Proper Use of Airflow/Air Velocity Measuring Instrumentation

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Course Description

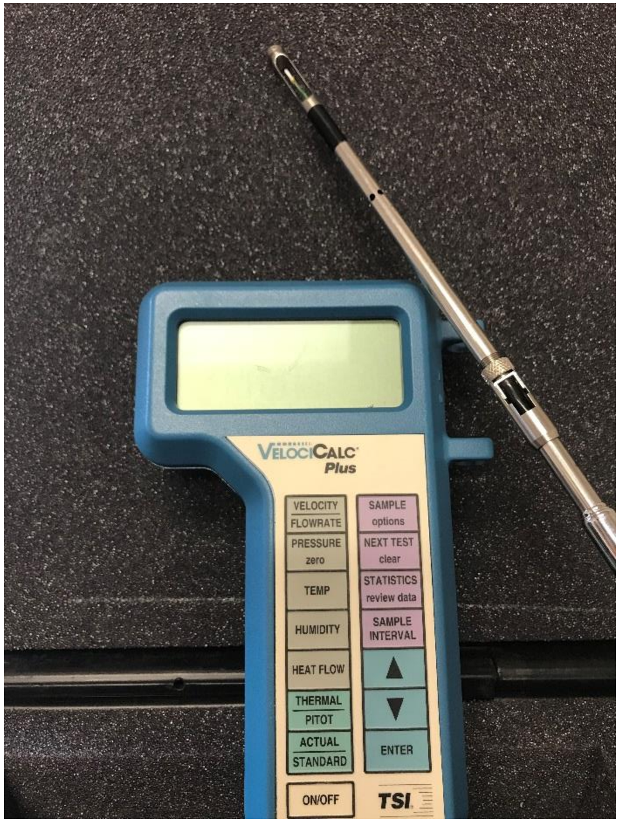
This overview will cover a variety of topics including understanding the different types of instruments used for air velocity/airflow measurement, best practices for properly selecting and using them, developing air velocity/airflow correction factors for various applications, and proper application of the AABC standards for air velocity/airflow measurement, including the data and information to be reported.

Learning Objectives

1. Understand the different types instruments used for air velocity/airflow measurement (thermal anemometers, rotating vane anemometers, flow hoods, etc.).
2. Understand industry best practice for the proper use and selection of air velocity/airflow measurement instruments.
3. Understand the development of air velocity/airflow correction factors for various applications.
4. Understand the proper application of the AABC standards for air velocity/airflow measurement, including the data and information required to be reported.

Types of Instrumentation
Thermal Anemometer

A thermal anemometer uses a heated probe element that is inserted into an airstream. Air speed can then be inferred from the heating power necessary to maintain the probe at a temperature elevation. This power should be some way proportional to air speed.



Types of Instrumentation

Mechanical Rotating Vane Anemometer

The mechanical rotating vane utilizes a revolution counter that is engineered and calibrated to read air velocity directly in feet of air. (Sometimes referred to as intrinsically safe).

Types of Instrumentation
Digital Rotating Vane Anemometer

The rotating vane is sensed by a magnetic or optical pickup and the signal is converted to a direct FPM.

Types of Instrumentation
Velocity Grid/Matrix

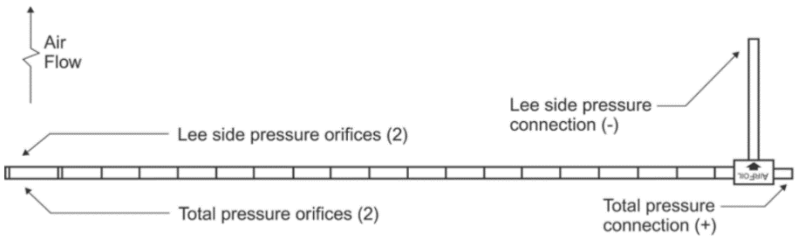
The velocity grid/matrix uses a Digital Micro-manometer to convert the pressure measurement across the grid/matrix to a FPM measurement.

Types of Instrumentation

Airfoil/Airflow Probe

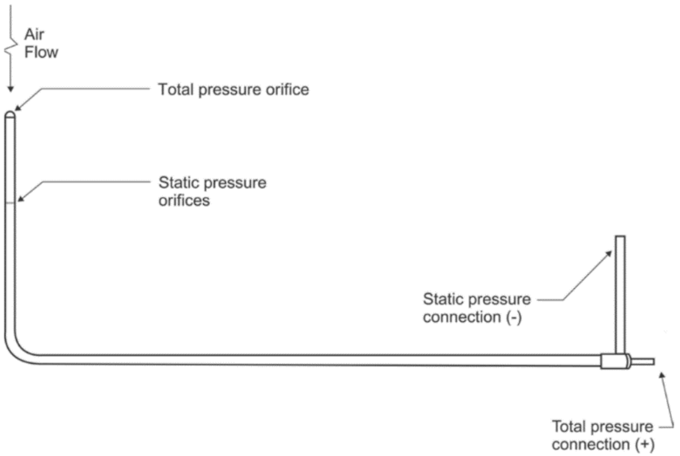
The airfoil/airflow probe uses a Digital Micro-manometer to convert the pressure measurement across the airfoil/airflow probe to a FPM measurement. The airfoil/probe amplifies the velocity pressure signal for increased sensitivity at low velocities.

