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# Standard Practice for MEASURING AIR LEAKAGE BY THE FAN-PRESSURIZATION METHOD[1]

This standard is issued under the fixed designation E 779; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

## 1. Scope

1.1 This practice represents a standardized technique for measuring air leakage rates through a building envelope under controlled pressurization or evacuation.

1.2 This practice is applicable to small temperature differentials and low-wind pressure conditions. For tests conducted in the field, it must be recognized that field conditions may be less than ideal. Nevertheless, strong winds and large indoor-outdoor temperature differentials should be avoided.

1.3 The proper use of this practice requires a knowledge of the principles of air flow and pressure measurement.

1.4 This practice is intended to produce a measure of air tightness of a building envelope. Because of differences between natural load and test conditions, however, such measurements cannot be interpreted as direct measurements of air change rates that would occur under natural conditions.

1.5 This practice is primarily intended for use in one-story buildings. If the air leakage is to be measured for taller buildings, the thermal stack effect needs to be considered. Annex A1 provides information for estimating stack effect.

## 2. Applicable Document

2.1 *ASTM Standard*:

E 741 Practice for Measuring Air Leakage Rate by the Tracer Dilution Method[2]

## 3. Summary of Practice

3.1 This practice consists of mechanical pressurization or de-pressurization of a building and measurements of the resulting air flow rates at a given indoor-outdoor static pressure difference. From the relationship between the air flow rates and pressure differences, the air leakage characteristics of a building envelope can be evaluated.

## 4. Significance and Use

4.1 Air leakage accounts for a significant portion of the thermal space conditioning load. It affects occupant comfort and indoor air quality.

4.2 In most commercial or industrial buildings, outdoor air is often introduced by design with air circulation systems. In most residential buildings, indoor-outdoor air exchange is attributable primarily to air leakage through cracks and construction joints.

4.3 Air leakage under natural conditions is very difficult to calculate, since it depends not only on wind speed and direction and indoor-outdoor temperature differences, but also on workmanship in construction, and on other building elements. Although there are standard formulas to estimate air leakage, they are only approximations.

4.4 The air leakage of a building under natural conditions, that is the air infiltration, is difficult to predict since it depends on many local variables. Air infiltration may be measured directly using the tracer dilution method

[1] This practice is under the jurisdiction of ASTM Committee E-6 on Performance of Building Constructions and is the direct responsibility of Subcommittee E06.41 on Infiltration Performances.

Current edition approved May 19, 1981. Published July 1981.

[2] *Annual Book of ASTM Standards*, Part 18.

(see Practice E 741). The induced-pressure method provides an indirect way to relate the infiltration rate to the leakage area of a structure.

4.5 The fan-pressurization method has several advantages over the tracer dilution method. The fan-pressurization method is a simpler measurement and produces a time-independent result that characterizes the quality of the building envelope. It can be used: (*1*) to compare the relative air tightness of several similar buildings, (*2*) to identify the leakage sources and rate of leakage from different components of the same building envelope, and (*3*) to determine the air leakage reduction for individual retrofit measures applied incrementally to an existing building.

4.6 When the absolute infiltration rate is needed, the tracer dilution method should be used over a wide range of wind speeds and directions and indoor-outdoor temperature differences. However, the measuring equipment and techniques for the tracer dilution method are relatively complicated. Also, the data analysis and correlation are more involved. It is better to use the fan-pressurization method for diagnostic purposes and measure the absolute infiltration rate with the tracer dilution method.

## 5. Descriptions of Terms

5.1 *air change rate*—air leakage in volume units per hour divided by the building space volume with identical volume units (normally expressed in air changes per hour, ACH or ACPH).

5.2 *air leakage rate*—the volume of air movement per unit time across the building envelope. This movement includes flow through joints, cracks, and porous surfaces, or combination thereof. The driving force for such an air leakage in service can be either mechanical pressurization and evacuation, natural wind pressures, or air temperature differentials between the building interior and the outdoors, or combination thereof.

5.3 *air leakage graph*—the graph that shows the relationship of measured air flow rates to the corresponding measured pressure differences.

5.4 *building envelope*—the boundary or barrier separating the interior volume of a building from the outside environment. For the purpose of this practice, the interior volume is the deliberately conditioned space within a building, generally not including the attic space, basement space, and attached structures, unless such spaces are connected to the heating and air conditioning system, such as a crawl space plenum.

