Airflow Testing Accuracy in the Field

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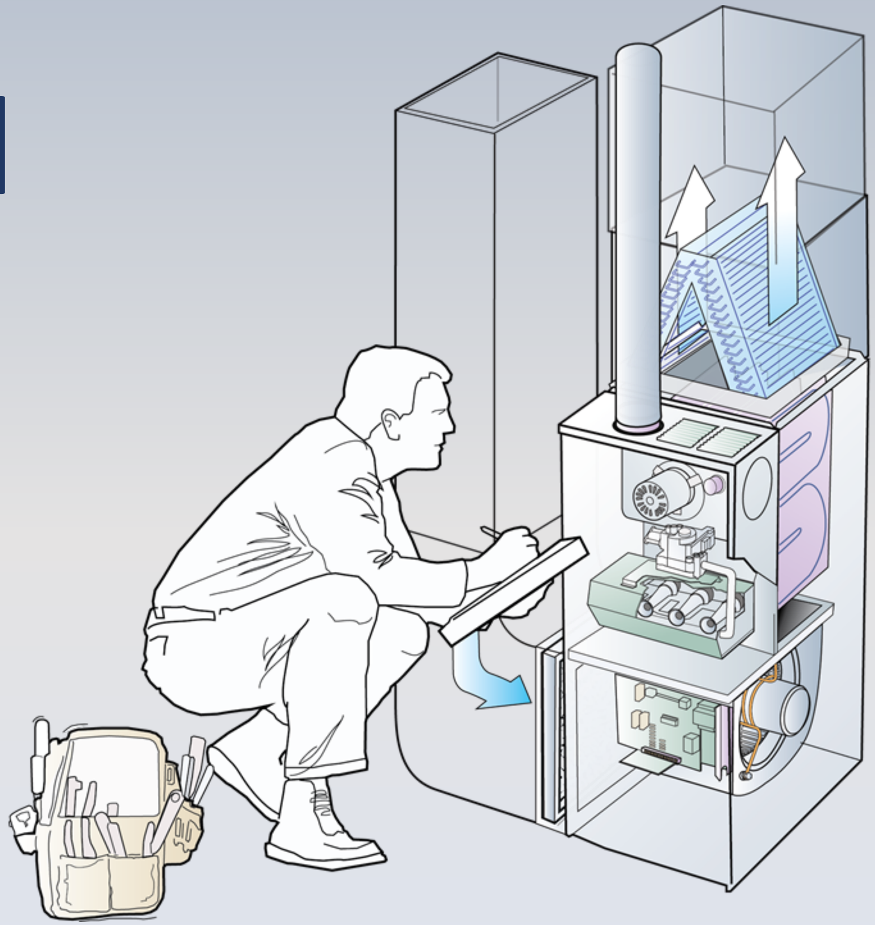

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Outline

- Why Airflow Measurement Accuracy is Important
- Factors Contributing to Field Measurement Accuracy
- Measurement and Instrument Types
- Specific Accuracy Considerations for Selected Field Measurements

Disclaimer: None of the references to specific manufacturers or products that may be made in this presentation constitute a recommendation by NCI, Inc. or Building Metrics, Inc. for or against purchasing or using the product.

Who We Are, and Why We're Up Here Together

BSR/ASHRAE Standard 221P

Substantial Full Public Review Draft

Test Method to Field-Measure and Score the Cooling and Heating Performance of an Installed Unitary HVAC System

Second Public Review (December 2018)
(Draft Shows Complete Proposed Standard)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

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ASHRAE, 1791 Tullie Circle, NE, Atlanta GA 30329-2305

- Pete and Ben are both mechanical engineers, paths have crossed many times over the past few years.
- Interested in field HVAC performance measurement, energy efficiency
  - Pete from the EM&V side
  - Ben from the program design and implementation side
- Both served on the WHPA Commercial Installation Committee
- Currently serve together on the ASHRAE 221P Standard Committee

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Importance of Airflow Accuracy

- Of the measurements that go into calculating delivered capacity, **airflow**…
  - Is least accurate
  - Has the largest potential range of accuracy

Field Measurement	Rough Accuracy Range
CFM Airflow	**+/-3% to 20%**
Temperature	+/-1% to 2%
Relative Humidity	+/- 2% to 3%

$$BTUh = 4.5 \times \boldsymbol{CFM} \times \Delta h$$

Air Flow Measurements in ASHRAE Standard 221P

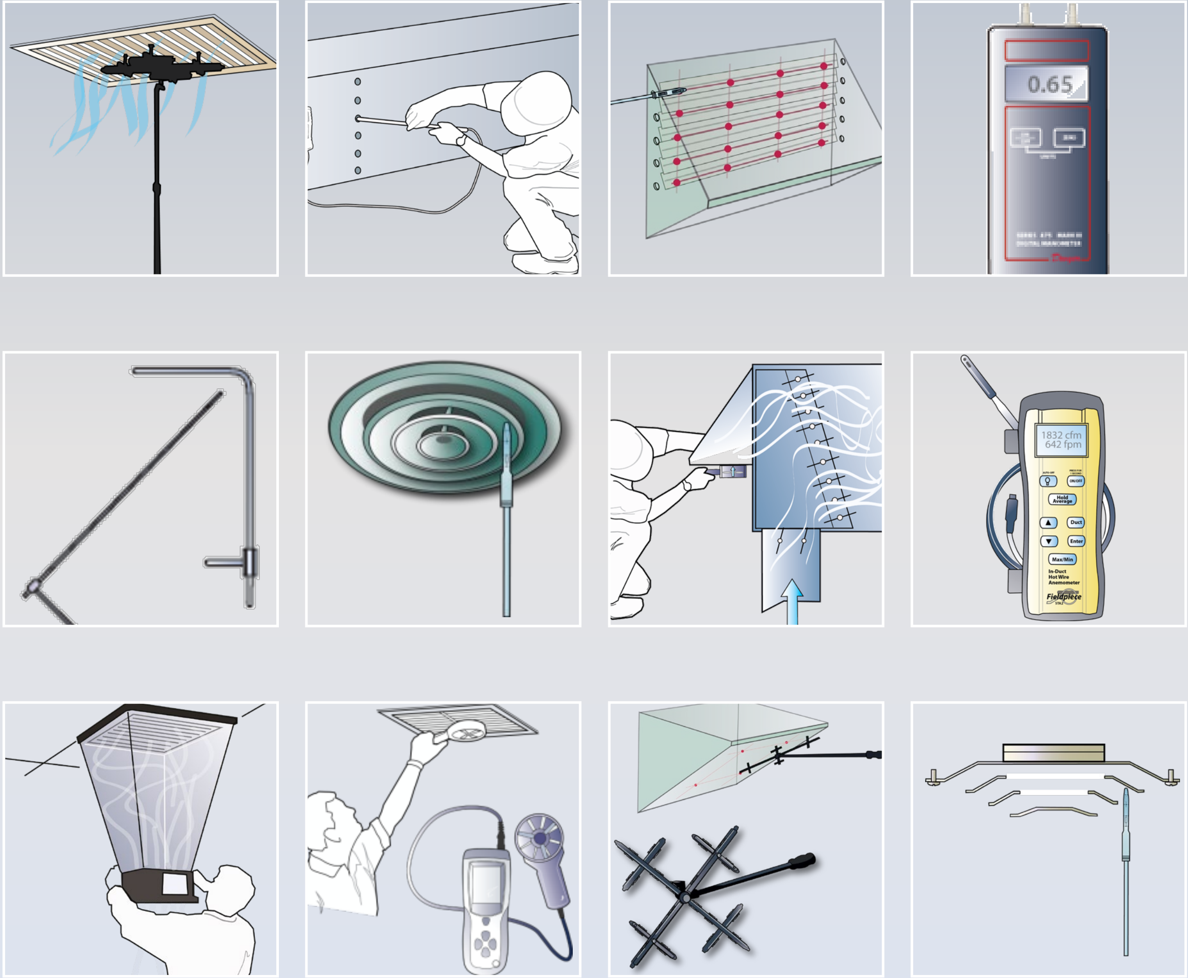
- Supply register flow (air delivered into space)
- Outside air flow (air entering the HVAC unit)

Factors Contributing to Accuracy in the Field

- Instrument accuracy
- Building and System Attributes
- Measurement Technique

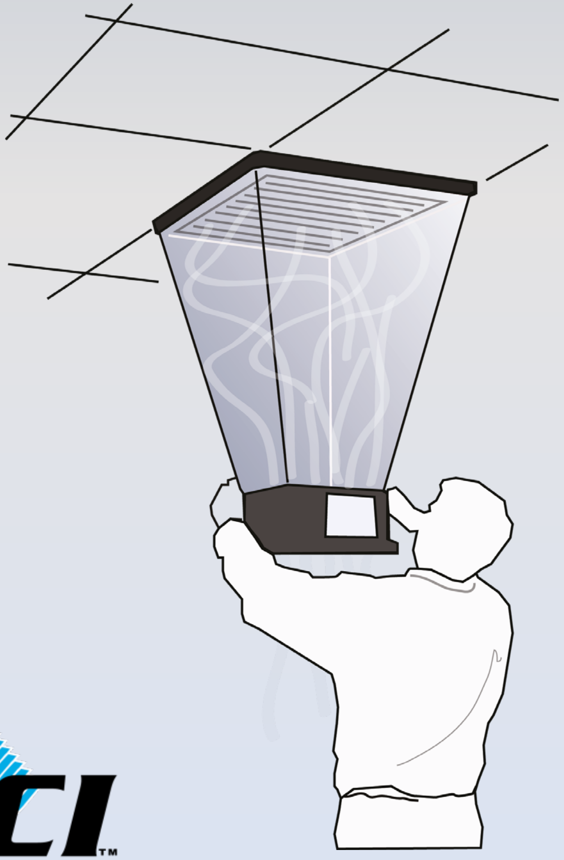
Field Airflow Measurements and Instruments