The lee side pressure port is not equivalent to the static pressure port of a pitot tube.



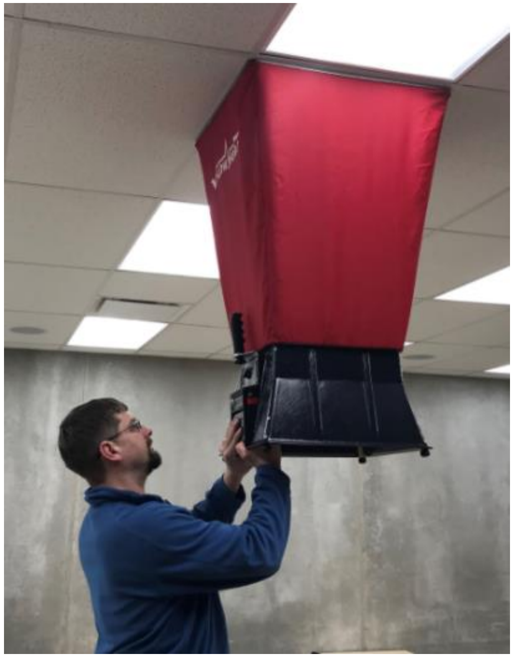
Types of Instrumentation
Pitot Tube

The pitot tube senses the total pressure and static pressure in the duct or plenum. It is a double wall tube, the inner tube senses total pressure and the outer tube senses static pressure. The difference between the two is the velocity pressure. The velocity pressure is converted to velocity in FPM. The pitot tube is used with a Digital Micro-manometer or Inclined Manometer.



Types of Instrumentation
Flow Hood/Capture Hood

The flow hood/capture hood directs the airflow across the flow sensing grid/matrix. The grid/matrix senses the total pressure and the static pressure which are combined to a single differential pressure. This differential pressure is transmitted to the digital micro-manometer for conversion to a direct airflow readout. There are various sizes to accommodate the variety of outlets/inlets. By definition the Flow Hood is a proportioning device.



Types of Instrumentation

Typical Specification	Thermal Anemometer	Mechanical Rotating Vane Anemometer	Digital Rotating Vane Anemometer	Velocity Grid/Matrix	Airfoil - Airflow Probe	Pitot Tube	Flow Hood – Capture Hood
Measurement Range	0 FPM to 6000 FPM	200 FPM to 10,000 FPM	50 FPM to 6000 FPM	25 FPM to 2500 FPM	25 FPM to 5000 FPM	50 FPM to 8000 FPM	25 CFM to 2500 CFM (1500 CFM exhaust)
Temp Range	40°F to 113°F		40°F to 113°F	40°F to 140°F	40°F to 140°F	40°F to 140°F	40°F to 140°F
Accuracy	±5% of reading or ±5 FPM whichever is greater		±1% of reading or ±4 FPM whichever is greater	±3% of reading ±7 FPM	±3% of reading ±7 FPM	±3% of reading ±7 FPM	±3% of reading ±7 CFM
Airflow Direction	Reports positive in both directions	Vane will rotate backwards	Vane will rotate backwards	Micro-manometer will report negative value	Micro-manometer will report negative value	Micro-manometer will report a “Neg Pitot” or “Error”	Micro-manometer will report negative value
Applications	Face velocity (grill, lab/kitchen hood, filter, coil); traverse; point air velocity	Face velocity (grill, lab/kitchen hood, filter, coil)	Face velocity (grill, lab/kitchen hood, filter, coil)	Face velocity (grill, lab/kitchen hood, filter, coil)	Face velocity (grill, lab/kitchen hood, filter, coil); traverse; point air velocity; low velocities	Duct Traverse; plenum traverse	Diffuser, Outlet, Grill, etc.

- Typical specifications for various manufacturers are noted. Consult individual manufacturer for specific technical data.
- Location of instrument within airstream, velocity profile and application of instrumentation will affect velocity measurement.

