STANDARD

ANSI/AMCA Standard 320-23

Laboratory Method of Sound Testing of Fans Using Sound Intensity

An American National Standard
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Air Movement and Control Association International

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Contents

Laboratory Method of Sound Testing of Fans Using Sound Intensity

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Laboratory Method of Sound Testing of Fans Using Sound Intensity

1. Purpose

This standard establishes a method of determining a fan's octave band sound power levels. When all method requirements are met, the reproducibility will be defined in accordance with Annex D.

2. Scope

This standard is intended to apply to fans of all types and sizes. It is limited to the determination of airborne sound emission for the specified setups. Vibration is not measured, and the sensitivity of airborne sound emission to vibration effects is not determined.

The size of a fan that can be tested in accordance with this standard is limited only by the practical aspects of the test setup.

In this standard, sound power levels are determined using sound intensity measurements on a measurement surface that encloses the sound source. Guidelines are provided on suitable test environment acoustical characteristics, the measurement surface and the number of intensity measurements. Test setups are designated generally to represent the physical orientation of fans as installed following ANSI/AMCA Standard 210 and used in ANSI/AMCA Standard 300.

3. References

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

AHRI Standard 230, Sound Intensity Testing Procedures for Determining Sound Power of HVAC Equipment, Air-Conditioning, Heating, and Refrigeration Institute, Arlington, VA USA.

AHRI Standard 260 (I-P), Sound Rating of Ducted Air Moving and Conditioning Equipment, Air-Conditioning, Heating, and Refrigeration Institute, Arlington, VA USA.

ANSI S1.13-2020, Measurement of Sound Pressure Levels in Air, Acoustical Society of America, Melville, NY USA.

ANSI S12.12-1992 (R2020), Engineering Method for the Determination of Sound Power Levels of Noise Sources Using Sound Intensity, Acoustical Society of America, Melville, NY USA.

ANSI S1.40-2006 (R2016), Specifications and Verification Procedures for Sound Calibrators, Acoustical Society of America, Melville, NY USA.

ANSI/AHRI Standard 250, Performance and Calibration of Reference Sound Sources, Air-Conditioning, Heating, and Refrigeration Institute, Arlington, VA USA.

ANSI/AMCA Standard 210-16 / ANSI/ASHRAE 51-16, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating, Air Movement and Control Association International Inc., Arlington Heights, IL USA.

ANSI/AMCA Standard 300-14, Reverberant Room Method for Sound Testing of Fans, Air Movement and Control Association International Inc., Arlington Heights, IL USA.

ANSI/AMCA Standard 301, Methods for Calculating Fan Sound Ratings from Laboratory Test Data, Air Movement and Control Association International Inc., Arlington Heights, IL USA.

ANSI/ASA S1.11-2014/Part 1/IEC 61260-1:2014 (R2019), Electroacoustics – Octave-band and Fractional-octave-band Filters – Part 1: Specifications, Acoustical Society of America, Melville, NY USA.

ANSI/ASA S12.5/ISO 6926, Acoustics – Requirements for the Performance and Calibration of Reference Sound Sources Used for the Determination of Sound Power Levels, Acoustical Society of America, Melville, NY USA.

ANSI/IEEE SI 10-2016, Standard for Use of the International System of Units (SI): The Modern Metric System, Institute of Electrical and Electronics Engineers, Piscataway, NJ USA.

ASHRAE RP-1314, Reflections of Airborne Noise at Duct Terminations, ASHRAE, Peachtree Corners, GA USA.

4. Definitions/Units of Measure/Symbols

The acoustical definitions and symbols used in this standard are taken from appropriate American National Standards Institute (ANSI) standards whenever possible; some have been expanded to fit the specific needs of this standard. The non-acoustical terms and units used are defined in ANSI/AMCA Standard 210 and are consistent with those used in ANSI/AMCA Standard 300 and ANSI/IEEE SI 10.

4.1 Definitions

4.1.1 Blade passage frequency (BPF)

The frequency of fan impeller blades passing a single fixed object, calculated by the following formula:

$$BPF = \frac{\text{Number of Blades} \times \text{Fan RPM}}{60} \quad \text{Hz} \qquad \text{Eq. 4.1}$$

4.1.2 Decibel (dB)

A dimensionless unit of level, in logarithmic terms, for expressing the ratio of a power or power-like quantity to a similar reference quantity (see sections 4.1.14, 4.1.15 and 4.1.16).

4.1.3 Ducted fan

A fan having a duct connected to its inlet or outlet or both.

4.1.4 Dynamic capability

Dynamic capability is equal to the |PRI| - K dB, where the Pressure-Residual Intensity (PRI) index is determined during the phase calibration of the intensity instrumentation and K is equal to 10 dB for the purposes of this standard. This parameter is a pseudo signal-to-noise ratio that provides a check of the validity of the intensity measurement.

4.1.5 End reflection

A phenomenon that occurs whenever sound is transmitted across an abrupt change in area, such as at the end of a duct in a room. When end reflection occurs at the end of a duct in a room, some of the sound is reflected back into the duct and does not escape into the room.

4.1.6 Frequency range of interest

For general purposes, the frequency range of interest includes the octave bands with mid-band frequencies from 63 Hz to 8,000 Hz, i.e., from the lower cutoff of the 63 Hz band to the upper cutoff of the 8,000 Hz band.

4.1.7 Informative

A term that indicates the reference or annex is provided as advice to the user of this standard.

4.1.8 Measurement position
A microphone location on the measurement surface (see Section 6.3 and figures 10.1 to 10.8) when using the point method (see Section 7.2.2). Each face of the measurement surface must have a minimum of two measurement positions. The area associated with the measurement position used for calculations will be the area of the face divided by the number of measurement positions on the face.

4.1.9 Nonducted fan
A fan without ducts connected to its inlet and outlet.

4.1.10 Normative
A term that indicates the reference or annex contains requirements that are mandatory to comply with this standard.

4.1.11 Octave band
A band of sound covering a range of frequencies in which the highest frequency is twice the lowest frequency. The fan industry reports sound power levels in eight standardized octave bands as shown in Table 1A.

4.1.12 One-third octave band
A band of sound covering a range of frequencies in which the highest frequency is the lower frequency multiplied by the cube root of two. The fan industry measures sound power levels in 24 one-third octave bands as shown in Table 1B.

4.1.13 Shall and should
The word “shall” indicates a mandatory requirement; the word “should” indicates an advisory statement.

4.1.14 Sound intensity level, L_I, in decibels
Ten times the logarithm (base 10) of the ratio of absolute value (magnitude) of the sound intensity, I, to the reference intensity, I_{ref}.

$$L_I = 10\log_{10}\left(\frac{|I|}{I_{ref}}\right) dB \qquad \text{Eq. 4.2}$$

4.1.15 Sound power level, L_W, in decibels
Ten times the logarithm (base 10) of the ratio of the sound power, W, to the reference power, W_{ref}.

$$L_w = 10\log_{10}\left(\frac{W}{W_{ref}}\right) dB \qquad \text{Eq. 4.3}$$

4.1.16 Sound pressure level, L_p, in decibels
Ten times the logarithm (base 10) of the square of the ratio of the sound pressure, p, to the reference pressure, p_{ref}. Unless otherwise stated, the sound pressure, p, is the root-mean-square (rms) pressure.

$$L_p = 10\log_{10}\left(\frac{p}{p_{ref}}\right)^2 dB \qquad \text{Eq. 4.4}$$

4.1.17 Sub-surface
When using the scanning method (see Section 7.2.1), when the individual faces of the measurement surface (see Section 6.3 and figures 10.1 to 10.8) exceed 1 m^2 in area, the face will be segmented into some number of sub-surfaces that are no larger than 1 m^2 and equal in size. Each sub-surface will be scanned separately and summed.

4.2 Units of measure

All units used in this standard are defined in ANSI/AMCA Standard 210. The primary units are The International System of Units, also known as Le Systéme International d’Unités (SI), with inch-pound (I-P) units given as the secondary reference.