- There are **many** different airflow measurement applications in HVAC
- Requires multiple instruments and techniques
- Each application has its own challenges and accuracy considerations

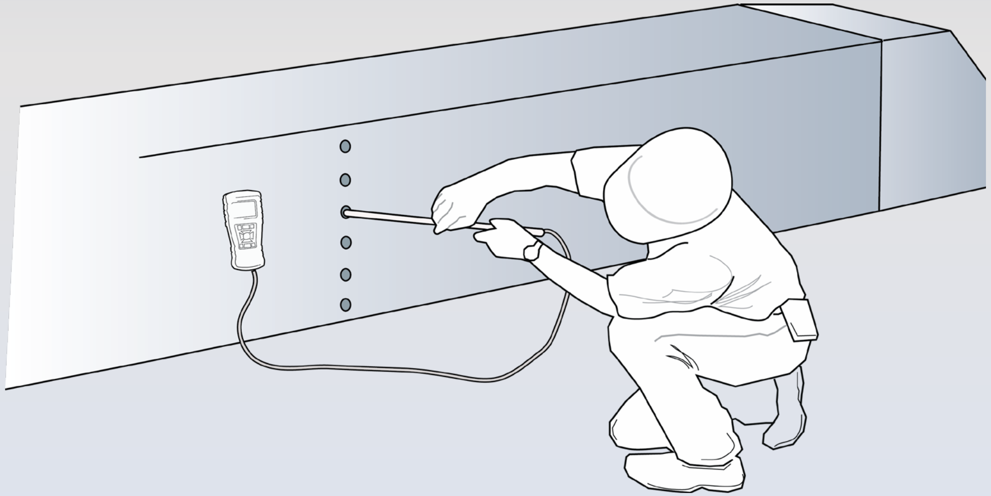


Our Focus Today

CFM Through Registers and Grilles Using a Capture Hood



CFM Through Ducts Using a Thermal Anemometer or Pitot Tube Traverse



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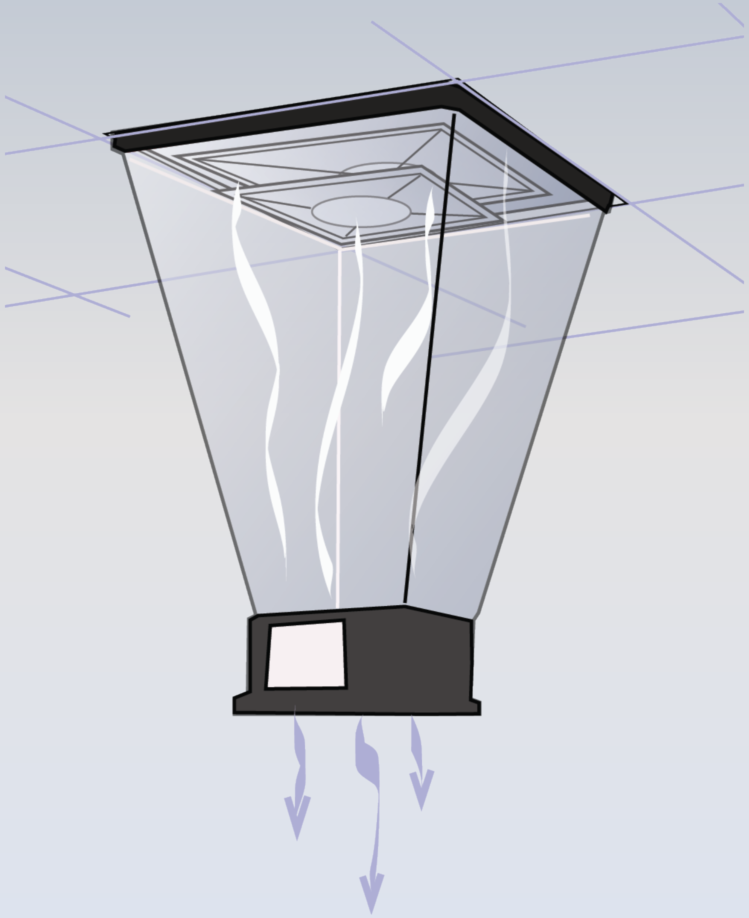
Capture Hood Accuracy

Instrument accuracy	± 3% ± 7 CFM
Building and System Attributes	May decrease accuracy to ± 10% or more
Measurement Technique	Can decrease accuracy further to ± 30% or more



Research

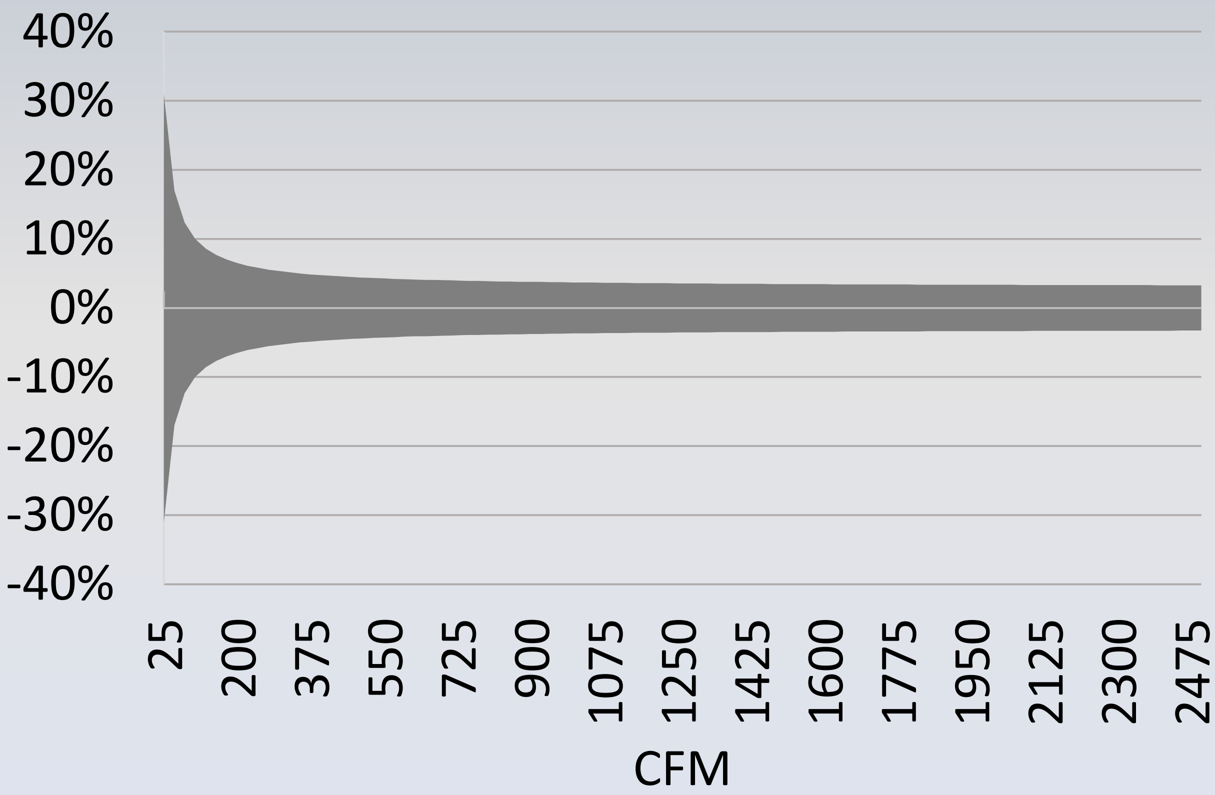
- Most of the research to date has come from Laurence Berkeley National Laboratory (Wray et al. 2001, 2002, 2003, 2012)
- In summary the research:
  - Focused on residential airflow measurement applications (i.e. lower flows, smaller registers and grilles)
  - Included some non-commercialized and prototype devices, while excluding many commercially available devices
  - Concludes that fan-powered flow hoods are generally more accurate than non-powered flow hoods
  - Notes field usability issues with powered flow hoods including battery life, complicated setup, weight, and longer measurement times
  - Notes large size and accuracy issues for residential applications with non-powered flow hoods
  - Notes that addition of flow conditioning devices significantly improves accuracy in non-powered flow hoods
  - Recommends establishing a standard for flow hood accuracy that takes includes considerations for actual use in the field

Research cont.

- Whyte, et al. The Measurement of Air Supply Volumes and Velocities in Cleanrooms. University of Scotland. 2010
  - Found hood measurements on swirl diffusers biased 56% high compared to measurements with a 4-way or no diffuser
  - Demonstrated positive impacts on accuracy through flow conditioning including screens and barriers perpendicular to flow

Accuracy Throughout Measurement Range

- Industry leading hood has a range of 25 to 2500 CFM
- Accuracy spec is ± 3% **± 7 CFM**
- Accuracy is lower at the lower end of the measurement range
- ± 31% at 25 CFM
- ± 10% at 100 CFM



