulting from the ith measurement, in decibels; reference = 20 µPa;

N_{M} is the total number of measurements.

NOTE Any derived average sound pressure levels is averaged on an energy basis as defined above unless otherwise agreed to by the parties to the test.

8.3 Calculation of surface time-averaged sound pressure levels

The surface time-averaged sound pressure level, $\overline{L_p}$, shall be calculated by correcting the mean time-averaged sound pressure level, $\overline{L'_{p(\mathrm{ST})}}$, for background noise ($K_1$, see 8.1) and for the influence of the test environment (K_2, see Annex A) using Formula (8):

$$\overline{L_p} = \overline{L'_{p(\mathrm{ST})}} - K_1 - K_2 \tag{8}$$

The environmental correction, K_2, accounts for the influence of a non-ideal environment (e.g. the presence of sound absorption or reflected sound).

a) For accuracy grade 2:

For grade 2 accuracy, K_2 shall be less than or equal to 4 dB. The procedures given in Annex A shall be used to calculate the value of the environmental correction, K_2.

b) For accuracy grade 3:

For grade 3 accuracy, K_2 shall be less than or equal to 7 dB. The procedures given in Annex A shall be used to calculate the value of the environmental correction, K_2.

8.4 Calculation of sound power level

Calculate the sound power level characterizing the noise emitted by the source from Formula (9).

$$L_W = \overline{L_p} + 10\lg\frac{S}{S_0} \mathrm{dB} \tag{9}$$

where

S is the area, in square meters, of the measurement surface;

S_0 1 m^2.

8.5 Calculation of directivity index and directivity factor

If required, values of the directivity index and directivity factor may be calculated using the procedures given in Annex D. For determination of gas turbine exhaust outlet directivity, this document does not apply, however, information can be found in Bibliographic reference [18].

9 Information to be recorded

9.1 General

The following information, when applicable, shall be compiled and recorded for all measurements made according to the requirements of this document.

9.2 Noise source under test

a) Description of the turbine set under test (including its dimensions).

b) Operating conditions for instance power, speed, temperatures, pressures, mass flows, etc.

c) Mounting conditions and location of the turbine operating floor in relation to the turbine set and the foundation floor.

d) If the machine has multiple noise sources which are only temporarily operating source(s), description of the source(s) in operation during measurements.

e) Number and location of auxiliary and ancillary plant noise sources likely to influence the noise at microphone locations.

f) Number, type, location and extent of noise control screens and/or enclosures.

9.3 Acoustic environment

a) Description of test environment:

If indoors, describe physical treatment of walls, ceiling and floor; include a sketch showing location of source(s), all room contents and other important details, for example, openings in the floor.

If outdoors, include a sketch showing location of the source with respect to surrounding terrain, including physical description of the test environment. The nature of the reflecting (ground) plane shall be recorded.

b) Acoustical qualification of test environment according to Annex A.

c) Air temperature, barometric pressure, relative humidity, snow, and frost.

d) Wind speed and direction (for outdoor measurement only).

e) Sound power output of the reference noise source, if used.

9.4 Instrumentation

a) Equipment used for the measurements, including name, type, serial number and manufacturer.

b) Date and place of calibration of the instrumentation system.

c) Method used for checking the calibration of the microphones and other measurement equipment.

9.5 Acoustical data

a) The locations of the microphone positions (a sketch can be included, if necessary) and the measurement distance.

b) The area(s), S, of the measurement surface(s).

d) The measured sound pressure level, L_{pi}, at each measurement point, i.

e) The background sound pressure level at each measurement point.

f) Information for calculating the environmental correction factor according to one of the procedures of Annex A.

g) Remarks on subjective impression of noise (audible discrete tones, impulsive character, spectral content, temporal characteristics, etc.).

9.6 Date and location

The location, time, and date when the measurements were performed, the name of the person responsible for the measurements, and names of any witnesses.

10 Test report

The test report shall contain the information indicated in Clause 9 and the statement that the results have been obtained in full conformity with the procedures of this document and the grade of accuracy.

Only data (see Clause 9) need be reported which is required by the ultimate user of the information.

The following minimum data shall be reported:

a) description of the turbine under test, including the provision of noise control screens and/or enclosures;

b) operating conditions;

c) the sound pressure levels at each microphone position all around the turbine set under test, corrected for the background noise;

d) environmental correction factor(s);

e) the surface sound pressure level(s);

f) if required, the sound power level(s);

g) the date and time when the measurements were performed.

In some cases, it can be necessary to add further information and interpretation of the results according to the task and the purpose of the measurements.

