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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

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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).

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.