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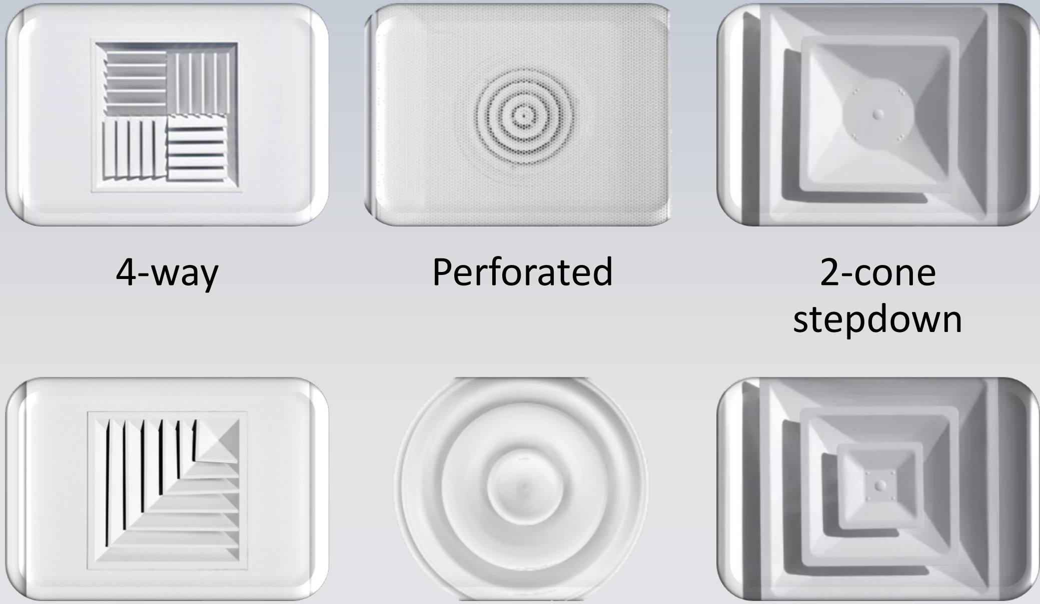
Field Supply Register Variety

- Hoods typically calibrated in a lab with a single type of register or no register at all
- Wide variety of registers used in real buildings can significantly impact on accuracy
- Manufacturers have started to design ways to compensate
  - Flow conditioning (straightening)
  - Specific calibration by register type



4-way | Perforated | 2-cone stepdown

2-way directional | Round stepdown | 3-cone stepdown

Photos adapted for Fair Use from: http://truaire.com/

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Whyte et al. CFD simulation of a airflow through a hood from a 4-way diffuser vs. a swirl diffuser: http://eprints.gla.ac.uk/40969/1/40969.pdf

Register Impacts

- Some diffusers allow air to flow uniformly over the sensing element and allow hood to work as designed
- Others cause air to flow erratically over the sensing element and cause measurements to be biased either high or low

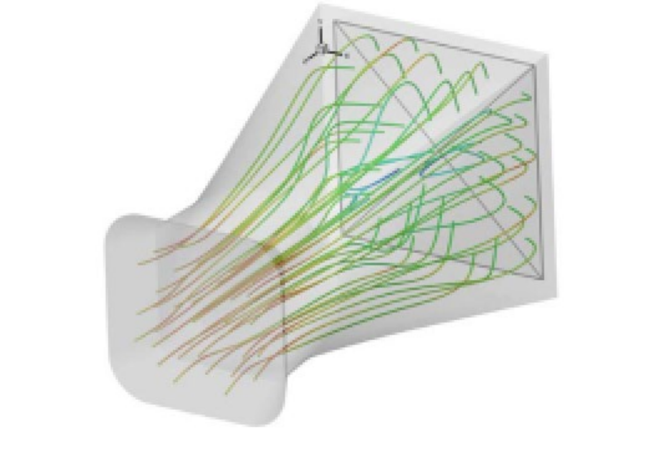

Figure 6 Airflow through a hood coming from a 4-way diffuser

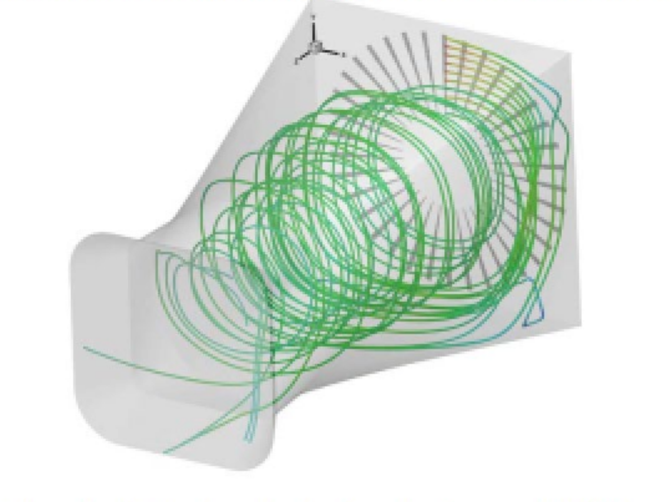

Figure 7 Airflow through a hood coming from a swirl diffuser

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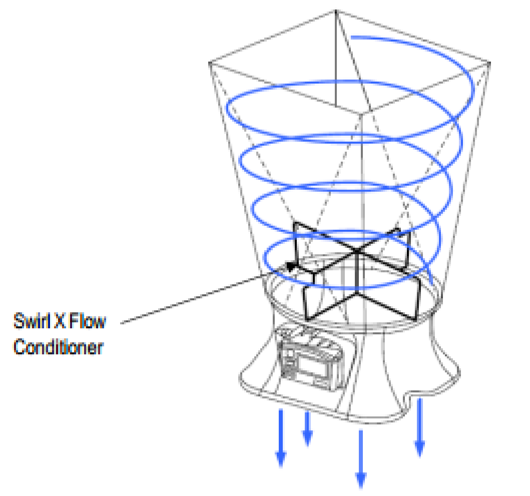
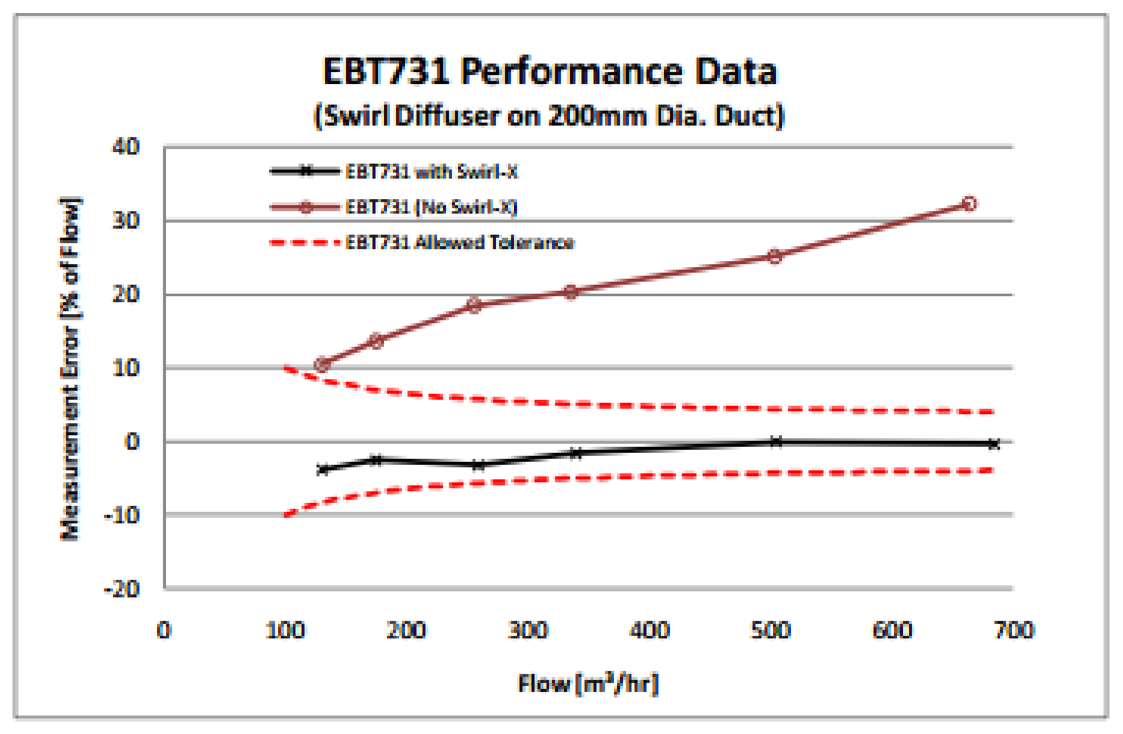
Flow Conditioning

- Multiple manufacturers have begun integrating or selling add-on flow conditioning or straightening devices in their hoods
- TSI/Alnor includes a picture and some data in the owners manual for the EBT731:

https://www.tsi.com/getmedia/643561c1-4d2a-43b1-a557-88b549a9da80/EBT730-731_Owners_Mnl_6005725_US?ext=.pdf