Table 1A — ANSI/ASA S1.11 Octave Bands

Nominal midband frequency (Hz)	63	125	250	500	1,000	2,000	4,000	8,000

Table 1B — ANSI/ASA S1.11 One-Third Octave Bands

Nominal midband frequency (Hz)	50	63	80	100	125	160	200	250	315	400	500	630
Nominal midband frequency (Hz)	800	1,000	1,250	1,600	2,000	2,500	3,150	4,000	5,000	6,300	8,000	10,000

4.3 Symbols

Table 2 — Symbols

Symbol	Description	SI Unit	I-P Unit
A_n	Area of n^th segment	m^2	ft^2
c	Speed of sound	m/s	ft/sec
d	Characteristic acoustic source dimension	M	ft
E_i	Duct inlet end correction	dB	dB
E_o	Duct outlet end correction	dB	dB
E_w	Adjustment to sound power level for duct end correction(s)	dB	dB
f	Frequency	Hz	Hz
I	Sound intensity	W/m^2	*
I_n	Sound intensity *I* at measurement position n	W/m^2	*
$\overline{I_n}$	Surface average sound intensity	W/m^2	*
I_{ref}	Reference intensity	pW/m^2 (10^{-12} W/m^2)	*
l	Measurement surface characteristic dimension (length)	M	ft
L_I	Sound intensity level (re. 1 pW/m^2)	dB	
$\overline{L_I}$	Surface average sound intensity level	dB	
L_{If}	Fan sound intensity level	dB	
$\overline{L_{If}}$	Surface average fan sound intensity level	dB	
L_{Iq}	RSS sound intensity level	dB	
$\overline{L_{Iq}}$	Surface average RSS sound intensity level	dB	
L_p	Sound pressure level (re. 20 μPa)	dB	
L_{pb}	Background sound pressure level	dB	
$\overline{L_{pb}}$	Surface average background sound pressure level	dB	
L_{pbn}	L_{pb} at measurement position n	dB	
L_W	Sound power level (re. 1 pW)	dB	

L_{Wi}	Fan inlet sound power level (ducted inlet)	dB	
L_{Wm}	Fan total sound power level (non-ducted fan)	dB	
L_{Wmi}	Fan inlet sound power level (non-ducted inlet)	dB	
L_{Wmo}	Fan outlet sound power level (non-ducted outlet)	dB	
L_{Wo}	Fan outlet sound power level (ducted outlet)	dB	
L_{Wq}	RSS calibration sound power level	dB	
p	Sound pressure	Pa	*
p_{ref}	Reference sound pressure, 20 μPa (2.0 × 10^{-5} Pa)	—	—
P_s	Fan static pressure	Pa	in. wg
P_t	Fan total pressure	Pa	in. wg
p_b	Barometric pressure	kPa	in. Hg
Q	Fan airflow rate	m^3/s	cfm
r	Measurement surface characteristic dimension (radius)	M	ft
S	Surface area of measurement surface	m^2	ft^2
S_{ref}	Reference area, 1 m^2	—	—
t_d	Dry bulb temperature	^{O}C	^{O}F
t_w	Wet bulb temperature	^{O}C	^{O}F
W	Sound power	W	
W_{ref}	Reference sound power, 1 pW (1.0 ×10^{-12})	—	—
δ_{WN}	Convergence index (with N measurement positions)	dB	
z	Measurement surface characteristic dimension (height above reflecting plane)	M	ft

**I-P units not used.*

5. Instruments and Methods of Test

5.1 Sound pressure microphones

Pressure-sensing microphones shall comply with the requirements of ANSI S12.12.

5.2 Sound intensity probes

The sound intensity probe shall consist of two pressure-sensing microphones and comply with the requirements of ANSI S12.12. To cover the entire frequency range of interest, it may be necessary to use more than one probe or microphone spacing.

5.3 Frequency analyzer

An octave band or one-third octave band filter set shall meet or exceed the Class 2 requirements of ANSI/ASA S1.11.

5.4 Reference sound source (RSS)

The RSS is used to qualify the performance of the sound intensity measurement system and personnel. To be used for these purposes, the RSS must be of appropriate type, calibrated accurately and properly maintained.

The reference sound source should comply with the requirements of ANSI/AHRI Standard 250. The RSS shall produce steady broadband sound over at least the frequency range from 50 Hz to 10,000 Hz. While ANSI/AHRI Standard 250 allows RSS calibration over a limited frequency range, this standard requires calibration over the entire range.

5.5 Frequency response of instrumentation system

The frequency response of the instrumentation system shall be flat over the frequency range of interest within the tolerances given in Table 3, applied as outlined in ANSI S12.12.

For sound intensity measurements, the use of two or more configurations of the intensity probe, or different probes, may be required to cover the entire frequency range in conformance with Table 3.

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

Table 3 — Tolerances for the Instrumentation System

One-Third Octave Band (Hz)	Tolerance (dB)
50–80	±1.5
100–4,000	±1.0
5,000–8,000	±1.5
10,000	±2.0

5.6 Transducer and instrumentation system calibration checks

Before and after each series of sound power determination, the following calibration checks shall be performed: A calibration check 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 that conforms to ANSI S1.40 and has an accuracy of ±0.5 dB or better shall be used for this purpose. In conformance with ANSI S1.40, the calibrator shall be checked at least once every year to verify that its output has not changed. Additionally, an electrical calibration of the instrumentation system over the entire frequency range of interest shall be performed periodically at intervals as recommended by the manufacturer(s), but not longer than two years.

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 at 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 degrees and placed with its acoustical center 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 its acoustical center 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 4 for the measuring equipment to be acceptable. The two sound intensities shall be of opposite sign.

Table 4 — Tolerance for Difference in Sound Intensity Levels for Field Check

One-Third Octave Band (Hz)	Difference (dB)
50–160	1.5
200–5,000	1.0
6,300–10,000	1.5

5.7 High-frequency correction

Per AHRI Standard 230, for measurement systems using 10-mm to 15-mm microphone spacers, the results of the performance verification in may be used to determine a high-frequency correction for each individual sound intensity probe and analyzer combination (see Section 5.8). The probe correction is the one-third octave band level (in decibels) that is added to the sound power—determined by the intensity measurements—to equal the sound power of the RSS. The high-frequency correction shall be applied to the 1,600-Hz through 10,000-Hz one-third octave bands.

Some manufacturers integrate this high-frequency probe correction in the analyzer, and it is applied automatically. If not, information on calculating this for your specific instrumentation can be found in Annex E.

5.8 Performance verification

Periodically, the instrumentation system's performance shall be verified by determining the sound power of a reference sound source using the procedures specified in ANSI S12.12. Qualified personnel shall perform this verification monthly or during sound measurements if this occurs at intervals greater than one month apart.

The measurement grid shall be as shown in AHRI Standard 230, Figure 10.9. The same intensity probe, windscreen and analyzer combination shall be used during performance verification and all subsequent measurements. The sound power, determined as noted in Section 5.7 above via intensity measurements with high-frequency correction, shall differ from the RSS value over the frequency range of interest by no more than the tolerance given in Table 5.

Sound power levels listed on an RSS calibration certificate are normalized to standard temperature and barometric pressure. The RSS sound power levels used for performance verification must be adjusted to site specific temperature and pressure according to the RSS manufacturer's instruction manual.

Table 5 — Tolerance for Sound Power Level Determined for a Reference Sound Source

One-Third Octave Band (Hz)	Tolerance (dB)
50–80	±3.0
100–160	±2.0
200–5,000	±1.5
6,300–10,000	±2.5

5.9 Qualification of sound intensity measurements

Per AHRI Standard 230, to conform with this standard, the quality of each measurement shall meet the following requirements for each one-third octave band:

$$PI_n < PRI_n - 10 \quad \text{Eq. 5.1}$$

Where:

PI_n = Pressure intensity (PI) index (mean-pressure level minus the intensity level) of the measurement for the nth one-third octave band, dB

PRI_n = Pressure residual intensity (PRI) index, determined by the phase calibration of the particular microphone pair, spacer and analyzer used for the measurement for the nth one-third octave band, dB

Measurements in each frequency band that do not meet this requirement are invalid. Measurements in each frequency band where the mean-pressure level is less than the intensity level (i.e., the PI index is negative) are also invalid. This condition often occurs when the measurement is influenced by flow-induced noise over the probe (see AHRI Standard 230).

This qualification requirement often is referred to as “dynamic capability” in literature. This parameter is a pseudo signal-to-noise ratio that provides a check of the validity of the intensity measurement.

5.10 Test method

The basis of the test method originates in ANSI S12.12. The test method covers a wider frequency range and contains requirements somewhat more specific and restrictive than those of ANSI S12.12; it also provides for sound power level adjustments as described below. Other than the adjustments, measurements made in conformance with this test method will also be in conformance with ANSI S12.12 over their common frequency range.

The basic requirement is measurement of the sound intensity distribution around the fan. A measurement surface is defined as that which encloses the entire fan, fan inlet or fan outlet, depending upon the objective of the test. A set of sound intensity measurements of this surface is made. The sound power level is calculated using the surface area and the measured sound intensity data. Adjustments are made, if needed, for the appropriate test configuration for duct end correction.

The sound power levels resulting from the test method can be identical to those produced using ANSI/AMCA Standard 300, within the accuracy of both methods, to the extent that each method is applicable and that the installations tested are identical. It should be noted that this test method differs substantially from ANSI/AMCA Standard 300 in both the test environment requirements and measured quantities.

6. Equipment and Test Setups

6.1 Test environment

6.1.1 Background noise

Sound power determination using intensity measurements is inherently less sensitive to background noise than methods based on sound pressure measurements, such as ANSI/AMCA Standard 300. 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, the dynamic capability requirement in Equation 5.1 will not be satisfied.

6.1.2 Nearby reflecting surfaces

Reflecting surfaces in the vicinity of the measurement surface can affect the source sound power as well as the ability to accurately sample the sound intensity on the measurement surface. Nearby reflecting surfaces may alter the sound power output of the fan equipment under test and should be limited to those surfaces usually encountered in a typical fan installation. If a reflecting surface is part of the fan equipment’s typical installation, 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, the dynamic capability requirement in Equation 5.1 will not be satisfied. In an extreme case the intensity may be negative, i.e., opposite the direction normal to the intensity measurement surface.

6.1.3 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, its sound pressure level 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" (i.e., 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 standard (i.e., increasing the direct sound from the source).

If reverberant sound is excessive, the dynamic capability requirement in Equation 5.1 will not be satisfied.

