BRITISH STANDARD

BS ISO 10494:1993

Incorporating Amendment No. 1 to BS 7721 : 1994 (renumbers the BS as BS ISO 10494:1993)

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

ICS 17.140.20; 27.040

British Standards

National foreword

This British Standard reproduces verbatim ISO 10494:1993 and implements it as the UK national standard.

The UK participation in its preparation was entrusted to Technical Committee MCE/16, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

In 2003, MCE/16 decided to confirm dual-numbered BS 7721 : 1994, ISO 10494:1993, and re-number it BS ISO 10494:1993. The text remains identical.

Cross-references

The British Standards which implement international publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, the ISO introduction page, a blank page, pages 1 to 23 and a back cover.

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Introduction

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

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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;

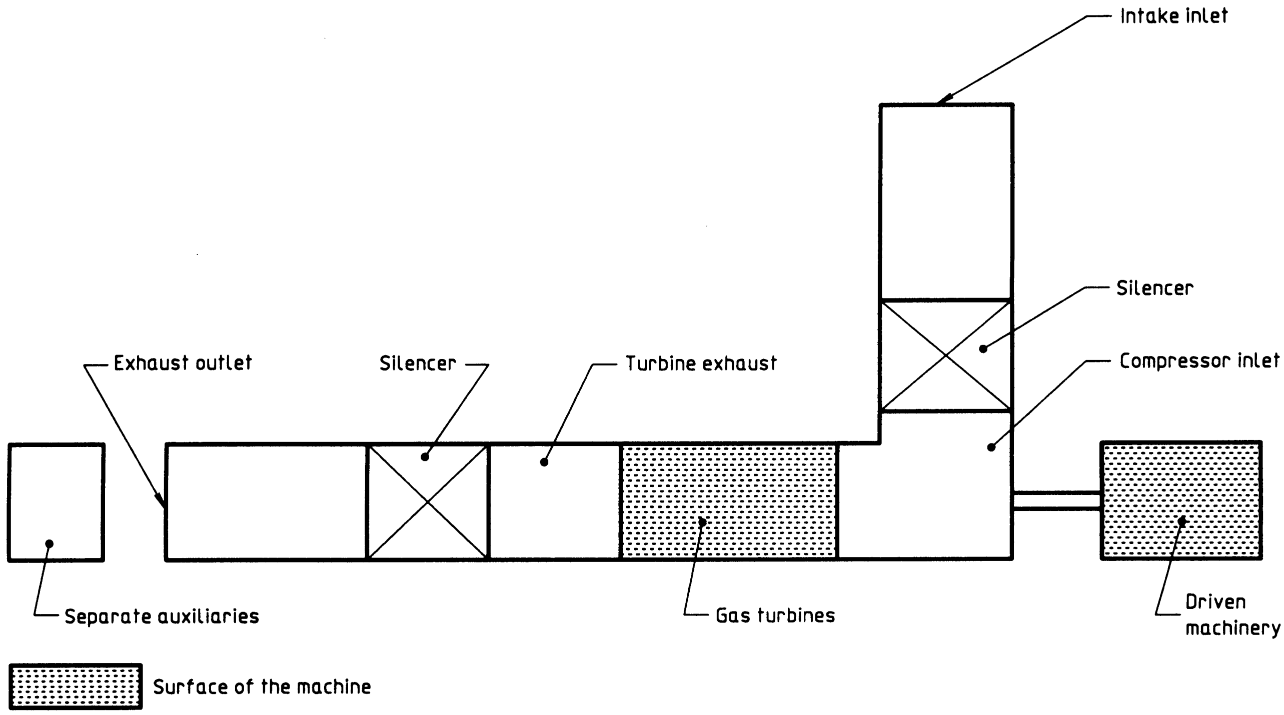


Figure 1 — Identification of the principal noise sources

— 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.

