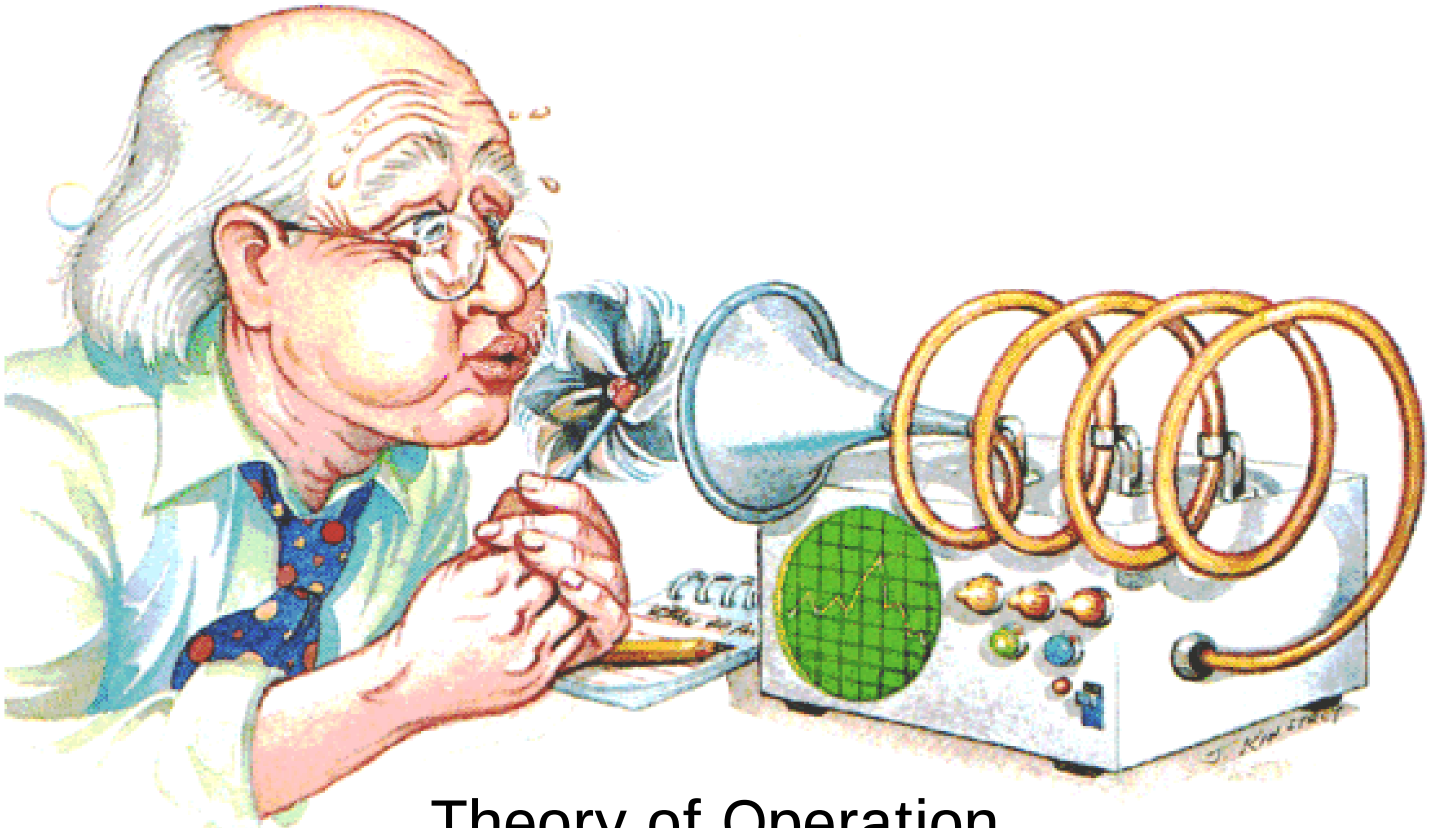
Annual Conference
Anaheim 27 Apr 2012

Survey of Airflow Measurement Devices



Theory of Operation
Measurement Uncertainty
Comparing Performance Potential

Survey of Airflow Measurement Devices

The information we will cover is intended to address the following issues in airflow rate determination:

1. Instrument performance specs are misunderstood, misleading, not easily comparable, unverifiable in field conditions
2. The **'set and forget'** design philosophy conflicts with continuous operating objectives in a **dynamic environment**
3. TAB guidelines/procedures overlook some superior measurement technologies that may be available to the technician at a site.

The information contained here, may help you to evaluate site equipment for TAB use.

Portable Instruments

NEBB Requirements for Air Measurements

FUNCTION	MINIMUM RANGE	MINIMUM ACCURACY	MINIMUM RESOLUTION	CALIBRATION INTERVAL
Air Temperature Measurement	-40 to 240 deg. F (US) -40 to 115 deg. C (SI)	**± 1% of reading**	**0.2 deg. F (US)** 0.1 deg. C (SI)	12 Months
Air Velocity Measurement **(Not for Pitot Traverse)**	50 to 2500 fpm (US)* 0.25 to 12.5 m/s (SI)	**± 5% of reading***	**20 fpm (US)** 0.1 m/s (SI)	12 Months
Air Volume Measurement (Direct Reading Hood)	100 to 2000 cfm (US) 50 to 1000 l/s	**± 5% of reading** ± 5 cfm (US) ± 2.5 l/s (SI)	**Digital 1 cfm (US)** Digital 0.5 l/s (SI) Analog - NA	12 Months

Which instruments and sensors can reliably provide this required level of performance in the field?

* ±5% of 50 fpm = ±2.5 fpm

ONE commercial Air Velocity Meter can provide the following:	0 to 5000 fpm (US) 0 to 25.4 m/s (SI)	**± 2% of reading**** (tested to ± 3% duct average in field)	**< 2 fpm (US)** **<** 0.01 m/s (SI) [analog output]	Factory Calibrated, recalibration is not normally needed

** also provides 0.1°C average temperature accuracy

Survey of Common HVAC Airflow Measurement Devices

Hand-held and Terminal Measurement Devices

Differential Pressure
- Pitot-static tubes
- Pitot-static grids
- Flow Capture Hoods

Thermal velocity meters
- Single point and
- Flow Capture Hoods

Vane Anemometers

Permanent Averaging Instruments

Differential Pressure
- Pitot-static tubes and arrays
- Piezo Rings
- DP Across a Louver
- DP Across a Fixed Obstruction

Thermal velocity meters
- Thermal Dispersion
- other thermal velocity meters

Vortex Shedders

Combination Damper / AFMS

Airflow Measurement Devices

grouped by common performance characteristics

Differential Pressure
- Pitot arrays
- Combination Damper/AFMS
- Piezo Rings
- DP Across a Fixed Louver
- DP Across an Obstruction
- Pitot-static grids
- DP Flow Capture Hoods

- Pitot-static tubes

Vane Anemometers

Thermal velocity meters
- Thermal Dispersion, independent multi-point, duct averaging

- Single-point Thermal meters

- Analog thermistor, dependent multi-point, duct averaging

- RTD single and multi-point

Vortex Shedders
- independent multi-point, duct averaging

Hand-held and Terminal Instruments

Direct Reading
Capture / Flow Hoods

Pitot-static Tube

Velocity “averaging” grid

Vane anemometers

Thermal velocity meters,
single point, directional

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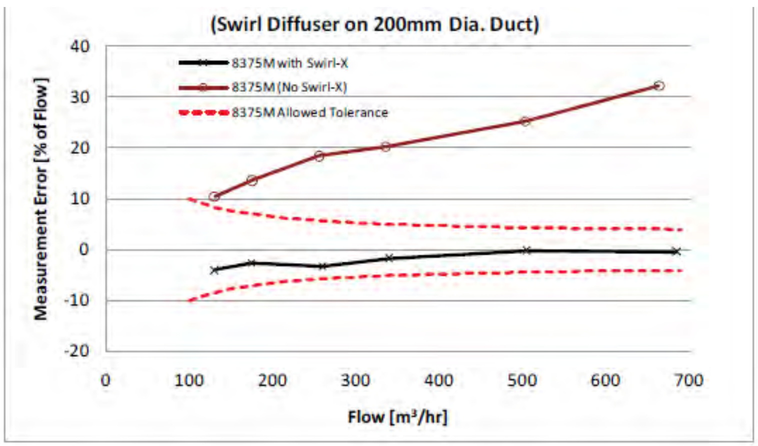
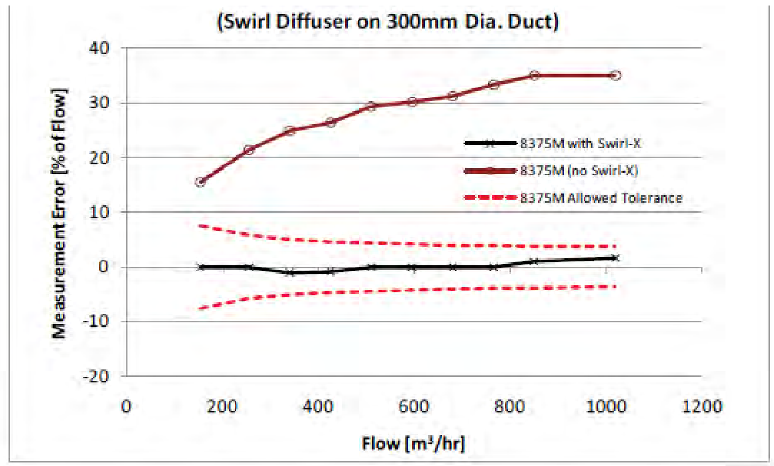
Portable Instruments

Capture Hoods





One Example:

range 0–2000 cfm (0–3400 m3/h, 0–950 l/s) (±60 CFM w/ 50 cfm RES.)

resolution 5 cfm from 25–250 cfm
10 cfm from 100–500 cfm
20 cfm from 400–1000 cfm
50 cfm from 800–2000 cfm

accuracy (±3% of reading, ± 7 cfm on one model)
SUPPLY ±3% of full scale, except ± 20 cfm on 250 cfm scale (± 8%)
EXHAUST ±3% of full scale, except ± 20 cfm on 250 cfm scale

Duct Traverse Sampling and Data Points

A **large sample can reduce** the impact from **random errors** and traversing a cross-sectional area of the duct is intended to **compensate for irregular velocity profiles**, thereby reducing the uncertainty in the average.

[specifically as applied to the Pitot traverse].

ASHRAE 111-2008 §7.6.2.3 The Traverse

Since field-measured airflows are rarely steady and uniform, ***accuracy can be improved by increasing the number of measuring points. …***

Duct Traverse Points (typ)

How many points are needed
when using a Pitot-static tube?
For hand-held thermal?
For rotating-vane anemometer?
For permanent instruments?

Are the requirements the same for different technologies with differing limitations?

NO! They are not!

AIR FLOW MEASUREMENT ACCURACY

David M. Schwenk

A research paper prepared by the Construction Engineering Research Laboratory (CERL) in Champaign, IL (est. 1995-96) was presented at a USACE Regional Conference.

The first three conclusions of their research are summarized below (based on test comparisons using an early ducted BiG Thermistor 3-sensor probe):

- An **air flow straightener is not required** to get an accurate airflow measurement
- Air flow instrumentation **need not be located more than 2 duct diameters downstream of an** [unvaned - radiused] **elbow**
- A **3-point averaging air flow measurement instrument can provide accuracy comparable to a 35-point traverse measurement and to a measurement based on ASHRAE or SMACNA guidelines.**

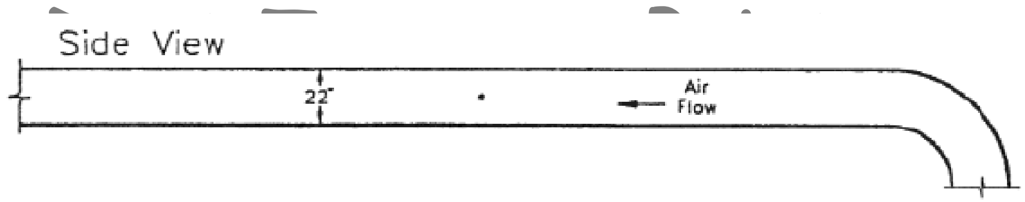


Figure 1. Traverse and Airflow Probe Locations in HVAC Test Facility Duct Section.