6.2 Fan installation

6.2.1 Setup categories

A number of specific fan test setups are allowed. Airflow direction and particular mounting arrangement of the test device determines the test setup. Test setups fall into two general categories. The first category is for a freestanding unit that would be placed entirely in the test room (see Figure 10.1). Results of this arrangement yield total sound power level (L_{Wm} or L_W) of the test unit. The second category is for units that would be tested with a chamber or two-room system, and only the inlet or outlet would discharge sound into the test room (see figures 10.2 through 10.8). This arrangement results in ratings of inlet (L_{Wmi} or L_{Wi}) or outlet (L_{Wmo} or L_{Wo}) sound power level only. Note the subscript m indicates that the sound power level is determined from measurements using a setup 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 setup.

Deciding which test setup is used for a particular fan will depend on how a product is expected to be rated and applied in the field.

6.2.2 Aerodynamic performance

Aerodynamic performance tests that are necessary to determine the point of fan operation shall be performed as specified in ANSI/AMCA Standard 210 or other fan aerodynamic performance test standard with a demonstrated accuracy equivalent to that of ANSI/AMCA Standard 210.

6.2.3 Mounting methods

Vibration is known to influence airborne sound emission. Resilient fan mounting and vibration isolation of any duct/fan connections may minimize vibration effects.

Fan mounting methods, fan connections to non-integral drivers and fan connections to aerodynamic performance test facilities are not specified. Any conventional method may be used, including vibration isolation devices and short flexible connectors. 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 made of metal or other rigid, dense, non-absorptive material, and have no exposed sound absorption material on the interior or exterior surfaces.

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

6.2.4 Duct length

The duct length in figures 10.6 through 10.8 shall be consistent with the procedures of ANSI/AMCA Standard 210. Care must be exercised to ensure that no duct resonances exist near specific frequencies of interest, e.g., blade passage frequency.

On chamber or two-room setups, the length of duct shall be consistent with ANSI/AMCA Standard 210 acceptable practices, which are necessary to accurately establish the point of rating.

6.3 Measurement surface

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

The shape and size of the measurement surface shall be chosen with reference to figures 10.1 through 10.8, noting whether the objective is fan total, inlet or outlet sound power. All faces of the measurement surface shall be at least 1 m from the source, whether duct termination, fan wheel or fan inlet. If it is not possible to satisfy the requirements of these figures, see Annex B. For casing-radiated sound power, see Annex C.

Care must be taken to ensure that wind-induced noise caused by flow over the intensity probe does not influence the measurements. A windscreen should be used at all times. On all faces of measurement surfaces, Section 5 requirements shall be met. Locations on the measurement surface where air velocity exceeds 3.8 m/s (750 fpm) should be avoided. 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 with excessive wind-induced noise do not exceed 10% of the total measurement surface area, such locations need not be measured when sampling sound on the measurement surface. The 10% requirement may necessitate expanding the test surface.

Reflecting surfaces are used as a boundary of the measurement surface as outlined in figures 10.2 through 10.8. When used this way, the reflecting surface area shall not be included in the measurement surface area, and no intensity measurements are made for it. Surfaces used as reflecting planes shall have an acoustical absorption coefficient of less than 0.06 over the frequency range of interest. When a free-standing acoustical baffle is used as one of the reflecting surfaces, rather than a wall between two separate spaces, the baffle edges shall extend 1 m beyond the intersecting edges of the faces of the measurement surface. Note that with a baffle wall, if the unmeasured side of the fan is not ducted to a separate space or elsewise acoustically attenuated, requirements of Section 5.9 may be difficult to achieve.

7. Observations and Conduct of Test

7.1 Information to be recorded

The following information, when applicable, shall be compiled and recorded for all measurements.

7.1.1 Laboratory and instrumentation identification

1. Test date
2. Laboratory name
3. Laboratory location
4. Technician name
5. List of equipment with calibration dates
6. Method and results of transducer and instrumentation calibration check (in conformance with Section 5.6)
7. Date and results of performance verification check (in conformance with Section 5.8)

7.1.2 Description of fan under test

1. Manufacturer
2. Model
3. Nominal size
4. Impeller diameter
5. Number of blades
6. Blade setting (adjustable pitch fans only)
7. Number of stator vanes (as applicable)
8. Inlet area
9. Outlet area

7.1.3 Fan installation and operating conditions

1. Mounting conditions
    a. Test figure
    b. Test installation type

2. Operating conditions
    a. Fan speed
    b. Fan airflow rate
    c. Fan static pressure or total pressure at actual test conditions
    d. Fan air density
3. Environmental conditions
    a. Barometric pressure
    b. Ambient dry-bulb temperature
    c. Ambient wet-bulb temperature
    d. Dry-bulb temperature at the fan inlet
    e. Static pressure at the fan inlet

7.1.4 Acoustical setup and test conditions

1. Intensity probe configuration parameters (microphone size, spacing, etc.)
2. Sketch of enclosed surface showing position in test laboratory and location of each intensity measurement surface
3. Whether a windscreen was used over the intensity probe
4. Whether scanning or the point method was used

7.1.5 Acoustical data

1. Surface average fan sound intensity level for each measurement surface and its surface area
2. Calculated sound power level for each measurement surface
3. Fan sound power level, total of all measurement surfaces. These measurements are unweighted
4. End correction data if applicable
    a. End correction values
    b. Duct length
    c. Flush or non-flush mounting of the duct
    d. Inside diameter of the orifice plate
5. Whether results in octave bands were calculated from measurements in octave bands or one-third octave bands

7.2 Measurement techniques and requirements

This section outlines the two acceptable methods for sound intensity measurement. Only one of the two methods shall be used per given test. However, it is acceptable for a user to run a second test with the other method.

7.2.1 Sampling of sound on the measurement surface using scanning method

A measurement surface shall be defined per the requirements of Section 6.3. The average sound intensity level is measured on each face of the measurement surface by scanning each face of the surface with an intensity probe. Unless deferring to Annex B for large fans, face areas greater than 1 m^2 shall be divided into sub-surfaces.

7.2.1.1 Number of sub-surfaces

Unless the fan (or duct termination) being tested is small enough for 1 m^2 faces (or smaller), each face of the enclosing surfaces shall be divided into sub-surfaces of known area. Preferably, these should be approximately equal in size and small enough to facilitate an operator’s reach and maintain even coverage with time. The suggested size for each sub-surface is 1 m^2 or smaller.

7.2.1.2 Scanning speed

Within human ability, the intensity probe shall move at a constant speed during each surface scan. This can be achieved by timing each pass of the intensity probe throughout the entire surface scan.

7.2.2 Sampling of sound on the measurement surface using point method

The average sound intensity level is measured on each measurement surface by defining sufficient intensity probe locations to satisfy the convergence index criteria. Measurement surfaces shall be chosen so the total enclosed fan surface is divided into surfaces as nearly equal in dimension and area as is practical.

7.2.2.1 Number of measurements points

The total number of measurement positions (total of all faces on the measurement surface) shall be selected to satisfy two criteria:

1. The convergence index, δ_{WN}, calculated using Equation 8.3 shall be satisfactory.
2. The number of measurement positions on each face shall be an even number and the total number of measurements shall be at least the larger of: (a) the number equal to the area of the measurement surface in square meters, rounded to the next higher whole number or (b) eight locations.

The convergence index must be calculated for each result of Equation 8.2 that is used in Equation 8.4. The convergence index is satisfactory when the calculated value is within the tolerance specified in Table 6. When results are reported over a frequency range for all 24 one-third octave bands (Table 1A), twice the Table 6 tolerance is permitted for a single frequency band or for two non-adjacent bands. The convergence index criterion applies to any frequency band that is reported, regardless of bandwidth.

Determining the required number of measurement positions may require experimentation, e.g., selecting a trial number then increasing it until a satisfactory convergence index is obtained. Selecting the correct number of points on the first try becomes easier as one becomes familiar with the test method and the acoustical properties of the fan design being tested. Most of the time, starting out with twice the minimum number of points as calculated in Section 7.2.2.1 will result in an acceptable convergence index. Experience may show you can use fewer points, but highly directive sources will require a higher number of points, at least on the surface the sound is directed toward.

The number of measurement positions need not be the same for all frequency bands. For some fans in some test environments, it may not be possible to satisfy the requirements of Table 6 using a reasonable number of measurement positions. In this event, it will be necessary to alter the test environment to determine sound power level in accordance with this standard. See Section 6.1 of this standard and/or ANSI S12.12 for recommendations.

Table 6 — Tolerance for the Convergence Index

One-Third Octave Band (Hz)	Tolerance (dB)
50–160	0.75
200–5,000	0.4
6,300–10,000	0.65

7.3 Measurements

7.3.1 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 standard provides different test setups for the testing of various fan types. Regardless of the test setup, the point of operation shall be determined. If the test setup conforms to one noted in ANSI/AMCA Standard 210, the point of rating can be established with sufficient accuracy. If the sound test setup does not conform to one noted in ANSI/AMCA Standard 210, sufficient data must be acquired so that the speed is known within ±1% and that the point of rating can be established within ±5%.

7.3.2 Sound intensity

Time average sound intensity levels in each third-octave band shall be made for the fan being tested. The direction of the intensity vector (positive or negative) also must be recorded. Intensity shall be measured on the measurement surface, with an intensity probe oriented perpendicularly to the measurement surface and facing the sound source.

The intensity the source radiates will be positive. For a set of tests at various fan points of operation, the intensity must be recorded for each operating point.