Annex A
(normative)

Qualification procedures for the acoustic environment

A.1 General

An environment providing a free field over a reflecting plane shall be used for measurements made according to this document. This environment may be a hemi-anechoic room, an outdoor space, or an ordinary room if the requirements given below are satisfied.

With the exception of the reflecting plane, reflecting objects shall be removed to the maximum extent possible from the vicinity of the machine under test. A test room shall ideally provide a hypothetical measurement surface which lies:

a) inside a sound field essentially undisturbed by reflections from objects nearby and the room boundaries; and,

b) outside the near field of the sound source under test.

For outdoor test sites which consist of a hard, flat ground surface such as asphalt or concrete, and with no sound-reflecting obstacles within a distance from the source equal to three times the greatest distance from the source centre to the lower measurement points, it can be assumed that the environmental correction, K_2, is less than or equal to 0,5 dB and is, therefore, negligible.

An obstacle in the proximity of the source may be considered to be sound reflecting if its width (e.g. diameter of a pole or supporting member) exceeds one-tenth of its distance from the reference box.

The evaluation of environmental influences is performed by selecting one of three alternative procedures used to determine the magnitude of the environmental correction, K_2. These procedures are used to determine if any undesired environmental influences are present and to qualify a given measurement surface for an actual source under test according to this document.

The first possibility for test (Reverberation method; see A.3.2) may be used if the source under test cannot be moved and if its dimensions are large. This test requires measurements of reverberation time.

The second possibility for test (Direct method; see A.3.3) is carried out with a reference sound source.

The third possibility for test (Approximate method; see A.3.4) shall be used only in rooms of length and width each less than three times the ceiling height.

The free-field qualification on a given measurement surface is satisfied by a given test room if the ratio of the sound absorption, A, of the room to the area, S, of the measurement surface is sufficiently large. In general, ratios $A / S > 10$ require no environmental corrections. For ratios A / S between 10 and 3, an environmental correction, K_2, can be determined according to the procedures given in this annex. In this case, K_2 is usually smaller than 4 dB. For ratios $A / S < 3$, the room correction factor, K_2, can exceed 4 dB and cause greater uncertainty for the sound power level determinations than those given in Table 3. If the measurement surface cannot be reduced and/or the environment cannot be improved, the measurements performed are of grade 3 accuracy. The reflecting plane should satisfy the requirements given in A.2.1. For outdoor measurements, additional precautions given in A.2.2 should be considered.

A.2 Environment conditions

A.2.1 Properties of reflecting plane

For outdoor measurements, the reflecting plane should be undisturbed earth, gravel, or an artificial surface of concrete or sealed asphalt. For indoor measurements, the reflecting plane is usually the floor of the room or a solid turbine operating deck.

When the reflecting surface is not a ground plane or the floor of the test room, care should be taken to ensure that the reflecting surface does not radiate any appreciable sound energy due to vibrations.

A.2.1.1 Shape and size

The reflecting plane should extend at least one-half a wavelength beyond the projection of the measurement surface on the plane for the lowest frequency of the frequency range of interest.

A.2.1.2 Absorption coefficient

The sound absorption coefficient of the reflecting plane should preferably be less than 0,1 over the frequency range of interest. This requirement is usually fulfilled when outdoor measurements are made over concrete, sealed asphalt, sand or stone surfaces. For indoor measurements, wooden and tile floors are permitted.

A.2.2 Precautions for outdoor measurements

Care should be taken to minimize the effects of adverse meteorological conditions (e.g. temperature, humidity, wind, precipitation, frost) on the sound propagation over the frequency range of interest or on the background noise during the course of the measurements. Extreme meteorological conditions should be avoided during the measurements.

If a device is used to shield the microphone from the effects of wind, proper corrections of the measured sound pressure levels shall be made. In all cases, the precautions indicated by the manufacturer in the instructions for the use of the instrument shall be observed.

A.3 Determination of the environmental correction based on room absorption

A.3.1 General

The environmental correction, K_2, shall be calculated from Formula (A.1):

$$K_2 = 10 \lg \left[1 + 4 \frac{S}{A} \right] \text{dB} \tag{A.1}$$

where

A is the equivalent sound absorption area, in square meters, of the room;

S is the area, in square meters, of the measurement surface.

A.3.2 Reverberation method

This test method shall be used only in rooms of length and width each less than three times the ceiling height.

The equivalent sound absorption area, A, in square meters, of the test room shall be calculated by the Sabine reverberation time equation Formula (A.2). At room temperatures between 15 °C and 30 °C:

$$A = 0{,}16 \frac{V}{T_n} \tag{A.2}$$

where

V is the volume, in cubic meters, of the test room;

T_n is the measured reverberation time (see ISO 3382-2), in seconds, for A-weighting or in frequency bands.

