Application Note

Using a rotating vane anemometer as a service tool in residential air distribution applications

Ever feel that balancing air distribution systems is more art than science? Especially in residential HVAC, where it's just you and an installation that's a far cry from any design drawings. No high-end tools and no certified TAB (Test-Adjust-Balance1) technicians to balance the installation or verify the engineering requirements.

Luckily, the resource gap between commercial and residential HVAC is closing fast.

Basic air flow measurement techniques involve duct traverses (multiple evenly spaced velocity readings) to analyze system air volume (cfm) and measuring GRD (Grill-Register-Diffuser) velocities or volumes for proportional balancing.

The problems start with system installation. Standard size duct and fittings rarely conform with the design requirements. Add to that mid-construction changes, unforeseen physical obstacles, material substitutions, and variations in assembly techniques and the resulting combination of "as designed" meets "as-built" can lead to systems that only a mother could love.

To compensate, every air distribution system needs to be balanced (adjusted for specified air delivery to each space) on start up. In fact, building health, occupant health, and national standards require that the correct proportions of outdoor air, return air and supply air are controlled and delivered as specified by the consulting engineer.

However, even if the system is balanced after installation, it's still hard to separate system characteristics from environmental impacts, what with duct and component friction and fitting losses and unpredictable changes in air direction due to turbulence-compression-rarefaction.

Fortunately, the newest generation of vane anemometers can help residential HVAC technicians analyze air distribution and balance installations without the help of a supporting army.

Vane Anemometers

Both deflecting vane and rotating vane anemometers have been around for many years.

Deflecting vane anemometers are very sensitive low pressure (or low velocity) instruments. They're typically designed either for directly reading face velocities, or for use with pressure pick-up devices, for accurately reading very low pressures.

Old-style rotating vane anemometers were mechanical instruments that could be calibrated to directly read velocities but didn't have calculators to convert velocity to volume. New digital vane anemometers offer expanded capabilities and simplified calculations at an affordable price for the multi-tasking HVAC mechanic.

The Meterman[2] TMA10 rotating vane anemometer is an ideal choice for residential HVAC work. This vane anemometer uses a 3 inch rotating propeller type vane that is positioned in a moving air stream to electronically calculate velocity directly from the rotating frequency of the vane (propeller).

GRD Basics

Grill: A louvered or perforated covering for an opening in an air passage
Register: A combination grill and damper assembly covering a supply air opening
Diffuser: An air distribution outlet that disperses air in various directions.

GRD selection is primarily based on cfm, face velocity, throw, pressure loss, noise criteria, usage (heating, cooling, both), and sometimes looks. Room load calculations will determine cfm. Face velocity and throw are primarily determined by GRD placement and room dimensions within noise criteria guidelines. Throw is the distance the air flows from the GRD until it reaches terminal velocity.

In general, the throw should be 75 to 110 percent of the distance between the GRD outlet and the first wall/ceiling/floor intersection. The dispersement pattern may be linear or divergent, whichever is best suited for the dimensions and characteristics of the of the space being conditioned. Adjustments that increase dispersement will reduce length of throw.

Supply GRD's are generally positioned to wipe a wall or ceiling surface and are selected and positioned to keep throw from entering the occupant zone, without creating stagnant zones.

For residences, 50 fpm is often considered the terminal velocity and should result in comfortable occupant zone

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The hand held vane is connected remotely to the meter, allowing the meter and vane to be positioned independently from each other. This rotating vane anemometer is designed to record multiple single point GRD face velocities, average the velocities, then calculate the cfm based on the GRD's effective area in sq. ft.

Accuracy of velocity reading is within two percent of the full scale (125 to 4900 fpm). Accuracy of velocity measurement is dependant on the perpendicular attitude of the vane to the air flow. Accuracy of volume measurements is dependant on the accuracy of the calculated free area of the GRD, relative uniformity of air distribution across the GRD, and sufficient steady state single point measurements equally spaced across the GRD.[3]

Although the TMA10 will display velocities from 0 to 4900 fpm, its acceptable range begins at velocities above 125 fpm. For velocities below 125 fpm, a deflecting vane anemometer should be used, but since recommended face velocities for residential GRD's is typically 500 to 750 fpm, the TMA10 is a good choice. And even though velocities from 0 to 125 fpm are out of range, the TMA10 can be used to estimate the throw of GRD's since terminal velocities are in the range of 50 to 150 fpm, depending on application.

Velocity measurements: Best practices

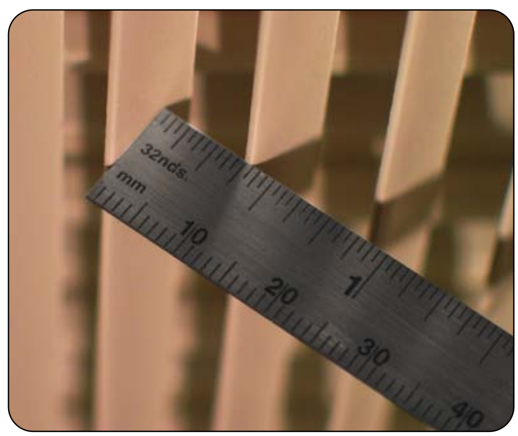
Since a rotating vane anemometer is intended for use with supply and return GRD's, let's look at some basic best practices.