7.3.2.1 Fan sound intensity levels, L_{If}
The intensity levels present when only the test fan is operating.

7.3.3 Test conditions
The test conditions shall be nearly the same for all sound readings. Operators and observers shall attempt to minimize 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 measurement position.

Measurements shall be the unweighted ("linear") time average over the observation period.

7.3.3.1 Scanning method
For the scanning method, at each measurement sub-surface, the averaging period shall be a minimum of 30 seconds for the 50 Hz through 160 Hz one-third octave bands and 15 seconds for the 200 Hz one-third octave band and up. (As modern meters generally will be measuring all bands at once, this sets the minimum averaging time to 30 seconds.)

7.3.3.2 Point method
For the point method, the averaging period shall be 15 seconds to account for any minor fluctuations.

8. Calculations

8.1 Surface average levels: $\overline{L_{pb}}$, $\overline{L_{If}}$ and $\overline{L_{Iq}}$

For each one-third octave band, the average intensity on the measurement surface is calculated from:

$$\bar{I} = \frac{\sum_{n=1}^{N} A_n I_n}{\sum_{n=1}^{N} A_n} \qquad \text{Eq. 8.1}$$

$\bar{I}$ = the surface average sound intensity (W/m^2)
I_n = the observed sound intensity at the nth of the N measurement positions or sub-surfaces (W/m^2)
A_n = the area associated with the nth of the N measurement positions or sub-surfaces (m^2)

If instruments report the average intensity in terms of dB, it can be converted to W/m^2 by:

$I_{(n)} = I_0 \cdot 10^{L_{i(n)}/10}$ where the $L_{i(n)}$ direction is away from the source, or
$I_{(n)} = -I_0 \cdot 10^{L_{i(n)}/10}$ where the $L_{i(n)}$ direction is toward the source

$$I_0 = 10^{-12}\ \mathrm{W/m^2}$$

For each one-third octave band, the average intensity level on the measurement surface is calculated from:

$$\overline{L_I} = 10 \log_{10}\left[\frac{\bar{I}}{I_{ref}}\right] \mathrm{dB} \qquad \text{Eq. 8.2}$$

Where:

$\overline{L_I}$ = the surface average sound intensity level for the one-third octave being calculated

If $\bar{I} \leq 0$, the result is invalid, and L_I cannot be calculated.

8.2 Background noise criterion

The average background sound pressure level on the measurement surface need not be measured directly if the dynamic capability criteria of Section 5.9 are meet, then the background sound level is not an issue.

8.3 Convergence index, δ_{WN}

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

$$\delta_{WN} = \overline{L_{IN}} - \overline{L_{IN/2}} \quad \text{Eq. 8.3}$$

Where:

$\overline{L_{IN}} - \overline{L_{IN/2}}$ = the surface average intensity levels calculated from N and N/2 observations of the intensity on the measurement surface, respectively

8.4 Sound power level, L_W

Sound power levels are calculated from Equation 8.4. Note that the equation varies with different product types and setups in the adjustment required for duct end corrections (if any).

$$L_W = \overline{L_{If}} + E_W + 10\log_{10}\left(\frac{S}{S_{ref}}\right) \text{ dB} \quad \text{Eq. 8.4}$$

Where:

$\overline{L_{If}}$ = the surface average fan sound intensity level

S = the surface area of the measurement surface

E_W = the adjustment for duct end corrections for ducted setups shown in figures 10.6 through 10.8 determined according to Annex A

S_{ref} = 1 if S is in m^2 and = 10.8 if X is in ft^2

$\overline{L_{If}}$ must have an acceptable convergence index, if applicable

9. Results and Report

9.1 Accuracy of results

Accuracy of test results, addressed in Annex D, depends upon several variables, including the type of test setup utilized and the acoustical conditions at the measurement site.

This standard requires measurements in 24 one-third octave bands specified in Table 1B. More accurate results will be obtained if observations are made and results first calculated in one-third octave bands, then are combined to produce octave band results.

9.2 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 (see Table 1A). One-third octave band data also may be reported (see Table 1B).

This standard does not require pure tone components to be separated from broadband sound. However, users with suitable instrumentation are encouraged to investigate and report pure tones separately (see ANSI S1.13, Appendix A).

9.3 Results

Results shall be reported as octave band sound power levels at a stated fan speed 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 setup used, airflow rate (Q), fan static (P_s) or total pressure (P_t), test standard and test setup figure used for air performance check, sampling method, date and name of laboratory. One-third octave band data may also be reported.

Final values of L_W, L_{Wm}, L_{Wo}, L_{Wmo}, L_{Wi} or L_{Wmi} shall be reported to the nearest decibel.

The test report shall specify which method—fixed points or scanning—is used in sampling.

9.4 Minimum information to be reported

A statement indicating whether all requirements of this standard were met.

9.4.1 Fan being tested

1. Description of the fan being tested
   a. Manufacturer
   b. Model
   c. Nominal size
   d. Actual impeller diameter
   e. Number of blades
   f. Blade pitch (adjustable or variable pitch axial fans only)
2. Operating conditions
   a. Test setup figure for air performance check
   b. Test installation type
   c. Fan speed
   d. Fan airflow rate
   e. Fan static pressure or total pressure at actual test conditions
   f. Fan air density (include *td*, *tw* and *pb*)

9.4.2 Laboratory

1. Laboratory name
2. Laboratory location
3. Test date

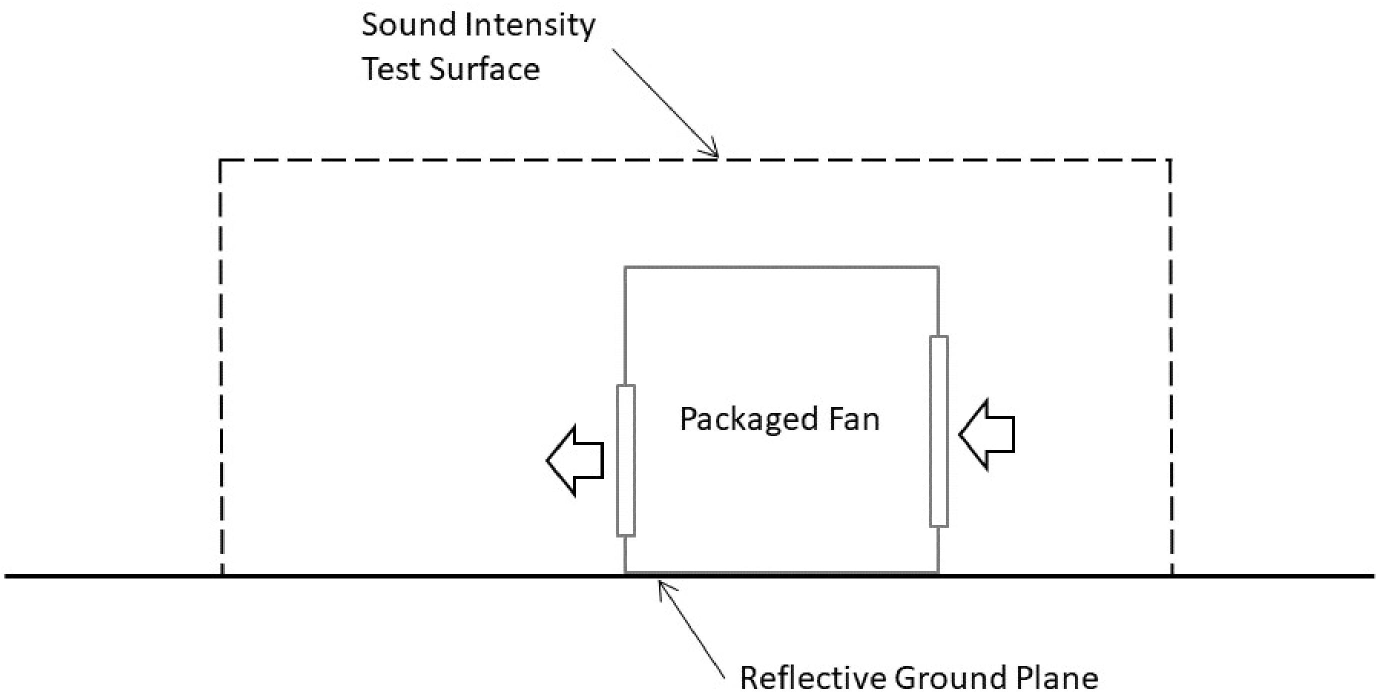
9.4.3 Acoustic data

Unweighted fan sound power levels (L_W, L_{Wm}, L_{Wo}, L_{Wmo}, L_{Wi} *or* L_{Wmi}) in full octaves, reported to the nearest whole decibel (dB).

Octave band results are to be reported even when one-third octave band data is given.

The calculated sound power is for site conditions. These results can be adjusted to standard air according to Annex F (for adjusting measured sound power to standard air).

10. Figures



The following notes apply to all figures in this standard:

- When calculating sound power, all ducted configurations will apply duct end corrections.
- Appurtenances attached to the fan are considered part of the fan and shall be contained within the test surface.
- Orifices to control the operating point are not permitted on the tested end of a duct, unless integral to the fan.
- Measurement surfaces typically are located at least 1 m from the fan equipment. However, the measurement surface may be located close to a duct termination or fan inlet if the Section 5 requirements are met.
- Test room size, shape and acoustical treatment are not specified. Room parameters shall meet Section 5 requirements.
- The BV-3 vibration level should be achieved on the fan bearing that is adjacent to the driving shaft.
- "Test surface" as called out in the figures is equivalent to "measurement surface."

