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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Acoustics — Measurement of sound pressure levels of gas turbine installations for evaluating environmental noise — Survey method

Acoustique — Mesurage des niveaux de pression acoustique dus aux installations à turbine à gaz pour l'évaluation du bruit dans l'environnement — Méthode de contrôle

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Foreword

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

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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Acoustics — Measurement of sound pressure levels of gas turbine installations for evaluating environmental noise — Survey method

1 Scope and field of application

1.1 Scope

This International Standard specifies a survey method for measuring sound pressure levels of a complete gas turbine installation at specified locations around the installation for the purpose of evaluating environmental noise.

It also outlines descriptions of factors influencing sound pressure levels around such an installation, which should be taken into consideration when specifications are being drawn up.

NOTE — It is not the purpose of this International Standard to give recommendations for the method of calculation of the sound power level of a complete installation. The determination of sound power levels for individual noise sources will be dealt with in a future International Standard.

1.2 Field of application

1.2.1 The method is applicable to land-based stationary installations powered by gas turbines in single or multiple arrangements.

The method may be applied, but is not limited, to gas turbines driving generators, compressors or pumps. It may include associated equipment, such as load equipment and, where applicable, waste heat recovery systems. The method is not applicable when the mechanical power output from the gas turbine(s) is only a small part of the total output of the installation.

1.2.2 Gas turbines used for propulsion of vehicles are excluded from this International Standard as are gas turbines installed in vehicles to provide electrical, pneumatic or mechanical power for their own internal use.

1.2.3 This International Standard may be used as a guide for methods of measurement of sound pressure levels from the gas turbine and its associated equipment, as defined in 1.2.1, but not for the specification of those sound pressure levels.

1.2.4 This International Standard does not provide information on calculation or measurement procedures in situations where knowledge of the noise level is required at distances in excess of 200 m, since physical phenomena affecting sound propagation are complex and variable. In such cases, the uncertainties may exceed the values described in this International Standard.

2 References

ISO 266, *Acoustics — Preferred frequencies for measurements.*

IEC Publication 225, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

IEC Publication 651, *Sound level meters.*

IEC Publication 804, *Integrating-averaging sound level meters.*

3 Definitions

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

3.1 sound pressure level, L_p, in decibels: Ten times the logarithm to the base 10 of the ratio of the mean square sound pressure of a sound to the square of the reference sound pressure:

$$L_p = 10 \lg \frac{p^2}{p_0^2} \qquad \ldots (1)$$

where

p is the root mean square sound pressure;

p_0 is the reference sound pressure (20 µPa).

3.2 equivalent continuous sound pressure level, L_{eq}, in decibels: The mean square sound pressure level during the measurement period:

$$L_{eq} = 10 \lg \frac{1}{T} \int_0^T \frac{p^2(t)}{p_0^2} dt \qquad \ldots (2)$$

where

$p(t)$ is the instantaneous sound pressure;

p_0 is the reference sound pressure (20 µPa);

T is the observation time, in seconds.

3.3 background noise: The sound pressure level at the microphone positions which is not generated by the installation being tested at that location and at the relevant time.

3.4 gas turbine installation: A gas turbine, its driven equipment and all those items of auxiliary equipment and their associated buildings and/or enclosures which are listed for the purpose of specifying noise limits.

3.5 maximum installation dimension, l: Maximum dimension, measured either horizontally or vertically, between the outermost points of the installation (see 6.1 and 7.2).

3.6 measurement distance, d: The distance between a microphone position and the nearest point on the minimum perimeter (without re-entrant angles) of the installation.

4 Criteria for relevant measurements

4.1 General

Apart from the design configuration, only three factors would normally affect the sound measured at a given operating condition and at an orientation and distance relative to a gas turbine installation. These factors are as follows:

a) atmospheric conditions;

b) background noise;

c) in some cases, surrounding topography.

4.2 Atmospheric conditions

Atmospheric conditions can affect generation and propagation of sound in gas turbine installations. Consequently, measurements should not be carried out during periods of rain or snow or when the average wind speed, measured 1,5 m above the ground and during a sufficient time, exceeds 3 m/s (exceptionally, an average wind speed of up to, but not exceeding, 5 m/s may be accepted and recorded in the test report). Exceptional conditions of temperature and humidity at the site should be avoided. Cloudy or night-time conditions with wind speeds in the range from 1 to 3 m/s are preferred to minimize unusual effects due to temperature gradients.

4.3 Background noise

At the microphone positions, the sound pressure level (weighted and in each octave band) of the background noise should be more than 10 dB and at least 3 dB below the sound pressure level with the source operating.