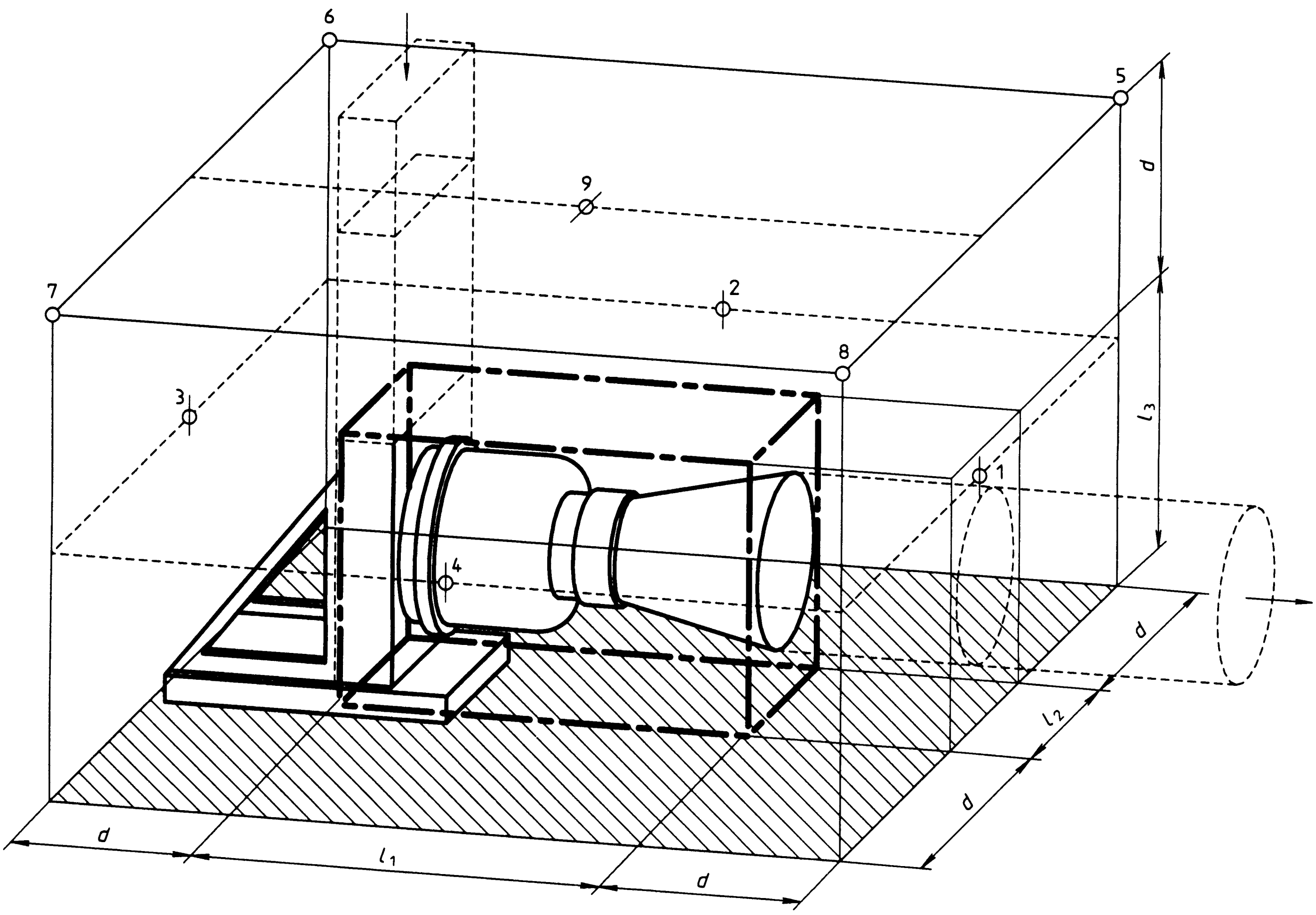


Figure 2 — Microphone locations (9 positions) and measurement surface for small gas turbine sets
($l_1 < 2$ m; $l_2 < 2$ m; $l_3 < 2,5$ m)

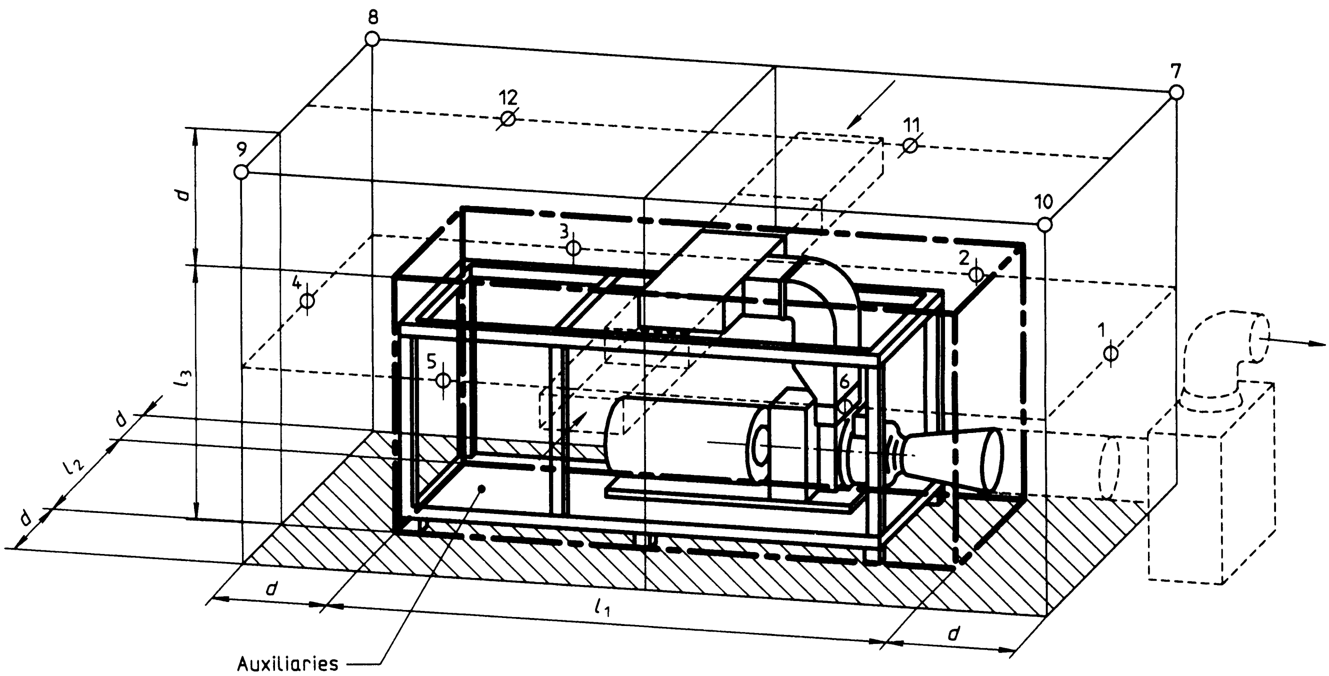


Figure 3 — Microphone locations and measurement surface for medium-sized gas turbine sets
($2\ \text{m} < l_1 < 4\ \text{m}$; $l_2 < 2\ \text{m}$; $l_3 < 2{,}5\ \text{m}$)

