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Industrial fans — Determination of fan sound power levels under standardized laboratory conditions —

Part 4:
Sound intensity method

Ventilateurs industriels — Détermination des niveaux de puissance acoustique des ventilateurs dans des conditions de laboratoire normalisées —

Partie 4: Méthode par intensité acoustique

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13347-4 was prepared by Technical Committee ISO/TC 117, *Industrial fans*.

ISO 13347 consists of the following parts, under the general title *Industrial fans — Determination of fan sound power levels under standardized laboratory conditions*:

— *Part 1: General overview*

— *Part 2: Reverberant room method*

— *Part 3: Enveloping surface methods*

— *Part 4: Sound intensity method*

Introduction

This part of ISO 13347 establishes a method for determining the sound power level of a fan. The method is reproducible in all laboratories which are qualified according to the requirements of this part of ISO 13347.

The method employs standard sound measurement instrumentation. The test set-ups are generally designed to represent the physical orientation of a fan as installed, in accordance with ISO 5801.

Since sound power levels are considered independent of the acoustic environment around the fan, a good comparison may be made between two or more fans proposed for any specific air performance condition. Moreover, these values establish an accurate base for estimating the acoustical outcome of the fan installation in terms of sound pressure levels. A successful estimate of sound pressure levels requires extensive information on the fan and the environment in which it is to be located.

It is often advantageous for the equipment user to employ acoustical consultation to ensure that all factors which affect the final sound pressure levels are considered. More detailed information on the complexity of this situation may be found in acoustic textbooks.

This part of ISO 13347 has been developed in response to the need for a reliable and accurate enveloping surface method for determining the sound power levels of fan equipment. Where possible, it has been based on existing National standards and combines state-of-the-art with practical considerations.

At a meeting of ISO/TC 117 in October 1997, it was resolved that the latest editions of ISO 9614-1 and AMCA 320 should be used as the basis for this part of ISO 13347.

This edition continues the original philosophy of the National Standards in combining the theoretical and the practical. Where there have been successful improvements in the state-of-the-art, full advantage is taken.

Industrial fans — Determination of fan sound power levels under standardized laboratory conditions —

Part 4:
Sound intensity method

1 Scope

This part of ISO 13347 applies to industrial fans as defined in ISO 5801 and ISO 13349. It is limited to the determination of airborne sound emission for the specified set-ups. Vibration is not measured, nor is the sensitivity of airborne sound emission to vibration effects determined.

The sizes of the fan, which can be tested in accordance with this part of ISO 13347, are limited only by the practical aspects of the test installations.

This part of ISO 13347 determines sound power by using sound intensity measurements on a measurement surface which encloses the sound source. It provides guidelines on the acoustical environment, ambient noise, measurement surface, and number of measurements. The test set-ups are generally designed to represent the physical orientation of a fan installed in accordance with ISO 5801 and also used in ISO 13347-2.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5136, *Acoustics — Determination of sound power radiated into a duct by fans and other air-moving devices — In-duct method*

ISO 5801:1997, *Industrial fans — Performance testing using standardized airways*

ISO 9614-1:1993, *Acoustics — Determination of sound power levels of noise source using sound intensity — Part 1: Measurement at discrete points*

ISO 9614-2, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning*

ISO 13347-1:2004, *Industrial fans — Determination of fan sound power levels under standardized laboratory conditions — Part 1: General overview*

ISO 13347-2:2004, *Industrial fans — Determination of fan sound power levels under standardized laboratory conditions — Part 2: Reverberant room method*

ISO 13349:1999, *Industrial fans — Vocabulary and definitions of categories*

IEC 61094-2:1992, *Measurement microphones — Part 2: Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique*

3 Instruments and methods of test

3.1 General

Full details of the instrumentation and its requirements are given in ISO 13347-1. Particular requirements for this part of ISO 13347 are given in the following subclauses.

3.2 Reference sound source (RSS)

The RSS shall be used to qualify the performance of the sound intensity measurement system and personnel, and to determine a sound power level adjustment for the specific site conditions. To be used for these purposes, the RSS shall be of an appropriate type, be calibrated accurately and be properly maintained. All requirements for the RSS are specified in ISO 13347-1.

NOTE For sound intensity measurements, the use of two or more different configurations of the intensity probe, or different probes, may be required to cover the entire frequency range in conformance with Table 1.

The useful frequency range for accurate sound intensity measurements is dependent upon the character of the sound field. Care should be taken to verify that sound intensity measurements are accurate in the actual measurement environment.

Table 1 — Tolerances for the instrumentation system

One-third octave band centre frequency Hz	**Tolerance** dB
50 to 80	± 1,5
100 to 4 000	± 1,0
5 000 to 8 000	± 1,5
10 000	± 2,0
12 500	± 3,0

3.3 Transducer and instrumentation system calibration checks

Before and after each sound power determination, the following calibration checks shall be performed. A calibration cheek of the entire measuring system at one or more frequencies within the frequency range of interest shall be made for each microphone. An acoustical calibrator conforming to IEC 61094-2 and having an accuracy of ± 0,5 dB shall be used for this purpose. In conformance with IEC 61094-2, the calibrator shall be checked at least once every year to verify that its output has not changed. In addition, an electrical calibration of the instrumentation system over the entire frequency range of interest shall be performed periodically, at intervals of not more than one year.

In addition to the calibration check, the field check procedure for sound intensity measurement specified by the manufacturer shall be performed. If no field check procedure is specified, the following procedure shall be performed.

The intensity probe shall be placed on the measurement surface, oriented normal to the surface, at a position where the noise is characteristic for the fan equipment under test. The sound intensity shall be measured. The intensity probe shall be rotated through 180° and placed with its acoustical centre in the same position as the initial measurement. The sound intensity shall be measured again. The intensity probe should be mounted on a stand or other mechanical device so that its acoustical centre retains the same position when the probe is rotated. For the octave band with the highest level, the absolute difference between the two levels shall be less than the value in Table 2 for the measuring equipment to be acceptable. The two sound intensities shall be of opposite sign.

Table 2 — Tolerances for difference in sound intensity levels for field check

Octave band centre frequency Hz	Difference dB
63 to 125	1,5
250 to 4 000	1,0
8 000	1,5

3.4 Performance verification

Periodically, the performance of the instrumentation system shall be verified by determining the sound power of a reference sound source using the procedures specified in ISO 13347-1.

