International Standard ISO 1680/2

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Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machinery — Part 2 : Survey method

Acoustique — Code d'essai pour le mesurage du bruit aérien émis par les machines électriques tournantes — Partie 2: Méthode de contrôle

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Foreword

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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.

International Standard ISO 1680/2 was prepared by Technical Committee ISO/TC 43, *Acoustics*.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

It cancels and replaces ISO Recommendation R 1680-1970, of which it constitutes a technical revision.

Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machinery — Part 2: Survey method

0 Introduction

This part of ISO 1680 is based on ISO 3746 and has been drafted in accordance with ISO 3740.

The main purpose of this part of ISO 1680 is to specify a survey method requiring less effort for the measurements than laid down in the engineering method (see ISO 1680/1) and which, in general, results in a lower grade of accuracy. It may also be applied in those cases where one or several conditions (such as operating conditions, number or positioning of microphones) for an otherwise engineering type of measurement cannot be obtained.

1 Scope and field of application

1.1 General

This part of ISO 1680 defines a measurement method for rotating electrical machines operating under steady noise conditions, the result of which can be expressed in sound power levels so that all machines tested using this code can be directly compared.

This part of ISO 1680 applies to the measurement of airborne noise from rotating electrical machines, such as motors and generators (d.c. and a.c. machines) of all sizes, when fitted with all auxiliaries which are necessary to achieve the agreed operating conditions (see clause 6).

This part of ISO 1680 requires the sound pressure levels to be measured on a rectangular parallelepiped surface enveloping the machines from which the A-weighted sound power level produced by the machine is calculated. It outlines the procedures which shall be used to evaluate the test environment and specifies the characteristics of suitable measuring instruments.

This part of ISO 1680 applies to measurements carried out in environmental conditions that meet the criteria given in clause 4 and annex A (environmental correction $K \leqslant 7$ dB, correction for background noise $\leqslant 3$ dB).

1.2 Measurement uncertainty

Measurements carried out in conformity with this part of ISO 1680 usually result in standard deviations which are equal to or less than those given in table 1.

Table 1 — Uncertainty in determining A-weighted sound power level by the survey method

Application	Standard deviation dB
For a source which produces sounds that contain prominent discrete tones	5
For a source which produces broad-band sounds without prominent discrete tones	4

NOTES

1 The standard deviations in table 1 include the effects of allowable variations in the positioning of the measurement positions and in the selection of the stipulated measurement surface.

2 The standard deviations given in table 1 reflect the cumulative effects of all causes of measurement uncertainty, excluding variations in the sound power level 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 results may be considerably better (that is, smaller standard deviations) than the uncertainties given in table 1 would indicate.

3 If the method specified in this part of ISO 1680 is used to compare the A-weighted sound power levels of similar machines which radiate noise acoustically omnidirectional and broad-band in its character, the uncertainty in comparison tends to result in a standard deviation which is equal to or less than 3 dB, provided that the measurements are carried out in the same environment.

4 The standard deviations given in table 1 may be higher when the environmental correction, K, established in accordance with the procedure given in annex A, exceeds 7 dB.

2 References

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

ISO 1680/1, *Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machinery — Part 1: Engineering method for free-field conditions over a reflecting plane.*

ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards and for the preparation of noise test codes.*

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

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

ISO 6926, *Acoustics — Determination of sound power levels of noise sources — Characterization and calibration of reference sound sources.*[1)]

IEC Publication 34-1, *Rotating electrical machines — Part 1: Rating and performance.*

IEC Publication 651, *Sound level meters.*

3 Definitions

For the purposes of this part of ISO 1680, the following definitions apply.

3.1 sound pressure level, L_p, **in decibels:** Twenty times the logarithm to the base 10 of the ratio of the sound pressure to the reference sound pressure. The weighting network used shall be indicated: for example, A-weighted sound pressure level, L_{pA}. The reference sound pressure is 20 µPa.