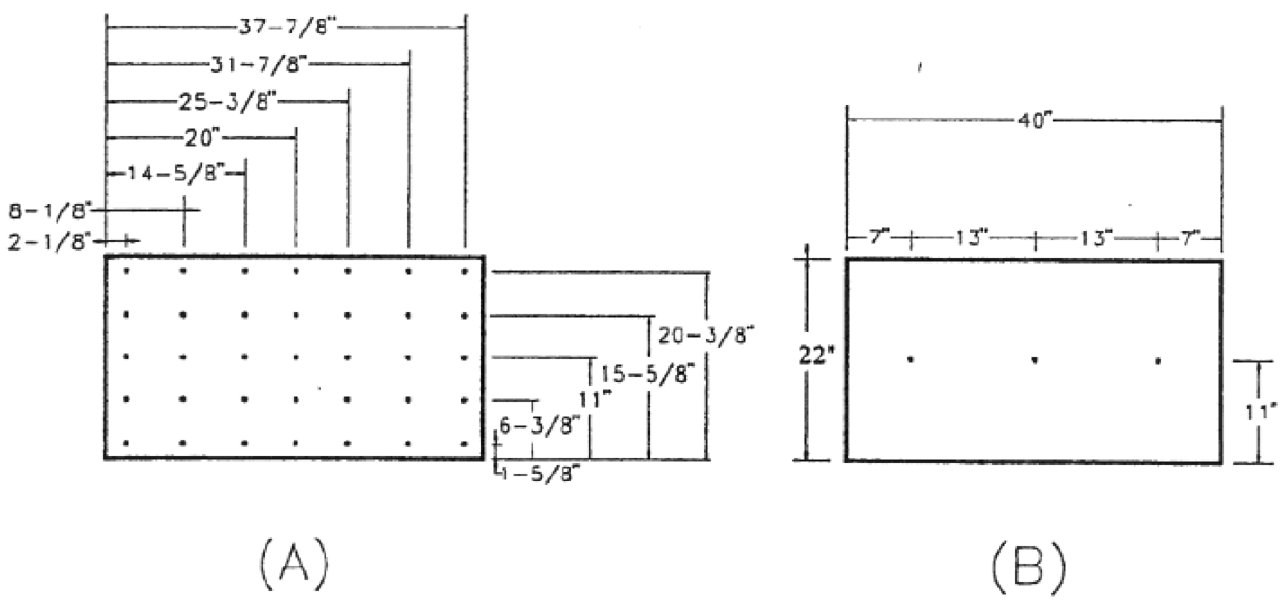


Figure 2. Point locations for: A) 35-point Traverse, B) 3-point Probe

Duct Traverse Sampling Points

This paper does not suggest that three sensing points can compensate for a highly variable velocity profile, only that:

1. the technologies are substantially different and **have different sources of potential error**
   [suggests that requirements and limitations cannot be equated]

2. the **total number of sampling points needed for an effective average should be DIFFERENT for each instrument**
   [both should be increased with the severity of conditions selected for measurement]

Portable Instruments

Pitot-static tubes - limitations / problems

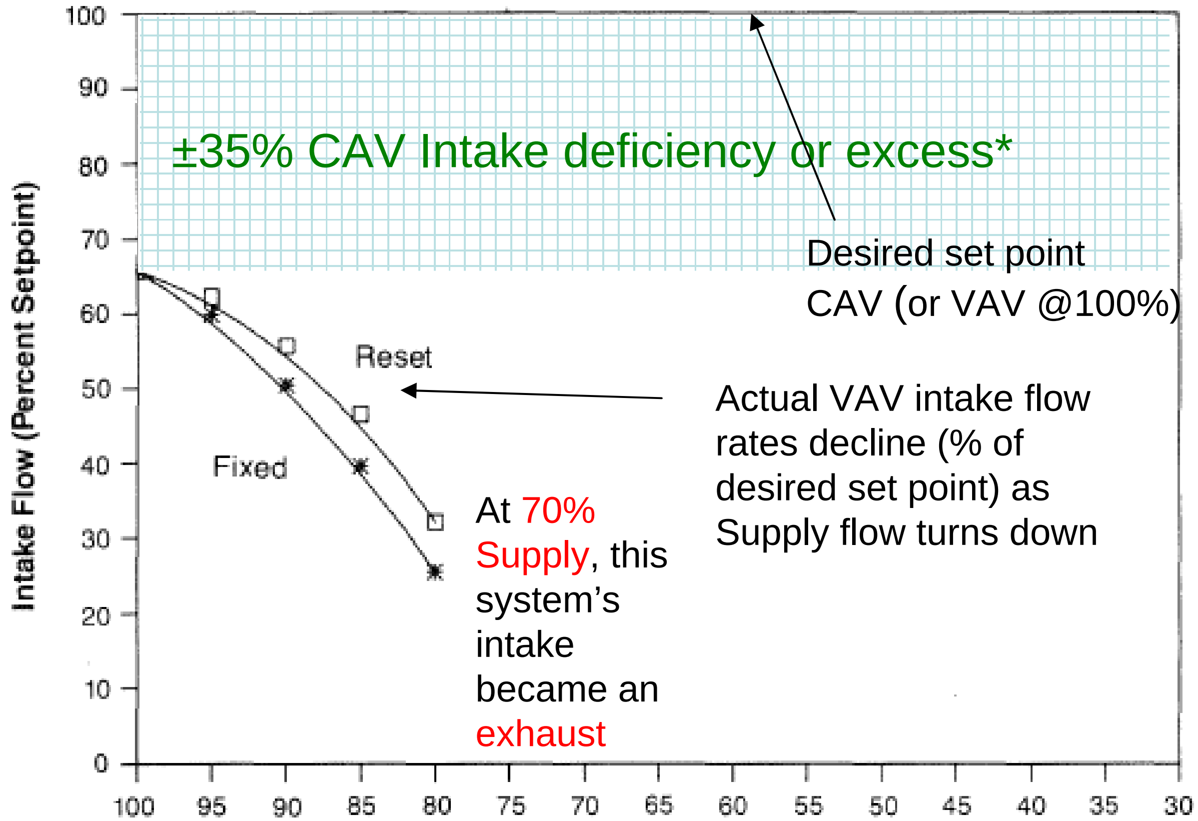
- **Low velocity limitation** (<700 fpm) = the difference in pressures is very small and hard to measure. Errors in the instrument could be greater than the measurement!
- **Lack of maintenance** = clogged or pinched tubes/lines, the resulting in calculation errors.
- **Misalignment** creates errors demanding more training, attention and greater care by the technician.
- **Leakage** in lines or ductwork
- **K-factors change** with velocity
- **Density** often ignored

Fixed-position Intake Dampers and Proportional Reset are ***not acceptable***

due to MA plenum pressure variations. Without continuous measurement and control, intake rates can not be maintained!

"Measurement for the control of fresh air intake"
ASHRAE Journal, October 1990

*NOTE: Example depicts control deficiencies and a 'negative' impact. Realistic control errors could easily be positive, causing unnecessary conditioning of Outdoor Air.



Combined Wind & Stack Effect on Fixed Position Intake Damper Systems
Analysis of an intake system with a set point velocity of 400 ft/min (2.03 m/s). (Solberg, Dougan, Damiano 1990)

Fixed-position Intake Dampers and Proportional Reset are ***not acceptable***

due to MA plenum pressure variations. Without continuous measurement and control, intake rates can not be maintained!

DIRECT Motivators

ASHRAE Standards 62.1 (ventilation), **90.1** (energy), **189.1** (high performance green buildings)

ICC Mechanical Code – IMC Chapter 4: Ventilation

LEED Rating Systems – 2009 and proposed 2012 certification requirements

CA Title XXIV Energy Code – 2009

INDIRECT Pressure

1. Standards and Codes have **effectively eliminated** these methods by making it **economically disadvantageous to use them**.
2. The industry has embraced the energy savings potential of variable speed/capacity/demand control to automatically adjust systems in response to changing conditions.
3. This type of **dynamic operation** demands **dynamic control**.

Fixed-position Intake Dampers and Proportional Reset are ***not acceptable***

1. These historical system designs are **dependant upon TAB field measurements** for set up and to verify performance.
2. Intake systems (CAV and VAV) are **very difficult to measure directly**
3. It's **nearly impossible to estimate them reliably using indirect means allowed by most guidelines/procedures** (the assumptions required produce a large amount of uncertainty in the result).

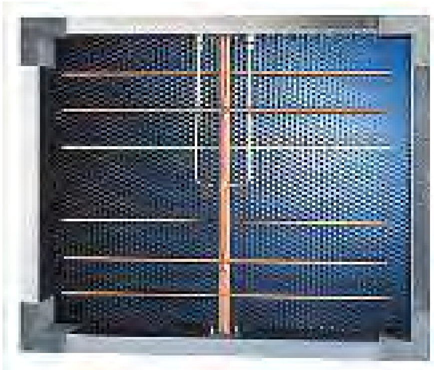
WHAT CAN WE DO?

All Permanent Instruments are not Created Equal !!

Everything is NOT accurate to 2%, contrary to their promotional literature, and especially not under field conditions.

Permanently Installed Instruments

Pitot Arrays and Probes



Averaging Pitot Array Stations with Honeycomb

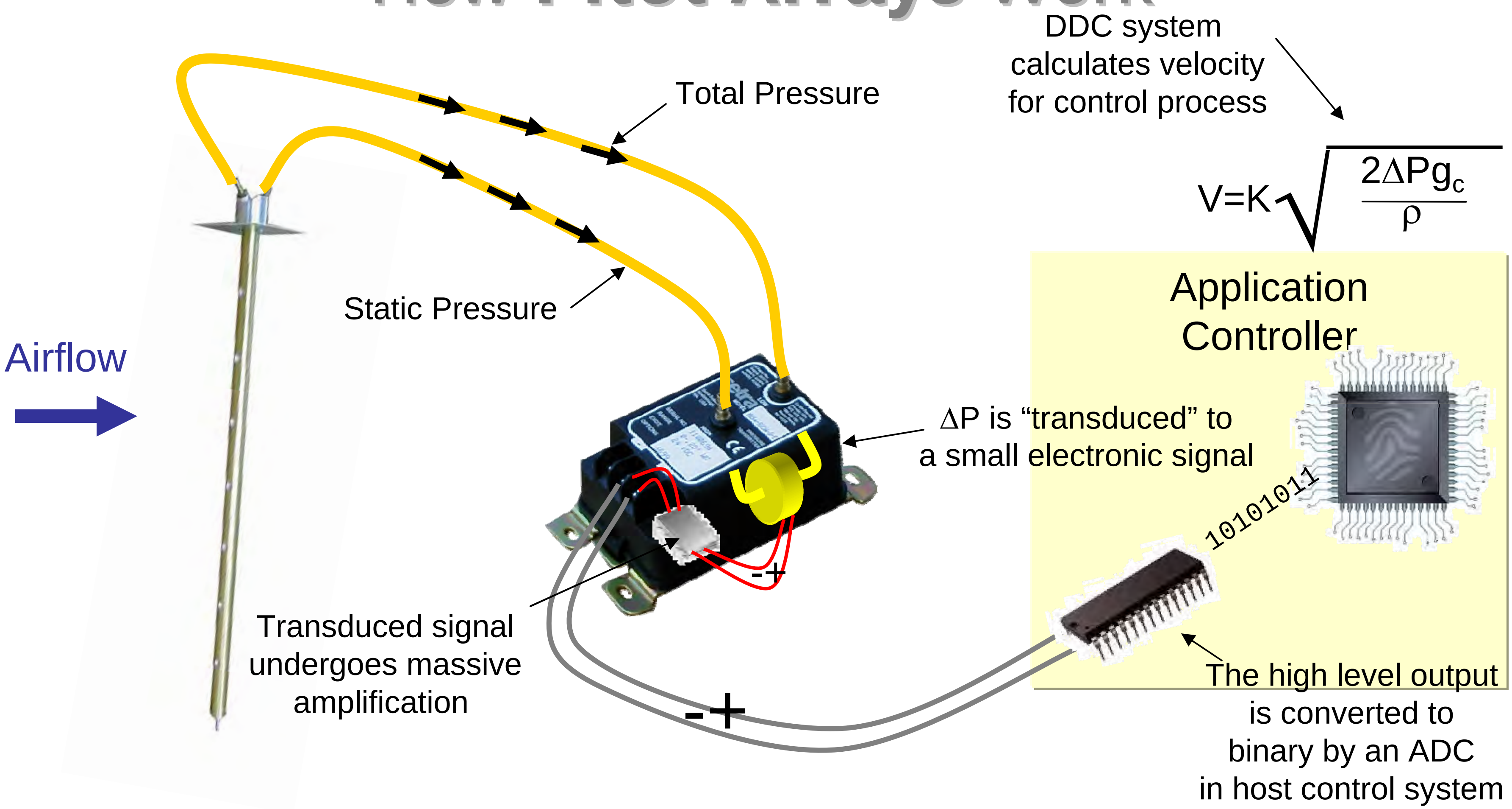
Averaging Pitot Array Probes

Combination Pitot Array & Dampers

Terminal Box Flow Ring/Cross

Combination Pitot Array/Damper with Honeycomb

How **Pitot Arrays** Work



Accuracy = Probe Uncertainty + Transducer Uncertainty + Conversion Error

Probe Uncertainty: K factor

Usually assumed to be 0.999 to 1, but will deviate when the airflow rate is under approx. 1,000 FPM