Manometers

Fluid Filled

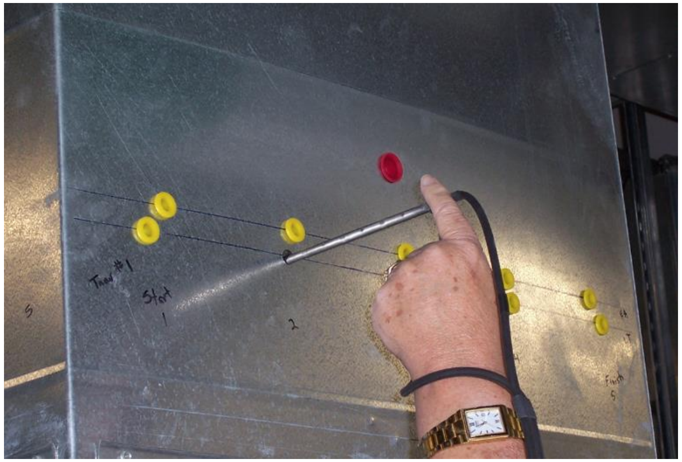
Electronic

Manometers

- Standard air conditions (Sea Level)
  - Barometric Pressure = 29.92 in. Hg
  - Temperature = 70°F
- TAB density corrections shall be made when temps are greater than or less than 30°F of standard air or altitude is greater than 2000 ft above sea level.
- Rule of Thumb
  - 2% correction for each 1000 ft above sea level
  - 1% correction for each 10°F above or below 70°F

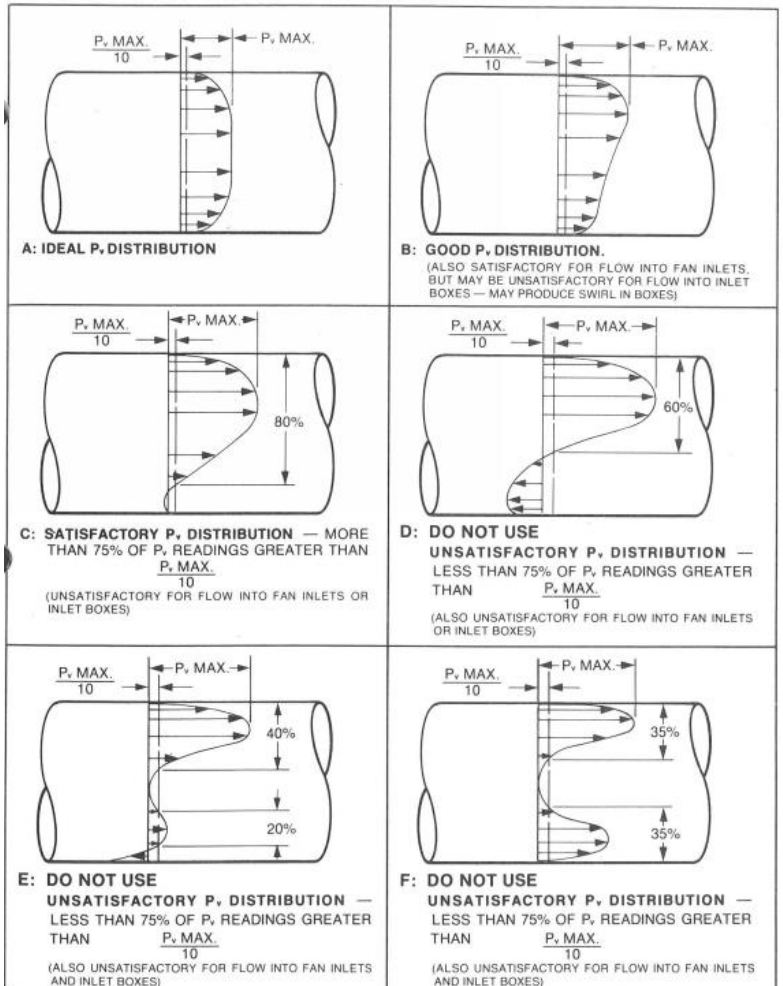
Proper Instrument Application

- Goal - Accurate and Repeatable Measurements
- Requires:
  - Proper use of instrumentation.
  - Understanding instrument operation & limitations.
  - System design/operation.
  - Good velocity profile.



Proper Instrument Application

Good Velocity Profile



TYPICAL VELOCITY PRESSURE DISTRIBUTIONS ENCOUNTERED IN VELOCITY PRESSURE MEASUREMENT PLANES IN FAN-SYSTEM INSTALLATIONS.
Figure 9-1

AMCA Publication 203-90

5

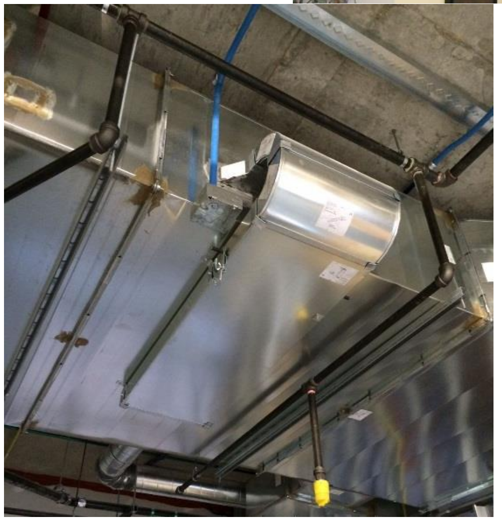
Duct Traverse

- **The primary/preferred airflow measurement method is a duct traverse.**
- **Ideal traverse plane**: AABC, AMCA & ASHRAE all identify the ideal traverse plane as
  - For **round duct:** 2 ½ diameters from condition (discharge, elbow, etc.) for up to 2500 fpm. Add 1 diameter for each additional 100 fpm.
  - For **rectangular duct:** $E_L = (4a*b/\pi)^{0.5}$, where “a” & “b” are the duct dimensions.
  - Accuracy of the traverse is better at 1000 fpm or above.