For the purpose of determining K_{2A} directly from A-weighted measured values, the use of the reverberation time measured in the frequency band with a mid-band frequency of 1 kHz is recommended.

This method is not suitable for use in a laboratory-quality hemi-anechoic room or for outdoor measurements.

A.3.3 Determination of the equivalent absorption area A with a reference sound source (direct method)

A reference sound source meeting the requirements of ISO 6926 shall be mounted in the test environment near the noise source under test. The radius of the hemispherical measurement surface should be preferably 2 m, but in no case smaller than 1 m and not smaller than two times the largest diameter of the reference sound source. The distance from the source to other reflecting surfaces shall be greater than the diameter of the measurement hemisphere.

NOTE Normally the reference sound source is calibrated for use in positions away from walls with the reference source either directly on the floor or on a stand at a specified elevation above the floor. If the reference sound source is used in other positions, unless it has been calibrated specifically in these positions, systematic errors can occur at low frequencies.

The microphone positions shall be on the fixed point array with the coordinates given in ISO 3744:2010, Table B.2. If environmental conditions make it necessary to use the survey methods with a lower grade of accuracy, then the microphone positions shall be on the fixed point array with the coordinates given in ISO 3746:2010, Table B.2.

The mean background noise-corrected time-averaged sound pressure level from the reference sound source on the hemispherical measurement surface, $\overline{L_{p(\text{in situ})}}$, shall then be determined in accordance with 8.2 and 8.3.

The equivalent absorption area, A, is then calculated using Formula (A.3):

$$A = \frac{4S}{(S/S_0) \times 10^{0{,}1\left[\overline{L_{p(\text{in situ})}} - L_{W(\text{RSS})}\right]} - 1} \tag{A.3}$$

where

S is the area, in square meters, of the hemispherical measurement surface;

S_0 1 m^2;

$\overline{L_{p(\text{in situ})}}$ is the mean time-averaged sound pressure level of the reference sound source mounted near to the noise source under test, corrected for background noise but not for the influence of the environment (see 8.3), in decibels;

$L_{W(\text{RSS})}$ is the sound power level of the calibrated reference sound source under the meteorological conditions of the test, in decibels.

If the static pressure or other atmospheric conditions differ significantly from the reference conditions for the determination of the calibrated sound power level of the reference sound source, $L_{W(\mathrm{RSS})}$, calculation of the sound power level of the reference sound source under *in situ* conditions, $L_{W(\mathrm{RSS},in\ situ)}$, is recommended, in accordance with the manufacturer's instructions.

If $L_{W(\mathrm{RSS})}$ is not known, or if it is not possible to calculate $L_{W(\mathrm{RSS},in\ situ)}$ from $L_{W(\mathrm{RSS})}$, repetition of the measurements described above with the reference sound source in an acoustic free field over a reflecting plane outdoors to obtain a reference mean time-averaged sound pressure level, $L_{p(\mathrm{ref})}$, is recommended. From these measurements the equivalent absorption area in the environment where the noise source under test is mounted is calculated using Formula (A.4):

$$A = \frac{4S}{10^{0,1\left[L_{p(in\ situ)} - L_{p(\mathrm{ref})}\right]} - 1} \tag{A.4}$$

A.3.4 Approximate method for measurements made with A-weighting

This test method shall be used only in rooms of length and width each less than three times the ceiling height. In order to ascertain the acoustic characteristics of the test environment, K_{2A} shall be determined from Formula (A.1) using a value of A given by Formula (A.5):

$$A = \alpha S_V \tag{A.5}$$

where

α is the mean sound absorption coefficient, given for A-weighted quantities in Table A.1;

S_V is the total area, in square meters, of the boundary surfaces of the test room (walls, ceiling and floor).

Table A.1 — Approximate values of the mean sound absorption coefficient, α

Mean sound absorption coefficient, α	Description of room
0,05	Nearly empty room with smooth hard walls made of concrete, brick, plaster or tile
0,10	Partly empty room; room with smooth walls
0,15	Right cuboid room with furniture; right cuboid machinery room or industrial room
0,20	Irregularly shaped room with furniture; irregularly shaped machinery room or industrial room
0,25	Room with upholstered furniture; machinery or industrial room with sound-absorbing material on part of ceiling or walls
0,30	Room with sound-absorbing ceiling, but no sound absorbing materials on walls
0,35	Room with sound-absorbing materials on both ceiling and walls
0,50	Room with large amounts of sound-absorbing materials on ceiling and walls

A.4 Qualification requirements for measurements outdoors

For very large rooms in relation to the volume of the turbine set, and for workspaces which are not totally enclosed, the value of the environmental correction, K_2, may be assumed to be equal to zero. For measurements outdoors, the reflecting plane shall have properties defined in A.2.1 and the background sound levels shall meet the requirements of 4.2.