Flow Conditioning and Register Type Calibration

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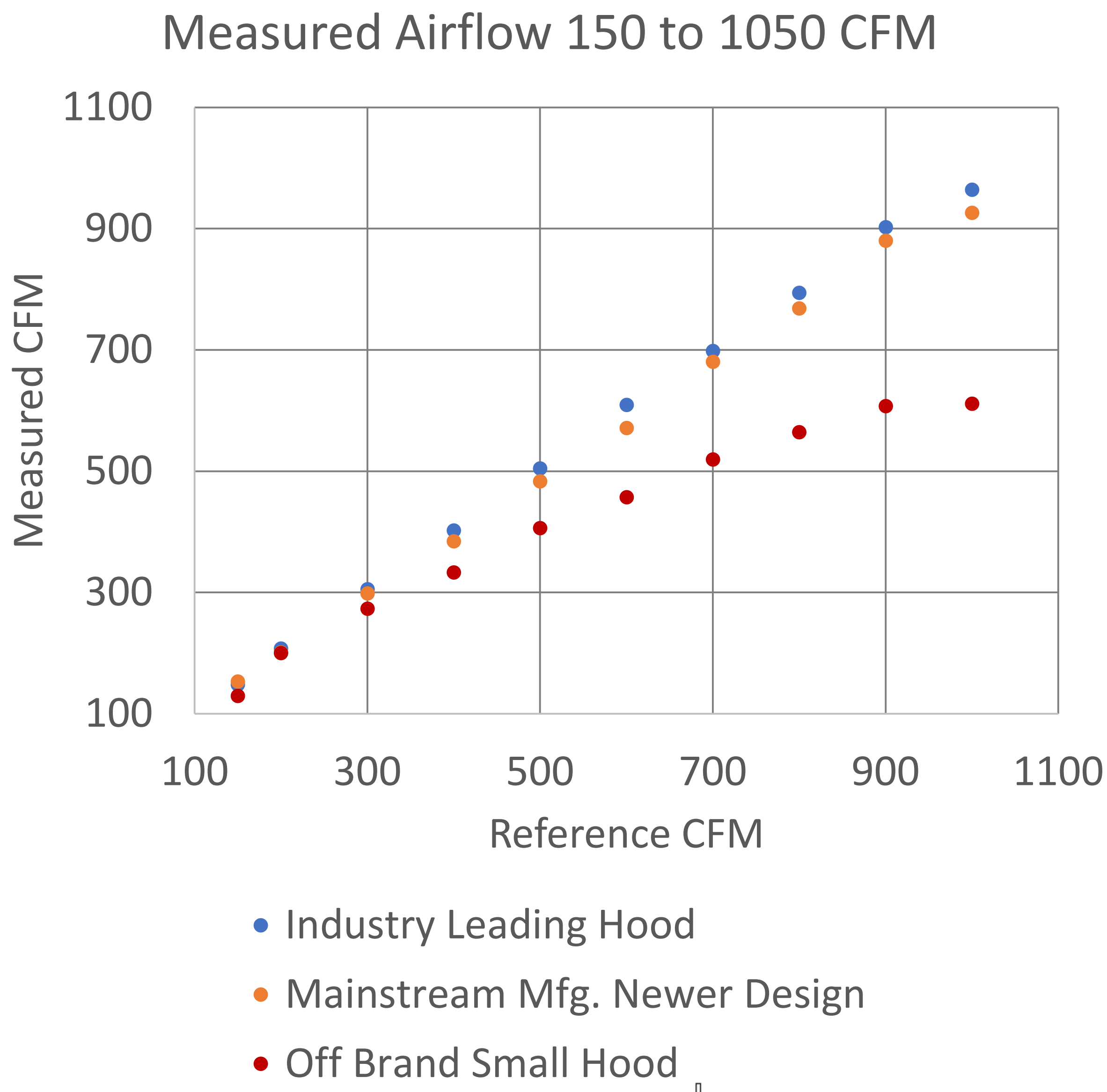
- One hood manufacturer has incorporated flow conditioning integral to the design of the hood
- In addition to specific calibration profiles for various types of registers

Resistance to Flow

- Typical hoods with an opening of about 12”x12” don’t cause excessive resistance within typical measurement ranges
- Hoods with smaller openings can create a large pressure drop when used for higher airflows
- Restriction through a hood can reduce flow through the grille you’re measuring giving a false measurement
- The data for an off brand hood with small opening shows error exceeding 20% at flows 600 CFM and higher
- Manufacturer claims range up to 1200 CFM with airflow velocity accuracy of +/-0.5%



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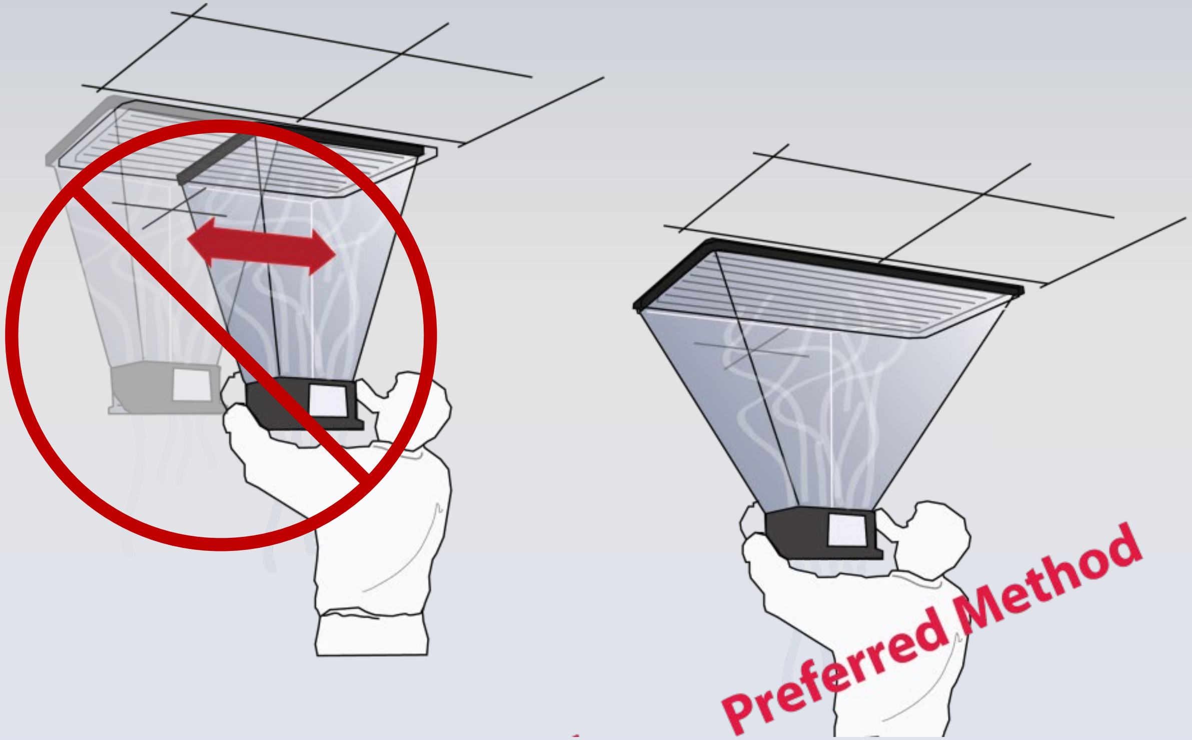
Measuring Non-Standard Grilles

- Many registers are 2’x2’ square, and that’s what most hoods are designed for
- Other shapes and sizes require specialized skirts and/or adapters to accurately measure
- Sometimes it’s necessary to field-fabricate adapters



Powered Flow Hoods

Pros

- Flow hoods that include a fan
  - Compensates for restriction caused by the hood
  - Minimizes effect of uneven flow through different types of registers
- Have been shown to be very accurate in low flow and other situations that present accuracy challenges for non-powered hoods

Cons

- Currently only available from 2 overseas manufacturers
- Limited measurement range less than 235 CFM or 500 CFM depending on mfg., limits use on returns and in commercial applications
- Battery to power fan limits working time before recharge and adds weight

Looking to the Future

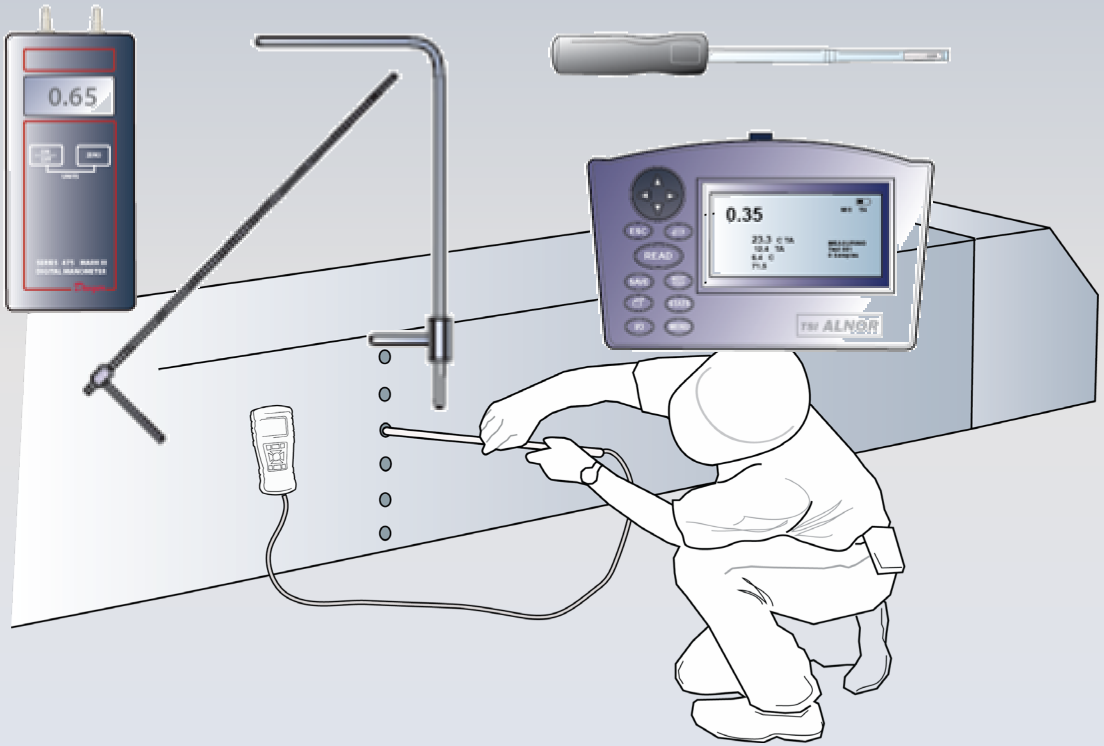
- Proposed standard method of test for accuracy specifications
- Additional research on field measurement accuracy
  - Include the latest developments in non-powered and powered flow hoods
  - Look at both residential and commercial applications
- Potential further improvements in non-powered flow hoods
  - Further developing and optimizing flow conditioning approaches
  - Expanding and improving register-specific calibration approaches
- Potential further improvements in powered flow hoods
  - Increasing measurement range
  - Longer life, faster charging, lighter weight battery technology
  - Focus on ergonomics and field usability

Why do a duct traverse?