Duct Traverse

Example:

- 10,000 cfm, 30” x 20” duct, 2400 fpm
- $E_L = (4a*b/\pi)^{0.5} = 27.6”$
  2 ½ * 27.6” = 69.1”
- 69.1” (~ 6’) straight duct required



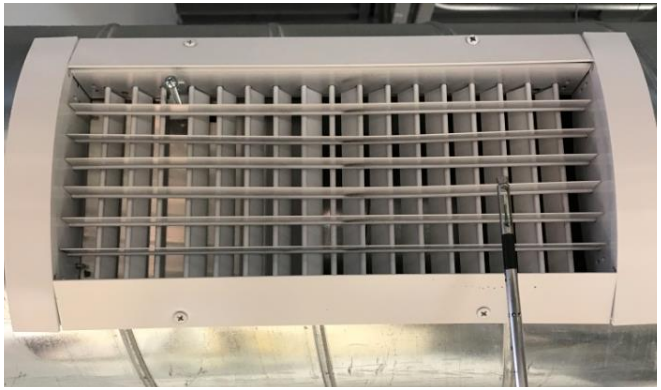
Air Velocity/Flow Measurement Challenges

Air Velocity/Flow Measurement Challenges

- Select the instrumentation that will provide the most accurate and repeatable measurement.
- Understand the system to be tested.
- Understand the proper use/limitations of instrumentation.
  - Thermal anemometer does not report a negative measurement
  - What area do you use for free area to calculate the CFM?
  - What is the velocity profile of the outlet/inlet (Jet Velocities)?
  - Experience and knowledge with testing conditions & instrumentation is key.
  - Refer to the Owners' Manual for instrumentation and equipment information!!!!

Air Velocity/Flow Measurement
Face Velocities

- Always rely on a duct traverse if at all possible. A duct traverse can still be performed if an ideal traverse plane is not available, use good judgement and past experience to evaluate the data.
- If face velocity reading of filters, coils, kitchen/lab hoods, etc. are to be utilized then the development of a “Flow Factor (Ff), Correction Factor (Cf) or Velocity Factor (Kv)” is required.



Air Velocity/Flow Measurement Options
Face Velocities

Shortridge Instruments, Inc. Operating Instructions

6.1 VELOCITY CORRECTION FACTORS

Prior to the development of capture hoods for measuring air flow directly, face velocity and jet velocity measurements were used to calculate air flow. Since the primary interest was in determining accurate volumetric air flow, obtaining accurate velocity measurements was not a priority. Only the repeatability of the velocity readings was considered to be important.

The manufacturers of the various air movement devices developed what became known as A_k or "area correction factors". These A_k factors actually corrected for the variations in velocity reading for the different types of instruments being used to measure velocity. It was necessary to develop different A_k factors for each type of test instrument used to test velocity, because each type is affected differently by the configuration of a given air movement device (AMD).

Use of the terms A_k or area constant diverted attention from the fact that average face velocity readings taken with different instruments on the same AMD were not the same, nor were readings taken with the same instrument likely to be the same on two or more AMDs with identical areas, but with different configurations.

We continue to use A_k factors when calculating the air flow for diffusers with uneven air throw and other special applications. The use of an A_k factor is not appropriate, however, in the measurement of face velocities, work zone velocities or in calculating air flow from velocity measurements at most air movement devices such as clean room HEPA filters, chemical exhaust hoods, safety cabinets, laminar flow work stations, coil and filter face velocities, kitchen exhaust hoods or any air movement device that affects velocity measuring instruments by its shape or configuration.

Various air measurement instruments will display differing readings when used on various (AMD) air movement devices, but the resulting calculated velocity or flow will be the same if the correct "k" factor is used for each particular instrument on that device. This correction factor is not an area correction factor,"A_k" (and never really was), but is actually a "Kv" velocity correction factor which must be applied to the velocity readings obtained with a specific instrument used in a specific manner on a specific AMD.

The area of the AMD is the gross active face area (frame to frame actual face area, plus leakage or bypass areas). The measured velocity multiplied by the correct "Kv" results in a corrected velocity reading that represents the true average face velocity relative to the gross active area. The measured velocity multiplied by the "Kv" multiplied by the active face area results in a calculated volumetric flow in cfm, l/s, etc.
Ideally, the manufacturers of the various air movement devices (AMD) will eventually develop and provide Kv correction factors and procedures to be used with each of their products and various velocity measurement instruments.

In the meantime, Kv factors will have to be established through field testing of AMDs in the following manner.