3.2 surface sound pressure level, $\overline{L_{pf}}$, **in decibels:** The sound pressure level averaged over the measurement surface and corrected as required in clause 8. The weighting network used shall be indicated: for example, A-weighted surface sound pressure level, $\overline{L_{pAf}}$. The reference sound pressure is 20 µPa.

3.3 sound power level, L_W, **in decibels:** Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. The weighting network used shall be indicated: for example, A-weighted sound power level, L_{WA}. The reference sound power is 1 pW ($= 10^{-12}$ W).

3.4 measurement surface: A hypothetical surface of area S enveloping the source on which the microphone positions are located and which terminates on the reflecting plane.

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

3.6 measurement distance: The minimum distance between the reference box and the measurement surface.

3.7 background noise: The sound pressure level at each microphone position with the source inoperative.

4 Acoustic environment

4.1 Criteria for adequacy of the test environment

Test environments that meet the qualification requirements of annex A are suitable for measurements in accordance with this part of ISO 1680. The test environment shall be adequately isolated from extraneous noise (see 4.2).

To comply with this part of ISO 1680, the environmental correction K shall not exceed 7 dB.

4.2 Criterion for background noise

At each microphone position, the A-weighted sound pressure level of the background noise shall be at least 3 dB below the A-weighted sound pressure level with the source operating.

NOTE — Results determined with higher levels of background noise are not in accordance with this part of ISO 1680, but may be useful as an indication of the upper limit of the sound power level of the source.

The effects of noise sources other than the rotating electrical machine, for example coupled machinery (see 6.3) or wind (see 4.3) which may increase the background noise shall be minimized.

4.3 Wind

The wind velocity existing at the test site or caused by the machine under test shall be less than 6 m/s. A windscreen should be used for wind velocities above 1 m/s to ensure that the level of the background noise (caused by the cumulative effect of the wind and other background noise sources) is at least 3 dB below the level with the source operating.

5 Instrumentation

5.1 General

A sound level meter that meets the requirements for a type 1 instrument in accordance with IEC Publication 651 shall be used with the time weighting "S".

The observer shall not stand between the microphone and the source, the sound power level of which is being determined.

5.2 Calibration

At least before each series of measurements, an acoustical calibrator with an accuracy of ±0,5 dB shall be applied to the microphone to calibrate the entire measuring system, including cable, if used, at one or more frequencies. One calibration frequency shall be in the range from 250 to 1 000 Hz. The calibrator shall be checked annually to verify that its acoustical output has not changed.

1) At present at the stage of draft.

6 Installation and operation of the machine

6.1 Machine mounting

If practicable, the machine should be mounted in the same way as it would be for normal usage. Care should be taken to minimize the transmission and the radiation of structure-borne noise from all mounting elements including the foundation. Usually, this minimizing can be achieved by resilient mounting for smaller machines. Larger machines can usually only be tested under rigid mounting conditions.

6.1.1 Resilient mounting

The natural frequency of the support system and the machine under test shall be lower than a quarter of the frequency corresponding to the lowest rotational speed of the machine.

The effective mass of the resilient support shall not be greater than 1/10 of that of the machine under test.

6.1.2 Rigid mounting

The machines shall be rigidly mounted to a surface with dimensions adequate for the machine type (for example by foot or flange fixed in accordance with the manufacturer's specifications). The machine shall not be subject to additional mounting stresses from incorrect shimming.

The mass of the support shall be at least twice that of the machine under test.

6.2 Operation of machine during test

The machine shall operate at no load, at rated voltage(s) and speed(s) and with the corresponding excitation(s) (see IEC Publication 34-1).

For a.c. machines, the sinusoidality of the supply voltage and the degree of unbalance of the supply voltage system shall comply with the same limits that are specified in IEC Publication 34-1.

Synchronous machines shall be run with the excitation current which permits the rated voltage at no load.

For machines not suitable for no-load operation, e.g. machines with the behaviour of series-wound motors, the operating conditions shall be agreed upon and stated in the test report.

A method for estimating the difference in the level of the noise from a machine between no-load operating conditions and rated load or any other specified load is given in annex B.