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

- Acoustical energy in a duct that terminates in a second room or chamber does not interfere with intensity measurements on a test surface in the first room. This requires adequate transmission loss between adjoining rooms and the possible addition of absorptive material within the second room to absorb this energy.
- Adequate absorption takes place at the end of an untested duct so any energy radiated from the duct termination does not interfere with the intensity measurement.
- Duct construction allows the transmission loss through the duct wall to be great enough to eliminate any sound emission additions inside the enclosed intensity measurement surface.
- No resonances are 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 levels.

Figure 10.1 — Free Inlet Plus Free Outlet (Packaged Fan)

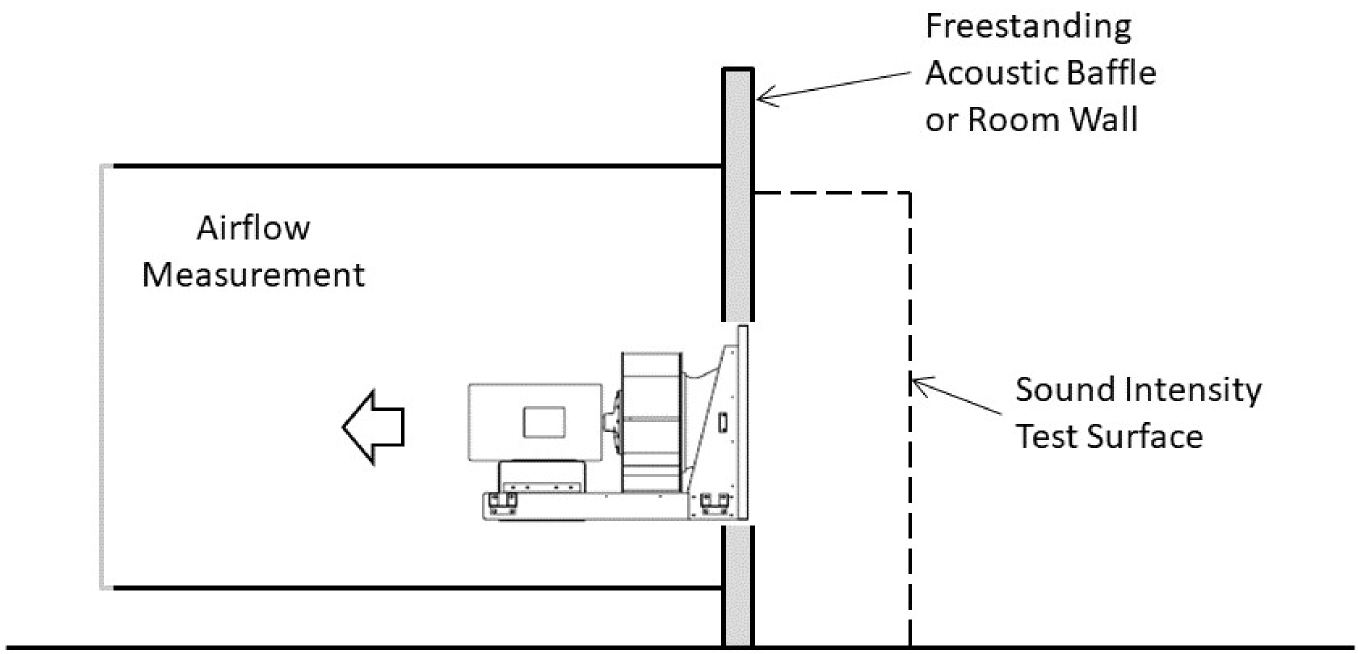


Figure 10.2 — Free Inlet (Plenum Fan)

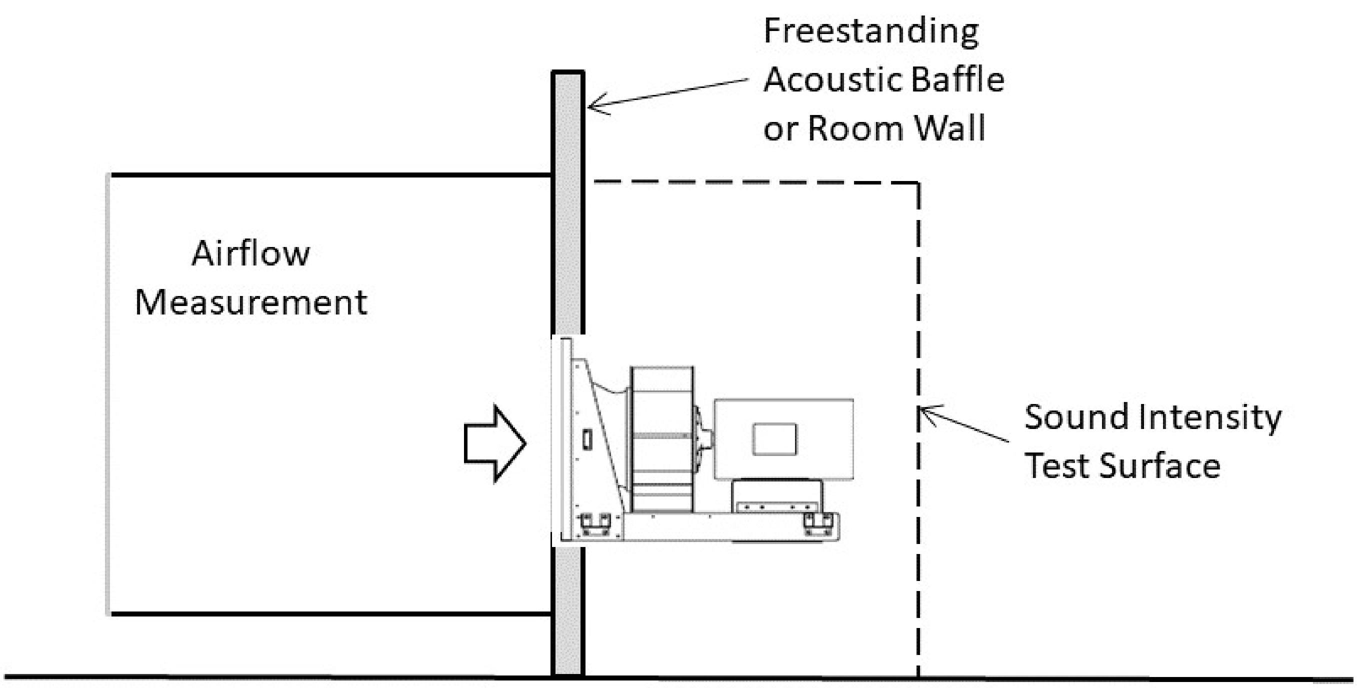


Figure 10.3 — Free Outlet (Plenum Fan)

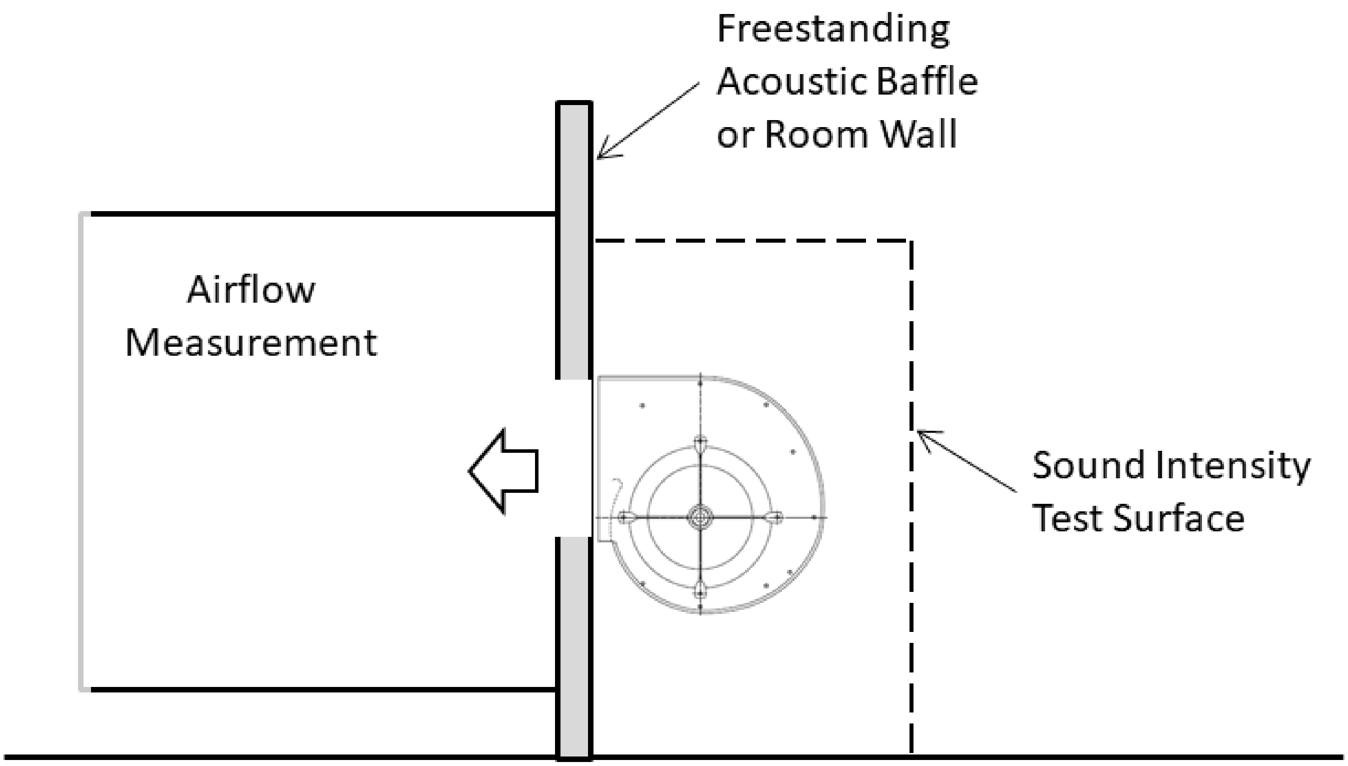


Figure 10.4 — Free Inlet (Housed Fan)

