STANDARD

ANSI/AMCA Standard 500-L

Laboratory Methods of Testing Louvers for Rating

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1. Purpose

The purpose of this standard is to establish uniform laboratory test methods for louvers. Characteristics to be determined include air leakage, air performance (pressure drop), water penetration, wind-driven rain, wind-driven sand and operational torque.

It is not the purpose of this standard to establish minimum or maximum performance ratings.

2. Scope

This standard may be used as a basis for testing louvers with air as the test gas.

Tests conducted in accordance with the requirements of this standard are intended to demonstrate the performance of a louver and are not intended to determine the acceptability of performance. It is not in the scope of this standard to indicate actual sequences of testing or to specify minimum or maximum criteria for testing.

The parties to a test for guarantee purposes may agree to exceptions to this standard in writing prior to the test. However, only a test that does not violate any mandatory requirement of this standard shall be designated as a test conducted in accordance with this standard.

3. Definitions/Units of Measure/Symbols

3.1 Definitions

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

3.1.1 Absolute pressure (p)
The value of a pressure when the datum pressure is absolute zero. It is always positive.

3.1.2 Adjustable blade louver
A louver in which the blades may be operated either manually or by mechanical means.

3.1.3 Air density (ρ)
The mass per unit volume of air.

3.1.4 Air leakage
The amount of air passing through a louver when it is in the closed position and at a specific pressure differential. It is expressed as the volumetric rate of air passing through the louver divided by the face area.

3.1.5 Air performance - pressure drop (ΔP)
The difference in pressure between two points in a flow system, usually caused by frictional resistance to fluid flow through an opening in a duct or other flow system.

Air performance - pressure drop is a measure of the resistance to airflow across a louver. It is expressed as the difference in static pressure across the louver for a specific rate of airflow.

3.1.6 Barometric pressure (p_b)
The absolute pressure exerted by the atmosphere at the location of measurement.

3.1.7 Beginning point of water penetration
The free area velocity at the intersection of a simple linear regression of test data (per AMCA Publication 511, Section 11) and the line of 3.05 g (0.01 oz.) of water per m^2 (ft^2) of free area.

3.1.8 Blade
A typically horizontally orientated component (can run vertically or any other direction) that spans from one frame member to another frame member. It may be fixed, adjustable, or a combination of both.

3.1.9 Combination louver
A louver having both fixed and adjustable blades.

3.1.10 Core area
The product of the minimum height, H, and minimum width, W, of the front opening in the louver assembly with the louver blades removed (see Annex D).

3.1.11 Core area velocity
The airflow rate through the louver divided by the core area.

3.1.12 Core ventilation rate
The airflow rate through the core area of the louver.

3.1.13 Determination
A complete set of measurements for a particular point of operation of the test louver. The measurements must be sufficient to determine all appropriate performance variables as defined in Section 3.1.6.

3.1.14 Dry-bulb temperature (t_d)
The air temperature measured by a dry temperature sensor.

3.1.15 Energy factor
The ratio of the total kinetic energy of the airflow to the kinetic energy corresponding to the average velocity of air.

3.1.16 Face area
The total cross-sectional area of a louver, duct or wall opening.

3.1.17 Face area velocity
The airflow through a louver divided by its face area.

3.1.18 Fixed blade louver
A louver in which the blades do not move.

3.1.19 Free area
The minimum area through which air can pass.

For horizontal blade louvers, free area is determined by multiplying the sum of the minimum distances between intermediate blades, top blade and head, and bottom blade and sill by the minimum distance between jambs.

For vertical blade louvers, free area is determined by multiplying the sum of the minimum distances between intermediate blades, left blade and left jamb, and right blade and right jamb by the minimum distance between head and sill.

3.1.20 Free area velocity (V_{fa})
The airflow rate through a louver divided by its free area.

3.1.21 Gauge pressure
The value of a pressure when the reference pressure is the barometric pressure at the point of measurement. It may be negative or positive.

3.1.22 Head frame member
A horizontally orientated frame member located at the top of a vertically positioned louver. See also multi-piece frame member. A shaped louver may have a non-horizontally orientated frame member located at or near the top of the louver and may have that frame member be considered either a head or jamb frame member.

3.1.23 Jamb frame member
A vertically orientated frame member located at the side of a vertically positioned louver. See also multi-piece frame member. A shaped louver may have non-vertically orientated jamb frame member(s).

3.1.24 Louver
A device comprised of multiple blades that, when mounted in an opening, permits the flow of air but inhibits the entrance of other elements.

3.1.25 Louver calibration plate
A plate having an opening of the same geometric shape and dimensions as the core area of the test specimen.

3.1.26 Louver exterior face
The vertical plane containing the most exterior portion of a louver frame excluding a drip edge on a sill or an integrated sill pan.

3.1.27 Multi-piece frame member
A frame member made from two or more pieces of material joined together (via weld, screw, bolt, rivet, snap, crimp, wedge, press, glue, etc.) to form a single unified frame member. All pieces of a multi-piece frame member shall be considered a single unified body and shall take on the role/responsibility/function of a head, sill, or jamb frame member. All appropriate parts of a multi-piece frame member shall be considered when calculating free area and core area. Use of sealant to prevent air/water infiltration is not considered to be the joining of two pieces together (i.e., a top/bottom blade being sealed to the underside of a head/sill frame member). Pieces of a multi-piece frame member do not always span the entire length of the longest multi-piece frame member piece (i.e., a multi-piece sill frame member that has a sill blade stop piece that is made up of two similar/same pieces and are butted up to each other somewhere along the span of the multi-piece sill frame member or a sill piece that runs past/under the jamb frame members but also has a sill blade stop piece that stops at or in between the jambs).

3.1.28 Percent of free area
The percent of free area is the free area thus calculated, divided by the gross area of the air control louver × 100. See louver cross sections in Figures 1A and 1B.

3.1.29 Pressure (P)
A force per unit area. This corresponds to energy per unit volume of fluid.

3.1.30 Pressure differential
The change in static pressure across a louver.

3.1.31 Sand louver
A louver comprised of multiple blades that, when mounted in an opening, permits the flow of air while minimizing the ingress of airborne sand particles.

3.1.32 Shall and should
The word *shall* is to be understood as mandatory and the word *should* as advisory.

3.1.33 Shaped louver
A louver with a non-rectangular frame.

3.1.34 Sill frame member
A horizontally orientated frame member located at the bottom of a vertically positioned louver. See also multi-piece frame member. A shaped louver may have a non-horizontally orientated frame member located at/near the bottom of the louver and may have that frame member be considered either a sill or a jamb frame member.

3.1.35 Standard air
Air with a density of 1.2 kg/m^3 (0.075 lbm/ft^3), a ratio of specific heats of 1.4, and a viscosity of 1.8185 × 10^{-5} Pa-s (1.222 ×10^{-5} lbm/ft-s). Air at 20 °C (68 °F) temperature, 50% relative humidity, and 101.3207 kPa (29.92 in. Hg) barometric pressure has these properties approximately.

3.1.36 Static pressure (P_s)
That portion of the air pressure that exists by virtue of the degree of compression only. If expressed as gauge pressure, it may be negative or positive.

3.1.37 Static temperature (t_s)
The temperature that exists by virtue of the internal energy of the air only. If a portion of the internal energy is converted to kinetic energy, the static temperature will be decreased accordingly.

3.1.38 Target velocity
Used in terms of “target core velocity” or “target free area velocity.” A velocity that is chosen prior to running a test point. The velocity is at lab conditions (not adjusted to standard air conditions). Various target velocities may be required to be run to gather enough data to calculate a performance rating.

3.1.39 Test
A series of determinations for various points of operation of a louver.

3.1.40 Total pressure (P_t)
The air pressure that exists by virtue of the degree of compression and the rate of motion. It is the algebraic sum of the velocity pressure and the static pressure at a point. Thus, if the air is at rest, the total pressure will equal the static pressure.

3.1.41 Velocity pressure (P_v)
That portion of the air pressure that exists by virtue of the rate of motion only. It is always positive.

3.1.42 Water carryover
Water that passes through a louver during a specified velocity of the Water Penetration test.

3.1.43 Water carryover point
A specific volume of water penetration per square meter (square foot) of louver free area that shall be 3.05 g/m^2 (0.01 oz/ft^2) of free area.

3.1.44 Water density (ρ_W)
Mass per unit volume of water.

3.1.45 Water penetration
The amount of water passing through a louver while air is flowing through it at a specific free area velocity. It is expressed as the weight of water passing through the louver divided by the free area at a specified free area velocity.

3.1.46 Water-sheeting tape
Tape with hydrophilic properties that cause water to adhere to and spread out over the tape's surface with the tape remaining wetted (as opposed to hydrophobic properties that cause water to form beads that easily slide off of the surface).

3.1.47 Wet-bulb depression
The difference between dry-bulb and wet-bulb temperatures at the same location.

3.1.48 Wet-bulb temperature (t_w)
The temperature measured by a temperature sensor covered by a water-moistened wick and exposed to air in motion. When properly measured, it is a close approximation of the temperature of adiabatic saturation.

3.1.49 Wind-driven-rain louver effectiveness (E_w)
At any core area velocity through the louver, the insertion loss of the louver assembly divided by the water penetration of the calibration plate at that velocity times 100, rounded to one decimal place.

3.1.50 Wind-driven-sand louver effectiveness (E_s)
At any free area velocity as defined in Table 6, the total mass of sand rejected divided by the total mass of sand injected times 100.

3.2 Units of measure

3.2.1 System of units
SI units (The International System of Units, *Le Systéme International d'Unités*) are the primary units employed in this standard, with I-P units (inch-pound) given as the secondary reference. SI units are based on the fundamental values of the International Bureau of Weights and Measures, and I-P values are based on the values of the National Institute of Standards and Technology, which are in turn based on the values of the International Bureau.

3.2.2 Basic units
The SI unit of length is the meter (m) or the millimeter (mm); the I-P unit of length is the foot (ft) or the inch (in.). The SI unit of mass is the kilogram (kg); the I-P unit of mass is the pound-mass (lbm). The SI unit of mass flow rate is kilogram per second (kg/s); the I-P unit of mass flow rate is pound-mass per second (lbm/s). The unit of time is either the minute (min) or the second (s). The SI unit of temperature is either the degree Celsius (°C) or the degree kelvin (°K); the I-P unit of temperature is either the degree Fahrenheit (°F) or the degree Rankine (°R). The SI unit of force is the newton (N); the I-P unit of force is the pound force (lbf).

3.2.3 Airflow rate
The SI unit of volumetric airflow rate is cubic meter per second (m^3/s); the I-P unit of volumetric airflow rate is cubic foot per minute (cfm).

3.2.4 Airflow velocity
The SI unit of airflow velocity is meter per second (m/s); the I-P unit of airflow velocity is foot per minute (fpm).

3.2.5 Water flow rate
The SI unit of liquid volume is the liter (L); the I-P unit of liquid volume is the gallon (gal). The SI unit of liquid flow rate is liter per second (L/s); the I-P unit of liquid flow rate is gallon per minute (gpm).

3.2.6 Pressure
The SI unit of pressure is the pascal (Pa); the I-P unit of pressure is either inch water gauge (in. wg) or inch mercury column (in. Hg). Values in units of in. Hg shall be used only for barometric pressure measurements. In. wg shall be based on a one-inch column of distilled water at 68 °F under standard gravity and a gas column balancing effect based on standard air. In. Hg shall be based on a one-inch column of mercury at 32 °F under standard gravity in a vacuum.

3.2.7 Torque (*T*)
The SI unit of torque is the newton-meter (N-m); the I-P unit is the pound inch (lbf-in.).

3.2.8 Gas properties
The SI unit of density is kilogram per cubic meter (kg/m3); the I-P unit of density is pound-mass per cubic foot (lbm/ft3). The SI unit of viscosity is the pascal-second (Pa-s); the I-P unit of viscosity is pound-mass per foot-second (lbm/ft-s). The SI unit of gas constant (per molar mass) is joule per kilogram-Kelvin (J/kg-K); the I-P unit of gas constant is foot-pound force per pound mass-degree Rankine (ft-lbf/lbm-°R).

3.2.9 Dimensionless groups
Various dimensionless quantities appear in the text. Any consistent system of units may be employed to evaluate these quantities unless a numerical factor is included, in which case units must be as specified.

3.2.10 Physical constants
The value of standard gravitational acceleration shall be taken as 9.80665 m/s^2 (32.174 ft/s^2) at mean sea level at 45° latitude. The density of distilled water at saturation pressure shall be taken as 998.278 kg/m^3 (62.3205 lbm/ft^3) at 20 °C (68 °F). The density of mercury at saturation pressure shall be taken at 13,595.1 kg/m^3 (848.714 lbm/ft^3) at 0 °C (32 °F). The specific weights in kN/m^3 (lbf/ft^3) of these fluids under standard gravity in a vacuum are numerically equal to their densities at corresponding temperatures.

3.3 Symbols and subscripts

See Table 1 for a list of symbols and subscripts.

Table 1 — Symbols and Subscripts

Symbol	Description	SI Unit	I-P Unit
A	Area of cross section	m^2	ft^2
Ac	Louver core area or area of hole in calibration plate	m^2	ft^2
C	Nozzle discharge coefficient	dimensionless	
C_D	Discharge loss coefficient	dimensionless	
C_H	Core height	mm	in.
C_W	Core width	mm	in.
D	Diameter and equivalent diameter	m	ft
D_L	Depth of louver	mm	in.
E	Energy factor	dimensionless	

E_w	Wind-driven-rain-louver effectiveness	%	
E_s	Wind-driven sand-louver effectiveness	%	
L	Nozzle throat dimension	m	ft
$L_{x,x'}$	Length of duct between planes x and x’	m	ft
M	Chamber dimension	m	ft
mi	Sand supplied to the injector	kg	lbm
mu	Mass of rejected sand	kg	lbm
n	Number of readings	dimensionless	
P_s	Static pressure	Pa	in. wg
P_{sx}	Static pressure at plane x	Pa	in. wg
P_t	Total pressure	Pa	in. wg
P_{tx}	Total pressure at plane x	Pa	in. wg
P_v	Velocity pressure	Pa	in. wg
P_{vx}	Velocity pressure at plane x	Pa	in. wg
p_b	Corrected barometric pressure	Pa	in. Hg
p_e	Saturated vapor pressure at *t*wx	Pa	in. Hg
p_p	Partial vapor pressure	Pa	in. Hg
Q	Louver airflow rate	m^3/s	cfm
Q_S	Volumetric airflow rate at standard air	m^3/s	cfm
Q_x	Airflow rate at plane x	m^3/s	cfm
q_d	Water penetration rate	L/h	gpm
q_{do}	Water penetration rate of calibration plate test	L/h	gpm
q_s	Water supply rate	L/h	gpm
q_{so}	Water supply rate of calibration plate test	L/h	gpm
q_u	Water rejection rate collected upstream of the test louver	L/h	gpm
q_{uo}	Water rejection rate of calibration plate test	L/h	gpm
q_v	Airflow rate	m^3/s	cfm
q_{vo}	Airflow rate through calibration plate	m^3/s	cfm
q_w	Specified water/rainfall penetration rate	mm/hr	in./hr
PL-X	Setup connection plane		
PL-Y	Setup connection plane		
PL-Z	Setup connection plane		
PL-A	Airflow connection plane		

PL-B	Airflow connection plane		
PL-C	Airflow connection plane		
R	Gas constant	J/kg-K	ft-lb/lbm-°R
Re	Reynolds number	dimensionless	
T	Torque	N-m	lbf-in.
t_{dx}	Dry-bulb temperature at plane x	°C	°F
t_s	Static temperature	°C	°F
t_{wx}	Wet-bulb temperature at plane x	°C	°F
V	Velocity	m/s	fpm
v_w	Wind velocity	m/s	fpm
v_c	Core velocity	m/s	fpm
y	Thickness of straightener element	m	ft
Y	Nozzle expansion factor	dimensionless	
α	Static pressure ratio for nozzles	dimensionless	
β	Diameter ratio for nozzles	dimensionless	
γ	Ratio of specific heats	dimensionless	
ΔP	Pressure differential	Pa	in. wg
ΔP_n	Pressure differential across nozzle	Pa	in. wg
ΔP_s	Pressure drop at standard air	Pa	in. wg
$\Delta p_{x,x'}$	Pressure differential between planes x and x'	Pa	in. wg
μ	Air viscosity	Pa-s	lbm/ft-s
ρ	Air density	kg/m^3	lbm/ft^3
ρ_w	Water density	g/m^3	lbm/ft^3
ρ_x	Air density at plane x	kg/m^3	lbm/ft^3

See Table 2 for a list of additional subscripts.

Table 2 — Additional Subscripts (including Planes of Measurement)

Subscript	Description
c	Converted parameter
corr	Corrected
LS	Louver and system
fa	Free area
l	Outlet of louver under test
m	Measuring point at the airflow meter

n	Value at selected point of airflow rate/static pressure curve
nom	Nominal
o	Measured value with calibration plate
r	Reading
s	System
x	Plane 0, 1, 2, ..., as appropriate
0	Plane 0 (general test area)
1	Plane of inlet of louver being tested
2	Plane of outlet of louver being tested
3	Plane of pitot traverse
4	Plane of duct *P*s measurement downstream of louver being tested
5	Plane of nozzle inlet *P*s measurement
6	Plane of nozzle discharge station
7	Plane of *P*s measurement in chamber downstream of louver being tested
8	Plane of *P*s measurement in chamber upstream of louver being tested
9	Plane of duct *P*s measurement of upstream louver being tested (used to show correct values against reference values)

4. Instruments and Methods of Measurement

4.1 Accuracy

The following specifications for instruments and methods of measurement include both accuracy requirements and specific examples of equipment capable of meeting those requirements. Equipment other than the examples cited may be used, provided the accuracy requirements are met or exceeded.

4.2 Pressure

The total pressure at a point shall be measured on an indicator, such as a manometer, with one leg open to atmosphere and the other leg connected to a total pressure sensor, such as a total pressure tube or the impact tap of a pitot-static tube.

The static pressure at a point shall be measured on an indicator, such as a manometer, with one leg open to the atmosphere and the other leg connected to a static pressure sensor, such as a static pressure tap or the static tap of a pitot-static tube.

The velocity pressure at a point shall be measured on an indicator, such as a manometer, with one leg connected to a total pressure sensor, such as the impact tap of a pitot-static tube, and the other leg connected to a static pressure sensor, such as the static tap of the same pitot-static tube.

The differential pressure between two points shall be measured on an indicator, such as a manometer, with one leg connected to the upstream sensor, such as a static pressure tap, and the other leg connected to the downstream sensor, such as a static pressure tap.

4.2.1 Manometers and other pressure-indicating instruments
Pressure shall be measured on manometers of the liquid column type using inclined or vertical legs or other instruments that provide a maximum uncertainty of 1% of the maximum observed test reading during the test or 3 Pa (0.01 in. wg), whichever is larger.

4.2.1.1 Calibration
Each pressure-indicating instrument shall be calibrated at both ends of the scale and at least nine equally spaced intermediate points in accordance with the following:

When the pressure to be indicated falls in the range of 0 to 0.5 kPa (0 to 2 in. wg), calibration shall be against a water-filled hook gauge of the micrometer type or a precision micromanometer.

When the pressure to be indicated is above 0.5 kPa (2 in. wg), calibration shall be against a water-filled hook gauge of the micrometer type, a precision micromanometer or a water-filled U-tube.

4.2.1.2 Averaging
Since the airflow and pressures through a louver in a typical system are never strictly steady, the pressure indicated on any instrument will fluctuate with time. In order to obtain a representative reading, either the instrument must be dampened or the readings must be averaged in a suitable manner. Multipoint or continuous record averaging can be accomplished with instruments and analyzers designed for this purpose.

4.2.1.3 Corrections
Manometer readings shall be corrected for any difference in gauge fluid from standard, any difference in gas column balancing effect from standard or any change in length of the graduated scale due to temperature. However, corrections may be omitted for temperatures between 14 °C and 26 °C (58 °F and 78 °F), latitudes between 30° and 60° and elevations up to 1500 m (5000 ft).

4.2.2 Pitot-static tubes
The total pressure or the static pressure at a point may be sensed with a pitot-static tube of the proportions shown in Figures 2A and 2B. Either or both of these pressure signals can then be transmitted to a manometer or other indicator. If both pressure signals are transmitted to the same indicator, the differential shall be considered the velocity pressure at the point of the impact opening.

4.2.2.1 Calibration
Pitot-static tubes having the proportions shown in Figures 2A and 2B are considered primary instruments and need not be calibrated, provided they are maintained in the specified condition.

4.2.2.2 Size
The pitot-static tube shall be of sufficient size and strength to withstand the pressure forces exerted upon it. The outside diameter of the tube shall not exceed 1/30 of the test duct diameter, excepting cases in which the length of the supporting stem exceeds 24 tube diameters. In these cases, the stem may be progressively increased beyond this distance. The minimum practical tube diameter is 2.5 mm (0.1 in.).

4.2.2.3 Support
Rigid support shall be provided to hold the pitot-static tube axis parallel to the axis of the duct within one degree and at the head locations specified in Figures 3A and 3B within 1.2 mm (0.05 in.) or 0.25% of the duct diameter, whichever is larger. Straighteners are specified so that flow lines will be approximately parallel to the duct axis.

4.2.3 Static pressure taps
The static pressure at a point may be sensed with a pressure tap of the proportions shown in Figure 4. The pressure signal can then be transmitted to an indicator.

4.2.3.1 Calibration
Pressure taps having the proportions shown in Figure 4 are considered primary instruments and need not be calibrated, provided they are maintained in the specified condition.

4.2.3.2 Averaging
An individual pressure tap is sensitive only to the pressure in the immediate vicinity of the hole. In order to obtain an average, at least four identical taps shall be manifolded into a piezometer ring. The manifold shall have an inside area at least four times that of each tap.

4.2.3.3 Piezometer rings
Piezometer rings are specified for upstream and downstream nozzle taps and for outlet duct or chamber measurements unless pitot traverse is specified. Measuring planes shall be located as shown in the test figure for the appropriate setup.

4.2.4 Other pressure-indicating instruments
Pressure measuring systems consisting of indicators and sensors other than manometers and pitot-static tubes or static pressure taps may be used if the combined uncertainty of the system including any transducers does not exceed the combined uncertainty for an appropriate combination of manometers and pitot-static tubes or static pressure taps.

4.3 Airflow rate
An airflow rate shall be calculated from either measurement of velocity pressure obtained by pitot traverse or measurements of pressure differential across a flow nozzle. Airflow rates less than 4.7 L/s (10 cfm) may be measured directly using an airflow meter.

4.3.1 Pitot traverse
Airflow rate may be calculated from the velocity pressures obtained by traverses of a duct with a pitot-static tube for any point of operation, provided the average velocity corresponding to the airflow rate is at least 6.35 m/s (1250 fpm).

4.3.1.1 Traverse point
The number and locations of the measuring stations on each diameter and the number of diameters shall be as specified in Figures 3A and 3B.

4.3.1.2 Averaging
The stations shown in Figures 3A and 3B are located on each diameter according to the log-linear rule. The arithmetic mean of the individual velocity measurements made at these stations will be the mean velocity through the measuring section for a wide variety of profiles.

4.3.2 Nozzles
Airflow rate may be calculated from the pressure differential measured across an airflow nozzle or bank of nozzles for any point of operation, provided the pressure differential across the nozzle bank is at least 25 Pa (0.1 in. wg). The uncertainty of the airflow rate measurement can be reduced by changing to a smaller nozzle or combination of nozzles for low airflow rates.

4.3.2.1 Size
The nozzle or nozzles shall conform to Figure 8A. Nozzles may be of any convenient size. However, when a duct is connected to the inlet of the nozzle, the ratio of nozzle throat diameter to the diameter of the inlet duct shall not exceed 0.525.

4.3.2.2 Calibration
The standard nozzle is considered a primary instrument and need not be calibrated if maintained in the specified condition. Reliable coefficients have been established for throat dimensions $L = 0.5D$ and $L = 0.6D$, shown in Figure 8A. Throat dimension $L = 0.6D$ is recommended for new construction.

4.3.2.3 Chamber nozzles
Nozzles without integral throat taps may be used for multiple nozzle chambers. In these cases, upstream and downstream pressure taps shall be located as shown in the test figure for the appropriate setup. Alternatively, nozzles with throat taps may be used. In these cases, the throat taps located as shown in Figure 8A shall be used in place of the downstream pressure taps shown in the test figure for the setup, and the piezometer for each nozzle shall be connected to its own indicator.

4.3.2.4 Ducted nozzles
Nozzles with integral throat taps shall be used for ducted nozzle setups. Upstream pressure taps shall be located as shown in the test figure for the appropriate setup. Downstream taps are the integral throat taps and shall be located as shown in Figure 8A.

4.3.2.5 Taps
All pressure taps shall conform to the specification in Section 4.2.3 regarding geometry, number and manifolding into piezometer rings.

4.3.3 Airflow meter
An airflow rate may be measured directly using a calibrated airflow meter capable of measuring airflow in increments of 0.2 L/s (25 ft^3/hr) or less. A direct-reading airflow meter may be used if the airflow is below 4.7 L/s (10 cfm).

4.3.4 Other airflow measurement methods
Airflow measurement methods that use a meter or a traverse other than flow nozzles or a pitot-static tube traverse described herein may be used if the uncertainty introduced by the method does not exceed that introduced by an appropriate flow nozzle or pitot-static tube traverse method. The contribution to the combined uncertainty in the airflow rate measurement shall not exceed that corresponding to 1.2% of the discharge coefficient for a flow nozzle.

4.4 Water flow rate

A calibrated flow meter capable of indicating flow in increments of 0.5 L/m (0.1 gpm) or less shall be used. Measurement accuracy shall be within 0.5% of the indicated flow rate. Water flow meters shall be calibrated against a known weight of water flowing for a measurement time period or factory calibrated.

4.5 Torque

A torque meter having a demonstrated accuracy of ±2% of observed reading may be used to determine power.

4.5.1 Calibration
A torque meter shall have a static calibration and may have a running calibration through its range of usage. The static calibration shall be made by suspending weights from a torque arm. The weights shall have certified accuracies of ±0.2%. The length of the torque arm shall be determined to an accuracy of ±0.2%.

4.5.2 Tare
The zero-torque equilibrium (tare) and the span of the readout system shall be checked before and after each test. In each case, the difference shall be within 0.5% of the maximum value measured during the test.

4.6 Air density

Air density shall be calculated from measurements of wet-bulb temperature, dry-bulb temperature and barometric pressure. Other parameters may be measured and used if the maximum error in the calculated density does not exceed 0.5%.

4.6.1 Thermometers

Both wet- and dry-bulb temperatures shall be measured with thermometers or other instruments with demonstrated accuracies of ±1 °C (±2 °F) and readability of 0.5 °C (1 °F) or finer.

4.6.1.1 Calibration

Thermometers shall be calibrated over the range of temperatures to be encountered during a test against a thermometer with a calibration that is traceable to NIST or other national physical measures recognized as equivalent by NIST.

4.6.1.2 Wet-bulb

The wet-bulb thermometer shall have an air velocity over the water-moistened wick-covered bulb of 3.5 to 10 m/s (700 to 2000 fpm). The dry-bulb thermometer shall be mounted upstream of the wet-bulb thermometer. Its reading will not be depressed.

4.6.2 Barometers

The barometric pressure shall be measured with a mercury column barometer or other instrument with a demonstrated accuracy of ±170 Pa (±0.05 in. Hg) and readable to 34 Pa (0.01 in. Hg) or finer.

4.6.2.1 Calibration

Barometers shall be calibrated against a mercury column barometer with a calibration that is traceable to NIST or other national physical measures recognized as equivalent by NIST. A convenient method of doing this is to use an aneroid barometer as a transfer instrument and carry it back and forth to the Weather Bureau Station for comparison. A permanently mounted mercury column barometer should hold its calibration well enough so that comparisons every three months should be sufficient. Transducer type barometers shall be calibrated for each test. Barometers shall be maintained in good condition.

