

ANSI/AMCA Standard 500-D-12

Laboratory Methods of Testing Dampers for Rating

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ASSOCIATION INTERNATIONAL, INC.**

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ANSI/AMCA Standard 500-D-12

Laboratory Methods of Testing Dampers for Rating



Air Movement and Control Association International

30 W. University Drive

Arlington Heights, Illinois

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AMCA Publication 511	<i>Certified Ratings Program - Product Rating Manual for Air Control Devices</i>

Related Standards

ANSI/AMCA Standard 510	<i>Methods of Testing Heavy Duty Dampers for Rating</i>
ANSI/AMCA Standard 520	<i>Laboratory Methods for Testing Actuators</i>

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Laboratory Methods of Testing Dampers for Rating

1. Purpose

The purpose of this standard is to establish uniform laboratory test methods for dampers. The characteristics to be determined include, as appropriate, air leakage, pressure drop, dynamic closure, and operational torque.

It is not the purpose of this standard to specify the testing procedures to be used for design, production, or field testing. Similarly, it is not the purpose of this standard to indicate or establish minimum or maximum performance ratings to be used for specifying these products.

2. Scope

This standard may be used as a basis for testing dampers when air is used as the test gas.

A test conducted in accordance with the requirements of this standard is intended to demonstrate the performance of a damper and is not intended to determine acceptability level for a damper. It is not within the scope of this standard to indicate the actual sequence of 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.

For more information on damper modulating control characteristics, see Annex C.

3. Definitions / Units of Measurement / Symbols

3.1 Definitions

3.1.1 Damper

A device mounted in a duct or opening which is used to vary the volume of air flowing through the duct or opening. It may be operated manually or mechanically and may have one or more blades.

3.1.1.1 Single blade damper

A damper having one blade.

3.1.1.2 Multi-blade damper

A damper having more than one blade. The damper is a parallel blade damper if the blades rotate in the same direction; and an opposed blade damper if adjacent blades rotate in opposite directions.

3.1.1.3 Curtain damper

A damper which uses a folded, interlocked series of blades.

3.1.1.4 Backdraft damper (shutter)

A backdraft damper is a damper which, when mounted in a duct or opening, permits the flow of air in one direction only. It is normally opened by the energy of the air stream, but may be opened and/or closed by mechanical means. A counter-balanced backdraft damper has weights and/or springs added to the blade or blades to facilitate or impede the opening or closing action.

3.1.2 Air control damper

A mechanical device which does not fit the definition of a damper and which when placed in a duct or opening is used to regulate airflow.

3.1.3 Free area

The minimum area through which air can pass. It 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 jams. The percent of free area is the free area thus calculated, divided by the gross area of the air control damper $\times 100$. See damper cross-sections (Figure 1).

3.1.3.1 Free area velocity

Airflow through a damper divided by its free area.

3.1.4 Face area

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

3.1.4.1 Face area velocity

Airflow through a damper divided by its face area.

3.1.5 Psychrometrics

3.1.5.1 Dry-bulb temperature (t_d)

Dry-bulb temperature is the air temperature measured by a dry temperature sensor.

3.1.5.2 Wet-bulb temperature (t_w)

Wet-bulb temperature is 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 Total temperature (t_t)

The temperature which exists by virtue of the internal and

kinetic energy of the air or gas. If the air or gas is at rest, the total temperature will equal the static temperature.

3.1.5.4 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.

3.1.5.5 Air density (ρ)

The mass per unit volume of air.

3.1.5.6 Standard air

Standard air is air with a density of 1.2 kg/m^3 (0.075 lbm/ft^3), a ratio of specific heats of 1.4, a viscosity of $1.8185 \times 10^{-5} \text{ Pa-s}$ ($1.222 \times 10^{-5} \text{ lbm/ft-s}$). 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)

Pressure is force per unit area. This corresponds to energy per unit volume of fluid.

3.1.6.2 Absolute pressure (p)

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

3.1.6.3 Barometric pressure (p_b)

Barometric pressure is the absolute pressure exerted by the atmosphere at the location of measurement.

3.1.6.4 Gauge pressure

Gauge pressure is 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)

Velocity pressure is 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)

Static pressure is 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)

Total pressure is 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 ($\Delta P_{x,x}$)

Pressure differential is the change in static pressure across a damper.