Annex B
(normative)

Gas turbines

B.1 General

In general, microphone positions shall be arranged on the measurement surfaces at equal distances from each other, with at least, one measurement position at each section of the gas turbine set.

B.2 Sound sources

For gas turbines and gas turbines sets, different noise sources can be defined (see Figure B.1), as follows:

— the surface of the machine itself;

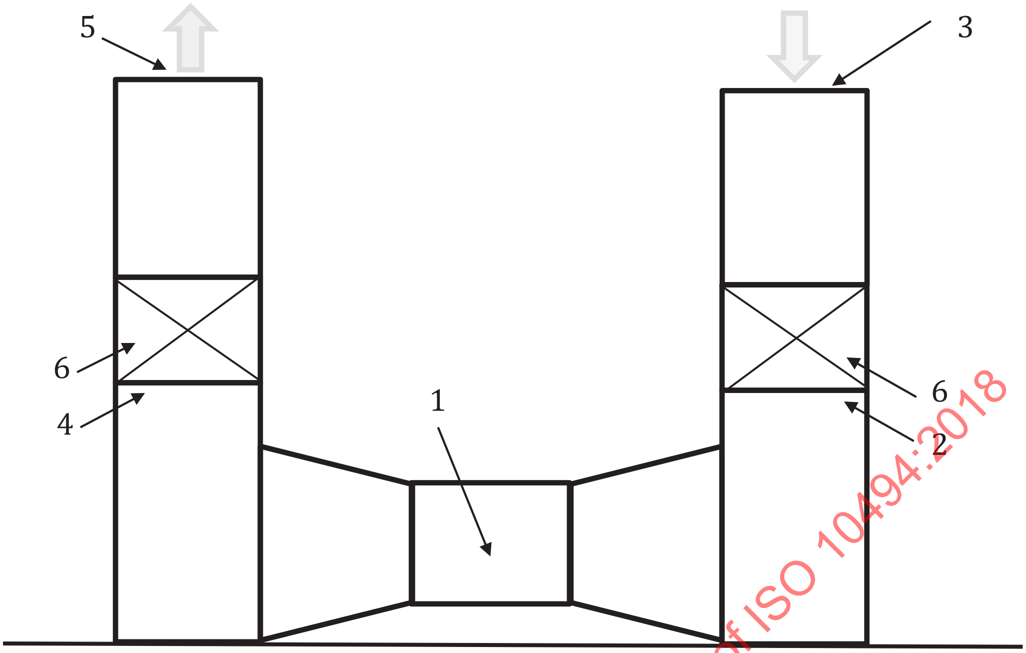
— the inlet of the compressor (compressor-inlet noises);

— the opening of the air intake (intake-inlet noise);

— the exhaust of the turbine (turbine-exhaust noise);

— the opening of the exhaust (exhaust-outlet noise);

— the sum of the noise emitted by the surface, and the openings of intake and exhaust (total noise).

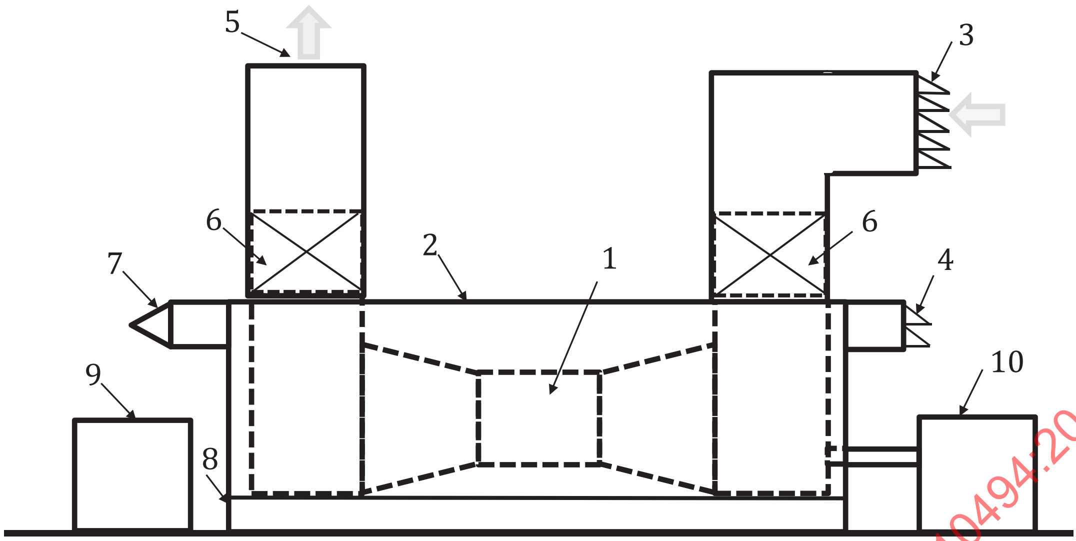


Key

1 gas turbine
2 compressor inlet
3 intake inlet
4 turbine exhaust
5 exhaust outlet
6 silencer