6.3 Auxiliary equipment and coupled machines

All auxiliary equipment (loading machines, gears, transformers, external cooling systems) and coupled machines which are necessary for the operation of the machine under test, but which do not form an integral part of the machine, shall not significantly affect the noise measurement (see 8.1). If they do, they should be shielded acoustically or located outside the test environment.

7 Sound pressure levels on the measurement surface

7.1 Reference box and measurement surfaces

In order to facilitate the positioning of the microphone positions, a hypothetical reference box is defined (see 3.5). When defining the dimensions of this reference box, elements protruding from the machine which are unlikely to be major radiators of sound energy may be disregarded.

The microphone positions lie on the measurement surface (see 3.4).

For rotating electrical machines, regardless of their size, the measurement surface shape is a rectangular parallelepiped (see figures 2 to 4) the sides of which are parallel to the sides of the reference box and spaced out at a distance d (measurement distance) from the reference box.

The measurement distance, d, shall be at least 0,15 m. Distances larger than 1 m may be excluded by the environmental requirements given in this part of ISO 1680 (see clause 4 and annex A). The preferred measurement distance is 1 m.

7.2 Microphone array

7.2.1 Complete measurement position array

From figure 1, the principle of how to construct the measurement array for different sizes of reference box can be derived.

Each side of the measurement surface shall be treated separately. If the length or width of the side of the measurement surface under consideration exceeds $3d$, this side is divided into a minimum number of partial areas so that their lengths and widths do not exceed $3d$ (see figure 1).

To comply with the survey method of this part of ISO 1680, one measurement position is placed at the middle of each partial area.[1)]

The resulting complete measurement array is shown in figures 2 to 4 for different sizes of the reference box.

1) The array is not in complete accordance with ISO 3746 but in principle. The modification was made to achieve compatibility with the measurement array for the engineering method (see ISO 1680/1), for which additional measurement positions are placed at the corners of each partial area, except at those corners which lie in the reflecting plane.

For irregularly shaped machines (see figure 5), the measurement array is fixed according to the same procedure.

Neighbouring measurement positions may be connected to achieve continuous paths along which the microphone is carried continuously with constant velocity (see figures 2 to 4).

7.2.2 Simplified measurement position array

The arrangement of the measurement positions given in figures 1 to 4 may, especially for large machines, be simplified, if, for that type of machine, it can be shown, with the help of preliminary investigations on some machines of that type, that the sound field is adequately uniform and that measurements lead to values of sound power level deviating by no more than 1 dB from those determined with a complete arrangement of measurement positions.

For sources that produce a symmetrical radiation pattern, it may be sufficient to distribute the measurement positions over only a portion of the measurement surface. This is acceptable if, for that type of machine, it can be shown, with the help of preliminary investigations on some machines of that type, that the measurements lead to values of sound power level deviating by no more than 1 dB from those determined with a complete arrangement of measurement positions.

7.2.3 Measurement positions for large, irregularly shaped machines

For large, irregularly shaped machines, the reference surface may be composed of several separate reference boxes placed in juxtaposition so that they just enclose the different parts of the machine (see figure 5). The construction of the reference surface and of the measurement surface and the distribution of the microphone positions shall be clearly described in the measurement test report.

7.3 Measurement of sound pressure levels

Environmental conditions may have an adverse effect on the microphone used for the measurements. Such conditions (for example, due to strong electric or magnetic fields, wind, impingement of air discharged from the machine under test, high or low temperatures) shall be minimized by proper selection or positioning of the microphone. The microphone shall always be directed in such a way that the angle of incidence of the sound waves is that for which the microphone is calibrated.

The A-weighted sound pressure level shall be measured at each microphone position on the measurement surface. The measurements shall be carried out after the machine has reached a steady condition of the defined operating mode. Measurements of the background noise shall be made at each microphone position after the machine under test has been switched off.