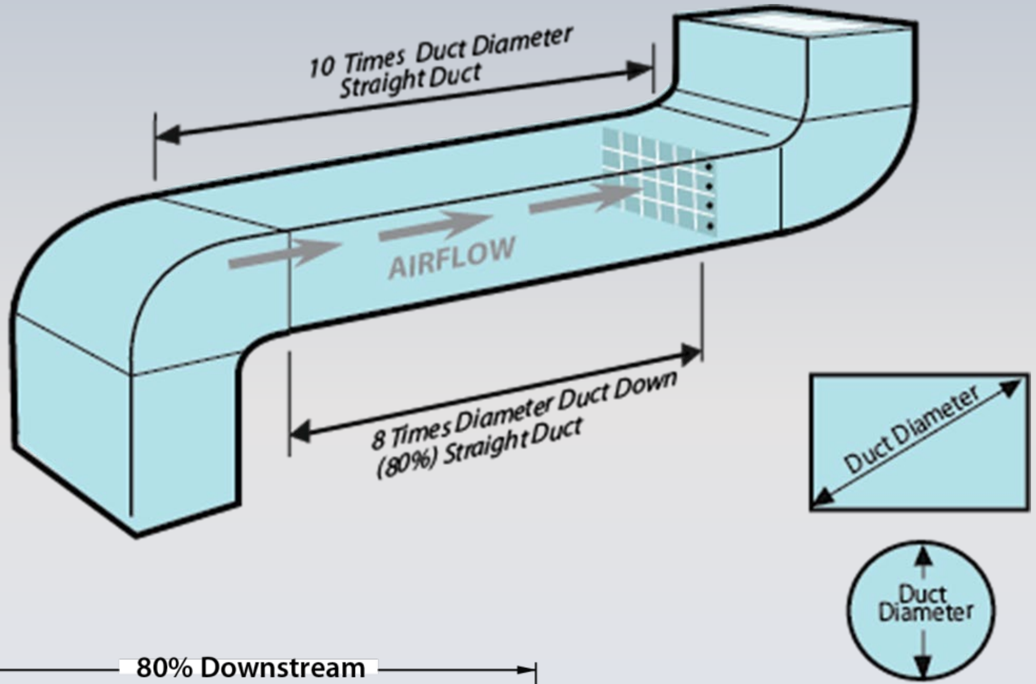
- Measure flow in situations where flow hoods cannot be used
- Need to know duct rather than register airflow
- Develop correction factors for flow hood measurements on non-standard diffusers
- Develop field Ak factors for registers when combined with register traverse

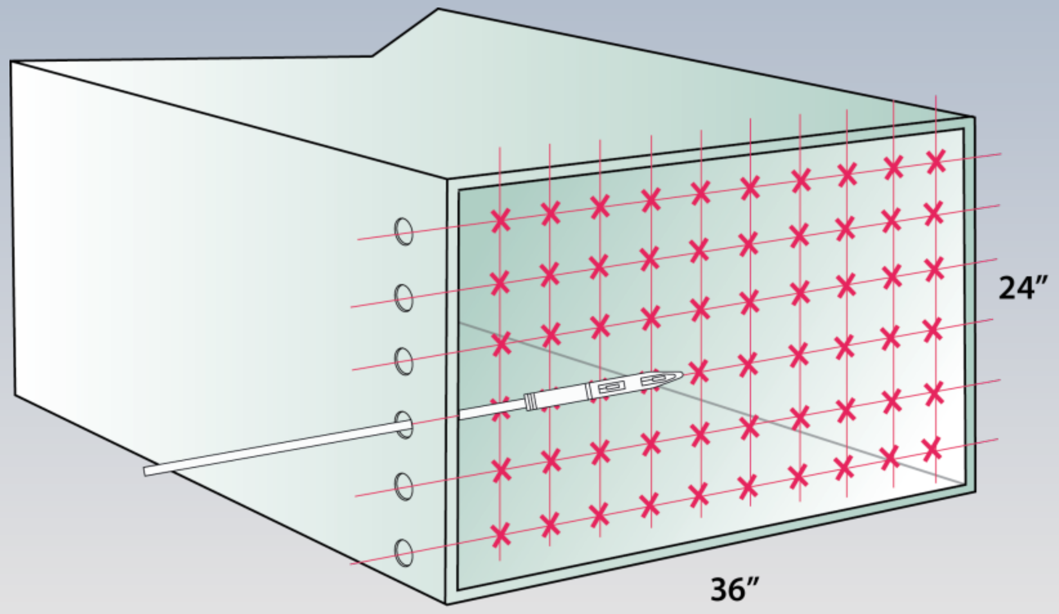
Duct Traverse

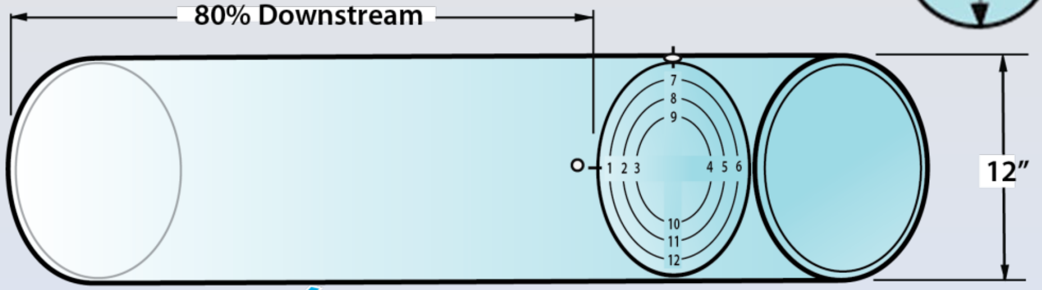
- Can be accomplished with a pitot tube or thermal anemometer

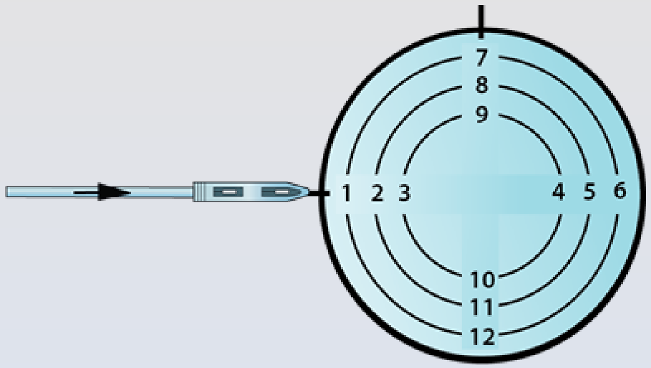


Duct Traverse Locations









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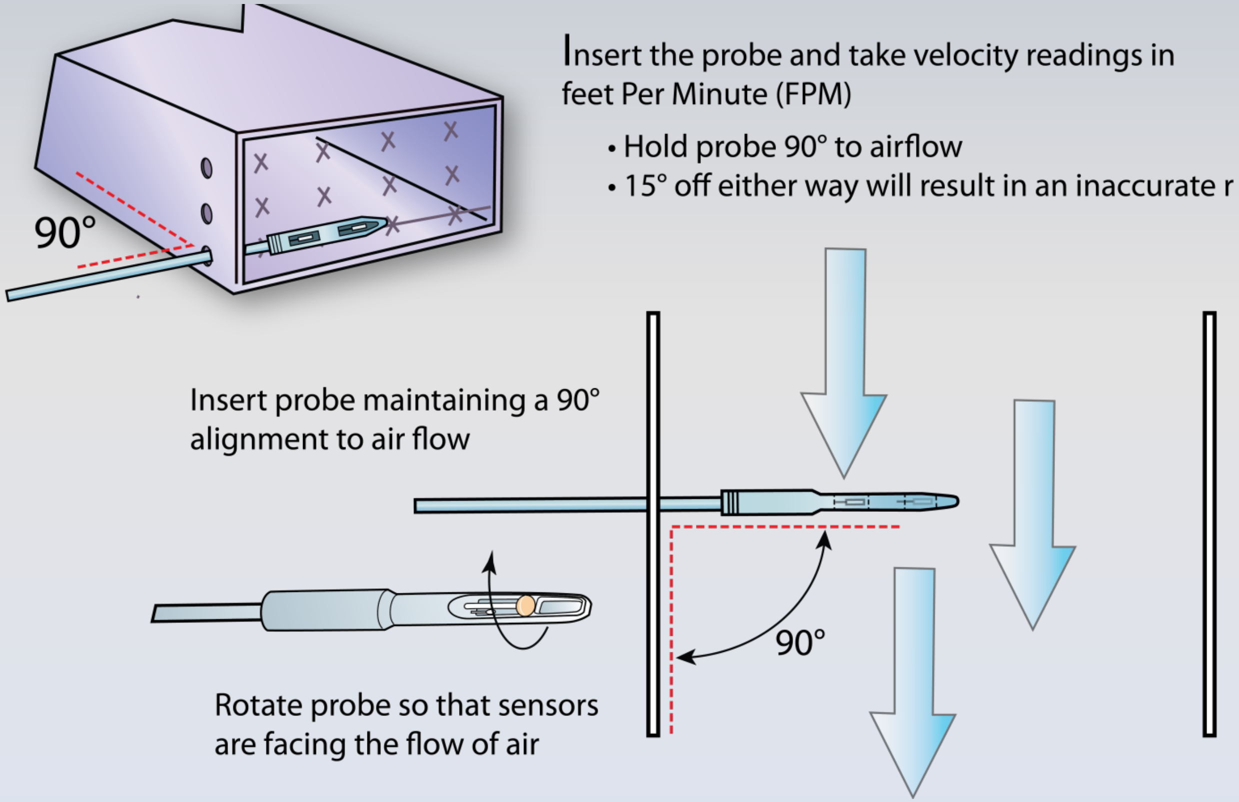
Gold Standard Traverse Accuracy +/- 3%