Figure B.1 — Identification of principle noise sources, gas turbine

For some gas turbines an enclosure is included. In those cases, the noise needs to be measured outside of the enclosure. Auxiliary equipment and different types of driven machinery may also be included in a turbine set (see Figure B.2).



Key

1 gas turbine
2 gas turbine enclosure
3 gas turbine intake inlet
4 gas turbine enclosure ventilation air inlet
5 gas turbine exhaust outlet
6 silencer
7 gas turbine enclosure ventilation air outlet
8 base plate
9 separate auxiliaries
10 driven equipment (cold end drive)

NOTE Driven equipment can be hot or cold end drive depending upon gas turbine design

Figure B.2 — Identification of principle noise sources, gas turbine set

B.2.1 Intake-inlet noise

The intake-inlet noise is the noise emitted from the opening of the air intake of the gas turbine or the gas turbine set into the atmosphere.

B.2.2 Compressor-inlet noise

The noise emitted from the compressor into the inlet system is called compressor-inlet noise.

B.2.3 Turbine-exhaust noise

The noise emitted from the turbine into the exhaust system is called turbine-exhaust noise.

B.2.4 Exhaust-outlet noise

The exhaust-outlet noise is the noise emitted from the opening of the exhaust of the gas turbine or the gas turbine set into the atmosphere.

B.2.5 Total noise

For a small installation where the air intake and gas exhaust are included in the reference box, the total noise is measured.

B.2.6 Auxiliary equipment and driven machines

Components included in the test are to be defined clearly and agreed to by the parties involved. Usually, they comprise the basic equipment necessary for the proper operation of the gas turbine or the gas turbine set at its final position.

All auxiliary equipment which is necessary for the operation of the turbine set under test, but not part of it, shall not significantly influence the noise measurement.

B.3 Microphone positions gas turbine

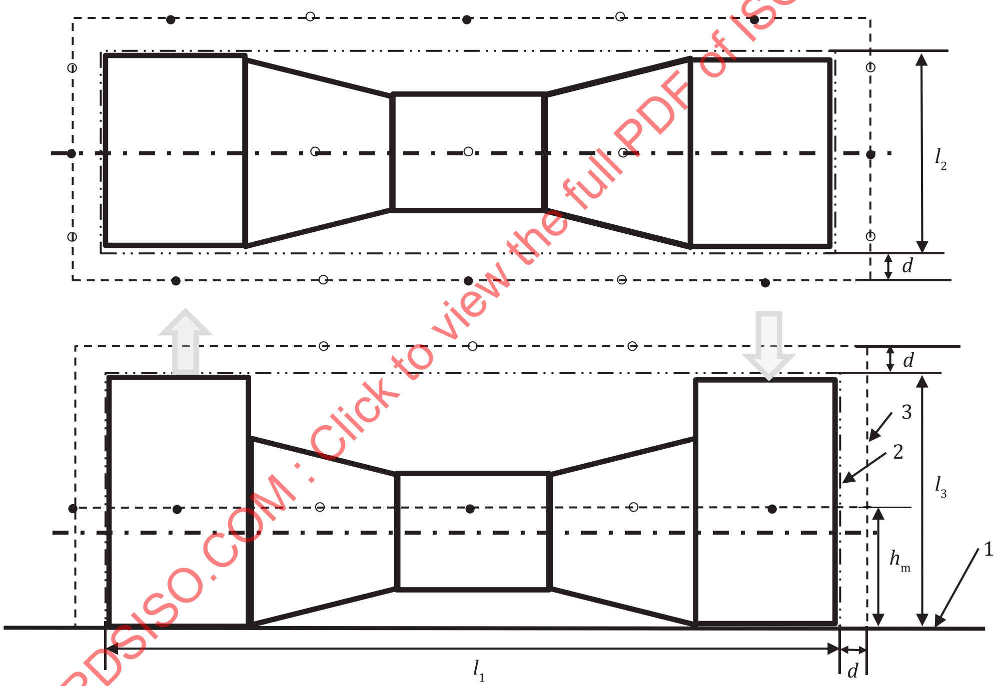
B.3.1 Surface noise

The gas turbine or the gas turbine set is enveloped by a hypothetical reference surface, which is the smallest rectangular parallelepiped that just encloses the source and terminates on a reflecting plane, also when there is a distance between the machine and the reflecting plane. (See Figures B.3 and B.4).