This margin may sometimes be improved by selecting a suitable time for carrying out the measurements or by changing one or more of the measurement positions within the limits specified in 7.2.

If this is not possible, the results determined with a higher background noise shall be corrected as specified in 9.2.

4.4 Topography

The topography of the site may affect the precision of the measurements; large reflecting surfaces, high buildings, modified ground absorption conditions and thick vegetation are all likely to affect the results. Any such factors shall be clearly identified in the test report.

5 Instrumentation

5.1 Sound level measuring system

A sound level measuring system that meets the requirements laid down for type 2 instruments in IEC Publication 651 shall be used with the S meter characteristic, with the frequency-weighting characteristics A and C and octave band filter capability.

NOTE — The F meter characteristic may be used to check that interfering events are not influencing the measurements.

The octave band filter set shall meet the requirements laid down in IEC Publication 225. The centre frequencies of the frequency bands shall correspond to those of ISO 266, from 31,5 Hz to 8 000 Hz.

5.2 Calibration

To ensure that the requirements of IEC Publications 225 and 651 are complied with, the measuring system shall be calibrated annually over its entire frequency range.

Before and after each series of measurements, an acoustical calibrator with an accuracy of ±0,5 dB shall be applied to the microphone to check the reference alignment of the entire measuring system, including cable and tape recorder, if used, at one or more frequencies.

One of these frequencies shall be in the nominal range from 250 HZ to 1 000 Hz. If there is a discrepancy exceeding 1,0 dB, the test series shall be repeated.

The field calibrator shall be checked annually to verify that its output has not changed.

5.3 Windscreen

A microphone windscreen shall be used. Its effect on the response of the sound level measuring system shall not exceed ±0,5 dB at frequencies below 2 000 Hz, and ±1 dB at frequencies from 2 000 Hz to 10 000 Hz.

6 Installation and operation of the gas turbine

6.1 Installation

The items of the installation for which the noise limits are to apply shall be specified. Any item of acoustical significance, regardless of whether it is essential for the operation of the installation or not and regardless of whether it emits sound or not, shall be included in the noise limits specification.

The items of the installation to be specified may include

— fired or unfired boilers;

— chimneys;

— steam turbines;

— cooling towers;

— fans;

— turbo-generators;

— compressors;

— transformers, etc.

NOTE — Items which are not essential for the operation of the installation or which do not emit sound may, nonetheless, affect the acoustical field of the installation.

The number of gas turbine units in operation simultaneously, for which the noise limits are applicable, shall be stated.

6.2 Gas turbine operation

All gas turbines and auxiliary equipment required for normal operation of the machine, throughout the range of operating conditions, shall be running at steady-state conditions and at the specified rated load, as required by the procurement specification.

If required, sources of temporary noise (such as starting devices, compressor bleeds, steam bleeds, etc.) shall be measured separately.

All enclosure doors and access panels shall be closed.

7 Measurement positions

7.1 General

The measurement positions shall be located at the specified measurement distance, d, from the installation, as defined in 3.6 and 7.2, and preferably with two positions on the main axis of the installation.

Precautions shall be taken to avoid unwanted barriers being situated between the measuring system and the gas turbine installation.

7.2 Measurement distance

The measurement distance d (see the figure) shall be selected and its value stated in the noise specification.

This specified measurement distance shall be one of the following:

$d = 100$ m for $l \leqslant 50$ m (preferred value for d)

$d = 150$ m for $50 \text{ m} < l < 100$ m

$d = 200$ m for $100 \text{ m} \leqslant l$

where l is the maximum installation dimension (see 3.5).

The measurement positions may be moved depending on local conditions (background noise, acccessibility, reflecting surfaces, screens, or topographical conditions) as defined in 8.3. If the distance has to be changed, it shall be as close as possible to the measurement distance, d, and in all cases shall not be greater than 200 m and not be less than 1,5 l or 50 m, whichever is the greater.

NOTE — If the difference between background noise and system noise is too low, additional measurements should be carried out at a closer distance (see also 4.3).

7.3 Number and location of measurement positions

The minimum number of measurement positions shall be eight, the points being approximately equally spaced (see the figure).

If the source contains directional components, the number of measurement positions shall be increased to indicate the magnitude of the directivity pattern.

7.4 Microphone position

The microphone shall be located between 1,4 and 1,6 m above ground level, or at greater heights if specified, and at least 3,5 m from walls, buildings or other sound-reflecting structures, except where otherwise specified.

8 Measurement of sound pressure levels

8.1 Quantities to be measured

Gas turbine installation environmental noise is specified by

a) mandatory measurements of A-weighted sound pressure levels;

b) optional measurements of C-weighted sound pressure levels, for example to display very low or very high frequency tones;

c) optional measurements of sound pressure levels in the nine octave bands with centre frequencies from 31,5 Hz to 8 000 Hz.