- Fully developed flow
- Multiple measurements
- Measurements relatively uniform
  - ASHRAE 111 criterion: >75% of measurements > 10% of max velocity
- 10 diameters straight run
- Measure at least 8 diameters downstream, 2 diameters upstream of obstruction
- Duct diameter should be at least 30 times the diameter of the Pitot tube.
- Flow parallel to duct wall

Probe Direction



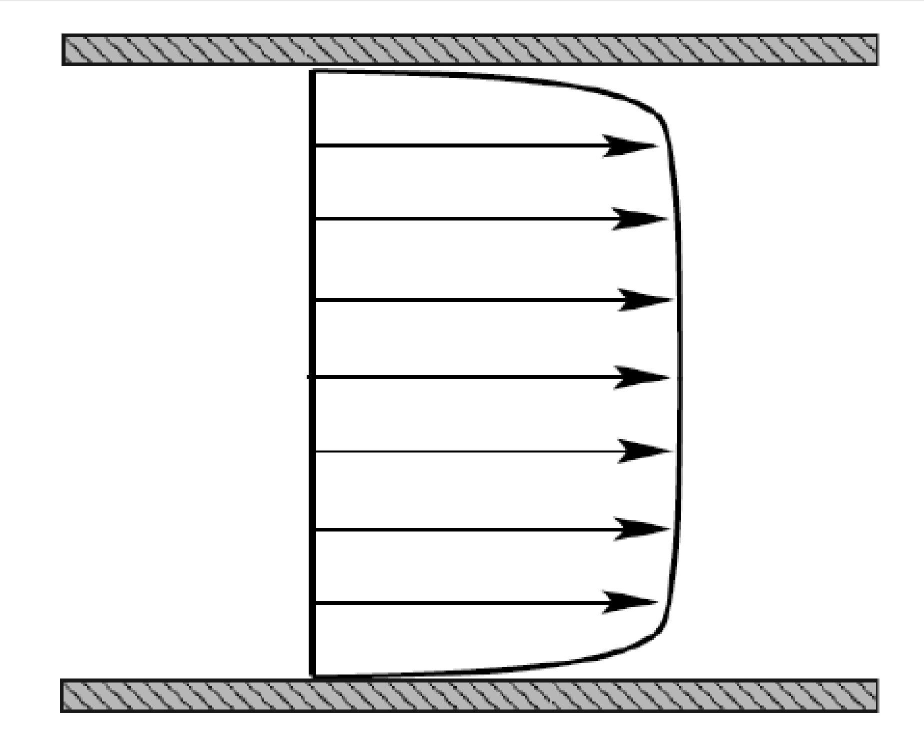
Rotate probe to get max velocity

Reality of Field Conditions

- Insufficient straight run
- Non-uniform flow distribution
- Not enough measurements
- Flow not parallel to duct – swirl or eddys
- Fan outlets are the worst

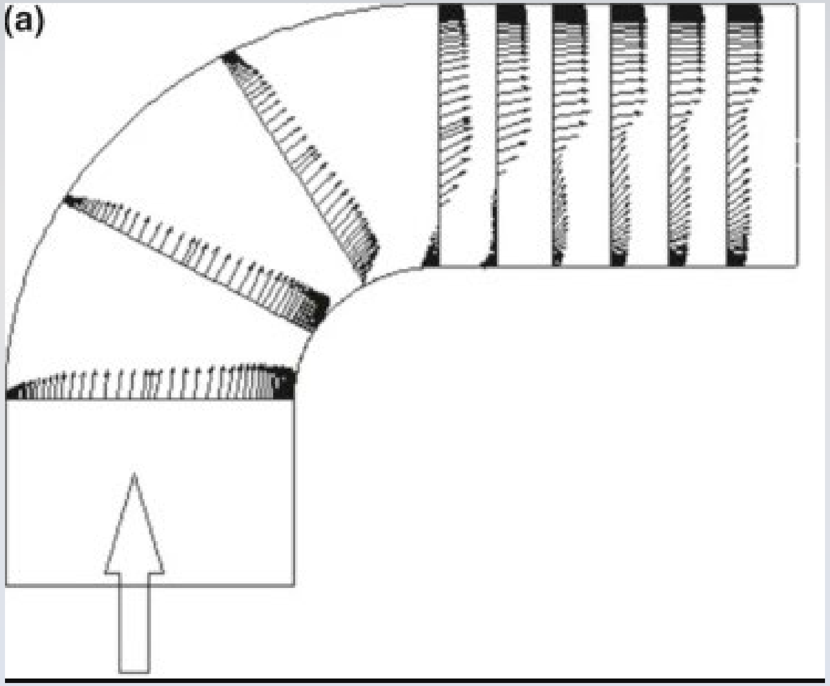
Fully Developed Flow Profile

- Symmetric flow pattern
- Fairly uniform across duct
- Flow parallel to duct wall
- No eddys
- Zero velocity at wall, but goes to near average velocity close to the wall

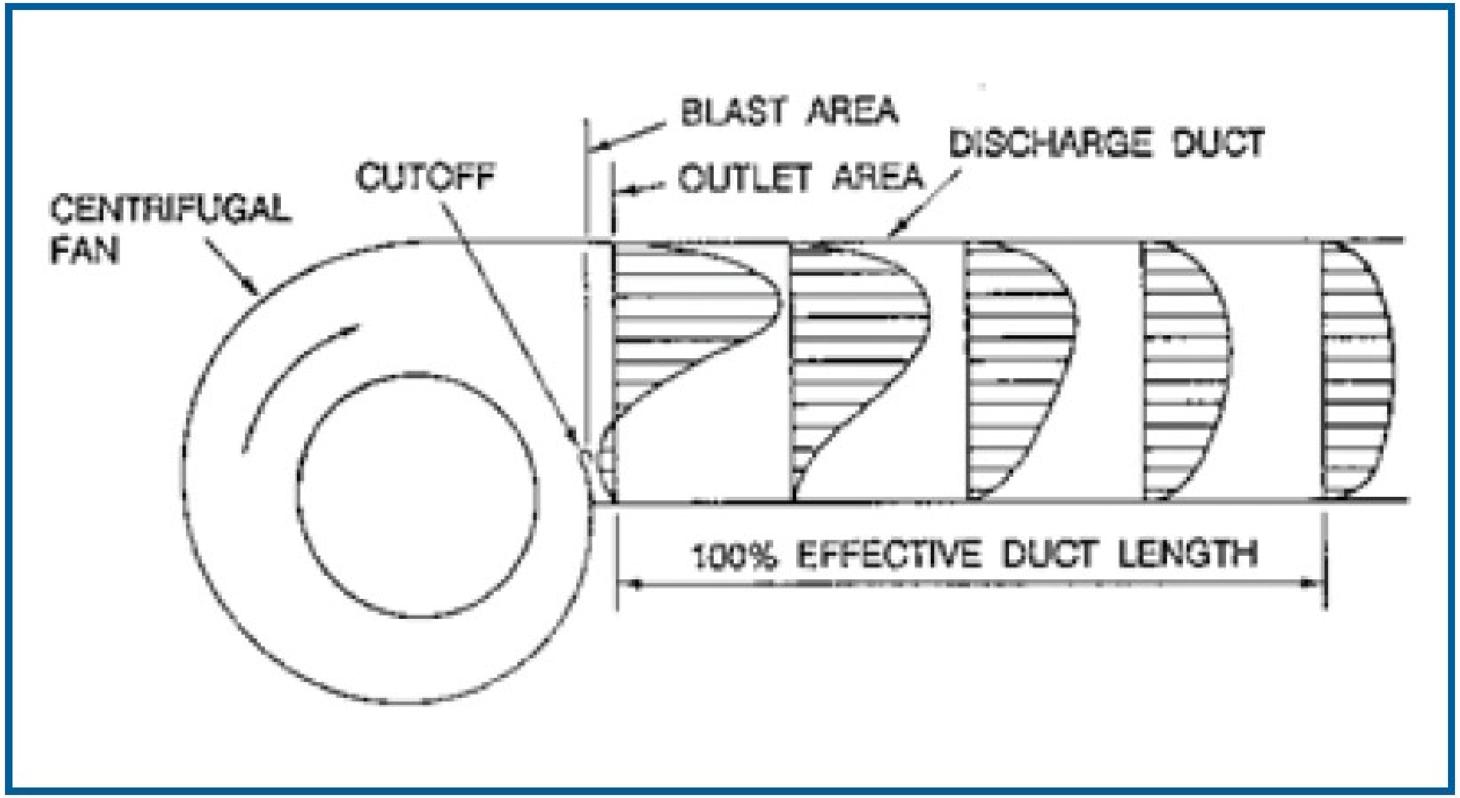


Flow Near Elbow

- Becomes asymmetric near entrance
- Some reverse flow near exit
- Asymmetry becomes less as downstream distance increases

