

ANSI/AMCA Standard 500-L-12

Laboratory Methods of Testing Louvers for Rating

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ANSI/AMCA Standard 500-L-12

Laboratory Methods of Testing Louvers for Rating



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Related AMCA Documents

Related Publications

AMCA Publication 501	<i>Application Manual for Louvers</i>
AMCA Publication 504	<i>Application Manual for Sun Control Devices</i>
AMCA Publication 511	<i>Certified Ratings Program - Product Rating Manual for Air Control Devices</i>
AMCA Publication 512	<i>AMCA Listing Label Program</i>

Related Standards

ANSI/AMCA Standard 540	<i>Test Method for Louvers Impacted by Wind Borne Debris</i>
ANSI/AMCA Standard 550	<i>Test Method for High Velocity Wind Driven Rain Resistant Louvers</i>

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Laboratory Methods of Testing Louvers for Rating

1. Purpose

The purpose of this standard is to establish uniform laboratory test methods for louvers. Characteristics to be determined include air leakage, pressure drop, water penetration, wind driven rain, 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 used 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 acceptability level of performance. It is not the scope of this standard to indicate actual sequences of testing, nor is it in its scope 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 which 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 Measurement / Symbols

3.1 Definitions

3.1.1 Louver

A louver is a device comprised of multiple blades which, when mounted in an opening, permits the flow of air but inhibits the entrance of other elements.

3.1.1.1 Fixed blade louver

A louver in which the blades do not move.

3.1.1.2 Adjustable blade louver

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

3.1.1.3 Combination louver

A louver having both fixed and adjustable blades.

3.1.3 Free area

The minimum area through which air can pass.

For horizontal blade louvers, free area is determined by mul-

tiplying 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, it 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.

The percent of free area is the free area thus calculated, divided by the gross area of the air control louver $\times 100$. See louver cross-sections (Figure 1).

3.1.3.1 Free area velocity

Airflow through a louver divided by its free area.

3.1.4 Face area and core area

3.1.4.1 Face area

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

3.1.4.1.1 Face area velocity

Airflow through a louver divided by its face area.

3.1.4.2 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 G).

3.1.4.2.1 Louver calibration plate

The louver calibration plate is a plate having an opening of the same geometric shape and dimensions as the core area of the test specimen.

3.1.4.2.2 Core area velocity

The airflow rate through the louver divided by the core area.

3.1.4.2.3 Core ventilation rate

The airflow rate through the core area of the louver.

3.1.5 Psychrometrics

3.1.5.1 Dry-bulb temperature (t_d)

The air temperature measured by a dry temperature sensor.

3.1.5.2 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.

3.1.5.3 Wet-bulb depression

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

3.1.5.4 Stagnation (total) temperature (t_t)

The temperature that exists by virtue of the internal and kinetic energy of the air. If the air is at rest, the stagnation (total) temperature will equal the static temperature.

3.1.5.5 Static temperature (t_s)

The temperature which exists by virtue of the internal energy of the air only. If a portion of the internal energy is converted into kinetic energy, the static temperature will be decreased accordingly.

3.1.5.6 Air density (ρ)

The mass per unit volume of air.

3.1.5.7 Standard air

Standard air is air with a density of 1.2 kg/m³ (0.075 lbm/ft³), a ratio of specific heats of 1.4, 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.

3.1.6 Pressure

3.1.6.1 Pressure (P)

Force per unit area. This corresponds to energy per unit volume of fluid.

3.1.6.2 Absolute pressure (p)

The value of a pressure when the datum pressure is absolute zero. It is always positive.

3.1.6.3 Barometric pressure (p_b)

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

3.1.6.4 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.

3.1.6.5 Velocity pressure (P_v)

That portion of the air pressure which exists by virtue of the rate of motion only. It is always positive.

3.1.6.6 Static pressure (P_s)

That portion of the air pressure which exists by virtue of the degree of compression only. If expressed as gauge pressure, it may be negative or positive.

3.1.6.7 Total pressure (P_t)

The air pressure which 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.

3.1.6.8 Pressure differential

The change in static pressure across a louver.

3.1.7 Performance variables

3.1.7.1 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.

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.

3.1.7.2 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.

3.1.7.3 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.

3.1.7.4 Wind-driven rain

3.1.7.4.1 Louver effectiveness

The effectiveness of a louver at any core area velocity through the louver is the insertion loss of the louver assembly divided by the water penetration of the calibration plate at that velocity.

3.1.8 Miscellaneous

3.1.8.1 Shall and should

The word *shall* is to be understood as mandatory; the word *should* as advisory.

3.1.8.2 Determination

A determination is 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 3.1.7.

3.1.8.3 Test

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

3.1.8.4 Energy factor

Energy factor is the ratio of the total kinetic energy of the

airflow to the kinetic energy corresponding to the average velocity of air.

