STANDARD

ANSI/AMCA Standard 250-22

Laboratory Methods of Testing Jet Fans for Performance

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Air Movement and Control Association International

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Laboratory Methods of Testing Jet Fans for Performance

1. Purpose

This standard establishes uniform methods for laboratory testing of jet fans to be installed in, but not limited to, road/rail/mining tunnels and carpark garage applications.

2. Scope

This standard deals with the determination of technical characteristics needed to verify manufacturing of the specified performance characteristics of jet fans for longitudinal applications (e.g., thrust and airflow). It does not cover those fans designed for ducted applications, nor those designed solely for air circulation (e.g., ceiling fans and table fans).

The test procedures described in this standard relate to laboratory conditions only. The measurement of performance under in-situ conditions is not part of this standard.

The parties to a test may agree on exceptions to this standard in writing prior to the test. However, only tests that do not violate any mandatory requirements of this standard shall be designated as tests conducted in accordance with this standard.

3. Normative References

The following documents 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 Standard 204-20, Balance Quality and Vibration Levels for Fans, Air Movement and Control Association International Inc., Arlington Heights, IL USA.

ANSI/AMCA Standard 210-16, 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 320-08 (R2013), Laboratory Methods of Sound Testing of Fans Using Sound Intensity, Air Movement and Control Association International Inc., Arlington Heights, IL USA.

ISO 5801:2017, Fans — Performance testing using standardized airways, International Organization for Standardization, Geneva, Switzerland.

ISO 13347-2:2004, Industrial fans — Determination of fan sound power levels under standardized laboratory conditions — Part 2: Reverberant room method, International Organization for Standardization, Geneva, Switzerland.

ISO 13347-3:2004, Industrial fans — Determination of fan sound power levels under standardized laboratory conditions — Part 3: Enveloping surface methods, International Organization for Standardization, Geneva, Switzerland.

ISO 13347-4:2004, Industrial fans — Determination of fan sound power levels under standardized laboratory conditions — Part 4: Sound intensity method, International Organization for Standardization, Geneva, Switzerland.

ISO 13350:2015, Fans — Performance testing of jet fans, International Organization for Standardization, Geneva, Switzerland.

4. Definitions and Symbols

4.1 Definitions

For the purposes of this standard, the following definitions apply:

4.1.1 Absolute pressure
Pressure above a perfect vacuum; the sum of gauge pressure and atmospheric pressure. The value is always positive.

4.1.2 Air
A mixture of various gases forming the earth's atmosphere and commonly used to denote any gaseous medium measured, moved or controlled in an HVAC system.

4.1.3 Barometric pressure
The absolute pressure exerted by the atmosphere at a location of measurement.

4.1.4 Chamber
An airway in which air velocity is small compared with that at the fan inlet or outlet.

4.1.5 Dry-bulb temperature
Air temperature measured by a temperature-sensing device without modifications to compensate for the effects of humidity.

4.1.6 Efficacy
Ratio of thrust to impeller power.

Note: An alternative definition of thrust efficacy is defined as thrust divided by motor input power. This results in a lower value as the motor losses are also included.

4.1.7 Fan
A device that utilizes a power-driven rotating impeller for moving air or gases. The internal energy (enthalpy) increase imparted by a fan to a gas does not exceed 25 kJ/kg (10.75 BTU/lbm).

4.1.8 Fan dynamic pressure
The dynamic pressure at the fan outlet calculated from fan outlet velocity and inlet density.

4.1.9 Fan efficiency
Ratio of fan output power to impeller power, expressed as a percentage.

4.1.10 Fan guard
A screen or other device used to prevent ingestion of objects at the fan inlet or outlet.

Note: Guards can have a marked effect on thrust performance and sound level. Where they are specified, it shall be made quite clear between the supplier and customer whether the performance includes the effects of the guards.

4.1.11 Fan outlet area
The full circular area at the fan outlet, where D is the internal diameter of the fan.

$$A_2 = \frac{\pi D^2}{4} \quad \text{Eq. 4.1}$$

4.1.12 Fan outlet velocity
Average velocity of air emerging from an outlet measured in the outlet plane.

4.1.13 Fan output power
The product of volume airflow and fan dynamic pressure.

4.1.14 Fan vibration velocity
The filtered vibration velocity in the 10 Hz-10 kHz frequency range measured in accordance with this standard.

4.1.15 Impeller balance grade
The impeller balance specification in accordance with the method detailed in ANSI/AMCA Standard 204.

4.1.16 Impeller power
The mechanical power supplied to the fan impeller.

4.1.17 Impeller tip speed
Tangential velocity of the impeller blade tips.

4.1.18 Jet fan
A fan used for producing a jet of air in a space, unconnected to any ducting. Typical function is to add momentum to air within a duct or tunnel.

4.1.19 Motor input power
The electrical power supplied to the terminals of an electric motor drive.

4.1.20 Overall efficiency
Ratio of fan output power to motor input power, expressed as a percentage.

4.1.21 Rotational speed
The rotational speed of an impeller. If a fan has more than one impeller, fan speeds are the rotative speeds of each impeller.

4.1.22 Shall and should
In AMCA standards, the word “shall” is understood to be normative; the word “should” as advisory.

4.1.23 Sound power level, L_w
Acoustic power rating from a sound source measured in decibels and equal to 10 times the logarithm (base 10) of the acoustic power in watts with reference to 10^{-12} watts.

4.1.24 Sound pressure level, L_p
The acoustic pressure at a point in space where the microphone or listener’s ear is situated. It is defined as 20 times the logarithm (base 10) of the sound pressure fluctuation with reference to 20 μPa (micropascals).

4.1.25 Standard air
Air with a density of 1.2 kg/m^3 (0.075 lbm/ft^3), a specific heat ratio of 1.4, a viscosity of 1.819 × 10^{-5} Pa•s (1.222 × 10^{-5} lbm/ft-sec) and an absolute pressure of 101.325 kPa (408.0 in. wg). Air at 20°C (68°F), 50% relative humidity and 101.325 kPa (29.92 in. Hg) has these properties, approximately.

4.1.26 Static pressure at a point
The portion of air pressure that exists by virtue of the degree of compression only. If expressed as gauge pressure, it may be negative or positive.

4.1.27 Test enclosure
A room or other space used for testing purposes.

4.1.28 Thrust
The force exerted by a fan in a specific direction.

4.1.29 Thrust/power ratio
Ratio of thrust to impeller power or ratio of the thrust to motor input power.

4.1.30 Volume airflow rate
The volume of air that passes through a given area in unit time.

4.2 Symbols

See Table 1 for a list of symbols.

Table 1 – Symbols and Subscripts

Symbol	Description	SI Unit	I-P Unit
A_2	Fan outlet area	m^2	ft^2
A_a	Impeller annulus area	m^2	ft^2
D	Fan inlet or outlet inside diameter	m	ft
d	Silencer center body diameter	m	ft
H_R	Fan impeller power	W	hp
H_{R0}	Fan impeller power converted to standard density	W	hp
H_u	Fan output power	W	hp
L_{pb}	Background sound pressure level	dB	dB
L_{pc}	Sound pressure level correction	dB	dB
$L_{p(m)}$	Recorded sound pressure level of fan and room background as measured over the normal mic path	dB	dB
$L_{p(r)}$	Recorded sound pressure level of reference sound source (RSS) and room background as measured over the normal mic path	dB	dB
L_w	Sound power level, reference 1 picowatt	dB	dB
L_{wr}	Sound power level of the RSS	dB	dB
L_{w1}	Outlet sound power level, forward direction	dB	dB
L_{w2}	Outlet sound power level, reverse direction	dB	dB
L_p	Sound pressure level, reference 20 μPa	dB	dB

N	Impeller rotational speed	rps	rpm
P_{sx}	Static pressure at plane x	Pa	in. wg
P_v	Fan velocity (dynamic) pressure	Pa	in. wg
P_{vi}	Pitot velocity pressure of i^{th} traverse measurement	Pa	in. wg
Q	Volume airflow	m^3/s	cfm
r_T	Efficacy (thrust/power ratio)	N/kW	lbf/Hp
T_c	Fan thrust corrected to standard air density	N	lbf
T_m	Measured thrust	N	lbf
u	Impeller tip speed	m/s	ft/min
v_2	Fan outlet velocity	m/s	ft/min
V_1	Fan vibration velocity, forward direction	mm/s	in./s
V_2	Fan vibration velocity, reverse direction	mm/s	in./s
W_{m0}	Measured motor input power converted to standard density	W	hp
W_m	Measured motor input power	W	hp
x_i	Pitot tube insertion length	mm	in.
η_R	Fan impeller efficiency	%	%
η_e	Overall efficiency	%	%
ρ	Fan air density	kg/m^3	lbm/ft^3
ρ_a	Inlet ambient air density taken as equal to the air density in the test enclosure	kg/m^3	lbm/ft^3
ρ_{std}	Standard air density	kg/m^3	lbm/ft^3

5. Characteristics to be Measured

5.1 General

For a jet-type tunnel fan to be applied correctly and provide satisfactory performance and reliability in service, it is necessary to determine several technical performance characteristics in addition to knowing the more obvious mechanical features, such as weight and overall installation dimensions.

5.2 Volume airflow rate

Volume airflow rate is calculated from the thrust measured in a standard configuration. Volume airflow rate only needs to be measured separately if required for contractual reasons. Note, it is difficult to measure airflow rate in a jet fan without somehow influencing fan operation.

5.3 Thrust

Friction on the tunnel walls, inlet and outlet losses and, sometimes, traffic drag combined with gradients and wind effects at tunnel portals, result in a pressure drop through the tunnel. The pressure drop is matched by the sum of the pressure increases from the jet fans due to the momentum transfer between the fan discharge airflow and the airflow in the tunnel. As it is impossible to measure the momentum of the fan discharge airflow and the rate of change of momentum is equal and opposite to the thrust, thrust is measured instead.

5.4 Input power

To calculate the cost of operating jet fans (there may be a substantial number) in a tunnel, it is necessary to know the fan motor's input power. If needed, fan shaft power can be calculated from the motor input power.

5.5 Sound power level

Sound levels, usually at inlet and outlet, are established to ensure that the jet fan and silencer combination is optimized to match the tunnel sound level requirements.

