INTERNATIONAL STANDARD

ISO 10494

First edition
1993-07-01

Gas turbines and gas turbine sets — Measurement of emitted airborne noise — Engineering/survey method

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

Reference number
ISO 10494:1993(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10494 was prepared jointly by Technical Committees ISO/TC 192, *Gas turbines* and ISO/TC 43, *Acoustics*.

Annex A forms an integral part of this International Standard. Annexes B, C and D are for information only.

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Introduction

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

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

This page intentionally left blank

Gas turbines and gas turbine sets — Measurement of emitted airborne noise — Engineering/survey method

1 Scope

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

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

1.3 This International Standard applies to gas turbines and gas turbine sets

— for 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.

1.4 The methods defined in this International Standard apply to the measurement of the noise emission of a gas turbine or gas 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.

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

NOTES

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

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

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

International Standard	Classification of method[1]	Test environment[2]	Volume of source	Character of noise	Sound power levels obtainable	Optional information available
ISO 3741	Precision (grade 1)	Reverberation room meeting specified requirements	Preferably less than 1 % of test room volume	Steady, broad-band	In one-third-octave or octave bands	A-weighted sound power level
ISO 3742				Steady, discrete-frequency or narrow-band		
ISO 3743	Engineering (grade 2)	Special reverberation test room		Steady, broad-band, narrow-band or discrete-frequency	A-weighted and in octave bands	Other weighted sound power levels
ISO 3744	Engineering (grade 2)	Outdoors or in large room	Greatest dimension less than 15 m	Any	A-weighted and in one-third-octave or octave bands	Directivity information; sound pressure levels as a function of time; other weighted sound power levels
ISO 3745	Precision (grade 1)	Anechoic or semi-anechoic room	Preferably less than 0,5 % of test room volume	Any		
ISO 3746	Survey (grade 3)	No special test environment	No restrictions; limited only by available test environment	Any	A-weighted	Sound pressure levels as a function of time; other weighted sound power levels

1) See ISO 2204.

2) If the requirements for the test environment are not met, the sound power level of the source shall be determined using another method of measurement that shall be agreed to by the manufacturer and the customer.

Table 2 — Limits for correction

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

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

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

Values in decibels

Grade of accuracy	Octave band centre frequency					A-weighted
	31,5 Hz/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						5
NOTE — The uncertainty in determining sound power levels expressed as the largest value of the standard deviation for air intake inlet and gas exhaust outlet may be higher.						

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 354:1985, *Acoustics — Measurement of sound absorption in a reverberation room.*

ISO 2204:1979, *Acoustics — Guide to International Standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings.*

ISO 2314:1989, *Gas turbines — Acceptance tests.*

ISO 3744:1981, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane.*

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

ISO 3746:1979, *Acoustics — Determination of sound power levels of noise sources — Survey method.*

ISO 3977:1991, *Gas turbines — Procurement.*

ISO 6926:1990, *Acoustics — Determination of sound power levels of noise sources — Requirements for the performance and calibration of reference sound sources.*

IEC 651:1979, *Sound level meters.*

IEC 942:1988, *Sound calibrators.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 free field: A sound field in a homogeneous, isotropic medium free of boundaries. In practice it is a field in which the effects of the boundaries are negligible over the frequency range of interest.

3.2 free field over a reflecting plane: A sound field in the presence of one reflecting plane on which the source is located.

3.3 anechoic room: A test room whose surfaces absorb essentially all the incident sound energy over the frequency range of interest, thereby affording free-field conditions over the measurement surface.

3.4 semi-anechoic room: A test room with a hard reflecting floor whose other surfaces absorb essentially all the incident sound energy over the frequency range of interest, thereby affording free-field conditions above a reflecting plane.

3.5 surface sound pressure: The sound pressure averaged in time on a mean-square basis, averaged over the measurement surface using the averaging procedures specified in this International Standard and corrected for the effects of background noise and the influence of reflected sound at the measurement surface.

3.6 surface sound pressure level, $\overline{L_{pf}}$**:** Ten times the logarithm to the base 10 of the ratio of the square of the surface sound pressure to the square of the reference sound pressure. The reference sound pressure is 20 µPa. The surface sound pressure level is measured in decibels.

NOTE 3 The weighting network or the width of the frequency band used should be indicated; for example, A-weighted sound pressure level, octave band sound pressure level, one-third-octave band sound pressure level, etc.

3.7 sound power level, L_W: Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference power. The reference sound power is 1 pW (= 10^{-12} W). The sound power level is measured in decibels.

NOTES

4 The weighting network or the width of the frequency band used should be indicated; for example, A-weighted sound power level, octave band sound power level, one-third-octave band sound power level, etc.

5 The mean sound pressure level at some reference radius is numerically different from the sound power level and its use in lieu of the sound power level is not recommended.