A reference surface composed of several rectangular parallelepiped surfaces can be used, in case of large machines.

Depending on the design and/or the dimensions of the machine set, the openings for air intake and exhaust may be situated within the measurement surface.

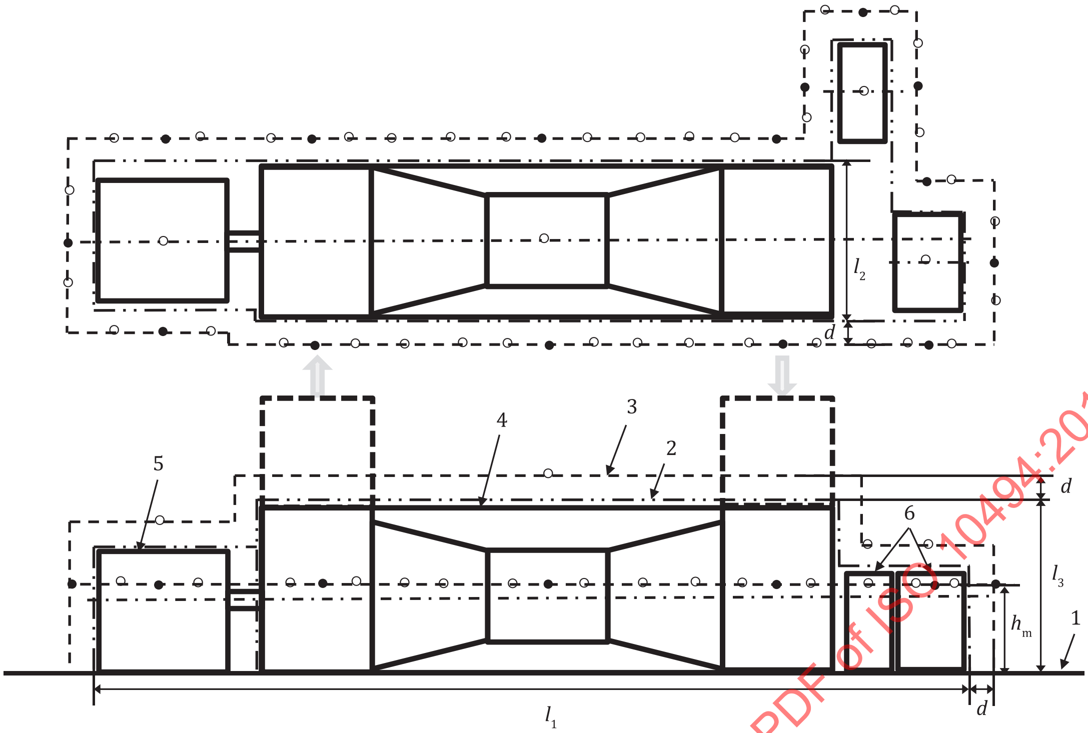
The measurement distance, *d*, shall be 1 m from the reference box to the measurement surface.



Key

- • key microphone positions
- ○ additional microphone positions
- 1 reflective surface
- 2 reference box
- 3 measurement surface
- *d* measurement distance, 1 m
- h_m height of microphone locations over reflective surface
- l_i length, height, width of reference box

Figure B.3 — Microphone locations and measurement surface for small gas turbine sets
(l_1 < 2 m; l_2 < 2 m; l_3 < 2,5 m)



Key

•	key microphone positions	6	auxiliaries
○	additional microphone positions	d	measurement distance, 1 m
1	reflective surface	h_m	height of microphone locations over reflective surface
2	reference box	l_i	length, height, width of reference box
3	measurement surface		
4	enclosure (optional)		
5	driven equipment (hot end drive)		

NOTE Driven equipment can be hot or cold end drive depending upon gas turbine design.

Figure B.4 — Microphone locations and measurement surface for medium and large gas turbine sets (l_1 > 2 m; l_2 > 2 m; l_3 > 2,5 m)

B.3.2 Key microphone positions on the measurement surface

In Figures B.3 and B.4, the location of the key microphone positions is prescribed by black filled circles.