5.6 Vibration velocity

For reasons of safety, reliability and maintainability, it is essential that a realistic vibration velocity is specified and recorded on tunnel fans. These shall be measured at the support points in accordance with ANSI/AMCA Standard 204.

5.7 Efficacy of jet fans

Jet fan thrust ratio is thrust divided by input power. Refer to Section 10 for calculation methodology.

6. Instrumentation and Measurements

6.1 Dimensions and areas

The measurement of dimensions and the determination of areas shall be in accordance with ANSI/AMCA Standard 210 or ISO 5801.

6.2 Pressure and temperature

6.2.1 Instruments for pressure measurement
Manometers for the measurement of differential pressure, and barometers for the measurement of atmospheric pressure in the test enclosure, shall comply with the requirements of ANSI/AMCA Standard 210 or ISO 5801.

6.2.2 Instruments for temperature measurement
Thermometer(s) shall comply with the requirements of ANSI/AMCA Standard 210 or ISO 5801.

6.3 Thrust

6.3.1 Force balance systems
By using calibrated weights, force balance systems (measurement instrumentation) shall permit the determination of force with an allowable uncertainty no greater than ±1%.

6.3.2 Force transducers
By using calibrated weights, force transducers (measurement instrumentation) shall permit the determination of force with an allowable uncertainty no greater than ±1%.

6.4 Input power

Determination of input power to the electric motor or impeller shall be carried out in accordance with ANSI/AMCA Standard 210 or ISO 5801.

6.5 Impeller rotational speed

Impeller rotational speed shall be determined in accordance with ANSI/AMCA Standard 210 or ISO 5801.

6.6 Sound level

The sound level measuring system, including microphones, windshields, cables, amplifiers and frequency analyzer, shall be in accordance with the requirements in ANSI/AMCA Standard 300.

6.7 Vibration velocity

Instruments measuring root-mean-square (RMS) vibration velocity shall be used to record fan vibration velocities. These shall be in accordance with ANSI/AMCA Standard 204.

7. Determination of Airflow Rate

7.1 General

Because thrust, rather than airflow rate, is the primary measured product of a jet fan and represents the rate of change in momentum, airflow rate per this standard shall be calculated from measured thrust.

$$Q = v_2 \times A_2 = \sqrt{\frac{T_m}{\rho_a A_2}} \times A_2 \qquad \text{SI} \qquad \text{Eq. 7.1}$$

$$Q = v_2 \times A_2 = 340.3\sqrt{\frac{T_m}{\rho_a A_2}} \times A_2 \qquad \text{IP} \qquad \text{Eq. 7.2}$$

Q can be derived using equations 7.1 or 7.2 based on measured thrust or by using equations 10.1 or 10.2 based on converted thrust.

If it is desired to measure airflow rate separately from the thrust measurement for contractual reasons, three methods are provided. It should be noted that each of these three measurement methods has the potential to alter fan operation, so varying results should be expected.

The most convenient method uses a venturi nozzle or conical inlet, connected upstream of the jet fan, as the airflow measuring device. The second makes use of an upstream chamber test configuration. In this case, an auxiliary fan forms part of the test setup enabling the fan's operating point to be simulated correctly. The third method uses a pitot traverse at the jet fan inlet.

It should also be noted that the airflow through a jet fan has no direct relationship with the airflow through a tunnel.

7.2 Direct connected airflow measuring device

The airflow measuring device shall be connected via suitable means to the fan inlet as illustrated on Figure 1. Details of the venturi nozzle shall comply with ANSI/AMCA Standard 210. Details of the conical inlet shall comply with ISO 5801. To determine airflow rate in accordance with this standard, an anti-swirl device is not required.

Airflow rate for the venturi nozzle is calculated in accordance with ANSI/AMCA Standard 210, Section 7. Airflow rate for a conical inlet is calculated in accordance with ISO 5801, Annex A.

7.3 Upstream chamber method

Installation of the fan in the chamber is illustrated in Figure 2. This arrangement simulates a free inlet, free outlet installation. The inlet silencer shall extend into the chamber by at least one fan diameter.

The upstream sections of the measurement chamber shall be in accordance with ANSI/AMCA Standard 210 inlet chamber setups or ISO 5801 inlet test chambers. To establish the correct operating point, with no adverse pressure across the fan, a test system auxiliary fan shall be controlled such that:

$$P_{s3} = P_{s2} = 0 \qquad \text{Eq. 7.3}$$

Where P_{s3} is the static pressure in the fan chamber and P_{s2} is the static pressure at the fan outlet.

If it is not possible to control the auxiliary fan accurately, it may be necessary to measure the airflow at more than one operating point on either side of 0 static pressure and fit a line between points to determine the airflow rate at 0 static pressure.

7.4 Upstream pitot traverse method

An upstream pitot traverse as outlined in Figure 8 shall be used to determine airflow for axial jet fans in accordance with ANSI/AMCA Standard 210, provided the following conditions are met:

1. The jet fan includes an inlet silencer or casing extension at least one fan inlet diameter in length.
2. The inlet silencer or casing extension includes a bell mouth or radiused inlet.
3. The inlet silencer or casing extension has a constant cross-sectional area (no converging area or tapered center bullet).

   The pitot-static tube shall meet the dimensional requirements of ANSI/AMCA Standard 210. As an alternative to a pitot-static tube, a double-reverse tube (or S tube) total pressure tap can be used, provided it is calibrated.

The airflow shall be calculated from measured traverse velocity pressures, P_{vi}, according to the following equation:

$$Q = \left(\pi \frac{(D^2 - d^2)}{4}\right) \cdot \sqrt{2} \cdot \sqrt{\frac{\left(\frac{\sum \sqrt{P_{vi}}}{n}\right)^2}{\rho_a}} \qquad \text{SI} \qquad \text{Eq. 7.4}$$

$$Q = \left(\pi \frac{(D^2 - d^2)}{4}\right) \cdot 1097.8 \cdot \sqrt{\frac{\left(\frac{\sum \sqrt{P_{vi}}}{n}\right)^2}{\rho_a}} \qquad \text{IP} \qquad \text{Eq. 7.5}$$

8. Determination of Thrust

8.1 General

There are two basic configurations available for fan thrust measurement: suspended configuration and supported configuration. In addition to the need to measure force accurately, the first method requires that the suspension elements be kept precisely vertical and parallel with a vertical plane(s) passing through the fan axis, while the second method requires accurate construction and leveling of the support assembly. In either case, thrust shall be determined using calibrated weights, spring balance or force transducer.

8.2 Conversion to standard air density

The measured thrust, T_m, shall be converted to standard air density using the following equation.

$$T_c = T_m \left(\frac{\rho_{std}}{\rho_a}\right) \quad \text{Eq. 8.1}$$

8.3 Suspended configuration

Figure 3 shows a typical arrangement of a suspended configuration. The fan is suspended from a framework or gantry with the suspension elements at least one fan diameter in length. The frame shall allow free airflow, particularly at the fan inlet. Below or surrounding the fan is a rigid framework that serves a threefold function:

1. Provides the reference point for the fan test assembly under static conditions.
2. Provides support for a pulley system to take calibrated weights or a spring balance.
3. Provides a reaction point for a force transducer.

Under operating conditions, the measuring system loads are adjusted to return the fan to the static position, within ±2 mm (0.08 in.), and thus ensure that the suspension elements are precisely vertical. The thrust can then be measured directly.

Note: For fans, there are other methods of calculating thrust, such as measuring the angle of suspension elements from the vertical or the change in height between the fan in “off” and “operational” positions and calculating thrust. However, with the thrust/weight ratios typical of a jet fan, it is doubtful whether the desired accuracy of thrust measurement can be attained by these other methods.

8.4 Supported configuration

Arrangements of the supported configuration are shown on Figures 4A, 4B and 4C. The fan is supported via low friction linear bearings or leaf springs on a rigid framework. The fan, to an extent limited by stops, is free to move in either direction. Before commencing any tests, the assembly shall be carefully leveled in each direction, such that the same force is required to move the assembly along the fan axis in either direction.

Under operating conditions, the measuring system loads are adjusted to ensure movement is not restrained by stops. Thrust can then be measured directly. In the case of the use of a force transducer, the fan can be allowed to abut the sensor directly.

8.5 Calibration

To ensure thrust is measured to the required accuracy, steps shall be taken to minimize errors caused by setting up/rigging the test arrangement.

Though calibrated weights or spring balances are specified, if a spring balance is employed to register thrust and supported via a pulley, its weight must be accurately known and added to the measured thrust.

If a force transducer is being used to measure thrust, it shall be calibrated, for example, by using a pulley and weight system before each series of tests. Calibration shall be made with the test fan installed on the test rig, or an equivalent weight added to the test rig to simulate the weight of the fan. Special car
e shall be taken during calibration to ensure the measured thrust returns to zero when the force is removed.

Where the supported method is being used with linear bearings (Figures 5A and 5B), precautions shall be taken to ensure that the force required to move the fan in either direction is the same and the assembly is therefore level.

With the fan running, a force sufficient to change the thrust reading shall be applied to the test fan. The measured thrust should change according to the amount of force added. Any variation between the applied force and the change in measured thrust shall be used as a calibration value.

8.6 Test procedures

Ambient conditions shall be measured prior to startup and throughout the test as specified. Thrust, power and speed measurement shall be averaged for a minimum of 120 seconds. Thrust readings shall be recorded when both thrust and power input readings have stabilized or at least 10 minutes after startup. Power stability is established when the averaged results from two successive 120-second readings differ by not more than 1%. Thrust stability is established when the averaged results from two successive 120-second readings differ by not more than 2%.

8.7 Test enclosure

Substantial clearances are needed around the test fan for the test enclosure to effectively simulate an infinitely large space around the fan. Figures 5A and 5B show the minimum clearances required in the test enclosure. If the test is conducted outdoors, these minimum clearances are still required.

Minimum distances to building surfaces around the test fan shall be:

- ≥1.5*D* to the floor with a minimum distance of 2 m (79 in.)
- ≥3.0*D* to a wall on the inlet
- ≥10.0*D* to a wall on the outlet
- ≥3.0*D* to any side walls surrounding the fan with a minimum distance of 2 m (79 in.). If there is another return path for the air from the discharge to the inlet, this minimum distance is reduced to 2*D*. Care must be taken to ensure air entering the test facility near the inlet is equal to or less than 0.3 m/s, taken at 2 m from the fan inlet.
- ≥2.0*D* to the ceiling or roof trusses with a minimum distance of 2 m (79 in.)

