

AMCA Standard 300-05

Reverberant Room Method for Sound Testing of Fans



**AIR MOVEMENT AND CONTROL
ASSOCIATION INTERNATIONAL, INC.**

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AMCA Standard 300 - 05

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Forward/Authority

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Foreward

This standard was originally developed in response to the need for a reliable and accurate method of determining the sound power levels of fan equipment. The original document was written by the AMCA P158NB Sound Test Code Committee. Where possible, it was based on ASHRAE Standard 36-62, and combined state-of-the-art with practical considerations. It was first published as a Recommended Practice in February 1962, and adopted as a Standard Test Code in October 1963. The sound power reference level now used in this standard was changed in January 1965, from 10-13 watts to 10-12 watts. The third edition (January 1967) AMCA 300-67 Test Code for Sound Rating included minor revisions. In 1974, minor editorial changes were made, and size-speed conversions were transferred to AMCA 301 Methods for Calculating Fan Sound Ratings From Laboratory Test Data. The 1985 edition continued the original philosophy of combining the theoretical and the practical. The 1996 edition was improved by increasing the accuracy of Reference Sound Source values through improvements in calibration requirements and procedure, and where appropriate, calling for units of measure in SI (I-P) sequence. Where there have been successful improvements in state-of-the-art, full advantage has been taken. This latest edition refines the duct end correction factors to values whose source can be traced to its origin.

Introduction

This standard establishes a method of determining the sound power levels of a fan. The method is reproducible in all laboratories that are qualified to the requirements of this standard.

The method employs standard sound measurement instrumentation, applied to rooms that are restricted to certain acoustic properties. The test setups are designed generally to represent the physical orientation of a fan as installed, following ANSI/AMCA 210 Laboratory Methods of Testing Fans for Aerodynamic Performance Rating. Sound is defined as radiant mechanical energy that is transmitted by pressure waves in air; it is the objective cause of hearing. Sound pressure level is described mathematically as a logarithmic quantity derived from sound pressure. The unit of sound pressure level is the decibel, referenced to a base of 20 micropascals, or 20 microbar. The sound pressure level at any given point in space depends on the distance between the source and the receiver, reflection if in an enclosed room, proximity of the source to other sound sources, etc.

Sound in a room is the result of one or more active sound power sources within that room. Sound power is the total sound energy radiated per unit time. Sound power level is described mathematically as a logarithmic quantity derived from the sound power. The unit of sound power level is the decibel referenced to 1 picowatt ($1.0\text{E-}12$ watt). Sound power levels determined through use of this standard are useful for comparison between fans and in acoustical design.

Since sound power is independent of acoustic environment, two or more fans proposed for a specific aerodynamic performance condition may be evaluated by comparison to determine whether one is more suitable for an application than another. Moreover, fan sound power levels 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 fan equipment user to employ acoustical consultation to ensure that all factors that affect the final sound pressure levels are considered. Additional information on the complexity of this situation may be found in other documents available elsewhere.

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REVERBERANT ROOM METHOD FOR SOUND TESTING OF FANS

1. Scope

This standard applies to fans of all types and sizes. This standard is limited to the determination of airborne sound emission for the specified setups. Vibration is not measured, nor is the sensitivity of airborne sound emission to vibration effects 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 setups. Dimensional limitations, test subject dimensions, and air performance will control the test room size and power and mounting requirements for the test subject.

The test setup requirements in this standard establish the laboratory conditions necessary for a successful test. Rarely will it be possible to meet these requirements in a field situation. This standard is not intended for field measurements.

2. Normative references

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

ANSI/AMCA 210-99 / ANSI/ASHRAE 51-1999 *Laboratory Methods of Testing Fans for Aerodynamic Performance Rating*, Air Movement and Control Association International, Inc., 30 W. University Drive, Arlington Heights, IL 60004-1893 U.S.A., 1999

ANSI S1.4-1983; S1.4A-1985 *Specification for Sound Level Meters*, Acoustical Society of

America, 120 Wall St., 32nd Floor, New York, NY 10005-3993 U.S.A., 1985 (AMCA #2315-83-AO)