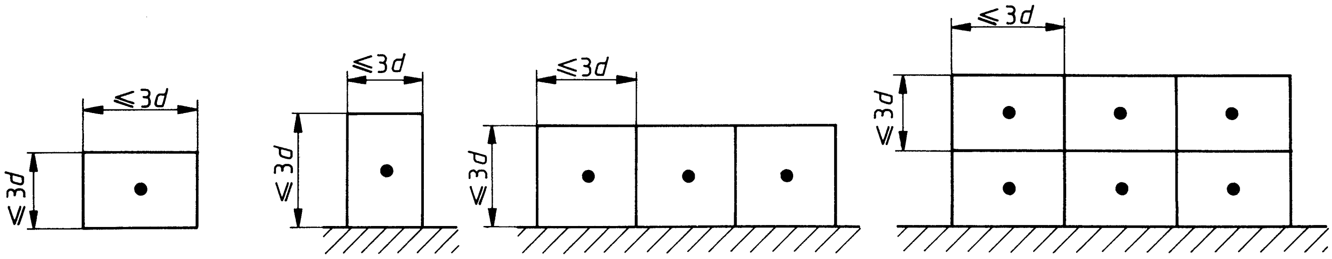


Figure 1 — Procedure for fixing the measurement positions where a side of the measurement surface exceeds 3*d*

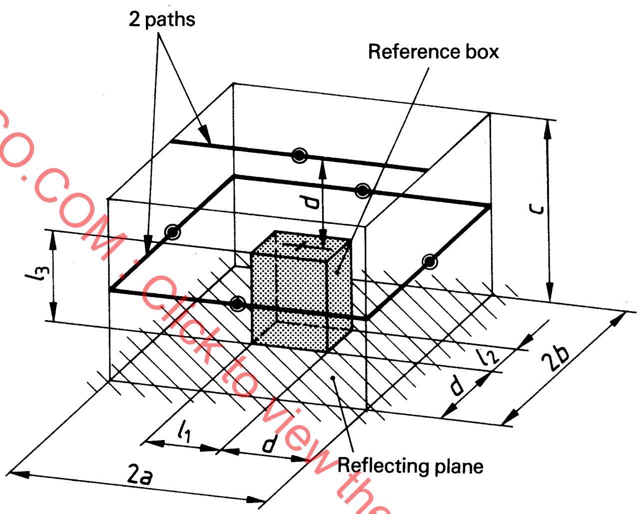


Figure 2 — Example of a measurement surface and measurement positions (paths) for a small machine
($l_1 \leqslant d$, $l_2 \leqslant d$, $l_3 \leqslant 2d$, where d is the measurement distance, normally 1 m)

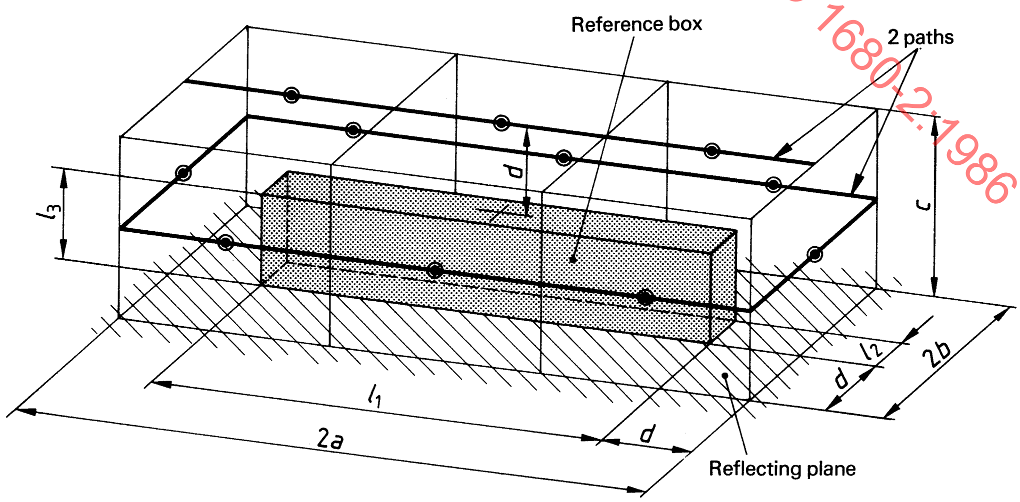


Figure 3 — Example of a measurement surface and measurement positions (paths) for a long machine
($4d < l_1 \leqslant 7d$, $l_2 \leqslant d$, $l_3 \leqslant 2d$)