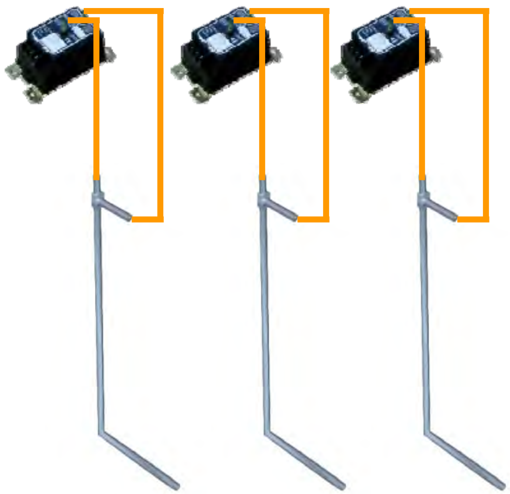
- As a result, the airflow rate calculated using the "assumed" K factor can have significant error.

$$V = K \sqrt{\frac{2 \Delta P g_c}{\rho}}$$

Probe Uncertainty: Averaging Error

	Sensor 1	Sensor 2	Sensor 3	Avg. Pressure	Avg. FPM	Error
Pitot Tube	2200	1800	500		1500	
Pitot Array	0.301745	0.201995	0.015586	0.173109	1666	11%

Independent Laboratory Pitot Tubes



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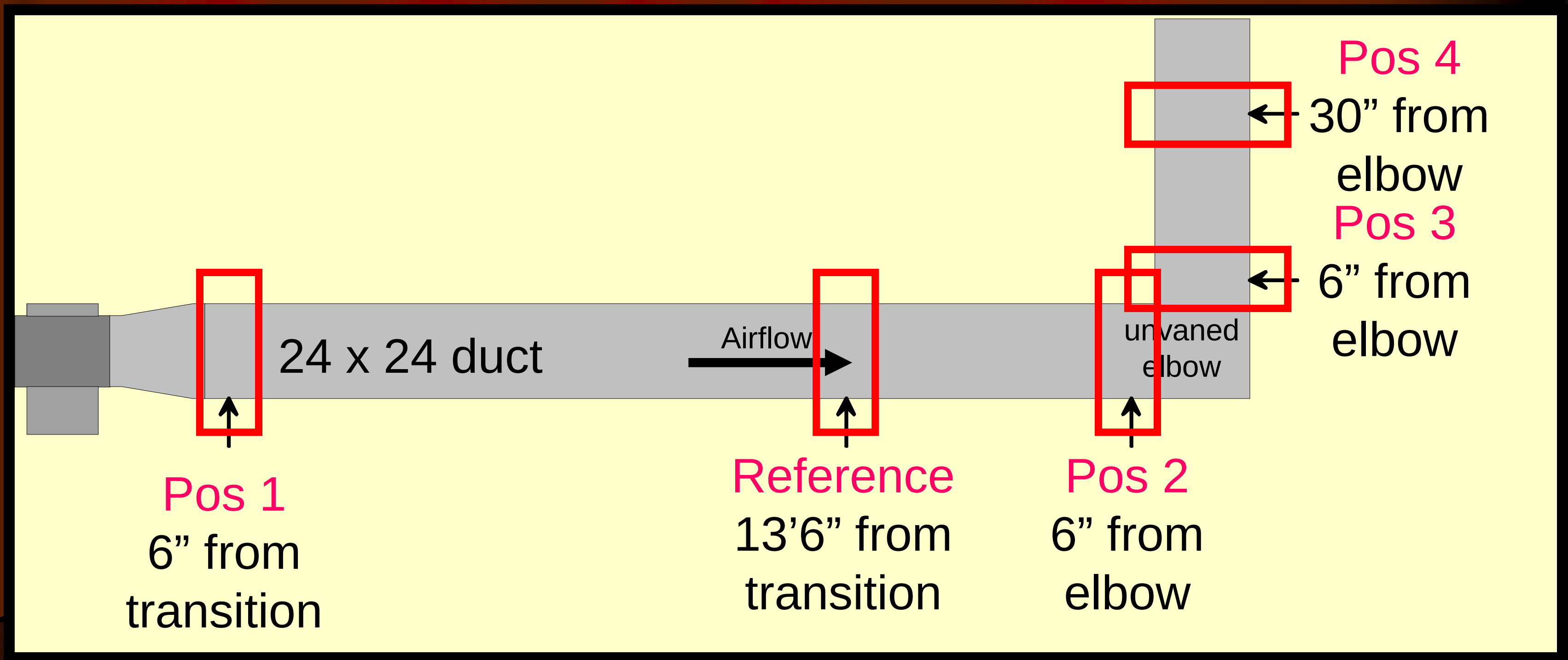
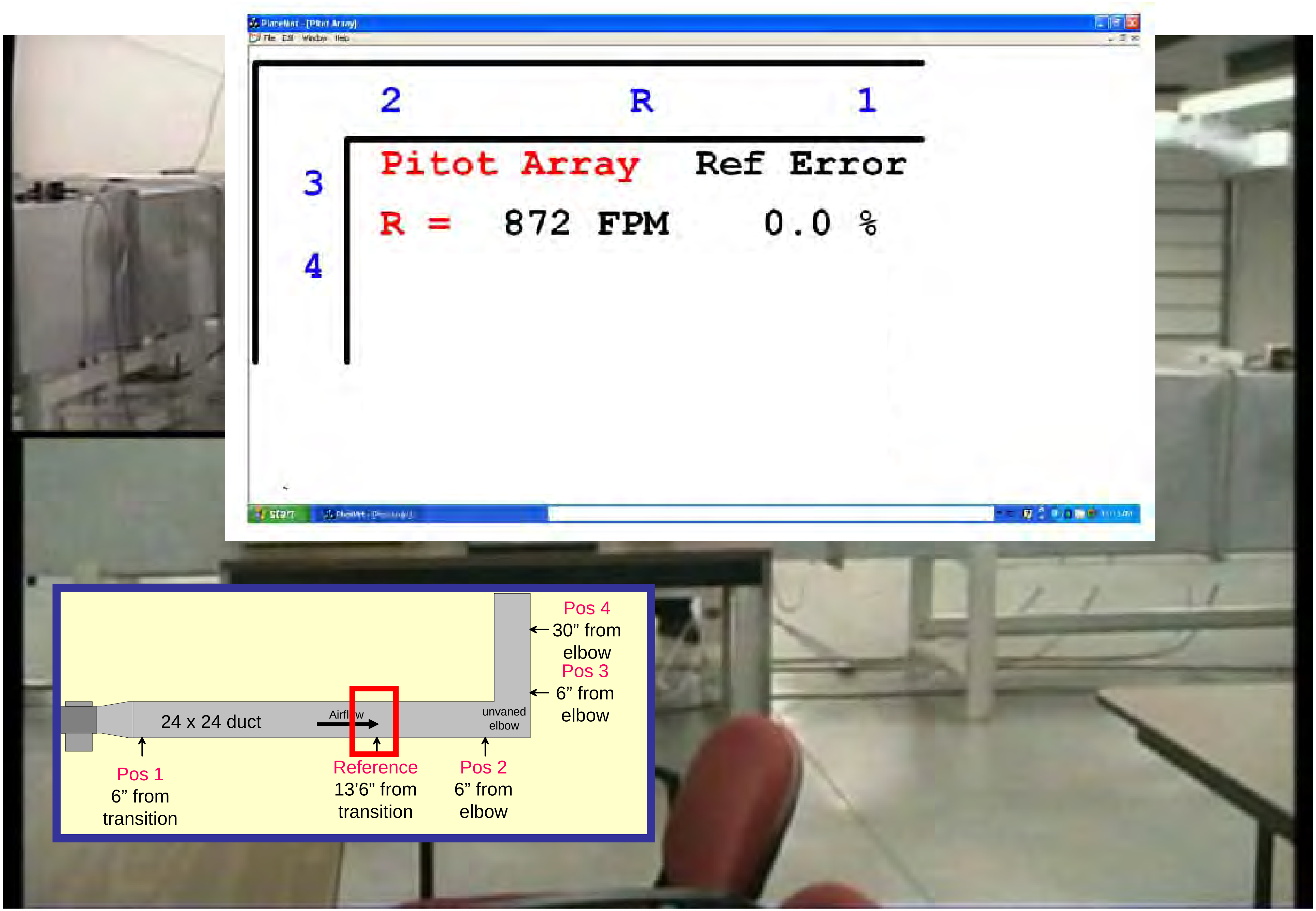
Pitot Tube Array

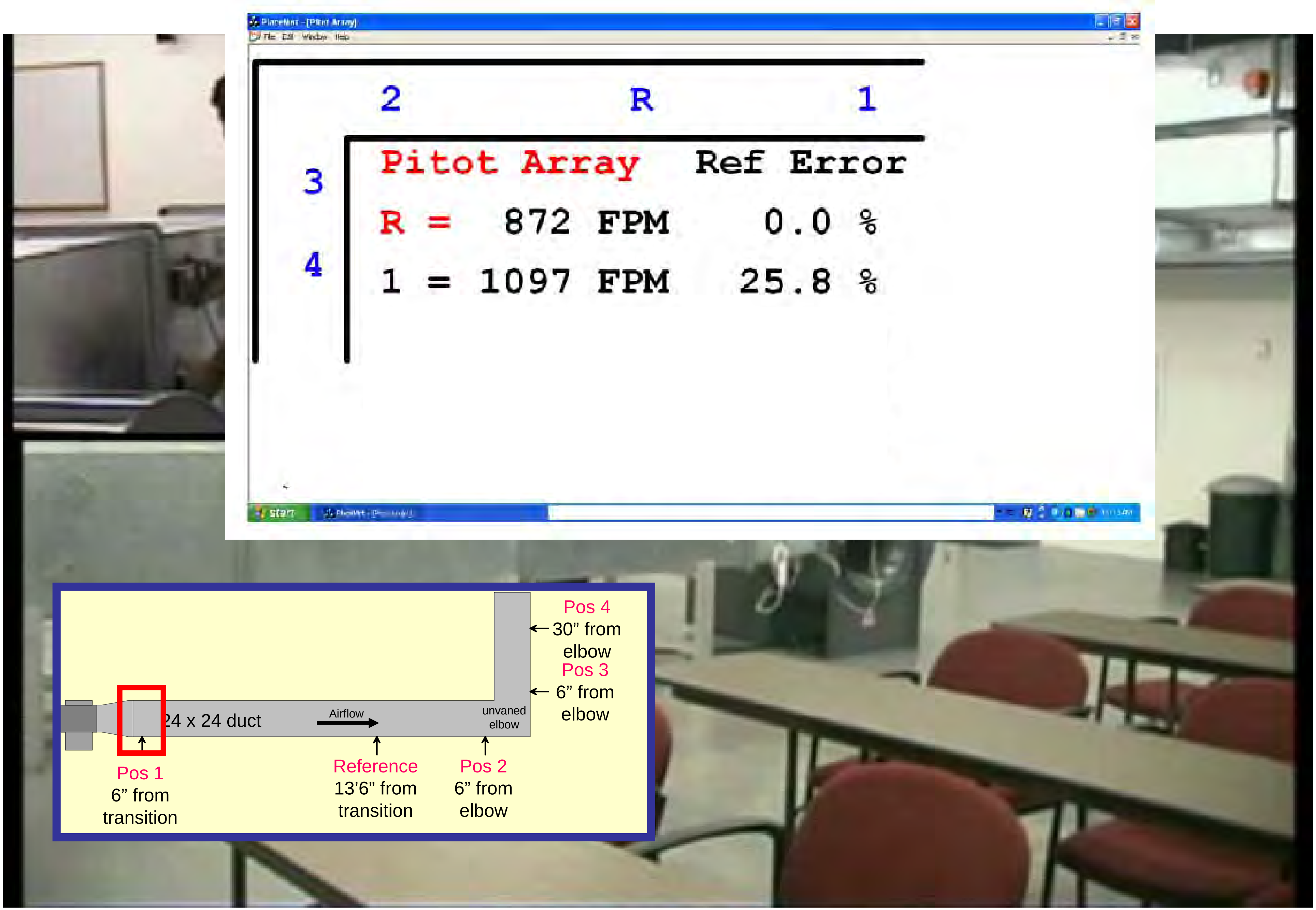
Single Sensing Point Device (transducer)