5.5 *Reference Standard Conditions*—The reference standard conditions for this practice are:

| | |
|---|---|
| Air temperature | 21.2°C (70°F) |
| Air density | 1.202 kg/m³ (0.075 lb/ft³) |
| Pressure | 101.3 kPa (2116 lbf/ft²) |

5.6 *test pressure difference*—the actual pressure difference across the building envelope, expressed in kilopascals (or pounds-force per square foot) or in inches of water (or inches of mercury).

## 6. Apparatus

6.1 The following description of apparatus is general in nature. Any arrangement of equipment using the same principles and capable of performing the test procedure within the allowable tolerances is permitted.

6.2 *Major Components* (see Fig. 1):

6.2.1 *Air-Moving Equipment*—A fan, blower, or blower door assembly, that is capable of moving air into and out of the conditioned space at required flow rates under a range of test pressure differences. The system shall provide constant air flow at each incremental pressure difference at fixed pressure for the period required to obtain readings of air flow rate.

6.2.2 *Pressure-Measuring Device*—A manometer or pressure indicator to measure pressure difference with an accuracy of ± 2.5 Pa (± 0.01 in. $H_2O$).

6.2.3 *Air Flow or Velocity-Measuring System*—A device to measure air flow within ±6 % of the average value. The calibration of this air flow-measuring system shall follow the manufacturer's instructions, and be recorded as such. The instrument may also be calibrated in a calibrating wind tunnel.[3]

6.2.4 *Wind Speed-Measuring Device*, to give an accuracy within ±0.8 km/h (0.5 mph) at 8 km/h (5 mph). Perform wind speed measurements at a distance three to five building heights away from the building. List the height

[3] "Ventilation System Testing from Industrial Ventilation: A Manual of Recommended Practice," American Conference of Industrial Hygienists, Committee on Industrial Ventilation, Lansing, Mich. 48902.

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above ground at which wind speed is measured.

6.2.5 *Temperature-Measuring Device*, to give an accuracy of ±0.5°C (1°F).

6.2.6 *Air Flow-Regulating System*—A device such as damper, or variable motor speed control, that will regulate and maintain air flow and pressure to specific limits.

6.2.7 The air duct layout shall be able to accommodate both pressurization and evacuation. (For the blower door assembly, no ducting is required.)

6.2.8 The size of the air duct and the capacity of the fan or blower shall be matched so that the linear flow velocity within the air duct falls within the range of measurement of the air flow meter (see Annex A3).

6.3 *Blower Door Assembly* (Fig. 2) is an accepted variation. Components peculiar to this assembly are:

6.3.1 *Blower Door*—A door mount for fan or blower. It must be adjustable to fit common door openings.

6.3.2 The fan or blower possesses a variable-speed motor to accommodate the wide range of required flow rates up to 5100 $m^3/h$ (3000 $ft^3/min$). The fan or blower shall be calibrated individually according to the manufacturer's instructions, and be recorded as such.[4] Alternatively, calibration can be done with a set of standard air flow orifices as described in Annex A3.

6.3.3 *Fan Speed Controls and RPM Indicator*—To indirectly measure the air flow rate using a calibration graph as illustrated in Fig. 3. See Annex A3 for developing the graph.

## 7. Safety Precautions

7.1 Glass should not break at the pressure differences normally applied to the test structure. However, for added safety, adequate precautions such as the use of eye protection should be taken to protect the personnel.

7.2 The test is most likely conducted in the field. Therefore safety equipment required for general field work also applies, such as safety shoes, hard hat, etc.

7.3 Because air-moving equipment is involved in this test, provide a proper guard or cage to house the fan or blower and to prevent accidental access to any moving parts of the equipment.

7.4 When the blower or fan is operating, a large volume of air is being forced into or out of a building. Provide proper shields or guards at the inlet or outlet of the air duct.

7.5 Noise may be generated by the moving air. Therefore, make available hearing protection for personnel who must be close to the noise.

## 8. Procedure

8.1 Make general observations of the condition of the building. Take notes on the windows, doors, opaque walls, roof, and floor.

8.2 Measure and record the wind speed and direction, and outdoor temperatures before, during, and after the test.

8.3 Measure and record the indoor temperatures and relative humidities before, during, and after the test so that their average values can be estimated.

8.4 Place the air-moving apparatus near the structure. Connect the air duct or blower door assembly to the building envelope, using a window, door, or vent opening. Seal or tape openings to avoid leakage at these points.