ANSI S1.11-2004 *Specification for Octave Band and Fractional Octave Band Analog and Digital Filters*, Acoustical Society of America, 120 Wall St., 32nd Floor, New York, NY 10005-3993 U.S.A., 1986 (AMCA #1727-86-AO)

ANSI S1.40-1984 *Standard Specification for Acoustical Calibrators*, Acoustical Society of America, 120 Wall St., 32nd Floor, New York, NY 10005-3993 U.S.A., 1984 (AMCA #1895-84-AO)

ANSI S12.5-1990 *Requirements for the Performance and Calibration of Reference Sound Sources*, Acoustical Society of America, 120 Wall St., 32nd Floor, New York, NY 10005-3993 U.S.A., 1990 (AMCA #1863-90-AO)

ANSI S12.12-1992 *Engineering Method for the Determination of Sound Power Levels of Noise Sources Using Sound Intensity*, Acoustical Society of America, 120 Wall St., 32nd Floor, New York, NY 10005-3993 U.S.A., 1992 (AMCA #1850-92-AO)

ANSI/IEEE/ASTM SI 10-1997 *Standard for Use of the International System of Units (SI): The Modern Metric System*, Institute of Electrical and Electronic Engineers, 345 east 47th Street, New York, NY 10017 U.S.A., 1997 (AMCA #2924-97-AO)

3. Definitions / units of measure / symbols

3.1 Definitions

3.1.1 Blade Passage Frequency (BPF): The frequency of fan impeller blades passing a single fixed object, per the following formula:

$$BPF = (\text{number of blades})(\text{fan rotational speed, rev/min}) / 60, \text{ in Hz.}$$

3.1.2 Chamber: An enclosure used to regulate airflow and absorb sound; it may also conform to air test chamber conditions given in ANSI/AMCA 210.

3.1.3 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 3.1.13 and 3.1.14)

3.1.4 Ducted Fan: A fan having a duct connected to either its inlet, its outlet, or to both.

3.1.5 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 some of the sound entering the room is reflected back into the duct and does not escape into the room.

3.1.6 Frequency: The number of times in one second that a periodic function repeats itself.

3.1.7 Informative: A term that indicates that the referenced material is provided as advice to the reader but does not constitute a mandatory requirement.

3.1.8 Non-ducted Fan: A fan without a duct connected to either its inlet or outlet.

3.1.9 Normative: A term that indicates that the referenced material, if applied, constitutes a mandatory requirement.

3.1.10 Octave Band: The interval between any two frequencies having a ratio of two. Fan sound power levels are reported in eight standardized octave bands shown in Table 1. Fan sound power levels may also be reported in one-third octave bands, also shown in Table 1.

3.1.11 Reverberant Room: An enclosure meeting the requirements of Annex A, or Annex A and Annex B.

3.1.12 Shall and Should: The word *shall* is to be understood as mandatory; the word *should* as advisory.

3.1.13 Sound Power Level: The value, expressed in decibels (dB), of ten times the logarithm (base 10) of the ratio of the sound power W to the reference sound power W_{ref} , according to:

$$L_W, \text{ in dB} = 10 \log_{10} (W / W_{\text{ref}}) \quad (3-1)$$

3.1.14 Sound Pressure Level: The value, expressed in decibels (dB), of twenty times the logarithm (base 10) of the ratio of the sound pressure p to the reference sound pressure p_{ref} , according to:

Table 1 - Standardized octave and one-third octave bands [5]

Octave Bands

Band no.	1	2	3	4	5	6	7	8
ANSI Band no.	18	21	24	27	30	33	36	39
Center frequency f , Hz	63	125	250	500	1000	2000	4000	8000

One-Third Octave Bands

<u>Band 1</u>				<u>Band 2</u>				<u>Band 3</u>				<u>Band 4</u>	
ANSI Band no.	17	18	19	20	21	22	23	24	25	26	27	28	
Center freq. f , Hz	50	63	80	100	125	160	200	250	315	400	500	630	
<u>Band 5</u>				<u>Band 6</u>				<u>Band 7</u>				<u>Band 8</u>	
ANSI Band no.	29	30	31	32	33	34	35	36	37	38	39	40	
Center freq. f , Hz	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000	

$$L_p, \text{ in dB} = 20 \log_{10} (p / p_{\text{ref}}) \quad (3-2)$$

3.1.15 Wavelength: The distance between two points having the same phase in two consecutive cycles of a periodic wave, along a line in the direction of propagation [5]. Wavelength (λ) is determined by frequency and the speed of sound in the air through which the wave propagates:

$$\lambda = c / f \quad (3-3)$$

where:

f = frequency, Hz

c = 343 m/s @ 20°C (1125 ft/s @ 68°F)

The value for c is acceptable for use in this standard within the limits of $\pm 5^\circ\text{C}$ (9°F) for standard air.