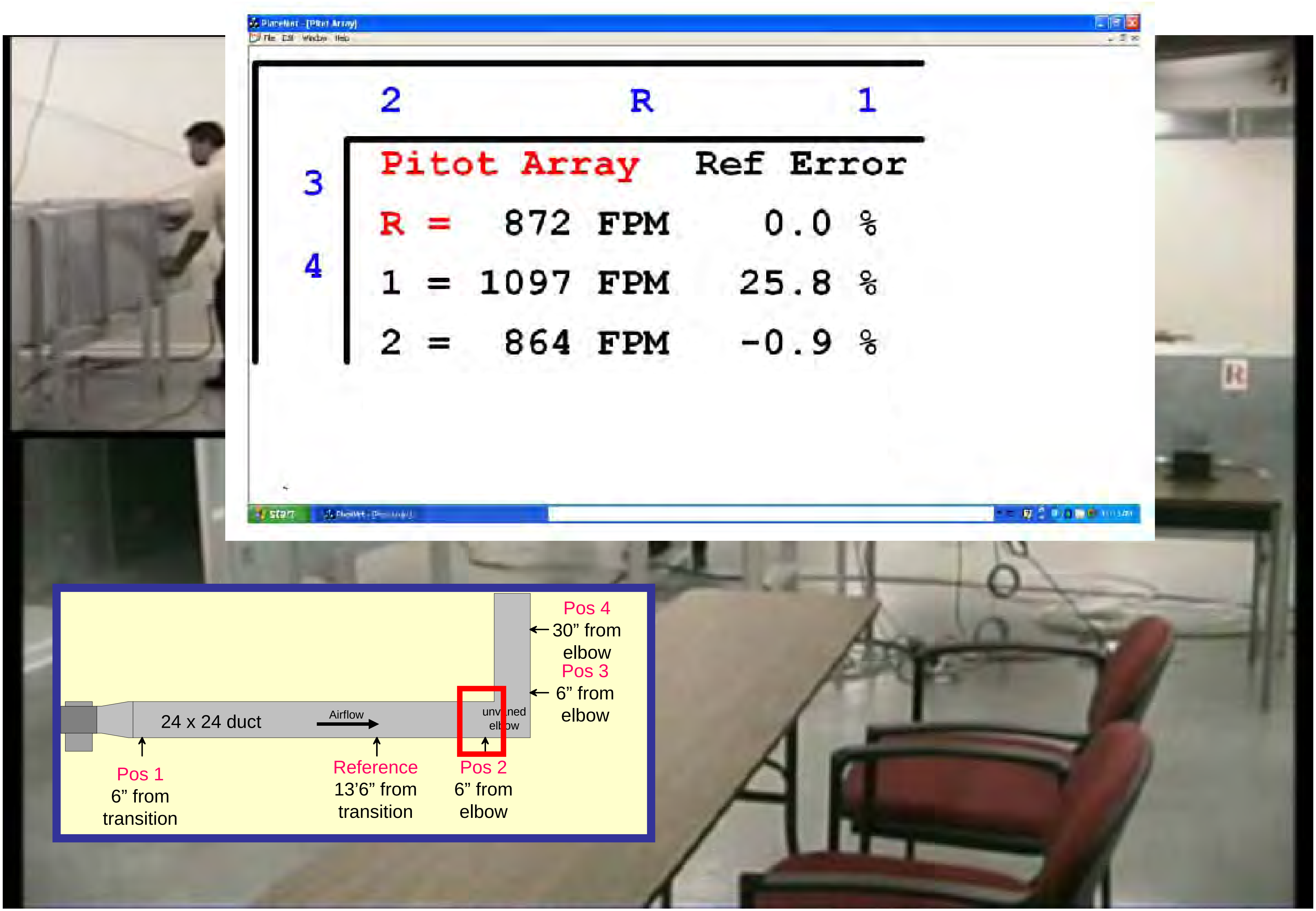
"ELBOW" Test

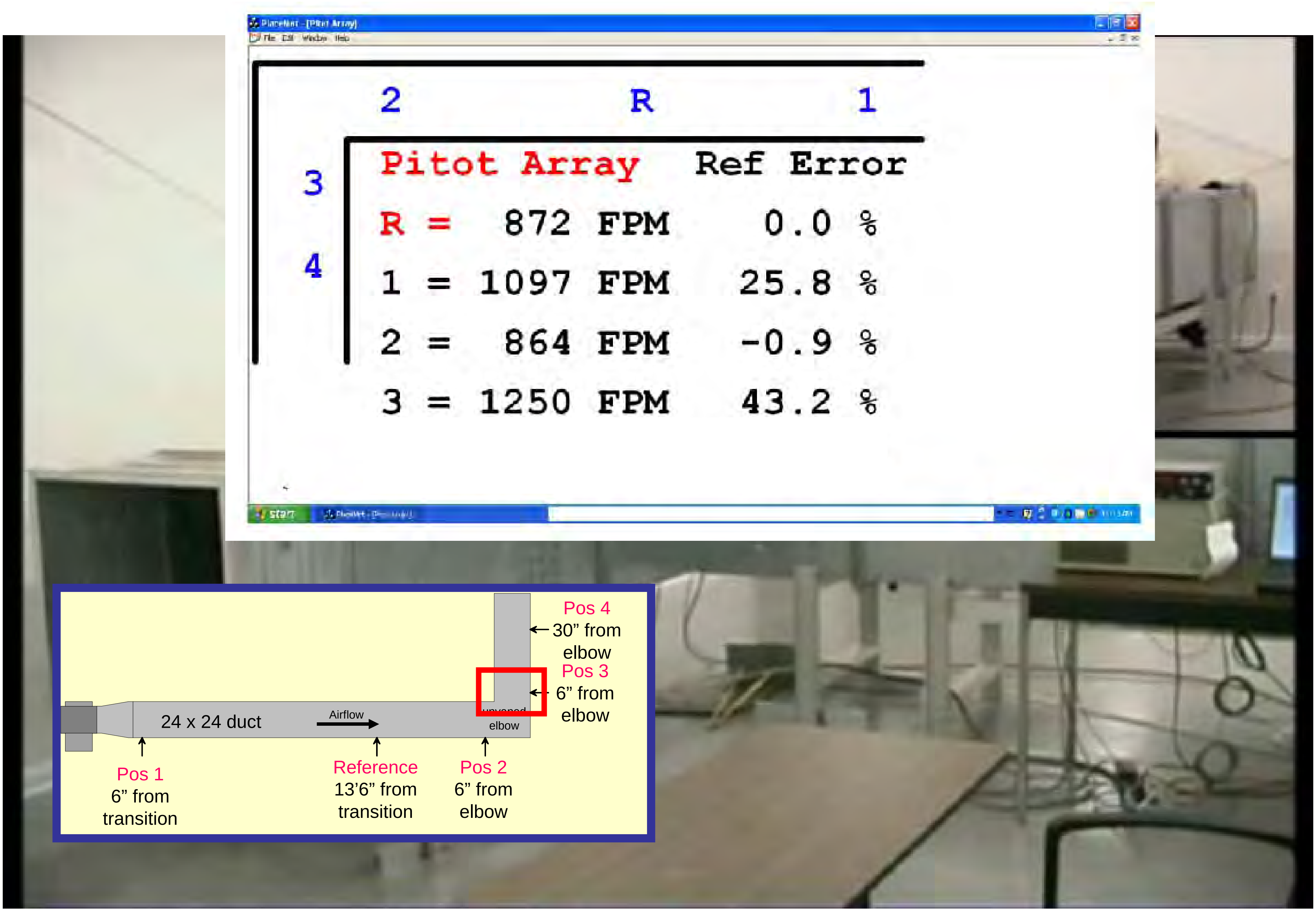
Real-world demonstration of averaging error



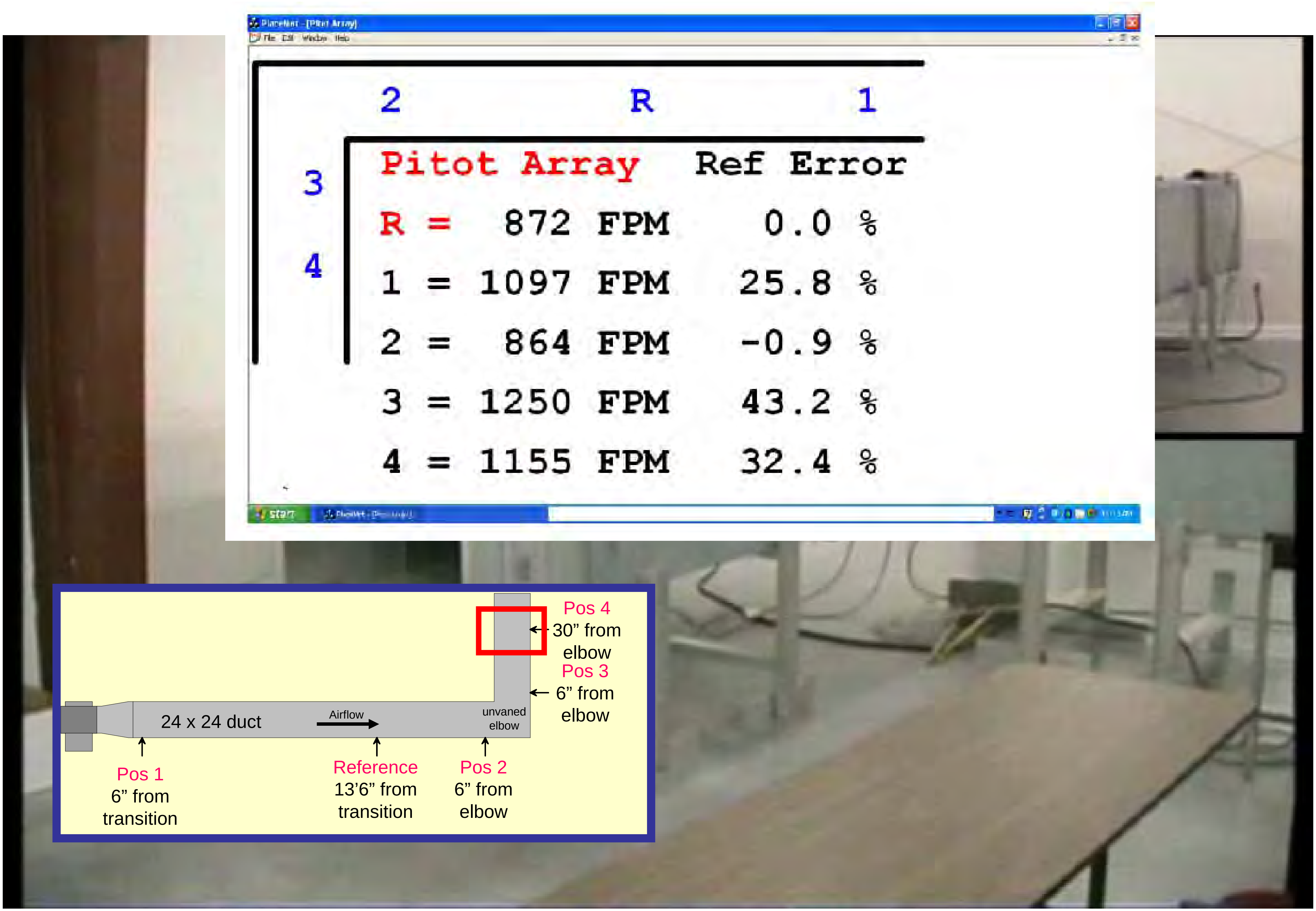

2
R
1
3
4
Pitot Array
Ref Error
R = 872 FPM
0.0 %
Pos 4
30” from elbow
Pos 3
6” from elbow
24 x 24 duct
Airflow
unvaned elbow
Pos 1
6” from transition
Reference
13’6” from transition
Pos 2
6” from elbow


2 R 1
3
4
Pitot Array Ref Error
R = 872 FPM 0.0 %
1 = 1097 FPM 25.8 %
Pos 4
30" from elbow
Pos 3
6" from elbow
24 x 24 duct
Airflow
unvaned elbow
Pos 1
6" from transition
Reference
13'6" from transition
Pos 2
6" from elbow


2
R
1
3
4
Pitot Array
Ref Error
R = 872 FPM 0.0 %
1 = 1097 FPM 25.8 %
2 = 864 FPM -0.9 %
Pos 4
30” from elbow
Pos 3
6” from elbow
24 x 24 duct
Airflow
unvaned elbow
Pos 1
6” from transition
Reference
13’6” from transition
Pos 2
6” from elbow



2
R
1
3
4
Pitot Array Ref Error
R = 872 FPM 0.0 %
1 = 1097 FPM 25.8 %
2 = 864 FPM -0.9 %
3 = 1250 FPM 43.2 %
Pos 4
30" from elbow
Pos 3
6" from elbow
24 x 24 duct
Airflow
elbow
Pos 1
6" from transition
Reference
13'6" from transition
Pos 2
6" from elbow