- Return grill recommended maximum face velocities should not exceed 500 fpm.
- Filter grill recommended maximum face velocities should not exceed 300 fpm.
- Supply outlet face velocity best practices recommends 500 to 750 fpm for acceptable noise criteria.

Velocity measurements taken with the rotating vane anemometer must be consistent and repeatable. The proper procedure is to divide the flow area of the GRD into areas of 3 inch to 5 inch equally spaced grids. A single point steady state velocity measurement is made within each of these grids. (It is not acceptable to use the averaging mode to sweep across the GRD face since this is not accurate and is not consistently repeatable.)

The anemometer will total and average up to eight single point velocity readings. The user can then input the free area in square feet of the GRD into the meter and the meter will calculate cfm. GRD manufacturers publish either free area in sq. in., core area or effective area in sq ft (Ak) (see sidebar). These values should be sought out and used in order to more closely approach accurate calculations

Even when armed with the manufacturer's data, accuracy will be compromised as the air approach pattern to the GRD becomes more turbulent. When manufacturers' data is not available, proportional measurements will only be as consistent as the effective area measurement factors between similar designs with similar fin settings. Effective area is greatest when fins are set for zero percent deflection, while effective area is reduced as fin angle of deflection is increased.



To find free area, place rule perpendicular to one fin and measure distance to adjacent fin edge. In this case, the free distance is 3/8 in (or 0.375 in), not the manufactured fin spacing of 1/2 in.

Volume: Estimating effective area (Ak) in the field.

When GRD manufacturers' data is not available, measure the space between the fins. Most GRD's have a fin spacing of 1/3 in, 1/2 in, or 3/4 in. At 0 degree fin angle, the width between the fins will be

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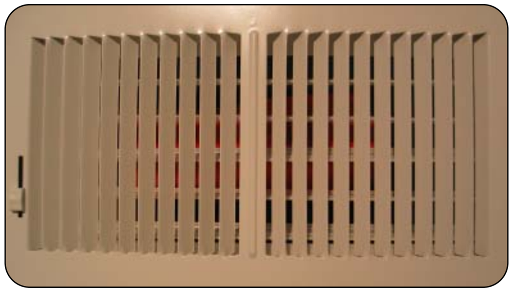
velocities. Outlet air will entrain (draw in) secondary room air to mix the two before reaching terminal velocity. Floor and ceiling registers and diffusers usually take advantage of surface effect to increase throw. The wall or ceiling side of the discharge air will not entrain secondary room air as long as it is wiping the surface.

If a significant heat gain or loss through the wall or ceiling surface has not been properly anticipated, sometimes adjusting the register vanes to avoid surface effect will entrain more secondary room air and result in less heat sink effect from the room surface. Placement and discharge patterns should be selected to avoid throw velocities in the occupant zone to avoid discomfort.

Tip: Get baseline readings first, before adjusting air volumes, so that you can quantify changes. While there may be a large percentage of error in accuracy of air volume readings, comparisons of changes as a percentage will be accurate as long as the testing procedures are consistent and repeatable.



There are 20 spaces between the fins, and two spaces between the center two fins with a different free area.
20 spaces = 0.375 x 5.375 x 20 = 40.3125 sq in
2 spaces at center =
0.3125 (5/16 in) x 5.375 x 2 = 3.3593 sq in
Add the two (40.3125 + 3.3593)
for a total of 43.6713 sq in
Convert to sq ft 43.67 / 144 = 0.303 sq ft effective area.
This is the value entered into area screen on TMA10

correspondingly 1/3 in, 1/2 in, or 3/4 in, but since GRD fins are typically set at an angles, the net space between the fins will be correspondingly less than 1/3 in, 1/2 in, or 3/4 in. Use a steel rule with the 0 inch mark at the end (no space between the end and the 0 mark). Place the end of the rule perpendicular to a fin and measure the distance to the edge of the adjacent fin.

For instance, if the angle of the fin is 40 degrees, when placed correctly, the angle of the rule to the face of the register mounting surface will be 50 degrees. Take this width between the fin measurement and multiply by the length of the opening for the area between the two fins. Multiply the area between two fins by the number of fin spaces within the panel. Repeat this procedure for the remaining panels. To convert area from square inches to square feet, divide the area in square inches by 144.

cfm = Ak x face velocity, where cfm = cubic feet per minute

Ak = effective area in square feet

Face Velocity = feet per minute velocity

(To convert free area from square inches to square feet, divide the area in square inches by 144.)

Most registers have more than one panel. One panel may deflect air 40 degrees right, a second panel may deflect air 40 degrees left, maybe a third panel may deflect air 40 degrees vertically.