The sound power level determined for the reference source shall differ from its calibrated value over the frequency range of interest by no more than the tolerances given in Table 3.

Table 3 — Tolerances for sound power level determined for reference sound source

Octave band centre frequency Hz	Tolerance dB
63	± 5,0
125	± 3,0
25 to 500	± 2,0
1 000 to 4 000	± 1,5
8 000	± 2,5

3.5 Test method

The basis of the test method originated in ISO 9614-1. The test method covers a wider frequency range and contains requirements somewhat more specific and restrictive than those of ISO 9614-1, and also provides for sound power level adjustments as described below. With the exception of the adjustments, however, measurements made in conformance with this test method will be in conformance with ISO 9614-1 over their common frequency range.

The basic requirement is the measurement of the sound intensity distribution around the fan. A measurement surface is defined which encloses the entire fan, fan inlet, or fan outlet, depending upon the objective of the test. A set of sound intensity measurements is made about this surface. The results of these measurements are compared with a set containing half the number of measurements, to ensure the adequacy of the number of measurements and the accuracy of the data. The sound power level is calculated using the surface area and the measured sound intensity data. Adjustments shall be made for duct-end corrections, if required, and based on measurements of a calibrated RSS.

Prior to sound intensity measurements on the source of interest, the sound intensity measurement instrumentation and personnel are to be qualified by conducting measurements about an RSS.

The sound power levels resulting from the test method can be expected to be identical to those that would be produced using ISO 13347-2, within the uncertainty of both methods, to the extent that each method is applicable and that the installations tested are identical. It should be noted that the present method differs substantially from ISO 13347-2 in both the test environment requirements and the measured quantities.

4 Equipment and test set-ups

4.1 Test environment

4.1.1 Background noise

Sound power determination using intensity measurements is inherently less sensitive to background noise than are methods based on sound pressure measurements (such as ISO 13347-2), although an excessive amount of background noise will not permit accurate sound power determination by any method. In general, background noise should not be a problem in using the present method provided that, on the measurement surface, the sound pressure level of background noise does not exceed the sound pressure level of direct sound from the fan equipment of interest.

If the background noise is excessive, sound power determination according to the procedures of this part of ISO 13347 may not be possible. The test environment shall be such that the background noise criterion of 6.2 is satisfied.

4.1.2 Nearby reflecting surfaces

Reflecting surfaces in the vicinity of the measurement surface can have an effect on the source sound power, and on the ability to accurately sample the sound intensity on the measurement surface. Nearby reflecting surfaces will tend to increase the sound power output of the fan equipment under test, and should be limited to those surfaces usually encountered in a typical installation of the fan. If a reflecting surface is part of the typical installation of the fan equipment, a similar surface shall be used during testing.

If the presence of a nearby reflecting surface interferes with sampling of sound intensity on the measurement surface, sound power determination according to the procedures of this standard may not be possible. To evaluate whether a nearby reflecting surface is in fact the cause of the difficulty, the procedure of Annex A is recommended.

4.1.3 Reverberation control

In addition to the difficulties associated with nearby reflecting surfaces, diffuse reverberant sound at the measurement surface can limit the accuracy of sound intensity measurements if this sound is excessive. In general, reverberant sound should not be a problem in using this standard provided that, on the measurement surface, the sound pressure level of reverberant sound does not exceed the sound pressure level of direct sound from the fan equipment of interest.

Excessive reverberation usually can be controlled by introducing a modest amount of sound absorbing material at the boundaries of an acoustically “hard” (reflective) room. Alternatively, it may be possible to reduce the relative strength of the reverberant sound by moving the measurement surface closer to the sound source of interest within the limits of this part of ISO 13347 i.e., increasing the direct sound from the source. Application of this standard in a reverberation chamber qualified for use with ISO 13347-2 is not recommended without use of supplemental absorption material, and/or special care in defining the measurement surface.

If reverberant sound is excessive, sound power determination according to the procedures of this part of ISO 13347 may not be possible. To evaluate whether excessive reverberant sound is in fact the cause of difficulty, the procedure of Annex A is recommended.

4.2 Fan installation

4.2.1 Set-up categories

A number of specific fan test set-ups are allowed. They are determined by the airflow direction and the particular mounting arrangement of the test device. These test set-ups fall into two general categories. The first category is for a free-standing unit that would be placed entirely in the test room (see Figure 1). Results of this arrangement yield the total sound power level ($L_{W\mathrm{m}}$ or L_W) of the test unit. The second category is for those units that would be tested with a chamber or two-room system and where only the inlet or outlet would discharge sound into the test room (see Figures 2 or 3).

This arrangement results in ratings of inlet ($L_{W\mathrm{mi}}$ or $L_{W\mathrm{i}}$) or outlet ($L_{W\mathrm{mo}}$ or $L_{W\mathrm{o}}$) sound power level only. Note that the subscript «**m**» indicates that the sound power level is determined from measurements using a set-up not requiring an end correction adjustment, while values without the subscript «**m**» are determined by applying an end correction to measurements on a ducted test set-up.

The choice of which test set-up is used for a particular fan will depend on the way a product is expected to be rated and applied in the field.

4.2.2 Aerodynamic performance

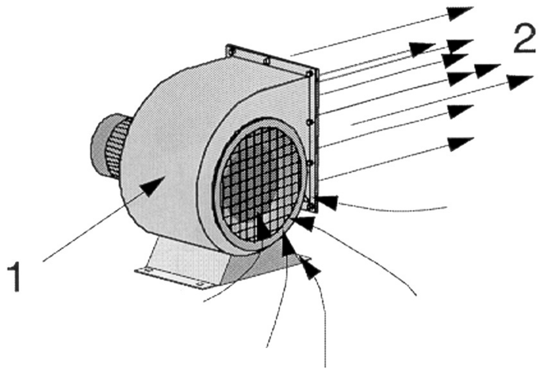
Where aerodynamic performance tests are necessary to determine the point of operation of the fan, these shall be performed as specified in ISO 5801.

4.2.3 Mounting methods

Vibration is known to influence airborne sound emission. Vibration effects may be minimised by resilient mounting of the fan and vibration isolation of any duct used.