8.5 If a damper is used to control air flow, it should be in a fully closed position at the beginning of a test. Turn on the fan or blower, adjust the damper or air flow regulator to increase the air flow, take readings of air flow rate and induced pressure difference.

8.5.1 When the blower door assembly is used, the determination of the rpm and pressure differentials from the control panel enables flow to be measured (Annex A3). Interpolation shall be used for other pressure differentials than those recorded in the calibration procedure (see Annex A3).

8.6 The range of the induced pressure difference shall be from 12.5 to 75 Pa (0.05 to 0.3 in. $H_2O$) depending on the capacity of the air-handling equipment. Since the capacity of the air-handling equipment, the tightness of the building, and the weather conditions affect leakage measurements, the full range of the higher values may not be achievable. In such cases a partial range encompassing at least five data points shall be the substitute.

8.7 Increments of 12.5 Pa (0.05 in. $H_2O$) shall be used for the full range of induced pressure differences.

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[4] "Fan Engineering Handbook," 7th edition, Buffalo Forge Company, Buffalo, N. Y., 1970.

8.8 At each pressure increment, measure the air flow rate in cubic metres per hour (cubic feet per minute).

8.9 A uniform pressure shall be maintained in the conditioned space to within a range of less than 20 % of measured inside and outside pressure difference.

8.10 A maximum variation of pressure due to the external influence, such as wind or thermal stack effect, or both, shall be no more than 10 % of the measured inside and outside pressure difference.

8.11 Preferred test conditions are: (*1*) on-site wind speed of 8.0 km/h (5.0 mph) or less and (*2*) indoor and outdoor temperature difference of 11°C (20°F) or less. This helps to stabilize the induced pressure difference between inside and outside the building envelope. When the wind speed is over 16 km/h (10 mph), halt the test. When the wind speed is between 8 and 16 km/h (5 and 10 mph), conduct tests with caution.

8.12 For each test, collect data for both pressurization and evacuation.

## 9. Data Analysis and Calculations

9.1 All the measured air leakages shall be converted to air flow rates in cubic metres per hour (cubic feet per minute) at reference conditions.

9.2 If the air leakage is not measured directly from a flow meter, then additional calculations are needed to convert, for instance, pitot tube pressure to linear velocity and then volume flow rate. In the case of a calibrated motor fan, the flow rate can be obtained through the calibration curve of the motor fan.

9.3 Plot the measured air leakage against the corresponding pressure differences to complete the air leakage graph for both pressurization and evacuation (see Fig. 4).

## 10. Report

10.1 The report shall contain at least the following information:

10.1.1 *Test Site Description*:

10.1.1.1 Location and construction:

(*a*) Date built,

(*b*) Wall, ceiling, and floor area,

(*c*) Volume,

(*d*) Floor plan and site plan, and

(*e*) Attic, basement, or crawl space.

10.1.1.2 Openings in exterior shell:

(*a*) Doors,

(*b*) Windows,

(*c*) Ventilation openings,

(*d*) Chimneys, and

(*e*) Condition of openings during test (for example, broken windows, open doors, etc.)

10.1.1.3 HVAC Systems:

(*a*) Furnace,

(*b*) Blower capacity, and

(*c*) Duct location.

10.1.2 *Pressurization Measurements*:

10.1.2.1 Technique employed,

10.1.2.2 Equipment used,

10.1.2.3 Calibration of air flow meter, and

10.1.2.4 Measurement results.

10.1.3 *Weather*:

10.1.3.1 Off-site conditions (nearby weather station),

10.1.3.2 On-site conditions (measurement location),

10.1.3.3 Apparatus,

10.1.3.4 Wind speed/direction,

10.1.3.5 Temperature (indoor and outdoor), and

10.1.3.6 Humidity (indoor and outdoor).

10.1.4 Plot of air leakage graph (see Fig. 4).

## 11. Precision and Accuracy

11.1 At present, the precision and accuracy of this practice is largely dependent on the instruments and apparatus used and on the ambient conditions under which the data are taken. A reasonable estimate of the uncertainty at a given pressure difference is about 10 % or less.

11.2 It is easier to take data at higher pressure differences than at lower differences. Therefore, special care should be exercised when measurements are taken at low pressure differences.