3.1.7 Performance variables

3.1.7.1 Pressure drop (ΔP)

Pressure drop is a measure of the resistance to airflow across a damper. It is expressed as the difference in static pressure across a damper for a specific rate of airflow.

3.1.7.2 Closure pressure

Closure pressure is the differential pressure across the damper when the damper is closed.

3.1.7.3 Airflow leakage

Airflow leakage is the amount of air passing through a damper 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 damper divided by the face area.

3.1.7.4 Ambient temperature dynamic closure

Ambient temperature (0°C - 49°C (32°F - 120°F)) dynamic closure is the ability of a damper to properly travel from the full open to the full closed position while exposed to specific airflow conditions at ambient temperature. The specific airflow conditions are the airflow face velocity when the damper is in the open position and the pressure differential across the damper in the closed position. The airflow face velocity is the velocity established with the damper in the open position. The pressure differential is established when the damper is in the closed position. All airflow measurements and pressure differential measurements are established at ambient conditions and are corrected to standard air. The damper can be tested in either a ducted or in-wall installation.

3.1.7.5 Elevated temperature dynamic closure

Elevated temperature dynamic closure is the ability of a damper to properly travel from the full open to the full closed position while exposed to specific airflow conditions at a specified elevated air temperature.

The specific airflow conditions are the airflow face velocity when the damper is in the open position and the pressure differential across the damper in the closed position. The airflow face velocity is the velocity established with the damper in the open position. The pressure differential is established when the damper is in the closed position. All airflow measurements and pressure differential measurements are established at ambient conditions and are corrected to standard air. This test is conducted in a ducted installation only.

3.1.7.6 Ambient temperature operation

Ambient temperature (0°C - 49°C (32°F - 120°F)) operation is the ability of a damper to properly travel from the full open to full closed position and, if a motorized damp-

er, back to a full open position while exposed to specific airflow conditions at ambient temperature. The specific airflow conditions are the airflow face velocity when the damper is in the open position and the pressure differential across the damper in the closed position. The airflow face velocity is the velocity established when the damper is in the open position. The pressure differential is established when the damper is in the closed position. All airflow measurements are established at ambient conditions and are corrected to standard air.

3.1.7.7 Elevated temperature operation

Elevated temperature operation is the operational ability of a damper to properly travel from full open to full closed position at elevated temperatures and, if a motorized damper, operate back to a full open position while exposed to specified airflow conditions. The specified airflow conditions are the airflow face velocity when the damper is in the open position and the pressure differential across the damper in the closed position. The airflow face velocity is the velocity established when the damper is in the open position. The pressure differential is established when the damper is in the closed position. All airflow measurements are established at ambient temperature conditions and are corrected to standard air.

3.1.7.8 Dynamic operation torque

Dynamic operation torque is the torque at varying angles of rotation of the axle which operates the damper from the full open, to the full closed, and back to the full open position while exposed to specific airflow conditions. The specific airflow conditions are the airflow face velocity when the damper is in the open position and the pressure differential across the damper in the closed position. All airflow measurements and pressure differential measurements are established at ambient conditions and are corrected to standard air.

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 damper. The measurements must be sufficient to determine all appropriate performance variables as defined in Section 5.7.

3.1.8.3 Test

A determination or a series of determinations for various points of operation of a damper.

3.1.8.4 Energy factor

Energy factor is the ratio of the total kinetic energy of the flow to the kinetic energy corresponding to the average velocity.

3.1.8.5 Seating torque

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

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.

*Bibliographic references are indicated by brackets; mandatory references are indicated by superscripts.

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 pound mass (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 the degree 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 (lbf).

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 (m³/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 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 vacuo. The mm Hg shall be based on a one mm column of mercury at 0 °C under standard gravity in vacuo.

3.2.5 Torque

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

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

3.2.7 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.

3.2.8 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 lbm/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 lbm/ft^3) at 0°C (32°F) [3]. The specific weights in kg/m^3 (lbm/ft^3) of these fluids in vacuo under standard gravity 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 accuracy requirements and/or 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

4.2.1 General

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.

4.2.2 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.

