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Acoustics — Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment — Engineering method

Acoustique — Détermination des niveaux de puissance acoustique d'installations industrielles multisources pour l'évaluation des niveaux de pression acoustique dans l'environnement — Méthode d'expertise

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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 voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 8297 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

Annex A of this International Standard is for information only.

Introduction

0.1 This International Standard specifies an engineering method for determining the sound power level of multisource industrial plants which is relevant to the assessment of the noise they contribute to points in the environment around the plant. It is based on measuring the sound pressure level on a closed path (measurement contour) surrounding the plant and determining an appropriate measurement surface.

The method is intended to be applied to large industrial plants having multiple noise sources under any specified operating conditions and to other large sources provided that they can be assumed to radiate substantially uniformly in all horizontal directions.

The method described in this International Standard complies with the general recommendations given in ISO 2204.

0.2 Data obtained using this International Standard are suitable for the following purposes.

a) To calculate the sound pressure level at given points around a plant under specified weather conditions provided that the distance of such points from the geometrical centre of the plant area is at least 1,5 times the greatest dimension of the plant area (see figure 1). All individual sources within the plant area are thereby treated as a single point source at the geometrical centre of the plant.

b) To identify industrial areas or particular parts of such areas in terms of their contribution to the sound pressure levels at given points in the environment.

c) To compare different sources (complete plants or component installations) in terms of their sound power level.

d) To monitor the noise emission of a plant.

Acoustics — Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment — Engineering method

1 Scope

1.1 General

This International Standard specifies an engineering method (grade 2, as defined in ISO 2204) for determining the sound power levels of large multisource industrial plants relevant to the evaluation of sound pressure levels in the environment. These sound power levels may be used in an appropriate prediction model for such an evaluation.

The method is limited to large industrial plants with multiple noise sources (a combination of an unspecified number of individual sources) having their main dimensions in the horizontal plane, and which radiate sound substantially uniformly in all horizontal directions.

Unweighted sound pressure levels are measured in octave bands.

The results obtained are expressed both in octave-band sound power levels and, if required, in A-weighted sound power levels.

1.2 Type and size of noise source

The method is applicable to industrial areas where most of the equipment operates outdoors, not enclosed by a building, e.g. petrochemical complexes, factories, stone quarries, crushing plants and pithead installations. The method is also applicable when there are moving sources performing cyclic or continuous operations, such as drag lines or cable conveyors, provided that the measurements can be related to at least one cycle of operation.

It is applicable to industrial plants in which the largest horizontal dimension of the plant area lies between 16 m and approximately 320 m.

1.3 Types of noise

This International Standard applies to sources which radiate broad-band noise, narrow-band noise, discrete tones, repetitive impulsive noise and combinations of such components. The procedure given is applicable to steady noise and to non-steady noise provided that it is statistically stationary. It is not suitable for measuring isolated bursts of sound energy. The method is best suited for broad-band steady noise.

1.4 Measurement uncertainty

The uncertainty inherent in the method due to the layout of the plant depends mainly on the average distance, $\bar{d}$, between the measurement contour and the boundary of the plant, in relation to the square root of the plant area, S_p, and is given in table 1.

Table 1 — Uncertainty inherent in the method

Value of $\bar{d}/\sqrt{S_p}$	Uncertainty 1) dB
0,05	$^{+3,0}_{-3,5}$
0,1	± 2,5
0,2	$^{+2,0}_{-2,5}$
0,5	$^{+1,5}_{-2,0}$

1) Expressed as a 95 % confidence interval for one determination.

These uncertainties arise from spatial variations in the sound pressure levels (averaged over time) at the different measurement positions, owing to the inhomogeneous distribution of sound sources within the plant. They do not include uncertainties due to variations in the noise emissions of the sources over a period of time.

NOTE 1 In cases where background noise corrections in accordance with 9.5.4 cannot be applied, the uncertainties may be greater than those given in table 1.