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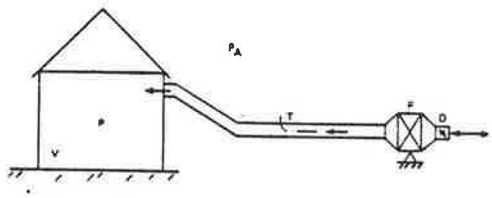


NOTE: D—Damper or Variable Motor Speed Control
F—Fan or Blower
P—Inside Pressure
P—Ambient Pressure
T—Air Flow Meter
V—Test Space

FIG. 1 Major Components of Apparatus

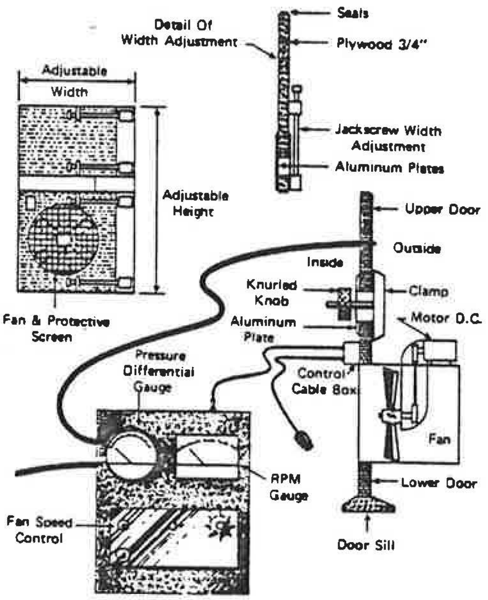


FIG. 2 Blower Door Assembly

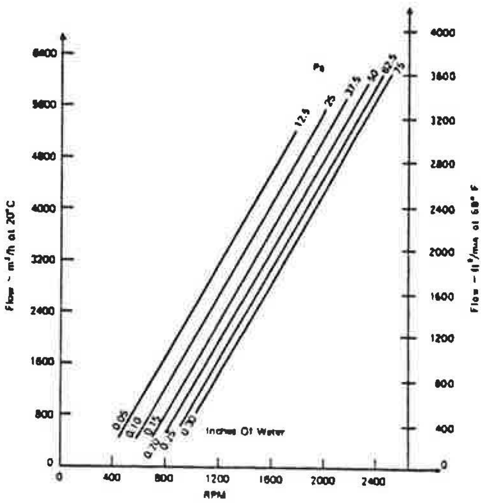


FIG. 3 Example of a Fan Speed/Air Flow Calibration Graph

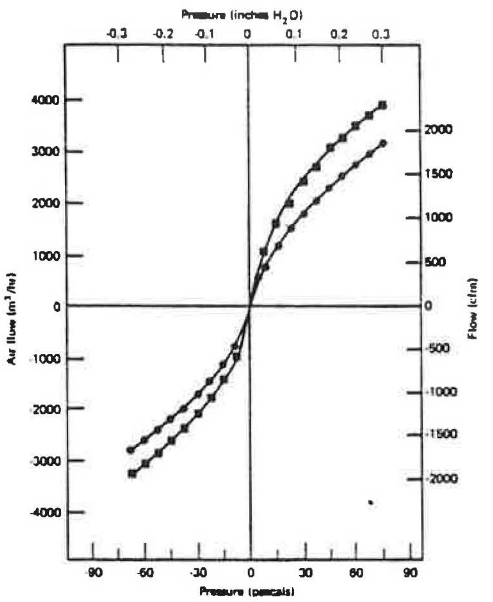


FIG. 4 Air Leakage Graph

# ANNEXES

## A1. STACK EFFECT

A1.1 In the case of high-rise or tall buildings, precautionary steps should be taken to eliminate or compensate for the thermal stack (chimney) effect.

A1.2 For two-story or taller buildings, the thermal stack effect must be estimated or measured to be sure that it is within the 10 % of the induced pressure difference. As a rule, the stack effect is approximately 0.1 Pa per story per °C ($2.1 \times 10^{-4}$ in. $H_2O$ per story per °F).

## A2. MEASUREMENTS[6]

A2.1 When air leakage measurements are performed according to this practice at high altitudes (low atmospheric pressure) and at high or low temperatures, a correction factor, $Q$, should be applied to the flow rate measurement:

$$Q = Q_m \left(\frac{294}{273 + T}\right)\left(\frac{B}{101.3}\right)$$

where:

$Q_m$ = measured flow rate,
$T$ = air temperature, °C, and
$B$ = barometric pressure, kPa.