The method of mounting fans, of connecting them to non-integral drivers, and of connecting them to aerodynamic performance test facilities is not specified. Any conventional method may be used, including vibration isolation devices and short flexible connectors. Other than these, sound and vibration absorptive material may not be incorporated in the test fan unless it is a standard part of the unit. Ducts shall be of metal or other rigid, dense non-absorptive material, and have no exposed sound absorption material on the interior or exterior surfaces.

The driving motor and drive, when not an integral part of the fan, may be damped or enclosed in any manner that does not expose sound absorption material within the measurement surface. When the driving motor and drive are an integral part of the test unit, they may not be treated in any manner, and normal belt tensions, bearings and lubricants shall be used.



Key

1 fan

2 airflow

Figure 1 — Fan total sound testing (A: free inlet, free outlet)

4.2.4 Duct length

The length of duct shown in Figures 2 and 3 is consistent with the procedures of ISO 5801. Care shall be exercised to ensure that no duct resonance exists in close proximity to specific frequencies of interest, e.g., blade passage frequency.

In chamber or two-room set-ups, the length of duct shall be consistent with acceptable practices from ISO 5801, which are necessary to accurately establish the point of rating.

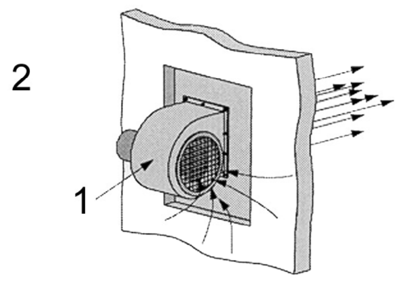
4.2.5 Fan total sound testing (A: free inlet, free outlet)

Figure 1 shows the test configuration used with a free inlet/outlet fan arrangement to establish the fan's total sound power.

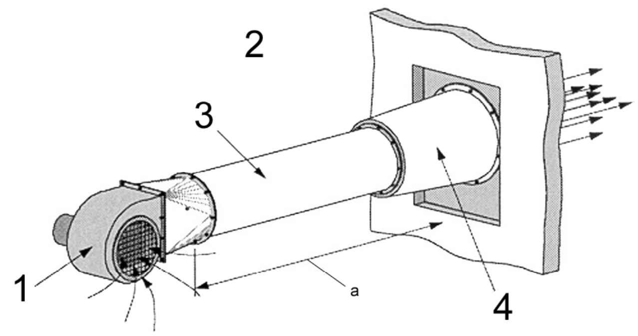
Installation type	E_W dB	Sound power level
A: Free inlet Free outlet	0	L_W(A,tot)

NOTE This test procedure and the above calculations are based on the following assumption: that resonances are not present on either the fan structure, supporting devices, or driving devices that provide any significant pure tones that may add to the fan recorded sound levels.

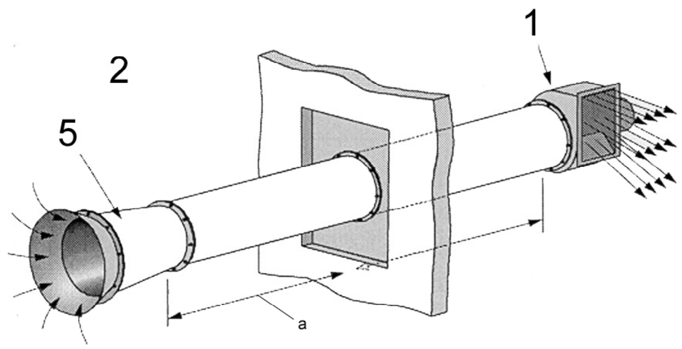
Appurtenances attached to the fan are considered as part of the fan and shall be contained within the test measurement surface.



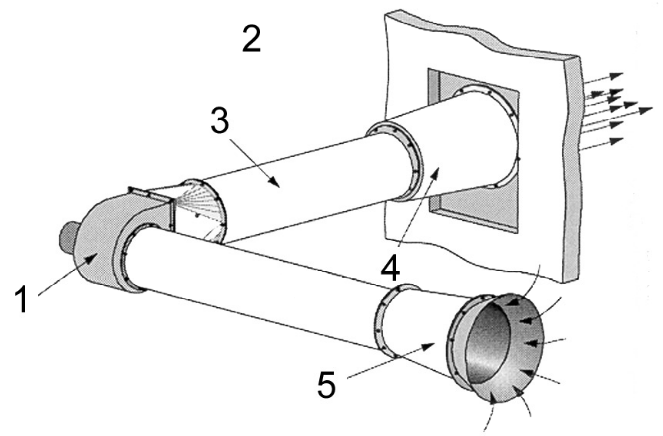
a) A: free inlet, free outlet



b) B: free inlet, ducted outlet



c) C: ducted inlet, free outlet



d) D: ducted inlet, ducted outlet

Key

1 fan

2 test room

3 common part

4 simplified anechoic termination

5 transmission element

[a] May require acoustical treatment.

Figure 2 — Fan inlet sound testing

4.2.6 Fan inlet total sound testing

Figure 2 a) to d) shows the test configuration to determine total sound power on the fan inlet.

Installation type		E_W dB	Sound power level
A:	Free inlet Free outlet	O	L_W (A,in)
B:	Free inlet Ducted outlet	O	L_W (B,in)
C:	Ducted inlet Free outlet	E_i	L_W (C,in)
D:	Ducted inlet Ducted outlet	E_i	L_W (D,in)

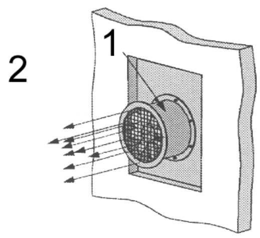
This test procedure and calculations are based on the following assumptions.

a) Acoustical energy in an outlet duct which terminates in a second room or chamber does not contribute to fan test sound pressure levels. This requires adequate transmission loss between adjoining rooms and the addition of absorptive material within a chamber to absorb this energy.