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 266:1975, *Acoustics — Preferred frequencies for measurements.*

ISO 1996-1:1982, *Acoustics — Description and measurement of environmental noise — Part 1: Basic quantities and procedures.*

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

ISO 3744:1994, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane.*

IEC 225:1966, *Octave, half-octave and third-octave band filters intended for the analysis of sound and vibrations.*

IEC 651:1979, *Sound level meters.*

IEC 804:1985, *Integrating-averaging sound level meters.*

IEC 942:1988, *Sound calibrators.*

3 Definitions

For the purposes of this International Standard, the following definitions apply. (See also figure 1.)

3.1 sound power level: The sound power level of the plant which is relevant to the calculation of the sound pressure level in the environment at a position remote from the plant. It is expressed in decibels.

It is ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. The reference sound power is 1 pW $(10^{-12}\ \text{W})$.

The width of a restricted frequency band shall be indicated: for example octave-band sound power level, one-third octave-band sound power level, etc.

Sound power level is denoted by the following symbols according to context:

L_W (for frequency bands);

L_{WA} (for A-weighted sound power level).

NOTE 2 The sound power level of the plant, as determined by this International Standard, may differ from the sum of the sound power levels of the individual sources in the plant.

3.2 sound pressure level, L_p: 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. It is expressed in decibels. The reference sound pressure is 20 μPa.

The width of a restricted frequency band shall be indicated, for example, octave-band sound pressure level, one-third octave-band sound pressure level, etc.

3.3 plant area, S_p: The area in which all the sources of the plant are contained. It is expressed in square metres.

3.4 measurement area, S_m: The total area enclosed by the measurement contour. It is expressed in square metres.

3.5 measurement distance, d**:** The distance from the measurement position being considered to the nearest point on the perimeter of the plant area. It is expressed in metres.

3.6 distance between measurement positions, D_m**:** The distance between adjacent measurement positions, measured along the measurement contour. It is expressed in metres.

3.7 characteristics height of the plant, H**:** The average height of the noise sources within the plant. It is expressed in metres.

3.8 equivalent continuous sound pressure level, $L_{eq,T}$**:** The value of the sound pressure level of a continuous steady sound that within a measurement time interval, T, has the same mean-square sound pressure as the sound under consideration the level of which varies with time. It is expressed in decibels.

The equivalent continuous sound pressure level over the measurement time interval, T, is given by the following equation:

$$L_{eq,T} = 10 \lg \left[\frac{1}{T} \int_0^T \frac{p_t^2}{p_0^2} dt \right] \text{dB}$$

where

p_0 is the reference sound pressure (= 20 µPa);

p_t is the instantaneous sound pressure of the sound signal, in pascals.

4 Symbols

Symbols used throughout this International Standard are as follows.

d	Measurement distance, in metres
$\bar{d}$	Average measurement distance, in metres
D_m	Distance between measurement positions (microphone positions), in metres
h	Microphone height, in metres
h_k	Height of the midpoint of the kth noise source, in metres
H	Characteristic height of the plant, in metres
i	Designation of the ith microphone position
l	Length of the measurement contour, in metres
$L_{eq,T}$	Equivalent continuous sound pressure level determined over a measurement time interval, T, in decibels
$\overline{L_p}$	Octave-band sound pressure level averaged over the measurement contour, in decibels
$\overline{L_p^*}$	Corrected average octave-band sound pressure level along the measurement contour, in decibels
L_{pi}	Octave-band sound pressure level at the ith microphone position on the measurement contour, in decibels
L_W	Sound power level of the plant for the evaluation of sound pressure levels in the environment in a given octave band, in decibels
L_{WA}	A-weighted sound power level of the plant for the evaluation of sound pressure levels in the environment, in decibels
n	Number of noise sources in the plant
N	Total number of microphone positions along the measurement contour
p_0	Reference sound pressure (= 20 µPa)
p_t	Instantaneous sound pressure, in pascals
S_m	Measurement area, in square metres
S_0	Reference area $\left(= 1 \text{ m}^2 \right)$
S_p	Plant area, in square metres
α	Sound attenuation coefficient for air, in decibels per metre
ΔL_α	Sound attenuation due to atmospheric absorption, in decibels
ΔL_F	Near-field error
ΔL_M	Correction term for a directional microphone, in decibels
ΔL_S	Area term, in decibels
θ	Angle at which the sensitivity of a directional microphone has fallen by 3 dB, in degrees