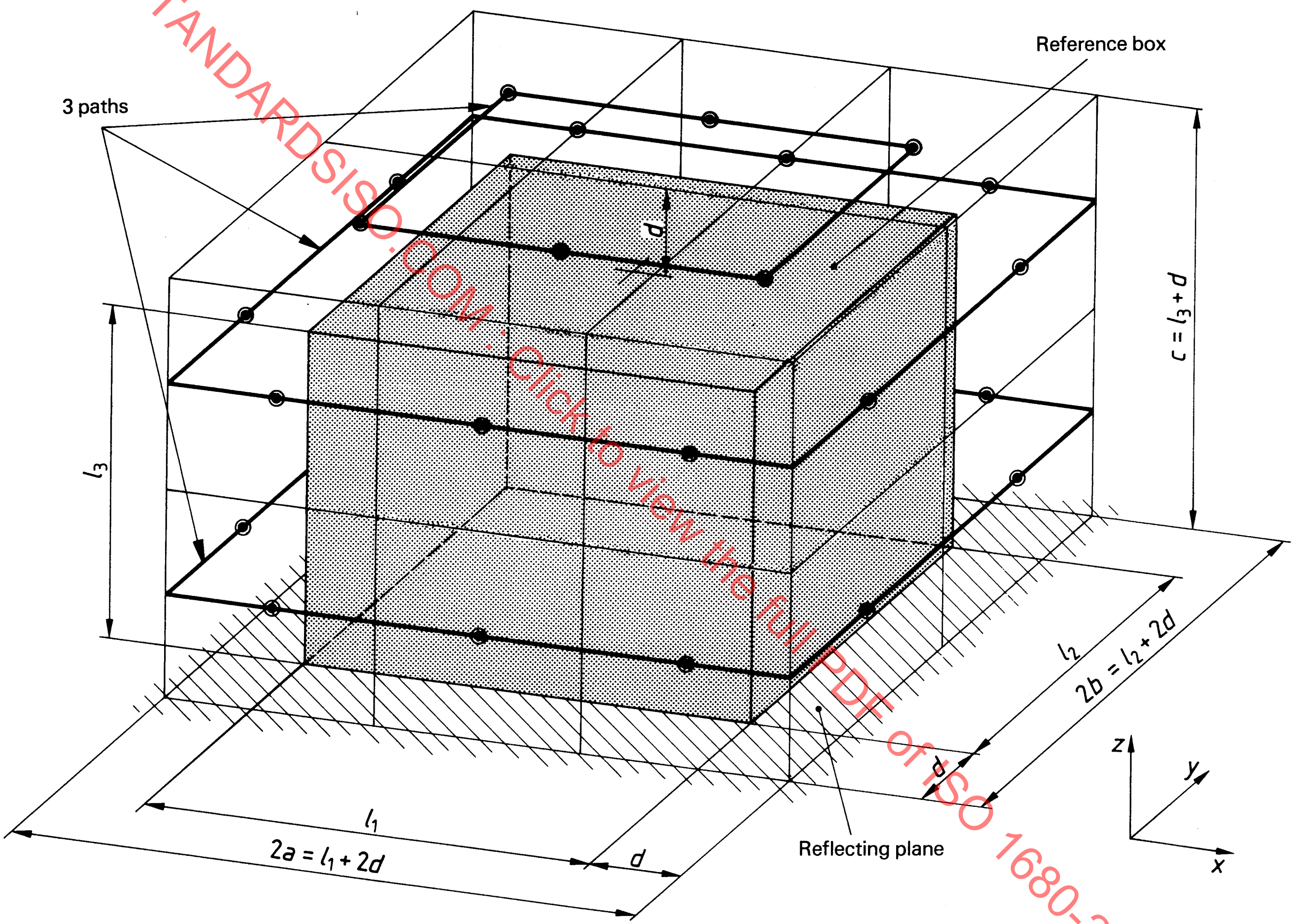


Figure 4 — Example of a measurement surface and measurement positions (paths) for a large machine
($4d < l_1 \leqslant 7d$, $d < l_2 \leqslant 4d$, $2d < l_3 \leqslant 5d$)

8 Calculation of surface sound pressure level and sound power level

8.1 Correction for background noise

The sound pressure levels recorded at each of the microphone positions shall be corrected for background noise in accordance with table 2.