4.6.2.2 Corrections

Barometric readings shall be corrected for any difference in mercury density from standard or any change in length of the graduated scale due to temperature. Refer to the manufacturer’s instructions.

4.7 Voltage

Actuator input voltage during the test shall be within 1% of the voltage shown on the actuator nameplate.

4.8 Meters

Electrical meters shall have certified accuracies of ±1.0% of observed reading. It is preferable that the same meters shall be used for the test as for the calibration.

4.9 Pneumatic actuator supply air pressure

Pneumatic actuator supply air pressure during a test shall be within 5% of the desired test pressure.

4.10 Pressure gauges

Supply air pressure for pneumatic actuators shall be measured with a pressure gauge or other instrument with a demonstrated accuracy of ±10 kPa (1 psi) and a readability of 10 kPa (1 psi) or less.

4.11 Chronometers

Time measurements shall be made with a watch having minimum accuracy of ±0.2% per day.

4.12 Rain gauge

Rain gauges shall have an accuracy of ±2% of reading.

5. Equipment and Setups

5.1 Setups

Seven test louver setups are diagramed in Test Figures 5.1, 5.2, 5.4, 5.5, 5.6, 5.11 and 5.12. Eight airflow measurement setups are diagramed in Test Figures 6.1, 6.2, 6.3, 6.4, 6.5, 6.6 A, 6.6 B and 6.6 C.

5.1.1 Installation Types

There are four categories of installation types that can be used with louvers. The installation types and the corresponding test louver setup figures are as follows:

Test Figure 5.1 — Free Inlet, Ducted Outlet
Test Figure 5.2 — Ducted Inlet, Free Outlet
Test Figures 5.4, 5.5, 5.6, 5.11 — Free Inlet, Free Outlet
Test Figure 5.12 — Ducted Inlet, Ducted Outlet

5.1.2 Leakage

The ducts, chambers and other equipment utilized should be designed to withstand the pressure and other forces to be encountered. All joints between the louver and the measuring plane should be designed for minimum leakage.

5.2 Duct

A duct may be incorporated in a laboratory setup to provide a measuring plane or to simulate the conditions the louver is expected to encounter in service or both. The dimension *D* in the test louver setup figure is the inside diameter of a circular cross section duct or equivalent diameter of a rectangular cross section duct with inside transverse dimensions *a* and *b*, where:

$$D = \sqrt{\frac{4ab}{\pi}} \qquad \text{Eq. 5.1}$$

5.2.1 Transformation Pieces (Figure 9)

5.2.1.1

Transformation pieces used to connect a louver being tested and a duct with a measuring plane shall not contain any converging element that makes an angle with the duct axis greater than 7.5° or a diverging element that makes an angle with the duct greater than 3.5°.

5.2.1.2

Transformation pieces used to connect a variable exhaust system to a flow measuring nozzle shall have a maximum included angle of 7°.

5.2.1.3

Transformation pieces used to connect a duct containing a louver being tested and a flow measuring duct shall not contain any converging or diverging element that makes an angle with the duct axis greater than 30°.

5.2.1.4
Transformation pieces used to connect a duct that provides a measuring plane to a variable supply system or a chamber shall not be restricted as to size or shape.

5.2.2 Roundness
The portion of a pitot traverse duct within 1/2 duct diameter of either side of the plane of measurement shall be round within 0.5% of the duct diameter. The remainder of the duct shall be round within 1% of the duct diameter. The area of the plane of measurement shall be determined from the average of four diameters measured at 45° increments. The diameter measurements shall be accurate to 0.2%.

5.2.3 Straighteners
Straighteners or star straighteners shall be used where indicated in the test figures. The downstream plane of the straightener or star straightener shall be located between 5 and 5.25 duct diameters upstream of the plane of the pitot traverse or piezometer station. The form of the straightener or star straightener shall be as specified in Figure 10A or 10B.

5.3 Chamber

A chamber may be incorporated in a laboratory setup to provide a measuring station or to simulate the conditions the louver is expected to encounter in service or both. A chamber may have a circular or rectangular cross-sectional shape. The dimension *M* in the airflow measurement setup diagram is the inside diameter of a circular chamber or the equivalent diameter of dimensions *a* and *b*, where:

$$M = \sqrt{\frac{4ab}{\pi}} \qquad \text{Eq. 5.2}$$

5.3.1 Outlet chamber
An outlet chamber (Test Figure 5.4) shall have a cross-sectional area at least 15 times the free area of the louver being tested.

5.3.2 Inlet chamber
An inlet chamber (Test Figure 5.5) shall have a cross-sectional area at least three times the free area of the louver being tested.

5.3.3 Airflow settling means
Airflow settling means shall be installed in a chamber, where indicated on the test setup figure, to provide proper airflow patterns.

Where a measuring plane is located downstream of the settling means, the settling means is provided to ensure a substantially uniform flow ahead of the measuring plane. In this case, the maximum local velocity at a distance 0.1 *M* downstream of the screen shall not exceed the average velocity by more than 25% unless the maximum local velocity is less than 2 m/s (400 fpm).

Where a measuring plane is located upstream of the settling means, the purpose of the settling screen is to absorb the kinetic energy of the upstream jet and allow its normal expansion as if in an unconfined space. This requires some backflow to supply the air to mix at the jet boundaries, but the maximum reverse velocity shall not exceed 10% of the calculated plane “A” mean jet velocity.

Where measuring planes are located on both sides of the settling means within the chamber, the requirements for each side as outlined above shall be met.

Generally, several screens in each airflow settling means will be required. Any combination of screens or perforated sheets may be used. However, three or four screens with decreasing percent of open area in the direction of airflow are suggested. It is also suggested that, within each settling means, screens of square mesh round wire be used upstream with perforated sheet used downstream. An open area of 50% to 60% is suggested for the initial screen.

5.3.4 Multiple nozzles

Multiple nozzles shall be located as symmetrically as possible. The centerline of each nozzle shall be at least 1.5 nozzle throat diameters from the chamber wall. The minimum distance between centers of any two nozzles in simultaneous use shall be three times the throat diameter of the larger nozzle.

5.4 Variable supply and exhaust systems

A means of varying the points of operation shall be provided in a laboratory setup.

5.4.1 Throttling device

A throttling device may be used to control the point of operation. The device shall be located on the end of the duct or chamber and shall be symmetrical about the duct or chamber axis.

5.4.2 Supply or exhaust fan

A fan may be used to control the point of operation of the test louver. The fan shall provide sufficient pressure at the desired airflow rate to overcome losses through the test setup. Means of airflow adjustment, such as a damper, pitch control or speed control, may be required. A supply fan shall not surge or pulsate during a test.

5.5 Wind-driven-rain simulation equipment

5.5.1 Wind simulation weather section

1. The louver or calibration plate shall be mounted and fixed in the center of a 3 m × 3 m (9.75 ft × 9.75 ft) square wall located at the rear of the weather section (see Test Figure 5.11).
2. The louver or the calibration plate shall be sealed to the wall.
3. The outside face of the louver shall face the wind and rain simulation test apparatus.

5.5.2 Rain simulation equipment

1. The simulated rain shall be produced by at least four nozzles in an array close to the discharge of the wind effect fan to suit the spread of rain required. A typical spray can be achieved by using the nozzles and control system as shown in Test Figure 5.11 and Annex B.
2. Simulated rain performance:
   The rain simulation equipment shall have the following performance capabilities with the calibration plate mounted in the test opening:
   a. The equipment shall produce a simulated rain penetration through the calibration plate at the specified rate (+10%, -0%) per square meter (10.76 ft^2) of opening.
   b. The simulated rainfall rate measured using a rain gauge in the positions specified in Figure 12 shall not deviate from the mean rainfall rate by more than ±15%.

5.5.3 Collection duct

1. The collection duct (see Test Figure 5.11) shall be sealed against the back of the weather section.
2. The collection duct shall have a water droplet elimination section at the downstream end to prevent carryover of airborne water droplets from the collection duct. The water eliminator shall be a louver that is 100% effective at 22.4 m/s (50 mph) with 203 mm/hr (8 in./hr) rain intensity and a 5 m/s (984 fpm) ventilation rate as tested per the wind-driven-rain test found in AMCA 500-L.
3. The collection duct shall have an airtight connection to the airflow measurement plenum.

5.5.4 Test specimen calibration plate

For the purpose of calibration tests, a calibration plate that will fit over the test plane and have an opening of the same dimensions as the core area of the louver to be tested shall be fabricated. This plate is used in the determination of the wind-driven rain through an opening the same size as the louver's core area.

5.5.5 Wind simulation equipment

1. An external fan shall direct air perpendicular to the louver test plane, as illustrated in Test Figure 5.11.
2. The air outlet of the fan and any silencing or straightening section shall not be less than 1 m (3.25 ft) diameter.
3. The fan shall be capable of producing the prescribed air velocity at 1 m (3.25 ft) in front of the test plane of the louver.
4. A fan air straightener section shall be assembled to the outlet of the fan to avoid swirling air currents.

5.6. Wind-driven-sand simulation equipment

Wind-driven-sand simulation equipment shall consist of a number of separate sections as illustrated in Figure 5.12. It shall be capable of producing an airflow rate through the sand louver's free area under test over the range of 1 m/s (197 fpm) to 7 m/s (1378 fpm), simulating blown sand and measuring pressure losses.

5.6.1 Wind-driven-sand chamber

The wind-driven-sand chamber shall consist of a duct with an inner dimension of 1230 mm × 1230 mm (48.43 in. × 48.43 in.), to house a 1220 mm × 1220 mm (48.03 in. × 48.03 in.) sand louver and a sand collection trough. The sand collection trough shall be the width of the sand injector section duct, be installed just upstream of the louver, and extend to the back face of the louver to collect sand rejected from the sand louver under test (see Test Figure 5.12).

The typical arrangement of an air performance - pressure drop measurement test is illustrated in Test Figure 6.3.

The trough size is as shown in Figure 5.12.

5.6.2 Wind-driven-sand injector equipment

Equipment for the sand injector shall consist of a fan, main funnel, feeder cone, injector tube, distribution tube and spreader plate. Construction of the equipment shall be as shown in Figures 13 and 14.

Position the equipment so that its outlet is 1.5 m (59.06 in.) from the sand louver under test and at the center top of the approach duct.

Air velocity of 20 m/s – 25 m/s (3937 fpm – 4921 fpm) in the distribution tube shall be obtained from the injector fan.

The main funnel shall be positioned directly above the feeder cone and be capable of holding at least 2 kg (4.41 lbm) of sand.

The sand feeder cone must penetrate the distribution tube by approximately 1 mm (0.04 in.) and shall be positioned vertically. The cone shall have an included angle of 45°.

A 3 g/s – 40 g/s (0.106 oz/s – 1.41 oz./s) rate of feed shall be the minimum range for the sand feeder.

Per Table 6, the sand feeder cones shall be calibrated for the required rate of feed.

6. Objectives, Observations and Conduct of Test

6.1 Air performance – pressure drop test

The objective of this test is to determine the relationship between the airflow rate and the pressure drop of a louver.

6.1.1 General requirements

6.1.1.1 Test
A test shall consist of five or more determinations taken at approximately equal increments of airflow rate covering the range desired.

6.1.1.2 Equilibrium
Equilibrium conditions shall be established before each determination. To test for equilibrium, trial observations shall be made until steady readings are obtained.

6.1.1.3 Test area ambient air measurements
Once during each test, the dry-bulb temperature of the air flowing in the general test area, the wet-bulb temperature, the barometric pressure and the ambient temperature at the barometer shall be recorded.

6.1.1.4 Airflow measurement
Airflow at the plane of measurement, when determined using a pitot-static tube measurement of velocity pressure, shall not be less than 6.35 m/s (1250 fpm). When nozzles are used, the minimum ΔPn shall be 25 Pa (0.1 in. wg) at the minimum airflow rate of the test.

6.1.1.5 Appurtenances
If a drain pan was or will be used during the water penetration test or wind-driven-rain test and any part of the drain pan extends higher than any part of the sill or sill member, then it shall be installed on the louver for the air performance - pressure drop test.

6.1.2 Data to be recorded

6.1.2.1 Test unit
The description of the test unit, including the model, the louver type (i.e., fixed blade louver, adjustable blade louver, combination blade louver, etc.), size and free area, shall be recorded.

6.1.2.2 Test setup
The description of the test setup, including specific dimensions, shall be recorded. Reference shall be made to the test figures in this standard. Alternatively, a drawing or annotated photograph of the setup shall be attached to the data.

6.1.2.3 Instruments
The instruments and apparatus used in the test shall be listed. Names, model numbers, serial numbers, scale ranges and calibration information shall be recorded.

6.1.2.4 Airflow measurement test data
Test data for each determination shall be recorded. Readings shall be made simultaneously whenever possible. For all types of tests, readings of ambient dry-bulb temperature (t_{d0}), ambient wet-bulb temperature (t_{w0}) and ambient barometric pressure (p_b) shall be recorded.

a. Pitot traverse test (Test Figure 6.1)
For a pitot traverse test, one reading of each velocity pressure (P_{v3r}) and static pressure (P_{s3r}) shall be recorded for each pitot station. In addition, readings for traverse-plane dry-bulb temperature (t_{d3}) shall be recorded.

b. Duct nozzle test (Test Figure 6.2)
For a duct nozzle test, one reading each of pressure drop (ΔP_n), approach dry-bulb temperature (t_{d5}) and approach static pressure (P_{s5}) shall be recorded.

c. Chamber nozzle test (Test Figures 6.3 and 6.5)
For a chamber nozzle test, the nozzle combinations and one reading each of pressure drop (ΔP_n), approach dry-bulb temperature (t_{d5}) and approach static pressure (P_{s5}) shall be recorded.

d. Outlet chamber test (Test Figure 6.4)
For an outlet chamber test, one reading each of outlet chamber dry-bulb temperature (t_{d5}), pressure drop (ΔP_n) and outlet chamber static pressure (P_{s5}) shall be recorded.

6.1.2.5 Test louver setup
Each louver should be tested in a setup that simulates its intended field installation (see Section 5.1.1). Table 3 displays allowable combinations of louver test setups for air performance - pressure drop determinations.

a. Louver with outlet duct (Test Figure 5.1)
One reading per determination of outlet duct static pressure (P_{s4}) shall be recorded.

b. Louver with inlet duct (Test Figure 5.2)
One reading per determination of inlet duct static pressure (P_{s9}) shall be recorded.

c. Louver with discharge chamber (Test Figure 5.4)
One reading per determination of discharge chamber static pressure (P_{s7}) shall be recorded.

d. Louver with inlet chamber (Test Figure 5.5)
One reading per determination of inlet chamber static pressure (P_{s8}) shall be recorded.

6.1.2.6 Discharge loss coefficient and class
For each test point, the discharge loss coefficient (C_D) and its correlating class number shall be recorded (see Annex G).

Table 3 — Allowable Combinations for Air Performance - Pressure Drop Testing

Louver Test Setups		Airflow Measurement Setups	
Test Figure	**Connection plane**	**Test Figure**	**Connection plane**
5.1	PL-Z	6.1	PL-B
		6.2	PL-B
		6.3	PL-A
		6.4	PL-A
5.2	PL-Y	6.1	PL-C
		6.2	PL-C
	PL-X	6.5	PL-B
5.4	PL-Y	6.1	PL-B
		6.2	PL-B
	PL-X	6.3	PL-B
		6.4	PL-B
5.5	PL-X	6.1	PL-C
		6.2	PL-C
	PL-Y	6.5	PL-A
5.12	PL-Z	6.3	PL-A

6.1.3 Conduct of test

6.1.3.1 General requirements

Tests shall be conducted at ambient temperatures between 10 °C and 40 °C (50 °F and 104 °F). A test determination is a complete set of measurements for one setting of airflow and pressure drop. The louver shall be tested with airflow in both directions (except products specifically labeled for airflow in only one direction).

For combination louver backdraft dampers, a test shall begin with the lowest airflow value, allowing the damper to seek its own equilibrium position with respect to pressure differential. If desired, the blade angle may be measured (degrees from closed) at each test point. To determine the differences in mechanical forces within the damper while opening versus closing, the test may be repeated, beginning with the minimum airflow value.

6.1.4 Presentation of results

The report and presentation of results shall include all the data as outlined in Section 6.1.2. Test results shall be converted to standard air density conditions. In addition, the following shall be recorded, as appropriate:

- Blade orientation
- Blade action
- Blade position (open or closed)
- Airflow direction
- Personnel
- Date
- Test ID#

- Lab name
- Lab location
- Reference to ANSI/AMCA Standard 500-L
- Test figure
- Any appurtenance, such as drain pans
- A front and rear photo of the louver
- Discharge loss coefficient and its correlating class number for each test point.

6.2 Airflow leakage rate

The purpose of this test is to determine the relationship between airflow leakage rate and static pressure for a louver mounted on a chamber at a given closing torque.

6.2.1 General requirements

6.2.1.1 Test

A test shall consist of five or more determinations taken at approximately equal increments of pressure differential covering the range desired.

6.2.1.2 Equilibrium

Equilibrium conditions shall be established before each determination. To test for equilibrium, trial observations shall be made until steady readings are obtained.

6.2.1.3 Test area ambient air measurements

Once during each test, the dry-bulb temperature of the air flowing in the general test area, wet-bulb temperature, the barometric pressure and the ambient temperature at the barometer shall be recorded.

6.2.1.4 Airflow measurement

Airflow at the plane of measurement when using a pitot-static tube shall not be less than 6.35 m/s (1250 fpm). When nozzles are used, the minimum ΔP_n shall be 25 Pa (0.1 in. wg) at the minimum airflow rate of test. A direct-reading meter may be used if the airflow is below 17 m^3/hr (10 cfm).

6.2.1.5 Seating torque measurement

Seating torque is the torque specified to properly seal the test louver.

a. Torque measurement

Calibrated weights and a distance measuring device having divisions of 1.0 mm (0.04 in.) or smaller shall be used. The torque arm is considered to be the minimum of distance from the vertical centerline of the weights to the centerline of the point of blade rotation. Direct torque measuring instrumentation with a tolerance of 0.5 N-m (4.5 lbf-in.) may be used as an alternative. Applied torque does not have to be measured if an actuator is installed.

b. Application of torque

The torque shall be applied with zero ΔP across the louver with its blades in the fully open position. The corresponding weight shall be lowered gradually, without impact loading, until the louver reaches its closed position with the normal pressure or voltage of the actuator. There should be no additional applied force.

6.2.2 Data to be recorded

6.2.2.1 Test unit

The description of the test unit, including the model, the louver type (i.e., adjustable blade louver, combination blade louver, etc.), size and face area, shall be recorded.

6.2.2.2 Test setup

The description of the test setup, including specific dimensions, shall be recorded. Reference shall be made to the test figures in this standard. Alternatively, a drawing or annotated photograph of the setup shall be attached to the data. This shall include:

a. Note of whether any head, sill, jamb, closure plate(s) and/or blade seals were used and the shape and material of the seal(s).
b. Note of whether any holes/gaps/voids (such as jamb gutter openings at the head area) were sealed.
c. Note of whether any fasteners were sealed to prevent leakage through the screw hole.

6.2.2.3 Instruments

The instruments and apparatus used in the test shall be listed. Names, model numbers, serial numbers, scale ranges and calibration information shall be recorded.

6.2.2.4 Airflow measurement

Test data for each determination shall be recorded. Readings shall be made simultaneously whenever possible. Three readings of ambient dry-bulb temperature (t_{d0}), ambient wet-bulb temperature (t_{w0}) and ambient barometric pressure (p_b) shall be recorded unless the readings are steady, in which case only one need be recorded.

a. Pitot traverse test (Test Figure 6.1)

For a pitot traverse test, one reading each of velocity pressure (P_{v3r}) and static pressure (P_{s3r}) shall be recorded for each pitot station. In addition, three readings of traverse-plane dry-bulb temperature (t_{d3}) shall be recorded unless the readings are steady, in which case only one need be recorded.

b. Duct nozzle test (Test Figure 6.2)

For a duct nozzle test, one reading each of pressure drop (ΔP_n), approach dry-bulb temperature (t_{d5}) and approach static pressure (P_{s5}) shall be recorded.

c. Chamber nozzle test (Test Figures 6.3 and 6.5)

For a chamber nozzle test, the nozzle combinations and one reading each of pressure drop (ΔP_n), approach dry-bulb temperature (t_{d5}) and approach static pressure (P_{s5}) shall be recorded. When using a chamber for leakage testing, criteria for velocity profile downstream of the nozzles and criteria for area ratio may be ignored.

d. Outlet chamber test (Test Figure 6.4)

For an outlet chamber test, one reading each of outlet chamber dry-bulb temperature (t_{d5}), pressure drop (ΔP_n) and outlet chamber static pressure (P_{s5}) shall be recorded.

e. Flow meter test (Test Figures 6.6 A and 6.6 B)

For a flow meter test, both airflow as indicated on the meter and inlet static pressure (P_{s9}) shall be recorded. A calibrated flowmeter capable of indicating flow in increments of 0.2 L/s (0.33 cfm) or less shall be used. Flow measurements per this test shall be limited to a maximum of 5 L/s (10 cfm).

6.2.2.5 Test louver setup
Table 4 displays allowable combinations of airflow leakage and louver test setups.

a. Louver with discharge chamber (Test Figure 5.4)
One reading of discharge chamber static pressure (P_{s7}) shall be recorded per determination.

b. Louver with inlet chamber (Test Figure 5.5)
One reading of inlet chamber static pressure (P_{s8}) shall be recorded per determination.

Table 4 — Allowable Combinations for Air Leakage Testing

Louver Test Setups		Airflow Measurement Setups	
Test figure	**Connection plane**	**Test figure**	**Connection plane**
5.4	PL-Y	6.1	PL-B
		6.2	PL-B
	PL-X	6.3	PL-B
		6.4	PL-B
5.5	PL-X	6.1	PL-C
		6.2	PL-C
	PL-Y	6.5	PL-A
		6.6 Flow Meter Test	

6.2.3 Conduct of test

6.2.3.1 General requirements
Tests shall be conducted at ambient temperature between 10 °C and 40 °C (50 °F and 104 °F). A test determination is a complete set of measurements for one setting of airflow leakage rate and pressure drop.

A combination louver-backdraft damper shall be mounted in its normal operating position and in such a manner that airflow leakage will force the damper blades to the closed position.

6.2.3.2 Test using airflow meter
Mount the louver as shown in Test Figure 6.6 A or 6.6 B. Perform the test as described in Section 6.2.2.4E.

6.2.3.3 Louver mounted on chamber (Test Figure 5.4 or 5.5)
This test consists of two parts, a device and system test and a system-only test. Both tests shall be conducted at approximately the same pressure increments. The louver shall be mounted on the chamber as shown in either Test Figure 5.4 or 5.5, as appropriate.

a. Chamber criteria
The following chamber criteria shall be met for a Test Figure 5.5 leakage test to be valid:

1. Close all nozzles and install the leakage chamber (Test Figure 6.6 C) on the downstream side of chamber with the 13 mm (0.5 in.) nozzle open. Increase the pressure upstream of the nozzles, in a minimum of five approximately equal increments to a minimum of 995 Pa (4 in. wg) static pressure or the maximum fan pressure. If the calculated airflow is greater than 4.47 × 10^{-5} × $(P\text{s})^{0.5}$ m^3/s (1.5 × $(P\text{s})^{0.5}$ cfm), then the nozzle wall has excessive leakage and must

be resealed and retested until the leakage value is less than 4.47 × 10^{-5} × $(Ps)^{0.5}$ m^3/s (1.5 × $(Ps)^{0.5}$ cfm).

2. Blank off the exiting end of the leakage chamber (the location of the leakage chamber (Test Figure 6.6 C) in step 1 above). Open the 13 mm (0.5 in.) or 19 mm (0.75 in.) nozzle. Increase the pressure upstream of the nozzles in a minimum of five approximately equal increments to a minimum of 995 Pa (4 in. wg) static pressure or the maximum fan pressure. If the calculated leakage is greater than 4.47 × 10^{-5} × $(P_s)^{0.5}$ m^3/s (1.5 × $(P_s)^{0.5}$ cfm), then the chamber downstream of the nozzles has excessive leakage and must be resealed and retested until the leakage value is less than 4.47 × 10^{-5} × $(Ps)^{0.5}$ m^3/s (1.5 × $(P_s)^{0.5}$ cfm).

3. Repeat step 1 to ensure nozzle wall leakage values were not affected by downstream leakage values. If airflow across the downstream tail end piece (Test Figure 6.6 C) is greater than 4.47 × 10^{-5} × $(P_s)^{0.5}$ m^3/s (1.5 × $(P_s)^{0.5}$ cfm), then repeat steps 1 and 2 above.

This procedure shall have been checked and documented no longer than six months before any AMCA-certified Test Figure 5.5 leakage test.

Note:
Upstream is referenced as being on the inlet (fan side) of the nozzles. System leakage is defined as the volume of air leaking into or out of the chamber with the louver blanked off or the opening covered. Louver leakage is defined as the volume of air leaking across the plane of the louver with the blades closed and torque applied per Section 6.2.1.5.

b. Maximum system leakage
The maximum system leakage that can be deducted is 4.47 × 10^{-5} × (P_s) 0.5 m^3/s (1.5 × (P_s) 0.5 cfm) or 2% of louver leakage (whichever is higher), if system leakage is measured higher than the maximum allowed.

If system leakage as measured is less than the maximum allowed, then actual system leakage becomes allowable system leakage.

c. System leakage pressure drop
The pressure drop across the nozzles for the system leakage test must be the same as or higher than the pressure drop across the nozzles for the corresponding louver leakage test when the system leakage test is equal to or more than 9.44 × 10^{-4} m^3/s (2 cfm) total. When system leakage is less than 9.44 × 10^{-4} m^3/s (2 cfm), the pressure drop restriction does not apply.

d. Other chamber configurations
For chambers other than Test Figure 5.5, an equivalent method of determining nozzle wall and chamber leakage shall be used.

e. Device and system test
Test determinations shall be carried out with the louver mounted on the chamber and airflow unobstructed.

System Test: The louver shall remain mounted on the chamber but shall be covered with a suitable solid board or other appropriate material to prevent air from flowing. Test determinations shall then be carried out with the airflow obstructed. For each determination, the device leakage shall be the leakage with the device in place (device and system) minus the system leakage at the identical pressure. Refer to Section 7.5 if device and system pressures are not identical.

6.2.3.4 Sealing of louver to test fixture

The louver shall be sealed to the test fixture in a manner that is typical of a louver being sealed to a building. Therefore, only the exterior perimeter face and/or the exterior-most part of the louver frame shall be sealed to the test fixture. Examples of sealing and fixtures are shown in Figure 5.13.

6.2.4 Presentation of results

The report and presentation of results at actual and standard air density shall include all the data as outlined in Section 6.2.2. In addition, the following shall be recorded:

- Method of closure
- Blade orientation
- Blade action
- Airflow direction
- Personnel
- Date
- Test ID#
- Lab name
- Lab location
- Reference to ANSI/AMCA Standard 500-L
- Test figure
- A front and rear photo of the louver

6.3 Water penetration test

The objective of this test is to define the point of beginning water penetration by finding the intake air velocity at which water begins to penetrate a louver. It is not intended to provide information on the amount of water that will penetrate the louver under service conditions (e.g., wind-driven rain). The purpose of the test is to provide a basis for comparing different louver designs, not to provide design data.

6.3.1 General requirements

6.3.1.1 Determinations

A test shall consist of four or more determinations taken at approximately equal increments of airflow rate covering the range desired. Each test determination shall be of equal duration for the prescribed length of time (minimum 15 minutes) at a selected constant airflow rate through the test louver.

6.3.1.2 Equilibrium

Equilibrium conditions shall be established before each determination. To test for equilibrium, trial observations shall be made until steady readings are obtained.