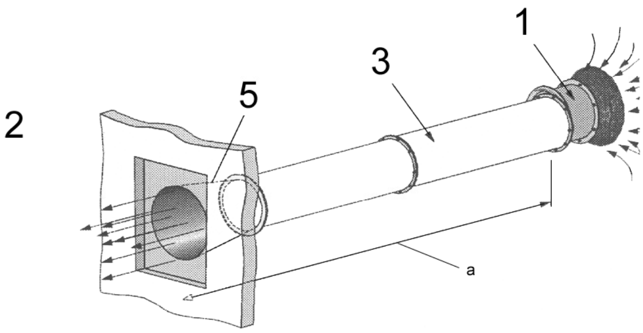
b) Adequate absorption takes place at the discharge of a duct in a second room or chamber so that any energy passing down that duct is adequately attenuated.

c) Duct construction is such that the transmission loss through the duct wall is large enough to eliminate any addition to measured room sound pressure levels.

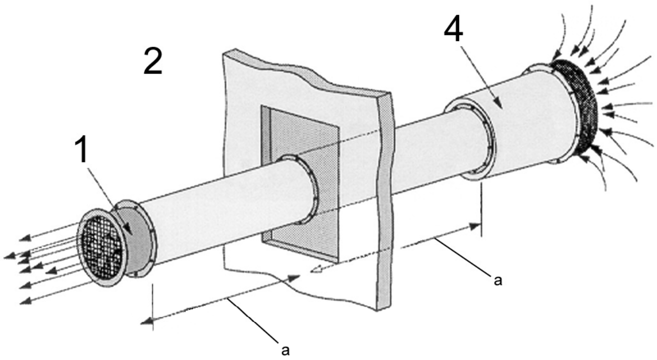
d) No resonance is present on either the fan structure, supporting devices or driving devices that provide any significant pure tones that may add to the recorded fan sound pressure levels.



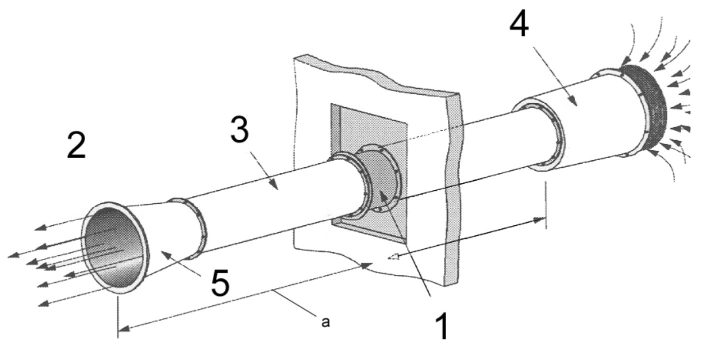
a) A: free inlet, free outlet



b) B: free inlet, ducted outlet



c) C: ducted inlet, free outlet



d) D: ducted inlet, ducted outlet

Key

1 fan

2 test room

3 common part

4 transmission element

5 simplified anechoic termination

[a] May require acoustical treatment.

Figure 3 — Fan outlet sound testing

4.2.7 Fan outlet total sound testing

Figure 3 a) to d) shows the test configuration to determine total sound power on the fan outlet.

Installation type		E_W dB	Sound power level
A:	Free inlet Free outlet	O	L_W (A,out)
B:	Free inlet Ducted outlet	O	L_W (B,out)
C:	Ducted inlet Free outlet	E_i	L_W (C,out)
D:	Ducted inlet Ducted outlet	E_i	L_W (D,out)

This test procedure and calculations are based on the following assumptions.

a) Acoustical energy in an outlet duct which terminates in a second room or chamber does not contribute to fan test sound pressure levels. This requires adequate transmission loss between adjoining rooms and the addition of absorptive material within a chamber to absorb this energy.

b) Adequate absorption takes place at the discharge of a duct in a second room or chamber so that any energy passing down that duct is adequately attenuated.

c) Duct construction is such that the transmission loss through the duct wall is large enough to eliminate any addition to measured room sound pressure levels.

d) No resonances is present on either the fan structure, supporting devices or driving devices that provide any significant pure tones that may add to the recorded fan sound pressure levels.

4.3 Measurement surface

The measurement surface shall be defined to enclose the source or sources of interest, and to exclude extraneous sound sources and extraneous absorption material. All of the measurement locations shall be on the measurement surface.

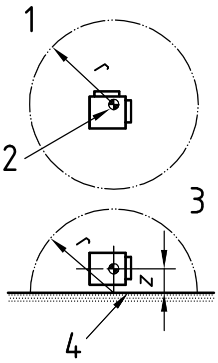
The shape and size of the measurement surface shall be chosen with reference to Figure 4, noting whether the objective is fan total, inlet, or outlet sound power. If it is not possible to satisfy the requirements of Figure 4, see Annex C. For casing-radiated sound power, see Annex C.

Locations on the measurement surface where air velocity exceeds 3 m/s shall be identified. Care shall be taken to ensure that wind-induced noise due to flow over the probe does not influence the measurements. A probe windscreen is used for this purpose. The windscreen shall then be used for all RSS and fan sound intensity measurements. At higher air velocities, for example in an outlet air jet, it may not be possible to eliminate wind-induced noise. Provided that all locations where wind-induced noise is excessive do not exceed 10 % of the total measurement surface area, such locations need not be measured when sampling the sound on the measurement surface.

Reflecting surfaces shall be used as a boundary of the measurement surface as outlined in Figure 4. When used in this way, the area of the reflecting surface shall not be included in the area of the measurement surface, and no intensity measurements are made for it.

4.4 Reference sound source (RSS)

To account for specific laboratory and test set-up conditions, a sound power level adjustment is determined from measurements on a RSS as specified in 5.2. If practicable, the fan equipment is removed and replaced with the RSS for this purpose, as shown in Figure 4. If the fan equipment cannot be removed, the RSS may be placed at another location in the same measurement environment. When another location is used, the RSS shall be located with respect to the measurement surface as shown in Figure 4, the measurement surface for the RSS shall be geometrically identical to that used for the fan equipment, and care shall be taken to duplicate the geometric configuration of reflecting surface(s), if any.