8.2 Specified level

The noise specification may include limits on either the maximum level at one or more of the measurement positions or the mean value determined from measurements at all the prescribed positions.

8.3 Test environment

The specification shall present topographic plans and data on the nature of the terrain and shall include details about reflecting surfaces and absorbing ground areas greater than 10 m^2, which are within $(d + 50)$ m of the installation (e.g. buildings, cooling towers, etc.).

NOTE — These factors may influence both the acoustical design of the installation and the measurement results.

In the absence of such a statement, the terrain is assumed to be a flat reflecting surface, without significant barriers or buildings.

8.4 Temporal characteristics of the sound

If the reading of the sound level meter varies over a range of no more than 5 dB, using the S meter characteristic, during the period of observation, the noise is considered to be steady for the purposes of this International Standard, and the level is taken to be the average of the maximum and minimum levels during the period of observation.

When the sound level varies over a range greater than 5 dB, the noise is considered to be non-steady and the levels to be noted are the minimum and maximum levels during the period of observation. In such a case, the determination of L_{eq} is required, using preferably an integrating sound level meter complying with IEC Publication 804 (or some temporal sampling scheme). The period of observation shall be long enough to give a representative indication of the range of fluctuation of the noise.

8.5 Background noise

The background noise shall be measured at each microphone position, using the A-weighting and, if required, C-weighting networks or each octave band filter, before and, if possible, after the gas turbine measurements.

If the background noise is non-steady, its level shall be determined as described in 8.4.

9 Calculation of sound pressure levels

9.1 Data correction for instrumentation

The first corrections to be applied to the readings shall be those relating to the instrumentation; these will include any factors for calibration, windscreen, microphone cable, etc.

9.2 Data correction for background noise

The sound pressure levels recorded at each of the microphone positions shall be corrected for the influence of the background noise in accordance with table 1.

Table 1 — Correction for background noise

Difference between sound pressure level measured with gas turbine operating and background sound pressure level alone dB	Correction to be subtracted from sound pressure level measured with gas turbine operating to obtain sound pressure level due to gas turbine alone dB
3	3
4	2
5	2
6	1
7	1
8	1
9	1
> 10	0

If the sound pressure level increases by 3 dB to 5 dB when the gas turbine is operating, the correction is applied but the results shall be given in brackets.

If the sound pressure level increases by less than 3 dB when the gas turbine is operating, the value may only be useful as an indication of the upper limit of the noise level produced by the installation.

9.3 Data correction for distance

If a measurement position is not at the specific distance d, a correction shall be applied, after any correction for background noise, using the following formula:

$$L_p(d) = L_p(d_1) - 20 \lg \frac{d}{d_1} \qquad \ldots (3)$$

where

d is the specified measurement distance;

d_1 is the actual measurement distance;

$L_p(d_1)$ is the sound pressure level, expressed in decibels, measured at distance d_1 and corrected for background noise.

This formula

a) assumes a hemispherical propagation from the nearest point of the installation;

b) disregards the effect of atmospheric absorption;

c) is not applicable when d_1 is less than 1,5 l.

If formula (3) is applied, the results shall be given in brackets.

All parties involved shall come to agreement on this procedure.

9.4 Data averaging

The mean sound pressure level of the installation shall be taken as the mean $\overline{L}_p(d)$ of the corrected measured levels at all positions around the installation.

Where the range of levels is 5 dB or less, the mean shall be taken as the arithmetic mean of the levels measured.

Where the range of levels is 6 dB or more, the mean sound pressure level shall be the level of the mean-square sound pressure obtained using the following formula:

$$\overline{L}_p(d) = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1\, L_{pi}(d)} \right] \qquad \ldots (4)$$

where

$L_{pi}(d)$ is the frequency-weighted or octave band sound pressure level, expressed in decibels, at position i;

N is the total number of measurement positions.

10 Measurement uncertainty

There is an uncertainty inherent in the measurements, mainly due to variations in meteorological conditions, operating conditions and to tolerances in the instrumentation.

Measurements carried out in accordance with this International Standard usually result in uncertainties which are less than or equal to those values given in table 2.

Table 2 — Uncertainties for sound pressure levels expressed in decibels

Frequency-weighted sound pressure levels		Centre frequencies of octave band sound pressure levels Hz		
A	C	31,5 to 125	250	500 to 8 000
3	5	5	4	3

The values given in table 2 reflect the cumulative effects of all causes of measurement uncertainty, excluding variations due to local topography.