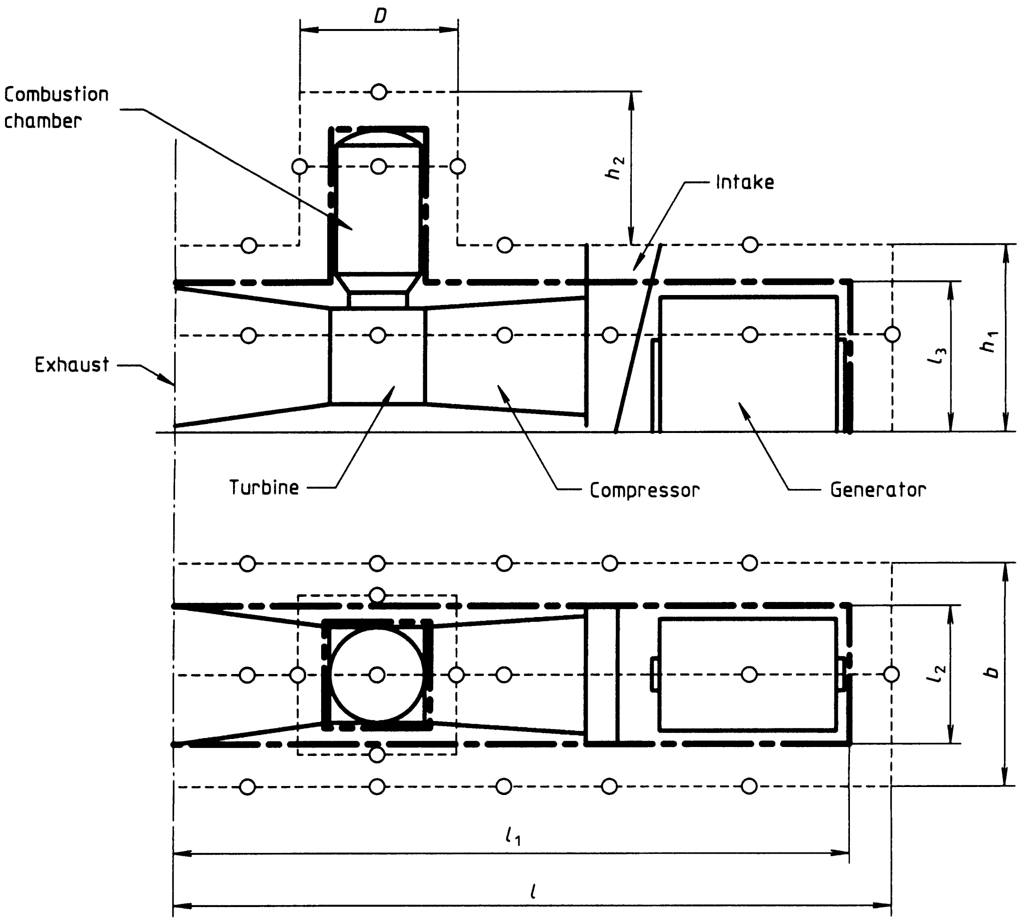
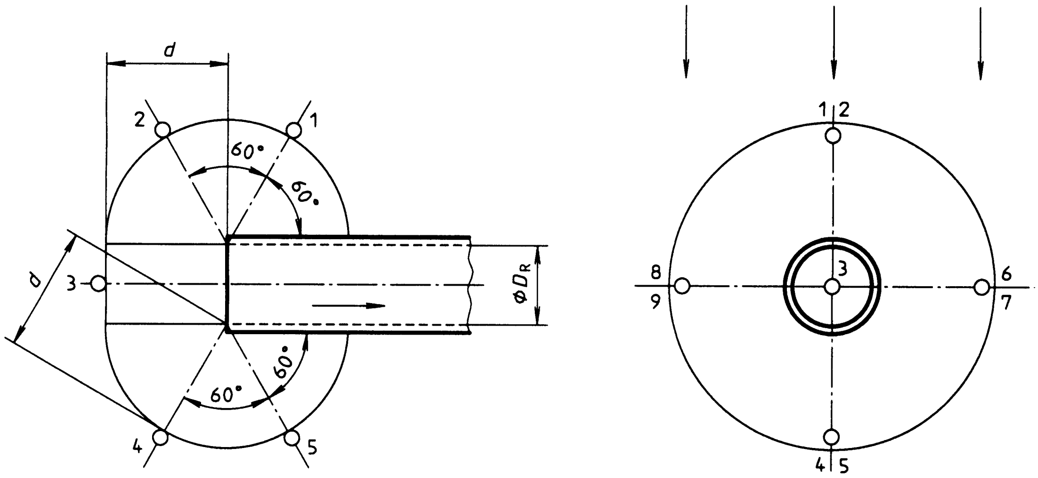


Figure 4 — Microphone locations for large gas turbine sets ($l_1 > 4$ m; $l_2 > 2$ m; $l_3 > 2,5$ m)

7.2.2.2 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 figure 5 or 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.



Key

○ is a measuring point (there are nine)

d is the measurement distance (d = 1 m)

D_R inside inlet duct diameter ($D_R \leqslant$ 1 m)