In addition to these minimum clearances, the cross-sectional area of the test enclosure in the plane through the midpoint of the fan length shall be at least 50 times the outlet area of the fan. Note that some of the above minimum distances will need to be increased to meet this minimum area ratio. If there is another return path for the air from the discharge to the inlet, the minimum area ratio is 30.

8.8 Test environment

Care must be taken to ensure ambient air currents do not affect thrust measurements. If the test is conducted indoors, the ambient air velocity shall be measured at various locations within the test enclosure prior to the test. The ambient air velocity at all locations shall not exceed 0.3 m/s (60 fpm) in any direction. During the test (with the fan operating), velocity measurements shall be taken at points 1*D* from the fan in the plane through the midpoint of the fan length and at the same height as the fan centerline. Velocities at these points shall not exceed 0.3 m/s (60 fpm) in the direction opposite fan airflow.

If the test is conducted outdoors, the ambient air velocity (wind) shall be monitored throughout the test at points 1*D* from the fan in the plane through the midpoint of the fan length and at the same height as the fan centerline. At no point during the test shall the ambient air velocity exceed 0.3 m/s (60 fpm) in the direction opposite fan airflow. If the wind conditions are variable, the uncertainty of the measurements will increase.

9. Determination of Input Power

9.1 General

Electrical input power is always measured during a jet fan test. Because density varies from lab to lab and day to day, this measured electrical power is converted to standard air density. This conversion assumes that motor efficiency is constant over the range of the conversion. Because density conversion is normally over small changes in density, this assumption is valid.

If fan laws will be used to calculate performance at other speeds or sizes, the impeller power must first be determined.

9.2 Measurement of electrical input power

Measurement of the power input to the electric motor shall be carried out in accordance with ANSI/AMCA Standard 210 or ISO 5801.

9.3 Impeller power

If fan impeller power is required, the motor shall be calibrated in accordance with ANSI/AMCA Standard 210. This calibration shall be used to convert measured electrical input power, W_m, to motor output (impeller) power, H_r.

9.4 Conversion to standard air density

The measured input power, W_m, shall be converted to standard air density using the following equation:

$$W_{m0} = W_m \left(\frac{\rho_{std}}{\rho_a}\right) \qquad \text{Eq. 9.1}$$

The fan impeller power, H_R, shall be converted to standard air density using the following equation:

$$H_{R0} = H_R \left(\frac{\rho_{std}}{\rho_a}\right) \qquad \text{Eq. 9.2}$$

10. Determination of Efficiency and Efficacy

10.1 General

Fan efficiency (ratio of output power to input power) and fan efficacy (ratio of thrust to input power) provide a convenient way to normalize fan performance and provide a basis for comparison of different fan designs.

10.2 Fan efficiency

Fan output power, the product of airflow and fan dynamic pressure, is determined from converted thrust.

Q can be derived using equations 7.1 or 7.2 based on measured thrust or equations 10.1 or 10.2 based on converted thrust.

$$Q = v_2 \times A_2 = \sqrt{\frac{T_c}{\rho_{std} A_2}} \times A_2$$ SI Eq. 10.1

$$Q = v_2 \times A_2 = 340.3 \sqrt{\frac{T_c}{\rho_{std} A_2}} \times A_2$$ I-P Eq. 10.2

and

$$P_v = \frac{1}{2} \rho_{std} v_2^2 = 0.5 \frac{T_c}{A_2}$$ SI Eq. 10.3

$$P_v = 0.09609 \frac{T_c}{A_2}$$ I-P Eq. 10.4

Fan overall efficiency, η_e, is calculated using the following:

$$\eta_e = \frac{H_u}{W_{m0}} = \frac{QP_v}{W_{m0}} = \frac{0.5 \sqrt{\frac{T_c}{\rho_{std} A_2}} T_c}{W_{m0}}$$ SI Eq. 10.5

$$\eta_e = \frac{H_u}{W_{m0}} = \frac{QP_v}{W_{m0}} = \frac{3.845 \sqrt{\frac{T_c}{\rho_{std} A_2}} T_c}{W_{m0}}$$ I-P Eq. 10.6

Fan impeller efficiency, η_s, is calculated using the following:

$$\eta_R = \frac{H_u}{H_{R0}} = \frac{Qp_v}{H_{R0}} = \frac{0.5 \sqrt{\frac{T_c}{\rho_{std} A_2}} T_c}{H_{R0}}$$ SI Eq. 10.7

$$\eta_R = \frac{H_u}{H_{R0}} = \frac{QP_v}{H_{R0}} = \frac{3.845 \sqrt{\frac{T_c}{\rho_{std} A_2}} T_c}{H_{R0}}$$ I-P Eq. 10.8

10.3 Fan thrust to power ratio

The thrust to power ratio may be specified and is shown in the equation below:

$$r_T = \frac{T_m}{W_m} = \frac{T_c}{W_{m0}} \qquad \text{Eq. 10.9}$$

11. Determination of Sound Level

11.1 General

Sound power levels for jet fans shall be either inlet (L_{wi}), outlet (L_{wo}) or total (L_{wt}) sound. Sound power measurements shall be conducted using one of the test methods outlined in Table 11.1, provided the setup complies with the requirements of the method used. The methods listed should yield identical results within the measurement uncertainty shown in Table 14.1 and qualified by the notes in Table 11.1.

Table 11.1 — Allowable Sound Test Methods

Test Standard	Method	Inlet Sound (L_{wi})	Outlet Sound (L_{wo})	Total Sound (L_{wt})
ANSI/AMCA Standard 300 or ISO 13347-2	Reverberant room	1	2	3
ISO 13347-3	Enveloping surface			4
ANSI/AMCA Standard 320 or ISO 13347-4	Sound intensity			4
ANSI/AMCA Standard 250 or ISO 13350	Semi-reverberant room	5	6	7

Notes:

1. For inlet sound testing in a reverberant room, fan inlet shall protrude into reverberant room by 1 to 1.5 fan diameters. To simulate free air operation, static pressure in reverberant room shall be minimized and shall be no more than 10 Pa (0.04 in. wg.).
2. For outlet sound testing in a reverberant room, fan outlet shall protrude into reverberant room by 1 to 1.5 fan diameters. To simulate free air operation, static pressure in reverberant room shall be minimized and shall be no more than 10 Pa (0.04 in. wg.).
3. For total sound testing in a reverberant room, fan size may be limited due to test fan volume in relation to room volume and outlet velocity over microphone.
4. For enveloping surface and sound intensity methods, separate measurements of inlet, outlet and radiated sound power can be added logarithmically to obtain total sound power.
5. For inlet sound testing in a semi-reverberant room, the measured inlet sound power level may include some influence from the outlet and radiated sound. Results of inlet sound power using this method can therefore be expected to be higher than the inlet sound power obtained with other methods, but lower than the total sound power obtained with other methods.
6. For outlet sound testing in a semi-reverberant room, the measured outlet sound power level may include some influence from the inlet and radiated sound. Results of outlet sound power can therefore be expected to be higher than the outlet sound power obtained with other methods, but lower than the total sound power obtained with other methods.
7. For the semi-reverberant room method, separate measurements of inlet and outlet sound power can be added logarithmically to obtain total sound power. Due to the issues in notes 6 and 7, total sound power obtained using this method can be expected to be higher than those obtained with other methods.

Measurements shall be performed while the jet fan is mounted on a bench closely duplicating the actual jet fan configuration (free inlet and free outlet without partition, and the bottom of the jet fan shall be a minimum of 2 m [79 in.] above the floor). In addition, the jet fan shall be operating at the rated speed and load (thrust).

Sound levels measured by the semi-reverberant method are more practical because apart from the sound measuring instrumentation, only a suitable enclosure and a calibrated reference sound source (RSS) are required. This standard describes the semi-reverberant method only, and the measurements are focused predominantly on the sound levels on the discharge side. This method may capture some radial and inlet sound effects, but they are lesser when compared with the discharge side.

Because the jet fan has only one operating point (free delivery), there is no complication that could arise from the noise generated by the "loading means." Similarly, because only open inlet or open outlet sound levels are required, anechoic terminators are unnecessary.

11.2 Test arrangement

Positioning of the fan, the calibrated RSS and the microphone paths are shown in Figure 6. All microphones on the secondary path and RSS locations shall be aligned vertically at the jet fan horizontal centerline. Only the midpoint for the microphones on the primary path shall be aligned vertically with the jet fan horizontal centerline.

11.3 Enclosure suitability

A total of six microphone locations equally spaced at 500 mm (20 in.) shall be implemented for the primary microphone path, with the midpoint location at a distance of 3 m (118 in.) from the location of the RSS (P_R). The six microphone locations shall be equally spaced at 500 mm (20 in.) for the secondary microphone path, with the midpoint location at a distance of 1.5 m (59 in.) from the location of the RSS. The primary and secondary microphone paths shall be located on an arc or a straight line of 2.5 m (99 in.) in length. The closest microphone to a reflecting surface should be at a distance of not less than 2 m (79 in.) from any major reflecting surface. No microphone location on the primary path shall be within 45° of the centerline of the jet fan discharge mouth (points P_A, P_B, P_C). The path itself shall be larger than 10° of being parallel to any room surface (i.e., from all vertical walls, floor and ceiling) and shall be located toward a corner of the room. The closest microphone location to the jet fan shall be placed left of the line from the RSS location (P_R) and clearing the edge of the outlet silencer (P_D). The paths shall be located so the microphone is not subjected to an air velocity in excess of 2 m/s (6.5 ft/sec). Refer to Figure 6.

The RSS shall be located such that its acoustic center is 1 m (39 in.) downstream of the jet fan discharge mouth and along a curvature within 3 m (118 in.) of radius of the midpoint of the primary path. The RSS shall not be closer to any major reflecting surface than 1 m (39 in.). The RSS shall meet the requirements of ANSI/AMCA Standard 300 (also see Annex A). The RSS shall be run within 2% of the speed at which it was calibrated.