3.1.16 Standard Air: Air having a density of 1.2 kg/m^3 ($0.075 \text{ lb}_m/\text{ft}^3$). Standard air has a ratio of specific heats of 1.4 and a viscosity of $1.8185\text{E-}03 \text{ Pa}\cdot\text{s}$ ($1.222\text{E-}05 \text{ lb}_m/\text{ft}\cdot\text{s}$). Air at 20°C (68°F), 50% relative humidity, and 101.325 kPa ($14.696 \text{ lb}_m/\text{in.}^2$, 29.92 in. Hg) barometric pressure has these properties, approximately).

3.2 Symbols

(See Table 2.)

4. Instruments / methods of measurement

4.1 Sound level meter

The sound level meter shall meet the requirements of ANSI S1.4 and S1.4A. The sound level meter should be capable of accepting a microphone extension cable.

4.2 Microphone system

The microphone system (transducer and any associated components and cable) shall meet the requirements for use in a Type 1 precision sound level meter according to ANSI S1.4 and S1.4A. A microphone with a nominal diameter of 13 mm (0.5 in.) is recommended.

4.3 Frequency analyzer and weighting system

An octave band or one-third octave band filter set is required and shall meet the Order 3 Type 3-D requirements of ANSI S1.11. An A-weighting network shall meet the requirements of ANSI S1.4 and S1.4A. Other weighting networks may be used to improve the accuracy, as outlined in Annex F.

4.4 Data recording equipment

This standard does not attempt to set limitations on data recording equipment. Considerations include long-term stability, ease of use, and the method of averaging the sound pressure signal.

Modern integrating-type analyzers that comply with IEC 804 are recommended because they produce L_p values eliminating any need for visual averaging. Graphic level recorders can be used to make permanent records and ease the problem of making visual averages from sound level meter indications.

4.5 Reference sound source (RSS)

The reference sound source should comply with the requirements of ANSI S12.5.

4.5.1 The RSS shall be a small, modified, direct-driven centrifugal fan having maximum overall dimensions of 610 mm (2 ft) or less.

4.5.2 The RSS shall produce steady broadband sound over at least the frequency range from 50 Hz to 10,000 Hz. It shall comply in all respects with the performance requirements of ANSI S12.5.

4.5.3 The RSS shall be equipped with vibration isolators that minimize transmitted vibration. The degree of isolation should be 20 dB or more. If metal springs are used as vibration isolators, rubber pads shall be used between the isolator and the structure of the reverberant room.

4.5.4 To ensure compliance with the stability requirements of ANSI S12.5, all operating parts of the RSS shall be rigidly and permanently