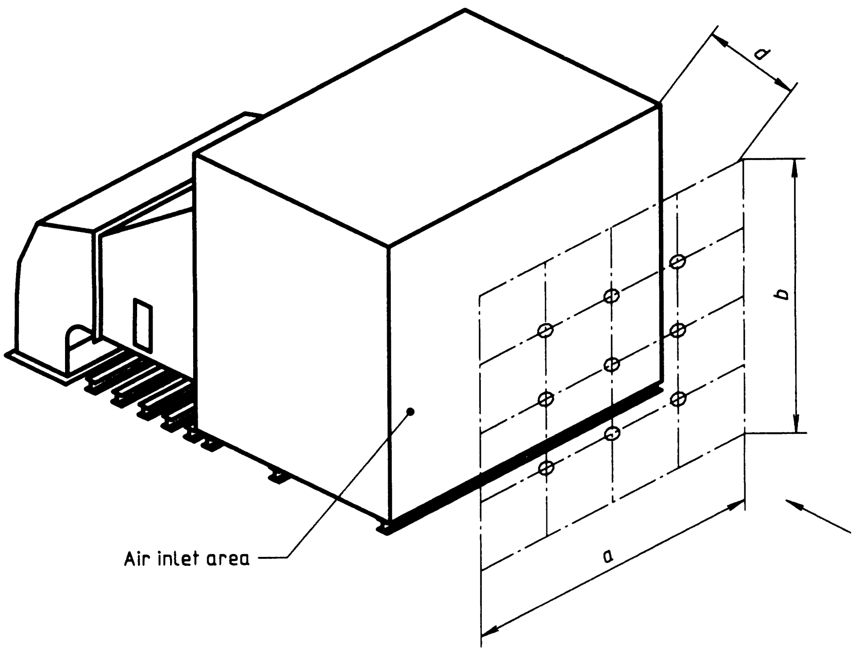
$$S = 2d\pi^2\left(\frac{D_R}{2} + \frac{2d}{\pi}\right) + \frac{D_R^2\pi}{4}$$

For $D_R/d \leqslant$ 0,18 the following formula is sufficient:

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

NOTE — See annex C for the effects of reflecting planes.

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



$S = ab$

$d = 1$ m

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

7.2.2.3 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 (see 7.2.2.2).

7.2.2.4 Turbine exhaust noise

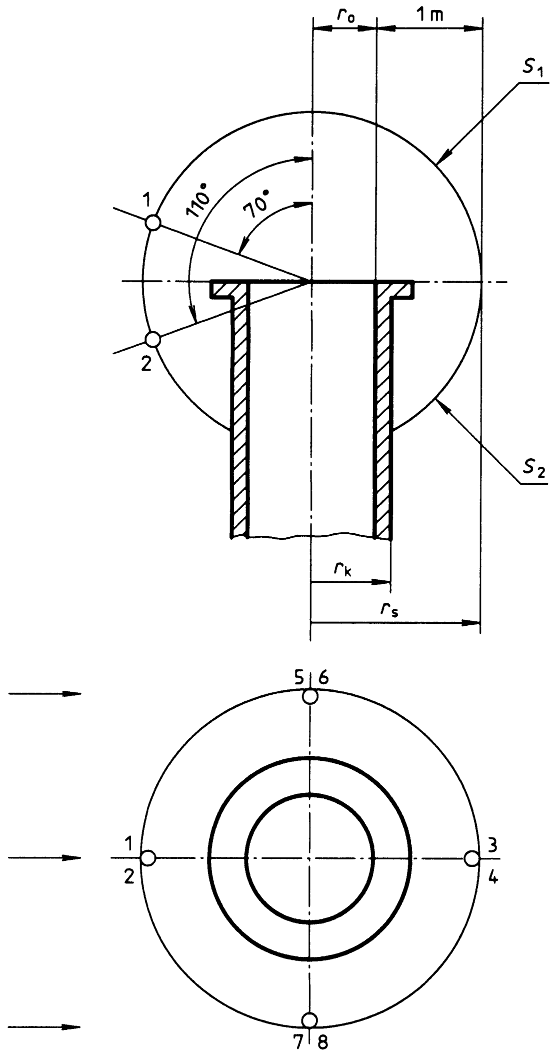
As there is no basic International Standard for sound power determination in pipes and ducts, and no microphones meeting the requirements of IEC 651 at gas turbine exhaust temperatures are available, the turbine-exhaust noise cannot be measured directly. It can be estimated as the sum of the exhaust-outlet 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 (see 7.2.2.5).

7.2.2.5 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 7 to 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

○ is a measuring point

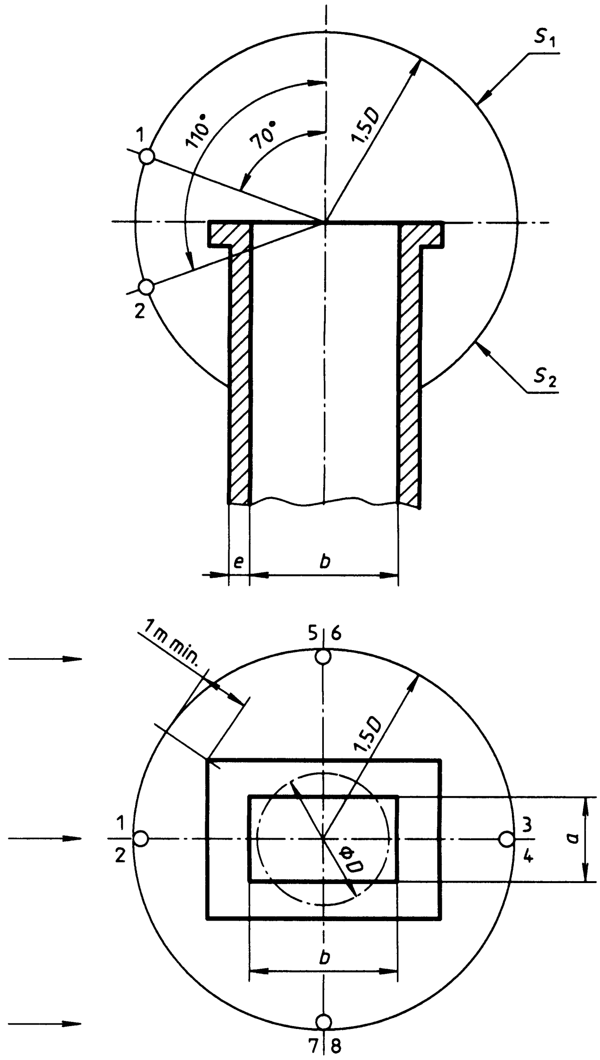
$2r_o$ is the inside pipe diameter (⩽ 1 m)