A2.2 When a standard pitot tube is used to measure the air velocity, the air velocity and the velocity pressure can be related as follows:

$$V = 4.422 \sqrt{\frac{P_v}{\rho}}$$

where:

$V$ = velocity, m/s
$P_v$ = velocity pressure, mm/Hg,
$\rho$ = density factor, calculated from

$$\rho = \rho_{st}\left(\frac{294}{273 + T}\right)\left(\frac{B}{101.3}\right)$$

$\rho_{st}$ = density of air at standard conditions.

A2.3 A standard pitot tube with an inclined manometer can be used with the following degree of accuracy:

| Velocity, m/s | Per cent Error (±) |
|---|---|
| 3 | 15.0 |
| 4 | 6.0 |
| 5 | 4.0 |
| 10 | 1.0 |
| 15 | 0.3 |
| 20 | 0.25 |

[5] "Standard Test Code," AMCA Standard 210-74, Air Moving and Conditioning Association, Park Ridge, Ill. 60068, 1974.

A2.4 If a pitot tube is used for measuring the linear velocity of air flow, several readings should be made across the duct area.[6] So that an average linear velocity can be obtained. $\bar{V}$. Thus the air flow rate is:

$$Q = (A)(\bar{V})$$

where $A$ is the cross-sectional area of the air duct.

A2.5 If the mechanical fan or blower is calibrated so that the air flow rate and static pressure difference, or rpm, can be accurately related to each other, then the air flow measuring device can be omitted. However, in this case, the calibration curve of the fan or blower shall be attached to the report.

## A3. FLOW RATE CALIBRATION

A3.1 Table A3.1 should be helpful in selecting an air flow meter.[3]

A3.2 Table A3.2 should be helpful in selecting pressure-measuring instruments.[3]

A3.3 *Calibration of the Blower Door*:

A3.3.1 The blower door is calibrated using a set of air flow orifices with the door mounted in a leakproof chamber. For each calibration orifice, obtain differential pressures of 12.5, 25, 37.5, 50, 62.5, and 75 Pa (0.05, 0.10, 0.15, 0.20, 0.25, and 0.30 in. $H_2O$) by varying the fan rpm.

A3.3.2 Plot the rpm-flow charts for the discrete differential pressures as shown in the sample calibration in Fig. 3.

[6] Ower, E., and Pankhurst, F. C., *Measurement of Air Flow in SI Metric Units*, 5th edition, Pergamon Press, New York, N.Y., 1977.

TABLE A3.1 Characteristics of Air Meters[A]

| Instruments | Range, m/s (ft/min.) | Hole Size (for ducts), mm (in.) | Range, Temperature[B] | Dust, Fume Difficulty | Calibration Requirements | Ruggedness | General Usefulness and Comments |
|---|---|---|---|---|---|---|---|
| Pitot Tubes with Inclined Manometer: | | | | | | | |
| Standard | 3.05-up (600-up) | 9.5 (3/8) | wide | some | none | good | good except at low velocities |
| Small size | 3.05-up (600-up) | 4.8 (3/16) | wide | yes | once | good | good except at low velocities |
| Double | 2.54-up (500-up) | 19.05 (3/4) | wide | small | once | good | special |
| Swinging Vane Anemometers: | | | | | | | |
| Alnor Velometer | 0.13-50.8 (25-10 000) | 15.88 (5/8) | 370°C (700°F) | some | frequent | fair | good |
| Rotating Vane Anemometers: | | | | | | | |
| Conventional | 0.15-50.8 (30-10 000) | not for duct use | narrow | yes | frequent | poor | special; limited use |
| Electronic (airflow development) | 0.13-1.02 (25-200)<br>0.13-2.54 (25-500)<br>0.13-10.16 (25-2000)<br>0.13-25.4 (25-5000) | not for duct use | narrow | yes | frequent | poor | special; can record; direct reading |
| Digital (airflow development | 1.02-25.4 (200-5000) | not for duct use | narrow | yes | frequent | poor | special |
| Bridle Vane Anemometers: | | | | | | | |
| Florite Air Velocity Meter | 0.25-12.7 (50-2500) | not for duct use | narrow | yes | frequent | fair | special |
| Heated Wire Anemometers: | | | | | | | |
| Anemotherm Model 60 | 0.05-40.64 (10-8000) | 9.5 (3/8) | medium | some | frequent | poor | good |
| Anemotherm gas flow meter | 0.05-25.4 (10-5000) | 25.4 (1) | 149°C (300°F) | no | frequent | good | not portable; for permanent station air flow |
| Flowtronic air meter 55A | 0-5.08 (0-1000)<br>5.08-10.16 (1000-2000)<br>10.16-20.32 (2000-4000) | 12.7 (1/2) | medium | yes | frequent | poor | good |
| Heated Thermocouple Anemometers: | | | | | | | |
| Alnor Thermoanemometer Model 8500 | 0.05-10.16 (10-2000)<br>2 scales | 7.94 (5/16) | narrow | yes | frequent | poor | good |
| Hasting precision air meter B-22 | 0.05-2.54 (10-500)<br>2.54-50.8 (500-10 000) | 7.94 (5/16) | narrow | yes | frequent | poor | good |
| Kurz air velocity meter 440 series | 0-60.96 (0-12 000) | 7.14 (9/32) | medium | some | frequent | good | good |
| Flow Corporation Series 800 | 0.05-20.32 (10-4000) | 12.7 (1/2) | narrow | yes | ... | poor | good |
| Alnor air velocity transducer system (AVT) | 0.10-2.54 (20-500)<br>0.254-5.08 (50-1000)<br>0.508-10.16 (100-2000) | 7.94 (5/16) | narrow | yes | frequent | poor | special; for permanent station use |