ϕ Aspect angle subtended at a microphone position by the extremities of the perimeter of the plant area, in degrees

5 Principle of measurement procedure

Plot a simply shaped closed path (measurement contour) surrounding the plant area (see 9.1). Measure the sound pressure level at equidistant microphone positions along the contour and calculate the average sound pressure level. Make corrections for proximity error, microphone directionality and air absorption (steps 5, 6 and 7 in clause 10). Calculate an appropriate area for the measurement surface, taking into account the area enclosed by the contour, the contour length and the microphone height (step 4 in clause 10), and use this to determine the relevant sound power level.

If the plant includes individual noise sources that are significantly elevated above ground, identify them and make additional measurements of the sound power levels of such sources.

6 Acoustic environment

Ensure, as far as is practicable, that the environment around the microphone positions complies with the following requirements:

a) there shall be no reflecting surfaces outside the measurement contour which can affect the sound pressure level measurements;

b) background noise levels shall be at least 6 dB, and preferably more than 10 dB, below the sound pressure level to be measured in each frequency band;

c) the wind speed and direction shall not change significantly during a set of measurements around the measurement contour.

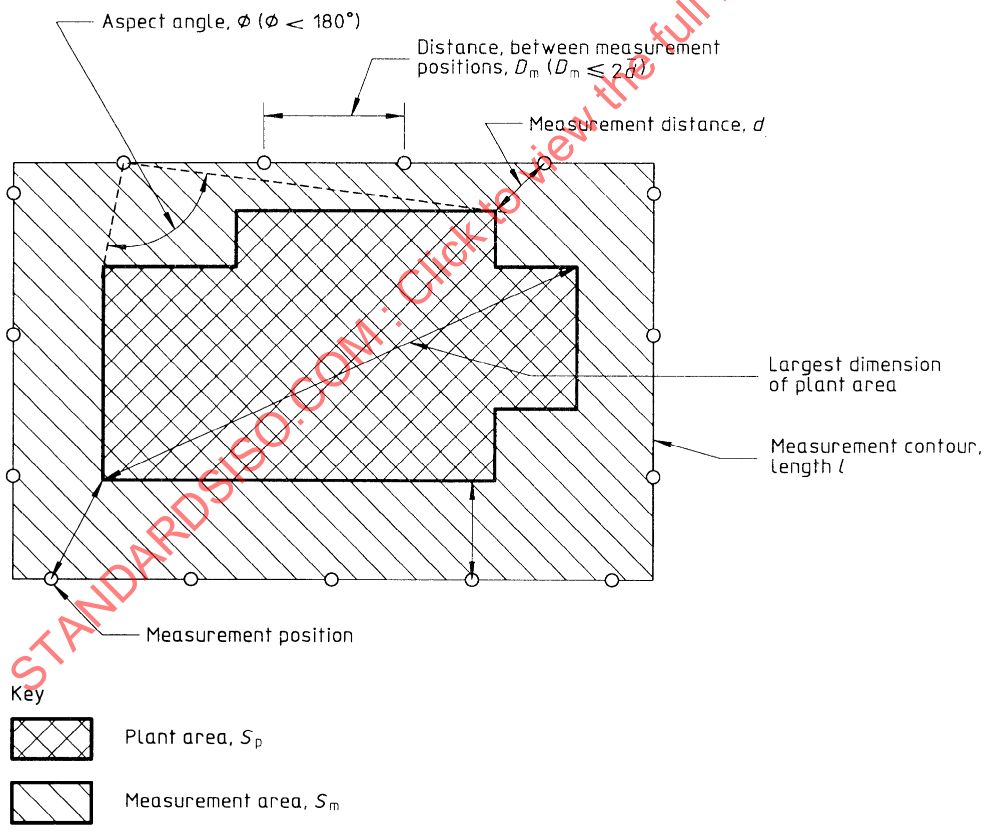

Figure 1 — General arrangement of measurement positions on the measurement contour around the plant

Report any deviations from the above requirements.