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

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

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

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



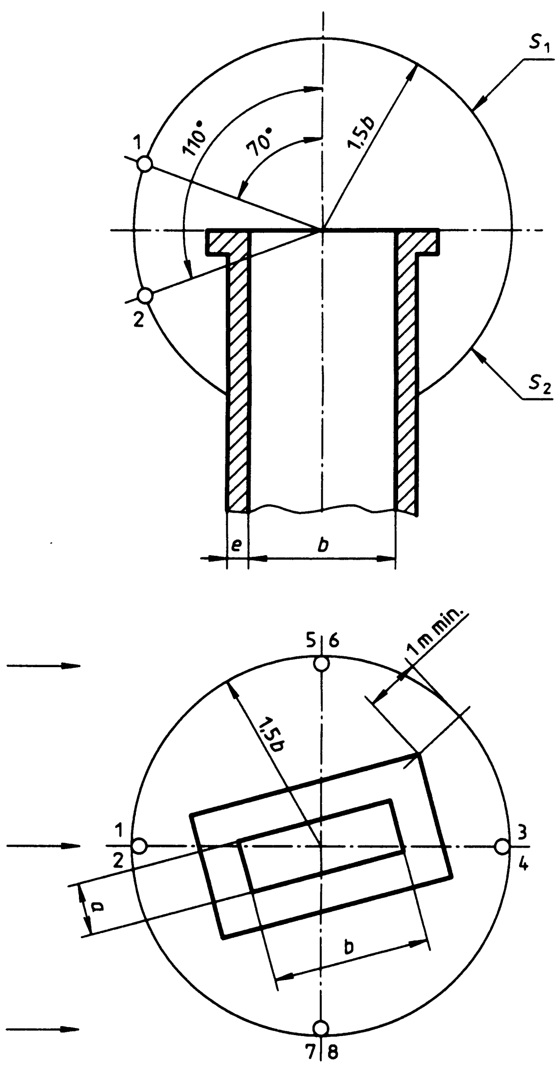
Key

D = equivalent diameter

$S_1 = 4{,}5\pi D^2 = 18ab$

$S_2 = 18ab\sqrt{1 - \frac{1}{9}\left(1 + \frac{e}{a}\right)\left(1 + \frac{e}{b}\right)}$

Figure 8 — Measurement surface and microphone positions for measuring exhaust-outlet noise when $b/a \leqslant 1{,}5$



Key

$S_1 = 4{,}5\pi b^2$

$S_2 = 4{,}5\pi b^2 \sqrt{1 - \frac{a}{2{,}25\pi b}\left(1 + \frac{e}{a}\right)\left(1 + \frac{e}{b}\right)}$

Figure 9 — Measurement surface and microphone positions for measuring exhaust-outlet noise when $b/a > 1{,}5$

7.3 Conditions of measurement

7.3.1 General

Environmental conditions may have an adverse effect on the microphone used for the measurements. Such conditions (for example, strong electric or magnetic fields, wind, impingement of air discharge from the equipment being tested, high or low temperatures) shall be avoided by proper selection or positioning of the microphone.

At the measurement positions, the microphone shall be directed with its specified main axis of sound incidence perpendicular to the measurement surface, but at the edges in the direction of the shortest distance to the corresponding edge and at the corners to the corresponding corner of the reference box.

The maximum wind speed for measurement according to this International Standard is approximately 5 ms^{-1}. In any case, the background noise level due to the wind should be at least 10 dB below the sound pressure level (A-weighted or by octave band) to be measured. The microphone manufacturer's instructions should be followed.

7.3.2 Calibration

During each series of measurements, a sound calibrator meeting the requirements of IEC 942 for 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 be carried out at least every 2 years.

7.3.3 Measurement of the A-weighted sound pressure level

With the machine operating, the sound pressure level shall be read on the sound level meter for each measuring point: $i = 1, 2, ..., n$ (or for all measurement paths) with frequency weighting A and time weighting slow, resulting in the sound pressure level L_{pA}.

7.3.4 Measurement of sound pressure spectrum

For the determination of spectra, the sound pressure level in each octave band is measured in a way similar to that given in 7.3.3.

For the frequency bands centred on or below 160 Hz, the measurement time shall be at least 30 s. For frequency bands on or above 200 Hz, the measurement time shall be at least 10 s.

NOTE 11 For special purposes, which are not considered in this International Standard (e.g. detecting special sound sources), it can be useful to use third-octave or narrow-band filters.

7.3.5 Measurement of background noise level

If background sound pressure levels have to be taken into account, they shall be measured at each microphone position as specified in 7.3.3 and/or 7.3.4, before the machine under test is put into operation or after it has been taken out of operation.

NOTES

12 During measurements at gas turbines and gas turbine sets, unavoidable background sound can be present. If a background noise correction 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 International Standard.

13 Background noise emitted by components which are not part of the gas turbine set but are necessary for its operation and which can operate only together with the gas turbine or the gas 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.

7.3.6 Corrections for background noise

The measured sound pressure levels shall be corrected for background noise in accordance with the values given in table 4.

NOTES

14 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 side of high background sound pressure levels.

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

8 Calculation of surface pressure level, sound power level and directivity factor

8.1 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, $\overline{L_{pm}}$, from the measured sound pressure levels L_{pi} (after applying corrections for background noise according to 7.3.6, if necessary) by using the following equation:

$$\overline{L_{pm}} = 10 \lg \left(\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L_{pi}} \right) \text{ dB} \qquad \ldots (1)$$

where

$\overline{L_{pm}}$ is the sound pressure level averaged over the measurement surface, in decibels; reference = 20 µPa;

L_{pi} is the A-weighted or band pressure level resulting from the i^{th} measurement, in decibels; reference = 20 µPa;

N is the total number of measurements.

