Measuring air velocity with the Fluke 975 AirMeter: Using the velocity probe

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Application Note

Air velocity is a key parameter in evaluating airflow system performance. As part of basic testing, adjusting and balancing of HVAC air distribution systems, most HVAC technicians now use an anemometer to measure air velocity at grilles-registers-diffusers, within a duct, or in open spaces.

Anemometers are typically very accurate tools, especially at low velocities, but they must compensate for air temperature, absolute pressure, and ambient absolute pressure. The Fluke 975 AirMeter tool has an accessory velocity probe that uses a thermal anemometer to measure air velocity. A temperature sensor in the probe tip compensates for air temperature, a sensor in the meter reads absolute pressure, and ambient absolute pressure is determined upon meter initialization. For users who prefer to calculate their own compensation factors, the meter will also display air velocity or volume at standard conditions.

This application note describes how to take accurate air volume measurements within a duct, air measurements at grilles-registers-diffusers, and other locations.


Measuring air velocity in a duct.

Air volumes within a duct

The ultimate goal of any duct system is to move the required air volume, while keeping all other factors within acceptable limits, and to deliver it in quantities and patterns that serve the intended purpose: heating, cooling, ventilating, exhausting, mixing, humidifying, dehumidifying, or otherwise conditioning the air within a space. Velocity within a duct is determined not only by application, but also by how the duct is designed. Key design factors include: The level of available static pressure that can be overcome by the fan due to friction losses and pressure drops of devices within the air stream; the cost of duct work; the space available for duct work; and acceptable noise levels.

To determine the air volume delivered to all downstream terminal devices, technicians use a duct traverse. Duct traverses can determine air volume in any duct by multiplying average velocity readings by the inside area of the duct. Traverses in main ducts measure total system air volume, which is critical to HVAC system performance, efficiency, and even life expectancy. The difference in air volumes between the main supply duct traverse and the main return duct traverse results in outdoor air volume. A traverse in run-outs is the most accurate way to determine the air volume delivered by the terminal device (grille-register-diffuser). A traverse in exhaust ducts reveals exhaust air volume.

A duct traverse consists of a number of regularly spaced air velocity measurements throughout a cross sectional area of straight duct. Preferably, the traverse should be located in a straight section of duct with ten straight duct diameters upstream and three straight duct diameters downstream of the traverse plane, although a minimum of five duct diameters upstream and one duct diameter downstream can give adequate results.

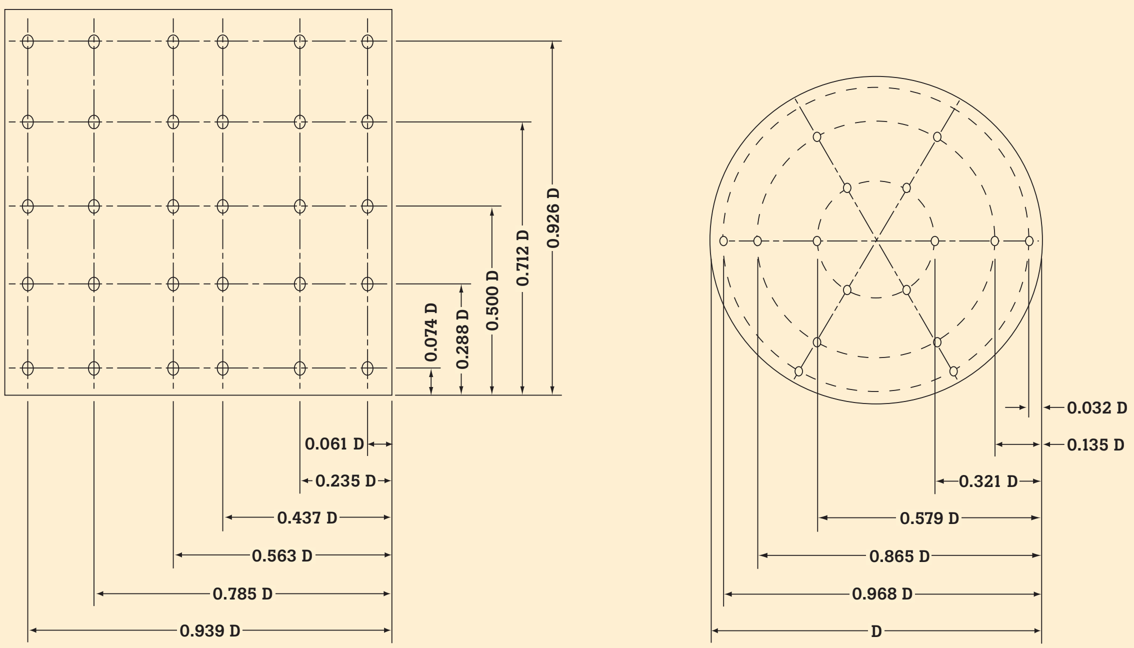
The number of measurements taken across the traverse plane depends on the size and geometry of the duct. Most duct traverses result in at least 18 to 25 velocity readings, with the number of readings increasing with duct size. The industry accepted measurement points across the traverse are determined by the Log-Tchebycheff rule for rectangular duct, and by the Log-Linear rule for round duct. Usually, technicians drill five to seven holes on one side of rectangular ducts, and two to three holes in round ducts, in order for the telescoping anemometer probe to access the traverse points. To ensure the anemometer is used in the direction of calibration, align the mark on the velocity probe tip with the impact direction. When extending the probe, align the wand section with the handle to help maintain the correct direction inside the duct.