NOTES

3 The influence of background noise can be reduced by the use of a directional microphone.

4 The principal sources of background noise are nearby industrial installations, road traffic and natural sounds.

7 Instrumentation

7.1 General

The instrumentation shall indicate the sound pressure level in octave bands so that an average value can be obtained over the measuring time. It may perform the time integral for the measurement time interval required by ISO 1996-1.

If available, an integrating-averaging sound level meter complying with the requirements of IEC 804 for a type 1 instrument shall be used. If this is not available, and provided that the plant noise is steady, it is permissible to use a sound level meter complying with the requirements of IEC 651 for a type 1 instrument.

NOTE 5 The use of a directional microphone can assist in reducing background noise from directions other than from the plant.

If a directional microphone is used, the directional characteristics shall be such that, for each octave band, the angle, θ, at which the sensitivity falls by 3 dB, shall exceed $\pm$ 30° and a correction in accordance with 10.6 shall be applied.

7.2 Octave-band analyser

An octave-band filter set complying with the requirements of IEC 225 shall be used. The centre frequencies of the frequency bands shall correspond to those of ISO 266.

7.3 Calibration

During each series of measurements, an acoustical calibrator in accordance with IEC 942 class 1 shall be applied to the microphone to verify the calibration of the entire measuring system at one or more frequencies over the frequency range of interest. The calibrator shall be checked at least once every year to verify that its output has not changed. In addition, an acoustic and an electrical calibration of the instrumentation system over the entire frequency range of interest shall be carried out at least every 2 years.

8 Operating conditions of the plant

If the plant operates in various modes, a separate set of measurements shall be made for each mode and a separate set of sound power levels shall be calculated. As far as is feasible, the mode of operation shall be long enough and steady enough for one complete set of measurements around the measurement contour. If this is not feasible, the mode shall be sufficiently repeatable for the measurements to be made at different measurement positions during its successive occurrences. The measurement time interval at each measurement position shall be sufficient to include all the variations of noise emission during the mode, including any repetitive impulsive noise.

9 Procedure

9.1 Measurement contour

9.1.1 Requirements for the measurement contour

The microphone positions shall lie on a closed path (measurement contour) around the plant area (see figure 1) and all the following requirements shall apply:

a) the average measurement distance, $\bar{d}$, shall exceed $0{,}05\sqrt{S_p}$ or 5 m, whichever is the greater, but shall not exceed $0{,}5\sqrt{S_p}$ or 35 m, whichever is the lesser.

   The average measurement distance, $\bar{d}$, shall be as large as the effects of background noise permit; the quotient $\bar{d}/\sqrt{S_p}$ shall be determined with an accuracy better than $\pm$ 30 %;

b) from any point on the measurement contour, the plant area shall be seen inside an aspect angle, θ, not greater than 180° (see figure 1);

c) the distance between adjacent measurement positions, D_m, on the measurement contour shall not be greater than $2\,\bar{d}$ (see figure 1).

9.1.2 Determining the measurement contour

9.1.2.1 Using a plot plan of the plant or a suitable map, draw a preliminary measurement contour around the plant area to comply with the requirements laid down in 9.1.1 a) and 9.1.1 b). Mark the measurement positions on this contour on the basis of the measurement laid down in 9.1.1 c).

9.1.2.2 Measure on the plan the distance d, in metres, from each measurement position to the nearest point on the plant perimeter and determine the mean value $\bar{d}$ according to the formula

$$\bar{d} = \frac{1}{N} \sum_{i=1}^{N} d_i$$

9.1.2.3 If the first measurement contour does not comply with the requirements of 9.1.1 a) and 9.1.1 b), select another measurement contour.

9.1.2.4 As far as is practicable, space the measurement positions equidistantly along the measurement contour; however, if particular positions have to be omitted owing to inaccessibility (occasioned, for example, by a river or canal) or to the presence of acoustic irregularities (occasioned, for example, by walls or buildings), report such omissions. If the number of omitted measurement positions exceeds 10 %, select an alternative measurement contour.