6.3.1.3 Water flow meter

A calibrated water flow meter shall be used during testing to determine the rate of water flow for the wetted wall manifold. Water flow through each water drop manifold dripper shall be regulated by adjustment of a valve and/or by controlled pumping of a known water volume.

6.3.1.4 Water flow rate

The water flow rate of the water drop manifold shall not be more than ±5% of the prescribed flow rate. The water flow rate of the wetted wall manifold shall not be more than ±5% of the prescribed flow rate.

6.3.1.5 Water collecting surface

The length of the water collecting surface inside the test plenum shall be a minimum of 150% of the vertical distance from the top of the louver to the water collecting surface below the louver. The width of the water collecting surface shall extend at least 305 mm (12 in.) beyond each side of the test louver.

6.3.1.6 Water drop manifold

The water drop manifold shall maintain a water flow rate of 0.59 L/hr (36 in.^{3}/hr) per dripper location, which equates to a rainfall rate of 102 mm/hr (4 in./hr). See Test Figure 5.6 for layout and design information of the water drop manifold. Each dripper shall be considered to cover an area of 5806 mm^2 (9 in.^{2}).

Drippers shall be controlled to maintain the required rainfall rate in individual droplets, as opposed to a continuous stream of water. Devices such as nails, pointed wires, metal barbed tube fittings or other means to develop raindrop formations are acceptable.

a. Water drop manifold calibration

Calibration shall be in such a way that each row of drippers is calibrated as a single group. Rows run parallel to the wetted wall manifold. Each row shall pass the tolerance requirement for the entire manifold assembly to qualify as passing calibration. Water collection for calibration shall last for a minimum of 5 minutes. For each row to be within tolerance, the total amount of collected water shall not be outside the range as determined by applying the flow tolerance of Section 6.3.1.4 to the below target masses:

- SI target mass (kg) = (Total # of drippers in the row being calibrated) * (102 mm / hr) * (1 hr / 60 min) * (Duration of calibration time period, min) * (5806 mm^2 / dripper) * (998.278 kg /m^3) * (1m^3 / 1,000,000,000 mm^3)

- I-P target mass (lbm) = (Total # of drippers in the row being calibrated) * (4 in. / hr) * (1 hr / 60 min) * (Duration of calibration time period, min) * (9 in.^{2} / dripper) * (62.3205 lbm/ft^3) * (1 ft^3 / 1728 in.^{3})

If a row is out of tolerance, visually scan the row for any drippers that appear to be dripping too fast/slow as compared to the rest of the drippers in that same row. Adjust the too fast/slow dripper(s) to drip at about the same rate as the rest of the drippers in the row. Repeat the timed calibration procedure of this section until the row is within tolerance.

All drippers shall have a drip rate that is not more than ±15% from the average drip rate of the remaining drippers in that same row.

6.3.1.7 Wetted wall manifold

The wetted wall manifold shall maintain a water flow rate of 3.10 L/m/min (0.25 gal/ft/min) through the spaced holes of the manifold. See Test Figure 5.6 for layout and design information for the wetted wall manifold.

Manifold sizing shall not interfere with the first row of raindrops from the water drop manifold. Water discharge holes in the manifold shall have a spacing of 51 mm ± 3 mm (2 in. ± 0.125 in.). A minimum of 31 discharge holes shall span across the wall opening. There shall be one discharge hole at the center of the wall opening with an equal number of holes on each side of the center hole. The manifold shall be mounted flush against the wetted wall surface with the water discharge holes directed approximately 15° downward toward and onto the wetted wall. A device can be used to ensure the water flow is directed toward and adheres to the wetted wall's surface while minimally disrupting the downward flow of the water on the wetted wall.

a. Wetted wall manifold calibration

Calibration shall be done by weighing the amount of water that is supplying the wetted wall manifold over a period of time and comparing it to the tolerance of the required flow rate. Water collection for calibration shall last a minimum of one minute. The total amount of collected water shall not be outside the range as determined by applying the flow tolerance of Section 6.3.1.4 to the below target masses:

- SI target mass (kg) = (3.10 L/m/min) * (Number of water discharge holes) * (50.8 mm) * (1 m / 1000 mm) * (Duration of calibration time period, min) * (1 m^3 / 1000 L) * (998.278 kg / m^3)

- I-P target mass (lbm) = (0.25 gal/ft/min) * (Number of water discharge holes) * (2 in.) * (1 ft / 12 in.) * (Duration of calibration time period, min) * (231 $in.^3$ / 1 gal) *(1 ft^3 / 1728 $in.^3$) * (62.3205 lbm / 1 ft^3)

If not within tolerance, adjust the water flow and repeat the above steps. Once within tolerance, the manifold's flow rate shall be recorded, and the flow rate shall be used during formal testing.

6.3.1.8 Water
The use of filtered, distilled, and/or softened water shall be allowed as an option to prevent mineral buildup.

6.3.2 Data to be recorded

6.3.2.1 Test unit
The description of the test unit, including the model, the louver type (i.e., fixed blade louver, adjustable blade louver or combination blade louver, etc.), size and free area, shall be recorded.

6.3.2.2 Test setup
The description of the test setup, including specific dimensions, shall be recorded. Reference shall be made to the test figures in this standard. Alternatively, a drawing or annotated photograph of the setup shall be attached to the data.

6.3.2.3 Instruments
The instruments and apparatus used in the test shall be listed. Names, model numbers, serial numbers, scale ranges and calibration information should be recorded.

6.3.2.4 Airflow measurement test data
Test data for each determination shall be recorded. Readings shall be made simultaneously whenever possible. For all types of tests, readings of ambient dry-bulb temperature (t_{d0}), ambient wet-bulb temperature (t_{w0}) and ambient barometric pressure (p_b) shall be recorded.

a. Airflow measurement using pitot traverse (Test Figure 6.1)
For pitot traverse tests, one reading each of velocity pressure (P_{v3r}) and static pressure (P_{s3r}) shall be recorded for each pitot station. In addition, three readings of traverse-plane dry-bulb temperature (t_{d3}) shall be recorded unless the readings are steady, in which case only one need be recorded.

b. Airflow measurement using duct nozzle (Test Figure 6.2)
For duct nozzle tests, one reading each of pressure drop (ΔP_n), approach dry-bulb temperature (t_{d5}) and approach static pressure (P_{s5}) shall be recorded.

c. Airflow measurement using chamber nozzle (Test Figures 6.3 and 6.5)
For chamber nozzle tests, the nozzle combinations and one reading each of pressure drop (ΔP_n), approach dry-bulb temperature (t_{d5}) and approach static pressure (P_{s5}) shall be recorded.

d. Airflow measurement using outlet chamber (Test Figure 6.4)
For outlet chamber tests, one reading each of outlet chamber dry-bulb temperature (t_{d5}) and pressure drop (ΔP_n) shall be recorded.

6.3.2.5 Test setup
Each louver shall be tested in accordance with one of the test figure combinations shown in Table 5.

a. Water carryover measurement
For each determination, water carryover shall be collected from all wetted surfaces inside the plenum (excluding the water trough) by any suitable method and placed on a scale with a resolution (increment/readability) of at least 0.01 gram (0.001 oz). Each determination's reading shall be recorded to the nearest 0.01 gram (0.001 oz).

Table 5 — Allowable Combinations for Water Penetration Testing

Test Louver Setups		Airflow Measurement Setups	
Test Figure	**Connection plane**	**Test Figure**	**Connection plane**
5.6	PL-X	6.1	PL-B
		6.2	PL-B
		6.3	PL-A
		6.4	PL-A

6.3.2.6 Test Duration
The time duration of the test points shall be recorded.

6.3.2.7 Test Results
The free area volumetric flow rate and free area velocity of the test points shall be converted to standard air density.

6.3.3 Conduct of test
The louver to be tested shall be 1220 mm × 1220 mm (48 in. × 48 in.). The tolerance is +0, -6.3 mm (+0, -0.25 in.). There shall be no appurtenances (screens) attached. There shall be no finish applied to the louver, although the surfaces may be cleaned. No portion of the louver (e.g., blades) shall extend beyond the louver exterior face, excluding a drip edge on a sill or an integrated sill pan. Test Figure 5.6 shall be used for the setup of the test chamber and other related devices.

The louver shall be mounted to the chamber in such a way that the louver exterior face is flush with the wetted wall. If a drain pan is used under the louver, it shall not extend more than 25.4 mm (1 in.) beyond the rear of the louver. The drain pan can extend, without limits, in front of the louver. All four sides of the louver shall be sealed to the wetted wall with smooth, wrinkle-free tape (such as duct tape). An additional top layer of water-sheeting tape shall be used at the head and jamb seams. The top water-sheeting tape shall be the last surface that the water passes over as it transfers from the wetted wall to the louver frame. The top water-sheeting tape shall be at least 50 mm (2 in.) in width and shall run full length from head to sill and jamb to jamb (at the head). A louver's sill shall not be taped to a sill pan, but the sill pan can be taped to the wetted wall. The louver shall be taped to the wetted wall to minimize accidental perimeter leakage between the louver frame and wetted wall or sill pan and wetted wall. Accidental perimeter leakage into the test chamber shall not be used for determining the louver's water performance rating. A water trough, as shown in Test Figure 5.6, can be used to catch and isolate accidental perimeter leakage. If an operating louver is being tested, adjust the blades so that they are fully open.

The water drop manifold shall be set to maintain the designated water flow rate as found in Section 6.3.1.6. The wetted wall manifold shall be set to maintain the designated water flow rate as found in Section 6.3.1.7.

Spot-check calibration of individual drippers (such as quick checks before every full test or between test points) shall be done on an as-needed basis as determined by the lab. The spot-check calibration shall use the target drip rate as determined by the last performed periodic calibration test. If a dripper appears to be out of tolerance (more than ±15% from the target drip rate), it shall be adjusted to be within tolerance.

Tests shall be conducted at target free area velocities that acquire at least two test points that are below and at least two test points that are equal to or above the water carryover point (3.05 g/m^2 (0.01 oz/ft^2) of free area). Water carryover for each chosen target velocity shall be recorded to the nearest 0.01 g/m^2 (0.001 oz/ft^2) of free area.

The free area velocities of test points shall be picked at even increments of 0.254 m/s (50 fpm). The test points shall not be below 0.254 m/s (50 fpm) or extend above 6.35 m/s (1250 fpm). Conversion to standard air is not required at this point of the test.

Exceptions:

1. If a test point is run at a target free area velocity of 6.35 m/s (1250 fpm) and the water carryover of the test point is less than the water carryover point, then the testing shall be stopped and the louver shall have a beginning point of water penetration free area velocity rating of “above 6.35 m/s (1250 fpm).”
2. If testing can only achieve one test point that is equal to or above the water carryover point, then the beginning point of water penetration shall be based on two test points that are below and one test point that is equal to or above the water carryover point. The rating shall be limited to a maximum value of 6.35 m/s (1250 fpm).
3. If testing at the two lowest free area target velocities [0.254 and 0.508 m/s (50 and 100 fpm)] cannot produce the two required test points that are below the water carryover point, then testing shall be stopped, and the louver shall not be given a beginning point of water penetration rating.

When data is organized based on lowest to highest tested free area velocity, the maximum difference between the target free area velocity and the beginning point of water penetration shall not be more than 1.524 m/s (300 fpm).

6.3.4 Presentation of results

The report and presentation of results at actual and standard air density shall include all the data as outlined in Section 6.3.2. In addition, the following shall be recorded:

- Personnel
- Date
- Test ID#
- Lab name
- Lab location
- Reference to ANSI/AMCA Standard 500-L
- Test figure
- Any appurtenances, such as drain pans
- Linear regression method
- The free area velocity where the beginning point of water penetration occurs in m/s (fpm)
- A front and rear photo of the louver

6.4 Wind-driven-rain test

The objective of this test is to measure the water rejection effectiveness of louvers subject to simulated rain and wind velocity at various intake airflow rates.

6.4.1 General requirements

1. The louver to be tested shall be mounted and sealed to the 3 m × 3 m (9.7 ft × 9.7 ft) wall at the rear of the weather section, as recommended by the manufacturer, to prevent any ingress of water other than through the louver blades.

2. The louver to be tested shall have a 1000 mm × 1000 mm (39.37 in. × 39.37 in.) core area with a tolerance of ±3 mm (±0.125 in.) with an extended frame with outside dimensions of 1213 mm × 1213 mm (47.75 in. × 47.75 in.) with a tolerance of +5, -0 mm (+0.19, -0 in.).

   The louver to be tested shall be inspected and have its free area measured.

   There shall be no appurtenances attached. There shall be no finish applied to the louver, although the surfaces can be cleaned. No portion of the louver shall extend beyond the louver exterior face, excluding a drip edge on a sill or an integrated sill pan.

   Mount the louver in the chamber with the louver exterior face flush with the face of the rear bulkhead of the weather section. If a drain pan is used under the louver, it shall not extend more than 25.4 mm (1 in.) beyond the rear of the louver. The drain pan can extend, without limits, in front of the louver. Tape the joint between the test setup and the louver using smooth, wrinkle-free tape. If an operating louver is being tested, adjust the blades so that they are fully open.

3. All tests shall be carried out at a simulated wind speed measured by means of a velocity meter (i.e., vane anemometer or pitot tube) on the center line of the fan and 1000 ± 50 mm (39.37 ± 2 in.) in front of the face of the louver. The velocity meter shall be removed before the rain simulation nozzles are turned on.

   The water flow rates shall be measured with a flow meter and set to the desired rates for each test. Water shall be collected from behind the louver and at the drain from the collection duct so that the amount of water penetration for the test period can be measured.

   A totalizer shall be installed to measure the total amount of water used during the test. The difference between the totalizer value and the water collected is used to calculate the percentage of penetration.

4. The rate of water and airflow shall be held to the tolerances given below:

Water supply rate	±2%
Water collection rate	±10%
Ventilation airflow rate	±5%
Wind velocity	±10%

5. Determinations:
   Test values shall be noted at regular intervals not more than 10 minutes apart, and the test period shall be complete when a minimum of four consecutive readings of values within the steady state tolerance have been noted. The minimum test period is 30 minutes.

6.4.2 Conduct of test
For additional information on recommended test conditions, see Annex F.

6.4.2.1 Calibration plate test
a. Mount the calibration plate in the test position (see Test Figure 5.11).
b. Mount the spray nozzles as illustrated in Test Figure 5.11.
c. Adjust the ventilation airflow rate (q_{vo}) to zero and set the wind speed to the specified value.
d. Set up the rain pattern as described in Section 5.5.2.

e. Adjust the water supply rate (q_{so}) so that the penetration rate (q_{do}) lies between +10%, -0% of the specified water penetration rate (q_w) through the calibration plate.
f. For the test period, the following values shall be measured and recorded:

- Water supply rate, q_{so}
- Water rejection rate, q_{uo}
- Water penetration rate, q_{do}
- Airflow rate through the plate, q_{vo} (except for a no-airflow test)
- Wind velocity, v_w (at the start and end of the test period)

g. Adjust the airflow (q_{vo}) through the plate to the next value in the test schedule and repeat steps 5 and 6.
h. When a test has been made at each of the values of q_{vo}, the test results shall be summarized and the penetration rate corrected by calculation, if the water supply rate has varied from the nominal value of $q_{s\ nom}$.

The nominal water supply rate ($q_{s\ nom}$) is the supply rate to the nozzles that will produce a penetration of the specified water penetration rate (q_w) through the calibration plate at the test airflow rate:

$$q_{s\ nom} = (q_w) \times \left(\frac{q_{so}}{q_{do}}\right) \times (A_c) \qquad \text{Eq. 6.1}$$

Where A_c is the open area of the calibration plate.

6.4.2.2 Louver test
Test the louver as follows:
a. Install the louver in the test opening (see Test Figure 5.11).
b. Install the spray nozzles as illustrated in Test Figure 5.11.
c. Adjust the airflow rate (q_v) to zero and the wind speed to the specified value.
d. The rain pattern shall be as established during the testing of the calibration plate.
e. Adjust the water supply rate as close as possible to $q_{s\ nom}$ as established during the testing of the calibration plate.
f. During the test period, the following values shall be measured and recorded:

- Water supply rate, q_s
- Water penetration rate, q_d
- Airflow rate through the louver, q_v (except for a no-airflow test)

g. Adjust the airflow rate (q_v) through the louver to the next value in the test schedule and repeat steps 5 and 6.

Note: Airflow rates should be ±5%, as established during the calibration plate test.

h. When a test has been made at each of the values of q_v, the test results shall be summarized and the penetration rate corrected by calculation, if the water supply rate has varied from the nominal value of $q_{s\ nom}$.

The corrected water penetration rate ($q_{d\ corr}$) is the water penetration rate that would be achieved if the water supply rate were equal to the nominal water supply rate ($q_{s\ nom}$) at the test ventilation airflow rate:

$$q_{d\ corr} = q_{s\ nom}\left(\frac{q_d}{q_s}\right) \qquad \text{Eq. 6.2}$$

6.4.3 Presentation of results

The report and presentation of results at actual and standard air density shall include all the data as outlined in Section 6.4.2. In addition, the following shall be recorded:

- Personnel
- Date
- Test ID#
- Lab name
- Lab location
- Reference to ANSI/AMCA Standard 500-L
- Test figure
- Any appurtenances, such as drain pans
- Free area sketch
- A front and rear photo of the louver

6.4.3.1 Additional data

a. Prepare a graph of the test results of the rain penetration through the calibration plate by plotting the following:

   - $q_{s\ nom}$ vs. v_c
   - q_{do} vs. v_c

b. Prepare a graph of the test results of the rain penetration through the louver by plotting the following:

   - $q_{s\ nom}$ vs. v_c
   - $q_{d\ corr}$ vs. v_c

c. Prepare a table of the effectiveness (E_w) and penetration classification (see Annex C and Table 7) of the louver at each tested louver core velocity (corrected to standard air) calculated from q_v/A_c.

$$E_w = \left(1 - \frac{q_{d\ corr}}{q_w A_c}\right) 100 \qquad \text{Eq. 6.3}$$

Which can also be expressed as:

$$E_W = \left(1 - \frac{q_{so} q_d}{q_{do} q_s}\right) 100 \qquad \text{Eq. 6.4}$$

Where:

E_W is wind driven rain louver effectiveness, %
A_c is louver core area, m² (ft²)
q_w is specified water/rainfall penetration rate, L/h (gpm)
q_s is water supply rate, L/h (gpm)
q_{so} is water supply rate of calibration plate, L/h (gpm)
q_d is water penetration rate, L/h (gpm)
q_{do} is water penetration rate of calibration plate test L/h (gpm)

Notes:
1. Louver effectiveness is defined in Section 3.1.49.
2. A_C is the open area of the calibration plate.
3. E_W is rounded to one decimal place.

6.5 Wind-driven-sand test

The objective of this test is to specify a method for measuring the sand rejection performance of sand louvers subject to air with airborne dry sand particles at different airflow rates through the louver under test. The test incorporated in this section establishes sand louver effectiveness when subjected to different masses of sand at various free area velocity rates. The information in this section is adapted from BS EN 13181:2001 and BS EN ISO 14688-1:2018.

6.5.1 General requirements

1. The louver to be tested shall be mounted and sealed, using smooth, wrinkle-free tape, within the sand injection chamber to prevent an ingress of sand other than through the louver blades.

2. The louver to be tested shall be a 1220 mm × 1220 mm (48 in. × 48 in.) outer dimension square louver with a tolerance of +0, -6.3 mm (=0, -0.25 in.). There shall be no appurtenances (screens) attached. There shall be no finish applied to the louver, although the surfaces can be cleaned. No portion of the louver shall extend beyond the louver exterior face, excluding a drip edge on a sill or an integrated sill pan.

   The louver shall be installed so that sand rejected from the sand louver can be collected in a sand collection trough installed upstream of the sand louver under test, as shown in Test Figure 5.12.

   The test program shall be carried out with dry sand as defined in Annex E. Test sand, once used, shall not subsequently be reused for test purposes.

3. The test shall be carried out at the free area velocities, with mass of sand and sand discharge durations as specified in Table 6. The sand must be discharged at a constant rate over the duration.

Table 6 — Sand Test Parameters (adapted from EN ISO 14688-1)

Quantity	Tolerance	Unit	Values				
Free area velocity	±5%	m/s (SI)	1	2.5	4	5.5	7
		fpm (I-P)	197	492	787	1083	1378
Mass of sand	±5%	kg (SI)	1	1	2	2	2
		lbm (I-P)	2.204	2.204	4.41	4.41	4.41
Discharge duration	±10%	s	200	75	100	70	60
Sand feed rate	±5%	kg/s (SI)	0.005	0.013	0.020	0.029	0.033
		lbm/s (I-P)	0.011	0.0286	0.044	0.064	0.073

4. A bag-type suction (vacuum) cleaner shall be used to collect all sand that has not passed through the sand louver's rear face (i.e., lodged within the louver plates, within the louver frame, remaining in the test duct upstream from the sand louver, in the sand rejection trough, etc.). A new vacuum cleaner bag shall be used for each test run. The vacuum cleaner and bag shall be weighed before and after the test.

Mass shall be measured by means of a scale, balance or similar device having a minimum accuracy of ±0.5% of the indicated weight of the sand and vacuum cleaner.

6.5.2 Conduct of test

6.5.2.1 Pretest of sand distribution

Proper sand distribution from the sand injection will ensure uniform coverage during the louver test.

a. Mount the louver in the test opening as per Section 6.5.1.2.

b. Cover nine squares of cardboard that are 25 mm × 25 mm (±5 mm) (0.98 in. × 0.98 in. [±0.20 in.]) on one side with double-sided adhesive tape.

c. Individually identify and weigh each square before fixing it to the sand louver.

d. Mount the squares to the sand louver in three rows with the sticky side facing upstream, as shown in Figure 15.

e. Make two strips of cardboard 25 mm (±5 mm) (0.98 in. [±0.20 in.]) in height and the full width of the test duct. Cover the upstream side with double-sided adhesive tape and weigh both strips together.

f. Secure the strips in an upright position at 250 mm (9.84 in.) and 350 mm (13.78 in.) from the face of the sand louver as shown in Figure 16 using fully concealed fasteners.

g. With the exhaust fan off and the sand injector blower operating, fill the sand injector main funnel with the specified amount of test sand for the free area velocity that will be tested in accordance with Table 6. Run the injector at the appropriate feed rate and duration shown in Table 6. After all sand has been dispensed, switch off the sand injector.

h. After switching off the sand injector, check for uniform sand distribution adhering to the nine squares on the sand louver by carefully removing the squares and weighing them individually. The ratio of weight difference between the sand in any two squares shall not exceed four to one.

i. Check for uniform distribution of sand adhering to the two strips attached to the floor. Weigh both strips together after sand is injected. The total combined difference in the weight of both strips from before and after the test shall not be more than 1% of the sand being injected.

j. If the results of the uniform sand distribution checks are not satisfactory, adjust the direction of the distribution tube and repeat steps 2-10 until satisfactory distribution is achieved.

6.5.2.2 Sand rejection test

a. With the louver installed in the test opening, ensure that all sand has been removed from the testing apparatus, including the louver, test duct and sand collection trough, prior to test commencement.

b. Switch on both the exhaust fan and the sand injector blower.

c. Record the pressure drop across the louver.

d. Fill the sand injector main funnel with the specified amount of test sand for the free area velocity that is going to be tested in accordance with Table 6. The sand shall be injected into the test duct by means of the main funnel and injector assembly at a consistent rate throughout the duration. The test time starts when the sand enters the test duct. Continuously monitor the injector to ensure it does not clog.

e. The free area and airflow/pressure drop must be remeasured after the completion of the sand rejection test.

f. After the measured weight of sand (mi) has been totally injected into the test duct, the exhaust fan and sand injector blower shall continue to run for two minutes.

g. Weigh the entire vacuum cleaner, including hose and power cord, with the bag.

h. Use the vacuum cleaner to collect all sand that has not passed through the louver as per Section 6.5.1.4.

i. Weigh again the entire vacuum cleaner and bag containing sand as per Section 6.5.1.4.

j. The difference in vacuum cleaner and bag weight shall be recorded as the mass of rejected sand (mu).

k. Reset the test apparatus for the next air velocity listed in Table 6, then repeat steps 1-10 until all velocity tests have been completed.

l. After completion of the sand rejection test for all velocities, keep both the primary and the sand injection fans running and record the pressure drop across the louver for all velocities in accordance with Table 6. Compare the results against the recorded pressure drop values measured in Step 3 and report the difference in percentage. If the maximum allowable deviation between recorded pressure Es drop readings exceeds 5%, repeat steps 3, 4, and 12.

m. The sand rejection effectiveness (E_s) is the percentage of sand that the louver has prevented from crossing the louver's downstream plane. The percentage shall be rounded to one decimal place.

$$E_s = mu/mi \times 100 \qquad \text{Eq. 6.5}$$

6.5.3 Presentation of results

The report and presentation of results at actual and standard air density shall include all the data as outlined in Section 6.5.2.2. In addition, the following shall be recorded:

- Date
- Test ID#
- Lab name
- Lab location
- Reference to ANSI/AMCA Standard 500-L
- Test figure
- Tested louver model name
- Core area
- Actual frame outer size
- Number of front blades
- Number of rear blades

- Louver free area
- Any appurtenances, such as sand collector and weighing device
- Personnel performing the test
- A front and rear photo of the louver

6.5.3.1 Graphing

Prepare a graph of the test results of the louver’s sand rejection effectiveness at different velocities by plotting the free area velocity (V_{fa}) calculated from Q/A_{fa} against the effectiveness percentage E_s calculated from $m_u/m_i \times 100$. See Figure 17.

6.6 Free area measurement

6.6.1 General requirements

6.6.1.1 Measurement

For horizontal blade louvers, free area is determined by multiplying the sum of the minimum distances between intermediate blades, top blade and head, and bottom blade and sill by the minimum distance between jambs.

For vertical blade louvers, free area is determined by multiplying the sum of the minimum distances between intermediate blades, left blade and left jamb, and right blade and right jamb by the minimum distance between head and sill.

For sand louvers, free area is determined by multiplying the sum of the minimum distance between the intermediate blades, left blade and left jamb, and right blade and right jamb by the minimum distance between the head and sill. Sand louvers typically have an exterior set and an interior set of blades. Free area shall be calculated for each set of blades as well as for the space between each set of blades. The louver’s free area shall be the minimum of the three calculated free areas. An access panel in the head shall be provided by the licensee for measurement of the minimum distance between the exterior and interior blades (Figure 1B measurements C3a and C3b). Measured blade tips shall extend into the access panel opening by at least 10 mm (0.38 in.), and the panel shall be horizontally centered at either an exterior blade or an interior blade. See Figures 1A and 1B.

Measurements to determine free area shall be made to the nearest millimeter (0.031 in.). If physical measurements cannot be taken because of blade shape, measurements from CAD drawings will be reported to the nearest 0.01 mm (0.001 in.).

6.6.1.2 Drawing requirements

Measurements to determine free area shall be compared with the design drawing. A design drawing with dimensions needed to calculate the free area shall be submitted prior to any testing that requires calculations with free area. Measurements from CAD drawings will be reported to the nearest 0.01 mm (0.001 in.).

If physical measurements cannot be taken because of blade shape, those measurements will not be required and will be obtained from design drawings.

6.6.1.3 Rounding of data

Free area shall be rounded to the nearest thousandths of a square meter. If displayed in square feet, the free area shall be rounded to the nearest hundredth.

6.6.2 Presentation of results

The report and presentation of results shall include all the data as outlined in Section 6.6.1. In addition, the following shall be recorded, as appropriate:

- The measured free area in m^2 (ft^2)
- Blade orientation (vertical or horizontal)
- Blade action (parallel or opposed, applicable for adjustable blade louvers)
- Personnel
- Date
- Test ID#
- Lab name
- Lab location
- Reference to ANSI/AMCA Standard 500-L
- Test figure
- Any appurtenance, such as drain pans
- A front and rear photo of the louver

7. Calculations

7.1 Calibration correction

Calibration corrections, when required, shall be applied to individual readings before averaging or other calculations. Calibration corrections need not be made if the correction is smaller than one-half the maximum allowable error, as specified in Section 4.