Before taking measurements, slide the protective sheath toward the wand handle in order to expose the sensors in the probe tip. For volume flow rate calculations, the Fluke 975 AirMeter™* will prompt for rectangular or round duct, then prompt for rectangular side dimensions or round diameter. Take the required number of velocity readings one at a time by pressing the "capture" key. If a velocity reading is taken prematurely, the Fluke 975 allows you to re-take it. When all velocity readings are complete, the AirMeter™ averages the readings and multiplies by the duct cross sectional area to get air volume, both at standard conditions and compensated for absolute pressure and temperature.

The velocity readings (FPM) are averaged and multiplied by the inside area of the duct (sq ft) which provides the air volume (CFM).

Q = V * A
Q = Air volume, CFM (cubic feet per minute) or M^3/s (cubic meters per second)
V = Velocity, FPM (feet per minute) or m/sec (meters per second)
A = Area of duct, inside dimension of duct in square feet or square meters

*For determining air velocity greater than 600 feet per minute (FPM) within a duct, an HVAC technician may also use a Pitot-static tube with an inclined manometer. Anemometers are the preferred choice below 600 FPM and are quite acceptable at higher velocities, too. The Fluke 975 AirMeter's anemometer measures over a range of 50 to 3000 fpm. In low pressure duct systems where sound is a concern, such as residences and health care facilities, velocity usually ranges from 400 to 900 FPM, while in high pressure duct systems, velocities can approach 3,500 FPM.



No. of points or traverse lines	Position relative to inner wall
5	0.074, 0.238, 0.500, 0.712, 0.926
6	0.061, 0.235, 0.437, 0.563, 0.765, 0.939
7	0.053, 0.203, 0.366, 0.500, 0.534, 0.797, 0.947

No. of measuring points per diameter	Position relative to inner wall
6	0.032, 0.135, 0.321, 0.679, 0.865, 0.968
8	0.021, 0.117, 0.184, 0.345, 0.655, 0.816, 0.883, 0.981
10	0.019, 0.077, 0.153, 0.217, 0.361, 0.639, 0.783, 0.847, 0.923, 0.981

Patterns of holes drilled in rectangular and round ducts when conducting a duct traversal. Taken from ANSI/ASHRAE Standard 111-1988.

Taking measurements at the intake of a rooftop unit.