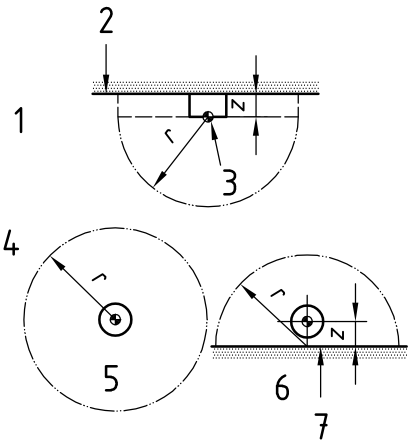


	Surface area S
Surface as shown	$2\pi r^2$
Circumscribing rectangular parallelepiped	$12r^2$

Key

1 fan
2 reference point
3 elevation
4 reflecting plane

a) Fan total sound testing



	Surface area S	
	Type I	Type II
Surface as shown	$2\pi r^2(r + 1)$	$2\pi r^2(r + 1)$
Circumscribing rectangular parallelepiped	$4r(3r + 21)$	$2r(3 + 21)$

Key

1 plane
2 reflecting plane (types I and II)
3 reference point
4 elevation
5 type I
6 type II
7 reflecting plane

b) Inlet or outlet sound testing

Figure 4 — Measurement surface definition

5 Test method

5.1 General

The test method shall be selected according to the sound power level which is to be determined and the size of the fan.

If a fan has a duct on the inlet and/or outlet side, then the sound power levels on the sides which are ducted should be determined by an in-duct method as detailed in ISO 5136. As an alternative method with a lower order of accuracy, measurements determined in an anechoic chamber, reverberant room or real room may be used with corrections added for the effect of duct end reflection. Where figures are obtained in such alternative methods (e.g. for small duct sizes or for other reasons) then this shall be clearly stated.

5.2 Sampling of sound on the measurement surface

The sound on the measurement surface is sampled at the measurement locations. A sufficient number of samples shall be obtained to ensure an accurate determination of the required surface average levels. Two methods can be used for sampling of the sound:

a) measurements at fixed points (see ISO 9614-1);

b) measurements while scanning surface segments (see ISO 9614-2). Either or both of these methods can be used, but the same procedure shall be used to determine all surface average levels.

Measurement locations shall be chosen so that the measurement surface is divided into segments as nearly equal in dimension and area as is practicable.

With reference to Figure 4a), the measurement surface is defined so that the reference point of fan equipment is over the origin of the hemisphere at height z.

With reference to Figure 4 b), the measurement surface is defined so that the reference point is at the origin of the hemisphere (Type I) or at elevation z above the origin of the half-hemisphere (Type II). For Type I test, RSS is on the reflecting plane centred over the projection of reference point (i.e., the duct centre and projection of hemisphere origin). For Type II test, if $l > z$, RSS is on reflecting plane 2 centred over the projection of reference point (i.e., the half-hemisphere origin), otherwise RSS is on reflecting plane 1 at the projection of reference point (i.e. the duct centre).

Additional points:

1) The measurement surface may be as shown in Figure 4 or may be the rectangular parallelepiped (“rectangular box”) that circumscribes the surface shown.

2) The measurement surface is defined relative to the reference point of the fan equipment. For Figure 2 or 3 inlet or outlet sound testing, the reference point is the centre of inlet or outlet, respectively. For Figure 1 total sound testing, the reference point is the centre of centres of inlet(s) and outlet(s).

3) The radius r shall be no less than 3 d, l or 1 m, whichever is larger, and shall be large enough for all parts of the measurement surface to be at least $2d$ from the fan equipment. For inlet or outlet sound testing, duct length l may be zero. Equipment under test shall be located with respect to the specified reflecting plane such that $0 < z < 0{,}3r$. Except for specified reflecting plane(s), all room surfaces shall be at least $2r$ from the measurement surface.

4) For inlet sound testing, d is defined as the gross inside diameter of the fan inlet. For outlet sound testing, d is defined as the gross inside diameter of the fan outlet. For a rectangular inlet or outlet, d is defined as $d = (4ab/\pi)^{0,5}$, where a and b are the gross inside transverse dimensions. For unhoused fans, d = impeller diameter/3.

Other than as limited above, test room size, shape, and acoustical treatment are not specified. Room parameters should be such that the level of reverberant sound at the measurement surface does not exceed the level of direct sound from the source of interest.

5.3 Number of measurements

The required number of measurement locations is determined by successively doubling the number of measurement locations until the convergence index $\delta_{W\mathrm{N}}$ for each frequency band of interest is less than the tolerance given in Table 4.

The convergence index shall be calculated using Equation (4).

The minimum final number of measurements shall be equal to 1 for each square meter of measurement surface area, or 8, whichever is larger.

For some fans in some test environments, it may not be possible to satisfy the requirements of Table 4 using a reasonable number of measurement locations. In this event, it will be necessary to alter the test environment in order to determine sound power level in accordance with this part of ISO 13347. See 7.1 and/or ISO 9614-1 for recommendations.

Table 4 — Tolerance for the convergence index

Octave band centre frequency Hz	**Tolerance** dB
63	± 0,5
125	± 0,5
25 to 500	± 0,25
1 000 to 4 000	± 0,25
8 000	± 0,5

5.4 Observations

5.4.1 Point of operation

Although the acoustical observations necessary to determine sound power output are the same for all fan types, the non-acoustical observations necessary to determine the aerodynamic point of operation differ. This part of ISO 13347 provides different test set-ups for the testing of various fan types. Regardless of the test set-ups, the point of operation shall be determined. If the test set-up conforms to one of the arrangements in ISO 5801, then the point of rating can be established with sufficient accuracy. If the sound test set-up does not conform to one of the test set-ups in ISO 5801, steps shall be taken to ensure that the speed is known within ± 5 %.

5.4.2 Background sound level

Observations of the average background sound pressure levels in each frequency band shall be made over the measurement surface. Background noise shall be observed with all noise sources which will be present while the fan is being tested and that are not directly associated with fan sound (examples of background sources are noise due to the motion of the microphone, and any noise due to external sources).

For a set of tests at various fan points of operation, $L_{p\mathrm{b}}$ need be observed only once, unless there is reason to believe that the background noise may have changed significantly.

5.4.3 Sound intensity

Observations of average sound intensity in each frequency band shall be made for the fan under test, and for the RSS when installed as specified in 4.5. If more convenient, sound intensity levels may be recorded, but care shall be taken to record also the direction of the associated intensity. All intensity shall be measured on the measurement surface, with the intensity probe oriented outward from and normal (perpendicular) to the measurement surface. For a set of tests at various fan points of operation, the RSS intensity needs to be observed only once, while the fan intensity shall be observed for each operating point. When practical, measurements on the RSS should be made for every fan test. It shall be permissible, however, to use results of RSS measurements made within one month, provided that the test environment, measurement surface, windscreen use, and RSS location are the same.