Table 2 — Corrections for background sound pressure levels

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

NOTE — If the differences Δ are smaller than 3 dB, it is not permissible to calculate the corrected sound pressure levels. In these cases, the uncorrected sound pressure levels are upper limits for the corrected ones.

8.2 Calculation of sound pressure level averaged over the measurement surface

An A-weighted sound pressure level, $\overline{L_{pA}}$, shall be calculated from the measured values of the A-weighted sound pressure level, L_{pAi} (after corrections for background noise are applied in accordance with 8.1, if necessary) by using the following equation:

$$\overline{L_{pA}} = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L_{pAi}} \right] \qquad \ldots (1)$$

where

$\overline{L_{pA}}$ is the A-weighted sound pressure level averaged over the measurement surface, in decibels; reference: 20 µPa;

L_{pAi} is the measured A-weighted sound pressure level at the i^{th} measurement position, after correction for background noise, in decibels; reference: 20 µPa;

N is the total number of measurement positions.

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

8.3 Calculation of surface sound pressure level

The A-weighted surface sound pressure level, $\overline{L_{pAf}}$, shall be obtained by correcting the value of $\overline{L_{pA}}$ 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:

$$\overline{L_{pAf}} = \overline{L_{pA}} - K \qquad \ldots (2)$$

where

$\overline{L_{pAf}}$ is the A-weighted surface sound pressure level, in decibels; reference: 20 µPa;

K is the mean value of the environmental correction to account for the influence of reflected sound, in decibels.

The value of K is determined as described in annex A; the method in clause A.3 is preferred, if this is not possible, the method given in A.4.1.1 should be used. If table 3 is not applicable, the procedure described in A.4.1.2 is recommended, but only if $\alpha \leqslant 0,3$.

For the purposes of this part of ISO 1680, the maximum allowable value of K is 7 dB.

8.4 Calculation of sound power level

The A-weighted sound power level of the source, L_{WA}, shall be calculated from the following equation:

$$L_{WA} = \overline{L_{pAf}} + 10 \lg \left(\frac{S}{S_0} \right) \qquad \ldots (3)$$

where, in accordance with figures 2 to 4,

$S = 4(ab + bc + ca)$ is the area of the measurement surface, in square metres; reference: $S_0 = 1$ m^2,

where

$a = 0,5\, l_1 + d$;