Table 2 - Symbols

SYMBOL	DESCRIPTION	UNIT OF MEASURE	
		SI	I-P
$A_{\min}$	Minimum distance to reverberant field	m	ft
c	Speed of sound	m/s	ft/s
D	Duct diameter	m	ft
E_o	End reflection factor, at duct outlet	dB	dB
E_i	End reflection factor, at duct inlet	dB	dB
E_W	End reflection factor, adjustment to sound power level	dB	dB
f	Frequency	Hz	Hz
J_1	Bessel function of the first kind, first order		
k	Wave number		
K_1	Modified Bessel function of the second kind, first order		
L_p	Sound pressure level, re 20 μ Pa (20 μ bar)	dB	dB
L_{pc}	Corrected fan sound pressure level	dB	dB
L_{pb}	Sound pressure level of room background, measured over the normal microphone path	dB	dB
L_{pm}	Sound pressure level of fan + room background, measured over the normal microphone path	dB	dB
L_{pq}	Sound pressure level of the RSS, corrected	dB	dB
L_{pqm}	Sound pressure level of RSS + room background, measured over the normal microphone path	dB	dB
L_W	Sound power level re 1 picowatt (1.0E-12 W)	dB	dB
L_{Wi}	Sound power level; transmitted to inlet duct from fan	dB	dB
L_{Wm}	Sound power level measured at the open inlet and outlet of the fan	dB	dB
L_{Wmi}	Sound power level measured at the open inlet of the fan	dB	dB
L_{Wmo}	Sound power level measured at the open outlet of the fan	dB	dB
L_{Wo}	Sound power level transmitted to the outlet duct from fan	dB	dB
L_{Wr}	Sound power level of RSS	dB	dB
p	Sound pressure	Pa	bar
p_{ref}	Sound pressure reference level, 20 μ Pa	Pa	bar
P_s	Fan static pressure	Pa	in. wg
P_t	Fan total pressure	Pa	in. wg
r	Ratio (of Duct area / Orifice area)	dimensionless	
R	Reflection coefficient	dimensionless	
s	Standard deviation	dB	dB
W	Sound power (in watts)	W	W
W_{ref}	Reference sound power (1 picowatt)	W	W
Z_M	Mechanical impedance	N-s/m	
α	Ratio of transmitted to reflected sound	dimensionless	
γ	Ratio of specific heats	dimensionless	
λ	Wavelength	m	ft
ω	Angular frequency	rad/s	rad/s

attached. No rubber or wearing parts shall be permitted (except lubricated bearings) and protection against corrosion shall be provided.

4.5.5 The RSS calibration shall consist of a determination of the sound power level radiated by the RSS (including vibration isolators) when it is in operation on a reflecting plane with radiation into a free field above that plane. The calibration shall be in accordance with ANSI S12.5 or as provided in Annex D. The maximum time interval since calibration shall not exceed that specified by the manufacturer or three years, whichever is shorter.

4.6 Test method

The test method is based on a Reference Sound Source (RSS) substitution for the determination of sound power. The reference document for this method is ANSI S12.51.

Application of the test method requires that the test subject fan be set in position in a test room that is qualified according to the requirements of Section 5.1.

Once the test room has been qualified, sound pressure levels are recorded with the RSS operating. The fan is then operated, without the RSS in operation, at various performance points of interest for the given test speed and the sound pressure levels are recorded. Since the sound power levels of the RSS are known, the substitution method is used to determine the sound power levels of the fan for each operating point.

Current ANSI and ASA documents on sound testing, facilities and equipment are useful references. See Annex J.

4.7 Accuracy of results

Accuracy of test results is addressed in Annex C and depends upon several variables, including the room qualification and the type of test setup utilized.

5. Equipment/setup

5.1 Reverberant room

An enclosure meeting the requirements of Annex A is mandatory for the purposes of this standard. An enclosure meeting the requirements of Annex B is recommended for broad-band sound testing and is mandatory for the purpose of investigating pure tones and narrow bands.

5.2 Setup categories

A number of specific fan test setups are allowed. They are determined by the airflow direction and the particular mounting arrangement of the test subject. The test setups 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 total sound power L_W of the test subject, non-ducted. For the total sound power of a ducted test subject located entirely in the test room, see Annex H.

The second category includes those fans that would be tested on a chamber or two-room system where only the inlet or outlet terminate in the test room (see Figures 2 and 3). These arrangements result in the determination of inlet (L_{Wi}) or outlet (L_{Wo}) sound power. Section 5.6 discusses the limitations that must be imposed on the test room for determining the position of the test subject and the location of the microphone. The choice of test setup for a specific test will depend on the way the fan is expected to be applied in the field.

5.3 Aerodynamic performance

Where an aerodynamic performance test is necessary to determine the point of operation of a test subject, the test shall be performed in accordance with ANSI/AMCA 210 or other fan aerodynamic performance test standard having a demonstrated accuracy equivalent to ANSI/AMCA 210.