3.2 Units of measure

3.2.1 System of units

SI units (The International System of Units, Le Système International d'Unités) [1] 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 [1], 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 unit of length is the meter (m) or millimeter (mm); I-P units are the foot (ft) or the inch (in.). The unit of mass is the kilogram (kg); the I-P unit is the poundmass (lbm). The unit of time is either the minute (min) or the second (s). The unit of temperature is either the degree Celsius (°C) or kelvin (K). I-P units are either the degree Fahrenheit (°F) or the degree Rankine (°R). The unit of force is the newton (N); the I-P unit is the pound (lb).

3.2.3 Airflow rate and velocity

3.2.3.1 Airflow rate

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

3.2.3.2 Airflow velocity

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

3.2.4 Water flow rate

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

3.2.5 Pressure

The unit of pressure is the pascal (Pa) or the millimeter of mercury (mm Hg); the I-P unit is either the inch water gauge (in. wg), or the inch mercury column (in. Hg). Values in mm Hg or in. Hg shall be used only for barometric pressure measurements. The 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. The in. Hg shall be based on a one inch column of mercury at 32 °F under standard gravity in a vacuum. The mm Hg shall be based on a one mm column of mercury at 0 °C under standard gravity in a vacuum.

3.2.6 Torque

The unit of torque is the newton-meter (N-m); the I-P unit is the pound-inch, (lb-in.).

3.2.7 Gas properties

The unit of density is the kilogram per cubic meter (kg/m^3); the I-P unit is the pound mass per cubic foot (lbm/ft^3). The unit of viscosity is the Pascal-second, (Pa-s); the I-P unit is the pound mass per foot-second ($\text{lbm}/\text{ft-s}$). The SI unit of gas constant is the joule per kilogram-kelvin ($\text{J}/\text{kg-K}$); the I-P unit is the foot-pound per pound mass-degree Rankine, ($\text{ft-lbf}/\text{lbm-}^\circ\text{R}$).

3.2.8 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.

3.2.9 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 [2]. The density of distilled water at saturation pressure shall be taken as 998.278 kg/m^3 ($62.3205 \text{ lbm}/\text{ft}^3$) at 20 °C (68 °F) [3]. The density of mercury at saturation pressure shall be taken at 13595.1 kg/m^3 ($848.714 \text{ lbm}/\text{ft}^3$) at 0 °C (32 °F) [3]. The specific weights in kg/m^3 (lbm/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.

4. Instruments and Methods of Measurement

4.1 Accuracy [4]

The specifications for instruments and methods of measurement which follow include both accuracy requirements and specific examples of equipment that are 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

Table 1
Symbols and Subscripts

Symbol	Description	SI Unit	I-P Unit
A	Area of cross-section	m^2	ft^2
A_c	Louver core area or area of hole in calibration plate	m^2	ft^2
C	Nozzle discharge coefficient	dimensionless	
D	Diameter and equivalent diameter	m	ft
D_h	Hydraulic diameter	m	ft
E	Energy factor	dimensionless	
E	Effectiveness	%	
F	Beam load	N	lb
g	Acceleration due to gravity	m/s^2	ft/s^2
G	Water volume flow rate	L/s	gpm
K_p	Compressibility coefficient	dimensionless	
l	Length of moment arm	m	in
L	Nozzle throat dimension	m	ft
L_e	Equivalent length of straightener	m	ft
$L_{x,xN}$	Length of duct between Planes x and xN	m	ft
M	Chamber dimension	m	ft
n	Number of readings	dimensionless	
N	Speed of rotation	rpm	rpm
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_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
R	Gas constant	J/kg-K	ft-lb/lbm-°R
Re	Reynolds Number	dimensionless	
T	Torque	N-m	lb-in
t_{dx}	Dry-bulb temperature at Plane x	°C	°F
t_s	Static temperature	°C	°F
t_t	Total 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
w	Weight of water	g	oz.
W	Rainfall rate	mm/hr.	in./hr.
y	Thickness of straightener element	m	ft
Y	Nozzle expansion factor	dimensionless	
z	Function used to determine K_p	dimensionless	
α	Static pressure ratio for nozzles	dimensionless	

Table 1 (continued)
Symbols and Subscripts

Symbol	Description	SI Unit	I-P Unit
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
$\Delta p_{x,x'}$	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_x	Air density at Plane x	kg/m ³	lbm/ft ³

Additional Subscripts (Planes of Measurement)

Subscript	Description
c	Converted parameter
corr	Corrected
DS	Louver and system
I	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 references values)

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 which 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:

1. 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.
2. 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 damped or the readings must be averaged in a suitable manner. Multi-point 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 specific weight of 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 [5] [6]

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 indica-

tor, 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 except that when the length of the supporting stem exceeds 24 tube diameters, 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 1 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 either from measurements of velocity pressure obtained by Pitot traverse or from measurements of pressure differential across a flow nozzle. Airflow rates less than 10 cfm may be measured directly using a airflow meter.