3.8 frequency range of interest: For general purposes, the frequency range of interest includes the octave bands with centre frequencies between 31,5 Hz and 8 000 Hz and the one-third-octave bands with centre frequencies between 25 Hz and 10 000 Hz. Any band may be excluded in which the level is more than 50 dB below the highest band pressure level. For special purposes, the frequency range of interest may be extended at either end, provided the test environment and instrument accuracy are satisfactory for use over the extended 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.

3.9 measurement surface: A hypothetical surface of area S enveloping the source on which the measuring points are located.

3.10 reference box: A hypothetical reference surface which is the smallest rectangular parallelepiped that just encloses the source and terminates on the reflecting plane.

3.11 measurement distance: The minimum distance from the reference box to the measurement surface.

4 Acoustic environment

4.1 General

The test environments that are suitable for measurements according to this International Standard include:

a) a laboratory room which provides a free field over a reflecting plane;

b) a flat outdoor area that meets the requirements of 4.2 and annex A;

c) a room in which the contributions of the reverberant field to the sound pressures on the measurement surface are small compared with those of the direct field of the source.

Conditions described under c) above are usually met in very large rooms as well as in smaller rooms with sufficient sound-absorptive materials on their walls and ceilings.

4.2 Criteria for 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 6 If it is necessary to make measurements in spaces which do not meet the criteria of annex A, standard deviations of the test results may be greater than those given in table 3. In those cases, the sound power level determined according to this International Standard may be useful for obtaining a valid upper limit for the sound power level of the gas turbine or the gas turbine set.

4.3 Criteria for background noise

At the microphone positions, 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 not greater (grade 3 result) than the sound pressure level measured in each frequency band within the frequency range of interest.

Care shall be taken to minimize the effects of wind which may increase the apparent background noise. 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 4.2 and 4.3, additional complex measurement methods, which are not part of this International Standard (e.g. noise intensity analysing devices) can be used to get an estimate for the noise emission.

If one of these methods is used for acceptance 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 651.

6 Object under test and test conditions

6.1 Object under test

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

— fuel pump,

— cooling water pump,

— heat exchanger,

— gears.

NOTE 7 In cases where the components necessary for the operation are not mounted at the gas turbine or the gas turbine set directly, they may have to be considered separately. It may also be preferable to determine the contribution of their sound to the overall gas turbine set sound level as a separate test.

6.2 Measurement conditions

6.2.1 Operating conditions

The test shall be performed under steady-state operating conditions of the gas turbine or the gas 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 in accordance with ISO 3977 shall be applied. Relevant operating conditions and atmospheric conditions (temperature, pressure, humidity, snow, frost) shall be recorded in the test report.

The operating conditions shall not be changed during the measurements and shall, as far as possible, be in accordance with operating conditions specified in ISO 2314.

During start-up and shut-down, the noise emission can be higher for short times. Under these conditions this International Standard is not applicable.

6.2.2 Installation

The gas turbine or the gas turbine set shall, as far as possible, be installed according to the operation on-site.

6.3 Sound sources

6.3.1 General

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

— the surface of the machine itself,

— the opening of the air intake ("intake-inlet noise"),

— the inlet of the compressor ("compressor-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").

If there are no noise-influencing components between the gas turbine and the openings, the noise at the opening of the air intake is equal to that at the inlet of the compressor, and/or the noise at the opening of the exhaust is equal to that at the outlet of the turbine.

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 gas turbine set shall be determined at the microphone positions on a measurement surface enveloping the gas turbine or the gas turbine set including the openings for air intake and exhaust.

6.3.2 Surface noise of the gas turbine or the gas turbine set

Surface noise is the noise emitted by the surface of the gas turbine or the gas turbine set. Noise emitted by air intake or exhaust openings are not included in the surface noise. They shall be eliminated from the measurement results by conducting them through pipes or ducts having a sufficient noise transmission loss into other rooms or into the open air.

The surface of the gas turbine or of the gas turbine set is, according to the definition given above, the outer contour of the turbine or the turbine set ready for operation. At the state of the art, it can be:

— a surface without any heat- or sound-reducing lagging;

— a surface partly or completely equipped with a thermal installation;