A particular 10 x 6, two-way deflecting register may have a core area of 0.369 sq ft, a free area of 0.325 sq ft, and an effective area of 0.185 sq ft. Multiplying the average velocity from the register by core or free area rather than effective area will produce a significant difference in calculated cfm.

Target air volumes are based on *ACCA Residential Load Calculation Manual J* room load calculations. Measure the cfm from the GRD and measure the sensible Delta-T, which is the temperature difference between the GRD discharge temperature and the occupied zone temperature. Plug these values into the sensible heat formula and compare to the Manual J load requirements of the room. The procedure is the same for both heating and cooling.[4]

Sensible Heat Formula

Btuh = cfm x Delta-T x 1.08

Where

Btuh = Btu's per hour

Cfm = cubic feet per minute of air from ***GRD's in room***

1.08 = 60 minutes per hour x 0.24 specific heat of dry air x 0.075 pounds of 70 °F air per cubic foot at sea level

Measurement procedures

The vane anemometer is factory equipped to display IP (Inch-Pound) measurements such as °F, fpm, cfm, but may be changed to display SI (Le Système International d'Unités; the international agreement on the metric system of units) units such as °C, mps, cms.

1. Divide the flow area of the GRD into equally spaced grids of 3 in to 5 in squares
2. Position the vane in the first grid area to measure velocity. The face of the vane should be held as close as possible to the GRD while maintaining a perpendicular aspect to the moving air stream. The vane should be held in the air stream for at least ten seconds so it can stabilize.
3. When the velocity reading has stabilized, press "**HOLD**" to store the reading. A number from 1 to 8 will briefly appear to indicate the sequence of

GRD manufacturers' area data

GRD data is published in one of three methods.

1. **Core Area:** expressed in square feet, this is the face area bounded by a line tangent to the edge of the opening through which air can pass. Core area does not account for the area occupied by vanes, nor does it compensate for fin angles of deflection.
2. **Free Area:** (or "see through" area) expressed in square inches, this value is accurate only in low velocity applications such as combustion air or transfer grills. This value is the core area minus the fin and/or damper dimensions and accounts for the reduced net area offered by the fin angle of deflection. As the fin angle of deflection increases, velocity increases, cfm decreases and net area decreases. Free area is the core area minus the thickness of the fins, and does not compensate for fin angles of deflection.
3. **Effective Area:** expressed in square feet (Ak). This value represents the free area minus the friction and compression of air as it moves through the GRD. The effective area is less than the free area for supply registers. This is the value that should be sought out and used for cfm calculations.

Tip: Consider disabling the auto-off feature, so the meter doesn't shut off during test procedures.[5]

stored readings.

4. Continue steps 2 and 3 until velocity readings from each of the grids have been stored in memory.
5. Press the **"AVERAGE"** button to read average velocity.
6. Press **"MODE"** button to enter effective area in square feet.
   a. The units digit will flash its value. (If the effective area does not need to be changed, press the **"MODE"** button to advance to the flow screen.)
   b. Each press of the **"HOLD"** button will increase the value of the flashing digit by one.
   c. Each press of the **"AVERAGE"** button will advance the flashing digit from units to tenths to hundredths to thousandsth.
   d. Press **"MIN/MAX"** then press **"HOLD"** to store the area value and advance to the flow screen.
7. Read and record the air volume (cfm) from the flow screen
8. To clear the stored values, press **"MODE"** to return to the velocity screen and hold the **"AVERAGE"** button until a double beep is heard.
9. Repeat above sequence for next set of readings.

[1]To learn more about Test-Adjust-Balance work, consult ASHRAE (American Society of Heating, Refrigeration, Air conditioning Engineers), ACCA (Air Conditioning Contractors of America), SMACNA (Sheet Metal, Air Conditioning National Association), AMCA (Air Movement & Control international) and NEBB (National Environmental Balancing Bureau).

[2]Formerly Wavetek

[3]Note: Readings taken at GRD's are not accurate measurements of air volume (cfm) unless they're compared to other GRD's in proportional measurements. GRD measurements can, however, accurately record changes in air volume percentages, as long as the same measuring device is used in a consistent manner using best practices methods.

[4]Note: Since the density of air becomes a significant factor at elevations above 2,000 feet, a value other than 0.075 must be used at increased elevations. In Denver, for instance, the air is only about 80 % as dense as at sea level, so more air has to be delivered to achieve the same Btuh. So our 1.08 factor becomes 60 x 0.24 x 0.061 pounds per cubic foot at 70 °F = 0.88

[5]To disable the auto-off feature, press "ON/OFF" and "HOLD" buttons simultaneously, release the "ON/OFF" button, after "n" appears on display, release the "HOLD" button.)

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Meterman Test Tools

website: www.metermantesttools.com
email: info@metermantesttools.com

6920 Seaway Blvd.
Everett, WA 98203
fax: 425-446-4882
tel: 877-596-2680

Meterman Test Tools Europe
P.O. Box 1186
5602 BD Eindhoven
The Netherlands

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