7.2 Density and viscosity of air

7.2.1 Atmospheric air density

The density of atmospheric air (ρ_0) shall be determined from measurements, taken in the general test area, of dry-bulb temperature (t_{d0}), wet-bulb temperature (t_{w0}), and barometric pressure (p_b) using Equations 7.1, 7.2 and 7.3.

$$p_e = 3.25{t_{w0}}^2 + 18.6t_{w0} + 692$$ SI Eq. 7.1

$$p_e = (2.96 \times 10^{-4}){t_{w0}}^2 - (1.59 \times 10^{-2})t_{w0} + 0.41$$ I-P Eq. 7.2

$$p_p = p_e - p_b\left(\frac{t_{d0} - t_{w0}}{1500}\right)$$ SI Eq. 7.3

$$p_p = p_e - p_b\left(\frac{t_{d0} - t_{w0}}{2700}\right)$$ I-P Eq. 7.4

$$\rho_0 = \frac{p_b - 0.378p_p}{\mathrm{R}(t_{d0} + 273.15)}$$ SI Eq. 7.5

$$\rho_0 = \frac{70.73(p_b - 0.378p_p)}{\mathrm{R}(t_{d0} + 459.67)}$$ I-P Eq. 7.6

Equation 7.1 is approximately correct for p_e for a range of t_{w0} between 4 °C and 32 °C (40 °F and 90 °F). More precise values of p_e can be obtained from ASHRAE Handbook—Fundamentals. The gas constant (R) may be taken as 287.1 J/kg-K (53.35 ft-lb/lbm-R) for air.

7.2.2 Duct or chamber air density

The density of air in a chamber at plane *x* (ρ_x) may be calculated by correcting the density of atmospheric air (ρ_0) for the pressure (P_{sx}) and temperature (t_{dx}) at plane *x* using:

$$\rho_x = \rho_0 \left(\frac{t_{d0} + 273.15}{t_{dx} + 273.15}\right)\left(\frac{P_{sx} + p_b}{p_b}\right)$$ SI Eq. 7.7

$$\rho_x = \rho_0 \left(\frac{t_{d0} + 459.67}{t_{dx} + 459.67}\right)\left(\frac{P_{sx} + 13.595p_b}{13.595p_b}\right)$$ I-P Eq. 7.8

If P_{sx} is numerically less than 1000 Pa (4 in. wg), ρ_x may be considered equal to ρ_0.

7.2.3 Air viscosity

Viscosity (μ) shall be calculated from:

$$\mu_x = (17.23 + 0.048t_a) \times 10^{-6}$$ SI Eq. 7.9

$$\mu_x = (11.00 + 0.018t_a) \times 10^{-6}$$ I-P Eq. 7.10

The value for 20 °C (68 °F) air, which is 1.819 × 10^{-5} Pa-s (1.222 × 10^{-5} lbm/ft-s), may be used for temperatures ranging between 4 °C (40 °F) and 40 °C (100 °F).

7.3 Louver airflow rate at test conditions

7.3.1 Velocity traverse

The louver airflow rate may be calculated from velocity pressure measurements (P_{v3}) taken by pitot traverse.

7.3.1.1 Velocity pressure

The velocity pressure (P_{v3}) corresponding to the average velocity shall be obtained by taking the square roots of the individual measurements (P_{v3r}) (see Figures 3A and 3B), summing the roots, dividing the sum by the number of measurements (n) and squaring the quotient as indicated by:

$$P_{v3} = \left(\frac{\sum \sqrt{P_{v3r}}}{n}\right)^2$$ Eq. 7.11

7.3.1.2 Velocity

The average velocity (V_3) shall be obtained from the density at the plane of traverse (ρ_3) and the corresponding velocity pressure (P_{v3}) using:

$$V_3 = \sqrt{\frac{2P_{v3}}{\rho_3}}$$ SI Eq. 7.12

$$V_3 = 1097.8\sqrt{\frac{P_{v3}}{\rho_3}}$$ I-P Eq. 7.13

7.3.1.3 Airflow rate

The airflow rate (Q_3) at the pitot traverse plane shall be obtained from the velocity (V_3) and the area (A_3) using:

$$Q_3 = V_3 A_3 \qquad \text{Eq. 7.14}$$

7.3.1.4 Louver airflow rate

The louver airflow rate at test conditions (Q) shall be obtained from the equation of continuity:

$$Q = Q_3 \left(\frac{\rho_3}{\rho}\right) \qquad \text{Eq. 7.15}$$

7.3.2 Nozzle

The louver airflow rate may be calculated from the pressure differential (ΔP) measured across a single nozzle or bank of multiple nozzles. See Figure 8A for nozzle requirements.

7.3.2.1 Alpha ratio

The ratio (α) of absolute nozzle exit pressure to absolute approach pressure shall be calculated from:

$$\alpha = \frac{P_{s6} + p_b}{P_{sx} + p_b} \qquad \text{SI} \qquad \text{Eq. 7.16}$$

$$\alpha = \frac{P_{s6} + 13.595 p_b}{P_{sx} + 13.595 p_b} \qquad \text{I-P} \qquad \text{Eq. 7.17}$$

or

$$\alpha = 1 - \frac{\Delta P}{\rho_x R (t_{dx} + 273.15)} \qquad \text{SI} \qquad \text{Eq. 7.18}$$

$$\alpha = 1 - \frac{5.2014 \times \Delta P}{\rho_x R (t_{dx} + 459.67)} \qquad \text{I-P} \qquad \text{Eq. 7.19}$$

The gas constant (R) may be taken as 287.1 J/kg-K (53.35 ft-lb/lbm-°R) for air. Plane *x* is Plane 4 for duct approach or Plane 5 for chamber approach.

7.3.2.2 Beta ratio

The ratio (β) of nozzle exit diameter (D_6) to approach duct diameter (D_x) shall be calculated from:

$$\beta = \left(\frac{D_6}{D_x}\right) \qquad \text{Eq. 7.20}$$

For a duct approach, $D_x = D_4$. For a chamber approach, $D_x = D_5$, and β may be taken as zero.

7.3.2.3 Expansion factor

The expansion factor (Y) may be obtained from:

$$Y = \sqrt{\alpha^{\frac{2}{\gamma}} \left(\frac{\gamma}{\gamma - 1}\right) \left(\frac{1 - \alpha^{\frac{(\gamma-1)}{\gamma}}}{1 - \alpha}\right)} \sqrt{\frac{1 - \beta^4}{1 - \beta^4 \alpha^{\frac{2}{\gamma}}}} \qquad \text{Eq. 7.21}$$

The ratio of specific heats (γ) may be taken as 1.4 for air. Alternatively, the expansion factor for air may be approximated with sufficient accuracy under this standard using:

$$Y = 1 - (0.548 + 0.71\beta^4)(1 - \alpha) \qquad \text{Eq. 7.22}$$

7.3.2.4 Energy factor

The energy factor (E) may be determined by measuring velocity pressures (P_{vr}) upstream of the nozzle at standard traverse stations and calculating:

$$E = \frac{\left(\frac{\Sigma\sqrt{P_{vr}}^3}{n}\right)}{\left(\frac{\Sigma\sqrt{P_{vr}}}{n}\right)^3} \qquad \text{Eq. 7.23}$$

Sufficient accuracy can be obtained for setups qualifying under this standard by setting $E = 1.0$ for chamber approach or $E = 1.043$ for duct approach.

7.3.2.5 Reynolds number

The Reynolds number (Re) based on nozzle exit diameter (D_6) in m (ft) shall be calculated using properties of air as determined in Section 7.2 and the appropriate velocity (V_6) in m/s (fpm) from:

$$Re = \frac{D_6 V_6 \rho_6}{\mu_6} \qquad \text{SI} \qquad \text{Eq. 7.24}$$

$$Re = \frac{D_6 V_6 \rho_6}{60\mu_6} \qquad \text{I-P} \qquad \text{Eq. 7.25}$$

Since the velocity determination depends on Reynolds number, an approximation must be employed. It can be shown that:

$$Re = \frac{\sqrt{2}}{\mu_6} C D_6 Y \sqrt{\frac{\Delta P \rho_x}{1 - E\beta^4}} \qquad \text{SI} \qquad \text{Eq. 7.26}$$

$$Re = \frac{1097.8}{60\mu_6} C D_6 Y \sqrt{\frac{\Delta P \rho_x}{1 - E\beta^4}} \qquad \text{I-P} \qquad \text{Eq. 7.27}$$

For duct approach, $\rho_x = \rho_4$. For chamber approach, $\rho_x = \rho_5$, and β may be taken as zero.

7.3.2.6 Nozzle discharge coefficient

The nozzle discharge coefficient (C) shall be determined from:

$$C = 0.9986 - \frac{7.006}{\sqrt{Re}} + \frac{134.6}{Re} \qquad \text{Eq. 7.28}$$

For $\mathrm{L/D}$ = 0.6 (Eq. 7.8), and

$$C = 0.9986 - \frac{6.688}{\sqrt{Re}} + \frac{131.5}{Re} \qquad \text{Eq. 7.29}$$

For $\mathrm{L/D}$ = 0.5 (Eq. 7.19).

For *Re* of 12,000 and above.

7.3.2.7 Airflow rate for ducted nozzles

The airflow rate (Q_5) at the entrance to a ducted nozzle shall be calculated from:

$$Q_5 = \frac{CA_6Y\sqrt{\frac{2\Delta P_n}{\rho_5}}}{\sqrt{1 - E\beta^4}} \qquad \text{SI} \qquad \text{Eq. 7.30}$$

$$Q_5 = \frac{1097.8CA_6Y\sqrt{\frac{\Delta P_n}{\rho_5}}}{\sqrt{1 - E\beta^4}} \qquad \text{I-P} \qquad \text{Eq. 7.31}$$

The area (A_6) is measured at the plane of the throat taps.

7.3.2.8 Airflow rate for chamber nozzles

The airflow rate (Q_5) at the entrance to a nozzle or multiple nozzles with chamber approach shall be calculated from:

$$Q_5 = Y\sqrt{\frac{2\Delta P_n}{\rho_5}}\Sigma(CA_6) \qquad \text{SI} \qquad \text{Eq. 7.32}$$

$$Q_5 = 1097.8\,Y\sqrt{\frac{\Delta P_n}{\rho_5}}\Sigma(CA_6) \qquad \text{I-P} \qquad \text{Eq. 7.33}$$

The coefficient (C) and area (A_6) must be determined for each nozzle and their products summed as indicated. The area (A_6) is measured at the plane of the throat taps or, for nozzles without throat taps, at the nozzle exit.

7.3.2.9 Louver airflow rate

The louver airflow rate (Q) at test conditions shall be obtained from the equation of continuity:

$$Q = Q_x \left(\frac{\rho_\mathrm{x}}{\rho}\right) \qquad \text{Eq. 7.34}$$

7.4 Density correction

The resistance of a duct system or the pressure drop of a louver is dependent on the density of the air flowing through the system or louver. At constant volume airflow rate, the pressure drop varies in direct proportion to the density. For example, a 10% increase in density would cause a 10% increase in pressure drop. A correction shall be made to adjust the pressure drop measured at test conditions to the pressure drop that would be measured at the same airflow rate with standard air density (1.2 kg/m^3 (0.075 lbm/ft^3)).

The correction shall be calculated from $Q_\mathrm{S} = Q_1$.

$$\Delta P_\mathrm{S} = \Delta P_{1,2} \left(\frac{1.2}{\rho_1}\right) \qquad \text{SI} \qquad \text{Eq. 7.35}$$

$$\Delta P_S = \Delta P_{1,2} \left(\frac{0.075}{\rho_1}\right) \qquad \text{I-P} \qquad \text{Eq. 7.36}$$

7.5 Air leakage/system leakage correction

For the purpose of establishing louver air leakage, the “system” air leakage must be subtracted from the “louver and system” air leakage. Because it is not practical to set up and test the exact pressure differential corrected to standard air for each pair of determinations, the subtraction may be accomplished by one of the methods below.

7.5.1 Subtraction by chart

The data from both tests shall be plotted on logarithmic graph paper. A straight line shall then be drawn through each set of data points. The louver air leakage airflow rate for any given pressure differential is the airflow rate difference between the plotted lines at that pressure differential.

7.5.2 Subtraction by data points

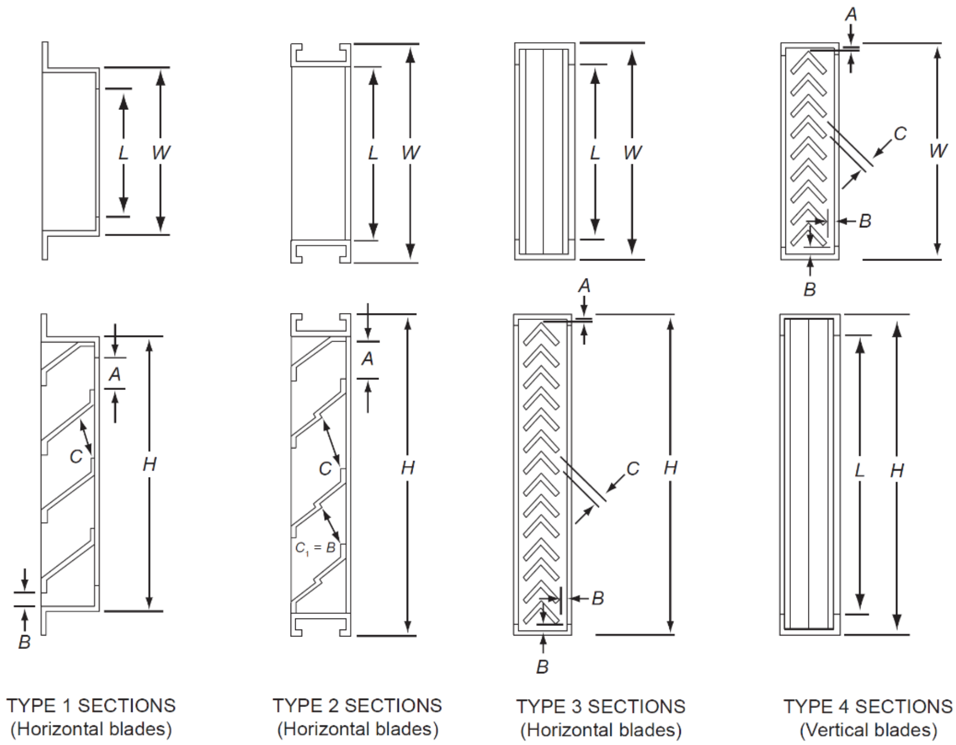
The air leakage airflow rates for a given set of pressure differential data may be subtracted directly, provided the “system” air leakage airflow rate is corrected to a pressure differential identical to the “louver and system” pressure differential. The converted airflow rate (Q_c) is determined by adjusting the tested airflow rate (Q_t) by the square root of the pressure ratio required to make the pressure differentials identical.

$$Q_c = Q_t \sqrt{\frac{\Delta \mathrm{P}_{LS}}{\Delta P_S}} \qquad \text{Eq. 7.37}$$

Where:

ΔP_LS = louver and system test pressure differential
ΔP_S = system test pressure differential

8. Figures



Free Area, m^2 ($in.^2$) = $\mathrm{L(A + B + [N \times C])}$

Percent of Free Area (%) $= \dfrac{\mathrm{L(A + B + [N \times C])100}}{W \times H}$

Figure 1A — Typical Louver and Frame Cross Section Showing Minimum Distance Formula

(See Figure 1A Notes on next page.)

Figure 1A Notes:
Horizontal blade louvers

A*	=	Minimum distance between the head and top blade* Note: Where the top blade dimension *C* is less than *A*, use the value for *C*
B*	=	Minimum distance between the sill and bottom blade*
C*	=	Minimum distance between adjacent blades. Note that in louver type 2, *C* may not be equal to *C*1*
N	=	Number of *C* openings in the louver
L	=	Minimum distance between louver jambs
W	=	Actual louver width
H	=	Actual louver height

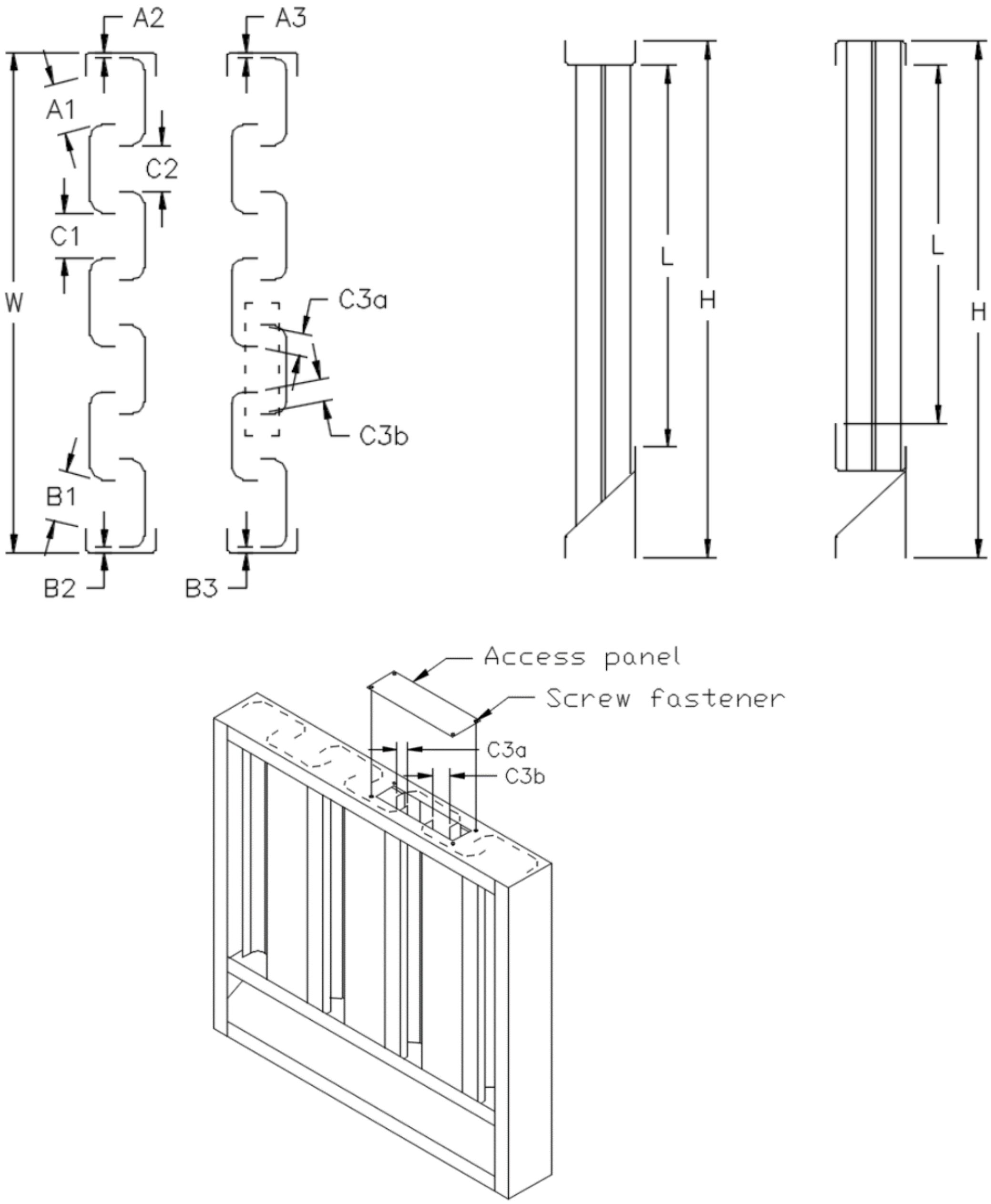
* The *A*, *B* and *C* spaces shall be measured within 76 mm (3 in.) of each blade end and averaged. If an adjustable blade's non-uniform end condition (rotation pin, pin receptor, or similar) is the reason for the most restrictive distance between the blades, then the *A*, *B*, and/or *C* space can be measured within 25.4 mm (1 in.) next to the non-uniform end condition.

Vertical blade louvers

A*	=	Minimum distance between the left jamb and left blade*
B*	=	Minimum distance between the right jamb and right blade*
C*	=	Minimum distance between adjacent blades*
N	=	Number of *C* openings in the louver
L	=	Minimum distance between louver head and sill
W	=	Actual louver width
H	=	Actual louver height

* The A, B and C spaces shall be measured within 76 mm (3 in.) of each blade end and averaged. If an adjustable blade's non-uniform end condition (rotation pin, pin receptor, or similar) is the reason for the most restrictive distance between the blades, then the A, B, and/or C space can be measured within 25.4 mm (1 in.) next to the non-uniform end condition.

Note: When measuring two louvers placed back-to-back, the free area of the combined louvers shall be determined as the smaller of the two free areas.



Left: Horizontal section cut, with a dashed area indicating the head frame access panel area.
Middle: Two examples of a vertical section cut.
Right: Example of access panel in head member.

Figure 1B — Typical Sand Louver and Frame Cross Section Showing Minimum Distance Formula

(See Figure 1B Notes on next page.)

Figure 1B Notes:

$A1$*	=	Minimum distance between the left jamb and exterior left blade *
$A2$*	=	Minimum distance between the left jamb and interior left blade *
$A3$	=	Minimum of $A1$ and $A2$
$B1$*	=	Minimum distance between the right jamb and exterior right blade *
$B2$*	=	Minimum distance between the right jamb and interior right blade *
$B3$	=	Minimum of $B1$ and $B2$
$C1$*	=	Minimum distance between adjacent exterior blades *
$C2$*	=	Minimum distance between adjacent interior blades *
$C3$a**	=	Minimum distance between exterior and interior blade, left side of blade **
$C3$b**	=	Minimum distance between exterior and interior blade, right side of blade **
$N1$	=	Number of $C1$ openings in the louver
$N2$	=	Number of $C2$ openings in the louver
$N3$	=	Number of $C3$ openings in the louver
L	=	Minimum distance between louver head and sill
W	=	Actual louver width
H	=	Actual louver height

* Shall be measured within 76 mm (3 in.) of each blade end and averaged. [Also change horizontal and vertical sections to match.]
** Shall be measured through the head access panel within 25 mm (1 in.) of the blade end.

$C3 = (C3\text{a} + C3\text{b}) / 2$

Exception: If (2 x $C3$) is greater than $C1$ or $C2$, then $C3$ shall be the minimum of $(C1)$ / 2 and $(C2)$ / 2

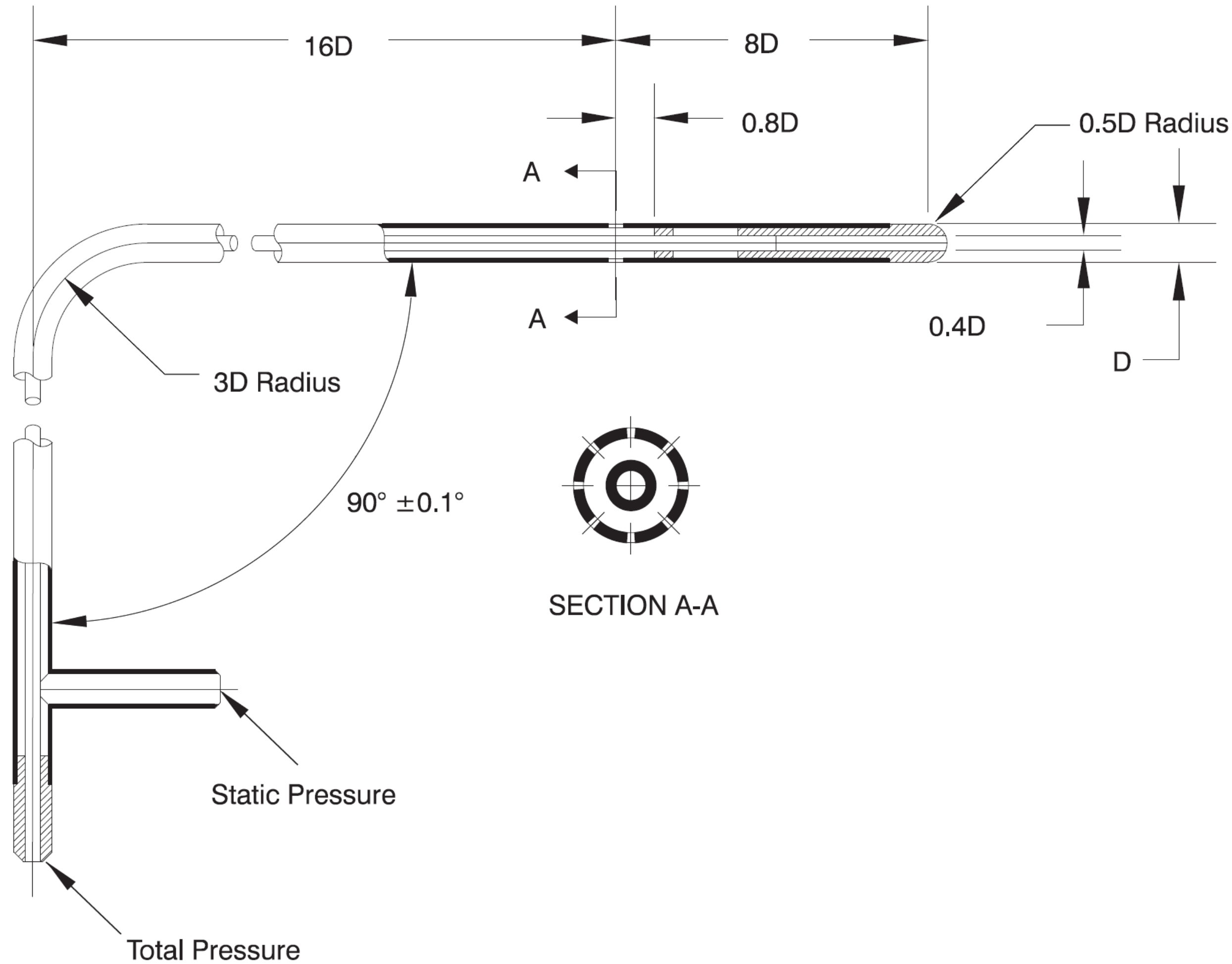
Free Area 1	=	Exterior blade free area = $L\,(A1 + B1 + [N1 \text{ x } C1])$
Free Area 2	=	Interior blade free area = $L\,(A2 + B2 + [N2 \text{ x } C2])$
Free Area 3	=	In-between exterior and interior blade free area = $L\,(A3 + B3 + [N3 \text{ x } C3])$

Exceptions:

1. If a blade support (strap, etc.) is attached to the exterior face of an exterior blade, then the value of L in “Free Area 1” shall be reduced by the value of the width of the blade support.
2. If a blade support (strap, etc.) is attached to an interior face of an interior blade, then the value of L in “Free Area 2” shall be reduced by the value of the width of the blade support.
3. If a blade support (strap, etc.) is located between the blades, then the value of L in “Free Area 3” shall be reduced by the value of the width of the blade support.

In each of the above three instances, if the blade support does not cross an A, B, or C gap, then the L value used for that specific gap shall not be reduced.