4.2.2.1 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 2.5 kPa (0 to 10 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 2.5 kPa (10 in. wg), calibration shall be against a water-filled hook gauge of the micrometer type, a precision micromanometer, or a water-filled U-tube.

4.2.2.2 Averaging

Since the airflow and pressures through a damper 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. Averaging can sometimes be accomplished mentally, particularly if the fluctuations are small and regular. Multi-point or continuous record averaging can be accomplished with instruments and analyzers designed for this purpose.

4.2.2.3 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).

4.2.3 Pitot-static tubes [5]

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

Table 1
Symbols and Subscripts

Symbol	Description	SI Unit	I-P Unit
a	Duct Width	m	ft
A	Area of Cross-Section	m^2	ft^2
A_c	Area of the chamber walls	m^2	ft^2
A_s	Area of the substitution walls	m^2	ft^2
A_1	Total surface area inside the chamber	m^2	ft^2
b	Duct Height	m	ft
C	Nozzle Discharge Coefficient	dimensionless	
D	Diameter and Equivalent Diameter	m	ft
E	Energy Factor	dimensionless	
E	Thermal Efficiency Ratio	dimensionless	
K_s	System Leakage Constant	dimensionless	
L	Nozzle Throat Dimension	m	ft
$L_{x,x'}$	Length of Duct Between Planes x and x'	m	ft
M	Chamber Dimension	m	ft
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 tw	Pa	in. Hg
p_p	Partial Vapor Pressure	Pa	in. Hg
q	Energy Rate	W	W
q_c	Energy Escaping the Chamber	W	W
q_d	Energy Escaping from the damper	W	W
q_L	Energy Generated by the Supply Air	W	W
Q	Damper Volumetric Airflow Rate	m^3/s	cfm
Q_s	Test Damper Volumetric Airflow at Standard Air Conditions	m^3/s	cfm
Q_x	Volumetric Airflow Rate at Plane x	m^3/s	cfm
R	Gas Constant	J/kg-K	ft-lbf/lbm-°R
R_e	Reynolds Number	dimensionless	
T	Torque	N-m	lb- in.
t_d	Dry-Bulb Temperature	°C	°F
t_s	Static Temperature	°C	°F
t_t	Total Temperature	°C	°F
t_w	Wet-Bulb Temperature	°C	°F
U_s	Thermal transmittance of the substitution wall	W/m^2	W/ft^2
U_c	Thermal transmittance of the chamber walls	W/m^2	W/ft^2
V	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	Damper 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
ΔP_s	Pressure Drop Across Test Damper at Standard Air Conditions	Pa	in. wg



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Table 1 (Continued)
Symbols and Subscripts

Symbol	Description	SI Unit	I-P Unit
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
d	Damper
DS	Damper and system
n	Nozzle
r	Reading
s	System
t	Test parameter
t1	Test number 1
t2	Test number 2
TP	Tail piece
x	Plane 0, 1, 2, ..., as appropriate
0	Plane 0 (general test area)
1	Plane 1 - Plane of inlet of damper being tested
2	Plane 2 - Plane of outlet of damper being tested
3	Plane 3 - Plane of Pitot traverse
4	Plane 4 - Plane of duct P_s measurement downstream of damper being tested
5	Plane 5 - Plane of P_s measurement at nozzle inlet
6	Plane 6 - Plane of P_s measurement at nozzle discharge station
7	Plane 7 - Plane of outlet chamber measurement station
8	Plane 8 - Plane of inlet chamber measurement station
9	Plane 9 - Plane of duct P_s measurement upstream of damper being tested

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.

4.2.3.1 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.

4.2.3.2 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 (0.10 in.).

4.2.3.3 Support

Rigid support shall be provided to hold the Pitot-static tube axis parallel to the axis of the duct within 1 degree 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.

4.2.4 Static pressure taps [6]

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.

4.2.4.1 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. Every precaution should be taken to ensure that the air velocity does not influence the pressure measurement.

4.2.4.2 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.

4.2.4.3 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.

4.2.5 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. These instruments shall be capable of reading data at a minimum of 100 samples per second.

4.3 Airflow rate

4.3.1 General

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. An airflow rate less than $0.005 \text{ m}^3\text{s}^{-1}$ (10 cfm) may be measured directly using a flow meter.