NOTE 16 When the range of values of L_{pi} does not exceed 5 dB, a simple arithmetic average will differ by not more than 0,7 dB from the value calculated using the energy average, equation (1).

Table 4 — Correction for background noise

Difference between sound pressure level measured with noise source operating and background sound pressure level alone dB	**Correction to be subtracted from sound pressure level measured with sound source operating to obtain sound pressure level due to noise source alone** dB	**Grade of accuracy**
3	3	Grade 3
4	2	
5	2	
6	1	Grade 2
7	1	
8	1	
9	1	
10	0	
> 10	0	

8.2 Calculation of surface sound pressure level

Obtain the surface sound pressure level, $\overline{L_{pf}}$, by correcting the value of $\overline{L_{pm}}$ for reflected sound to approximate the average value of the sound pressure level which would be obtained under free-field conditions, by using the following equation:

$$\overline{L_{pf}} = \overline{L_{pm}} - K \qquad \ldots (2)$$

where

$\overline{L_{pf}}$ is the surface sound pressure level, in decibels; reference = 20 µPa;

K is the mean value of the environmental correction over the measurement surface, in decibels.

For the purposes of this International Standard, the maximum allowable range of the environmental correction K is − 2 dB to + 2 dB.

a) For accuracy grade 2:

The environmental correction K accounts for the influence of a non-ideal environment (e.g. the presence of sound absorption or reflected sound). It typically ranges from − 2 dB (for measurements outdoors with absorbing ground) to + 10 dB (for measurement indoors in highly reverberant rooms). The procedures given in annex A shall be used to calculate the value of the environmental correction K.

b) For accuracy grade 3:

The environmental correction K typically ranges from 0 dB (for measurements outdoors) to more than 10 dB for measurements indoors in highly reverberant rooms. For the purposes of this International Standard, the maximum allowable value of the environmental correction K is 7 dB. The procedures given in annex A shall be used to calculate the value of the environmental correction K.

NOTE 17 The environmental correction K also depends on the frequency. When the sound pressure levels and the reverberation time are measured using the A-weighting, the uncertainty of K increases with the difference in the level distribution versus frequency of the sound of the machine and that of the source applied to determine the reverberation time. This uncertainty can be reduced by using octave-band data for sound pressure levels and environmental correction. See A.4.1.

8.3 Calculation of sound power level

Calculate the sound power level characterizing the noise emitted by the source from the following equation:

$$L_W = \overline{L_{pf}} + 10 \lg (S/S_0) \text{ dB}$$

where

L_W is the A-weighted or band power level of the source, in decibels; reference = 1 pW;

$\overline{L_{pf}}$ is the surface sound pressure level determined according to 8.2, in decibels; reference = 20 µPa;

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

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

8.4 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 C.

9 Information to be recorded

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

9.1 Noise source under test

a) Description of the noise source under test (including manufacturer's references, type, serial number, year of construction (if relevant), technical data, dimensions and dimensions of the reference box).

b) Operating conditions (power output and turbine speed during measurements).

c) Mounting conditions.

d) Location of the noise source in the test environment.

e) Description of the noise source(s) on the components (see 6.1) included in the test and in operation during the measurements, including the type of air intake and exhaust gas outlet systems.

9.2 Acoustic environment

a) Description of the test environment; if indoors, description of the physical treatment of walls, ceiling and floor; sketch showing the location of the source and room contents; if outdoors, sketch showing the location of the source with respect to the surrounding terrain, including a physical description of the test environment.

b) Acoustical qualification of the test environment according to annex A.

c) Air temperature in degrees Celsius, barometric pressure in pascals, and relative humidity.

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

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

9.3 Instrumentation

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

b) Bandwidth of frequency analyser.

c) Frequency response of the instrumentation system.

d) Method used for checking the calibration of the microphones and other system components; data and place of calibration.

e) Type and make of windscreen (if any).

9.4 Acoustical data

a) The shape of the measurement surface, the measurement distance, the location and orientation of the microphone positions or paths.

b) The area, S, of the measurement surface, in square metres.

c) The correction, in decibels, if any, applied in each frequency band for the frequency response of the microphone, frequency response of the filter in the passband, background noise, etc.

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

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

f) The environmental correction K calculated according to one of the procedures of annex A.

g) The surface sound pressure level, $\overline{L_{pf}}$, in decibels, expressed in terms of a weighted level (with A-weighting) and in terms of a level in each octave band of interest; reference = 20 µPa.

h) The sound power level, L_W, in decibels, calculated from the surface sound pressure level for A (or other) weighting and for all octave bands used; reference = 1 pW, if applicable.

9.5 Date and location

The location and date when the measurements were performed and the name of the person responsible for the measurements.

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 International Standard and the grade of accuracy.

In some cases, it may 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 International Standard. This environment may be a semi-anechoic room, an outdoor space, or an ordinary room if the requirements given below are satisfied.

The test room shall be large enough and, if possible, free from reflecting objects with the exception of the reflecting plane. The test room shall provide a measurement surface that lies

a) inside a sound field that is free of undesired sound reflections from the room boundaries;

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

For open 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 may be assumed that the environmental correction K is less than or equal to 0,5 dB and is, therefore, negligible.

NOTE 18 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 environmental correction K may also be assumed to be negligible for indoor environments which are laboratory anechoic rooms meeting the requirements of annex A of ISO 3745:1977.

The evaluation of environmental influences is performed by selecting one of two alternative procedures used to determine the magnitude of the environmental correction K. 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 International Standard.

The first possibility for test (Absolute comparison test; see A.3) is carried out with a reference sound source.