1. Determine the **gross active area of** the filter, coil, grille, opening or exhaust hood. Be sure to deduct the area of all obstructions to air passage such as support bands, T-bars, glue line and repaired areas on HEPA filters. The total intake area of an exhaust hood includes all areas of air entry, including the space behind and around the sash, under the threshold, and through service openings. It is accepted practice to assume that the velocity through these additional areas is the same as that of the sash opening area.

2. Determine the "actual" volumetric air flow through the given AMD air movement device. Pitot tube duct traverse is likely the most reliable means of determining the actual air flow. Direct air flow measurements can also be used in areas where duct air velocity measurements are not practical, by using the FlowHood with custom designed tops.

3. Calculate the effective average face velocity (fpm) by dividing the actual air flow measured in Step #2 (cfm) by the gross active face area (sq ft) calculated in Step #1.

4. Measure the average face velocity at the AMD using the VelGrid, AirFoil probe or other velocity instrument being tested for a Kv. Document the procedure used to obtain the average face velocity including all factors such as: the instrument used, the sensing probe positions, spacing of the velocity sample points and the number of readings taken to obtain the average for each measurement location. Always record the instrument type and any specific set up conditions such as whether readings were taken in local or standard air density (ADM-870 and ADM-870C models read both local and standard density), and whether or not the correction included temperature.

5. Calculate the velocity correction factor "Kv" for this particular AMD by dividing the effective average velocity obtained in Step #3 above by the measured velocity obtained in Step #4 above. This "Kv" factor should now be used routinely as a required multiplier to correct velocity readings taken at this specific AMD design, model and size. The specific procedures developed for measuring air velocities at a given AMD must always be used to obtain the air velocity measurements.

This "demanding" five step procedure seems to leave little room for the "art" of Testing and Balancing. This is not altogether true. The measurement of the air velocity in Step #4 is affected by the position and orientation of the air velocity measuring probe. By selective experimental positioning of the sampling point locations, a procedure can be developed which will result in a Kv for this particular AMD very near or equal to 1.0.

The face velocity test procedure should be included in the AMD test report. The result is a documented, repeatable face velocity measurement that can be confirmed by a trained technician using the proper instrumentation and following the test procedure. This procedure may also be used by laboratory personnel to retest the air flow at periodic intervals to confirm that the flow still conforms to test report data.

6.3 AIRFOIL VELOCITY MEASUREMENT
IMPORTANT: See Section 6.1 VELOCITY CORRECTION FACTORS

6.5 VELGRID AIR VELOCITY
IMPORTANT: See Section 6.1 VELOCITY CORRECTION FACTORS

Air Velocity/Flow Measurement Options
Face Velocities
Mechanical Rotating Vane Anemometer

Davis Anemometer

DIRECTIONS FOR DETERMINING CFM (CUBIC FEET PER MINUTE)

1. Take a 60 second reading at the face of the opening. For larger areas, it is recommended to take several readings at various locations along the opening and average these readings.
2. Apply the correction factor to your reading from the supplied sticker.
3. Multiply your corrected FPM anemometer reading times the square footage of the opening to obtain your CFM reading.

For testing open air spaces, it is recommended to divide the cross section into square foot areas, taking a separate reading for each area. Average all these anemometer readings to obtain a single reading for the open space.

Davis Anemometer

READING FPM	CORRECTION	READING FPM	CORRECTION
* 30	+14	1800	–60
* 50	+15	2000	–65
* 70	+15	2200	–75
** 90	+15	2400	–90
***100	+15	2600	–100
200	+15	2800	–110
300	+10	3000	–120
400	0	3200	–135
500	–5	3400	–150
600	–10	3600	–165
700	–15	3800	–175
800	–20	4000	–180
900	–25	4200	–190
1000	–30	4400	–195
1200	–35	4600	–200
1400	–45	4800	–225
1600	–55	5000	–260

***Over 5000 FPM deduct 7% from reading

Readings with asterisk apply only to model as indicated below.
* Ball Bearing
** Standard Model
*** High Speed Model

Flow/Correction Factors

Greenheck Document 452413

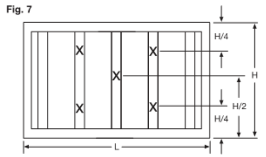
Testing Hood Air Volume

Baffle Filter - Rotating Vane Method

With all the filters in place, determine the total hood exhaust volume with a rotating vane anemometer as follows:

1. All cooking equipment should be on.
2. Measure the velocities. Velocity measurements should be taken at five locations per filter. These must be over a filter slot as in Fig. 7.

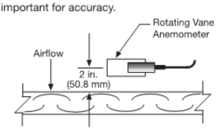
Fig. 7



Nominal Filter Size

Measure and record the velocity of each location.

A digital 2.75 in. (69.85 mm) rotating vane anemometer or equivalent is suggested. The center of the anemometer should be held 2 in. (50.8 mm) from the face of the filters. It is helpful to make a bracket to keep the anemometer at the 2 in. (50.8 mm) distance and parallel to the filter. Both squareness and distance are very important for accuracy.