B.3.3 Additional microphone positions on measurement surface

The number of additional microphone positions depends on the dimensions and on the number of different parts of the complete turbine set. Beginning at the key microphone positions, additional positions are arranged at equal distances around the gas turbine set. The distances are such that there is at least one measurement position at each casing of the turbine set.

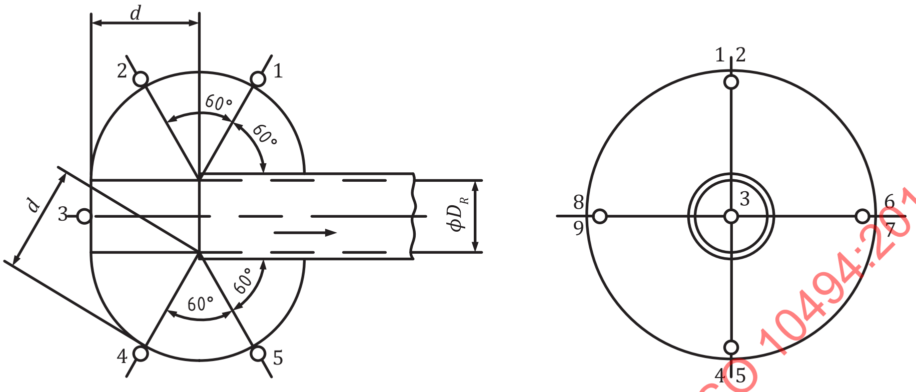
Especially at large gas turbine sets it is often unreasonably complex to measure also the overhead positions. In those cases, these optional measurement positions may be deleted.

B.3.4 Intake-inlet noise

The shape of the measurement surface and the microphone positions depend on the dimensions of the openings and their location with respect to reflecting surfaces. The most suitable of the examples shown in Figures B.5 or B.6 shall be used.

The intake-inlet noise can only be measured separately when the distance between the air-intake opening or the exhaust opening and the gas turbine or the gas turbine set is sufficient for the correction for background noise, K_{1A}, not to exceed 1,3 dB for a grade 2 result or 3 dB for a grade 3 result.

Since the method described above is for measurement of the intake opening only, the surfaces of the inlet ducting and filter house should be measured separately in accordance with B.3.1.



Key

○ measuring point (there are nine)

d measurement distance (d = 1 m)

D_R inside inlet duct diameter

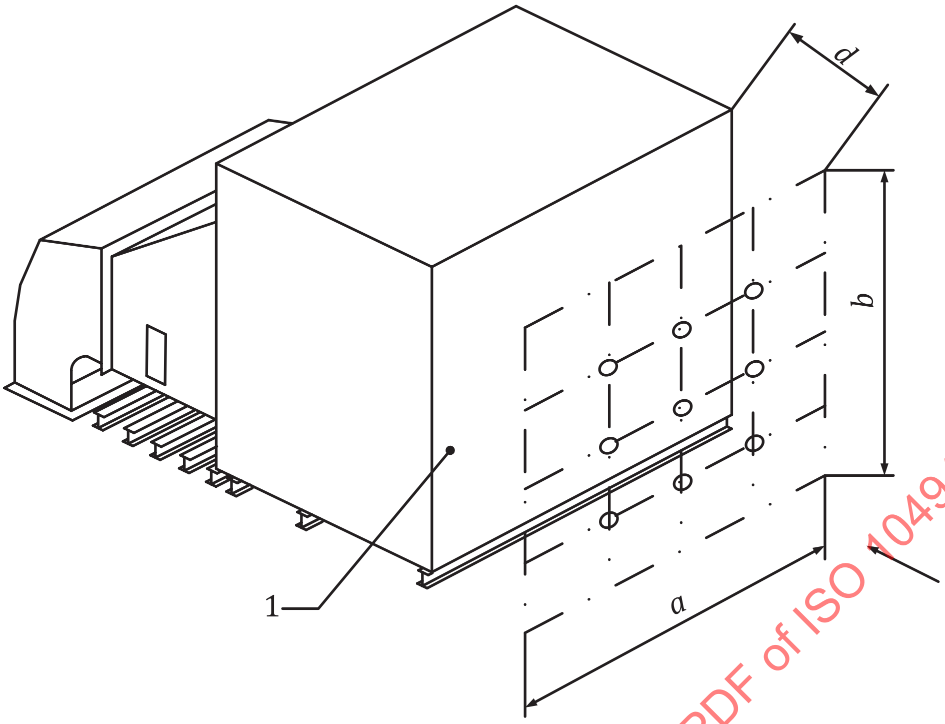
$$S = 2d\pi^2\left(\frac{D_R}{2} + \frac{2d}{\pi}\right) + \frac{D_R^2\pi}{4}$$

For $D_R/d \le 0{,}18$, the following formula is sufficient:

$$S = 4\pi\left(\frac{D_R}{2} + d\right)^2$$

NOTE See Annex D for the effects of reflecting planes.