Another possibility for test (Reverberation test; see A.4) 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 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 6, an environmental correction K can be determined according to the procedures given in this annex. In this case, K is usually smaller than 2 dB. For ratios $A/S < 6$, the room correction factor K may exceed 2 dB and cause greater uncertainty for the sound power level determinations than those given in table 3. In such cases, a smaller measurement surface, a better environment, or a measurement according to the survey method (see ISO 3746) should be chosen. 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 Environmental conditions

A.2.1 Properties of reflecting plane

Measurements may be made in one of the following environments:

— over a reflecting plane outdoors;

— in a test room with one reflecting surface, or

— in a test room with sound absorptive surfaces in which a reflecting plane is present.

NOTE 19 Particularly when the reflecting surface is not a ground plane or is not an integral part of a test room surface, care should be exercised to ensure that the plane does not radiate any appreciable sound 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 reference plane shall have acoustical characteristics approximating those of a perfect acoustical reflector over the frequency range of interest. For indoor measurements, a concrete floor is usually satisfactory. For outdoor measurements, a concrete or a smooth sealed asphalt surface should be satisfactory.

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) on the sound propagation over the frequency range of interest or on the background noise during the course of 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.

A.3 Absolute comparison test

A.3.1 Procedure

Mount a reference sound source with characteristics that meet the requirements of ISO 6926 in the test environment in essentially the same position as that of the source under test. Determine the sound power level of the reference sound source according to the procedures of clauses 7 and 8 without the environmental correction K (i.e., K is initially assumed equal to zero). The same measurement surface is used as during the measurements of the source under test. The environmental correction K, in decibels, is given by

$$K = L_W - L_{W\mathrm{r}}$$

where

L_W is the calculated A-weighted or band power level of the reference sound source using procedures of clauses 7 and 8 [with $K = 0$ in equation (2)], in decibels, reference = 1 pW (see ISO 3744);

$L_{W\mathrm{r}}$ is the name-plate A-weighted or band power level of the reference sound source, in decibels, reference = 1 pW.

A.3.2 Locations of reference sound source in test environment

A.3.2.1 Source can be removed from test site

The reference sound source shall be located on the reflecting plane, independent of the height of the machine. One single location is sufficient, even when very large machines are to be tested, provided the ratio of the length of the machine under test to its width is not greater than 2. If the ratio is greater than 2, the reference sound source shall be operated on the floor at four points. Assuming the projection of the machine under test on the floor to be approximately rectangular in shape, the four points are located at the middle points of the sides of the rectangle. To obtain L_W, the surface sound pressure level $\overline{L_{pf}}$ shall be calculated with the reference sound source located at each of the four points on the floor. At each point on the measurement surface, the sound pressure level shall be averaged for the four source locations on a mean-square basis, i.e., using equation (1) in 8.1.

A.3.2.2 Source cannot be removed from test site

The reference sound source shall be located on the upper surface of the machine which should preferably be acoustically reflective. This method should not be applied if the machine has highly absorptive surfaces (e.g. textile machines). In this case, the procedure given in A.4 should be followed.

A.3.3 Qualification requirements

For the measurement surface in a given test environment to be satisfactory for measurements according to the requirements of this International Standard, the environmental correction K shall be less than or equal to 2 dB. If the environmental correction K exceeds 2 dB, either a smaller measuring surface or a better test environment is required. The procedure shall be repeated. Alternatively, procedures using a reference sound source may be used or the guidelines given in ISO 3746 may be followed to determine the sound power levels of the source under test.

NOTE 20 Measurements procedures using a reference sound source, may yield sound power levels within the limits for the measurement uncertainty specified in 1.5, even for values of $K > 2$ dB.

A.4 Reverberation test

A.4.1 Test procedure

This test procedure is applicable to rooms that are approximately cubical in shape.

The environmental correction K is obtained from the expression

$$K = 10 \lg\left(1 + \frac{4}{A/S}\right) \text{ dB}$$

The value of K may be obtained from figure A.1 by entering the abscissa with the appropriate value of A/S. The area S of the measurement surface is calculated according to the requirements given in 7.1.

The total sound absorption A of the test room is determined from measurements of the reverberation time of the test room in octave bands for the entire frequency range of interest (see ISO 354).

The value of A is then

$$A = 0{,}16\ (V/T)$$

where

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

T is the reverberation time of the test room in octave bands, in seconds.

A.4.2 Qualification requirements

For the measurement surface in a test room to be satisfactory for measurements according to the requirements of ISO 3744, the ratio A/S should exceed 6.

If the above requirement cannot be satisfied, a new measurement surface shall be chosen. The new measurement surface should have a smaller total area, but still lie outside the near field (see 1.5). Alternatively, the ratio A/S may be increased by introducing additional sound-absorptive materials into the test room and then redetermining the value of the ratio A/S under the new conditions.

If the requirements of this clause cannot be satisfied for any measurement surface which lies outside the near field of the source under test, the particular environment chosen cannot be used for measurements on the source under test according to the requirements of this International Standard. A new test environment shall be selected or uncertainties exceeding the values given in table 3 shall be accepted.