4.3.2 Pitot traverse [7]

An airflow rate may be calculated from the velocity pressures obtained by traverses of a duct with a Pitot-static tube provided the average velocity corresponding to the airflow rate is at least 6.35 m/s (1250 fpm).

4.3.2.1 Traverse point

The number and locations of the measuring points on rectangular and round ducts shall be as specified in Figures 3A and 3B.

4.3.2.2 Averaging

The points shown in Figures 3A and 3B are located according to the log-linear rule for round ducts [8] and the log-Tchebycheff rule for rectangular ducts. The arithmetic mean of the individual velocity measurements made at these points will be the mean velocity through the measuring section for the subject velocity profiles [9].

4.3.3 Nozzles

Airflow rate may be calculated from the pressure differential measured across a flow 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.

4.3.3.1 Size

Nozzles shall conform to Figures 7A and 7B. 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.

4.3.3.2 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

7 [10]. Throat dimension $L = 0.6D$ is recommended for new construction.

4.3.3.3 Chamber nozzles

Nozzles without integral throat taps may be used for multiple nozzle chambers in which case 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 which case the throat taps located as shown in Figure 7A 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.

4.3.3.4 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 7A.

4.3.3.5 Taps

All pressure taps shall conform to the specification in Section 4.2.4 regarding geometry, number, and manifolding into piezometer rings.

4.3.4 Airflow meter

Airflow rates may be measured directly using a calibrated airflow meter capable of measuring airflow in increments of $0.0002 \text{ m}^3/\text{s}$ (25 cubic feet per hour) or less.

4.3.5 Other airflow measuring methods

Airflow measuring methods which utilize meters or traverses other than airflow nozzles or Pitot traverses may be used if the uncertainty introduced by the method does not exceed that introduced by an appropriate airflow nozzle or Pitot traverse method. The contribution to the combined uncertainty in the flow rate measurement shall not exceed that corresponding to 1.2% of the discharge coefficient for a flow nozzle [11].

4.4 Torque

4.4.1 Torque meter

A torque meter having a demonstrated accuracy of $\pm 2\%$ of observed reading may be used.

4.4.2 Calibration

A torque device 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 $\pm 0.2\%$. The length of the torque arm shall be determined to an accuracy of $\pm 0.2\%$.

4.4.3 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.

4.5 Air density

4.5.1 General

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%.

4.5.2 Thermometers

Both wet and dry-bulb temperatures shall be measured with thermometers or other instruments with demonstrated accuracy of $\pm 1^\circ\text{C}$ (2°F) and readability of 0.5°C (1°F) or finer.

4.5.2.1 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.

4.5.2.2 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.

4.5.3 Barometers

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

4.5.3.1 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 [13]. Barometers shall be maintained in good condition.

4.5.3.2 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.

4.6 Voltage

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

4.7 Electrical meters

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

4.8 Pneumatic actuator supply air pressure

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

4.9 Pressure gauges

Supply air pressure for a pneumatic actuator 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.

4.10 Chronometers

Time measurements shall be made with a watch having minimum accuracy of $\pm 0.2\%$.

4.11 Velocity meters

Air velocity meters shall have an accuracy $\pm 3\%$ (of reading) or ± 0.05 m/s (10 fpm), whichever is greater.

5. Equipment and Setups

5.1 Setups

Twenty damper setups are diagramed in Test Figures 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8 and 5.9. Six airflow measurement setups are diagramed in Test Figures 6.1, 6.2, 6.3, 6.4, 6.5 and 6.6.

5.1.1 Installation types

There are four categories of installation types which can be used with dampers.

The installation types and the corresponding test damper setup figures are:

Installation Type	Test Figure
Free inlet, ducted outlet	Test Figure 5.1
Ducted inlet, free outlet	Test Figure 5.2
Ducted inlet, ducted outlet	Test Figures 5.3A, 5.3B, 5.3C, 5.9
Free inlet, free outlet	Test Figures 5.4, 5.5, 5.7

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 damper and the measuring plane, including the nozzle wall if used, shall leak no more than 10% of the total flow at the test pressure or 9.44×10^{-4} m³/s (2 cfm), whichever is greater.

5.2 Ducts

5.2.1 General

A duct may be incorporated in a laboratory setup to provide a measuring plane or to simulate the conditions the damper is expected to encounter in service or both. The dimension, D , in the test damper 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:

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

5.2.2 Transformation pieces

Transformation pieces used in the test setups shall be in compliance with Figure 8.