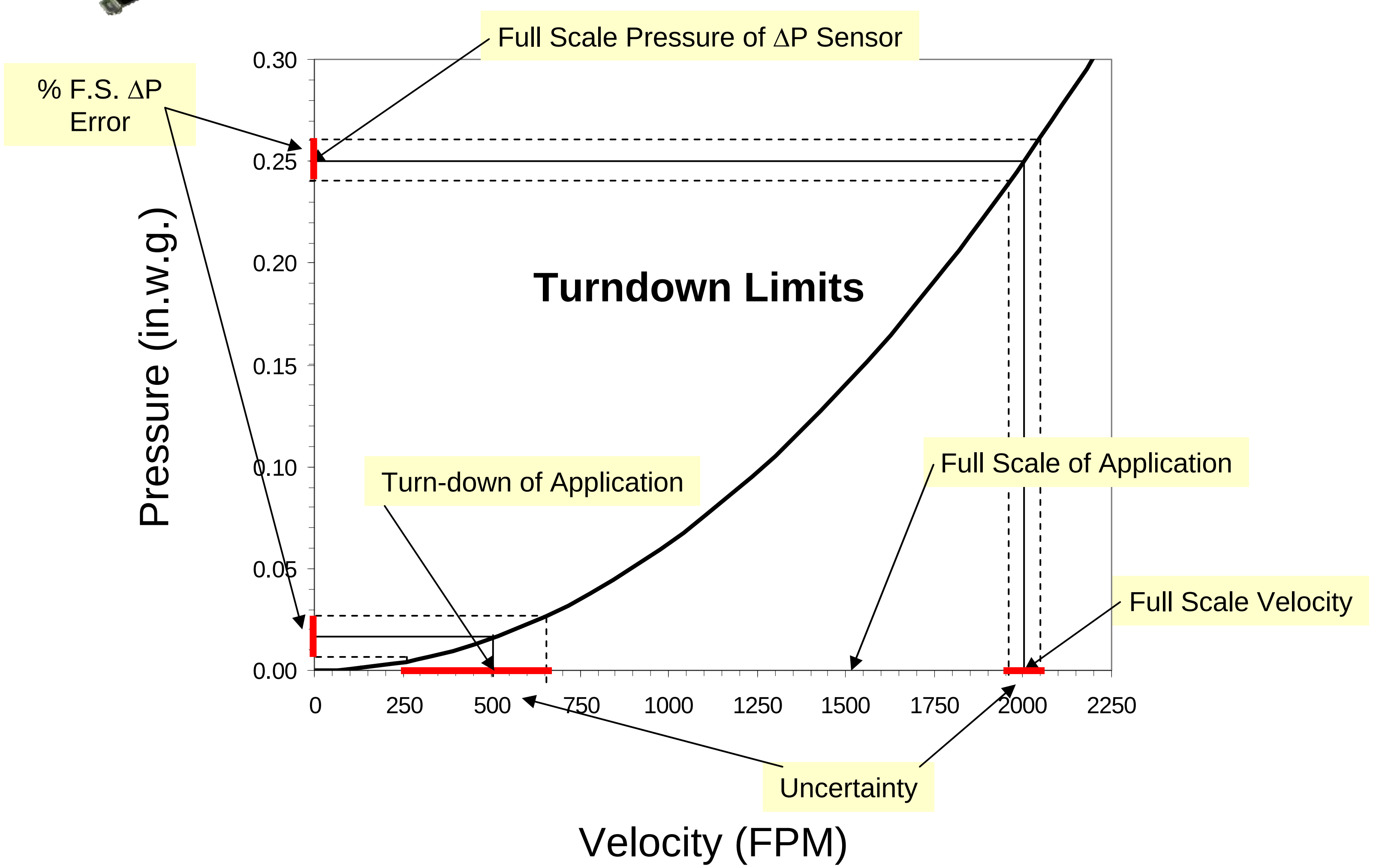


2
R
1
3
4
Pitot Array
Ref Error
R = 872 FPM 0.0 %
1 = 1097 FPM 25.8 %
2 = 864 FPM -0.9 %
3 = 1250 FPM 43.2 %
4 = 1155 FPM 32.4 %
24 x 24 duct
Airflow
unvaned elbow
Pos 1
6” from transition
Reference
13’6” from transition
Pos 2
6” from elbow
Pos 3
6” from elbow
Pos 4
30” from elbow

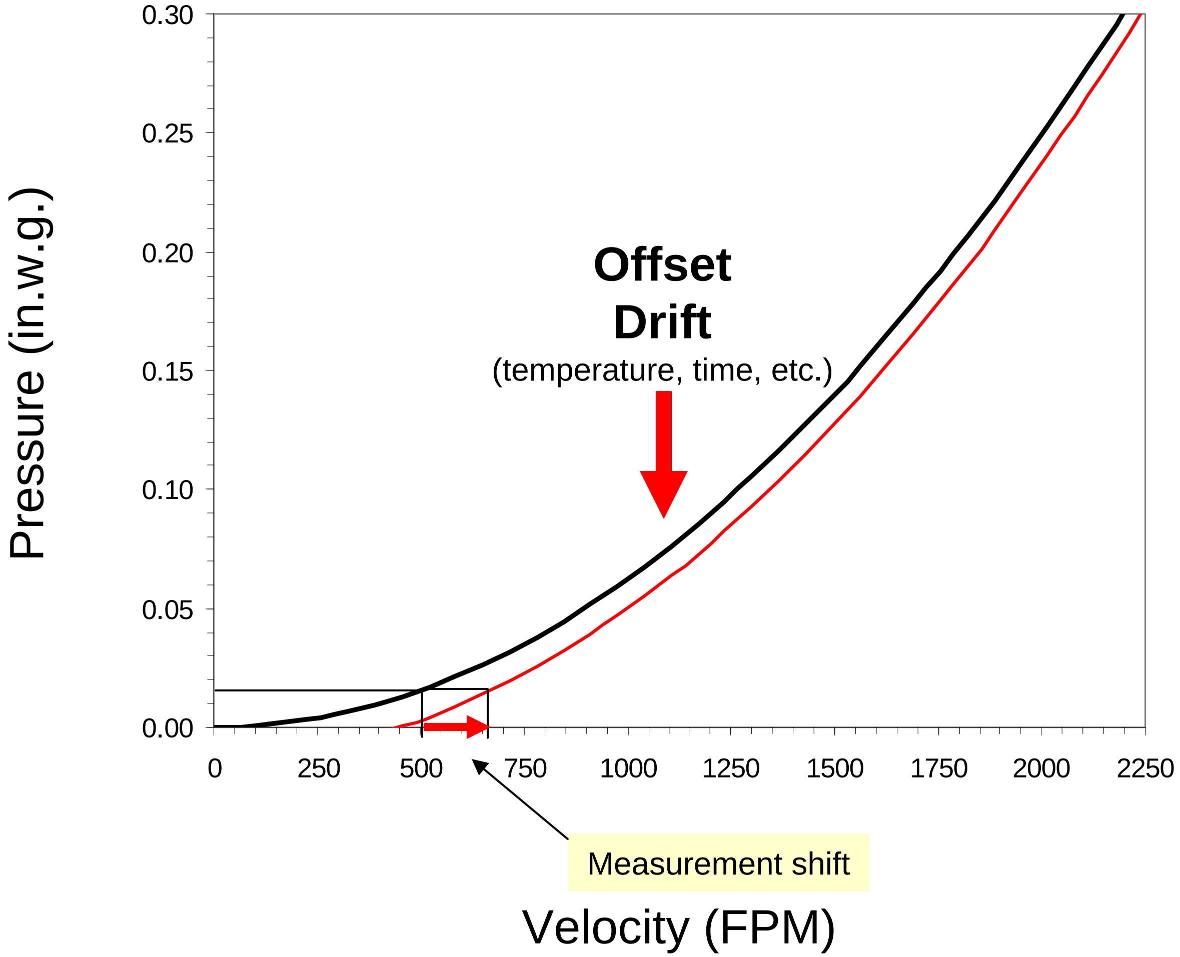
 ΔP Transducer Uncertainty

$$V=K\sqrt{\frac{2\Delta P g_c}{\square}}$$

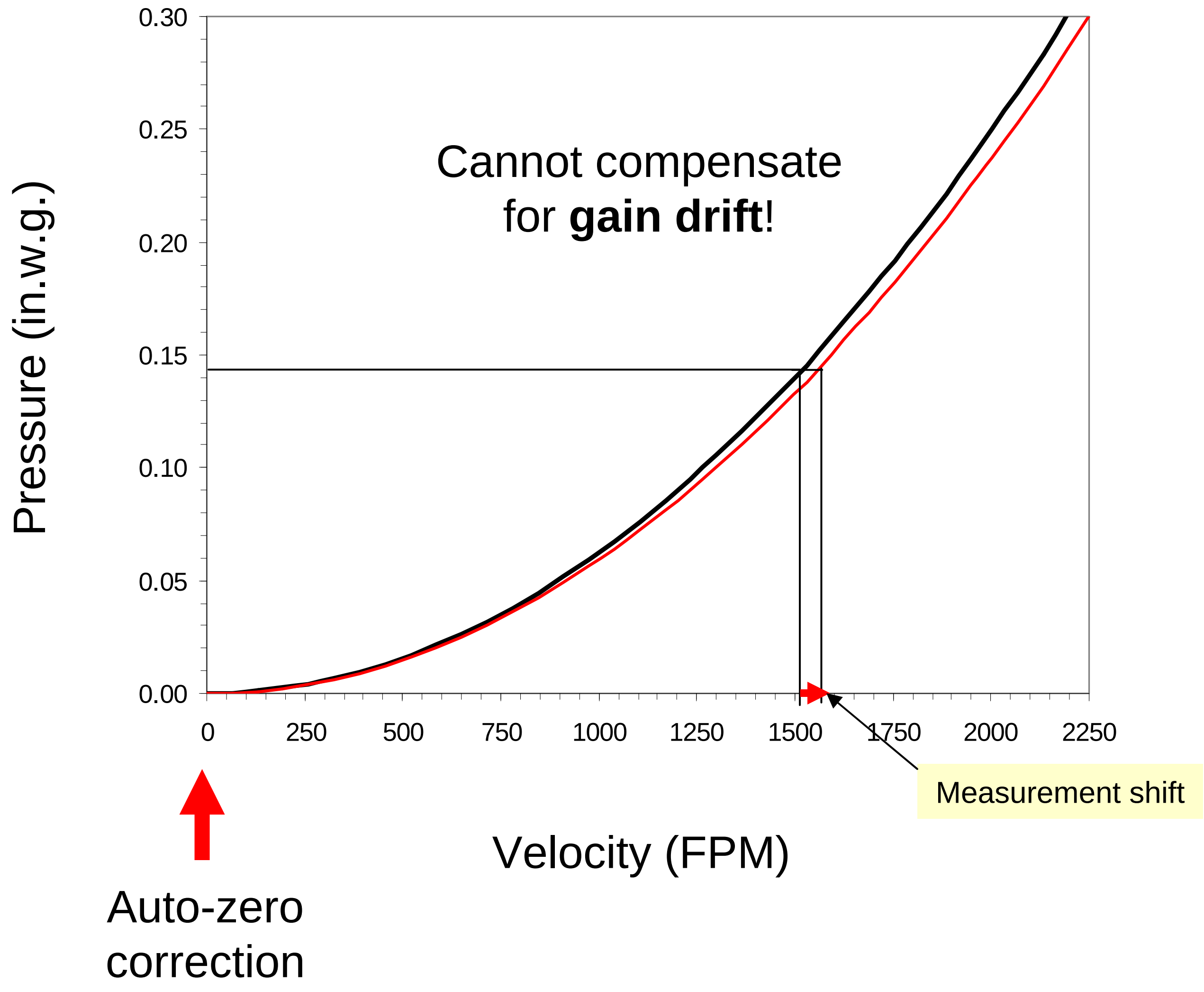
ΔP Transducer Uncertainty



ΔP Transducer Uncertainty



ΔP Transducer Uncertainty



ΔP Transducer Comparisons

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0.1% of Full Scale

1% of Full Scale

NOTE: Micromanometers used for Pitot traverse have the same issues of turndown, range-ability, low flow limitations, zero drift, etc.