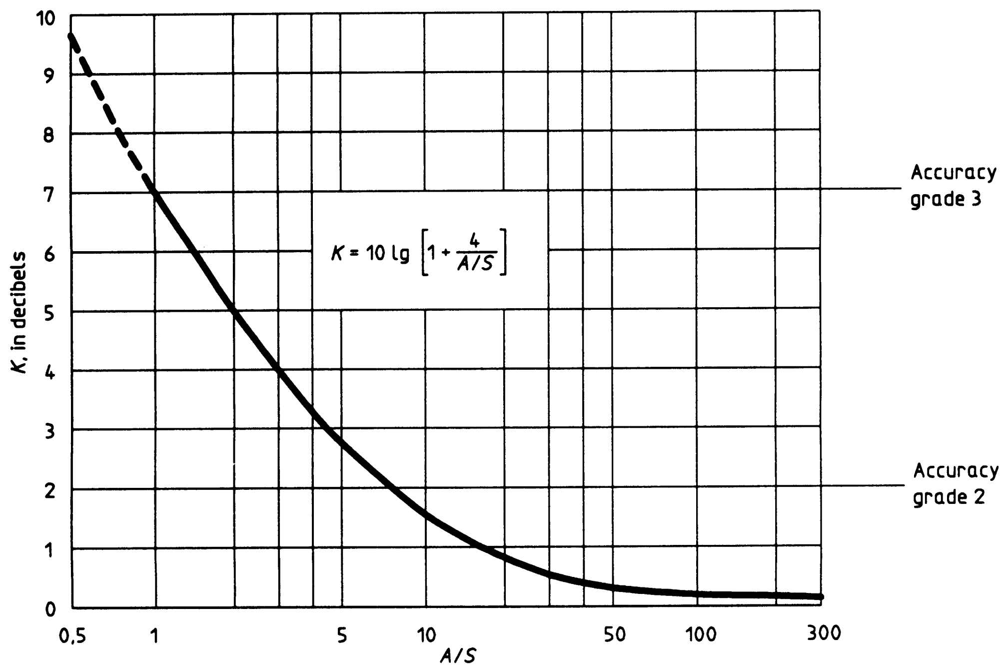


Figure A.1 — Environmental correction K, in decibels

Annex B
(informative)

Examples of suitable instrumentation systems

B.1 General

Basically, the instrumentation system consists of a microphone, an amplifier with filters, a squaring and averaging circuit, and an indicating device. There are several methods of processing or conditioning the filter outputs that may be used to obtain an estimate of the mean-square value of the output. These include use of detection equivalent to RC-smoothing, integration of the squared value of the filter outputs and digital methods. Some general aspects are described below.

B.1.1 RC-Smoothing, sound level meter

Many analog devices, including the sound level meter in accordance with IEC 651, employ RC-smoothing.

For the sound level meter set on time-weighting characteristic S, the average value of the meter deflection approximates the mean-square sound pressure level if the fluctuations are less than 5 dB.

NOTE 21 The microphone on the sound level meter should have a uniform frequency response at the angle of incidence specified by the manufacturer. A condenser microphone with a diameter of 13 mm will be suitable for this purpose. The microphone and its associated preamplifier (if any) should be placed in the test room and connected with the sound level meter by a cable that complies with the requirements of 5.2 of ISO 3744:1981. The system should be calibrated with the cable inserted between the preamplifier and sound level meter.

The sound level meter and the observer should be located in a room adjacent to the test room. The meter should be set on time-weighting characteristic S and the readings taken as described in 7.4.2 of ISO 3744:1981.

Other analog devices can provide smoothing with longer time-constants and should be used if the fluctuations exceed 5 dB.

B.1.2 Analog integrators

Another approach to r.m.s. detection is the "true" analog integrator that computes (approximately) the integral

$$e_{\text{r.m.s.}} = \left[\frac{1}{T} \int_0^T e_0^2(t)\ \mathrm{d}t \right]^{1/2}$$

where $e_0(t)$ is the filter output. The square and square roots are usually accomplished by non-linear analog elements. The integral may be computed either by conversion of $e_0(t)$ to a current and accumulation of charge on a capacitor, or by counting the number of cycles in a signal whose frequency is proportional to $e_0^2(t)$.

B.1.3 Digital systems

The r.m.s. value of the filter outputs may be determined by sampling, conversion to digital values, squaring and accumulating the results. The sampling rate can be either

a) high compared with highest frequency present in the filter output, or

b) relatively low compared with the highest frequency present, so that the resulting samples are (approximately) statistically independent.

In either case, the output of the detector after a specified time-interval should be within 3 % of the true r.m.s. value of the time function for all frequencies within the frequency range of interest.

B.2 Level recorders

A level recorder may be used either as a squaring, averaging and indicating device or exclusively as an indicating device.

In the first case, the time-constant of the instrumentation system is determined by the writing speed of the level recorder. Since the level recorder is a complicated electromechanical system, a simple rule for the determination of the resulting time-constant cannot be given. It is advisable to consult the manufacturer in this matter.

If the level recorder is used for indication only, the recorder will normally be set to record the d.c. output of a preceding squaring and averaging device, the time-constant of which will determine the resulting time-constant of the instrumentation system.

In both cases, the average value obtained will only be an acceptable approximation to the r.m.s. value if the pen fluctuations are less than 5 dB.

Annex C
(informative)

Calculation of directivity index and directivity factor using a hemispherical microphone array

The presence of a hard reflecting plane modifies the directivity pattern of a source. The directivity index and directivity factor may be obtained by considering the reflecting plane to be part of the source. The directivity index (DI) of the source may then be calculated, in decibels, from measurements in a free field above a reflecting plane by using the following equation:

$$\mathrm{DI} = L_{pi} - L_{pf} + 3 \qquad \text{. . . (C.1)}$$

where

L_{pi} is the sound pressure level, in decibels, measured in the particular direction in which DI is desired, at a distance r metres from the centre of the hemispherical measurement surface; reference = 20 µPa;

L_{pf} is the surface sound pressure level, in decibels, over the hemispherical measurement surface of radius r metres; reference = 20 µPa.

NOTE 22 In the report of the measurements, it may be sufficient to include only the highest value of DI and the direction in which it occurs. The directivity factor Q of the source, in a given direction, may be determined from the following equation:

$$Q = 10^{0,1\mathrm{DI}} \qquad \text{. . . (C.2)}$$

where DI is the directivity index in the same direction, in decibels, obtained from equation (C.1).

Annex D
(informative)

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