5.2.3 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% or 1.5 mm (1/16 in.) of the duct diameter, whichever is greater. The remainder of the duct shall be round within 1% or 3 mm (0.125 in.) of the duct diameter, whichever is greater. 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%.

5.2.4 Straighteners

Straighteners or star straighteners shall be used in ducts which provide measuring planes for airflow measurement. The downstream plane of the 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 shall be as specified in Figure 9A or Figure 9B [14].

5.3 Chambers

5.3.1 General

A chamber may be incorporated in a laboratory setup to provide a measuring station or to simulate the conditions the damper 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:

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

5.3.2 Outlet chamber (Test Figure 5.4)

An outlet chamber shall have a cross-sectional area at least fifteen times the free area of the damper being tested.

5.3.3 Inlet chamber (Test Figure 5.5)

Inlet chambers shall have a cross-sectional area at least three times the free area of the damper being tested.

5.3.4 Outlet/inlet plenum (Test Figure 5.7)

Plenum size shall be larger than the test damper by a minimum of 305 mm (12 in.) on all four sides. The plenum height shall be no less than the plenum length.

5.3.5 Airflow settling means

Airflow settling means shall be installed in a chamber where indicated on the test setup figures 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 6 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.

5.3.6 Multiple nozzles

Multiple nozzles shall be located as symmetrically as possi-

ble. 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

5.4.1 General

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

5.4.2 Throttling dampers

Throttling devices may be used to control the point of operation. Such devices shall be located on the end of the duct or chamber and shall be symmetrical about the duct or chamber axis.

5.4.3 Supply or exhaust fan

A fan may be used to control the point of operation of the test damper. 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. The airflow generating equipment is to be capable of producing the prescribed airflow and pressure conditions without the use of pressure relief dampers.

6. Objective, Observations, and Conduct of Test

6.1 Air performance - pressure drop test

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

For information regarding certification and the test sizes required for certification, see Annex C.

6.1.1 General requirements

6.1.1.1 Determinations

A test shall consist of five or more determinations taken at approximately equal increments of flow 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 Airflow measurement

Airflow velocity at the plane of measurement when determined by using a Pitot-static tube shall not be less than 6.35 m/s (1250 fpm). When nozzles are used to determine the

airflow rate, the minimum P_n shall be 25 Pa (0.1 in. wg) at the minimum airflow rate of the test.

6.1.2 Data to be recorded

6.1.2.1 Test damper

The description of the test damper, including the model, the damper type, (i.e., curtain damper, single blade damper, multi-blade damper) size, and face 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 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, 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.

6.1.2.4.1 Pitot 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 for traverse-plane dry-bulb temperature (t_{d3}) shall be recorded unless the readings are steady in which case only one need be recorded.

6.1.2.4.2 Duct nozzle test (Test Figure 6.2)

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

6.1.2.4.4 Single nozzle chamber test (Test Figure 6.4)

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

6.1.2.5 Test damper setup

Each damper shall be tested in a setup which simulates its intended field installation (see Section 5.1.1). Table 2 displays allowable combinations of airflow rate measurement and test damper setups.

6.1.2.5.1 Damper 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 Damper with inlet duct (Test Figure 5.2)

One reading per determination of inlet duct static pressure (P_{s9}), and the plane 9 dry bulb temperature (t_{d9}) shall be recorded.

6.1.2.5.3 Damper with inlet and outlet ducts (Test Figure 5.3, 5.3A, 5.3B, and 5.3C)

One reading per determination of pressure drop across the test damper (ΔP_{s9}) and the plane 9 dry bulb temperature (t_{d9}) shall be recorded.

6.1.2.5.4 Damper with outlet chamber (Test Figure 5.4)

One reading per determination of chamber static pressure (P_{s7}) shall be recorded.

6.1.2.5.5. Damper with inlet chamber (Test Figure 5.5)

One reading per determination of chamber static pressure (P_{s8}) and chamber temperature (t_{d8}) shall be recorded.

6.1.2.5.6 Damper with outlet plenum (Test Figures 5.7A and 5.7E)

One reading per determination of chamber static pressure (P_{s7}) shall be recorded.