5.4 Mounting methods

The method of mounting a test subject, or connecting it to a non-integral driver, or connecting it to an airflow test facility 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 subject unless it is a standard part of the fan. 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 test subject, may be damped or enclosed in any manner that does not expose sound absorption material to the test room. When a driving motor and drive are an integral part of the test subject, they may not be treated in any manner, and normal belt tensions, bearings, and lubricants shall be used. When a fan and its drive are both in the reverberant room, the test results may contain sound contributions from flanking paths as well as mechanical and/or electrical sound from the drive system.

5.5 Duct length

On a chamber or two-room setup, the length of duct shall be consistent with acceptable practice per ANSI/AMCA 210 necessary to accurately establish the point of rating.

The length of duct shown in Figures 2 and 3 is consistent with the procedures of ANSI/AMCA 210. Care must be exercised to ensure that no duct resonances exist in close proximity to specific frequencies of interest such as the Blade Pass Frequency.

5.6 Microphone traverse and room requirements

When using the substitution method, the minimum distance between the sound source and the nearest microphone position may be calculated from:

$$A_{\min} = C_2 10^{(L_{Wr} - L_{pq})/20} \quad (5-1)$$

Where:

$A_{\min}$ = the minimum distance between the sound source and the microphone, m(ft),

C_2 = 0.61 (if using SI units), (2.0 if using IP units), and

$(L_{Wr} - L_{pq})$ = is the maximum value for Octave Bands 2 to 7.

If the test room and test setup have been qualified in accordance with Annex A, the continuous microphone traverse used for the qualification shall also be used for the sound pressure measurements.

If a microphone traverse is used, it shall meet the following requirements:

- a) no point on the traverse shall be any closer than $A_{\min}$ from the sound source;
- b) no point on the traverse shall be any closer than 1.0 m (3.333 ft) to any surface of the test room;
- c) no point on the traverse shall, at any time, be closer than 0.5 m (1.67 ft) to any surface of a rotating diffuser;
- d) the microphone traverse should not lie in any plane within 10° of a room surface;
- e) the microphone shall swing or move on a normal path of an arc or straight line with a minimum distance of 3 m (10 ft) between the extreme points of travel;
- f) the maximum air velocity over the microphone shall be 1 m/s (200 fpm);
- g) room volume is not specified but the room must be large enough in volume such that the volume of the test fan and associated ductwork does not exceed 1% of the room volume;
- h) neither the RSS nor fan shall be within 300 mm (1 ft) of any room centerline.

5.7 Calibration of system

Before each sound power determination, the following calibration checks shall be performed. A calibration check shall be made of the entire measurement system at one or more frequencies within the frequency range of interest. An acoustical calibrator conforming to ANSI S1.40 and with an accuracy of ± 0.5 dB 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. In addition, an electrical calibration of the instrumentation over the entire frequency range of interest shall be performed periodically, at intervals of not more than one year.

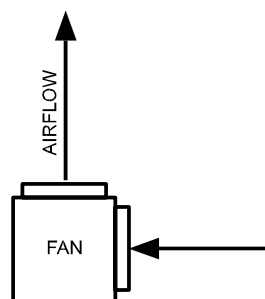
The microphone and its associated cable shall be chosen so that their sensitivity does not change by more than 0.2 dB over the temperature range encountered during the

measurement. If the microphone is moved, care shall be exercised to avoid introducing acoustical or electrical noise (for example, from gears, flexing cables, or sliding contacts) that could interfere with measurement.

The frequency response of the instrument system shall be flat over the frequency range of interest within the tolerances given in Table 3, and applied as outlined in ANSI S12.51.

Table 3 - Tolerances for the instrument system

One-third Octave Band Center Frequency (Hz)	Tolerance (dB)
40-80	± 1.5
100-4000	± 1.0
5000-8000	± 1.5
10000	± 2.0
12500	± 3.0



A: FREE INLET
FREE OUTLET

SOUND POWER CALCULATIONS

Installation Type	L_W Equation
A: Free Inlet Free Outlet	$L_{Wm} = L_{pc} + (L_{Wr} - L_{pq})$

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

1. Directivity from the fan is averaged by the reverberant room and the microphone location is such that it is sensing total averaged sound pressure levels.
2. 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 fan recorded sound pressure levels.

Section 5, Figure 1 - Fan total sound testing