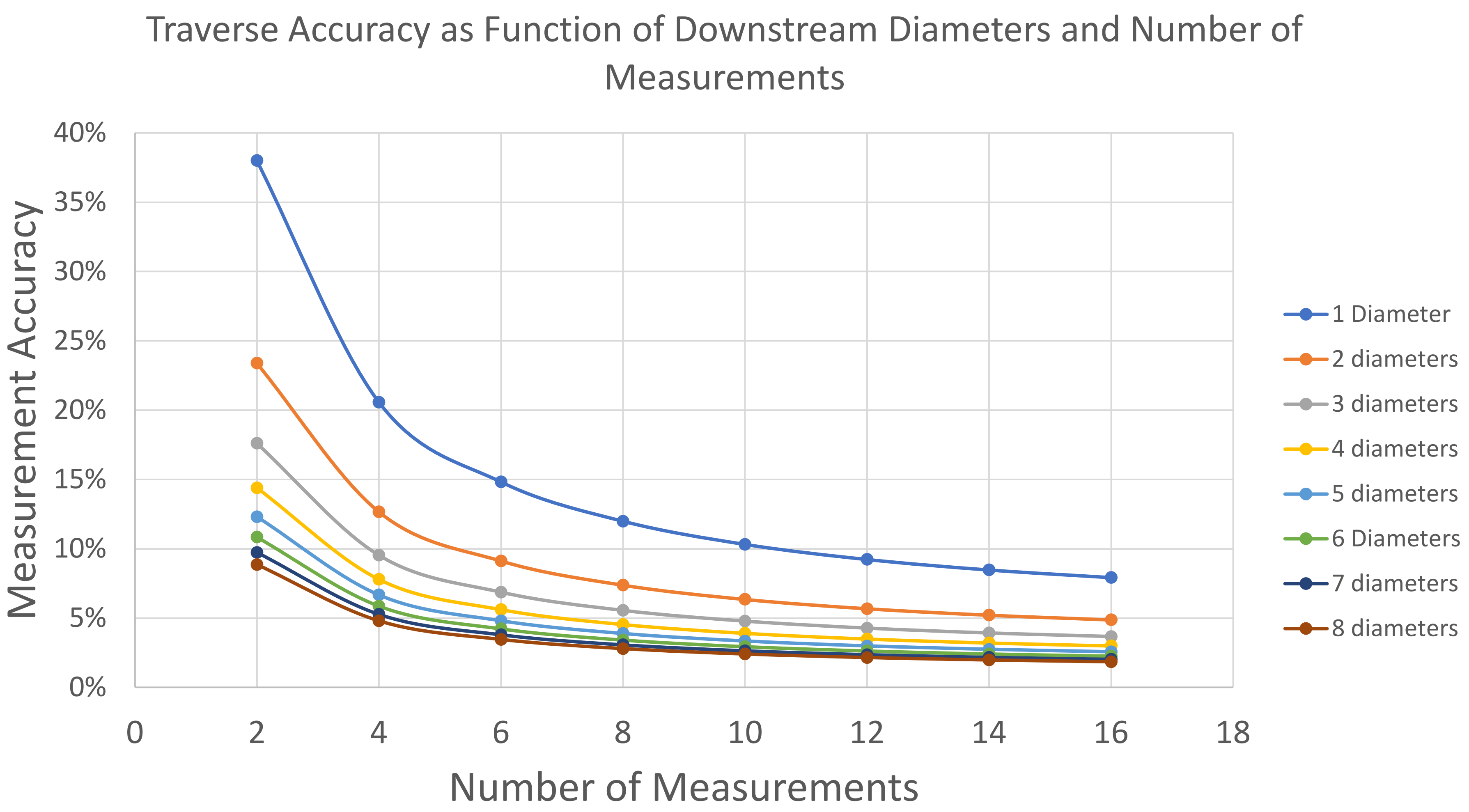


Flow Profile at Fan Discharge



Measurement of air flow in duct by velocity measurements

Isabelle Caré[1,a], Francis Bonthoux[2] and Jean-Raymond Fontaine[2]



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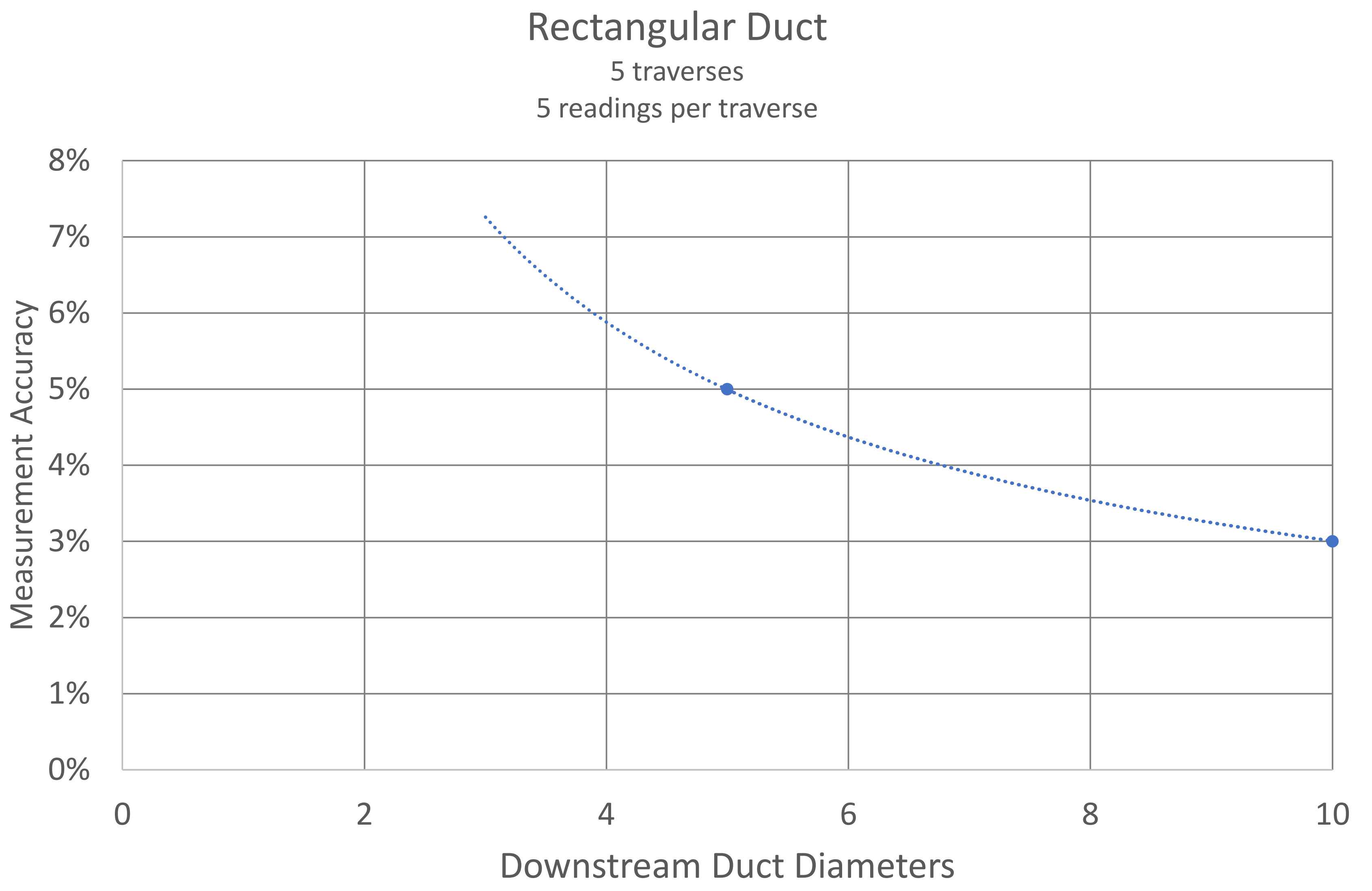


Rectangular Duct
5 traverses
5 readings per traverse
Measurement Accuracy
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
2
4
6
8
10
Downstream Duct Diameters

Anemometer Considerations

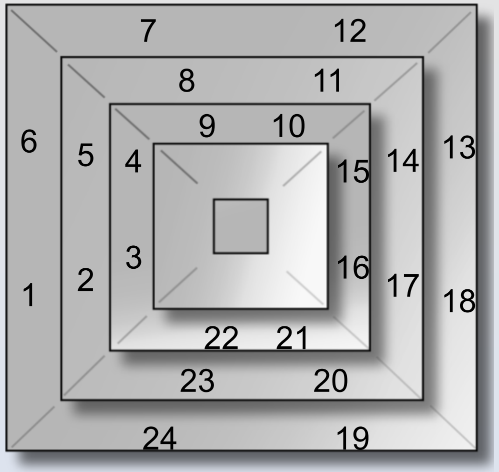
- Minimum velocity ranges
  - Thermal anemometer – low as 5 fpm; depends on the cost
  - Vane anemometer – 50 fpm typical
  - Pitot tube – 300 fpm typical (depends on manometer)
- Flow direction
  - Vane anemometer will detect flow direction
  - Hot wire won't pick up negative flows