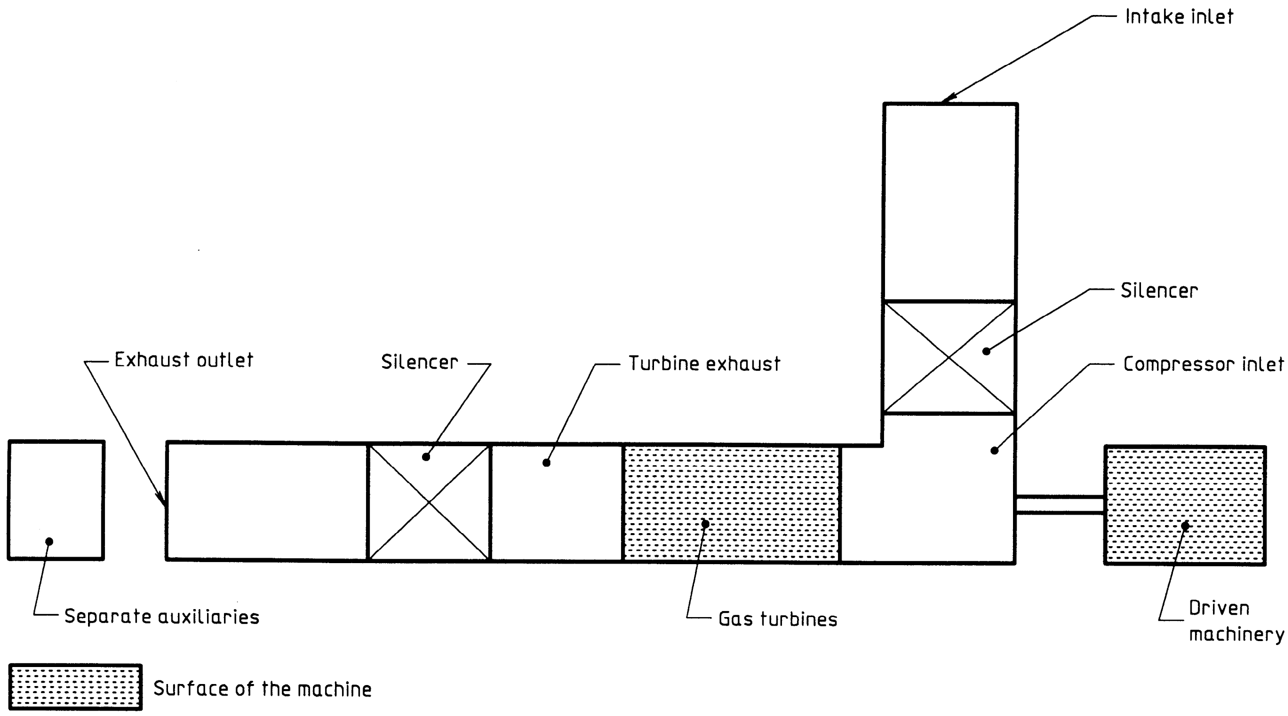

Figure 1 — Identification of the principal noise sources

— a surface partly or completely equipped with noise-attenuating material;

— a surface partly or completely enclosed with a combined thermal and acoustical insulation.

NOTES

8 For some types of gas turbine an enclosure is included. Then the "surface noise" is the noise emitted by the enclosure including that from openings in the enclosure.

In some cases, the enclosure can be entered during operation of the gas turbine. Then the sound pressure level within the enclosure can be measured additionally, but this is not part of the method given in this International Standard.

9 Also, in some cases, significant sound power is emitted by (parts of) the ducts for air intake or exhaust. The measurement of this surface noise is not part of the method given in this International Standard, but it can be performed in a way similar to the measurement of the surface noise of the gas turbine. The measurement conditions, especially the kind of noise-emitting surface and the measurement surface, should be described exactly.

6.3.3 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.

6.3.4 Compressor-inlet noise

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

6.3.5 Turbine-exhaust noise

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

6.3.6 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.

6.3.7 Total noise

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

7 Sound pressure levels on the measurement surface

7.1 Reference surface and measurement surface

To facilitate the location of the microphone positions, a hypothetical reference surface is defined. This reference surface is the smallest possible rectangular box (i.e. rectangular parallelepiped) that just encloses the source and terminates on the reflecting plane. When defining the dimensions of this reference box, 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 and terminates on the reflecting plane.

The measurement surface has the shape of a rectangular parallelepiped whose sides are parallel to those of the reference box; in this case, the measurement distance d is the distance between the measurement surface and the reference box.

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. 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.

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 shall be determined. The total sound power 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_{Wj}, in decibels, shall be calculated by using the following equation:

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

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;

$S_0 = 1 \text{ m}^2$

The n individual partial sound power levels can be combined to give the total sound power level L_{Wg}, in decibels, as follows:

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

where

n is the total number of partial sound powers;

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

NOTE 10 Microphone positions may have to be deleted in cases where they cannot be reached, or where measurement at these positions is dangerous, or where results are falsified, e.g. by temperature, steam, humidity, strong electric or magnetic field. This is permissible when it can be shown (e.g. by other investigations) that the surface sound pressure level and the sound power level do not deviate by more than 1 dB from those determined from measurements over the entire measurement surface.

7.2.2 Microphone positions

7.2.2.1 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 the reflecting plane, also when there is a distance between the machine and the reflecting plane. (See figures 2 to 4.)

In the case of large gas turbines or large gas turbine sets, a reference surface composed of several rectangular parallelepiped surfaces may be used.

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 (see 6.3.1).

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