L_{Iq} are the intensity levels present when only the RSS is operating with the background noise.

L_{If} are the intensity levels present when only the test fan is operating with the background noise.

5.4.4 Test conditions

The test conditions shall be as nearly as possible the same for all sound readings. Observers shall be away from the sound source and measurement surface, and in the same position, for all tests.

Operators and observers, if located in the test area, shall be away from the sound source and measurement location as much as practical. Operators and observers shall attempt to minimise their interference with the acoustical measurements, considering both blockage and reflection of sound, and in no event shall an operator or observer be positioned between the source and the measurement location.

Readings shall be the unweighted (“linear”) average over the observation period. At each measurement position, the observation period shall be a minimum of 30 s for frequency bands below 180 Hz, and 15 s for frequency bands above 180 Hz.

NOTE For frequency bands other than octaves, it may be desirable to adjust the minimum averaging time to maintain the same bandwidth-time product, and hence equivalent statistical confidence for random signals.

5.4.5 Information to be recorded.

The following information, when applicable, shall be compiled and recorded for all measurements made in accordance with the requirements of this part of ISO 13347.

a) Description of the fan under test:

1) manufacturer;

2) model;

3) nominal size;

4) impeller diameter;

5) number of blades;

6) blade setting (adjustable or variable pitch fans only);

7) number of stator vanes (as applicable);

8) inlet area;

9) outlet area.

b) Operating conditions:

  1) fan speed;

  2) fan airflow rate;

  3) fan static pressure or total pressure at actual test conditions;

  4) fan air density.

c) Mounting conditions:

  1) test figure;

  2) test installation type.

d) Test environment:

  1) barometric pressure;

  2) ambient temperature;

  3) relative humidity;

  4) static pressure at the fan inlet.

e) Laboratory and instrumentation:

  1) laboratory name;

  2) laboratory location;

  3) technician's name;

  4) list of equipment with dates of calibration;

  5) intensity probe configuration parameters (microphone size, spacing, etc.);

  6) method and results of transducer and instrumentation calibration checks;

  7) date and results of performance verification check;

  8) whether or not a windscreen was used over the intensity probe;

  9) whether the fixed point or scanning method was used.

f) Acoustic data:

  1) number of measurement positions;

  2) sketch of measurement surface showing position in test laboratory and location of measurement positions;

  3) location of RSS during testing;

  4) surface background sound pressure levels;

  5) surface average background sound pressure levels;

  6) surface reference-sound-source sound intensity level;

  7) surface average reference-sound-source sound intensity level;

  8) surface fan sound intensity level;

9) surface average fan sound intensity level;

10) convergence index;

11) RSS sound power level source adjustment;

12) unweighted fan sound power level;

13) end correction data if applicable:

   i) end correction values,

   ii) duct length,

   iii) flush, or non-flush, mounting of the duct,

   iv) inside diameter of the orifice plate,

   v) test date.

6 Calculations

6.1 Surface average levels

The average background sound pressure level on the measurement surface is calculated from:

$$\overline{L_{p\mathrm{b}}} = 10 \lg \left(\frac{1}{N} \sum_{n=1}^{N} 10^{0,1 L_n} \right) \mathrm{dB} \tag{1}$$

where

$\overline{L_{p\mathrm{b}}}$ is the surface average background sound pressure level, and

L_n is the background sound pressure level $L_{p\mathrm{b}}$ at the n^{th} of the N measurement positions observed.

The average intensity on the measurement surface is calculated from:

$$\overline{I} = \frac{1}{N} \sum_{n=1}^{N} I_n \tag{2}$$

and the average intensity level on the measurement surface is calculated from:

$$\overline{L_{\mathrm{i}}} = 10 \lg \left(\overline{I} / I_{\mathrm{ref}} \right) \mathrm{dB} \tag{3}$$

where

$\overline{I}$ is the surface average sound intensity;

$\overline{L_{\mathrm{i}}}$ is the surface average sound intensity level;

I_n is the sound intensity at the n^{th} of the N measurement positions observed;

I_{ref} is the reference intensity.

The above equations are used to calculate the surface average fan sound intensity $\overline{L_{\text{if}}}$ and the surface average RSS sound intensity level $\overline{L_{\text{iq}}}$ by substituting the appropriate measured intensity values into Equation (2).

NOTE If $\overline{I} \leqslant 0$, the results are invalid (see Annex A), and $\overline{L_{\text{i}}}$ cannot be calculated.

These equations assume equal-area weighting for all observed values. If the measurement surface area associated with the measurement positions varies for the observations, the equations should be modified to account for the actual area weighting.

6.2 Background noise criterion

Sound power levels shall be calculated from the measured data only when both $\overline{L_{\text{if}}}$ and $\overline{L_{\text{iq}}}$ exceed $\overline{L_{\text{pb}}}$. If this criterion is not met, the background noise shall be reduced and all observations repeated.

No corrections for the background sound pressure level shall be made.

6.3 Convergence index, δ_{Wn}

The convergence index δ_{Wn}, is calculated from the difference between successive calculations of the surface sound intensity level using N and N/2 observations:

$$\delta_{Wn} = \overline{L_{\text{in}}} - \overline{L_{\text{in}/2}} \tag{4}$$

where

$\overline{L_{\text{in}}}$ is the surface average intensity level calculated from N observations of the intensity on the measurement surface;

$\overline{L_{\text{in}/2}}$ is the surface average intensity level calculated from N/2 observations of the intensity on the measurement surface; respectively.

The convergence index shall be calculated for both the fan and the RSS surface average intensity levels.

6.4 Reference sound source adjustment, R_W

The sound power level reference source adjustment is calculated from:

$$R_W = L_{W\text{q}} - \overline{L_{\text{iq}}} - 10 \lg \left(\frac{S}{S_{\text{ref}}} \right) \text{dB} \tag{5}$$

where

$L_{W\text{q}}$ is the sound power level of the RSS obtained from the RSS calibration;

$\overline{L_{\text{iq}}}$ is the surface average RSS sound intensity level;

S is the surface area of the measurement surface.