11 Information to be reported

11.1 Gas turbine installation being tested

The following information shall be included in the test report:

a) purchaser or user;

b) location;

c) number of gas turbines, their model and manufacturer;

d) air intake temperature and atmospheric pressure;

e) load, shaft rotation speeds and operating conditions of the driven machine during the sound pressure measurements;

f) date and time of measurements;

g) description of gas turbines, driven equipment, auxiliary equipment and sound control treatment;

h) sketch of the installation with a scale and dimensions showing main items of installation, stack height, topographical and physical features and measurement positions (see the figure);

i) list of all equipment producing significant noise, in operation during measurements.

11.2 Acoustic environment

The following information shall be included in the test report:

a) description of the test environment (including a dimensioned sketch with a scale showing the location of source with respect to surrounding terrain, a physical description of the test environment, with position of significant buildings, structures or other reflecting objects, description of the ground surface surrounding the installation and proximity of other significant noise sources);

b) meteorological conditions at 1,5 m above ground, including temperature, relative humidity, wind speed and wind direction;

c) actual measurement distance, d_1, and reasons for moving the measurement positions from the specified distance.

11.3 Instrumentation

The following information shall be included in the test report:

a) name, manufacturer, model number, grade of precision, serial number of all equipment used;

b) method used to calibrate the instrumentation system;

c) date and place of calibration of the acoustical calibrator;

d) name of the personnel who carried out and observed the measurements.

11.4 Acoustical data

The following information shall be included in the test report:

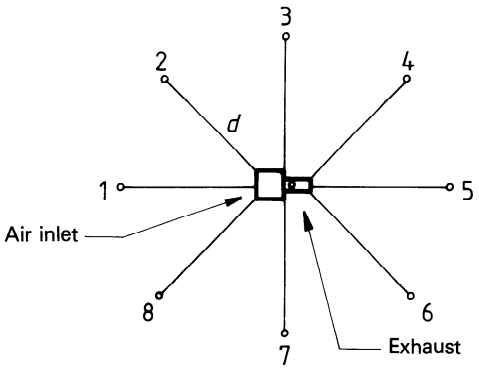
a) measured sound pressure levels at all microphone positions, reported to the nearest decibel (A-weighted, C-weighted and octave band sound pressure levels, if required; equivalent continuous levels, if required by time variations of sound level);

b) the corresponding levels of the background noise and the corresponding corrections, if any;

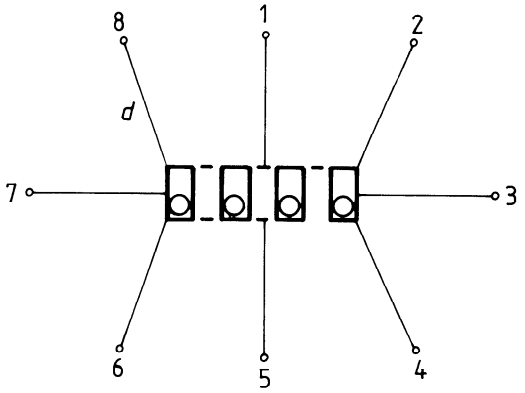
c) corrected sound pressure levels, $L_p(d)$, at the specified distance, d;

d) if required, mean sound pressure level, $\overline{L}_p(d)$, as determined in 9.4;

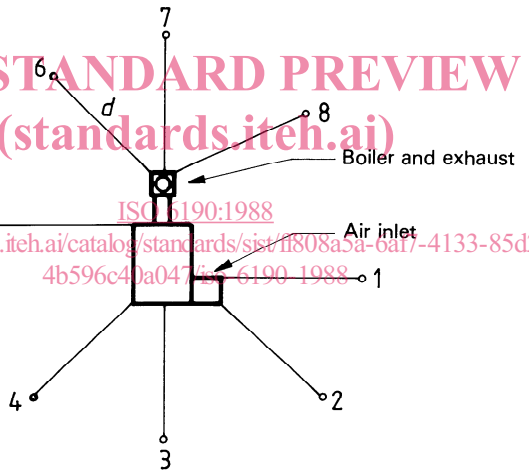
e) remarks on subjective impression of noise, with particular reference to time variations of noise level, audible discrete tones, spectral content, meteorological conditions, etc.



a) Package power plant (single unit)



b) Multiple unit



c) Gas turbine in building with separate air inlet and outdoor heat recovery boiler

Key

- ∘ Microphone positions
- *d* Specified measurement distance (preferably 100 m)

Figure — Microphone positions

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Descriptors : acoustics, turbines, gas turbine engines, tests, acoustic tests, determination, noise (sound).

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