With the RSS operating, but the test jet fan impeller stationary, readings of sound pressure level shall be made in each octave band along the primary microphone path and the average value along the path estimated. A secondary microphone path similar to that of the primary microphone and of the same length shall be established at a position halfway between the RSS and the midpoint of the primary microphone path and at right angles to the line joining them. With the RSS operating, but the test jet fan impeller stationary, readings of sound pressure level shall be made in each octave band along the secondary microphone path and the average value along the path estimated. The average sound pressure level along the secondary path in each octave band shall not be more than 3 dB above the average for the primary microphone path, both values being corrected for background sound pressure level in accordance with Section 11.5.

11.4 Measurement procedure

Before conducting actual measurements and with both the test jet fan and the RSS inoperative, the average sound pressure level in each octave band shall be determined along the primary microphone path. This shall be at least 6 dB in each octave band lower than the average sound pressure level measured when the jet fan and the RSS are each running alone. Corrections for background sound pressure level should be made as recommended in Section 11.5.

With the RSS in operation but with the test jet fan impeller stationary, readings of sound pressure shall be made in each octave band along the primary microphone path, and the average sound pressure level, Lp(r), shall be determined. With the RSS removed and the test jet fan running, readings of sound pressure level shall be made along the primary microphone path and the average sound pressure level Lp(m), in each octave band, determined. The values of Lp(r) and Lp(m), shall be corrected, where necessary, as recommended in Section 11.5, and the open inlet or open outlet sound power level of the jet fan, LW calculated, in each octave band, from:

$$L_W = L_{p(m)} - L_{p(r)} + L_{W(r)} \qquad \textit{Eq. 11.1}$$

Where L_W and L_{wr} are in dB and L_{wr} is the sound power level of the RSS.

For jet fans designed to provide thrust in one direction only, the inlet sound power level, L_{W1}, shall be quoted. Where the jet fan is designed to operate in either direction, L_{W1} shall be quoted for the forward direction together with a correction to arrive at the value of L_{W2} for reverse operation.

11.5 Combination of sound pressure levels

If the sound pressure level with the fan running exceeds the background sound pressure level with the fan stopped by 10 dB or more, no correction need be applied.

If the difference is less than 10 dB, corrections as given in Table 11.2 should be applied.

$$L_{pc} = 10log_{10}\left(10^{\left(\frac{L_{p(m)}}{10}\right)} - 10^{\left(\frac{L_{pb}}{10}\right)}\right) \qquad \text{Eq. 11.2}$$

Table 11.2 — Background Correction

dB Increase in Level Produced by the Fan	dB to be Measured from the Measured Value
3	3
4-5	2
6-9	1
10 or more	0

Note: When the increase is less than 3 dB, fan sound levels cannot be accurately measured.

12. Determination of Vibration Velocity

12.1 General

Energy transmitted through vibration has an impact on both the equipment and the installation facility. This standard describes the level of vibration that a jet fan is required to have while tested in the lab to ensure that the equipment is fault-free. Vibration in situ may arise as a problem, but that is to be handled as an in-situ system condition. For balance and vibration purposes only, jet fans tested under this laboratory standard shall be classified as BV-4, following the ANSI/AMCA Standard 204 list of categories. It shall be clear that the vibration measurements for jet fans specified in this standard are to be completed via an FFT spectrum vibration analysis, with results given as 0-peak velocity, filter-in at 1X and filter-out.

12.2 Test arrangement and criteria

Tests shall be conducted at the jet fan rated speed. Figure 7 illustrates the arrangement that shall be used for measuring vibration velocity. Tests shall be taken with the same jet fan configuration as will be supplied to the customer. In other words, upstream and/or downstream silencers should be fitted as appropriate.

A jet fan may be base, wall or ceiling mounted. Vibration velocities shall be made in the three orthogonal directions—axial, horizontal and vertical—at each measurement location using tri-axial or uni-axial accelerometers. An axial measurement shall always be made parallel to the shaft (rotor) axis of rotation and parallel to the mounting plane. A horizontal measurement shall always be made in a radial direction, perpendicular to the axial measurement and parallel to the mounting plane. A vertical measurement shall always be made in a radial direction, perpendicular to the axial measurement, perpendicular to the mounting plane and perpendicular to a horizontal measurement. See ANSI/AMCA Standard 204.

Vibration velocity measurement locations shall be at the impeller shaft bearings, the drive end (DE) and the opposite drive end (ODE). Where this is not possible, and in agreement with the customer, the measurements shall be mounted on the fan housing (H) in the shortest direct mechanical path between the transducer and the bearings where a solid signal path may be obtained between a bearing and the measuring transducer. For motors mounted on the housing by rods, measuring location shall be nearest to the tie in with the fan housing; for motors mounted on the housing by structural plates welded onto the fan housing, measuring location shall be at the mid-point of the welded interface.

No transducer shall be mounted on an unsupported panel, guard or elsewhere on the jet fan where a solid signal path cannot be obtained.

Vibration velocity measurements shall be carried out at each location for filter-in, at 100% jet fan running speed, and filter-out. Following the ANSI/AMCA Standard 204 balancing and vibration levels for a BV-4, it shall be noted that a factory test shall be concerned only with "start-up" levels.

12.3 Test procedure

- Set up jet fan on a rigid test bench.
- Install vibration sensors on the location to be measured — DE, ODE, H — in accordance with Table 12.1.
- Power on jet fan.
- Allow fan to reach full speed.
- Capture the FFT spectrum for filter-in and filter-out. Repeat capturing one more time for a total of two measurements per location.
- Turn off jet fan.
- Prepare report. (Vibration levels should be equal to or lower than the levels listed in Table 12.2.)

Table 12.1 — Vibration Sensor Locations and Direction

Instrument	DE			ODE			HOUSING		
	H	V	A	H	V	A	H	V	A
Tri-axial	X	X	X				X	X	X
Uni-axial	X	X				X	X	X	X

Note: H – Horizontal
V – Vertical
A – Axial

Please note that if the jet fan is uni-directional (forward), only vibration velocity with the jet fan in the forward direction is required. If the jet fan is bi-directional, vibration velocity measurements shall be performed in each forward and reverse direction.

12.4 Acceptance vibration velocity

Table 12.2 — Acceptance Vibration Velocity

Mounting Method	Max (mm/s)	Max (in./s)
Vibration isolators/flexibly mounted	3.8	0.15
Rigidly mounted	2.5	0.10

13. Presentation of Results

13.1 Product description

The test report shall include a product description that, at minimum, shall include the following information:

1. Fan manufacturer name
2. Model reference
3. Size of fan
4. Number of blades
5. Blade angle
6. Motor manufacturer name
7. Impeller rotational speed
8. Motor output rating and frame size
9. Electrical supply data
10. Test configuration
11. High temperature operating capability
12. Overall dimensions
13. Mounting dimensions
14. Fan assembly weight
15. Accessories, e.g., guards, vibration isolators
16. Condition monitoring equipment

13.2 Product performance

The performance of the product described in Section 10.1 shall include, at minimum, the information described in the following points 1 through 5. By agreement with the client, the data may be provided for forward and reverse operation.

It shall always be made clear which accessories were fitted when the performance tests were undertaken.

1. Thrust
2. Outlet air velocity; see Note 1 below
3. Motor input power
4. Maximum open inlet or open outlet sound power level; see Note 2 below
5. Maximum upstream and downstream vibration velocity

Note 1: It may be preferred, by prior agreement with the client, to present sound level data in an alternative form. For example, an A-weighted spherical sound pressure level at 10 or 3 m (33 or 10 ft), 45° in free field. Also, by agreement with the client, it shall be decided whether the sound level is given as a single total figure or in each octave band.

Note 2: If required for contractual reasons, the airflow rate may be determined by one of the methods given in ANSI/AMCA Standard 210 or ISO 5801.

14. Tolerances and Conversion Rules

14.1 Tolerances

The tolerance values listed in Table 14.1 apply to jet fans operating without external resistance and as tested in accordance with this standard.

As shown in Table 14.1, the tolerances are intended to take account of measurement uncertainty and manufacturing variations. When direct test results are not available, refer to Annex A.

14.2 Conversion rules

The conversion rules recommended in Annex A apply to fan assemblies with geometric similarity. In the case of jet fans, this means similarity of the following features:

- Silencer lengths
- Silencer pod geometry
- Silencer bellmouth shape
- Impeller hub to diameter ratio
- Impeller spinner profile
- Blade shape and solidity (number of blades)
- Blade setting angle
- Motor support design
- Motor frame size
- Blade tip clearance (smoke venting designs)

It is accepted that for practical reasons it is not reasonable for every fan configuration to be subjected to a direct test. Also, perfect geometric similarity is not always readily achievable. Nonetheless, it is incumbent on the manufacturer to authenticate any conversion rules used.

Application of conversion rules shall be limited as follows – When calculating the performance of another fan from a direct test and allowing for some departure from geometric similarity:

Fan size: ± one R20 step

Impeller speed = (test speed) × 1.3
or
(test speed)/1.3

Table 14.1 — Tolerances

Measured Parameter	Measurement Uncertainty	Manufacturing Variation	Notes
Thrust	±5%	±1%	1
Fan outlet velocity	±10%	±2%	1, 2
Input power	±1.5%	±2.5%	
Sound level	—	±2%	3

Notes:

1. It should be noted that while thrust is measured, the outlet air velocity is calculated from the thrust, using air density and a conventionalized outlet area.
2. The relatively large uncertainty of the outlet air velocity will, in most cases, have little practical importance in relation to the thrust to be installed in the tunnel, as it only concerns a secondary correction factor.
3. Uncertainty of measurement of broadband sound levels can be taken as 3 dB for the 125 Hz, 250 Hz and 8,000 Hz bands; 2 dB for 500 Hz band; and 1.5 dB for the 1 kHz and 4,000 Hz bands. While uncertainty will be greater than 3 dB for the 63 Hz band, no information is available. To allow for manufacturing deviations, a further 2 dB should be added.