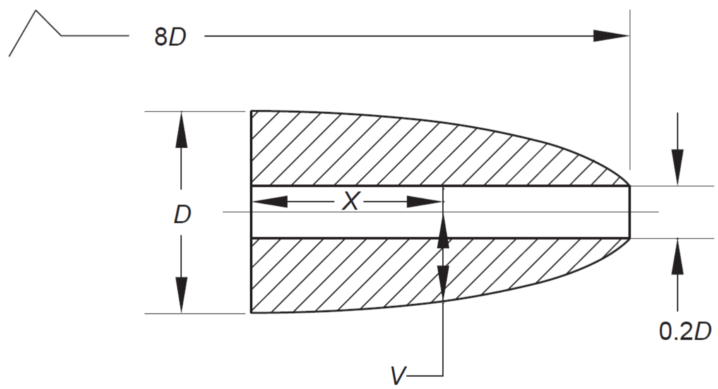
Free Area = minimum of Free Area 1, Free Area 2, and Free Area 3



Notes:

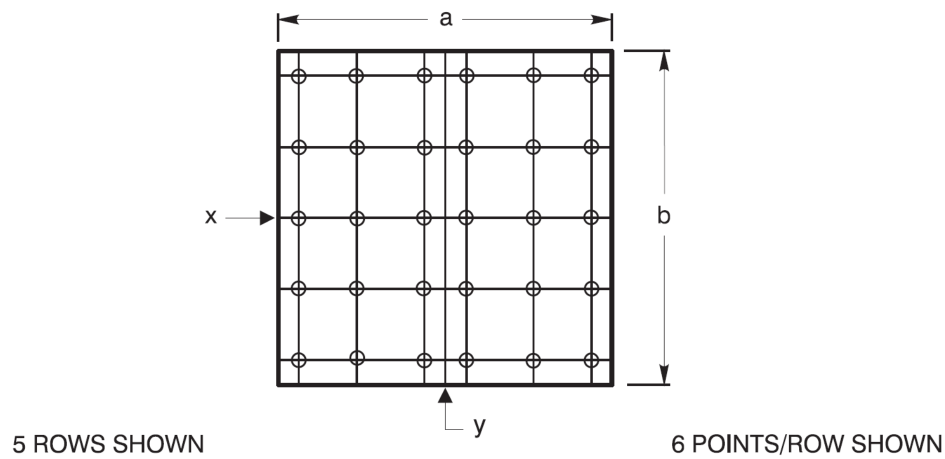
1. Surface finish shall be 0.8 micrometer (32 micro-in.) or better. The static orifices may not exceed 1 mm (0.04 in.) diameter. The minimum pitot tube stem diameter recognized under this standard shall be 2.5 mm (0.10 in.). In no case shall the stem diameter exceed 1/30 of the test duct diameter.
2. Head shall be free from nicks and burrs.
3. All dimensions shall be within ±2%.
4. Section A-A shows eight holes equally spaced and free from burrs. Hole diameter shall be 0.153D but shall not exceed 1 mm (0.04 in.). Hole depth shall not be less than the hole diameter.

Figure 2A — Pitot-Static Tube with Spherical Head



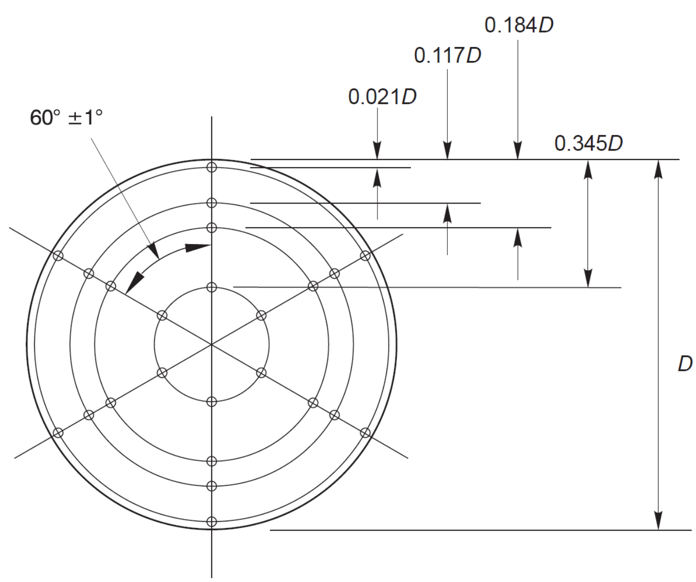
X/D	V/D
0	0.5
0.237	0.496
0.336	0.494
0.474	0.487
0.622	0.477
0.741	0.468
0.936	0.449
1.025	0.436
1.134	0.42
1.228	0.404
1.313	0.388
1.39	0.371
1.442	0.357
1.506	0.343
1.538	0.333
1.57	0.323
1.602	0.314
1.657	0.295
1.698	0.279
1.73	0.266
1.762	0.25
1.796	0.231
1.83	0.211
1.858	0.192
1.875	0.176
1.888	0.163
1.9	0.147
1.91	0.131
1.918	0.118
1.92	0.109
1.921	0.1

Figure 2B — Alternate Pitot-Static Tube with Ellipsoidal Head



Number of Points per Traverse Line	Distance from Centerline — *x*/*a* or *y*/*b*			
5	0	±0.212	±0.426	
6	±0.063	±0.265	±0.439	
7	0	±0.134	±0.297	±0.447

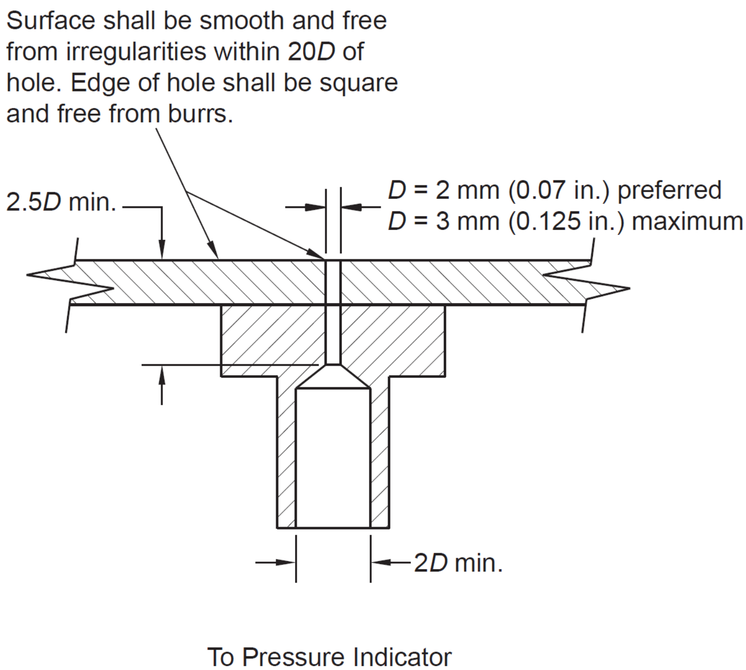
Figure 3A — Log-Tchebycheff Traverse Points for Rectangular Ducts



Notes:

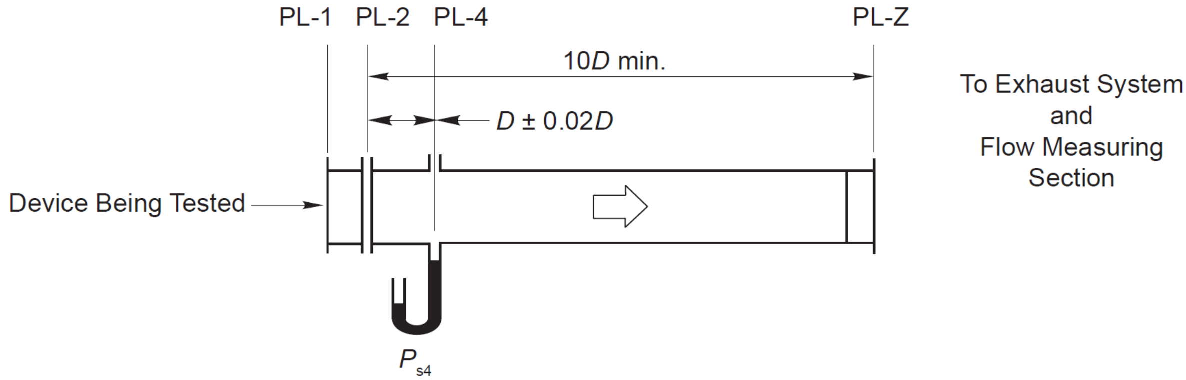
1. *D* is the average of four measurements at traverse plane at 45° angles measured to accuracy of 0.2% *D*.
2. Traverse duct shall be round within 0.5% *D* at traverse plane and for a distance of 0.5*D* on either side of traverse plane.
3. All pitot positions ±0.0025*D* relative to inside duct walls.

Figure 3B — Log-Linear Traverse Points for Circular Ducts



Note: A 2 mm (0.07 in.) hole is the maximum size that will allow space for a smooth surface 20*D* from the hole when installed 38 mm (1.5 in.) from a partition, such as in Test Figures 6.3 and 6.5.

Figure 4 — Static Pressure Taps



For rectangular ducts

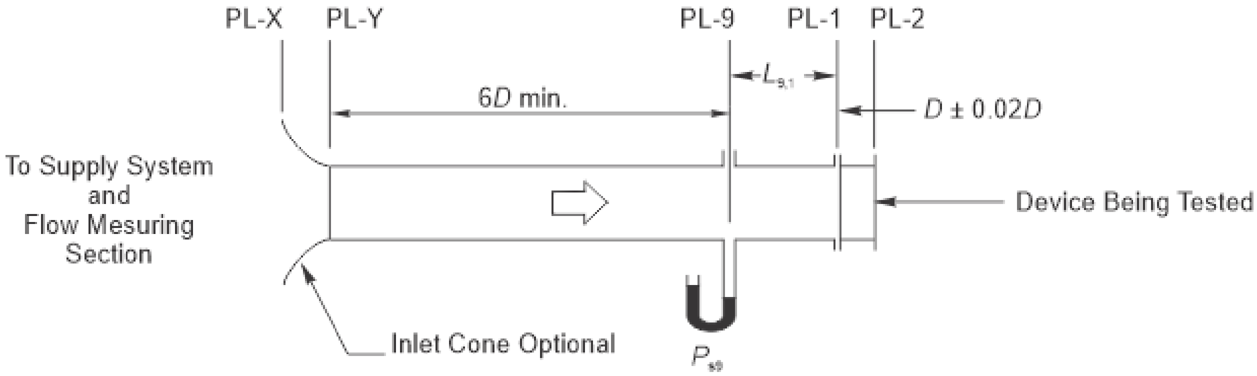
$$D = \sqrt{\frac{4ab}{\pi}}$$

Where:
a = duct width
b = duct height

For round ducts

D = duct diameter

Figure 5.1 — Test Louver Setup with Outlet Duct



For rectangular ducts

$$D = \sqrt{\frac{4ab}{\pi}}$$

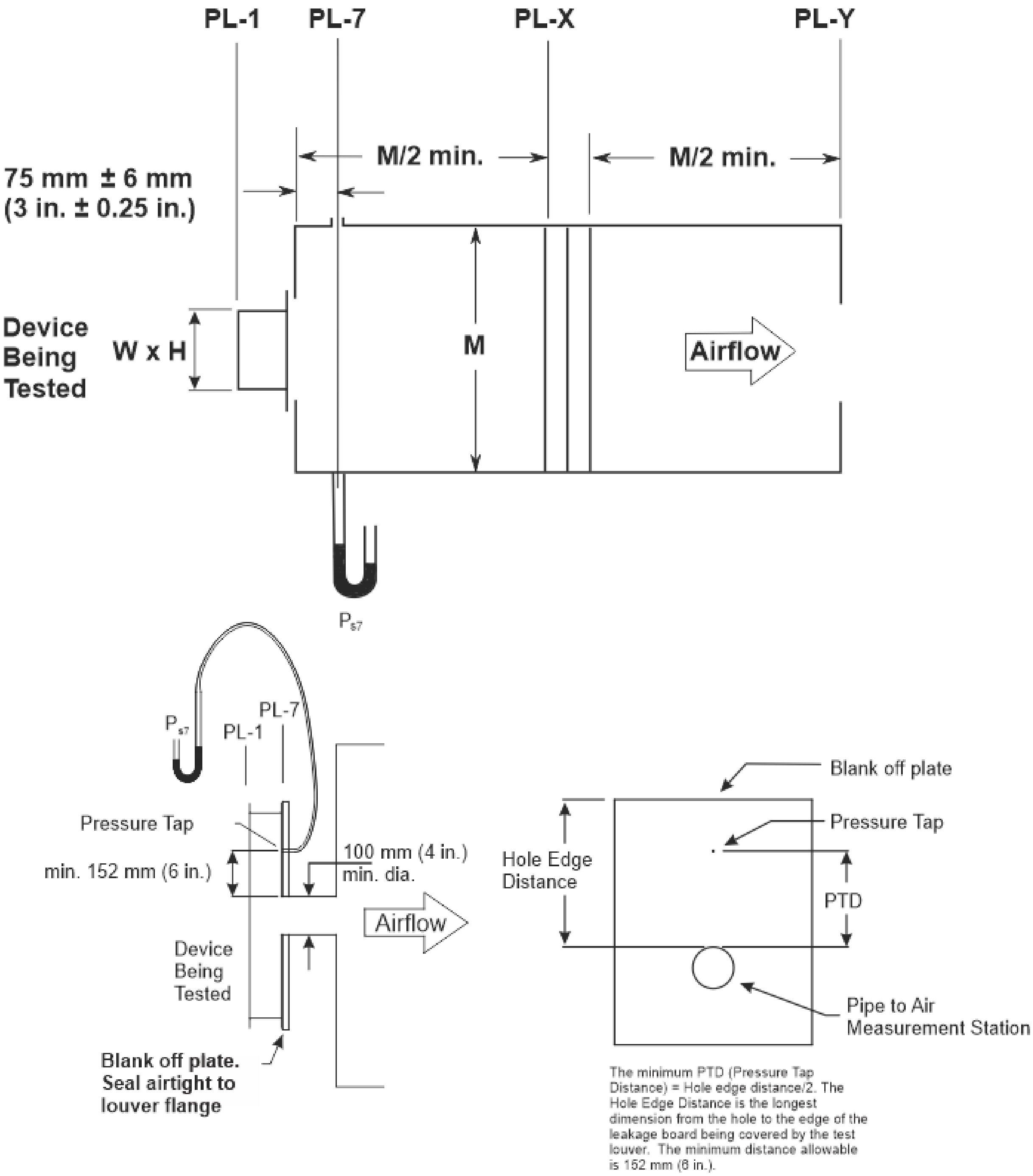
Where:
a = duct width
b = duct height

For round ducts

D = duct diameter

Figure 5.2 — Test Louver Setup with Inlet Duct

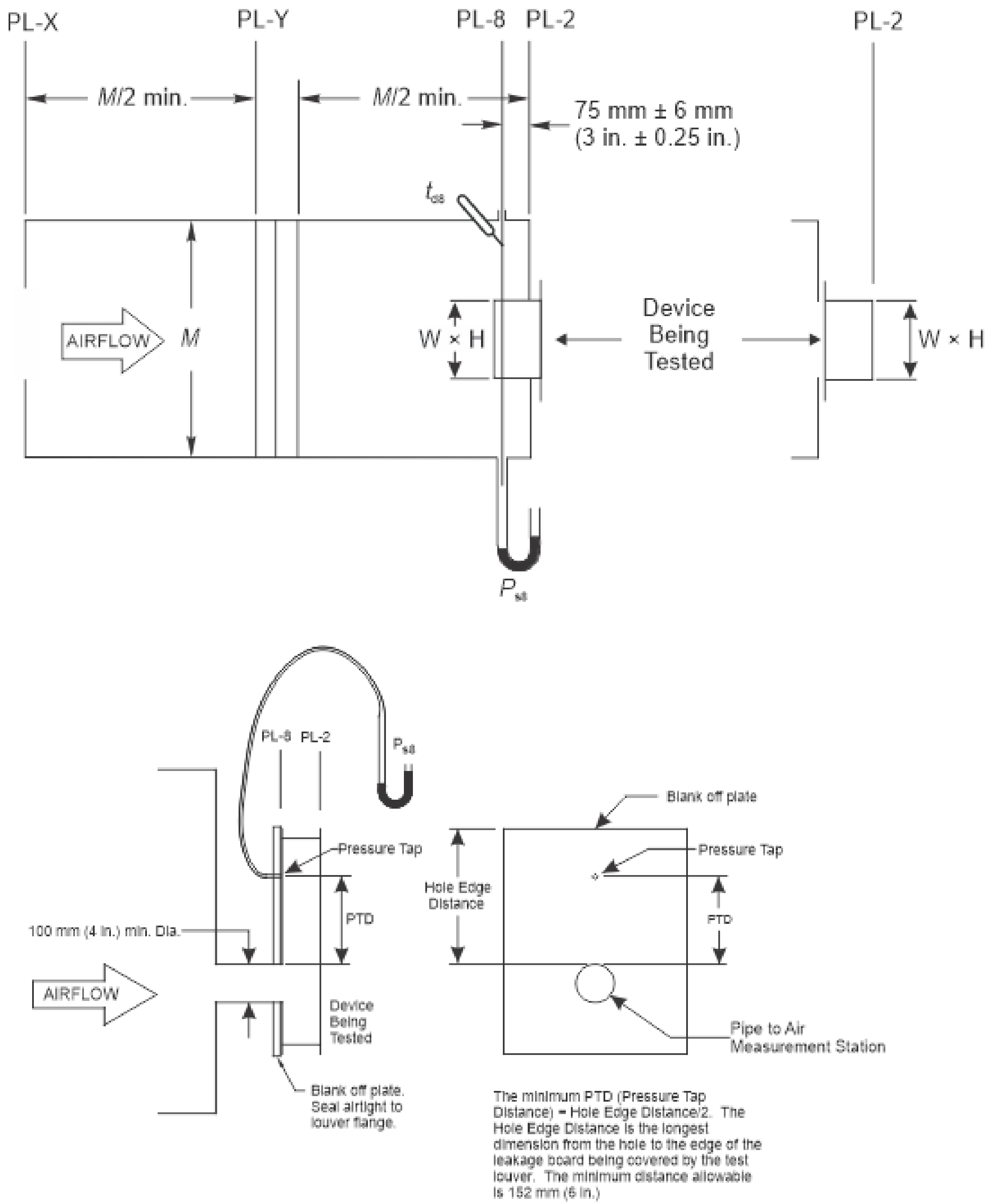
Figure 5.3 (Intentionally left blank)



Alternate Mount
(Leakage Test Only)

Note: For air performance - pressure drop testing, an outlet chamber shall have a cross-sectional area at least 15 times the free area of the louver being tested.

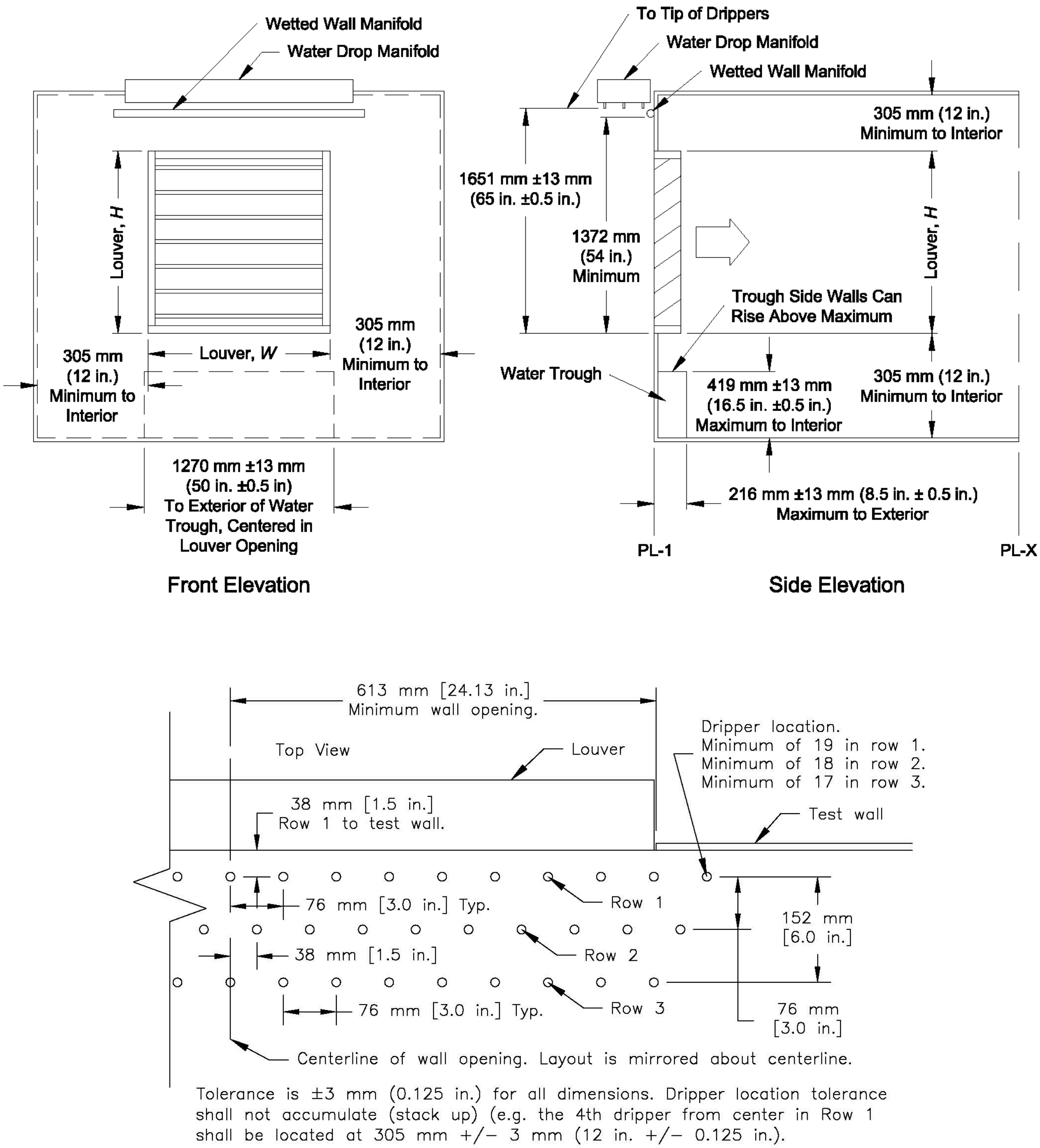
Figure 5.4 — Test Louver Setup with Outlet Chamber



ALTERNATE MOUNT
(Leakage Test Only)

Note: For air performance - pressure drop testing, an inlet chamber shall have a cross-sectional area at least three times the free area of the damper being tested.

Figure 5.5 — Test Louver Setup with Inlet Chamber



Plenum size shall be larger than the test louver by a minimum of 305 mm (12 in.) on all four sides.

Figure 5.6 — Louver Test Setup with Water Penetration Chamber

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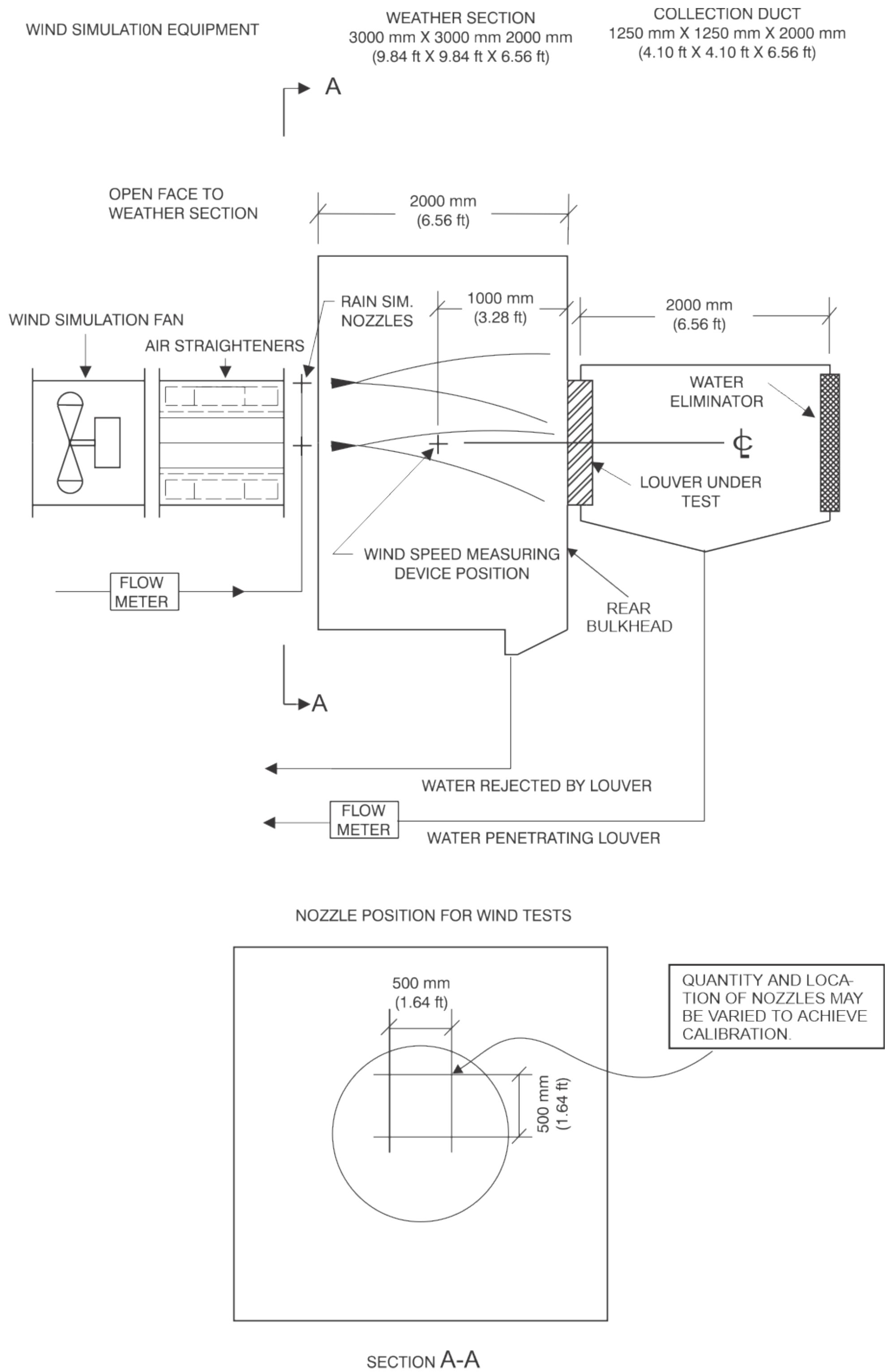
Figure 5.8 (Intentionally left blank)

Figure 5.9 (Intentionally left blank)

Figure 5.10 (Intentionally left blank)



This figure, adapted from HEVAC technical specification Laboratory Testing and Rating of Weather Louvres When Subjected to Simulated Rain, is courtesy of Heating Ventilating and Air Conditioning Manufacturers Association.