**Table A3.1**—*Continued*

| Instruments | Range, m/s (ft/min.) | Hole Size (for ducts), mm (in.) | Range, Temperature[B] | Dust, Fume Difficulty | Calibration Requirements | Ruggedness | General Usefulness and Comments |
|---|---|---|---|---|---|---|---|
| Variable Area Meter | | | | | | | |
| Airmeter (F. W. Dwyer Co.) | 1.02-6.10 (200-1200)<br>5.08-20.32 (1000-4000) | not for duct use | narrow | yes | occasional (needs cleaning) | good | satisfactory for estimates of flow |

[A] Reprinted by permission of the Committee on Industrial Ventilation. See footnote 3.

[B] Narrow: −7 to 66°C (20 to 150°F); Medium: −7 to 149°C (20 to 300°F); Wide: −18 to 427°C (0 to 800°F).

TABLE A3.2 Characteristics of Pressure Measuring Instruments (Static Pressure, Velocity Pressure, Differential Pressure)[A]

| Instrument | Range, Pa (in. water) | Manufacturer's Stated Precision, Pa (in. water) | Comments |
|---|---|---|---|
| Liquid Manometers: | | | |
| Vertical U-tube | No limit | 24.9 (0.1) | Portable. Needs no calibration. |
| Inclined 10:1 slope | Usually up to 2490 (10) | 1.245 (0.005) | Portable. Needs no calibration. Must be leveled. |
| Hook Gage | 0–5976 (0–24) | 0.249 (0.001) | Not a field instrument. Tedious, difficult to read. For calibration only. |
| Micromanometer (Meriam Model 34FB2TM) | 0–2490 (0–10)<br>0–4980 (0–20) | 0.249 (0.001) | Heavy. Need to locate on vibration-free surface. Not difficult to read; uses magnifier. |
| Micromanometer (Vernon Hill Type C) | 0.249–298.8 (0.001–1.2) | 0.0996 (0.0004) | Small; portable. Uses magnifier. Need experience to read to manufacturer's precision. Calibration needed. |
| Micromannometer (105) (Electric Microtonic, F. W. Dwyer, Mfg.) | 0–498 (0–2) | 0.0747 (0.0003) | Portable. Needs vibration-free mount. No magnifier. Slow to use. No eyestrain. No calibration needed. |
| Diaphragm and Mechanical: | | | |
| Diaphragm-magnehelic gage | 0–124.5 (0–0.5)<br>0–249 (0–1)<br>0–996 (0–4) | 2.49 (0.01)<br>4.98 (0.02)<br>24.9 (0.10) | Calibration recommended. No leveling, no mounting needed.<br>Direct reading. |
| Swinging vane anemometer<br>Alnor velometer | 0–124.5 (0–0.5)<br>0–4980 (0–20) | 5 % scale | Calibration recommended. No leveling, no mounting needed. Use manufacturer's exact recommendation for size of SP hole. |
| Pressure Transducers and Electronic Instruments: | | | |
| Pressure Transducers | 12.45–14.94 (0.05–6) | 0.3 % | Must be calibrated. Remote reading responds to rapid change in pressure. |

[A] Reprinted by permission of the Committee on Industrial Ventilation. See footnote 3.





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