15. Figures

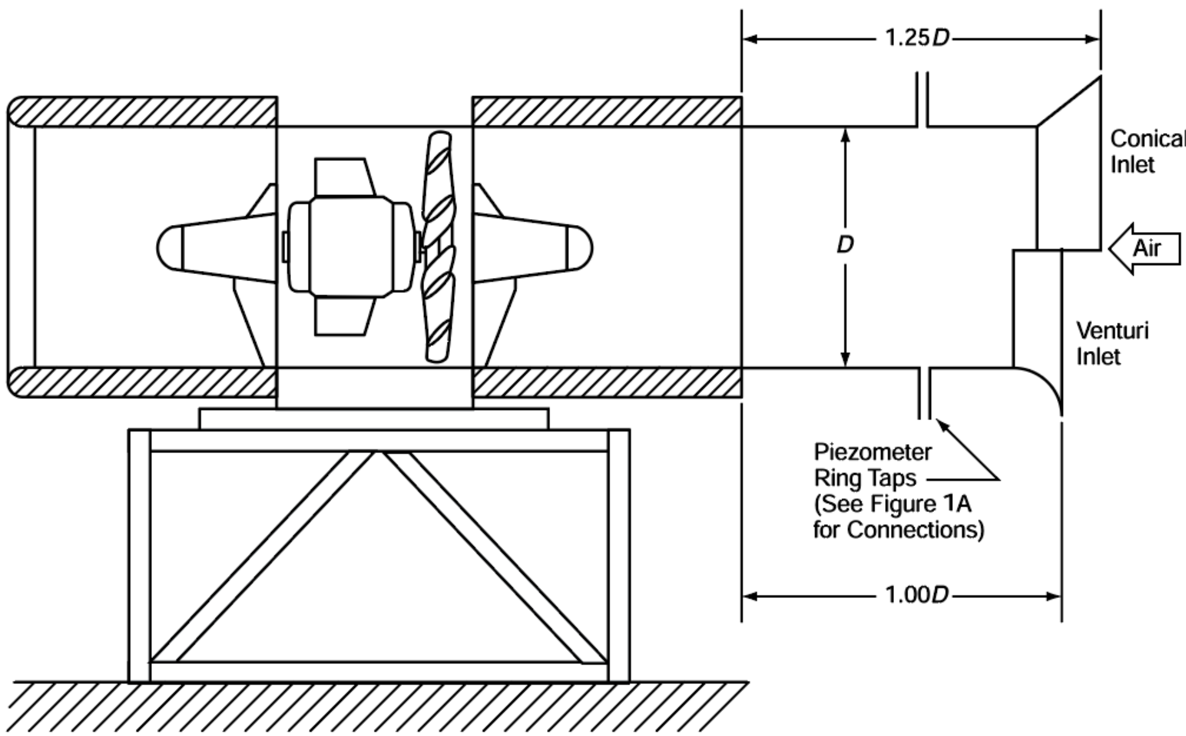
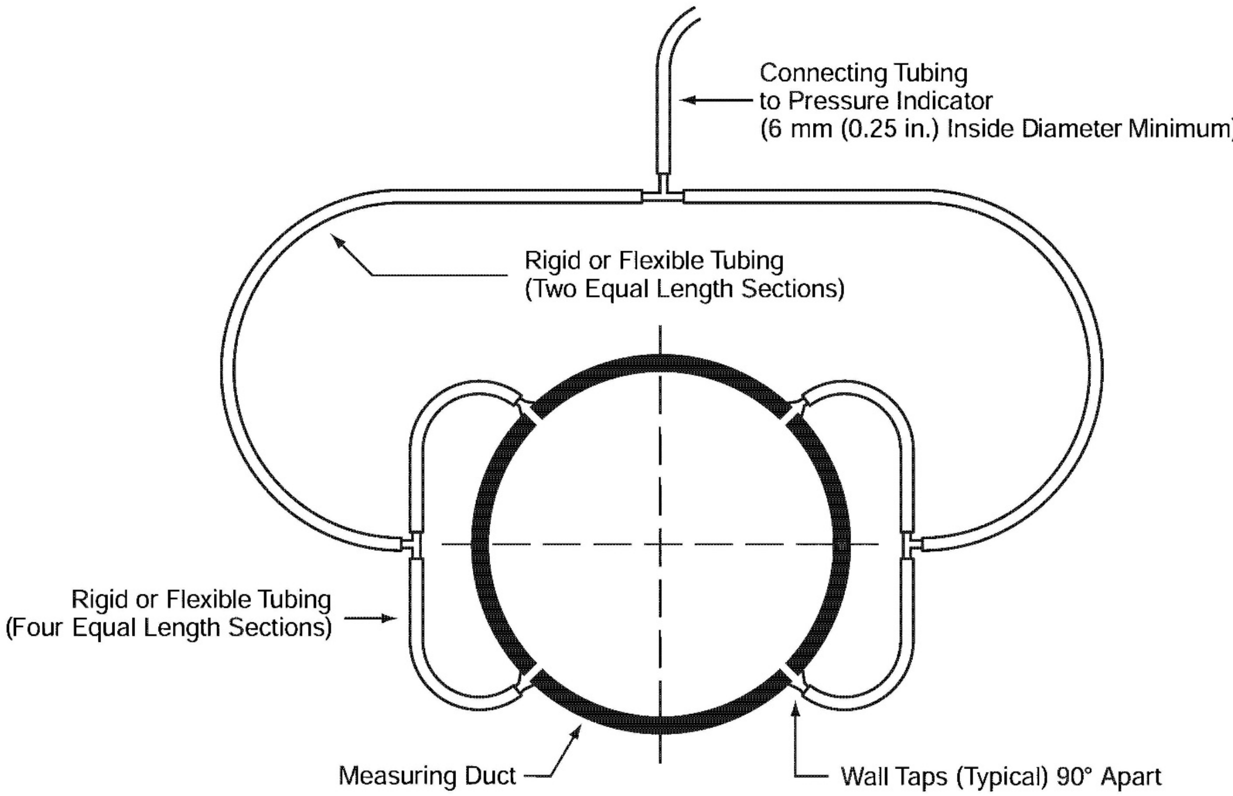


Figure 1 — Airflow Measuring Installation (Directly Connected)



Notes:

1. Manifold tubing internal area shall be at least four times that of a wall tap.
2. Connecting tubing to pressure indicator shall be 6 mm (0.25 in.) or larger in inside diameter (ID).
3. Taps shall be within ±13 mm (0.50 in.) in the longitudinal direction.

Figure 1A — Piezometer Ring Manifold

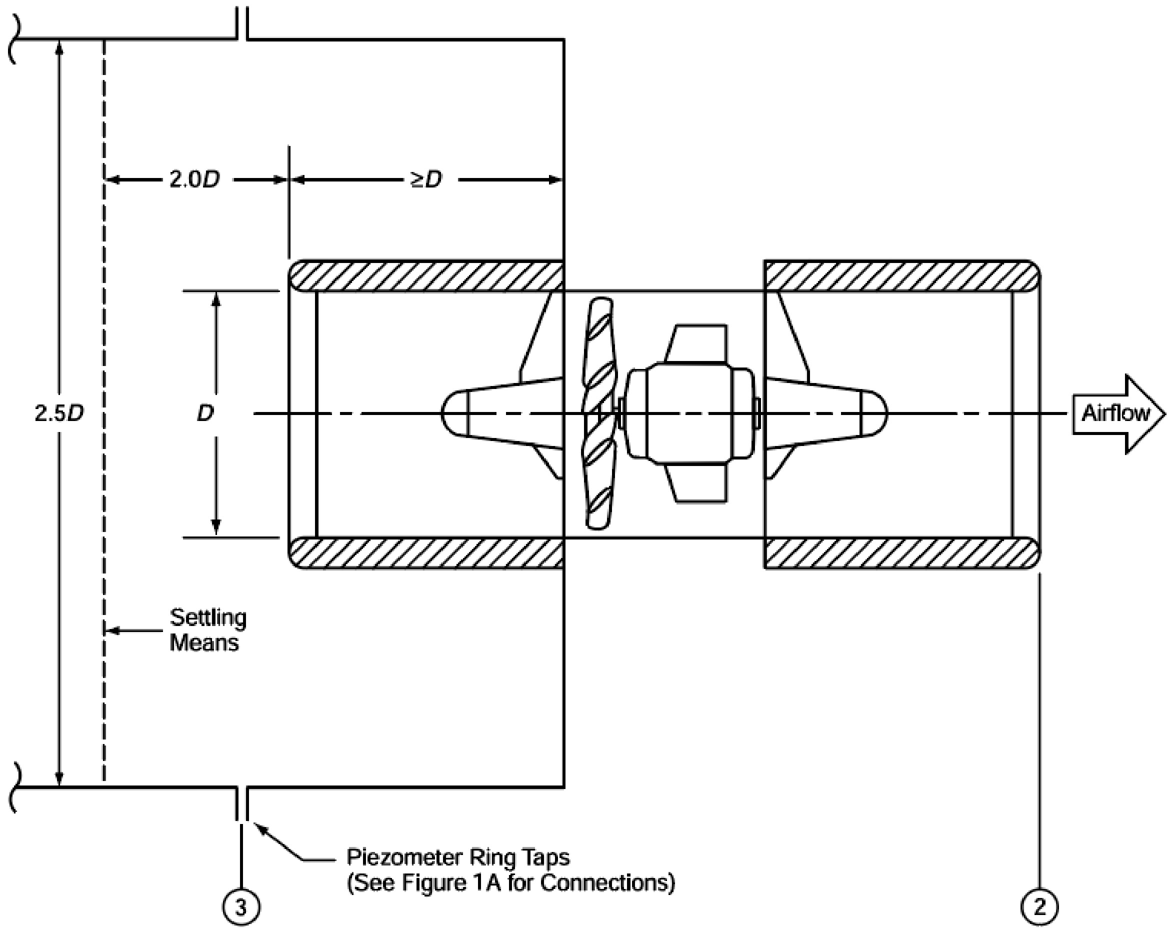


Figure 2 — Airflow Measuring Installation (Upstream Chamber)