$\overline{L_{\text{iq}}}$ should have an acceptable convergence index.

The maximum value of R_W shall not exceed the limits given in Table 5. When Table 5 limits are exceeded, the performance verification as in 3.4 shall be performed. Problems may exist in the RSS, the measurement system, or the observed measurements.

Table 5 — Limits for reference sound source adjustments

Frequency Hz	R_W limit value dB
63	± 5,0
125	± 3,0
25 to 500	± 2,0
1 000 to 4 000	± 1,5
8 000	± 2,5

6.5 Sound power level, L_W

Sound power levels are calculated from the equation below. Note that the equation varies with different product types and set-ups in the adjustment required for duct-end corrections (if any).

$$L_W = \overline{L_{if}} + R_W + E_W + 10 \lg \left(\frac{S}{S_{ref}} \right) \text{dB} \tag{6}$$

where

$\overline{L_{if}}$ is the surface average fan sound intensity level;

S is the surface area of the measurement surface;

R_W is the sound power level reference source adjustment calculated according to 6.4;

S_{ref} $= 1 \text{ m}^2$;

E_W is the adjustment for duct-end corrections (see Annex C of ISO 13347-1:2004), obtained from the test according to Figures 2 or 3, as appropriate.

$\overline{L_{if}}$ should have an acceptable convergence index.

7 Report and results

7.1 Uncertainty of results

Uncertainty of test results, addressed in Annex E of ISO 13347-1:2004, depends upon several variables, including the type of test set-up utilised and the acoustical conditions of the measurement site.

The standard requires measurements in eight octave bands. It should be noted that, in some cases, more accurate results will be obtained if observations are made and results first calculated in 1/3 octave bands, and then these are combined to produce octave band results.

7.2 Presentation of results

The test results are presented as sound power levels in decibels in each of the eight octave bands for each test speed and point of operation. Calculation methods for projection to other sizes, speeds or operating points are given in ISO 13349. This part of ISO 13347 does not require that pure tone components be separated from broadband sound. However, users having suitable instrumentation are encouraged to investigate and report pure tones separately.

7.3 Results

Results shall be reported as octave band sound power levels at a stated rpm for a stated fan size and point of operation. The report shall include the impeller diameter, number of blades, blade pitch (adjustable pitch fans), type, test set-up used, flow rate (Q), fan static (P_s) or total pressure (P_t), test standard and figures used for air performance check, indicate whether a windscreen was used, the method of calibration and calibration value for the windscreen method of sampling, date, and name of laboratory.

Final values of L_W, $L_{W\mathrm{m}}$, $L_{W\mathrm{o}}$, $L_{W\mathrm{i}}$, or $L_{W\mathrm{mi}}$ shall be reported to the nearest decibel.

The test report shall specify which methods, fixed points or scanning, are used in sampling.

7.4 Minimum information to be reported

a) Description of the fan under test:

   1) manufacturer;

   2) model;

   3) nominal size.

b) Operating conditions:

   1) fan speed;

   2) fan airflow rate;

   3) fan static pressure or total pressure at actual test conditions;

   4) fan air density.

c) Mounting conditions:

   1) test figure;

   2) test installation type.

d) Laboratory:

   1) name;

   2) location.

e) Acoustic data:

   1) unweighted fan sound power levels, in full octaves, reported to the nearest whole decibel (dB);

   2) test date.

Annex A
(normative)

Indicators for use in case of difficulty

ISO 9614-1 suggests a number of conditions that may cause difficulty in sound power level determination and suggests a number of indicators that could be helpful in determining the cause of difficulty. The indication of difficulty in sound power level determination is failure to obtain a satisfactory convergence index with a reasonable number of measurement positions.

In the application of this part of ISO 13347, the three most likely causes of difficulty are insufficient measurement distance r, excessive reverberant sound and nearby reflecting surfaces. Indicators D_{21} and D_{23} can be helpful in distinguishing between these.

$$D_{21} = \overline{L_{|\mathrm{i}|}} - \overline{L_{\mathrm{i}}} \tag{A.1}$$

$$D_{23} = \overline{L_p} - \overline{L_{\mathrm{i}}} + 10 \lg \left(p_{\mathrm{ref}}{}^2 / \rho c I_{\mathrm{ref}} \right) \mathrm{dB} \tag{A.2}$$

$$\approx \overline{L_p} - \overline{L_i}$$

where

$\overline{L_{\mathrm{i}}}$ is the surface average sound intensity level;

$\overline{L_{|\mathrm{i}|}}$ is the surface average level of the unsigned intensity, i.e., computed using the absolute value of the intensity regardless of direction;

$\overline{L_p}$ is the surface average sound pressure level.

If $D_{23} < 5$ dB, it is likely that the cause of difficulty is insufficient measurement distance r, or something other than reverberation or reflection.

If $D_{23} > 5$ dB and $D_{21} < 3$ dB, it is likely that the difficulty is due to excessive diffuse reverberant sound.

If $D_{23} > 5$ dB and D_{21} is nearly equal to D_{23}, it is likely that the difficulty is due to a nearby reflecting surface.

If $D_{23} > 5$ dB and D_{21} differs from D_{23} by more than a few dB, it is likely that the difficulty is due to a combination of both nearby reflecting surface(s) and excessive diffuse reverberant sound.

Annex B
(normative)

Alternative procedure for testing of large fan equipment

B.1 General

The size of fan equipment that can be tested within the requirements of this part of ISO 13347 is limited by the practical aspects of the test set-up. If the available test site or the size of the fan equipment to be tested is such that conformance with the measurement surface size or spacing requirements of Figure 4 is impractical, accurate sound power determination may still be possible. The alternative procedure of this annex permits sound power levels to be determined in accordance with ISO 9614-1 subject to the limitations set forth in 4.6. Test-to-test variability of this alternative procedure may be substantially greater than that of the standard procedure, but the absolute accuracy can be expected to be similar to that of the standard procedure.

B.2 Procedure

Except as provided below, all procedures and requirements of the standard sound test shall apply.