6.1.2.5.7 Damper with inlet plenum (Test Figures 5.7B and 5.7F)

One reading per determination of chamber static pressure (P_{s8}) and chamber temperature (t_{d8}) shall be recorded.

6.1.3 Conduct of test

6.1.3.1 General requirements

Each test shall be conducted at ambient temperatures between (0 °C - 49 °C (32 °F - 120 °F)). A test is a complete set of measurements (or determinations), with one set of measurements for each setting of airflow and pressure drop. The damper shall be tested with airflow in both directions with the exception of a backdraft damper or a damper specifically labeled for airflow in one direction.

6.1.3.1.1 Backdraft dampers

A test shall begin with the lowest airflow value, the damper being allowed 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 with the

Table 2

Allowable Combinations of Airflow Rate Measurement and Test Damper Setups (Pressure Drop Test)

Test Damper Setups		Airflow Measurement Setups	
Test Figure	Connection plane	Test Figure	Connection plane
5.1	Z	6.1	B
		6.2	B
		6.3	A
		6.4	A
5.2	Y	6.1	C
		6.2	C
	X	6.5	B
5.3	Y	6.1	C
		6.2	C
	X	6.5	B
5.4	Y	6.1	B
		6.2	B
	X	6.3	B
		6.4	B
5.5	X	6.1	C
		6.2	C
	Y	6.5	A
5.7A, 5.7E	X	6.1	B
		6.2	B
		6.3	A
		6.4	A
5.7B, 5.7F	Y	6.1	C
		6.2	C
		6.5	B

damper while opening vs. closing, the test may be repeated, beginning with the maximum airflow value.

6.1.3.1.2 Other dampers

The damper shall be fixed in its desired blade position for the duration of the test.

6.1.3.2 Damper mounted with inlet and outlet duct (Test Figure 5.3)

For a damper mounted in a duct system, as shown in Test Figure 5.3, the test determinations shall be carried out with the damper set in its desired blade position (except for a backdraft damper, see Section 6.1.3.1.1). This test shall be referred to as the damper and system test. The damper shall then be removed from the test installation and the upstream test duct connected directly to the downstream test duct. The test shall be repeated at approximately the same airflow rate as previously tested. This test shall be referred to as the system test. For each determination the pressure drop shall be the pressure with the damper in place (damper and system) at a given airflow minus the pressure at the identical

airflow with the damper removed (system). Refer to Section 7.6 if damper and system flows are not identical.

6.1.4 Presentation of results

The report and presentation of results shall include all the data outlined in Section 6.1.2. In addition, the following shall be recorded as appropriate:

Damper mounting position
 Damper mounting type (see Figure 1)
 Blade orientation
 Blade action
 Blade position (open or closed)
 Airflow direction
 Personnel
 Date
 Test ID#
 Lab name
 Lab location
 Reference to AMCA Standard 500-D

6.1.4.1 Performance curves

The results of a damper test shall be presented as performance curves.

6.1.4.1.1 Coordinates

A performance curve shall be drawn with airflow rate as abscissa. Static pressure shall be plotted as ordinate. If all results were obtained at the same air density or if results were converted to a nominal density, such density shall be listed; otherwise a curve with air density as ordinate shall be drawn.

6.1.4.1.2 Test points

The results for each determination shall be shown on the performance curve as a series of circled points, one for each variable plotted as ordinate.

6.1.4.1.3 Curve-fitting

A curve for each variable shall be obtained by drawing a continuous curve using the test points for reference. The curve shall not depart from the test points by more than 1% of any test value or 3 Pa (0.01 in. wg), whichever is greater, and the sum of the deviations shall approximate zero.

6.1.4.1.4 Discontinuities

When discontinuities exist they shall be identified with a broken line. If equilibrium cannot be established for any determination, the curves joining the points for that determination with adjacent points shall be drawn as broken lines.

6.1.4.1.5 Identification

Performance curve sheets shall list the test damper, test damper setup and airflow rate measurement setup. Sufficient details shall be listed to identify clearly the damper and setup. Otherwise, a report containing such information shall be referenced.

6.2 Airflow leakage rate using ambient air

The purpose of this test is to determine the relationship between one or more sets of airflow leakage rate and static pressure for a damper, backdraft damper or other air control damper mounted on a chamber at ambient conditions.