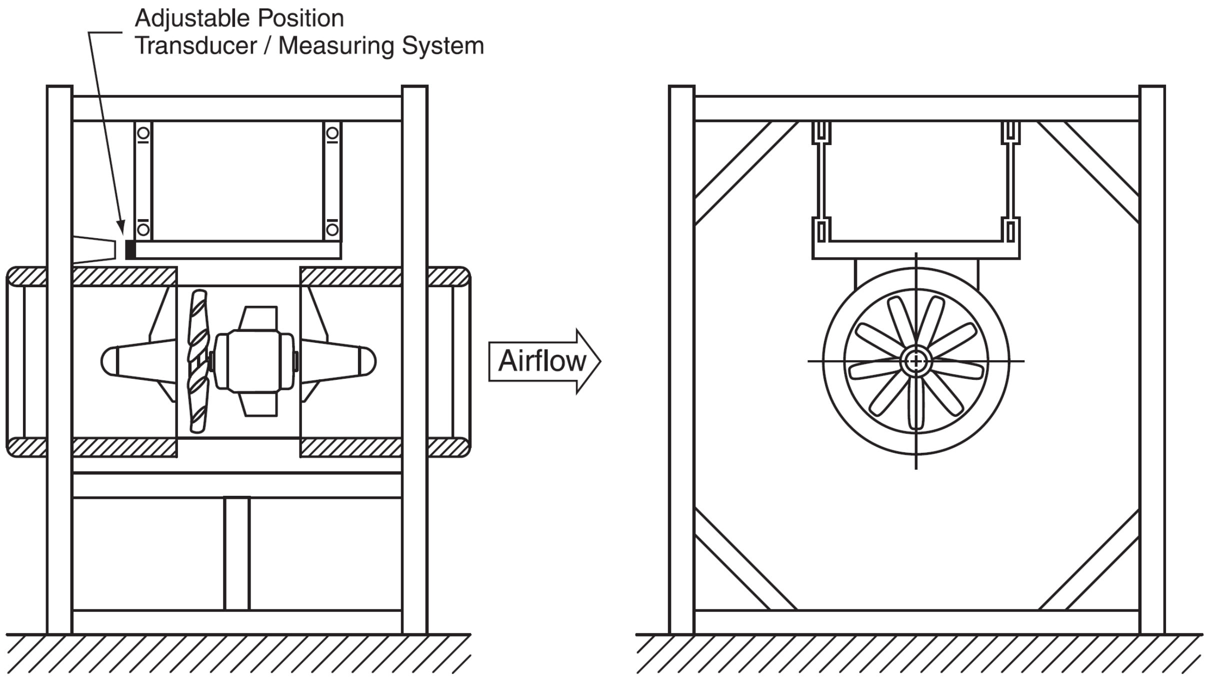
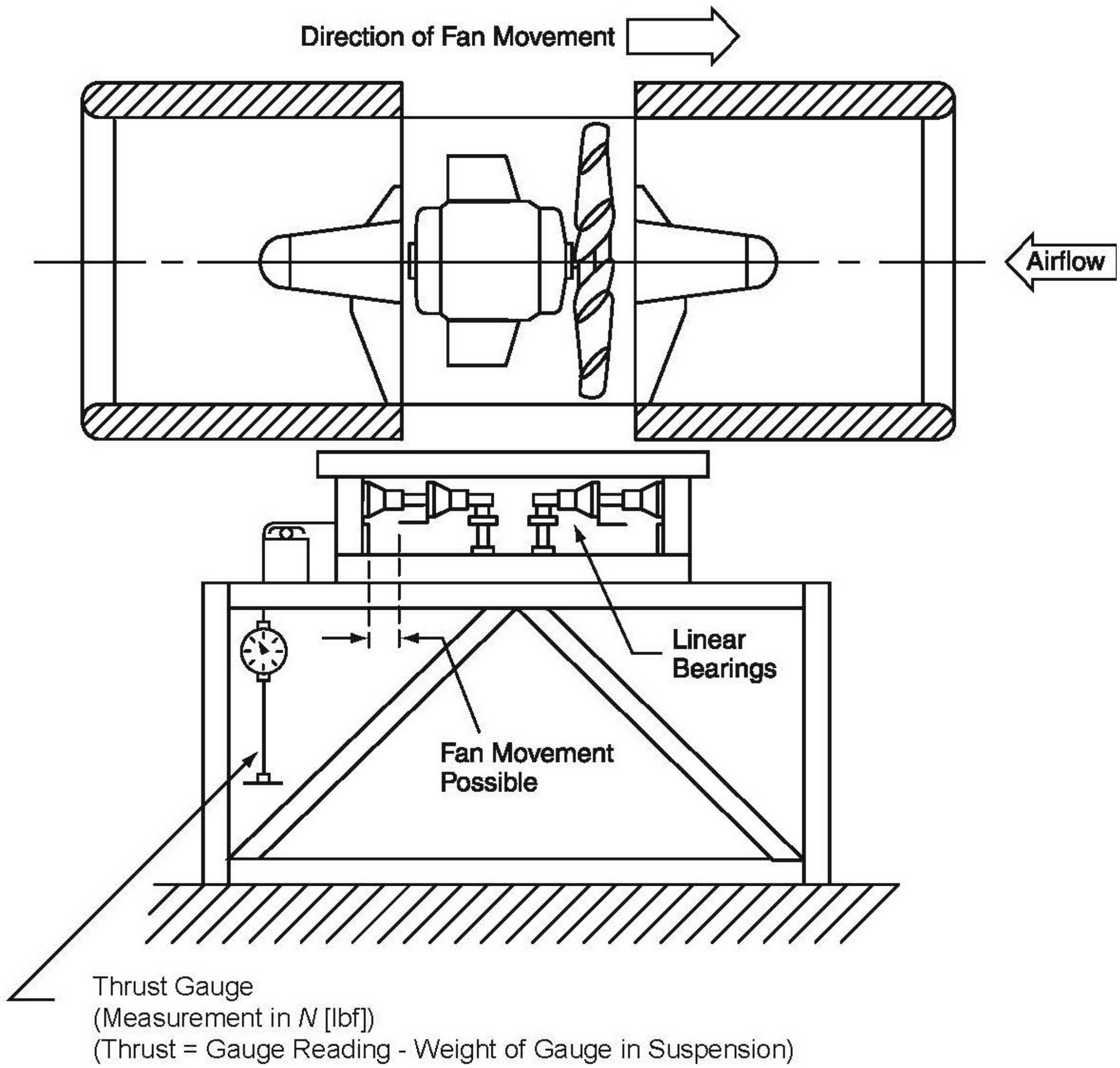
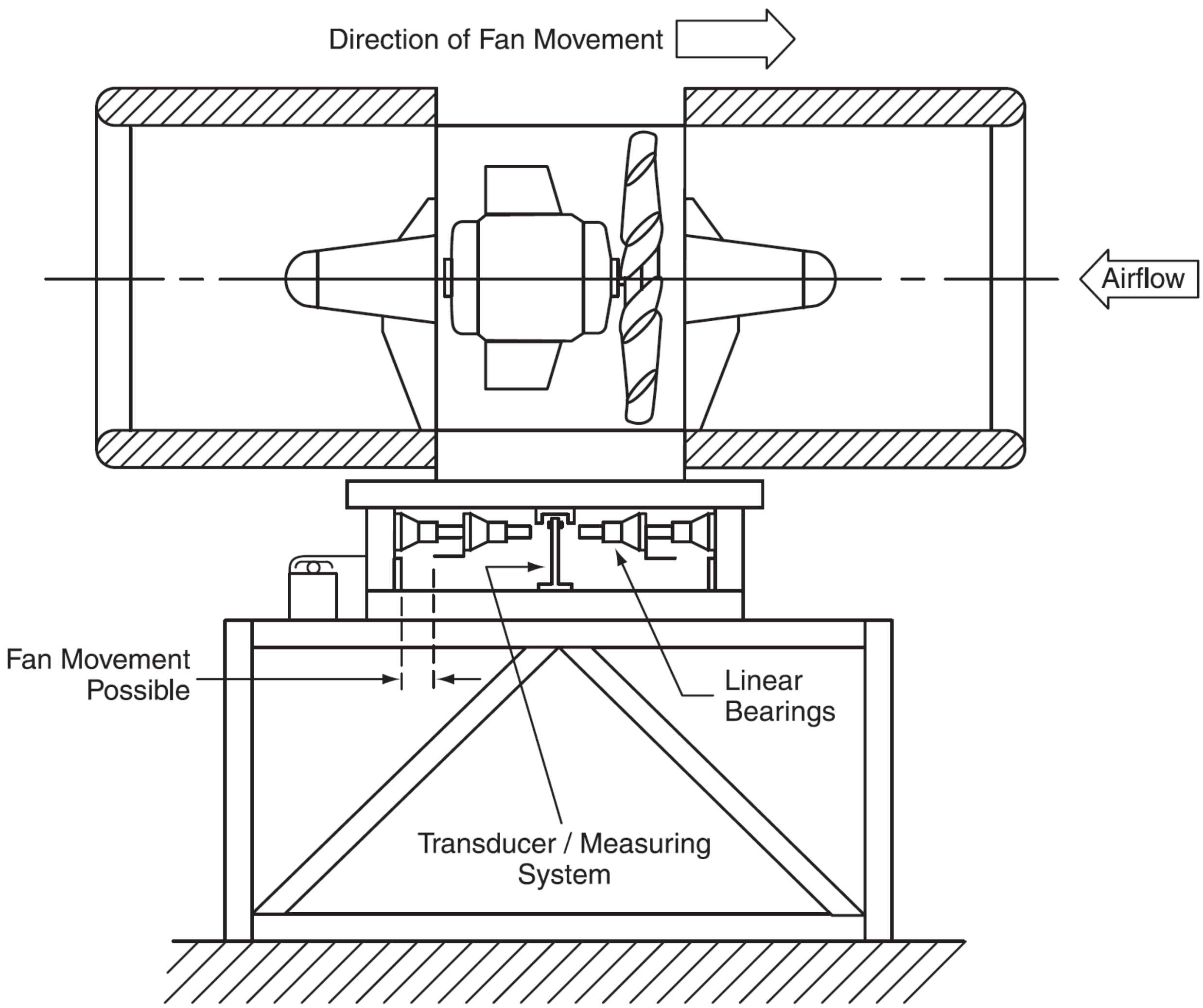


Figure 3 — Thrust Measuring Layout: Suspended Method with Adjustable Position Transducer Measuring System