Figure 5.11 — Louver Test Setup with Wind-Driven-Rain Chamber

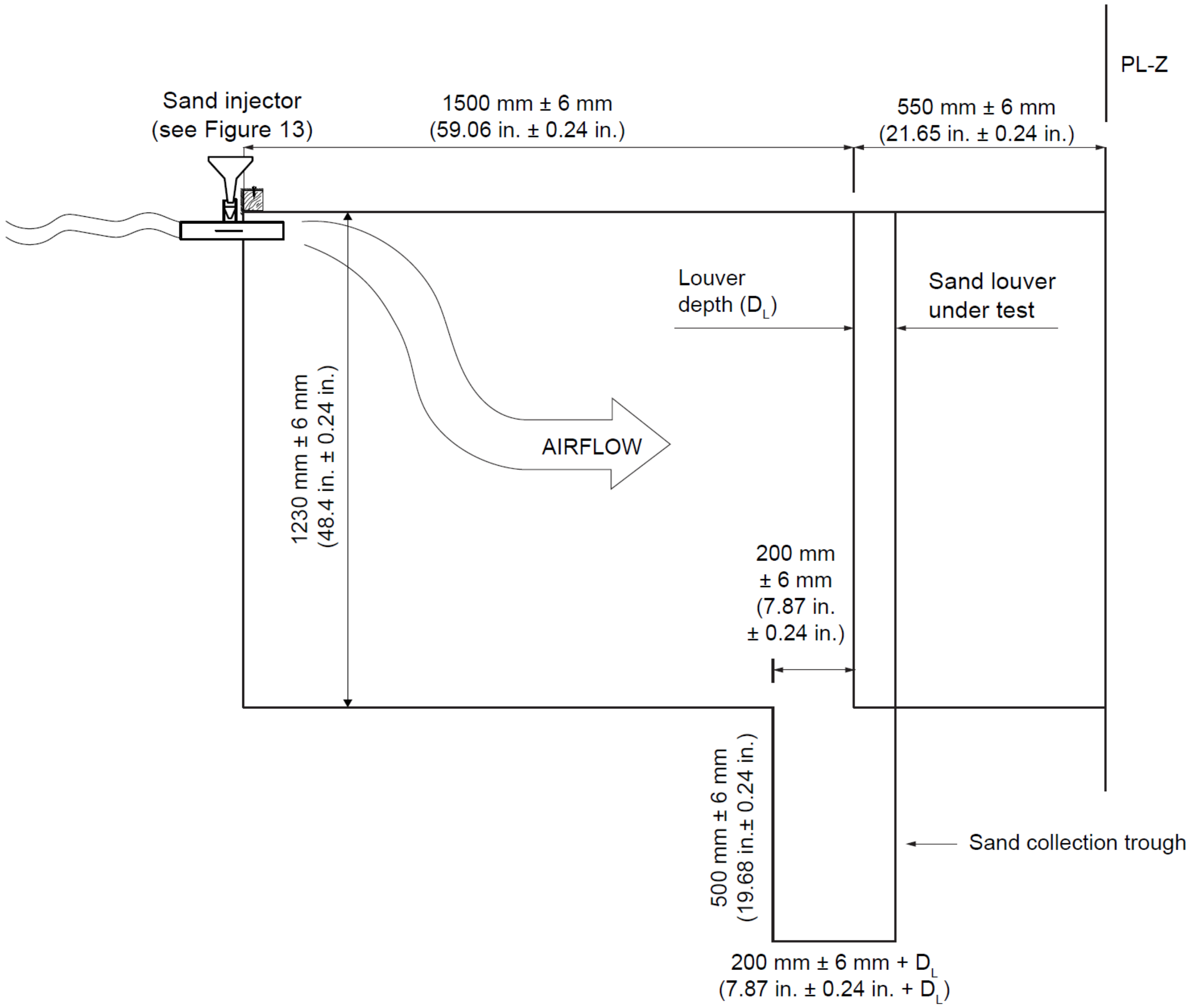


Figure 5.12 — Sand Louver Test Setup with Wind-Driven-Sand Chamber

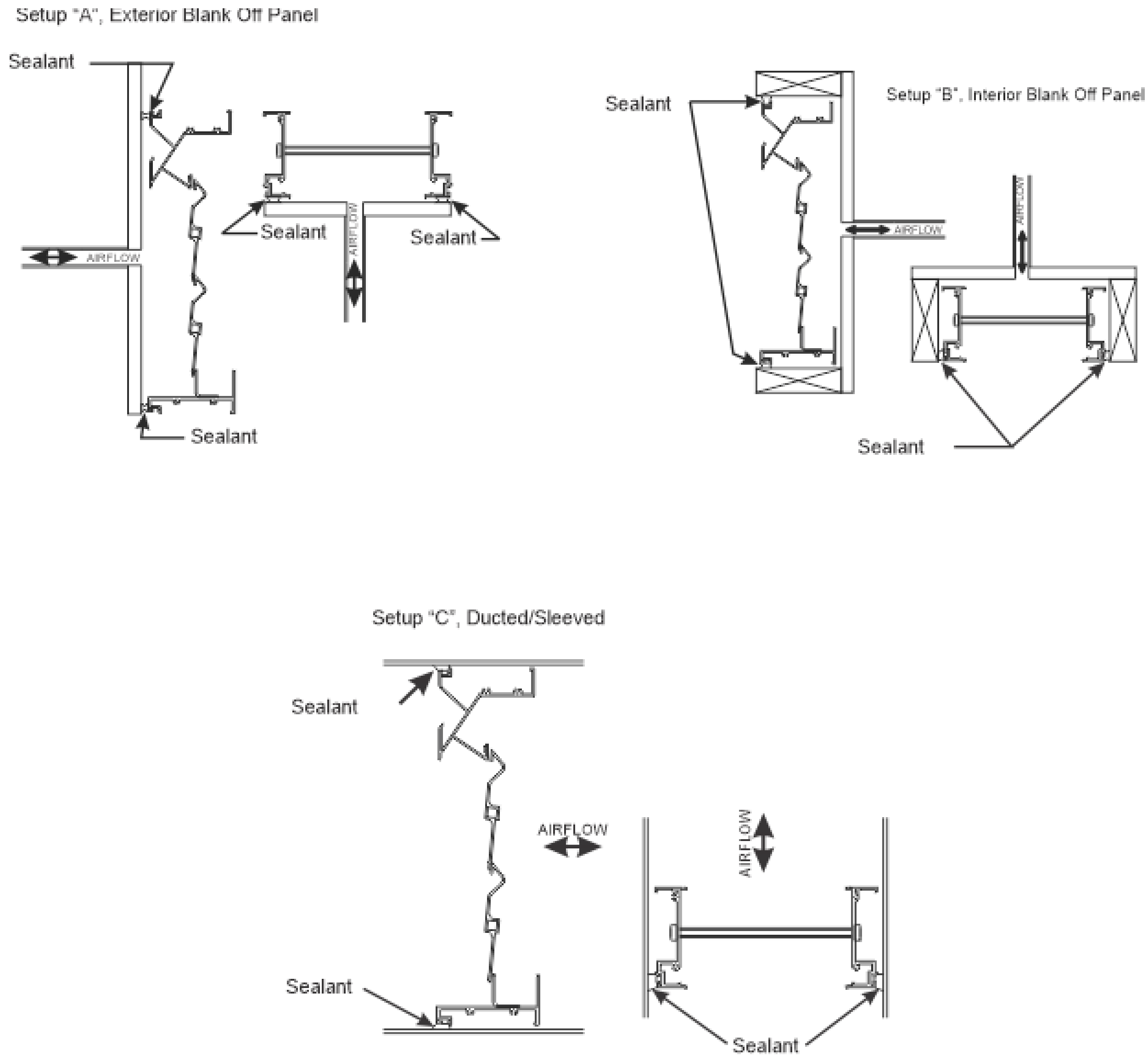
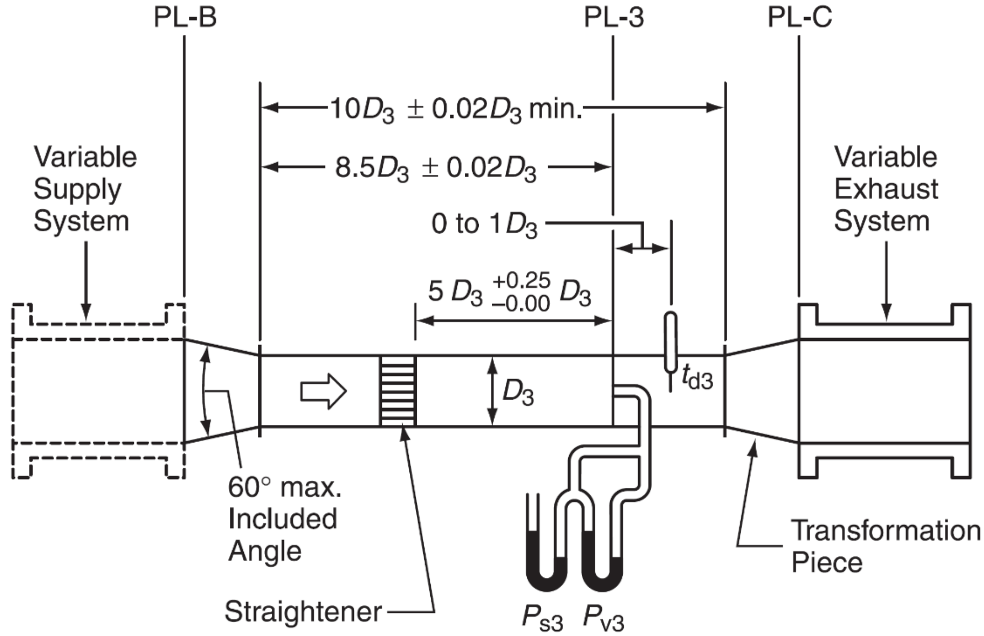


Figure 5.13 — Louver Sealing Requirements



$$Q = Q_3 \left(\frac{\rho_3}{\rho}\right)$$

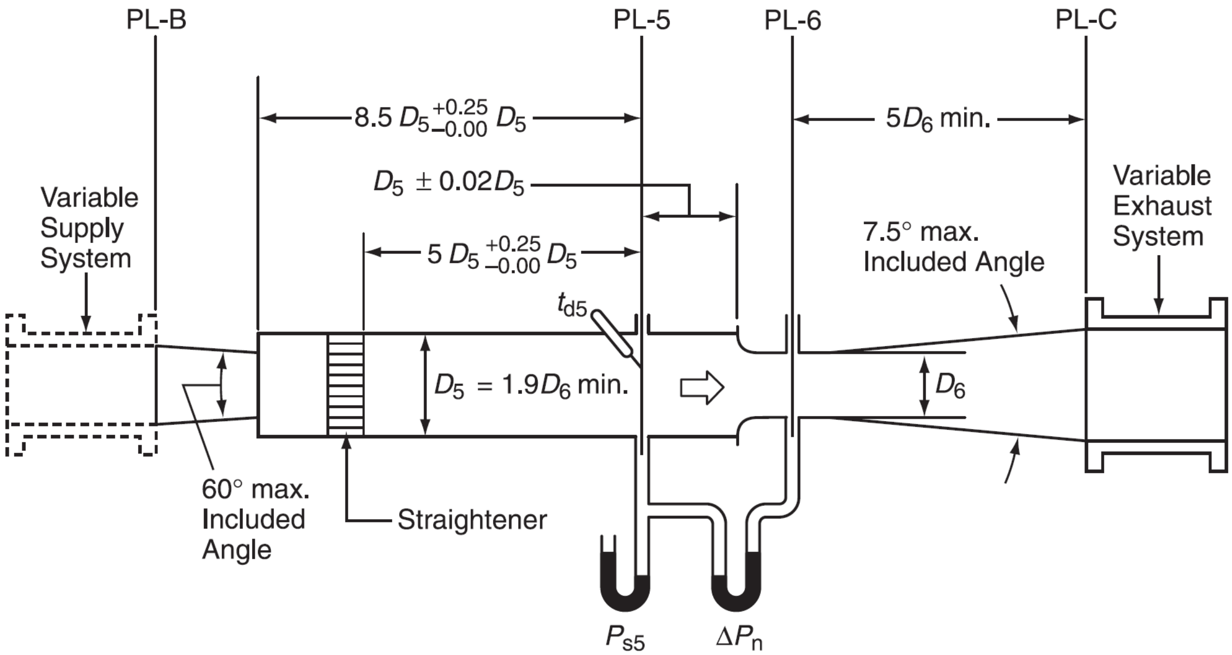
$$Q_3 = V_3 A_3$$

$$P_{v3} = \left(\frac{\sum \sqrt{P_{v3r}}}{n}\right)^2$$

$$V_3 = \left(\frac{2P_{v3}}{\rho_3}\right)$$ SI formula

$$V_3 = 1097.8\sqrt{\frac{P_3}{\rho_3}}$$ I-P formula

Figure 6.1 — Airflow Rate Measurement Setup: Pitot in Duct

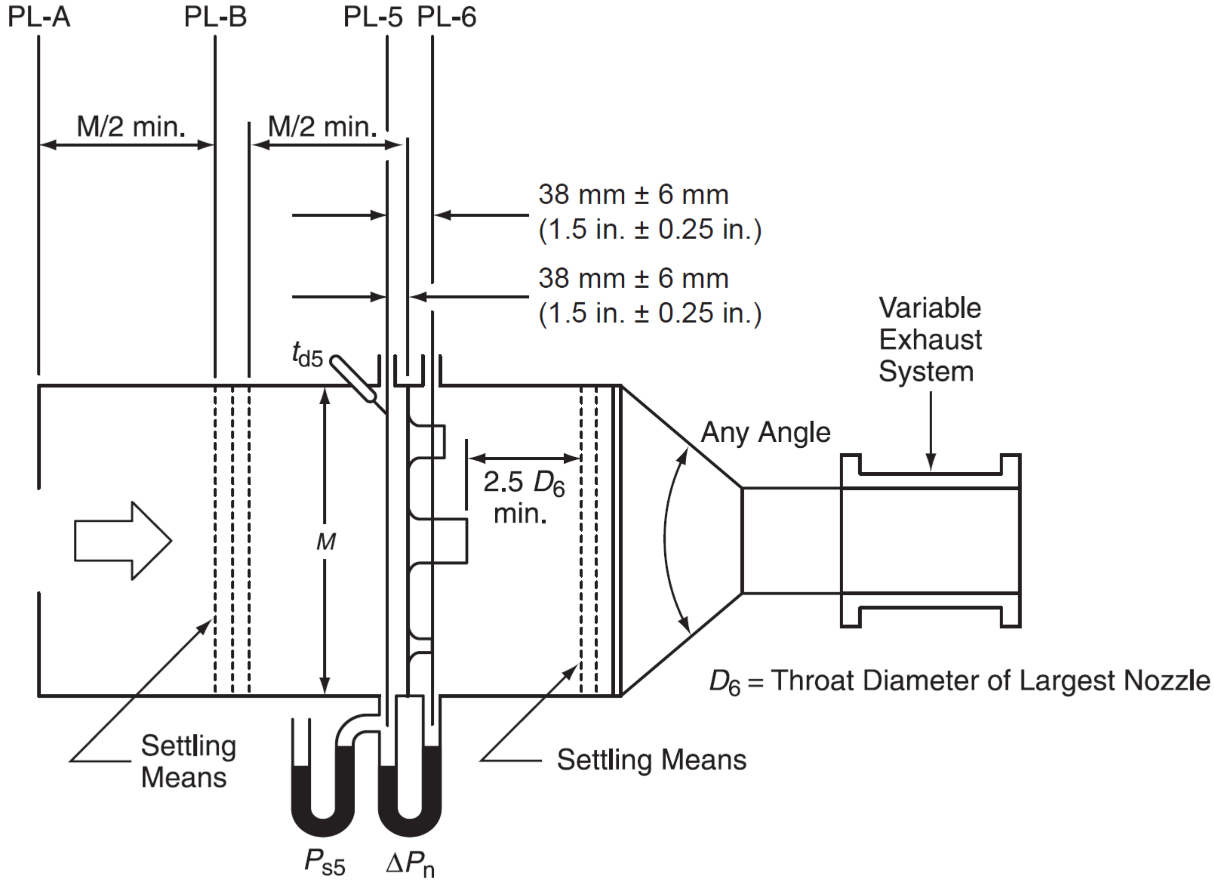


$$Q = Q_5 \left(\frac{\rho_5}{\rho} \right)$$

$$Q_5 = \frac{C A_6 Y \sqrt{\frac{2 \Delta P_n}{\rho_5}}}{\sqrt{1 - E \beta^4}}$$ SI formula

$$Q_5 = \frac{1097.8 C A_6 Y \sqrt{\frac{\Delta P_n}{\rho_5}}}{\sqrt{1 - E \beta^4}}$$ I-P formula

Figure 6.2 — Airflow Rate Measurement Setup: Nozzle on End of Duct



$$Q = Q_5 \left(\frac{\rho_5}{\rho} \right)$$

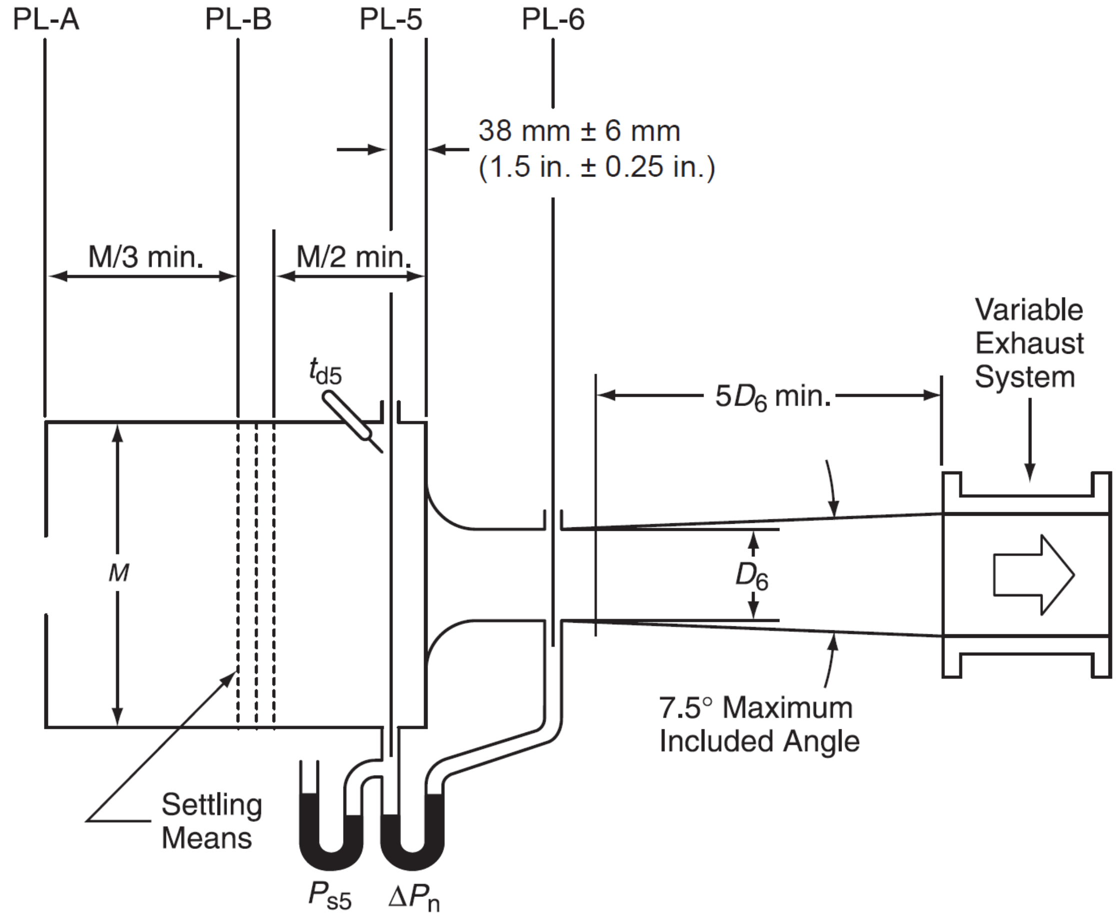
$$Q_5 = Y \sqrt{\frac{2 \Delta P_n}{\rho_5} \sum (C A_6)}$$

SI formula

$$Q_5 = 1097.8 Y \sqrt{\frac{\Delta P_n}{\rho_5} \sum (C A_6)}$$

I-P formula

Figure 6.3 — Airflow Rate Measurement Setup: Multiple Nozzle Chamber on Fan Inlet

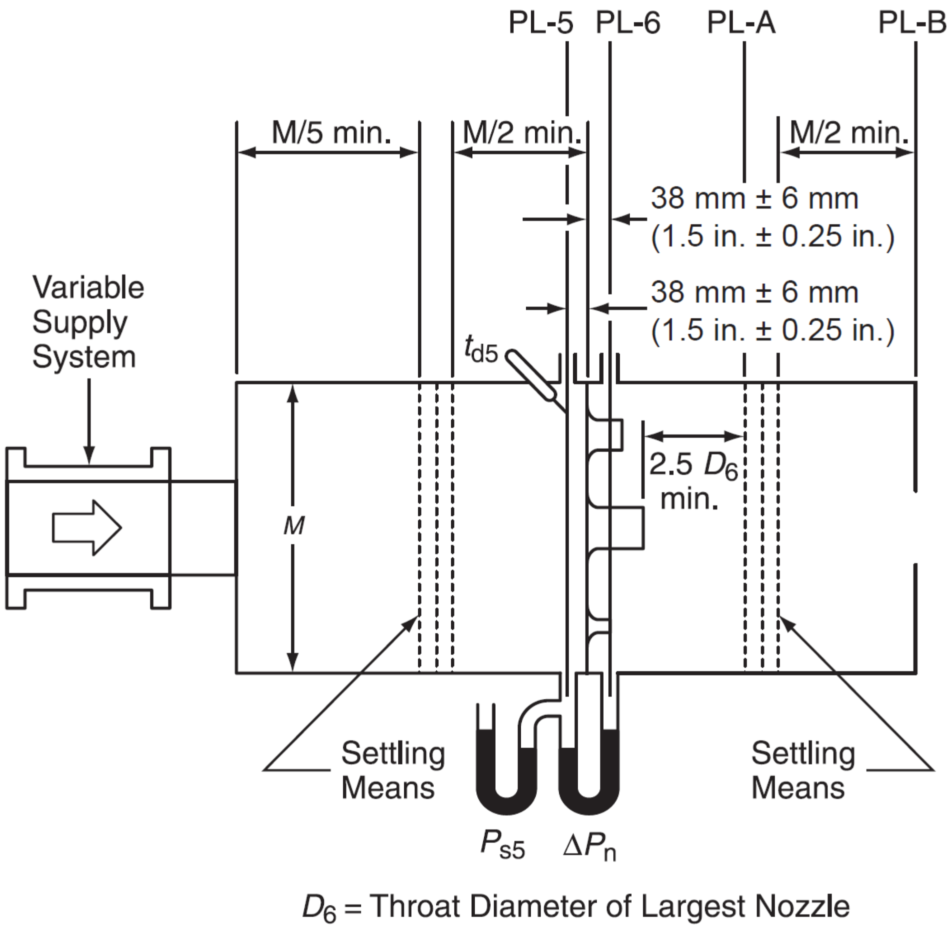


$$Q = Q_5 \left(\frac{\rho_5}{\rho} \right)$$

$$Q_5 = C A_6 Y \sqrt{\frac{2 \Delta P_n}{\rho_5}}$$ SI formula

$$Q_5 = 1097.8 C A_6 Y \sqrt{\frac{\Delta P_n}{\rho_5}}$$ I-P formula

Figure 6.4 — Airflow Rate Measurement Setup: Single Nozzle Chamber



$$Q = Q_5\left(\frac{\rho_5}{\rho}\right)$$

$$Q_5 = Y\sqrt{\frac{2\Delta P_n}{\rho_5}}\sum(CA_6)$$ SI formula

$$Q_5 = 1097.8Y\sqrt{\frac{\Delta P_n}{\rho_5}}\sum(CA_6)$$ I-P formula

Figure 6.5 — Airflow Rate Measurement Setup: Multiple Nozzle Chamber on Fan Outlet

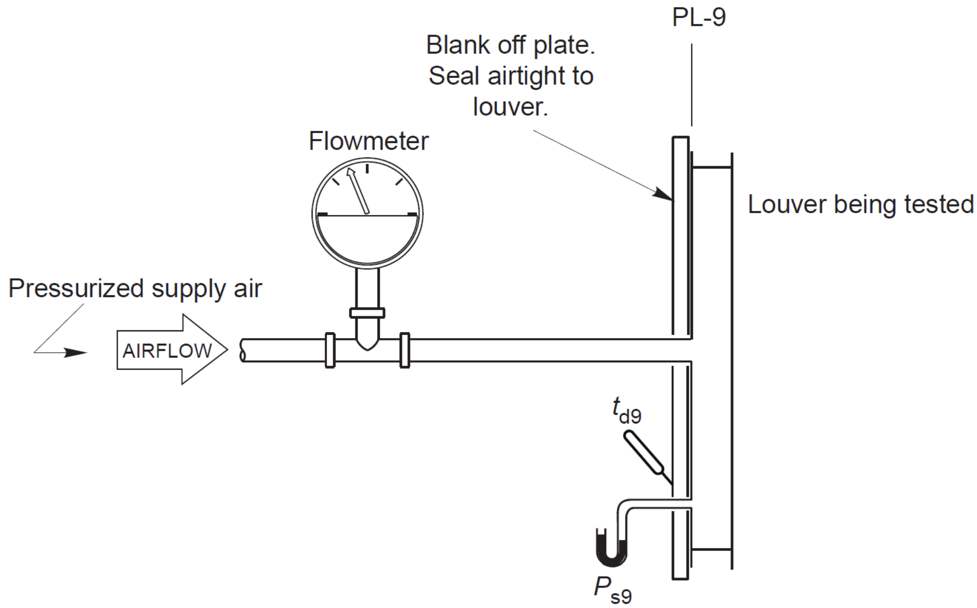


Figure 6.6 A — Test Louver Setup: Leakage Test with Louver Under Positive Pressure

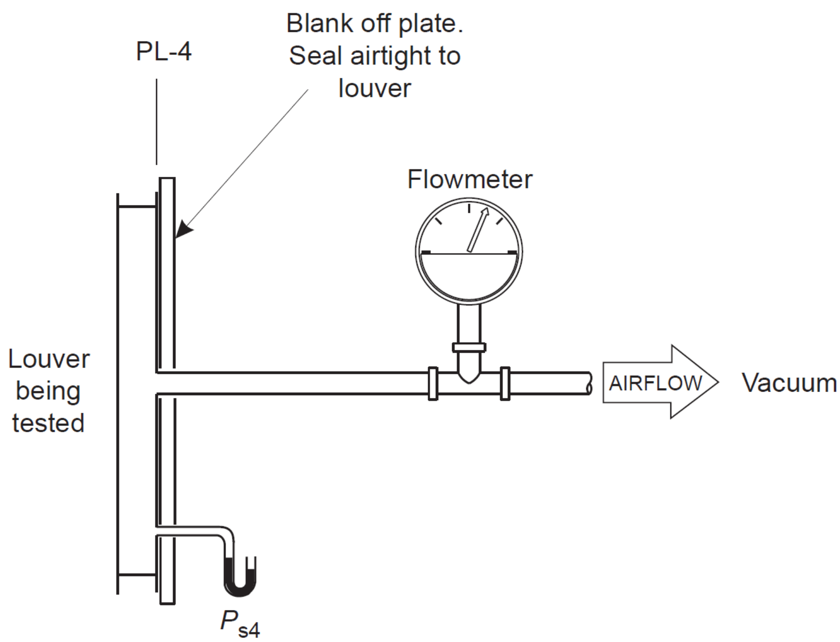
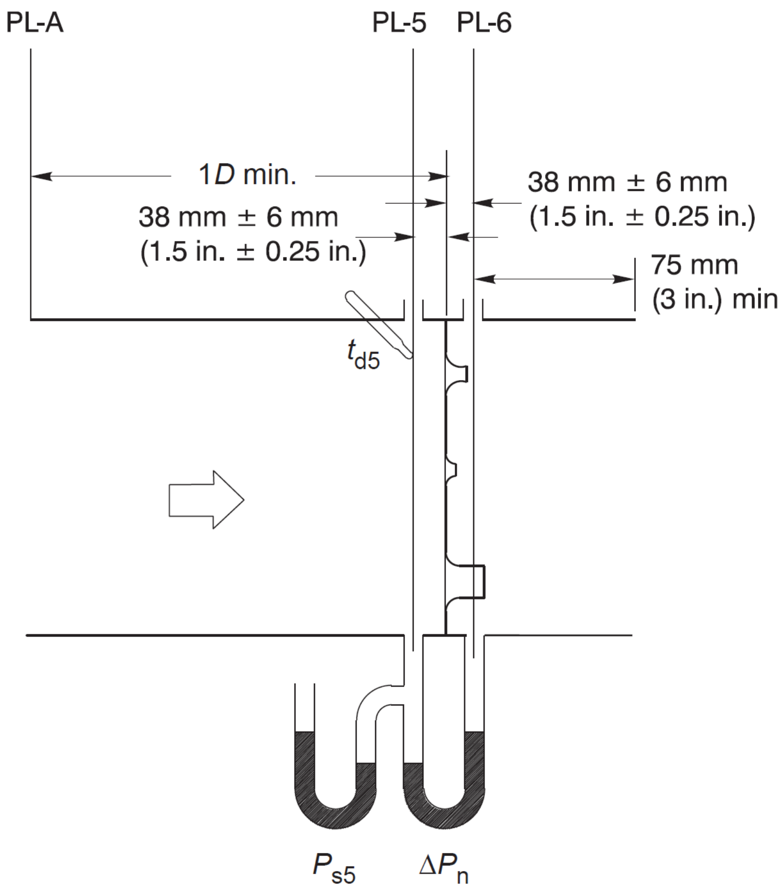