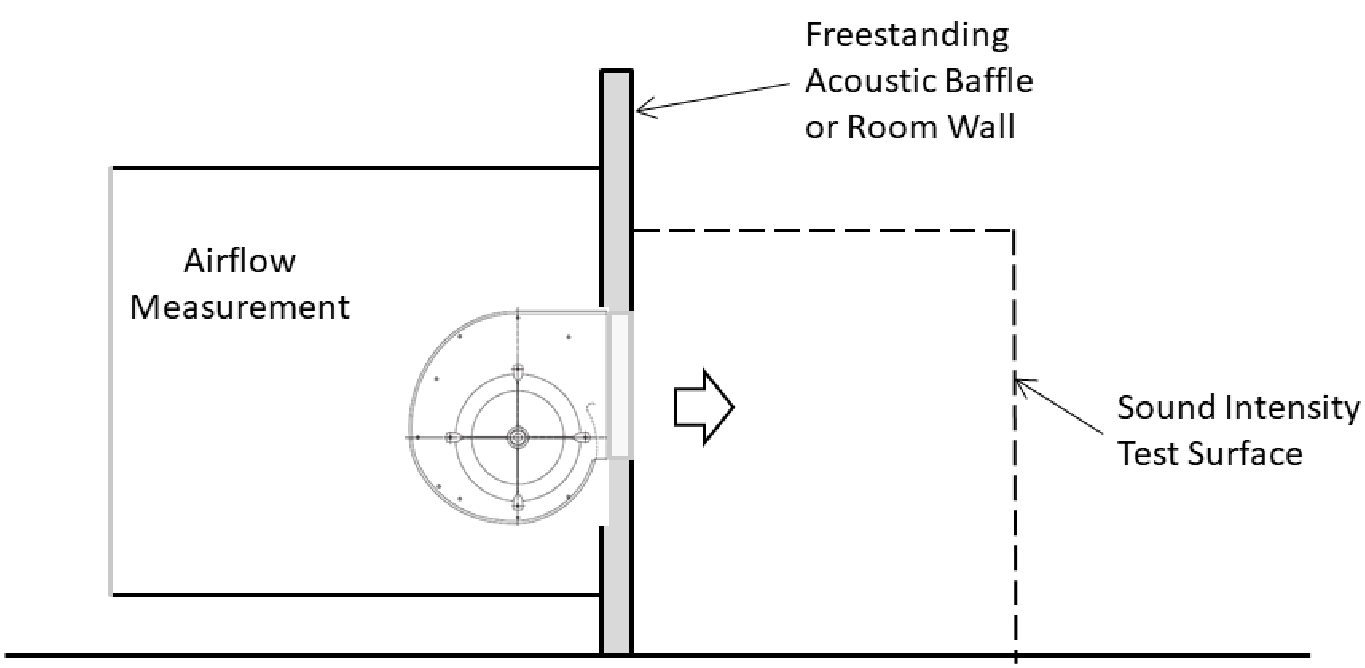


Figure 10.5 — Free-Outlet (Housed Fan)

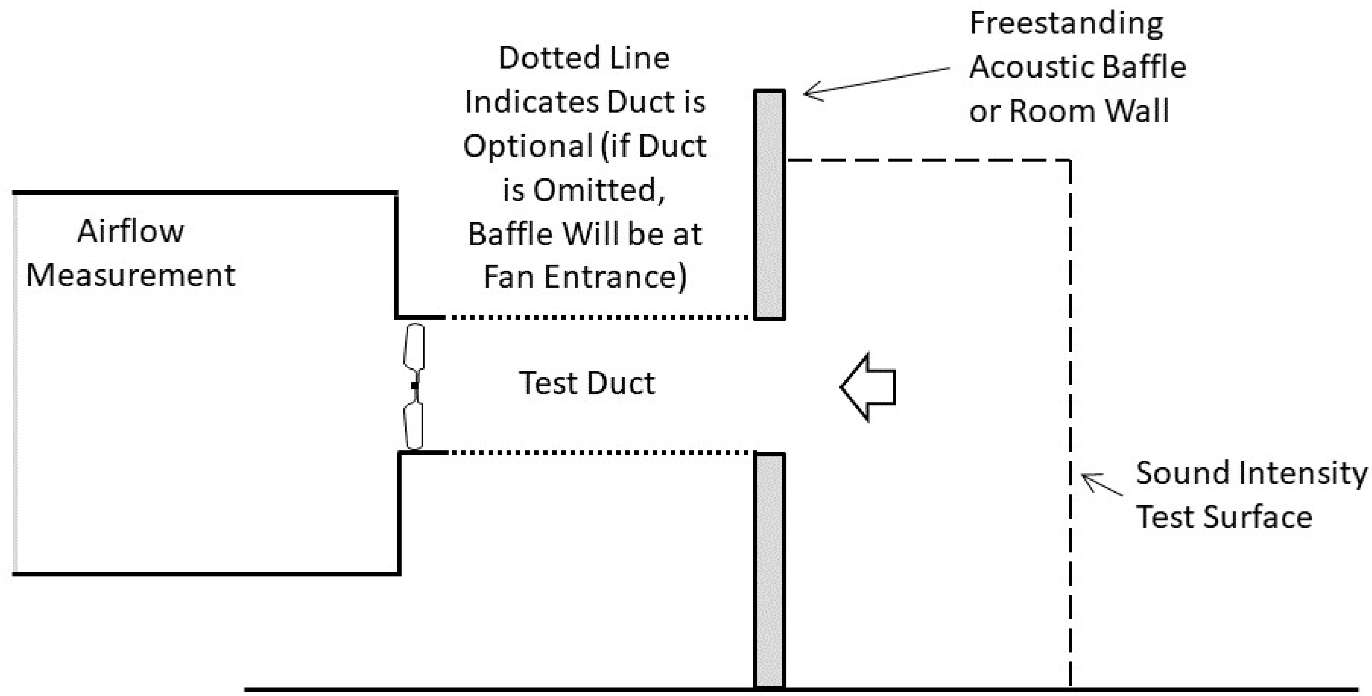


Figure 10.6 — Ducted Outlet (Housed Fan)

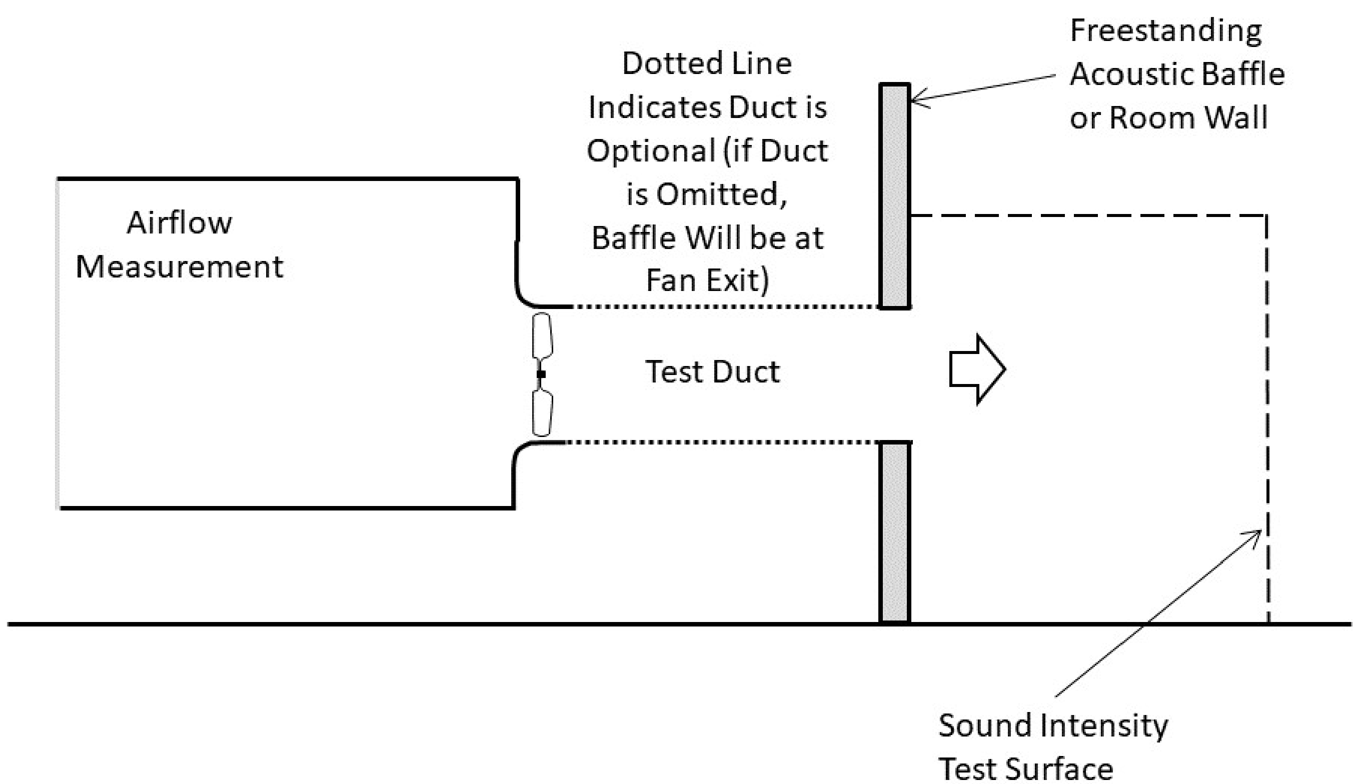


Figure 10.7 — Ducted or Free Inlet (Axial Fan)