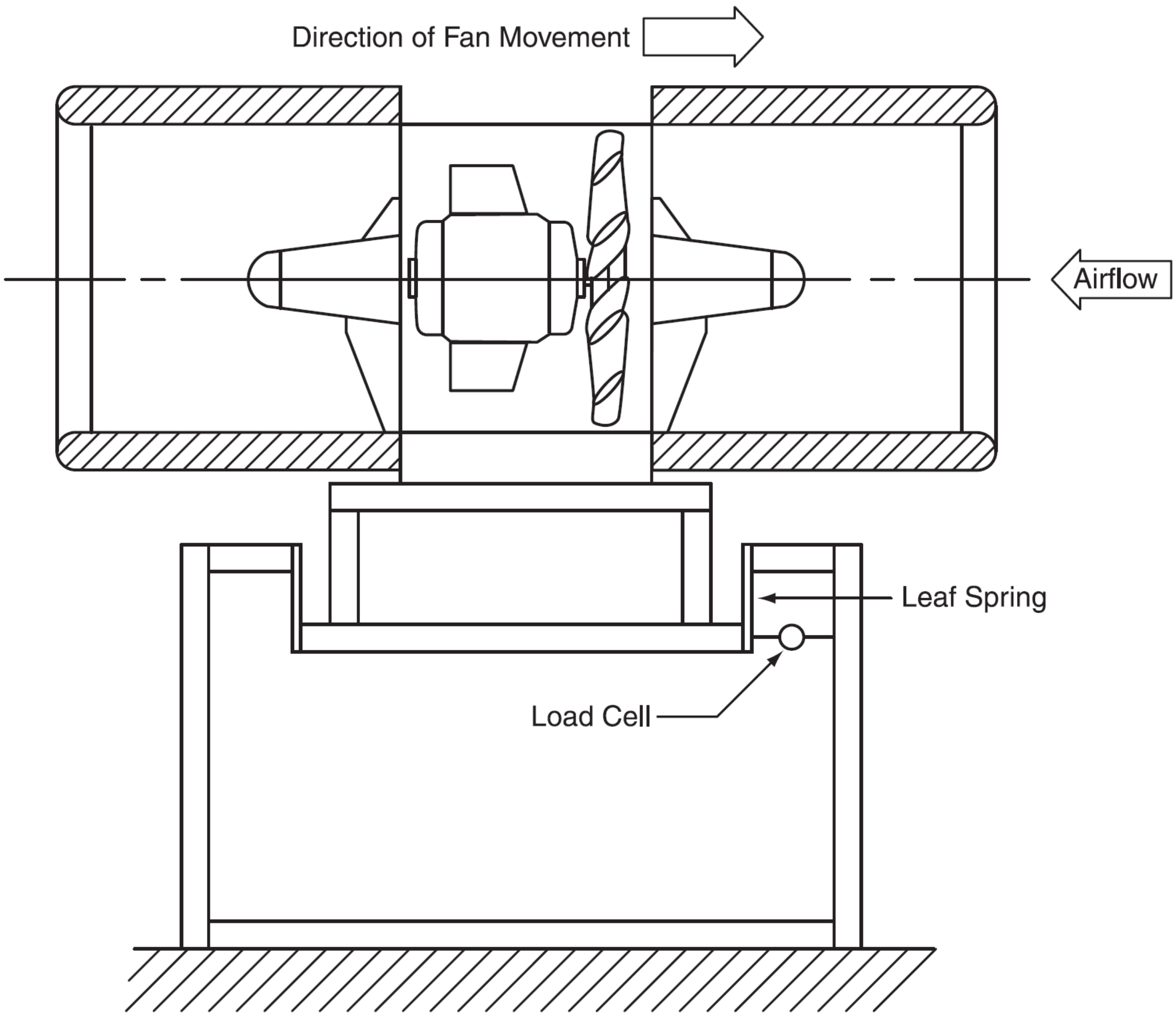
Note: The fan shall be leveled accurately prior to testing.

Figure 4A — Thrust Measuring Layout: Supported Method with Linear Bearings and Thrust Gauge in Suspension



Note: The fan shall be leveled accurately prior to testing.

Figure 4B — Thrust Measuring Layout: Supported Method with Linear Bearings and Transducer Measuring System



Note: The fan shall be leveled accurately prior to testing.

Figure 4C — Thrust Measuring Layout: Supported Method with Leaf Springs and Load Cell

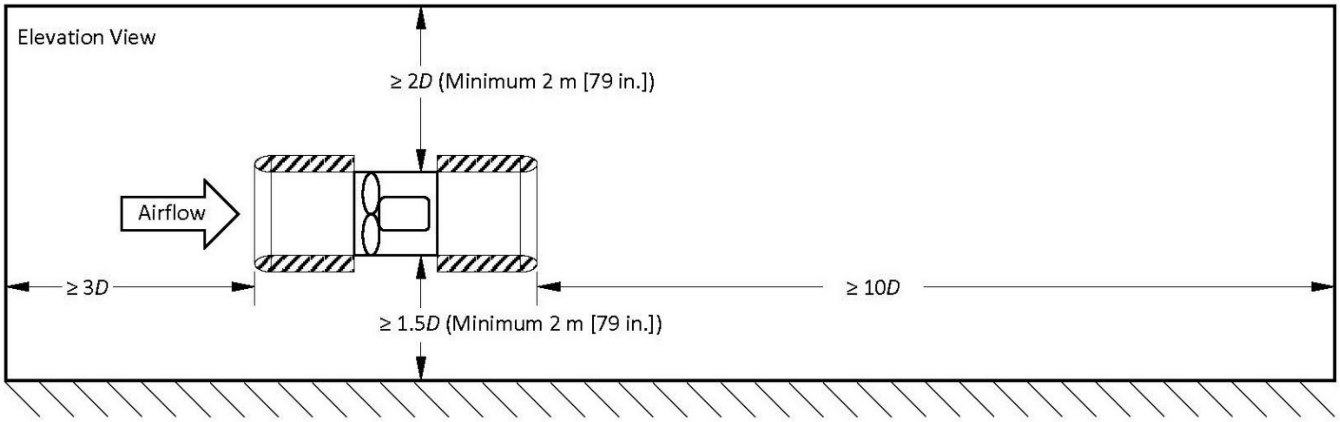


Figure 5A — Thrust Measuring Enclosure (Elevation)

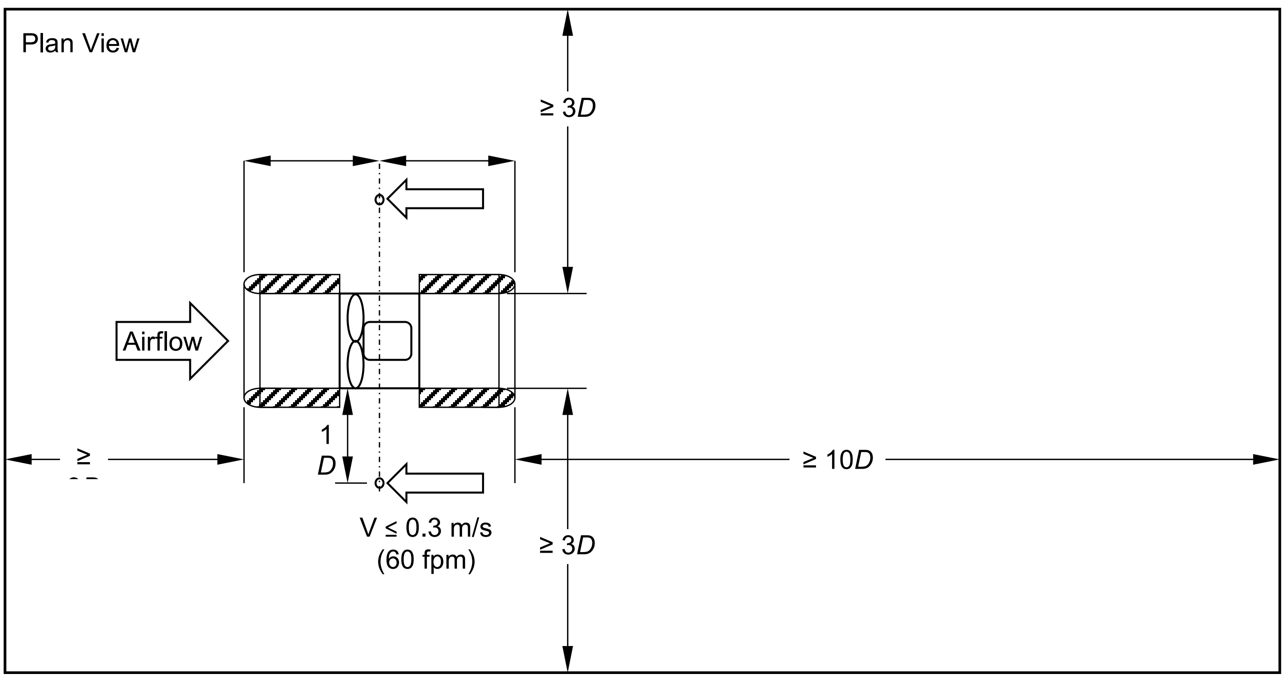


Figure 5B — Thrust Measuring Enclosure (Plan View)