Calculate the average velocity for the filter.

3. Determine the filter's conversion factor from the table.
4. Calculate the filter's volume in CFM (m^3/hr) by multiplying the average velocity by the conversion factor.
5. Calculate the hood's volume by repeating the process for the remaining filters and summing the individual filter volumes.

Nominal Filter Size (H x L)		Imperial Conversion Factor	Metric Conversion Factor
Inches	Millimeters		
16 x 16	400 x 400	1.63	.157
16 x 20	500 x 400	2.13	.198
20 x 16	400 x 500	1.90	.177
20 x 20	500 x 500	2.48	.230

Grille Free Area

Grille free area (AF/AC) is the area free of obstruction in a grille face. The more free space, the more unobstructed airflow. The following table provides the average percentage of free grille area, deflection degree, and grille model number

Table 1. Grille Free Area (A_F/A_C)

Model	Deflection (Degrees)	Free Area (%)
3F	45	52%
4F	45	62%
13R	0	86%
15R	0	83%
23R	45	44%
25R	30	62%
30R	0	75%
33R	38	61%
50F	N/A	90%
60 FL	0	42%
63 FL	30	38%
271 & 272	0	82%
	45	63%
	22.5	76%
300	see 271 & 272	
350	25	58%
		46%
		80%
		68%
		47%
		42%
		56%
		51%
		69%

Ac = .39 ft^2 18 x 4 14 x 5 12 x 6 8 x 8												
cfm		115	155	195	235	275	310	390	470	545	625	700
NC		—	—	—	—	18	22	28	34	39	43	46
Throw ft	0°	6-9-19	9-13-23	11-16-25	13-19-28	15-22-30	17-23-32	21-26-36	23-27-40	25-30-42	27-33-45	28-35-48
	22½°	5-7-15	7-10-18	9-13-20	10-15-22	12-18-24	14-18-26	17-21-29	18-22-32	20-24-34	22-26-36	22-28-38
	45°	3-5-10	4-6-11	5-8-13	7-10-14	8-11-15	9-12-16	11-13-18	12-14-20	12-15-21	13-16-23	14-17-24

NC 20 30 40

Performance Notes:

1. Tested in accordance with ASHRAE Standard 70-2006 "Method of Testing for Rating the Performance of Air Outlets and Inlets."
2. Air flow is in cfm.
3. All pressures are in in. w.g.
4. Throw values are measured in feet for terminal velocities of 150 fpm (minimum), 100 fpm (middle) and 50 fpm (maximum).
5. Throw data is based on supply air and room air being at isothermal conditions.
6. **Deflection** - The listed deflection settings refer to horizontal deflection. For a 20° upward deflection, use the room throw rating for a 0° setting and the total pressure for a 22 ½° horizontal setting.

   The performance tables are based on registers with core style 22 with an opposed blade damper. The performance of other core styles, with or without dampers, can be obtained by the application of correction factors to the tabulated performance data. The table of correction factors is included on page D80.
7. The performance tables are based on registers with F border. For ED border, the following correction factors must be applied due to the reduced core area for this border.

Listed Core Area	Multiply Throw	Multiply Total Pressure	Add NC
.15 - .30	1.30	2.6	+15
.34 - .90	1.14	1.7	+10
1.07 - 1.80	1.08	1.5	+5
2.08 - 6.25	1.04	1.2	+2

D-80

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimeter.

Titus

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RFORMANCE DATA

DELS: 300R, 300F, 300R-SS, 300R-HD, 301R, 301F, 301R-SS AND 301R-HD
FORMANCE BASED ON NOMINAL SIZES SHOWN IN BOLD

NC-20

n. ct e .)	Nom. Duct Area (ft^2)	Core Area (ft^2)	Core Vel.		300	400	500	600
			Vel. Press.		0.006	0.010	0.016	0.022
			Total Press.	0°	0.016	0.029	0.046	0.066
				22.5°	0.018	0.033	0.051	0.074
				45°	0.028	0.049	0.077	0.111
5	0.25	0.19	cfm		57	76	95	114
			NC		-	-	-	15
			Throw (ft)	0°	5-7-14	7-10-16	8-12-18	10-14-20
				22.5°	4-6-11	5-8-12	6-10-14	8-11-15
				45°	2-3-6	3-4-7	4-6-8	4-6-9
6	0.33	0.26	cfm		78	104	130	156
			NC		-	-	11	17
			Throw (ft)	0°	5-9-16	8-12-19	10-15-21	12-16-23
				22.5°	4-7-13	6-9-15	8-11-16	9-13-18
				45°	2-4-7	3-5-8	4-7-9	5-7-10

Captive Aire T&B Worksheet.xlsx

Modified on July 7, 2016

Exhaust Baffle Filter CFM Worksheet for Shortridge VelGrid

Job Number =

Job Name =

Hood Number 1 Information

Model = Length = Notes:

	Filter #1	Filter #2	Filter #3	Filter #4	Filter #5	Filter #6	Filter #7	Filter #8	Filter #9
Filter Size	No Filter	No Filter	No Filter	No Filter	No Filter	No Filter	No Filter	No Filter	No Filter
Velocity				E9					
CFM	0	0	0	0	0	0	0	0	0

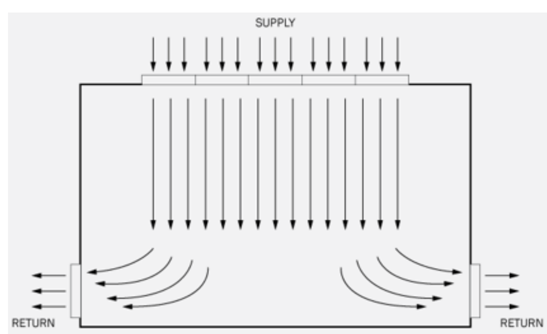
Air Velocity/Flow Measurement Options
The Flow Hood

The Flow Hood may require the development and use of correction factors when used on swirl diffusers, or on other types of diffusers with uneven air throw. The Flow Hood may not be appropriate for use on small supply outlets at high jet velocities or “nozzle” type outlets. These outlets cause an extreme concentration of air velocity on portions of the flow sensing grid. The Flow Hood readings may be inaccurate under such conditions. Consideration must be given to other system components, such as may be encountered on some single supply air outlet applications, where the Flowhood’s slight backpressure may directly affect fan performance. (Shortridge Instruments, Inc. Operating Instructions)

Verifying Flow Measurements

It is always the recommended practice to verify the flow measurements obtained with a capture hood by performing appropriate* multi-point, in-duct velocity traverses using a Pitot-static tube or a thermal anemometer.

*We recommend that you refer to the most up-to-date copy of the duct traverse specification you require from an approved regulatory or professional organization.



Flow/Correction Factors

AABC National Standards 7th Edition

3.5 Flow Factors for Airflow Measuring Devices

When reading diffusers, grilles, hoods, slots, etc. (for this discussion each item is referred to as a terminal), a flow factor shall be obtained, no matter what kind of instrument is used. To obtain a flow factor, a Pitot tube traverse is taken for each type of terminal. To avoid low flow errors, it is recommended that traverse average velocities be above 1,000 FPM (5.1 l/s). The terminal is tested with the airflow measuring device. ***Equation 3.11*** determines the flow factor (ff):

Equation 3.11 — Equation for Flow Factor

$$\textit{flow factor}\ (ff) = \frac{\textit{Traversed CFM}}{\textit{Instrument Reading}}$$

When establishing a flow factor, the density correction shall be taken in the traverse to establish the airflow measuring device flow factor at standard air. It should also be noted that the leakage shall be considered zero if there is no detectable leakage from the duct traverse location to the terminal.

Flow/Correction Factors

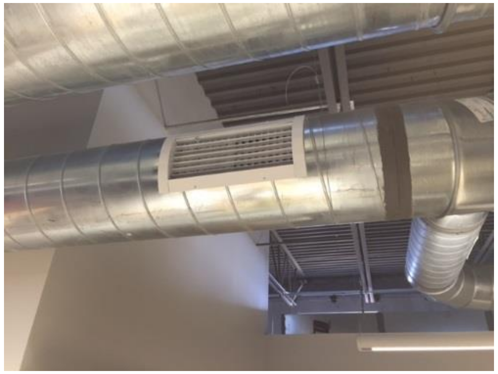
14”x6” Duct Mounted Supply Grille

Tech	Instrument	Grille Size	Vel – FPM	CFM	Ff – Cf - Kv
Cowden	RV	14x6	662	226	0.34
Shoesmith	RV	14x6	666	226	0.34
Cowden	Vel	14x6	647	226	0.35
Fowler	Vel	14x6	629	226	0.36

Pitot Tube Duct Traverse measured 226 CFM

Ff-Cf-Kv = 226 CFM / Vel – FPM

Manufacturer’s Data:
Nominal Duct Area=0.58 Ft²
45° Deflection Area Correction (AC)=0.63
Actual Grill Free Area = 0.37