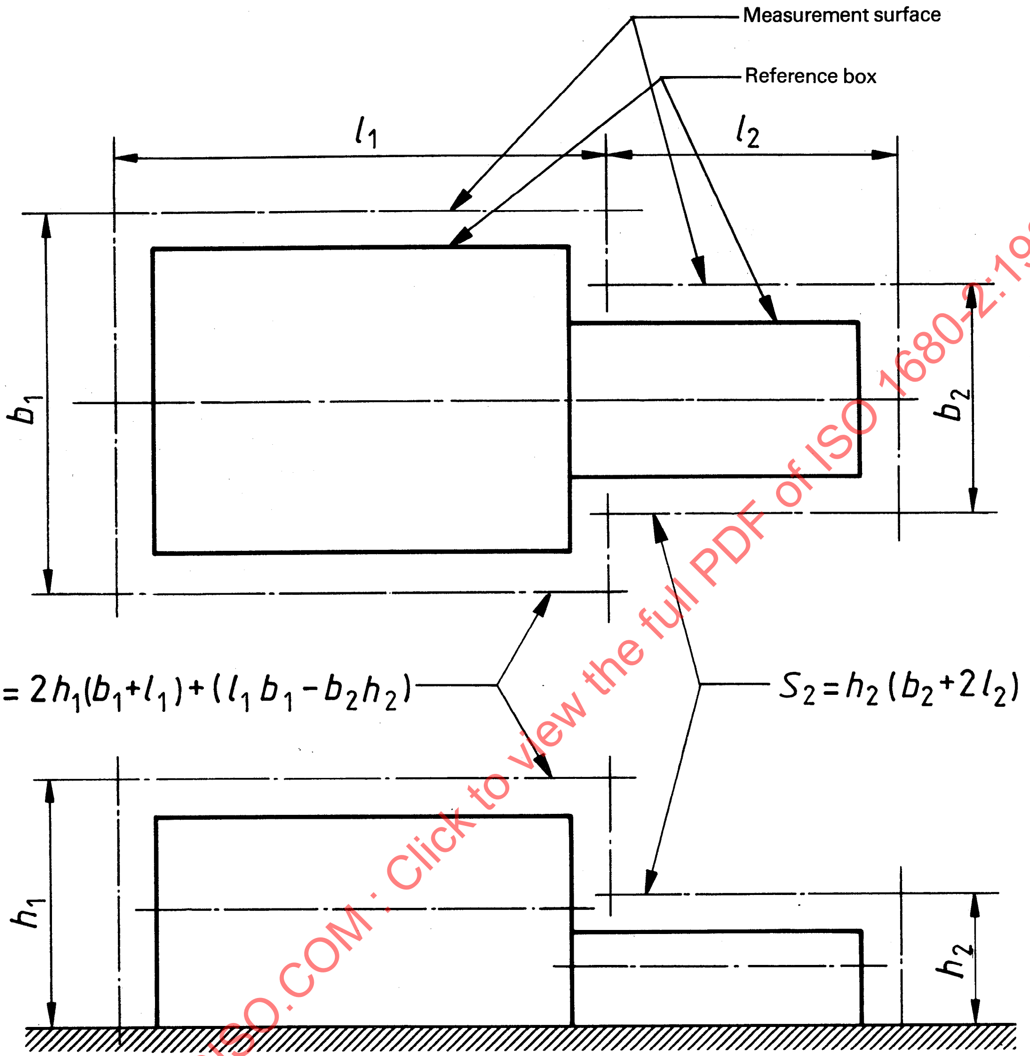
$b = 0,5\, l_2 + d$;

$c = l_3 + d$;

l_1, l_2, l_3 are the dimensions of the rectangular reference parallelepiped;

d is the measurement distance, normally 1 m.

For irregularly shaped machines, a measurement surface and the method for determining the sound power level are given in figure 5 as an example.



$$S_1 = 2h_1(b_1+l_1)+(l_1 b_1 - b_2 h_2)$$

$$S_2 = h_2(b_2+2l_2)+l_2 b_2$$

$$L_{WA_1} = \overline{L_{pAf_1}} + 10 \lg \left(\frac{S_1}{S_0}\right)$$

$$L_{WA_2} = \overline{L_{pAf_2}} + 10 \lg \left(\frac{S_2}{S_0}\right)$$

$$L_{WA} = 10 \lg [0{,}5(10^{0{,}1L_{WA_1}} + 10^{0{,}1L_{WA_2}})]$$

Figure 5 — Example of an arrangement for irregularly shaped machines

9 Information to be recorded

The following information, where applicable, shall be compiled and recorded for measurements carried out in accordance with the requirements of this part of ISO 1680.

9.1 Machine under test

a) Description of the machine under test (including its dimensions).

b) Operating conditions.

c) Mounting conditions.

d) If the machine has multiple noise sources, a description of source(s) in operation during the measurements.

9.2 Acoustic environment

a) Description of the test environment:

1) if indoors, description of physical treatment of walls, ceiling and floor, sketch showing location of machine under test and room contents;

2) if outdoors, a sketch showing location of machine under test with respect to surrounding terrain, including physical description of test environment. The nature of the reflecting (ground) plane shall be recorded.

b) Acoustical qualification of the test environment in accordance with annex A.

c) Wind velocity, if greater than 1 m/s.

d) Sound power level of the reference sound source, if used.