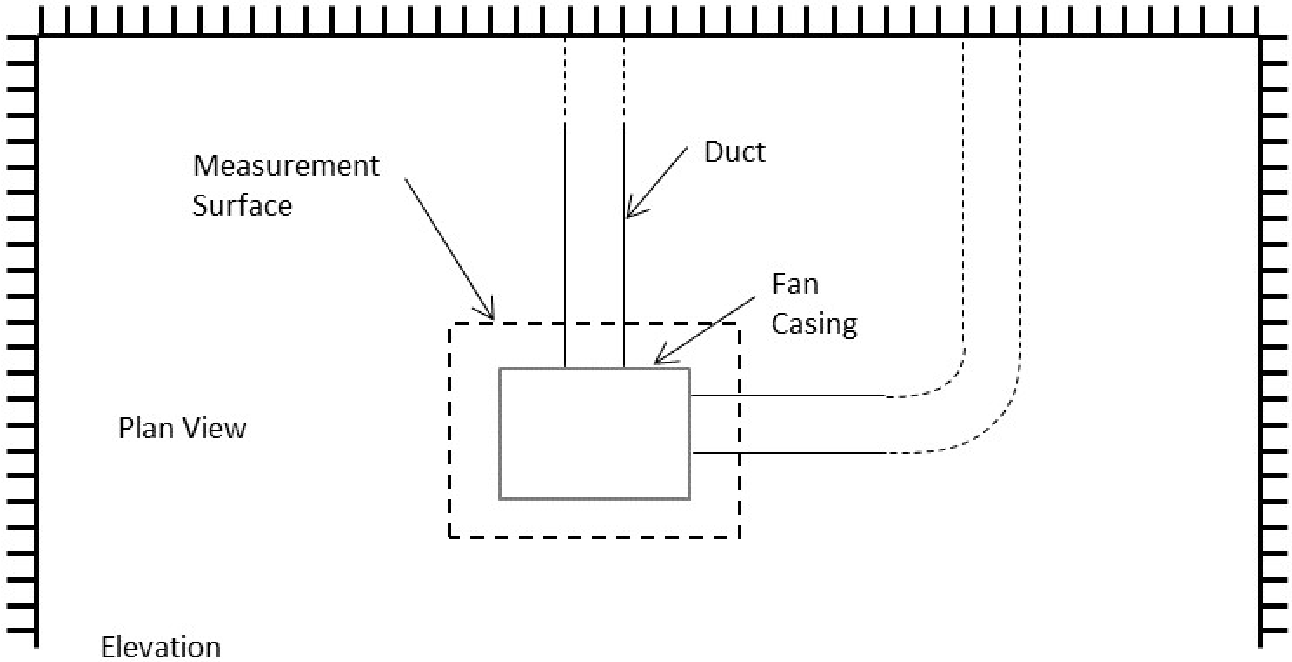


Figure 10.8 — Ducted or Free Outlet (Axial Fan)

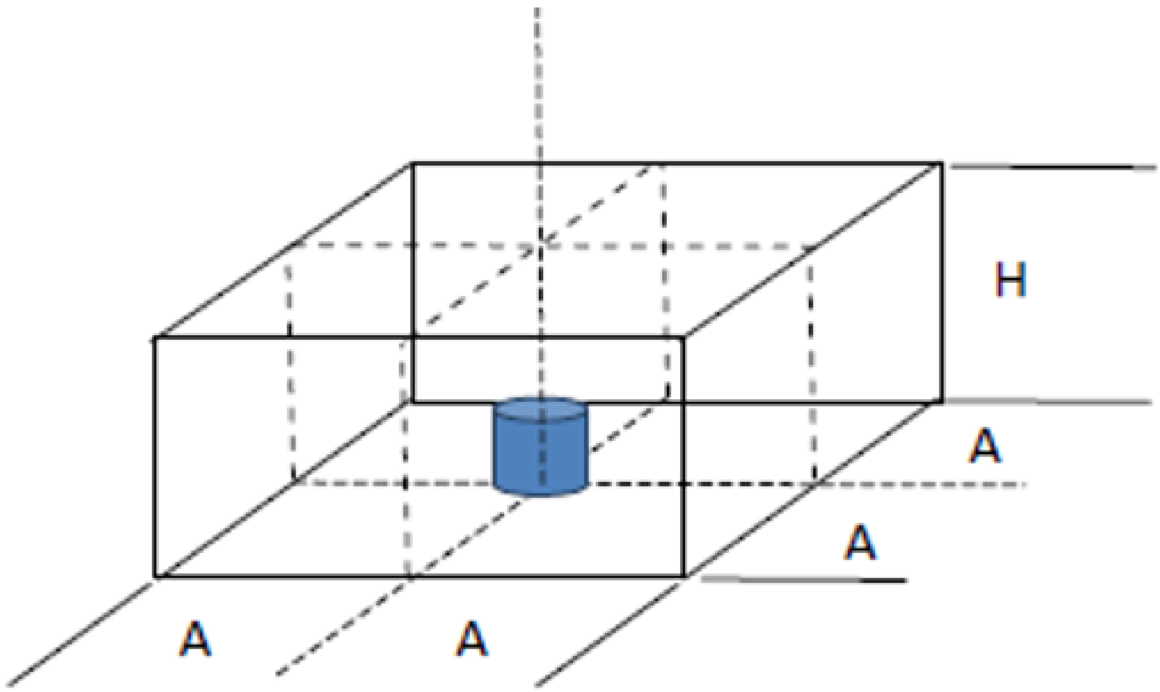


Figure 10.9 — Performance Verification Measurement Grid

Annex A
Duct End Reflection Correction (Normative)

A.1 Calculation of the acoustic test duct end correction

For ducted inlet or ducted discharge sound components tested in accordance with this standard, the duct end correction shall be added to each one-third octave band sound power level. The addition of the duct end correction to the tested sound power levels will provide the user with the sound power that would be transmitted into a non-reflecting duct system.

For a ducted discharge or ducted inlet tests, the value for the duct end correction depends on the duct termination in the test space. For an acoustic test duct terminating flush, or at a distance less than three effective diameters from any acoustically reflective surface, Equation A.2 shall be used to calculate the duct end correction. For an acoustic test duct terminating into the free space, or at a distance greater than or equal to three effective diameters from any reflective surface, Equation A.3 shall be used to calculate the duct end correction. These equations shall be used to calculate the duct end correction—for either a flush or free termination—at the center frequencies of each one-third octave band or octave band.

The effective diameter is defined as:

$$D_e = \left(\frac{4\times A}{\pi}\right)^{1/2} \qquad \text{Eq. A.1}$$

Where:

A = Cross-sectional area of the duct, ft^2
D_e = Effective diameter, ft

For a duct terminating flush or at a distance less than three effective diameters from the test space wall, acoustic baffle or termination surface, use Equation A.2:

$$E_{1(n)} = 10 \times \log_{10}\left[1 + \left(\frac{0.7\times C_0}{\pi\times f\times D_e}\right)^2\right] \qquad \text{Eq. A.2}$$

For a duct terminating at a distance greater than or equal to three effective diameters from a test space wall, acoustic baffle or termination surface, use Equation A.3:

$$E_{1(n)} = 10 \times \log_{10}\left[1 + \left(\frac{C_0}{\pi\times f\times D_e}\right)^2\right] \qquad \text{Eq. A.3}$$

Where:

C_o = Speed of sound in air, ft/s
D_e = Effective diameter (as shown in Equation A.2), ft
$E_{1(n)}$ = Acoustic test duct end correction for the n^{th} one-third octave band for a duct terminating flush
f = One-third octave band center frequency, Hz
n = One-third octave band of interest in the octave band

Historically, the transition from flush to free space termination was defined as one effective diameter. Recent research has shown that free duct termination effects are not fully exhibited for duct lengths shorter than three effective diameters.

Annex B
Testing of Large Fan Equipment (Informative)

B.1 General

The size of fan equipment that can be tested within the requirements of this standard is limited by the practical aspects of the test setup. 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 figures 10.1 through 10.8 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 ANSI S12.12, as defined in Section 5.10. 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 Number of measurements

The requirements of Section 7.2 shall be modified as follows:

The minimum number of measurements shall depend on the surface area of the measurement surface as set forth 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 6 tolerance for the convergence index shall continue to apply.)