Flow/Correction Factors

Nozzle Diffuser

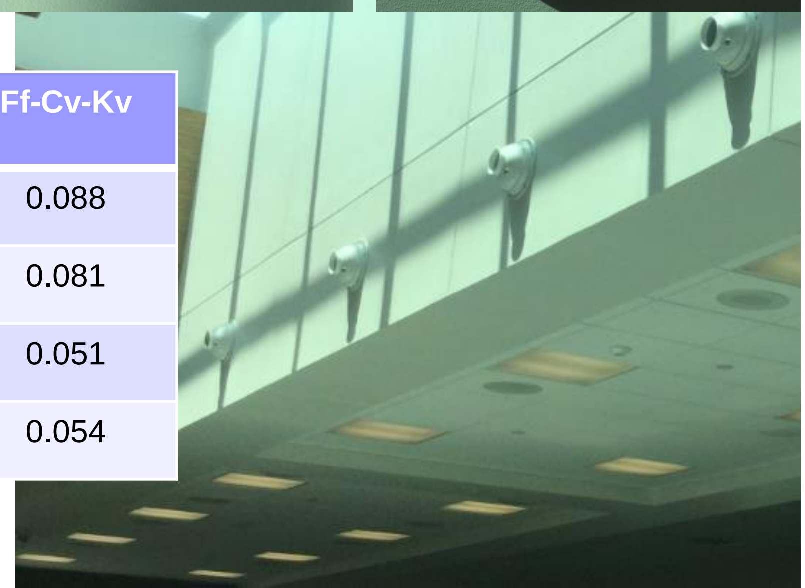
Ff = 0.088

Ff = 0.081

Ff = 0.051

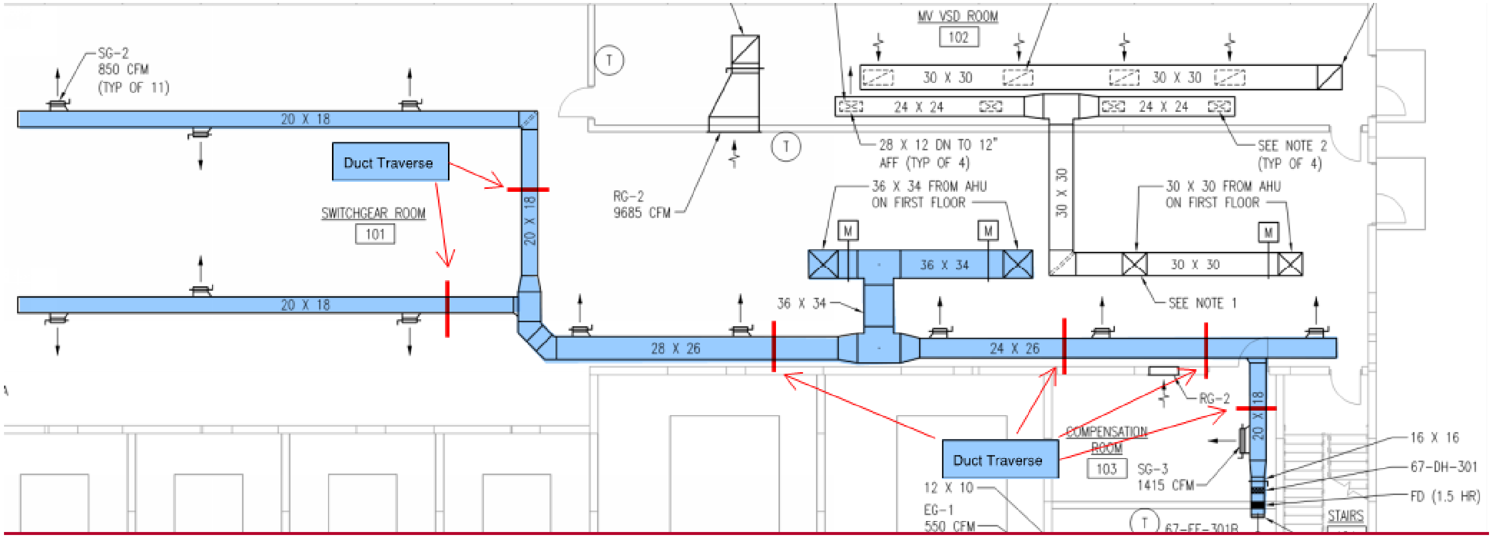
Ff = 0.054

Deflection	% Open	RV – FPM	Traverse CFM	Ff-Cv-Kv
0°	100	1284	113	0.088
38°	100	1272	103	0.081
0°	50	980	50	0.051
38°	50	963	52	0.054



Flow/Correction Factors

Multiple Duct Mounted Supply Grille



- What are your options?

Flow/Correction Factors

Flow Hood

Instrument	Outlet Size	Hood CFM	CFM	Ff – Cf - Kv
2’ x 2’ Hood	1”x4’	216 (2 Readings)	201	0.93
2’ x 4’ Hood	1”x4’	219	201	0.92
1’ x 4’ Hood	1”x4’	173	201	1.16

Pitot Tube Duct Traverse measured 201CFM

Ff-Cf-Kv = 201 CFM / Hood CFM

Flow/Correction Factors

Summary

- Review:
  - The fan system (VAV, CV, single fan, etc).
  - Type of outlet/inlet (How are deflection vanes set?)
  - Installation of ductwork & outlet/inlet (velocity profile).
- Select proper instrument.
- Experience, knowledge and “daily use” of the instruments allows for the best evaluation of the data obtained. Don’t get a number just to report a number.
- Develop the proper “Ff-Cv-Kv” and note in the report how it was developed.
  - What does an electronic micro-manometer do? It has built in “Factors” for different modes of operation based on laboratory testing.

THANK YOU!!

This concludes:

Proper Use of Airflow/Air Velocity Measuring Instrumentation

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