NOTE 6 In general, one stage of iteration should be sufficient to establish a satisfactory measurement contour on the plan, but further stages should be carried out if necessary.

A final check on the suitability of measurement positions should be carried out on the site.

9.2 Plant dimensions to be determined

When a satisfactory measurement contour has been drawn on the plot plan, determine the following dimensions with an accuracy better than ± 5 %:

a) the length of the measurement contour, l;

b) the measurement area, S_m;

c) the characteristic height of the plant, H.

Determine the height H from the average height of the noise sources in the plant, as derived from equipment lists and elevation drawings, using the following equation:

$$H = \frac{1}{n} \sum_{k=1}^{n} h_k$$

NOTE 7 Where the plant contains ten or more sources of heights less than 2 m, the average height may be taken as 1 m and their number in the above summation may be estimated to an accuracy of ± 10 %.

9.3 Microphone height

At each measurement position the height of the microphone above the ground, h, shall either be taken as the value calculated using the following equation

$$h = H + 0{,}025\sqrt{S_m}$$

or be 5 m, whichever is the greater.

If, for practical reasons, the microphone height required by this condition cannot be met, place the microphone as high as possible above the minimum height of 5 m and report this fact.

9.4 Microphone direction

At each measurement position, direct the reference direction of the microphone as specified in IEC 651 towards the plant area in such a way that this reference direction is horizontal and at an angle of 90° to the measurement contour.

9.5 Measurements of sound pressure level

9.5.1 General

In the case of steady noise, make measurements for a long enough time at each measurement position to ensure that the noise is steady. In any octave band, the measurement time interval shall be at least 1 min.

In the case of non-steady noise, varying or impulsive noise, use an integrating-averaging sound level meter.

Take the following measurements at each microphone position.

a) The sound pressure levels in octave bands from 63 Hz to 4 000 Hz during operation of the plant.

NOTE 8 Additional measurements may be made in the 31,5 Hz and 8 000 Hz bands.

b) The octave-band sound pressure levels produced by the background noise, if the plant operation can be stopped during a set of measurements. If the measurements of background noise are made at a different time of day from the plant measurements (e.g. at night), they are only valid if it can be shown that the background noise has not changed. This should be indicated by separate measurements of the background noise at positions where the plant noise is insignificant.

9.5.2 Measurements using a sound level meter

If a conventional sound level meter is used, switch to the time-weighting characteristic S. When the range of the fluctuations of the indicating pointer on the sound level meter is less than 5 dB, consider the noise to be steady for the purposes of this International Standard, and take the level to be the arithmetic mean of the maximum and minimum levels during the period of observation. If the range of the meter fluctuations during the period of observation is greater than 5 dB, consider the noise to be non-steady and use an instrument with an integrating system.

9.5.3 Measurements using integrating systems

If an instrument with an integrating system is used, the parameter measured is the steady value of the equivalent continuous sound pressure level, $L_{\mathrm{eq},T}$, at each measurement position which does not fluctuate by more than $\pm$ 0,5 dB. Use this as the value for L_{pi} in 10.1.

9.5.4 Correction for background noise

If the background noise level can be measured separately, correct the measured sound pressure levels of the plant plus background noise to allow for the background noise according to table 2.

Table 2 — Corrections for background noise

Values in decibels

Difference between sound pressure level measured with plant operating and background sound pressure level alone	Correction to be subtracted from sound pressure level measured with plant operating to obtain sound pressure level due to plant alone
< 6	Measurement invalid
6	1
7	1
8	1
9	0,5
10	0,5
> 10	0

If the background noise level cannot be measured separately because the plant cannot be stopped, and the measured sound pressure levels cannot be corrected, state this in the report and give a qualitative assessment of the possible error due to the background noise.

NOTE 9 In some cases, for example with background noise from road traffic, it may be possible to assess this by calculation.

10 Calculation of sound power levels for evaluating levels in the environment

NOTE 10 Throughout clause 10, reference should be made to clause 4 for explanation of the symbols used.