Figure B.5 — Measurement surface and microphone positions for measuring the intake-inlet noise when no reflecting plane exists



Key

○ measuring point
1 air inlet area
a air inlet width
b air inlet height
d measurement distance (d = 1 m)
$S = ab$

Figure B.6 — Measurement surface and microphone positions for measuring the intake-inlet noise emitted from inlet systems of the gas turbine

B.3.5 Compressor-inlet noise

At present, there is no International Standard available for the determination of the sound power level in pipes and ducts. Thus, the sound power level of the compressor-inlet noise can only be determined indirectly from the sound power level of the intake-inlet noise, taking into account the sound attenuation between the compressor inlet and the air-intake inlet when known.

When there are no noise-attenuating devices (silencer, elbow, etc.) or additional sources in the air intake system, the compressor-inlet sound power is approximately equal to the intake-inlet sound power, which is then evaluated in the same way as the intake-inlet noise.

B.3.6 Turbine exhaust noise

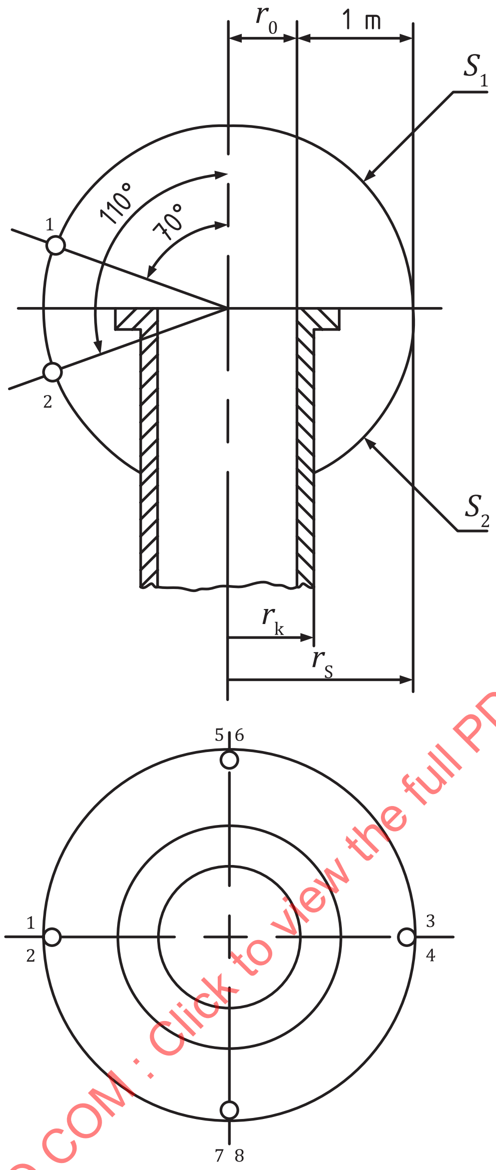
As there is no basic International Standard for sound power determination in pipes and ducts, and no microphones meeting the requirements of IEC 60268-4 at gas turbine exhaust temperatures are available, the turbine-exhaust noise cannot be measured directly. It can be estimated as the sum of the exhaust-outlet noise and the noise attenuation of the exhaust system, if these are known.

If there are no attenuating devices (silencer, elbow, etc.) or additional noise sources in the exhaust system, the turbine exhaust sound power is approximately equal to the exhaust-outlet sound power, which is evaluated in the same way as the exhaust-outlet noise.

B.3.7 Exhaust-outlet noise

The shape of the measurement surface and the microphone positions depend on the dimensions of the opening and their locations with respect to reflecting surfaces. The most suitable of the examples shown in Figures B.7 to B.9 shall be used.

The exhaust-outlet noise can only be measured separately when the distance between the exhaust opening or the air-intake opening and the gas turbine or the gas turbine set is sufficient for the correction for background sound, K_{1A}, not to exceed 1,3 dB for a grade 2 result or 3 dB for a grade 3 result.



Key

○ measuring point

$2r_0$ inside pipe diameter

$2r_k$ outside pipe diameter

r_s measurement radius

$S_1 = 2\pi(r_0 + 1)^2$

$S_2 = 2\pi(r_0 + 1)\sqrt{(r_0 + 1)^2 - r_k^2}$

NOTE Where access problems arise, other methods can be used by agreement between the manufacturer and the customer.

Figure B.7 — Measurement surface and microphone positions for measuring exhaust-outlet noise when no reflecting plane exists