B.3 Results

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

Table B.1 — Minimum 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)

One-Third Octave Band (Hz)	Number of Measurements
50–160	±1.5
200–630	±1.0
800–5,000	±0.8
6,300-10,000	±1.3

Annex C
Radiation of Sound by Fan Casing (Informative)

C.1 General

The following method may determine the sound radiated by the fan casing. 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 only to fans for which both inlet and outlet are ducted, and the drive system is internal to the fan casing.

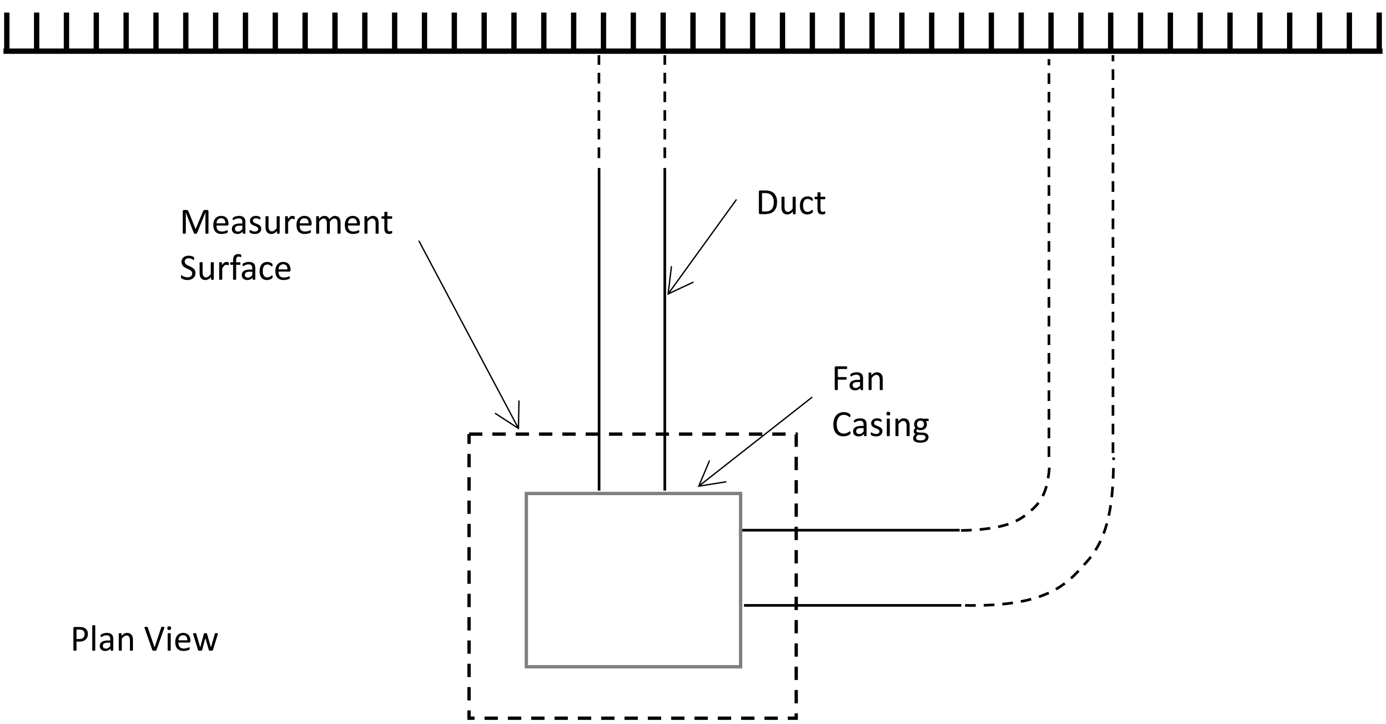
C.2 Setup

The fan setup and measurement surface shall be chosen with reference to Figure C.1.

The sound intensity measurements will include sound radiated from all sources, including sound from motor and drive; if the sound from extraneous sources is excessive, determination of the fan casing's sound power 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 so sound transmission through this equipment is minimized. If practicable, both fan inlet and outlet should be ducted to termination points outside the test room. If the termination points are inside the test room, better results are likely to be obtained when care is taken to minimize interfering sound at the measurement surface.

C.3 Measurements

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



Notes from Figure 10.1 apply.

Figure C.1 — Test Setup and Measurement Surface Definition for Fan Casing Sound

Annex D
Reproducibility (Normative)

D.1 Reproducibility

Sound power levels obtained from intensity measurements made in conformance with this standard shall result in measurement standard deviations that are equal to or less than those in Table D.1. This table includes uncertainty in the sound intensity measurement method due to the instrumentation, operator, test environment and background noise levels. The standard deviations in Table D.1 do not account for variations of sound power caused by changes in operating conditions.

The following table is adapted from AHRI Standard 230, Section 1.2:

Table D.1 — Reproducibility: Maximum Standard Deviations of Sound Power Level Determined in Accordance with AHRI Standard 230

One-Third Octave Band Center Frequency, Hz	One-Third Octave Band Maximum Standard Deviation of Reproducibility, dB
50–80	4.0
100–160	3.0
200–315	2.0
400–5,000	1.5
6,000–10,000	3.0

Annex E
High-Frequency Probe Corrections (Informative)

The spacing between microphones in an intensity probe determines the frequency range over which sound intensity can be measured. It typically will require two microphone spacings to cover the frequency range from 50 Hz to 10,000 Hz. An alternative to performing the measurements twice with two different spacers or using a four-microphone intensity probe is to apply a high-frequency correction to the intensity data to extend its usable range to a higher frequency.

For a given microphone pair and spacer, the correction is very stable over time. Some intensity hardware and analyzers have such functionality built-in, in which case the manufacturer's high-frequency correction procedure should be followed. For hardware without such functionality, a high-frequency correction may be calculated by using the intensity probe to measure the sound power of a reference sound source as described in Section 5.8. At frequencies above the traditional effective range of the spacer, the sound power—as measured by the intensity probe—will be observed to roll-off relative to the calibrated RSS sound power. The roll-off can then be used to calibrate future intensity measurements.

This high-frequency correction is only valid for the microphone pair and spacer used to generate it. It is recommended that more than one RSS measurement be used to create the high-frequency correction and that this correction be periodically updated as additional RSS performance verifications are collected. Table E.1 shows examples of high-frequency probe corrections; the first row is a measured correction that was found for a particular pair of microphones and spacer, and the second row is a theoretical roll-off. These are presented as typical examples; actual roll-off for any given pair of microphones and spacer will have to be measured.

Table E.1 — Examples of High-Frequency Probe Corrections

	One-Third Octave Band Center Frequency (Hz)										
Description	1,000	1,250	1,600	2,000	2,500	3,150	4,000	5,000	6,300	8,000	10,000
Measured: ½-in. microphones with 12-mm spacer	0.0	0.0	0.1	0.3	0.8	1.3	1.4	2.7	3.6	4.5	5.5
Theoretical: Roll-off for 12-mm spacer	0.0	0.1	0.1	0.1	0.2	0.4	0.6	0.9	1.5	2.5	4.3

Annex F
Correction to Standard Meteorological Conditions (Informative)

F.1 General

The intensity test method, by its nature, measures the sound power at test meteorological conditions. Often it may be desirable to report the sound power at standard meteorological conditions. This annex defines a method for this calculation.

F.2 Primary calculation

The sound power output of a fan varies with site conditions, primarily atmospheric pressure and temperature. This variance is primarily the result of two factors: changes in the characteristic acoustic impedance of the air (ρc) and changes in the mass flow through the fan. Although more precise calculations are available (see ANSI/ASA S12.5/ISO 6926), for the purposes of this standard, up to elevations of 5,000 ft (1,525 m), the effect can be calculated within +/- 0.1 dB using the ratio of standard air density to air density at test conditions. The measured fan performance (airflow, pressure, and power) shall also be adjusted to standard air according to AMCA 210 for reporting.

The sound power values derived from this standard can be corrected to standard air using a formula which is based on reconfiguring equation 5.16 of Section 5.5 of AMCA 301:

$$L_{w(std)} = L_{w(test)} + 20 \log \left({}^{0.075}/_{\rho_{test}} \right)$$ I-P Eq. F.1

$$L_{w(std)} = L_{w(test)} + 20 \log \left({}^{1.20}/_{\rho_{test}} \right)$$ SI Eq. F.2

F.3 Density calculation

When using this standard in a laboratory setting, site density will have already been calculated as part of the required test report information (see Section 9.4).

When using this standard for field tests, measure the barometric pressure and temperature for the site conditions. Barometric pressure and temperature from a local airport is typically accurate enough for this calculation.

The density shall be calculated as follows (derived from ANSI/AMCA Standard 210 with relative humidity of 50%):

$$\rho_{test} = ((70.73\, P_b) - 9.0902)/(53.35\, (t_d + 459.67))$$ I-P Eq. F.3

$$\rho_{test} = {}^{(P_b - 440.6)}\Big/_{(287.1\, (t_b + 273.15))}$$ SI Eq. F.4

If necessary, the average barometric pressure can be estimated from the elevation:

$$P_b = 29.921\, (1 - (0.000006877\, Elev))^{5.256}$$ I-P Eq. F.5

$$P_b = 101325\, (1 - (0.00002256\, Elev))^{5.256}$$ SI Eq. F.6

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