ΔP Transducer Comparisons

Based on Manufacturer's Specifications

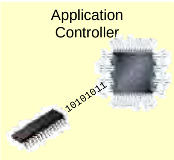
Transducer Accuracy: 1% of natural span (full scale)

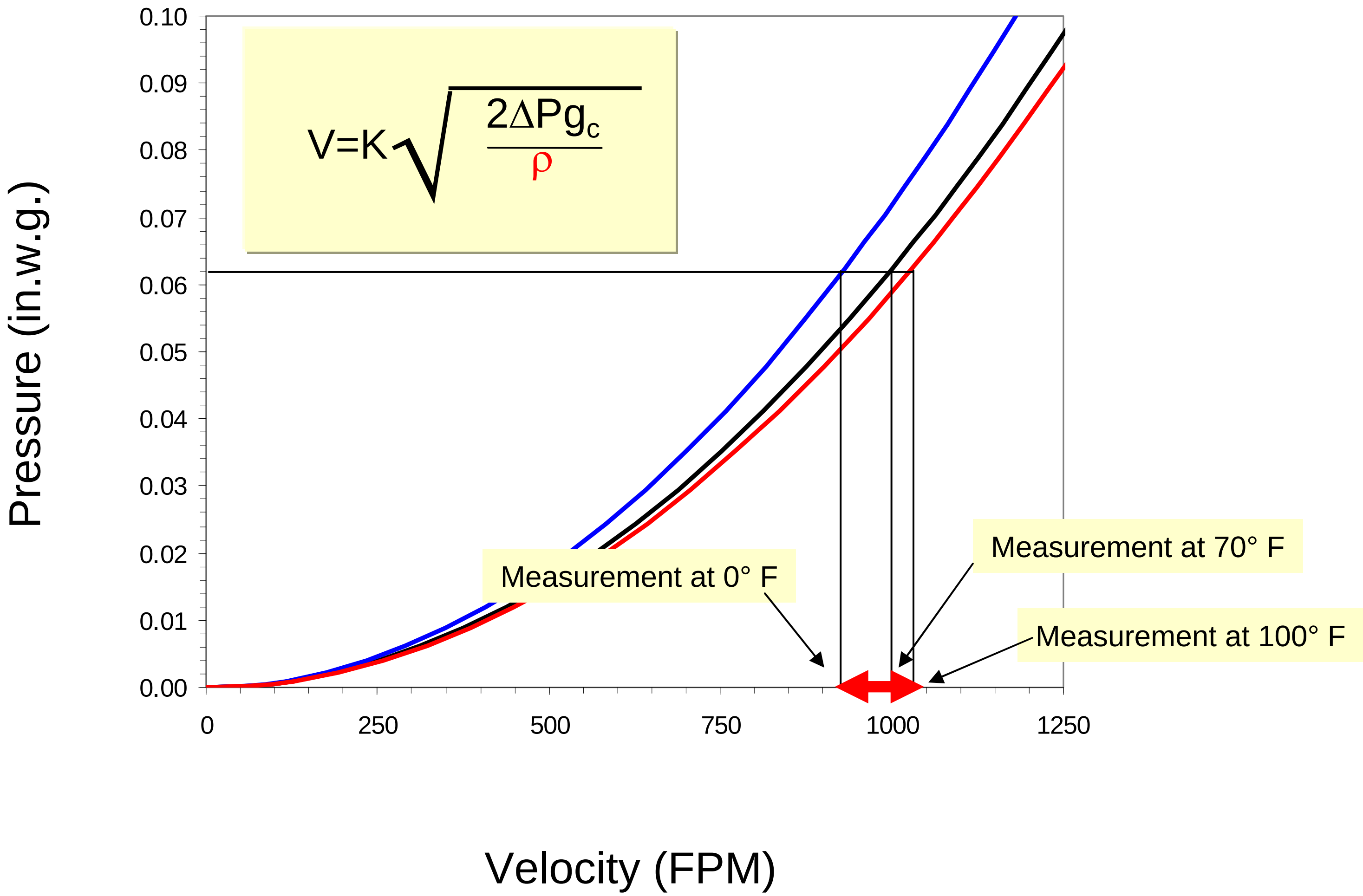
(not including Pitot array)

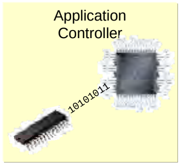
Natural Span	Transducer F.S. FPM (@100% span)	Airflow Rate (FPM)									
		10,000	5,000	2,500	2,000	1,500	1,000	750	500	250	150
10	12,665	0.8%	3.3%	14%	23%	46%	178%	236%	333%	597%	938%
5	8,955		1.6%	6.6%	11%	20%	56%	165%	248.6%	444%	689%
2	5,664		0.6%	2.6%	4.1%	7.4%	18%	34%	153%	303%	464%
1	4,005			1.3%	2.0%	3.6%	8.4%	15%	40%	225%	348%
0.5	2,832			0.6%	1.0%	1.8%	4.1%	7.4%	18%	153%	260%
0.25	2,003				0.5%	0.9%	2.0%	3.6%	8.4%	40%	188%
0.1	1,266						0.8%	1.4%	3.3%	14%	46%
0.05	896							0.7%	1.6%	6.6%	20%

Accuracy does not include temperature effect, drift, and other significant factors that compound transducer error!

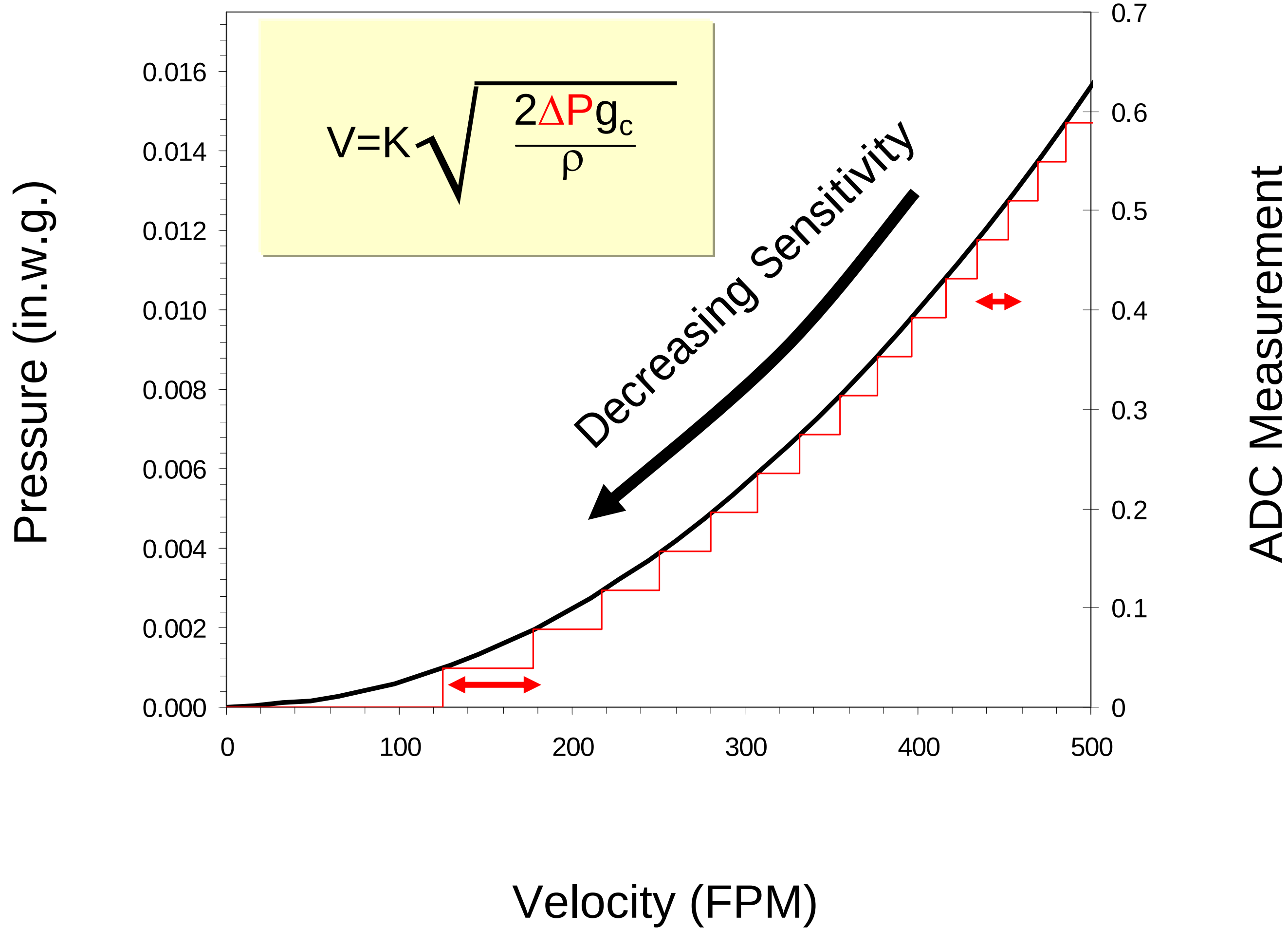
Conversion Uncertainty: Air Density







Conversion Uncertainty: ADC



ΔP Transducer Uncertainty

Typical Pressure Sensor Specification

Performance Data

	Standard	Optional	
Accuracy* RSS (at constant temp)	±1.0% FS	±0.4% FS	±0.25% FS
→ Non-Linearity, BFSL	±0.96% FS	±0.38% FS	±0.22% FS
→ Hysteresis	0.10% FS	0.10% FS	0.10% FS
→ Non-Repeatability	0.05% FS	0.05% FS	0.05%FS

Thermal Effects**	
Compensated Range °F(°C)	0 to +150 (-18 to +65)
→ Zero/Span Shift %FS/°F(°C)	0.033 (0.06)
Maximum Line Pressure	10 psi
Overpressure	Up to 10 psi (Range Dependent)
→ Long Term Stability	0.5% FS/1 YR

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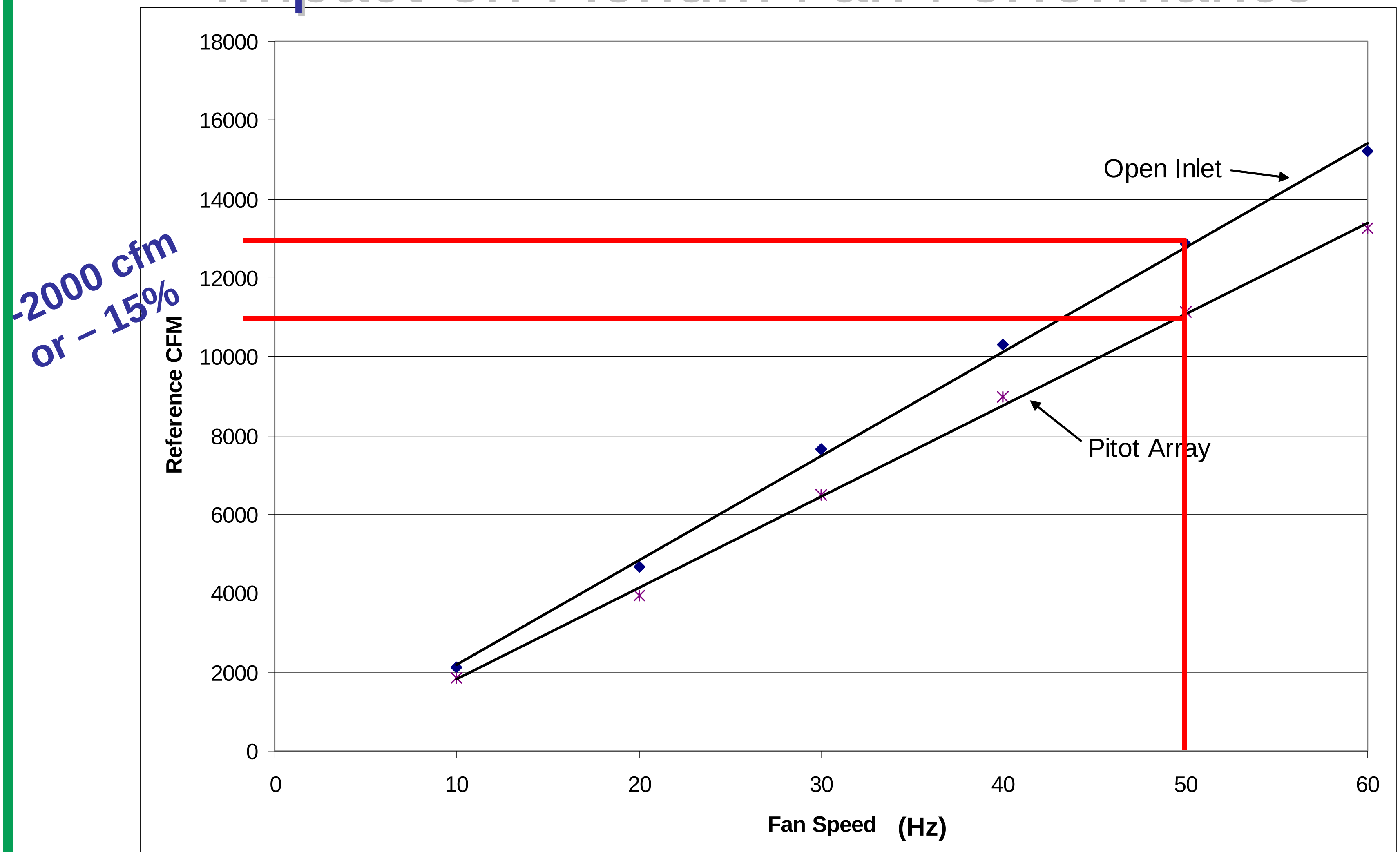
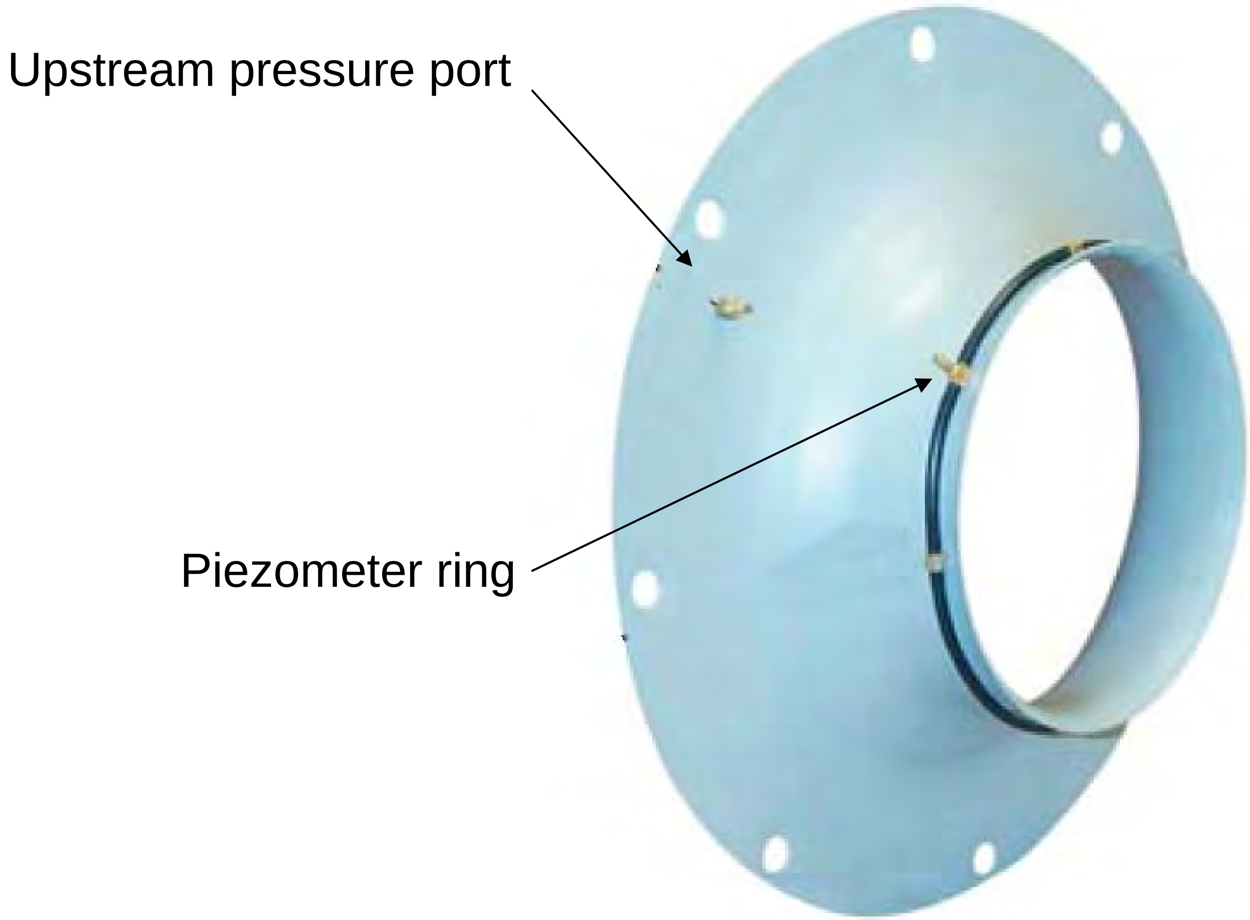
Pitot Array