B.2.1 Measurement surface

Item 3) in 5.2 shall be replaced by the following. The radius r shall be no less than d and shall be large enough for all parts of the measurement surface to be at least 1 m from the fan equipment. For inlet or outlet sound testing, duct length l may be zero. Equipment under test shall be located with respect to specified reflecting plan(s) such that the distance to the closest surface of the equipment is no more than r or 1 m, whichever is larger. Except for specified reflecting plane(s), all room surfaces should be at least $2r$ or 2 m, whichever is larger, from the measurement surface.

B.2.2 Number of measurements

The requirements of 5.2 shall be modified as follows. The minimum final number of measurements shall depend on the surface area of the measurement surface as indicated in Table B.1. For fan measurements, the tolerance for the convergence index shall be as given in Table B.2. (For RSS measurements, the Table 4 tolerance for the convergence index shall continue to apply.)

Table B.1 — Minimum final number of measurements (alternative procedure)

Surface area of measurement surface m^2	Number of measurements
less than 80	8
between 80 and 500	1 per 10 m^2
more than 500	50

Table B.2 — Tolerance for convergence index (alternative procedure)

Octave band mid-frequency Hz	Tolerance dB
63 to 125	± 1,5
250 to 500	± 1,0
1 000 to 4 000	± 0,8
8 000	± 1,3

B.3 Results

All reports shall be marked to indicate that this alternative procedure, and not the standard procedure, was followed.

Annex C
(normative)

Radiation of sound by fan casing

C.1 General

The sound radiated by the fan L_W(D,cas) casing may be determined by the following method. The method is applicable only to fans for which both inlet and outlet are ducted. Except as provided below, all procedures and requirements of the regular sound test apply.

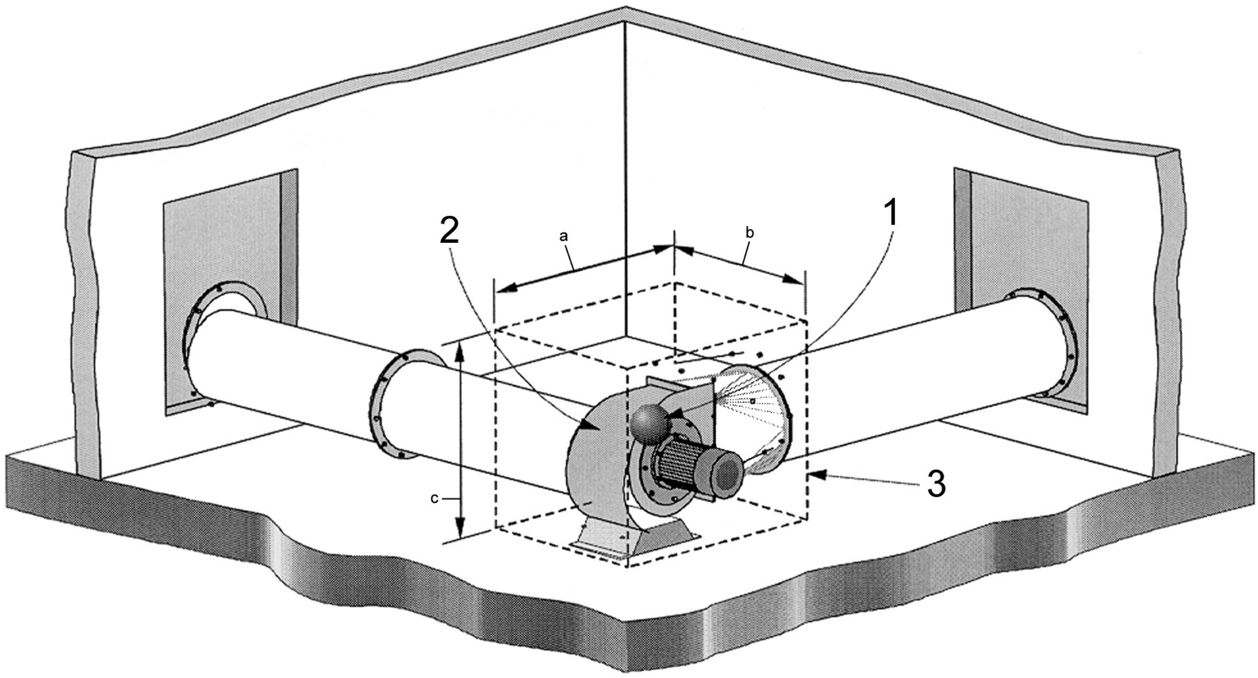
C.2 Set-up

The fan set-up and measurement surface shall be chosen with reference to Figure C.1.

The sound intensity measurements will include sound radiated from all sources, and if the sound from extraneous sources is excessive, determination of the sound power of the fan casing may not be possible. In general, this should not be a problem provided that, on the measurement surface, the sound pressure level due to extraneous sources does not exceed the sound pressure level of direct sound from the fan casing of interest. Ducts and connections should be constructed and secured such that sound transmission through this equipment is minimised. If practicable, both fan inlets and outlets should be ducted to termination points outside the test room.

C.3 Measurements

All measurements on the measurement surface shall be made using the scanning technique.



Key

1 RSS: Reference Sound Source

2 fan casing

3 measurement surface

a, b, c = measurement surface and dimensions

S_i, S_o = cross-sectional area of inlet and outlet at measurement surface

$S = ab + 2bc + 2ac - S_i - S_o$

The measurement surface should be a rectangular parallelepiped that shall enclose the fan casing and be approximately 0,3 m from it.

NOTE 1 At its closest location, the fan casing should be located at least 2 m from all reflecting surfaces, or no more than 0,3 m from a single reflecting surface and at least 2 m from all other reflecting surfaces.

NOTE 2 Inlet and outlet ducts, if terminated inside the test room, should terminate no less than 0,3 m from the measurement surface.

NOTE 3 Surfaces used as reflecting planes should have an acoustical absorption coefficient of less than 0,06 over the frequency range of interest.

NOTE 4 For RSS testing, the RSS should be located as shown on the reflecting plane at the geometric centre of the projection of the measurement surface on the reflecting plane.

NOTE 5 Other than as limited above, test room size, shape, and acoustical treatment are not specified. Room parameters should be such that, at the measurement surface, the level of reverberant sound, plus the sound room from all extraneous sources, does not exceed the level of direct sound from the fan casing.

Figure C.1 — Test set-up and measurement-surface definition for fan casing sound

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