4.3.1 Pitot traverse [7]

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 [8]. 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 [9].

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 [10]. 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 which case upstream and down-

stream pressure taps shall be located as shown in the test figure for the appropriate setup. Alternatively, nozzles with throat taps may be used in which case 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 cubic feet per hour) 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 utilize a meter or a traverse other than flow nozzles or 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 [11].

4.4 Water flow rate

A calibrated flow meter capable of indicating flow in increments of 0.5 liter per minute (0.1 gallon per minute) or less, per unit of time 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 $\pm 2\%$ 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

ic calibration shall be made by suspending weights from a torque arm. The weights shall have certified accuracies of $\pm 0.2\%$. The length of the torque arm shall be determined to an accuracy of $\pm 0.2\%$.

4.5.2 Tare

The zero torque equilibrium (tare) and the span of the read-out 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 $\pm 1^\circ\text{C}$ ($\pm 2^\circ\text{F}$) 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 test against a thermometer with a calibration that is traceable to the National Institute of Standards and Technology (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) [12]. The dry-bulb thermometer shall be mounted upstream of the wet-bulb thermometer so 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 $\pm 170\text{ Pa}$ ($\pm 0.05\text{ in. Hg}$) 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 the National Institute of Standards and Technology (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 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 $\pm 1.0\%$ 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 actuator shall be measured with a pressure gauge or other instrument with a demonstrated accuracy of $\pm 10\text{ kPa}$ (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 $\pm 0.2\%$ per day.

4.12 Rain gauge

Rain gauge shall have an accuracy of $\pm 2\%$ of reading.

5. Equipment and Setups

5.1 Setups

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

5.1.1 Installation Types

There are three categories of installation types which can be used with louvers. The installation types and the corresponding test louver setup figures are:

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

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:

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

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 which 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 one-half 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 [14].

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:

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

5.3.1 Outlet chamber

An outlet chamber (Test Figure 5.4) shall have a cross-sectional area at least fifteen 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 $0.1M$ 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. Airflow adjustment means, 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

5.5.1.1

The louver or calibration plate shall be mounted and fixed in the center of a 3 m x 3 m (9.75 ft x 9.75 ft) square wall located at the rear of the weather section (see Test Figure 5.11).

5.5.1.2

The louver or the calibration plate shall be sealed to the wall.

5.5.1.3

The outside face of the louver shall face the wind and rain simulation test apparatus.

5.5.2 Rain simulation equipment

5.5.2.1

The simulated rain shall be produced by at least 4 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 E.

5.5.2.2 Simulated rain performance

The rain simulation equipment shall have the following performance capabilities with the calibration plate mounted in the test opening:

1. Produce a simulated rain penetration through the calibration plate at the specified rate (+10%, -0%) per square meter (10.76 ft²) of opening.
2. The simulated rainfall rate measured using a rain gauge in the positions specified shall not deviate from the mean rainfall rate by more than 15%.

5.5.3 Collection duct

5.5.3.1

The collection duct (see Test Figure 5.11) shall be sealed against the back of the weather section.

5.5.3.2

The collection duct shall have a water droplet elimination section at the downstream end to prevent carry over of airborne water droplets from the collection duct. See Annex F for information on class and total amount of water allowed.

5.5.3.3

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 shall be fabricated which will fit over the test plane and have an opening of the same dimensions as the core area of the louver to be tested. This plate is used in the determination of the wind-driven rain through an opening the same size as the louver.

5.5.5 Wind simulation equipment

5.5.5.1

An external fan shall direct air perpendicular to the louver test plane, as illustrated in Test Figure 5.11.

5.5.5.2

The air outlet of the fan and any silencing or straightening section shall not be less than 1 m (3.25 ft) diameter.

5.5.5.3

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.

5.5.5.4

A fan air straightener section shall be assembled to the outlet of the fan to avoid swirling air currents.

6. Objective, 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, 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 by 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 ΔP_n 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 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_{w0}), ambient wet-bulb temperature (t_{d0}), and ambient barometric pressure (p_b) shall be recorded.

6.1.2.4.1 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, readings for traverse-plane dry-bulb temperature (t_{d3}) shall be recorded.

6.1.2.4.2 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.

6.1.2.4.3 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.

6.1.2.4.4 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 which simulates its intended field installation (see Section 5.1.1). Table 2 displays allowable combinations of louver test setups for air performance pressure drop determinations.

6.1.2.5.1 Louver with outlet duct (Test Figure 5.1)

One reading per determination of outlet duct static pressure (P_{s4}) shall be recorded.

6.1.2.5.2 Louver with inlet duct (Test Figure 5.2)

One reading per determination of inlet duct static pressure (P_{s9}) shall be recorded.