Impact on Plenum Fan Performance



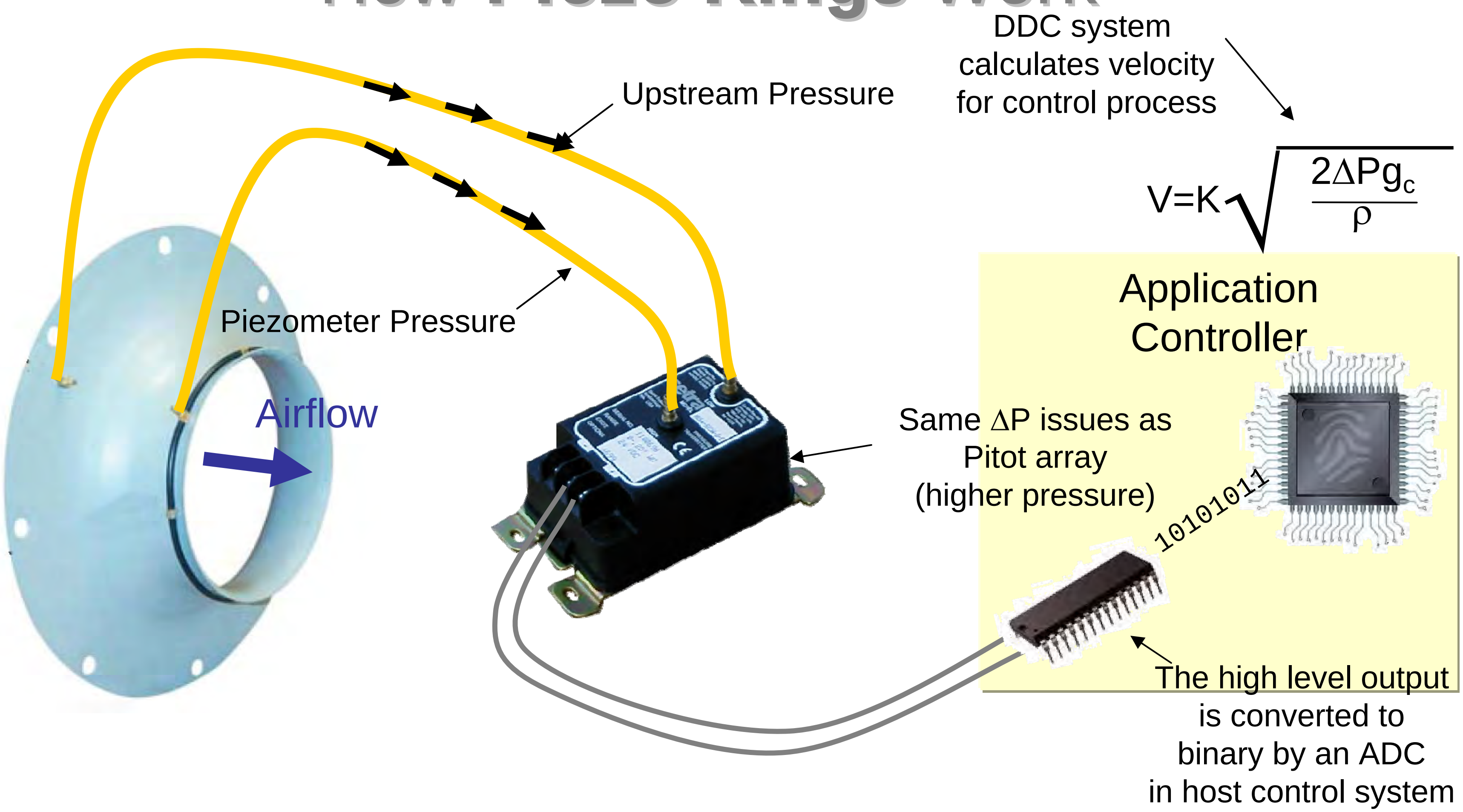
Permanently Installed Instruments

Piezo Rings in Fan Inlets



This is not like a Piezometer, which is a differential pressure method used as a reference in smaller airflow calibration tunnels for many years.

How Piezo Rings Work



Accuracy = Piezometer Uncertainty + Transducer Uncertainty + Conversion Error

Compare Error Sources

Pitot Arrays to Piezo Rings

✓ Yes	✓ Yes	K factor changes with turndown
✓ Yes	✓ Yes	Averaging error (single and fan wall systems)
✓ Yes	✓ Yes	% F.S. accuracy pressure transducer dilemma
✓ Yes	✓ Yes	Pressure transducer drift with time and temperature
✓ Yes	✓ Yes	Auto-zero gain error
✓ Yes	✓ Yes	Air density error if not corrected in B.A.S.
✓ Yes	✓ Yes	ADC error at host controls with turndown
✓ Yes	✓ Yes	Fouling from dirt and dust
✓ Yes	✓ Yes	Tubing leaks
✓ Yes	✓ Yes	Cross flow error
✓ Yes	✓ Yes	Water
✓ Yes	✓ No	Fan performance loss

The bottom line!

(Pitot arrays, Piezo rings & ΔP across fixed obstruction)

- **Non-linear averaging** can add significant error (all are essentially a single sensing point device).
- **% F.S. pressure sensor error** is significant with turndown (even on higher pressure Piezo rings).
- Pressure sensors are known to **drift** over time and with changes in temperature.
- **Calibration factors** (k factors) will change over the operating range of the device.

The bottom line!

(Pitot arrays, Piezo rings & ΔP across fixed obstruction - Cont'd)

- **Pressure leaks** are nearly impossible to detect.
- **Malfunction of the array** or "sensing" element cannot be reported to the B.A.S.
- **Cross flow** in tubes (array & Piezo)
- **Water accumulation** in tubes (array & Piezo)
- **Unacceptable affect on fan performance** (fan inlet mounted devices)

Permanently Installed Instruments

Pitot Arrays and Probes

"To reduce errors …. installation guidelines typically require straight, *unobstructed duct for 7.5 duct diameters upstream and 3 duct diameters downstream* *from the airflow measurement station* (1997 ASHRAE Handbook—Fundamentals, Chapter 14).

Placement - disturbances

Typically, averaging *Pitot-tube arrays are not accurate for flow rates below 600-800 fpm* *(3.05 to 4.06 m/s) unless auto zeroing and temperature-compensated differential pressure transmitters are used* (Drees et al. 1992; ANSI/ASHRAE Standard 111-1992). *….*

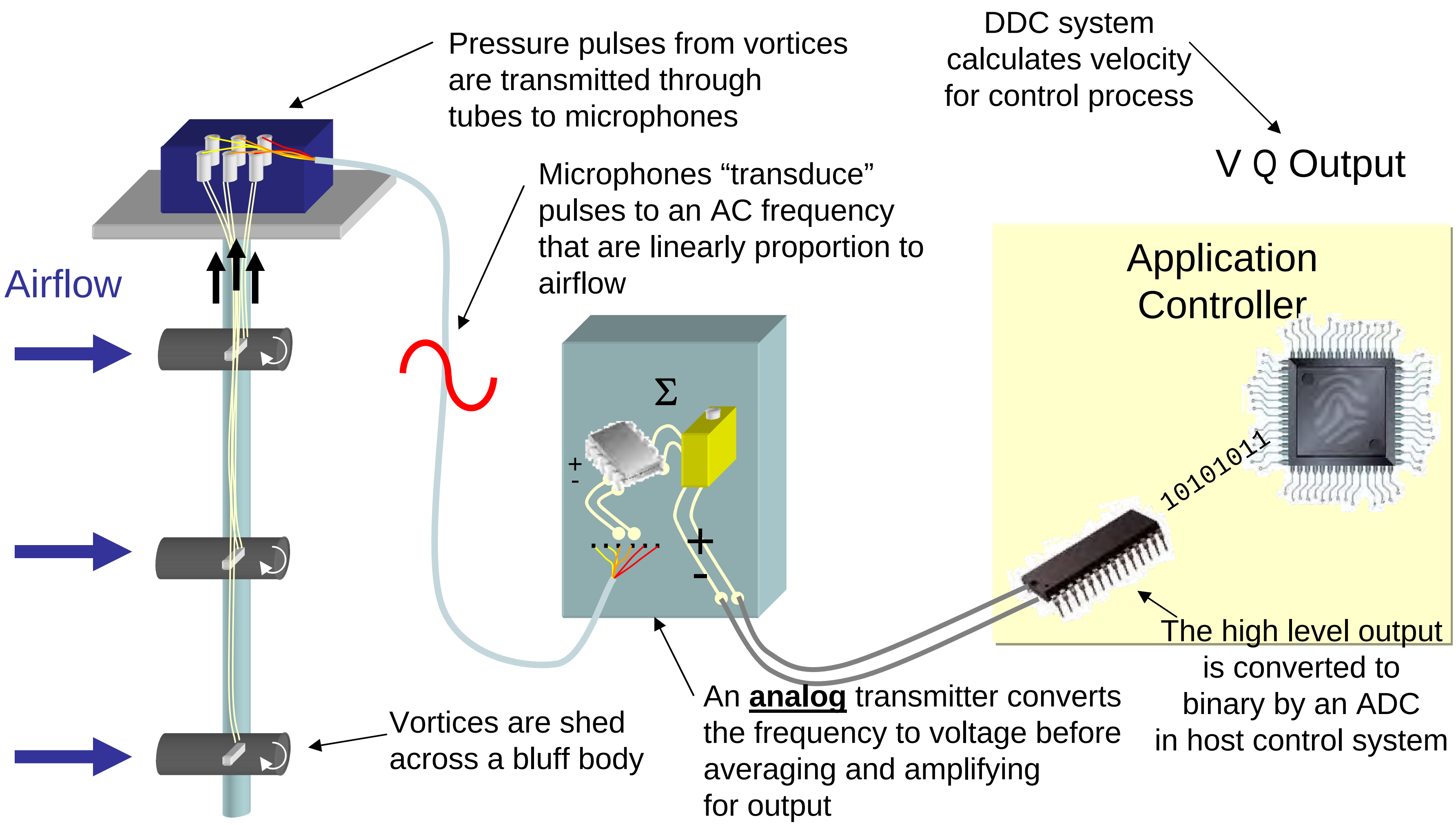
Low velocity limitations

Additionally, *small errors in the differential pressure transmitters can result in large errors in the calculated flow rate.*"

Transducer's contribution to error

Shroeder, Christopher C.; Krarti, Moncef; and Brandemuehl, Michael J:. "Error Analysis of Measurement and Control Techniques of Outside Air Intake Rates in VAV Systems" ASHRAE RP-980, ASHRAE TRANSACTIONS 2000, V. 106, Pt. 2.