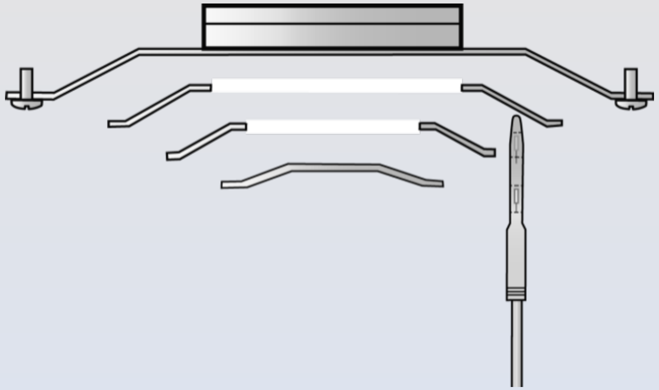
Shortcut for Small Round Ducts

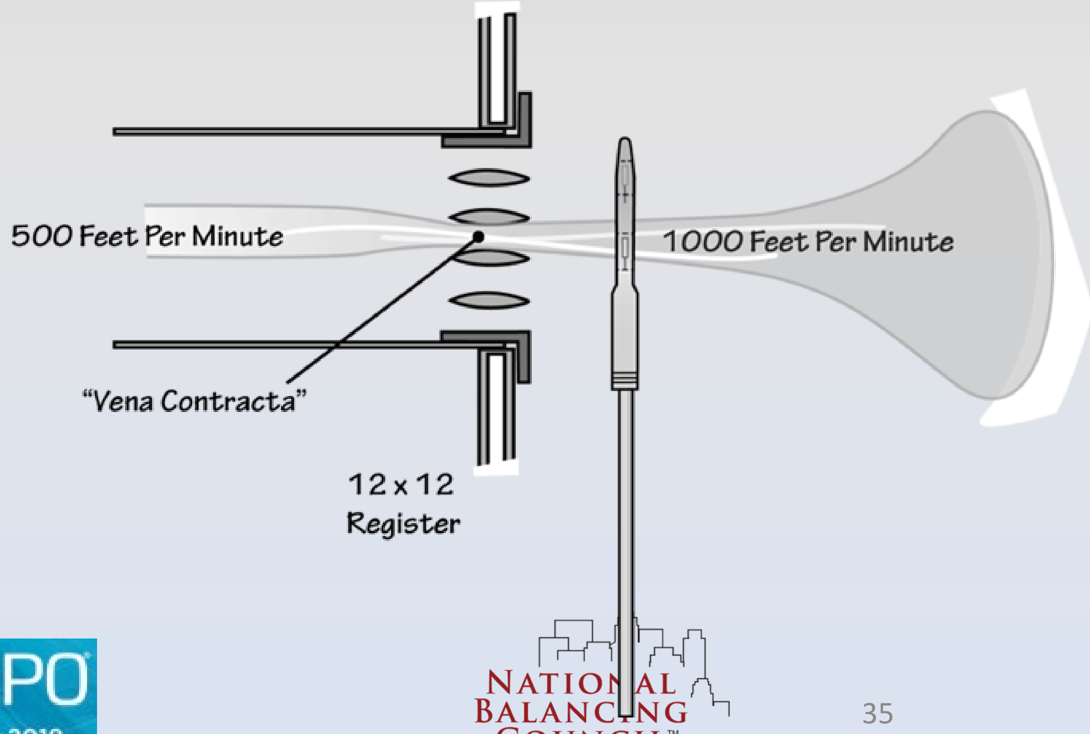
- It is also possible to take a single reading to measure air velocity or air volume flow in a duct,
- Measuring in the center of the duct and multiplying the reading by 0.9 to correct for the higher velocity at the center. If conditions are very good, an accuracy of ± 5 or 10 percent may be obtained this way.

Air flow measurements – Register traverse

- When a supply register is inaccessible, outside the hood specifications, or in question, an airflow traverse is used to verify the hood reading.
- Supply resisters require a correction factor to correct for air velocity increases through the register



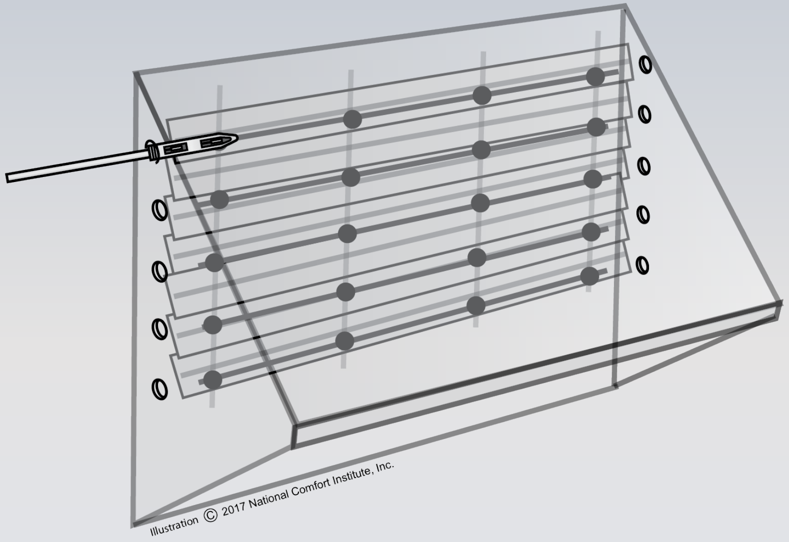


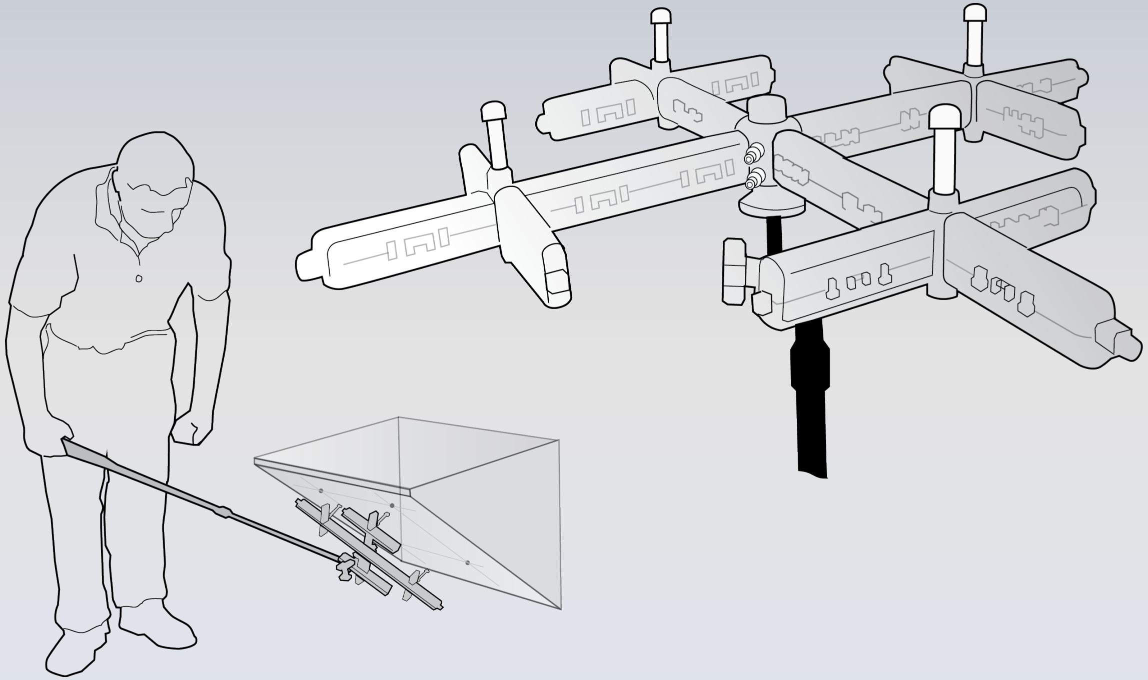


Outdoor Air

- Technique depends on outdoor conditions
- Calm conditions use a flow matrix or vane anemometer traverse
- Windy conditions use hotwire traverse in the eyebrow
- Research conducted by LBNL for the California Energy Commission recommends anemometer or flow grid measurements
  - Flow grid measurement accuracy +/-15.1% (range 15%-16%)
  - Anemometer measurement accuracy +/-15.8% (range 10% - 22%)

Air flow measurements –Outdoor air





Hot wire traverse

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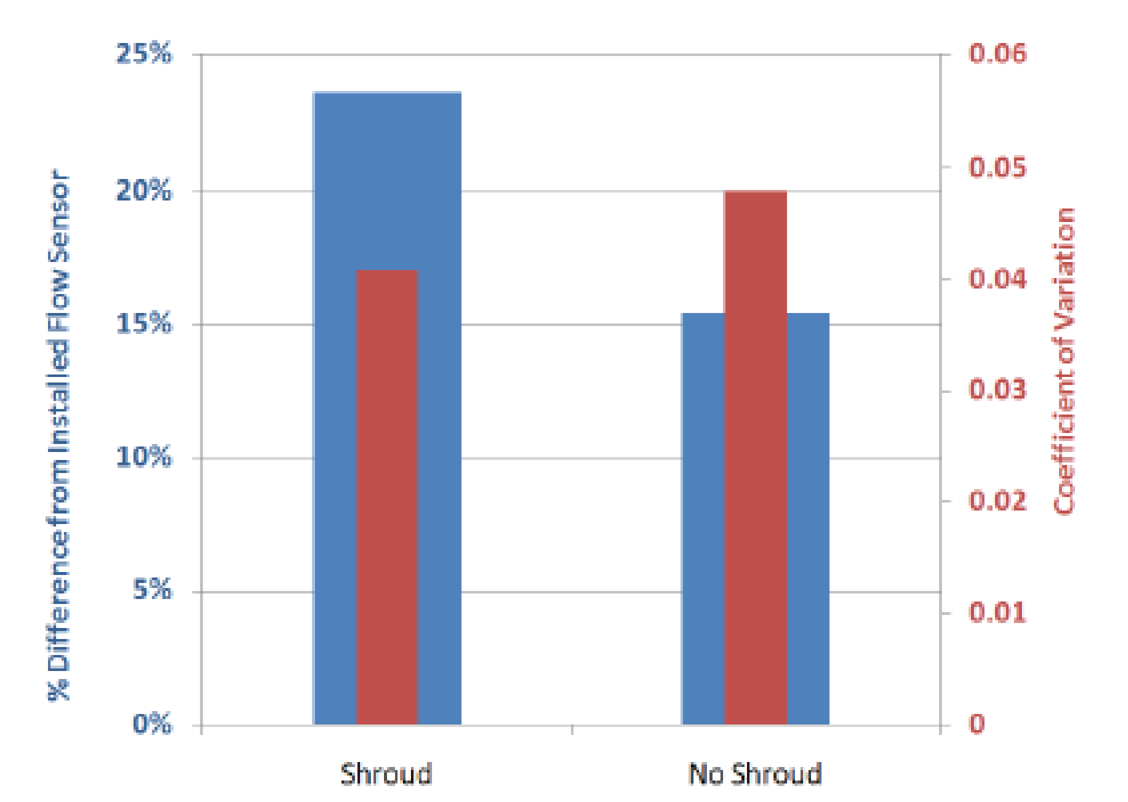
Outdoor air measurements

- Minimum velocity is an important criterion
- Outdoor air dampers generally designed for a maximum of 1000 fpm fully open
- Systems with low outdoor air fractions may require measures at very low velocities
  - Flow grid minimum velocity > 250 fpm
  - Vane anemometer > 50 fpm
  - Hot wire anemometer > 5 fpm

Building a Shroud Doesn't Help



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