9.3 Instrumentation

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

b) Method used to calibrate the instrumentation system.

c) The date and place of calibration of the acoustical calibrator.

9.4 Acoustical data

a) The locations of the microphone positions (a sketch may be included, if necessary) and the measurement distance.

b) The area S of the measurement surface.

c) The A-weighted sound pressure levels at all microphone positions.

d) The A-weighted sound pressure levels of the background noise for each measuring point and the corresponding correction, if any.

e) The environmental correction, K, calculated in accordance with annex A, specifying the method used.

f) The A-weighted surface sound pressure level, $\overline{L_{pAf}}$, over the measurement surface, in decibels; reference: 20 µPa.

g) The calculated A-weighted sound power level, in decibels; reference: 1 pW ($= 10^{-12}$ W).

h) If required, difference Δ of the levels of the noise between no-load and on-load operation.

i) Remarks on subjective impression of noise (audible discrete tones, impulsive character, spectral content, temporal characteristic, etc.).

j) The date when the measurements were carried out.

10 Information to be reported

The test report shall contain the statement that the sound power levels have been obtained in full conformity with the procedures of this part of ISO 1680.

The following information shall be reported:

a) a description of the machine under test;

b) the operating conditions;

c) the A-weighted sound power level, L_{WA}, in decibels, and, if required, sound power levels in frequency bands; reference: 1 pW;

d) if required, difference Δ of the levels of the noise between no-load and on-load operation;

e) the date when the measurements were carried out.

Annex A

Qualification procedures for the acoustic environment

(This annex forms an integral part of the standard.)

A.1 General

An environment providing an approximately free field over a reflecting plane shall be used for measurements made in accordance with this part of ISO 1680. The environment is provided by a suitable test area outdoors or by an ordinary room if the requirements given in this annex are satisfied.

Reflecting objects, with the exception of the reflecting plane, shall be removed to the maximum extent possible from the vicinity of the machine under test. The test room shall ideally provide a hypothetical measurement surface which lies

a) inside a sound field essentially undisturbed by reflections from nearby objects and the room boundaries, and

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

For the purpose of this survey method when carrying out measurements at frequencies above 100 Hz, the measurement surface is considered to lie outside the near field if the measurement distance from the source under test is equal to or greater than 0,15 m.

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 — An obstacle in the proximity of the source may be considered to be sound-reflecting if its width (for example, diameter of a pole or supporting member) exceeds 1/10 of the 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 ISO 3745.

The environmental correction, K, in equation (2) (see 8.3) accounts for the influence of undesired sound reflections from room boundaries and/or reflecting objects near the sound source under test.

If possible, the procedure for determining K given in clause A.3 should be used. If this is not possible, the method given in A.4.1.1 should be used. If table 3 is not applicable, the procedure described in A.4.1.2 is recommended but only if $\alpha < 0,3$ (i.e. $A = 0,16\,(V/T) < 0,3\,S_V$).

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 — 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 shall not be smaller than the projection of the measurement surface on the plane.

A.2.1.2 Acoustic absorption coefficient

The acoustic absorption coefficient of the reflecting plane, measured in accordance with ISO 354, should preferably be less than 0,1 over the frequency range of interest. This requirement is usually fulfilled when measurements are made over concrete, sealed asphalt or stone surfaces. For indoor measurements, wooden and tiled floors are permitted.

A.2.2 Reflecting objects

No reflecting objects which are not part of the source under test shall be located inside the measurement surface.

A.2.3 Precautions for outdoor measurements

Care should be taken to minimize the effects of adverse meteorological conditions (for example, 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 windscreen 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 to determine K

A.3.1 Procedure

A reference sound source with characteristics that meet the requirements of ISO 6926 shall be mounted in the test environment in essentially the same position as that of the source under test. The sound power level of the reference sound source is determined in accordance with 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 is given by

$$K = L_{WA} - L_{WAr}$$