Figure 6.6 B — Test Louver Setup: Leakage Test with Louver Under Negative Pressure



$$Q = Q_5\left(\frac{\rho_5}{\rho}\right)$$

$$Q_5 = Y\sqrt{\frac{2\Delta P_n}{\rho_5}\sum(CA_6)}$$ SI formula

$$Q_5 = 1097.8Y\sqrt{\frac{\Delta P_n}{\rho_5}\sum(CA_6)}$$ I-P formula

Figure 6.6 C — Leakage Chamber

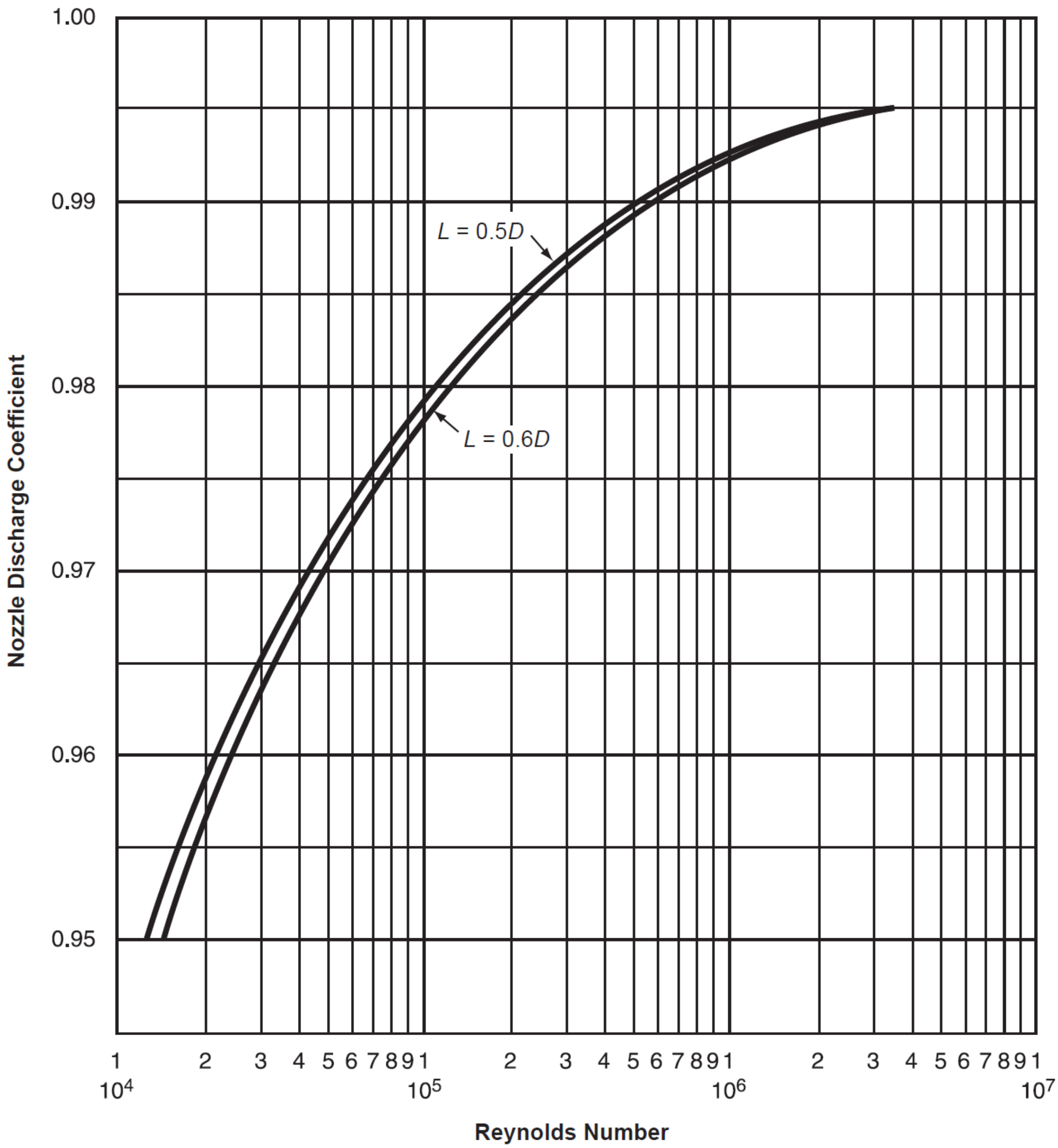
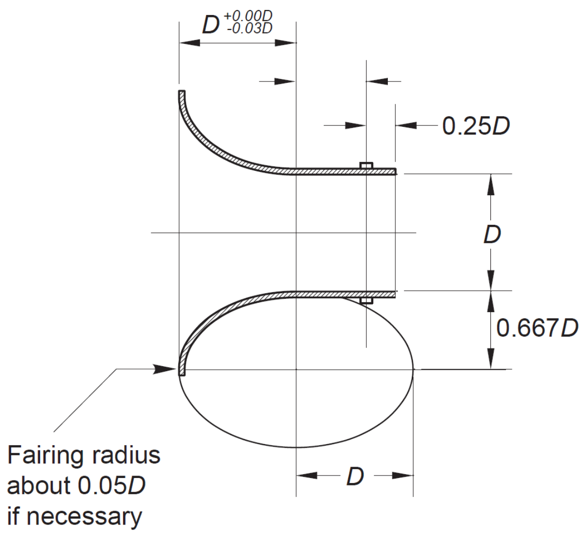
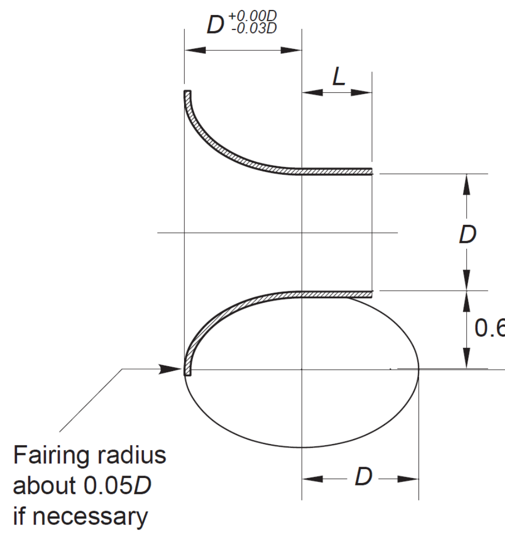


Figure 7 — Coefficients of Discharge for Flow Nozzles



Nozzle with Throat Taps



Nozzle without Throat Taps

Notes:

1. The nozzle shall have a cross section consisting of elliptical and cylindrical portions, as shown. The cylindrical portion is defined as the nozzle throat.
2. The cross section of the elliptical portion is one-quarter of an ellipse, having the large axis *D* and the small axis 0.667*D*. A three-radii approximation of the elliptical form that does not differ at any point in the normal direction by more than 1.5% from the elliptical form shall be used. The adjacent arcs, as well as the last arc, shall smoothly meet and blend with the nozzle throat. The recommended approximation that meets these requirements is shown in Figure 8B in John Cermak's Memorandum Report to AMCA 210/ASHRAE 51P Committee, June 16, 1992.
3. The nozzle throat dimension *L* shall be either 0.6*D* ± 0.005*D* (recommended) or 0.5*D* ± 0.005*D*.
4. The nozzle throat dimension *D* shall be measured (to an accuracy of 0.001*D*) at the minor axis of the ellipse and at the nozzle exit. At each place, four diameters approximately 45º apart must be within ±0.002*D* greater but not less than the mean of the nozzle throat diameter at the nozzle exit.
5. The nozzle surface in the direction of flow from the nozzle inlet to the nozzle exit shall fair smoothly so that a straight edge may be rocked over the surface without clicking. The macro-pattern of the surface shall not exceed 0.001*D* peak to peak. The edge of the nozzle exit shall be square, sharp and free of burrs, nicks or roundings.
6. In a chamber, the use of either of the nozzle types shown above is permitted. A nozzle with throat taps shall be used when the discharge is direct into a duct, and the nozzle outlet should be flanged.
7. A nozzle with throat taps shall have four such taps conforming to Figure 4 located 90° ± 2° apart. All four taps shall be connected to a piezometer ring.

Figure 8A — Nozzles

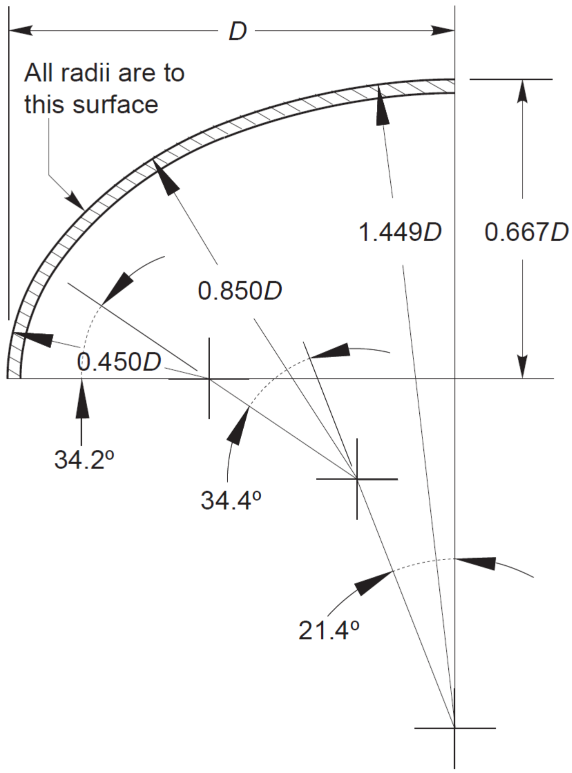
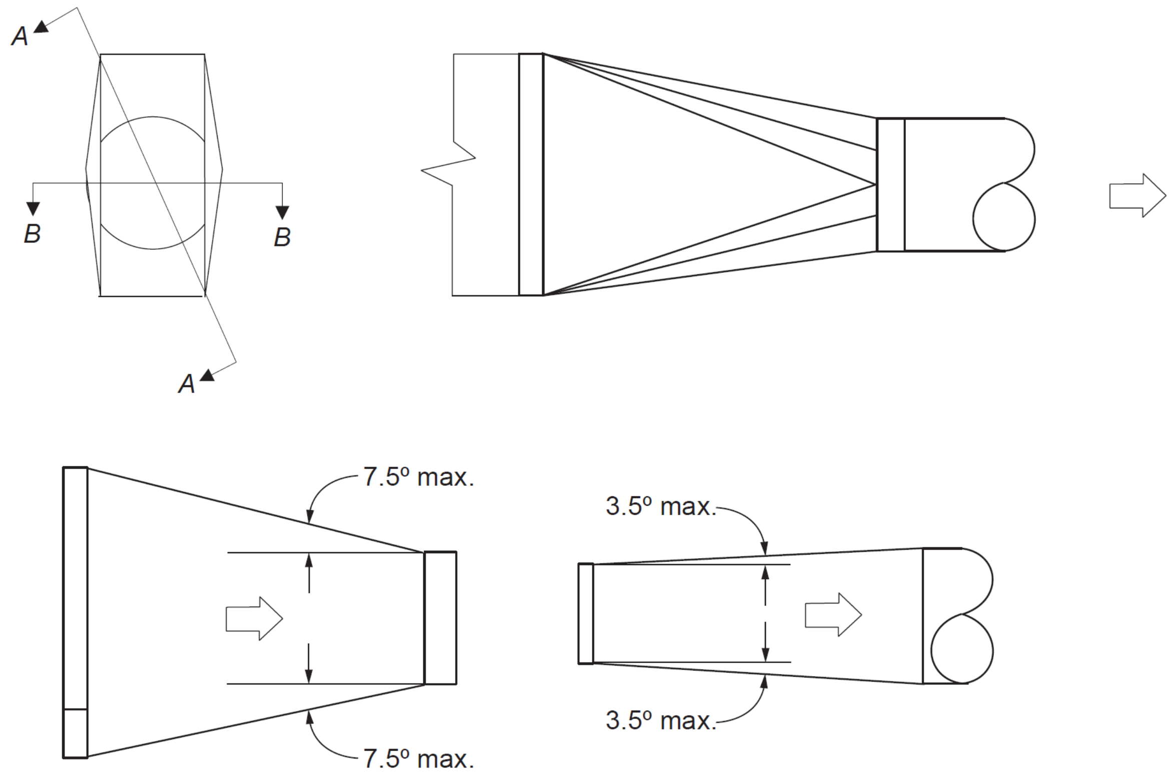


Figure 8B — Three Arc Approximation of Elliptical Nozzle



Section A-A
(Converging Section)

Section B-B
(Diverging Section)

Figure 9 — Transformation Pieces

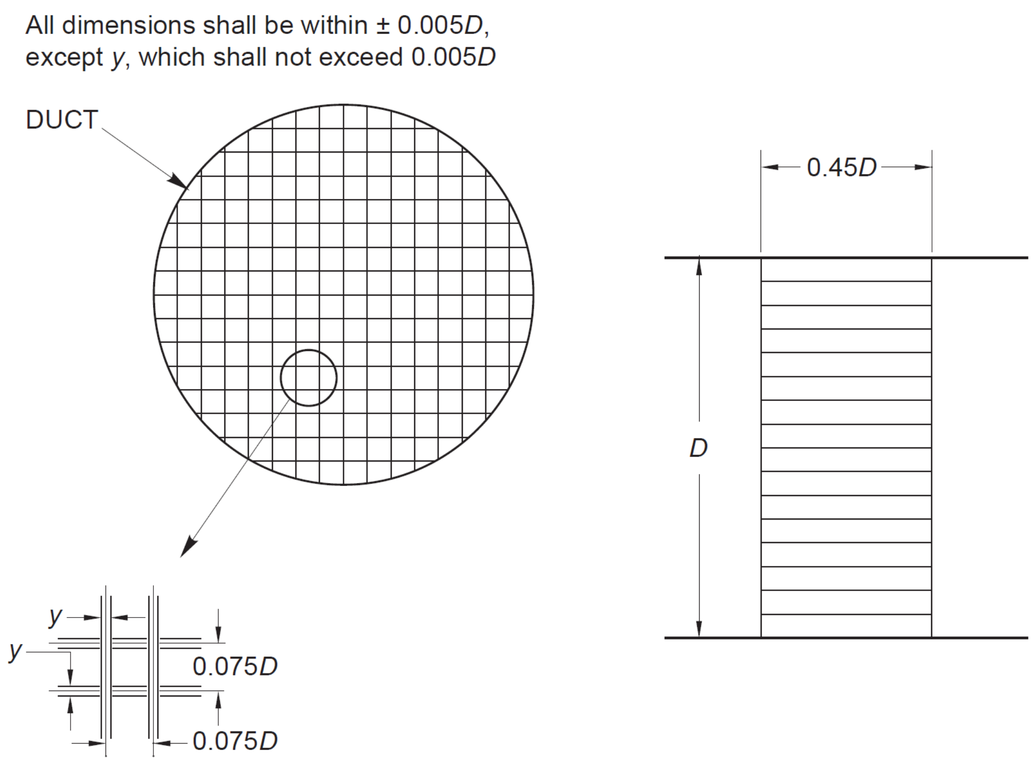
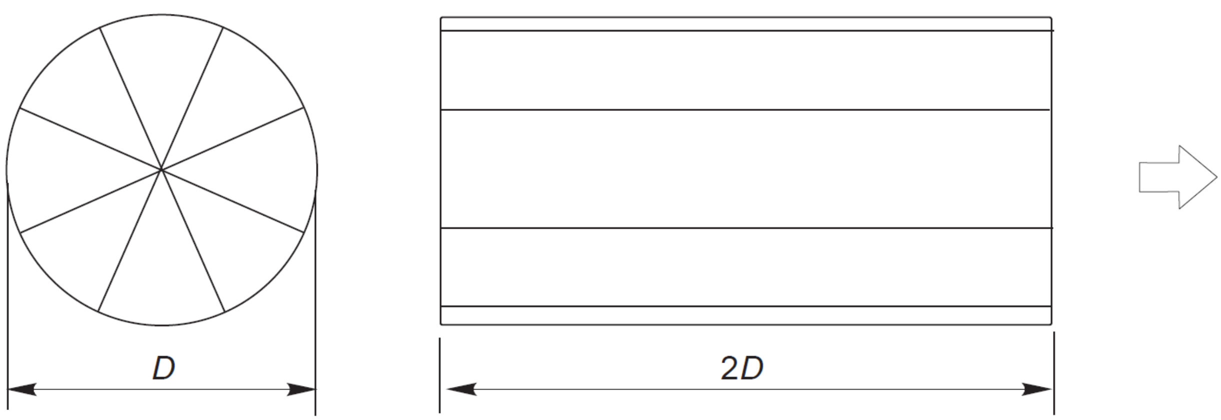
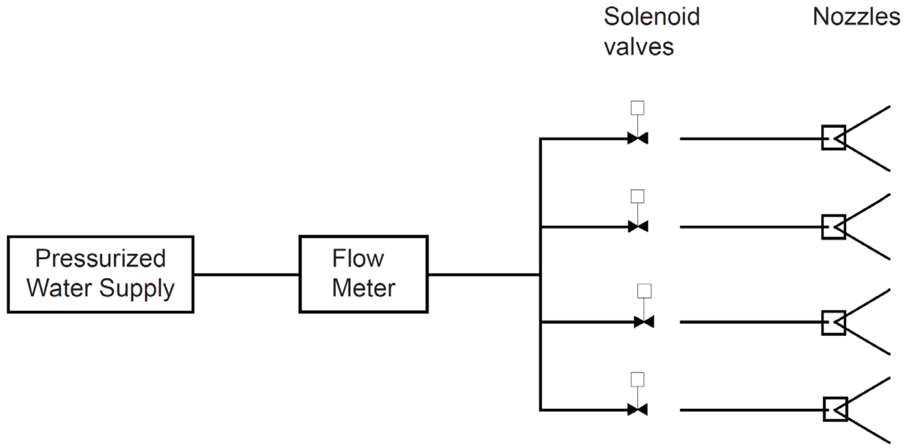


Figure 10A — Flow Straightener



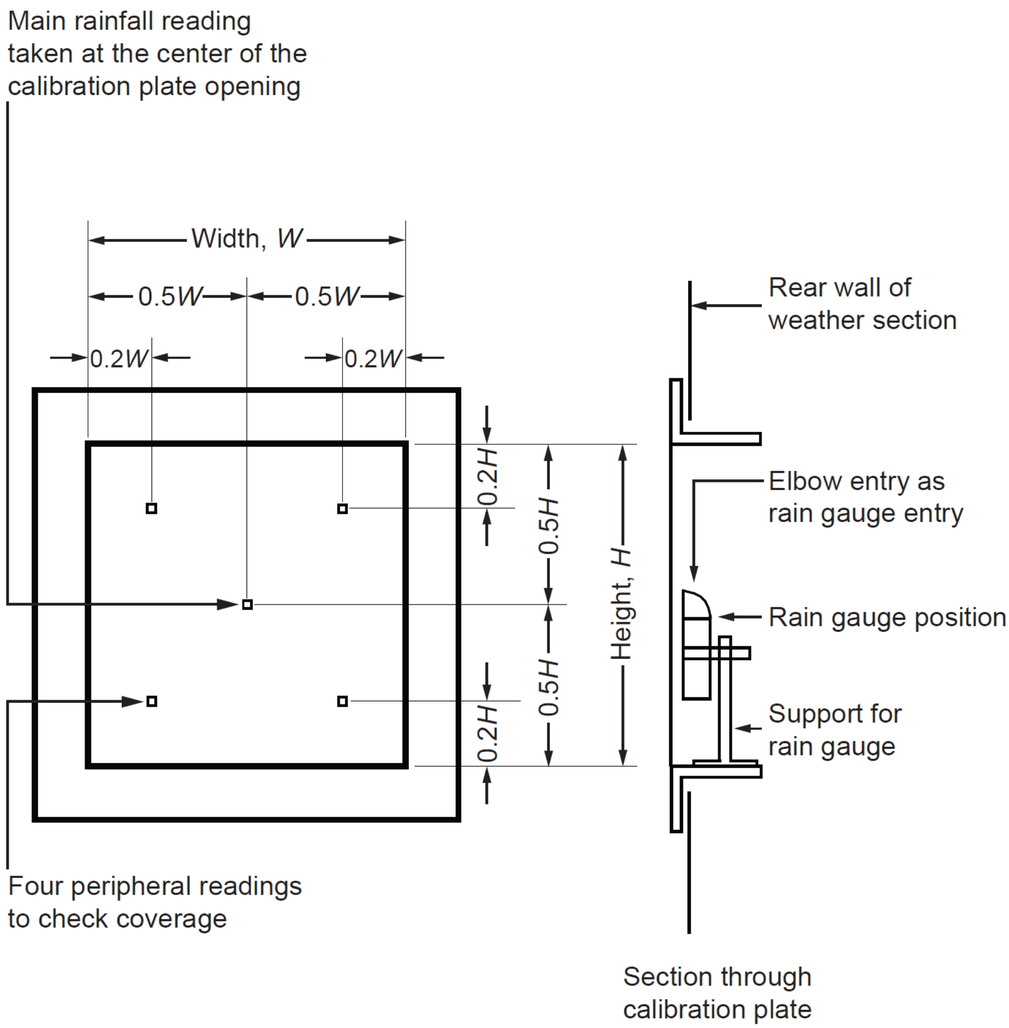
Note: The devices shown are the primary airflow straighteners for Section 5.2.3.

Figure 10B — Star Straightener



This figure, adapted from HEVAC Technical Specification, Laboratory Testing and Rating of Weather Louvers When Subjected to Simulated Rainfall, is courtesy of Heating Ventilating and Air Conditioning Manufacturers Association.

Figure 11 — Schematic Diagram of Nozzle Control System



This figure, reproduced from HEVAC Technical Specification, Laboratory Testing and Rating of Weather Louvers When Subjected to Simulated Rainfall, is courtesy of Heating Ventilating and Air Conditioning Manufacturers Association.