Air measurements at Grilles-Registers-Diffusers (GRDs)

Supply air GRDs are selected and positioned to deliver specified air volume in velocities and patterns that result in acceptable comfort and ventilation within the occupant zone. The occupant zone is considered to be one foot from walls and below head height. Velocity from a supply GRD normally does not exceed 800 FPM, and velocity into a return grille should not exceed 400 FPM in applications where noise would be objectionable. Velocity must be sufficient to mix the supply air with the room air outside of the occupant zone, while creating comfortable air patterns and temperatures within the occupant zone.

Throw is the distance the air travels from a GRD before reaching terminal velocity. Throw is normally 75 % to 110 % of the distance from the GRD to the next intersecting surface (wall) or terminal velocity point of adjacent GRDs. Terminal velocity is simply the velocity at the point within the throw that is chosen to stop measuring throw for engineering design reasons. Terminal velocity is typically 50 FPM to 75 FPM in residential and office spaces, but may be specified by the engineer to be as high as 125 FPM to 150 FPM in commercial applications. Generally, air velocities in the occupant zone at 50 FPM are not objectionable. Stagnant zones are created when velocities fall to 15 FPM. To determine space air patterns, use the velocity probe to "follow" the throw of GRDs .

To determine air volume delivered by a GRD, it's best to perform a duct traverse with the velocity probe in the duct run-out leading to the GRD. Alternately, use a traverse with the velocity probe at the face of a GRD, along with the GRD manufacturer's engineering data, to determine air volume.

Unlike a section of duct, the area of a GRD cannot be measured in the field due to the fact that the air changes direction and accelerates through the *vena contracta* (the vena contracta is an effect that occurs when air flowing through any opening "sticks" to the edges of the opening, effectively reducing the size of the opening). Even careful field measurements of the free area of a GRD to determine air volumes will result in gross miscalculations of air volume. The GRD manufacturer will publish an "effective area" (A_k = effective area in square feet) that can only be determined by laboratory tests that measure actual air volume and GRD face velocity (V_{avg} = average face velocity in feet per minute). This effective area can be used in the field for air volume calculations.

For a given GRD, the manufacturer will normally publish the effective area along with a range of face velocities with the resulting volume flow in cubic feet per minute (CFM) and pressure drop for each face velocity. These values are determined with straight duct connected to the GRD carrying non-turbulent air evenly distributed across the duct.

Calculating air volume from a GRD requires taking enough face velocity readings to get an average velocity. Set up a grid of test points across the face of the GRD that will result in a good average when finished. Grid spacing is typically three to five inches, no more than six inches, and a minimum of six stable velocity readings per throw direction. Position the velocity probe sensor flush with a supply GRD, or one inch (± .031 in) away from a return grille, and center the probe in the opening. Select the Fluke 975 AirMeter volume flow rate, rectangular duct, and enter 12 inches by 12 inches dimension. This will result in a CFM calculation that equals the average FPM calculation. The calculated CFM is then multiplied by the GRD manufacturer's A_k factor for the actual CFM.

CFM (cubic feet per minute) = A_k x V_{avg}
$\mathbf{A_k}$ = Effective area in square feet
$\mathbf{V_{avg}}$ = Average face velocity in feet per minute

Miscellaneous velocity readings

Ventilation air is often supplied through the outdoor air hood of a packaged rooftop unit. Within the hood is a bank of bug screens that can be traversed in a similar manner as return grilles. Enter the volume flow rate function of the Fluke 975 AirMeter, select rectangular duct, enter the dimensions of the bank of bug screens, capture a velocity reading approximately every six inches, and let the AirMeter calculate the CFM of ventilation air.

When the balance between outdoor air intake and exhaust air is incorrect, a potential for roof or building damage exists, and occupants entering a building can be confronted with an objectionable wind when the doors are opened. Building pressurization should be limited to 0.02 in to 0.1 in water column (w.c.) and best if kept below 0.05 inches w.c. The velocity probe can be used at the building entrance to help evaluate building pressure. A 1300 FPM air velocity through an open door equates to over 0.1 inches w.c. building pressurization, and a 15 mph wind in the face.

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Fluke Corporation
PO Box 9090, Everett, WA USA 98206

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa +31 (0) 40 2675 200 or
Fax +31 (0) 40 2675 222
In Canada (800)-36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

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