For information regarding certification and the test sizes required for certification, see Annex C.

6.2.1 General requirements

6.2.1.1 Determinations

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 Airflow measurement

When nozzles are used to determine the airflow rate, the minimum ΔP_n shall be 25 Pa (0.1 in. wg) at the minimum airflow rate of test. A direct reading airflow meter may be used if the airflow is below 4.7 L/s (10 cfm).

6.2.1.4 Seating torque measurement

(Might not apply to backdraft damper.)

6.2.1.4.1 Calibrated weights

A test shall be conducted with calibrated weights, springs, actuators or other dampers that may be used to apply the normal seating torque. The force to develop the torque shall be applied at a location consistent with the force which will be applied by the operating damper.

6.2.1.4.2 Application of torque

The torque shall be applied with zero ΔP across the damper with its blades at the full open position. The corresponding weight shall be lowered gradually, without impact loading, until the damper reaches its closed position and without additional applied force. Similarly, springs, actuators or other dampers should be permitted to close the damper in a manner that will not apply any additional force than normally applied.

6.2.2 Data to be recorded

6.2.2.1 Test damper

The description of the test damper, including the model, the damper type, (i.e., curtain damper, single blade damper, multi-blade damper) 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.

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

Test data for each determination shall be recorded. Readings shall be made simultaneously whenever possible. For each test, 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.

Table 3

Allowable Combinations of Airflow Rate Measurement and Test Damper Setups (Leakage Test)

Test Damper Setups		Airflow Measurement Setups	
Test Figure	Connection plane	Test Figure	Connection plane
5.4	Y	6.2	B
	X	6.3	B
		6.4	B
5.4 Alternate	X	6.3	B
5.5	X	6.2	C
	Y	6.2	A
5.5 Alternate	Y	6.5	A
5.6A Positive Pressure Leakage Test		----	----
5.6B Negative Pressure Leakage Test		----	----
5.8 Bubble Test		----	----
5.7A, 5.7E	X	6.2	B
		6.3	A
		6.4	A
5.7B, 5.7F	Y	6.2	C
		6.5	B

6.2.2.4.1 Duct nozzle test (Test Figure 6.2)

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

6.2.2.4.2 Chamber nozzle test (Test Figures 6.3 and 6.5)

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

6.2.2.4.3 Single nozzle chamber test (Test Figure 6.4)

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

6.2.2.4.4 Airflow meter test (Test Figure 5.6A)

For an airflow meter test, one reading each of airflow directly from the airflow meter (Q), damper inlet dry-bulb temperature (t_{d9}), and damper inlet static pressure (P_{s9}) shall be recorded. Airflow measurements using this test figure shall be limited to a maximum of 4.7 L/s (10 cfm).

6.2.2.4.5 Airflow meter test (Figure 5.6B)

For an airflow meter test, one reading each of airflow directly from the airflow meter (Q) and damper outlet static pressure (P_{s4}). Airflow measurements using this test figure shall be limited to a maximum of 4.7 L/s (10 cfm).

6.2.2.5 Test damper setup

Table 3 displays allowable combinations of airflow rate measurement and test damper setups.

6.2.2.5.1 Damper with outlet chamber (Test Figure 5.4)

One reading of chamber static pressure (P_{s7}) shall be recorded per determination.

6.2.2.5.2 Damper with inlet chamber (Test Figure 5.5)

One reading of chamber static pressure (P_{s8}) and chamber temperature (t_{d8}) shall be recorded per determination.

6.2.2.5.3 Damper with outlet plenum (Test Figures 5.7A and 5.7E)

One reading per determination of chamber static pressure (P_{s7}) shall be recorded.

6.2.2.5.4 Damper with inlet plenum (Test Figures 5.7B and 5.7F)

One reading per determination of plenum static pressure (P_{s8}) and plenum temperature (t_{d8}) shall be recorded.

6.2.2.5.5 Damper setup for bubble test (Test Figure 5.8)

For bubble tests, one reading per determination of test pressure (P_{s9}) and damper inlet dry-bulb temperature (t_{d9}) shall be recorded. The size of bubble formation shall also be recorded by noting if any bubbles exceed 1.6 mm diameter (1/16 in.) in 1 second or if any bubbles exceed 7mm (1/4 in.) diameter in 1 minute.