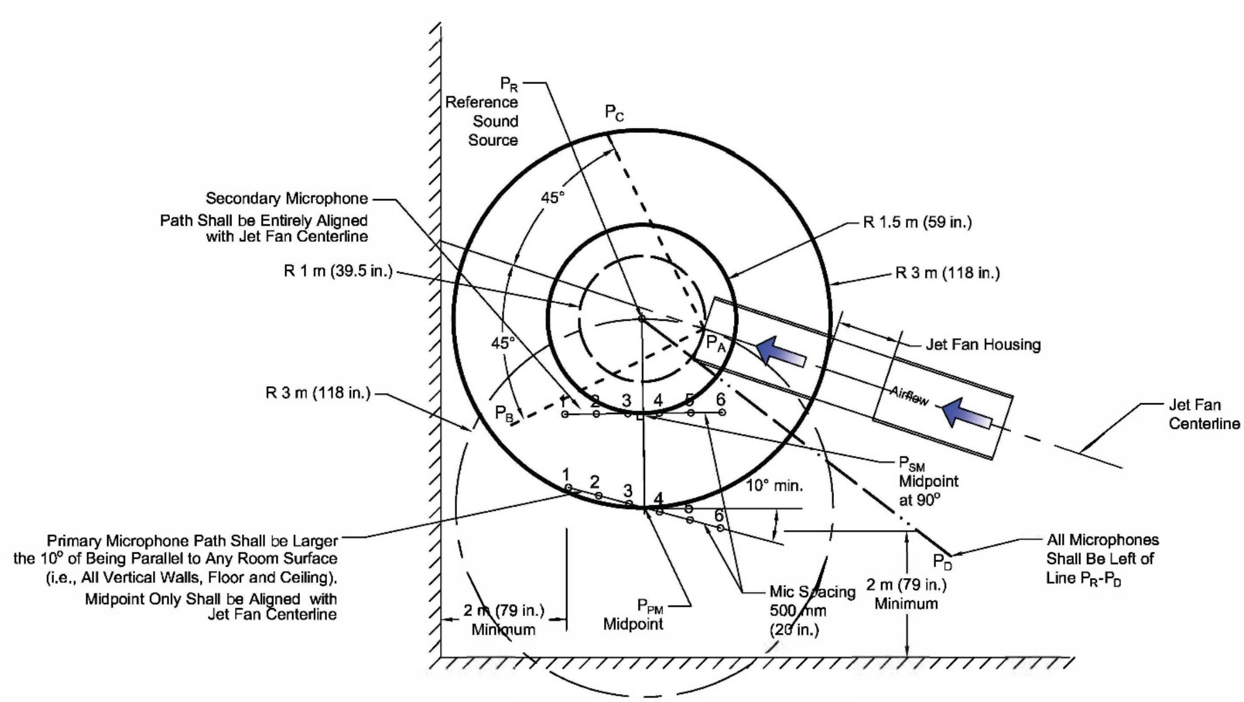
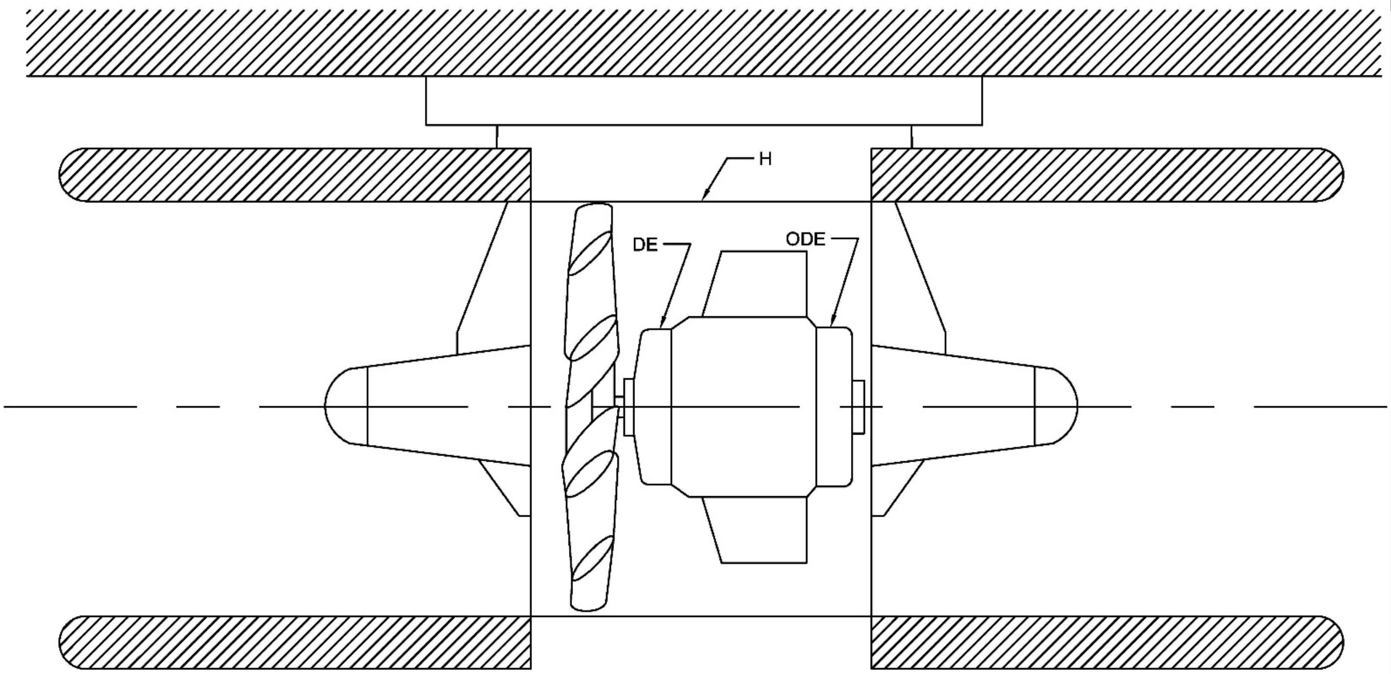


Figure 6 — Semi-Reverberant Enclosure



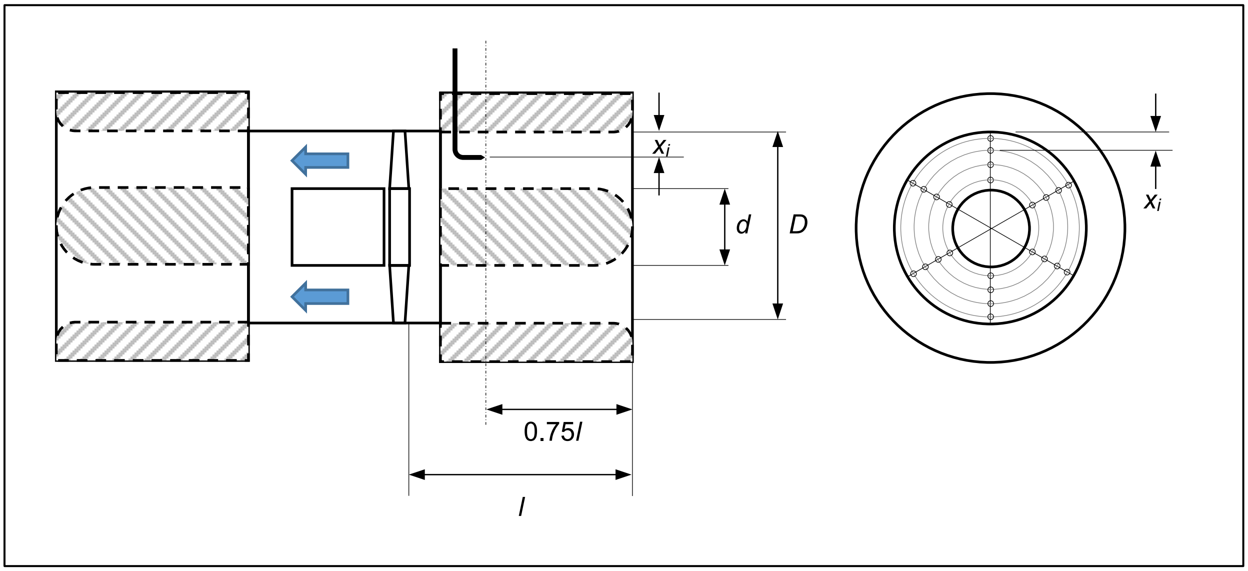
Vibration Levels to be Taken at Drive End (DE), Opposite Drive End (ODE) and Housing (H) Locations

Notes:

1. Can be base-mounted or ceiling-mounted.
2. It is recommended that measurements be made at the impeller shaft bearings. Where this is not possible, the pick-up shall be mounted in the shortest direct mechanical path between the transducer and the bearing. A transducer shall not be mounted on an unsupported panel, guard or elsewhere on the fan where a solid signal path cannot be obtained. A transducer may be mounted on a fan housing and/or flange where a solid signal path is obtained between a bearing and the measurement point.

   A horizontal measurement shall always be made in a radial direction, perpendicular to the axis of rotation. A vertical measurement reading shall always be made perpendicular to the axis of rotation, perpendicular to a horizontal reading. An axial measurement shall always be made parallel to the shaft (rotor) axis of rotation. See ANSI/AMCA Standard 204.

Figure 7 — Vibration Measuring Positions for Jet Fans



The traverse plane shall be located ¾ of the distance from the fan inlet to the impeller. The traverse points shall be located along six radial lines, equally spaced around the perimeter of the fan, with the following radial dimensions, x_i (Table 15.1):

Table 15.1 — Traverse Locations

Radial Position	Length, x_i
1	0.021·(*D*-*d*)
2	0.117·(*D*-*d*)
3	0.184·(*D*-*d*)
4	0.345·(*D*-*d*)

Figure 8 — Pitot traverse measurement location

Annex A
Conversion Rules (Normative)

A.1 General

The following conversion rules, subject to agreement between the supplier and client, shall be used when deriving the performance of a fan that has not been tested directly. Conversion is, in the main, based on the use of dimensionless coefficients. A different procedure is used for sound levels.

A.2 Performance coefficients

Flow Coefficient	Thrust Coefficient	Power Coefficient
$\varphi = \frac{Q}{A_a \times u}$ Where: A_a = impeller annulus area u = impeller tip speed = π x D_r x N	$\Theta = \frac{2T_c}{A_a \times \rho \times u^2}$ (See Note 2 below.)	$\Phi = \frac{2H_R}{A_a \times \rho \times u^3}$

Notes:

1. Fan thrust shall not be calculated. Gross errors may arise from calculation, principally due to the non-uniformity of air velocity at the fan outlet and a lack of certainty as to the fan outlet area.
2. The above performance coefficients differ from those in ISO 5801 but have been found to give good correlation of test data for axial flow jet fans.

A.3 Sound power levels

Total sound power levels shall be converted according to the following relationship. (See note below.)

$$L_{wc} = L_{wt} + 50log_{10}\left(\frac{N_c}{N_t}\right) + 70log_{10}\left(\frac{d_c}{d_t}\right) \quad \text{Eq. A.1}$$

Where:

d = nominal fan diameter
N = impeller rotational speed
c = calculated
t = test

Note: If the above relationship is used to calculate octave band sound levels, then suitable adjustments must be made if the blade passing frequency changes to a different octave band than that of the test fan.

RESOURCES

AMCA Membership Information
http://www.amca.org/member

AMCA International Headquarters and Laboratory
www.amca.org

AMCA White Papers
www.amca.org/whitepapers

Searchable CRP Database of AMCA Certified Products
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