10.1 Step 1

Calculate the average sound pressure level along the measurement contour, $\overline{L_p}$, in decibels, for each octave band from the following equation:

$$\overline{L_p} = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L_{pi}} \right] \text{ dB}$$

10.2 Step 2

If any value of L_{pi} exceeds the average $\overline{L_p}$ by more than 5 dB, select a new measurement contour at a greater distance from the plant. If this is not practicable, replace all values of L_{pi} which exceed the average $\overline{L_p}$ by more than 5 dB by $L_{pi}^{*} (= \overline{L_p} + 5 \text{ dB})$.

10.3 Step 3

Calculate a second corrected average sound pressure level around the measurement contour, $\overline{L_p^{*}}$, in decibels, for each octave band from the following equation:

$$\overline{L_p^{*}} = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L_{pi}^{*}} \right] \text{ dB}$$

where L_{pi}^{*} is the octave-band sound pressure level at the ith position after being corrected in accordance with 10.2.

10.4 Step 4

Calculate an area term, ΔL_S, in decibels, for the measurement surface (as defined in ISO 3744) using the following equation:

$$\Delta L_S = 10 \lg \left(\frac{2S_m + hl}{S_0} \right) \text{ dB}$$

where S_0 is a reference area equal to 1 m^2.

10.5 Step 5

Calculate a proximity correction term, ΔL_F, in decibels, from the following equation:

$$\Delta L_F = \lg \frac{\bar{d}}{4\sqrt{S_p}} \text{ dB}$$

NOTE 11 When the requirements of 9.1 are satisfied, ΔL_F may be expected to lie between − 0,9 dB and − 1,9 dB.

10.6 Step 6

Calculate a microphone correction term, ΔL_M, in decibels, from the following equation:

$$\Delta L_M = 3\left(1 - \frac{\theta}{90}\right) \text{ dB}$$

where $\Delta L_M = 0$ dB for an omnidirectional microphone.

10.7 Step 7

Calculate the sound attenuation term (due to atmospheric absorption), ΔL_α, in decibels, from the following equation:

$$\Delta L_\alpha = 0{,}5\alpha\sqrt{S_m} \text{ dB}$$

Typical values of α taken from ISO 3891 are given in table 3.

Table 3 — Decrease in sound pressure level during free propagation due to absorption in the air

Octave-band centre frequencies Hz	α dB/m
31	0
63	0
125	0
250	0,001
500	0,002
1 000	0,005
2 000	0,01
4 000	0,026
8 000	0,046

Values for each octave band given in table 3 are valid at a temperature of 15 °C and an average relative humidity of 70 %. If weather conditions differ markedly from these, use the appropriate values of air absorption for the temperature and relative humidity at the time of the noise measurements.

10.8 Step 8

Calculate the octave band sound power level, L_W, in decibels, from the following equation:

$$L_W = \overline{L_p} + \Delta L_S + \Delta L_F + \Delta L_M + \Delta L_\alpha$$

If steps 2 and 3 (see 10.2 and 10.3) have to be applied, replace $\overline{L_p}$ by $\overline{L_p^*}$.

10.9 Step 9

If required, calculate the A-weighted sound power level, L_{WA}, in decibels, from the following equation:

$$L_{WA} = 10 \lg \sum 10^{0,1(L_{Wj} + C_j)} \text{ dB}$$

where C_j is the A-weighting correction for the jth octave band.

The summation is taken over the appropriate octave bands.

11 Noise sources significantly elevated above the characteristic height of the plant

If the plant includes significantly elevated noise sources and if, owing to screening and/or directional characteristics of these sources, they did not feature in step 2 (see 10.2), identify them and determine their sound power levels in accordance with other applicable standards.

12 Information to be reported

The test report shall contain the statement that the sound power levels for the evaluation of sound pressure levels in the environment have been obtained in compliance with the requirements and the procedures of this International Standard.

The report shall contain at least the following information:

a) a map of the plant and the surrounding area, showing the outline of the plant area, the measurement contour and the measurement positions on the measurement contour, including the location of any background noise sources and reflecting structures and objects which may have affected the measured sound pressure levels; the locations of any sources measured independently (see clause 11) shall also be reported;