6.2.3 Conduct of test

6.2.3.1 General requirements

Each test shall be conducted at ambient temperature between (0 °C - 49 °C (32 °F - 120 °F)). A test is a complete set of measurements (or determinations), one set for each one setting of airflow leakage rate and pressure drop.

6.2.3.1.1 Backdraft dampers

A backdraft damper shall be mounted in its desired position and in such a manner so that leakage airflow will force damper blades to the closed position.

6.2.3.1.2 Other dampers

The damper shall be placed in its closed position. Where torque must be applied to a blade or shaft to drive the damper to its closed position, seating torque shall be applied as described in Section 6.2.1.4. Alternatively the damper may be held in its closed position using weights, springs, actuators, or any other damper normally used to close the damper. The damper shall be tested in both directions (except backdraft damper).

6.2.3.2 Bubble test

Mount the damper as shown in Test Figure 5.8. A bubble solution (commercial test solution or a solution consisting of equal parts liquid detergent, glycerin and water) shall be applied to the damper seal areas. Within a few moments, and before the bubble solution can dry, the wetted areas shall be checked. Pressure and size of bubble formation shall be recorded as stated in Section 6.2.2.5.5.

6.2.3.3 Flow meter test

Mount damper as shown in Test Figure 5.6. Perform test as described in Section 6.2.3.1.

6.2.3.4 Damper mounted with inlet or outlet chamber or plenum

For dampers mounted with an outlet or inlet chamber or plenum, as shown in Test Figures 5.4, 5.5, 5.7A, 5.7B, 5.7E, and 5.7F, the test determinations shall be carried out with the damper set in its desired blade position.

6.2.3.4.1 Chamber leakage test

The following chamber leakage test shall be conducted and documented no more than 6 months prior to any AMCA certified leakage tests.

Close all nozzles and pressurize the chamber or plenum in five approximately equal increments up to 2,489 Pa (10 in. w.g.) or to the maximum chamber/plenum pressure rating, whichever is less. Apply bubble solution to all seams and nozzle closures and check for leakage at each increment. Reference Section 6.2.3.2 for the solution and acceptance criteria. If acceptable leakage criteria is not met, reseal the area and retest until leakage requirements are met.

6.2.3.4.2 System Leakage Test

A system leakage test shall be conducted prior to each damper leakage test. For the system leakage test, the damper chamber opening shall be covered with a suitable solid board, or other material, and sealed to prevent airflow through the chamber opening. Five or more determinations shall be taken at approximately equal increments of pressure up to the maximum pressure that the damper will be tested to.

The maximum system leakage that can be deducted from the damper and system test is $7.48 \times 10^{-5} \times (P_s)^{0.5} \text{ m}^3/\text{s}$ ($2.5 \times (P_s)^{0.5} \text{ cfm}$) or 2% of damper leakage, whichever is higher. If the system leakage is measured higher than the maximum allowed system leakage, then the maximum shall be deducted from the damper and system test.

If the system leakage is measured to be less than the maximum allowed system leakage, then the actual system leakage shall be deducted from the damper and system test.

The static pressure during the system leakage test must be the SAME or HIGHER than the static pressure for the corresponding damper leakage test.

6.2.3.4.3 Damper and system test

After the system test, and with the damper mounted in its desired position, five or more determination shall be taken at approximately equal increments of pressure up to the maximum pressure the damper is to be rated to. For each determination the damper leakage shall be the leakage with the damper in place (damper and system) minus the system leakage at the identical pressure. Refer to Section 7.5 if damper and system pressures and system pressures are not identical.

6.2.3.4.4

For chambers other than Test Figure 5.5, an equivalent method of determining nozzle wall and chamber leakage shall be used. This test shall be referred to as the damper and system test. The chamber opening shall then be covered with a suitable solid board, or other material, which prevents airflow through the chamber opening. The test shall be repeated at approximately the same pressure increments as previously tested. This test shall be referred to as the system test. For each determination the damper leakage shall be the leakage with the damper in place (damper and system) minus the system leakage at the identical pressure. Refer to Section 7.5 if damper and system pressures and system pressures are not identical.

6.2.4 Presentation of results

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