Note: Calibration or weather louver core area = $W \times H$

Figure 12 — Core Area and Rainfall Coverage

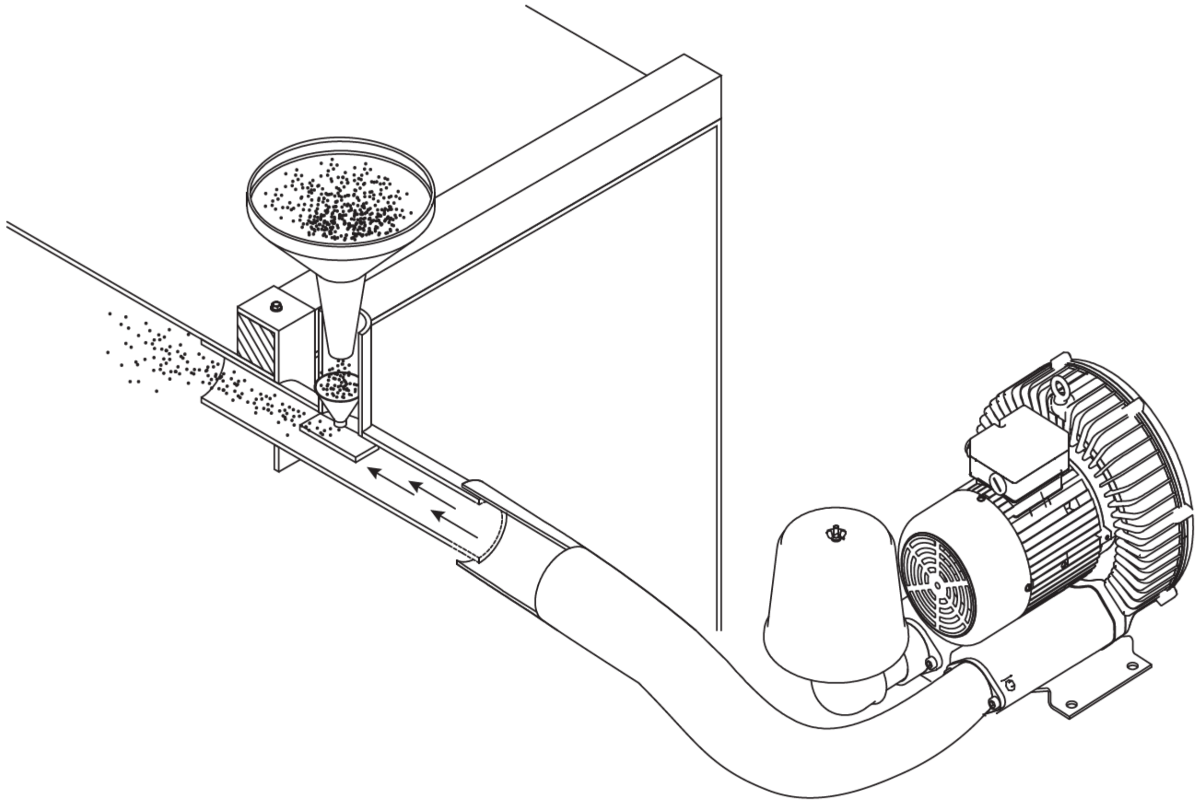


Figure 13 — Typical Sand Injector Equipment

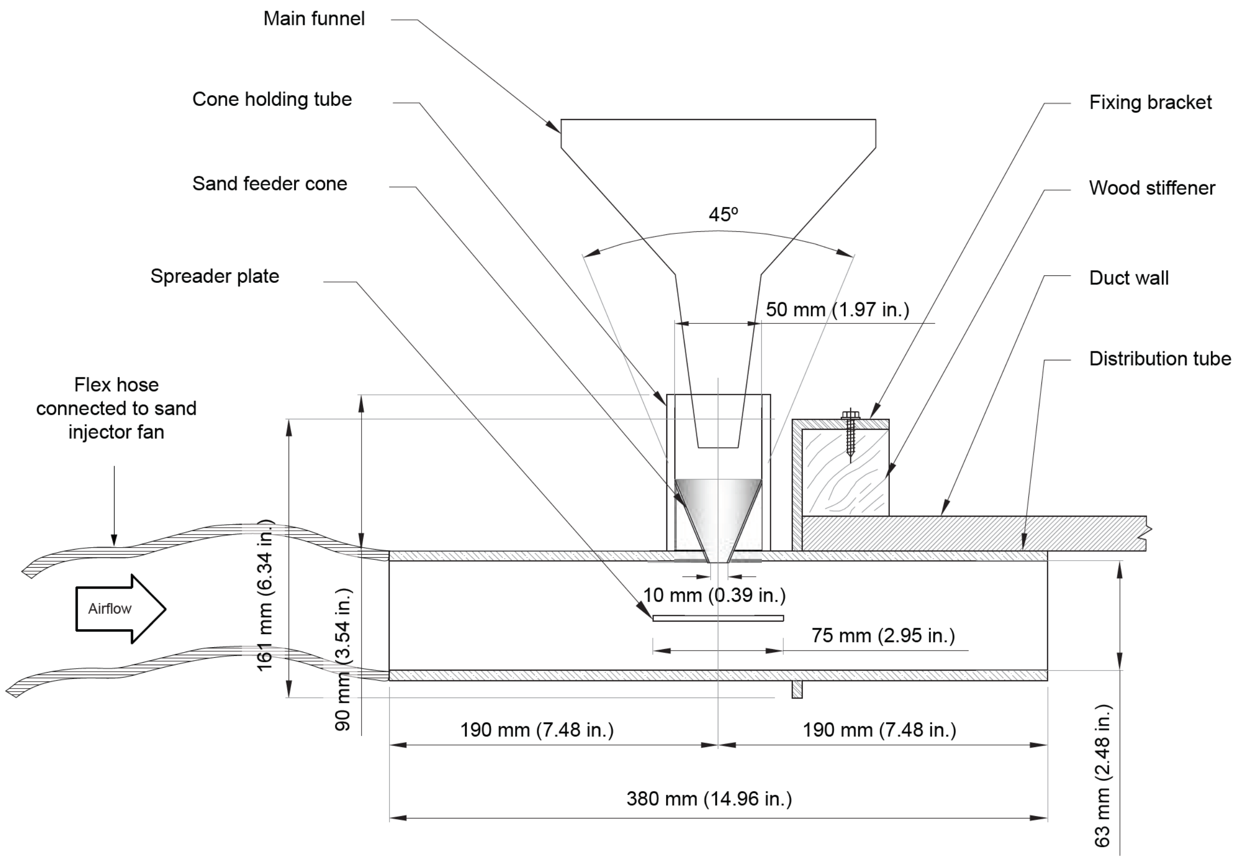


Figure 14 — Sand Injector Feeder Cone and Distribution Tube

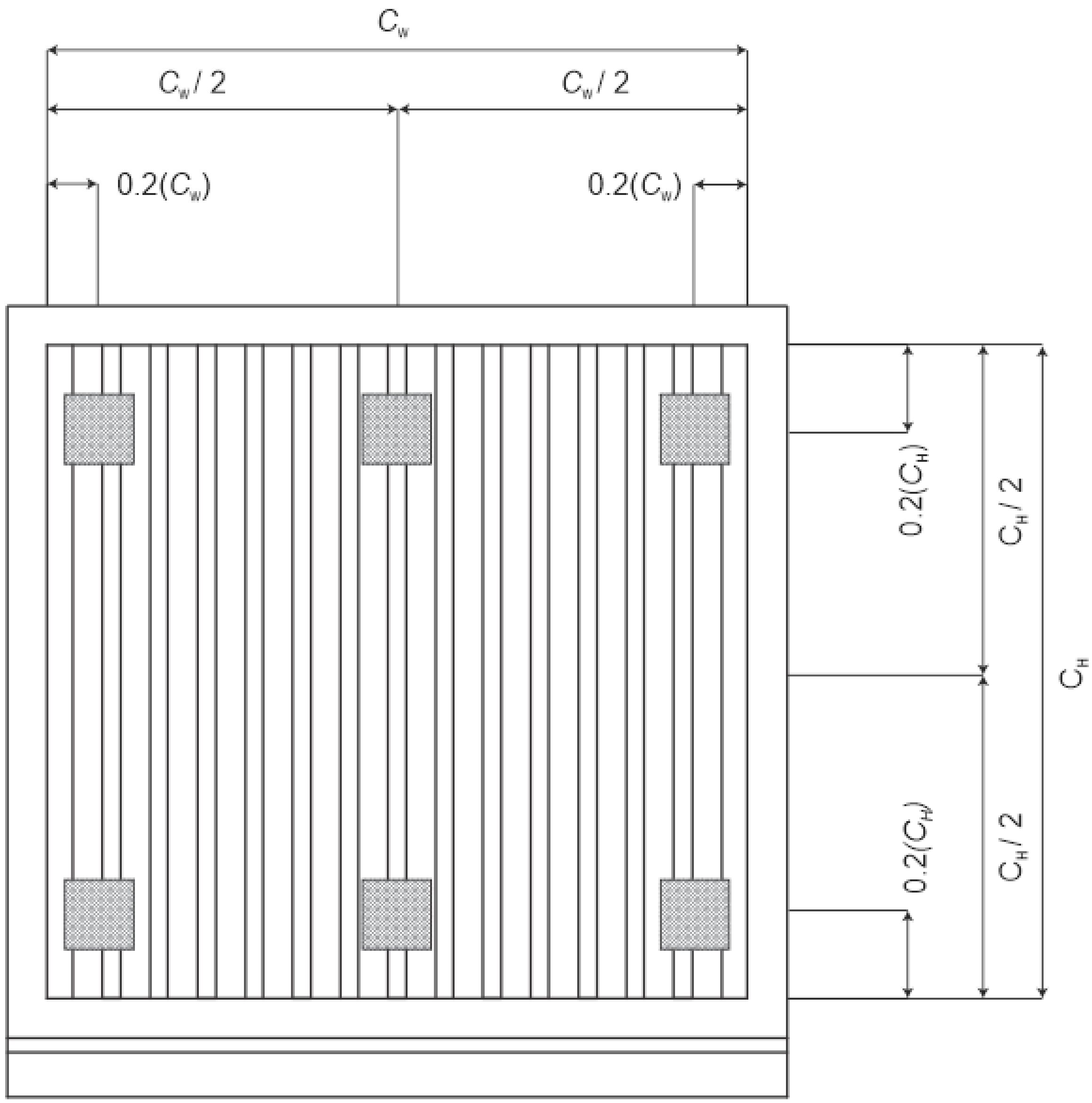


Figure 15 — Pretest of Sand Distribution: Arrangement of Squares

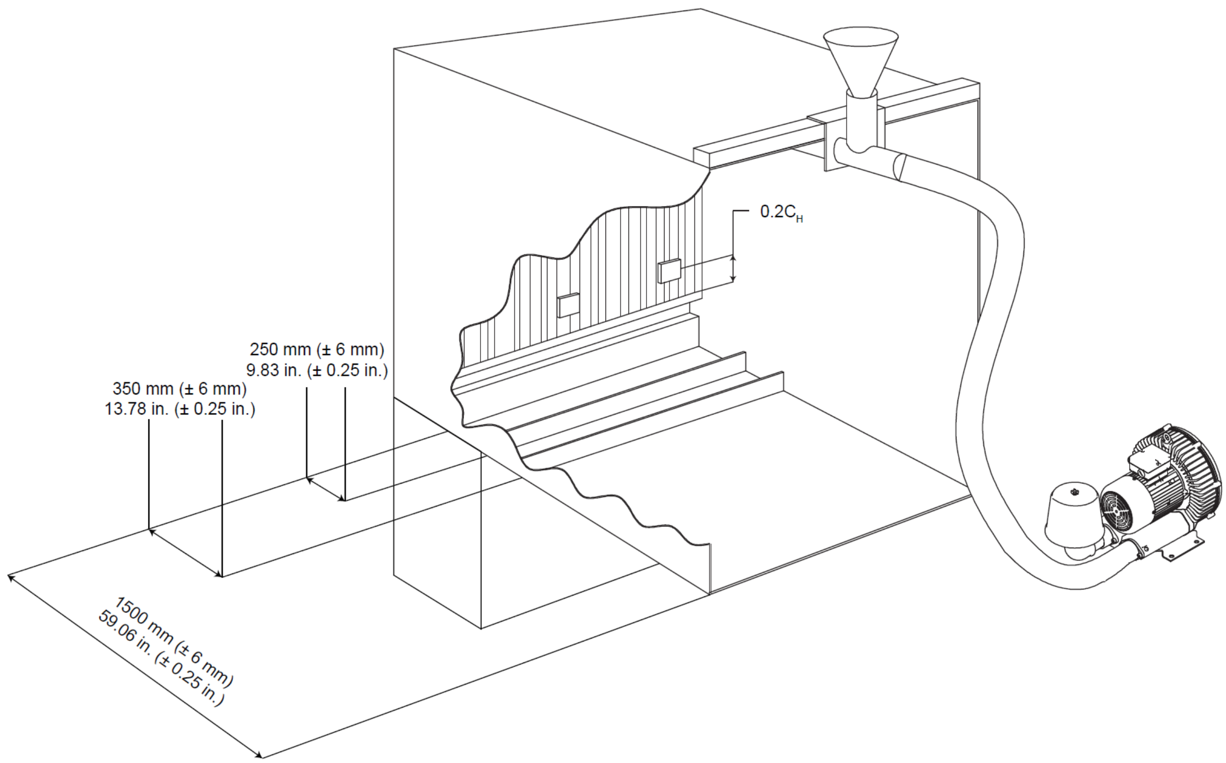


Figure 16 — Pretest of Sand Distribution: Arrangement of Strips

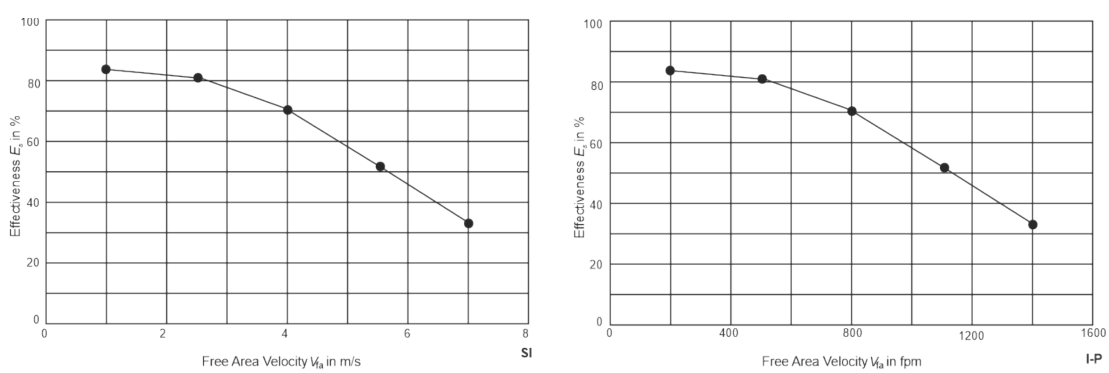


Figure 17 — Example Graphs of the Sand Rejection Effectiveness of a Louver

Annex A
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Annex B
Simulated Rain Spray Nozzles (Normative)

The general arrangement of the simulated rain spray nozzles shall be as indicated in Figure 5.11.

The overall required effect is to cover the area of the louver and calibration plate in a uniform manner.

To achieve a satisfactory trajectory, water flow rate, and droplet size from the nozzles, it is necessary to spray water from the nozzles in short bursts, with only one of the nozzles spraying at any instant, for a 76 mm/hr (3 in./hr) specified rainfall penetration rate. For a greater than 76 mm/hr (3 in./hr) specified rainfall penetration rate, water should be sprayed from additional nozzles, which can be achieved by connecting each nozzle array to an electrically or mechanically operated timer valve, as shown in Figure 11.

The water supply pressure to the nozzle array shall be kept constant and the water flow sufficient to ensure that the droplet size is significant.

The nozzles used shall be of the wide spray type, featuring a solid cone-shaped spray pattern with a square impact area and a spray angle of 93° to 115° with the specified capacity at 30 kPa (4.35 psi) pressure.

Annex C
Wind-Driven-Rain Performance (Normative)

Penetration classification

Louvers shall be classified by their ability to reject simulated rain. Table 7 shows different classifications based on the maximum simulated rain penetration per square meter (square foot) of louver core area. Effectiveness rating at a given louver core velocity is determined by the water penetration while the louver is subjected to a selected simulated rainfall rate and wind velocity.

Table C.1 — Classifications Based on Maximum Simulated Rain Penetration Per Square Meter of Louver Core Area

Class	Effectiveness	Maximum allowed penetration, $l/h/m^2$ (SI)		Maximum allowed penetration, $oz/h/ft^2$ (I-P)	
		76 mm/hr rainfall, 13 m/s wind velocity	203 mm/hr rainfall, 22.4 m/s wind velocity	3 in./hr rainfall, 29 mph wind velocity	8 in./hr rainfall, 50 mph wind velocity
A	100% to 99%	0.75	4.0	2.36	12.6
B	98.9% to 95%	3.75	20.0	11.8	67.8
C	94.9% to 80%	15.0	80.0	47.1	251.0
D	Below 80%	Greater than 15.0	Greater than 80.0	Greater than 47.1	Greater than 251.0

Note: These classifications apply at various core velocities.

Annex D
Core Area Measurements (Normative)

The core area measurement shall be measured to a frame profile feature that is at or within 12.7 mm (0.50 in.) of the exterior face of that same frame member. For this section, the phrase “setback region” is defined as the above possible locations for core measurement. In the examples below (Figures D.1, D.2 and D.3), the shaded section of the profile represents various profile features to be taken under consideration for the core measurement location. Following are exceptions for the sill frame member only:

1. The sill’s setback region shall begin at the exterior face of the jamb or head, whichever is more exterior.
2. Radii less than or equal to 6.35 mm (0.25 in.) shall be considered sharp corners, and measurements shall be taken to the sharp corner (Examples A2, B2, D2, and M2). If the sharp corner is an acute angle, then the measurement shall be taken at the point where a horizontal line intersects the profile’s radius (Example F2).
3. Where a curved or sloped surface occurs within the sill’s setback region, the measurement (after adhering to Exception 2) shall be taken at the location where the sloped or curved surface diverges from a vertical surface. This will typically force the measurement location to be close to the exterior face of the louver (Examples C2, D2, E2, and M2).
4. Where a baffle occurs in front of or within the sill’s setback region, the measurement shall be taken at the highest point of the baffle. A baffle is a profile feature that protects the sill’s wetted surface from direct wind and/or rain (Examples G2, H2, J2, and K2).
5. If the sill does not extend into the setback region, then the core measurement shall be taken to the sill’s lowest profile point (Example L2).

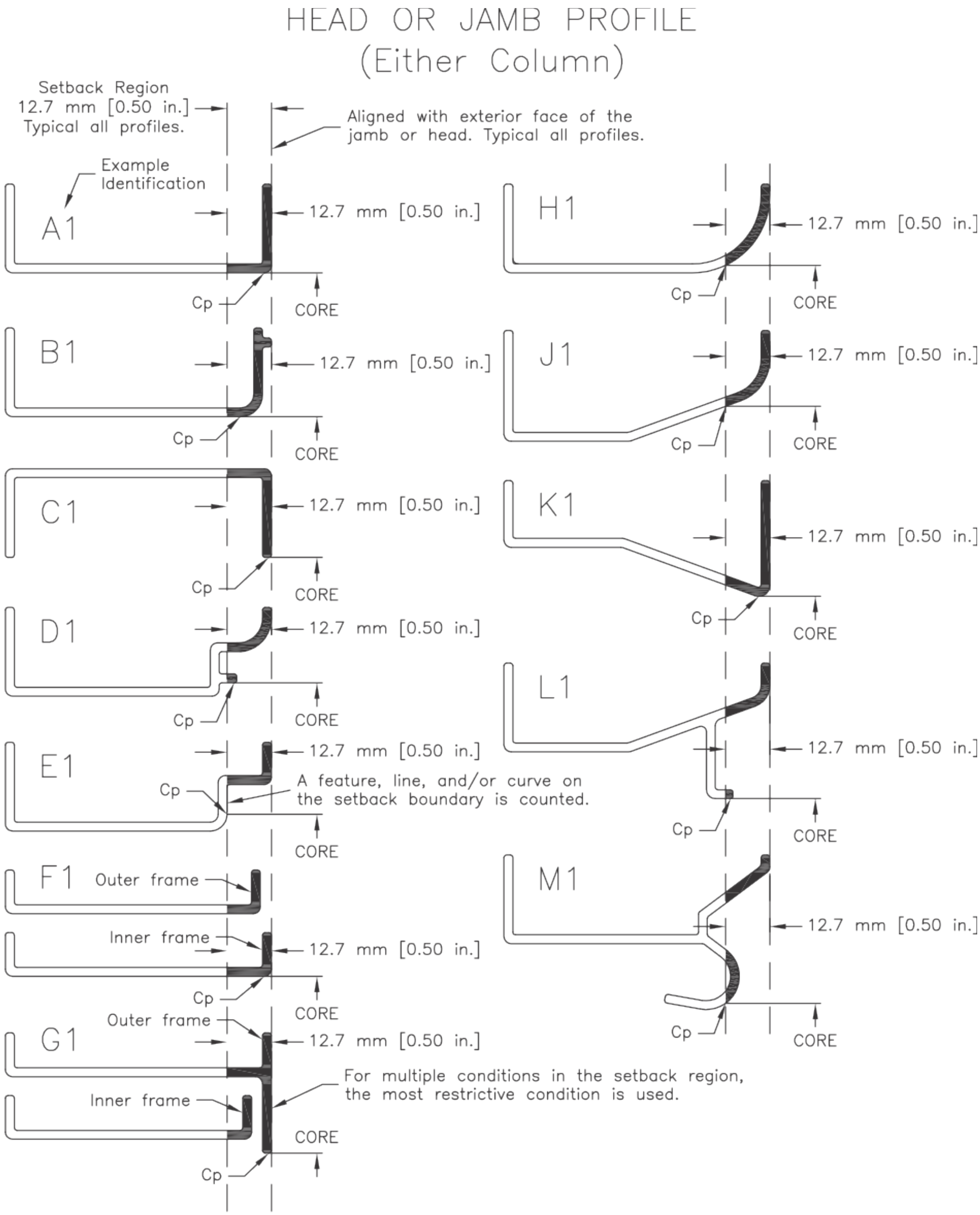

Figure D.1 — Head or Jamb Profiles

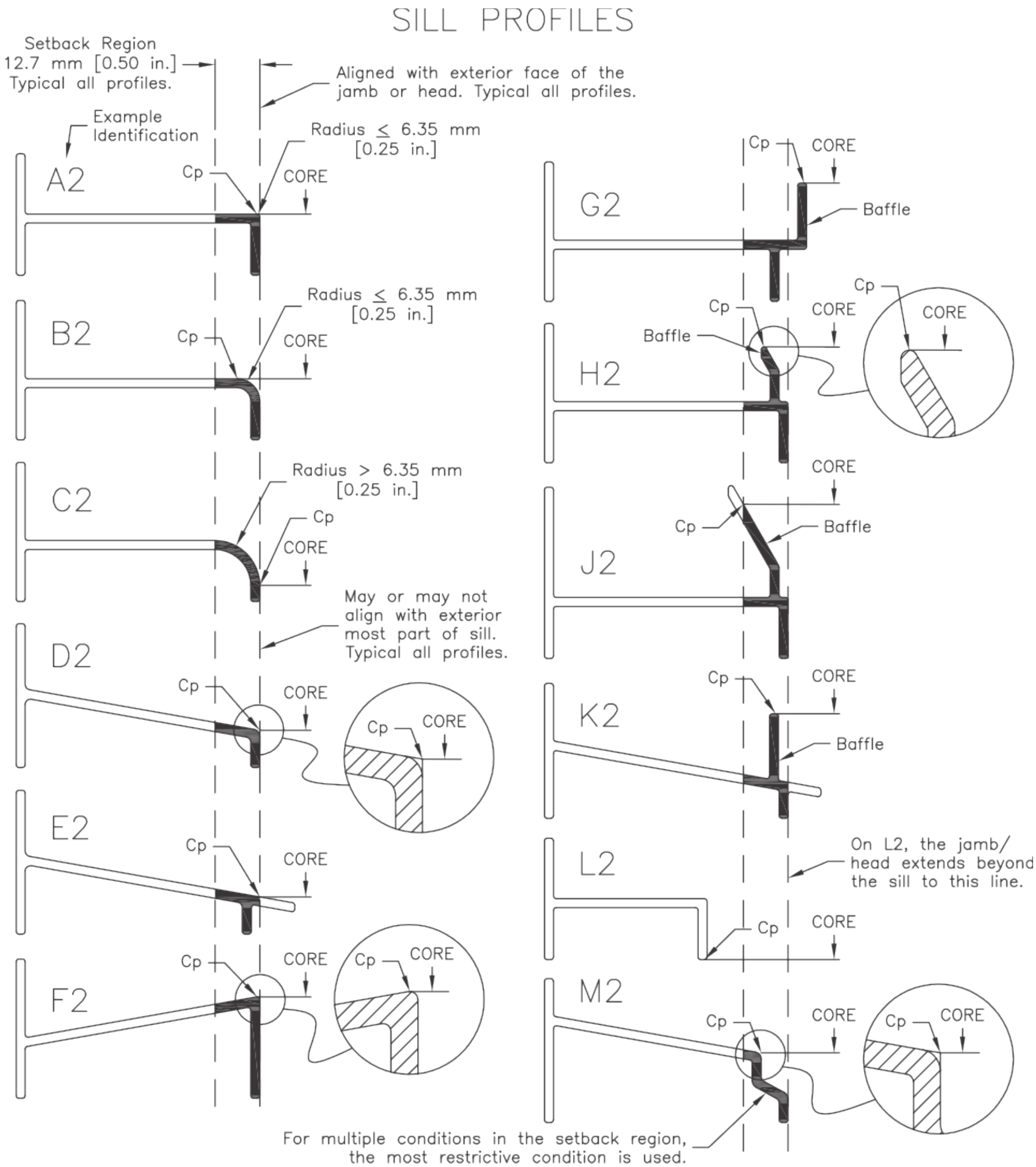

Figure D.2 — Sill Profiles

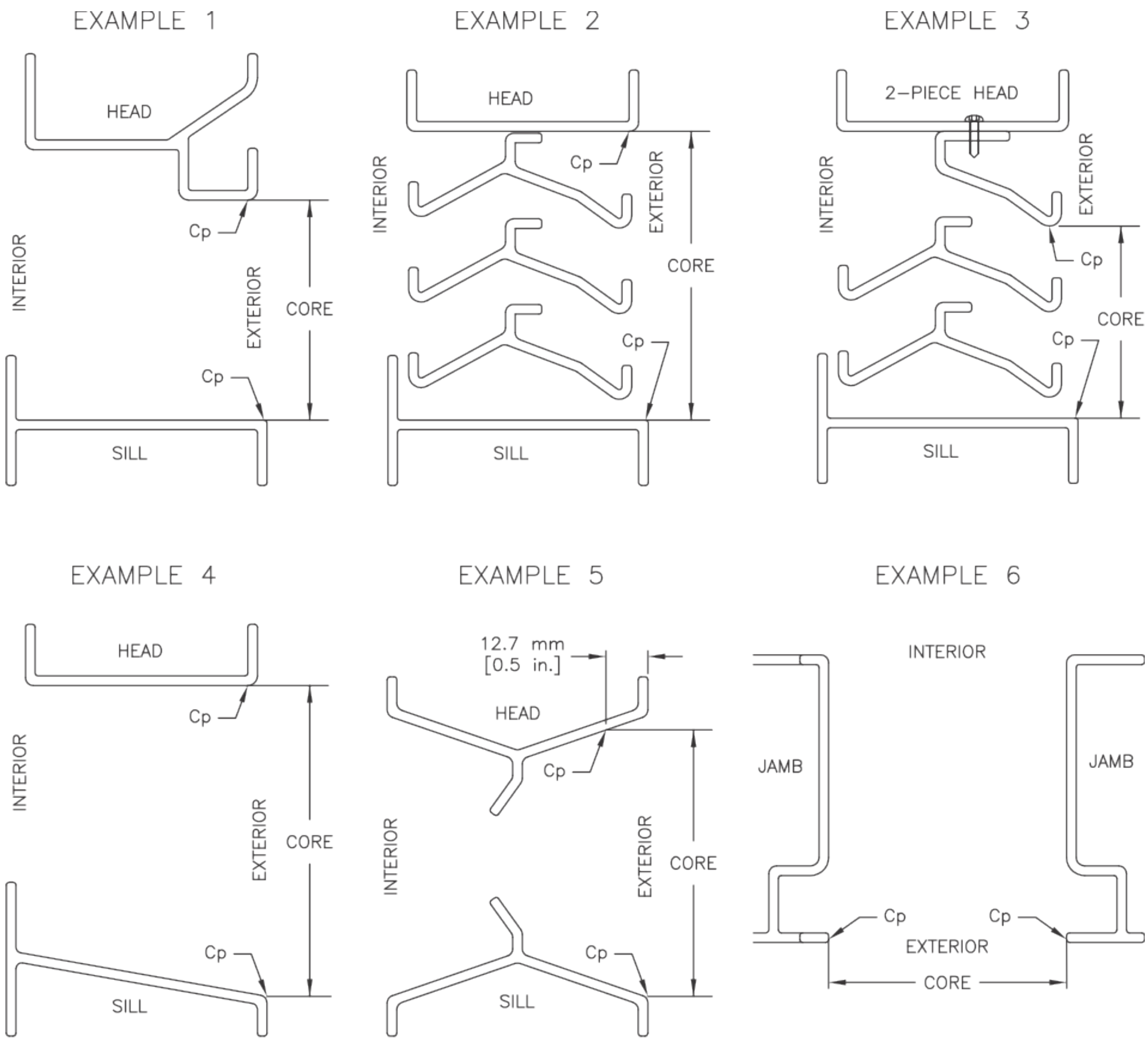

Figure D.3 — Head and Sill Examples

Annex E
Grading of the Sand Used for the Wind-Driven-Sand Test (Normative)

The standard test sand used throughout the wind-driven-sand test shall be dry and conform to Table 8.

Table E.1 — Requirements for Standard Test Sand

Grade (μm)	>699	423-699	353-422	251-352	211-250	152-210	104-151	76-103	<76
Mass (%)	0.5	3.0	12.0	30.0	20.0	27.0	6.0	1.0	0.5

The standard test sand specifications within Table 8 illustrate an overall grade of desert type sand and dust.

Annex F
Louvers to be Certified for their Wind-Driven-Rain Performance (Informative)

Louvers identified to be certified through AMCA Publication 511 shall follow the below guidelines:

1. The wind-driven-rain test shall be conducted using one of the two below combinations of specified rainfall penetration rate (v_c) and wind velocity (V_w):

    - 76 mm/hr and 13 m/s (3 in./hr and 29 mph)
    - 203 mm/hr and 22.4 m/s (8 in./hr and 50 mph)

2. The test shall be conducted at a maximum target core velocity (v_c) of 3.5 m/s (689 fpm) or 5.0 m/s (984 fpm). Additional test points shall be conducted at all target core velocities shown on the below list that are less than the chosen maximum target core velocity:

    - 0.0 m^3/s (0 fpm)
    - 0.5 m^3/s (98 fpm)
    - 1.0 m^3/s (197 fpm)
    - 1.5 m^3/s (295 fpm)
    - 2.0 m^3/s (394 fpm)
    - 2.5 m^3/s (492 fpm)
    - 3.0 m^3/s (591 fpm)
    - 3.5 m^3/s (689 fpm)
    - 4.0 m^3/s (787 fpm)
    - 4.5 m^3/s (886 fpm)

    Exceptions:

    a. If a test point achieves an effectiveness (E_w) rating of 100.0%, then testing of all lesser target core velocities shall be optional. An optional test point shall be allowed to be rated as 100.0% effective with a penetration classification rating of “A” under the same test conditions (specified rainfall penetration rate and wind velocity).

    b. If three test points receive a penetration classification rating of “A” and all three test points are sequential when ordered based on target core velocity, then testing of all lesser target core velocities shall be optional. An optional test point shall be allowed to receive a penetration classification rating of “A” under the same test conditions (specified rainfall penetration rate and wind velocity). An optional test point shall not receive an effectiveness (E_w) rating, unless the optional test point was actually tested.

    The above exception rules apply even if a lesser target core velocity test point is tested (the ratings of the lesser test point may be adjusted as noted).

Annex G
Discharge Loss Coefficient and Class (Normative)

Discharge Loss Coefficient (C_D) = (Actual Flow)/(Theoretical Flow)

$$\text{Theoretical Flow} = A_c\sqrt{2P_{s1}/\rho_1}$$ SI Eq. G.1

$$\text{Theoretical Flow} = 1097.8 \times A_c\sqrt{P_{s1}/\rho_1}$$ I-P Eq. G.2

Where:

A_c = core area, m^2 (ft^2) of the louver

P_{s1} = pressure drop across opening, Pa (in. wg)

ρ_1 = density, kg/m^3 (lbm/ft^3)

Table G.1 — Discharge Loss Coefficient Classes

Class	Discharge Loss Coefficient
1	0.4 and above
2	0.3 to 0.399
3	0.2 to 0.299
4	0.199 and below

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