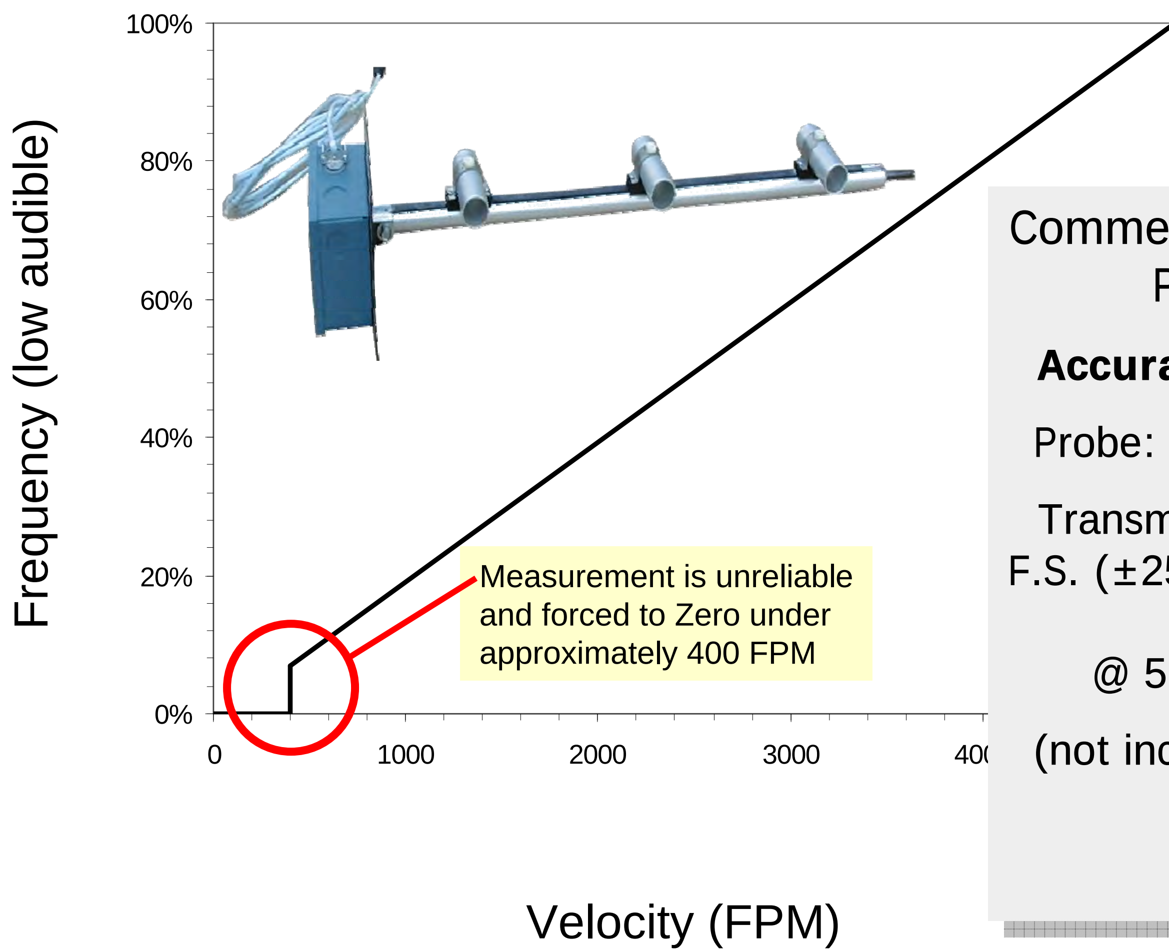
How **Vortex Shedders** Work



Accuracy = Probe Uncertainty + Transmitter Uncertainty + Conversion Error

Measurement Range & Uncertainty

Vortex Shedders



Commercially Available Products:

Accuracy Statement

Probe: ±2% of reading

Transmitter: ±0.5% of F.S. (±25 fpm throughout range
@ 5,000 fpm FS)

(not including sampling error)

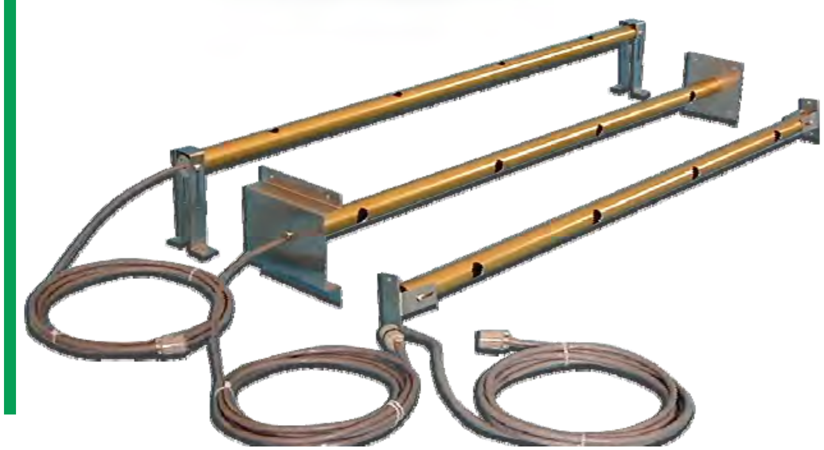
Concerns & Observations

Vortex Shedders

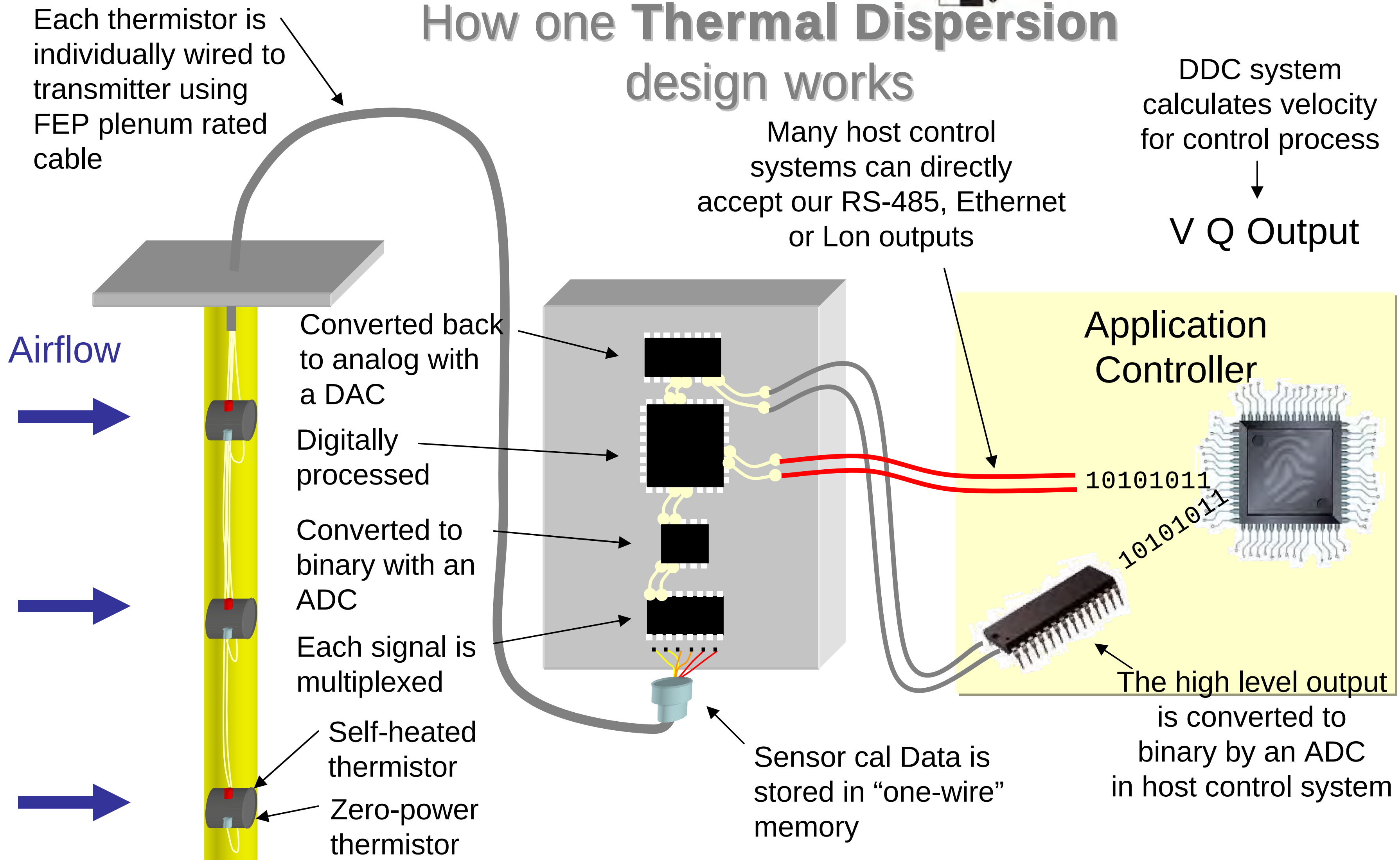
- Averaging error is high at low airflow rates
- Tubing failure in probes can be a problem
- Microphone failures reported
- Analog circuitry is prone to drift
- Potentiometers can drift and change calibration
- Transmitter requires periodic calibration to a frequency generator

Permanently Installed Instruments

Thermal Dispersion describes a specific processor-based thermal velocity meter. Other designs have used the terminology but without having all the key elements.



How one **Thermal Dispersion** design works



Accuracy = Probe Uncertainty + Transmitter Uncertainty + Conversion Error

Permanently Installed Instruments

How one **Thermal Dispersion** meter works

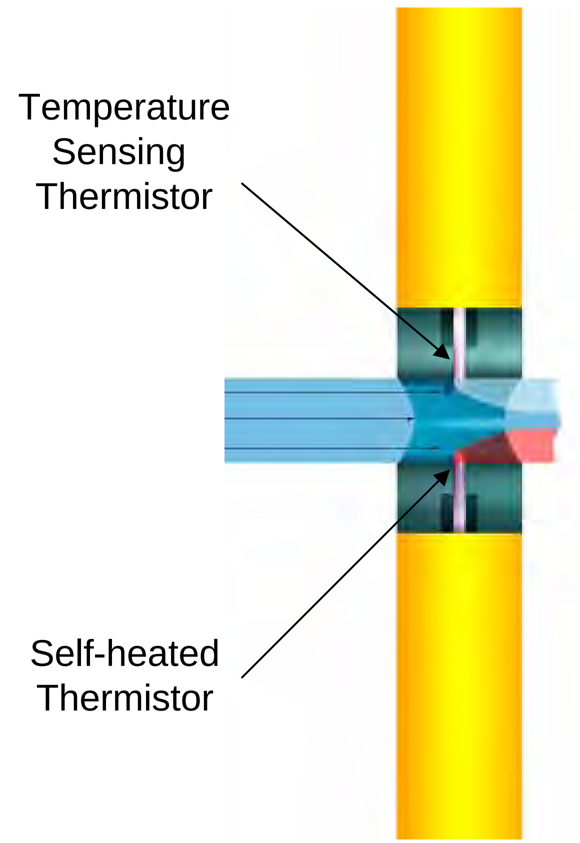
Heat dissipated to the airstream is directly related to the velocity and mass velocity.

$$Q = \frac{\kappa A}{d}\left[B + C\left(\frac{\rho v d}{\mu}\right)^{m}\right](T_H - T_A)$$

velocity

Power

ΔT

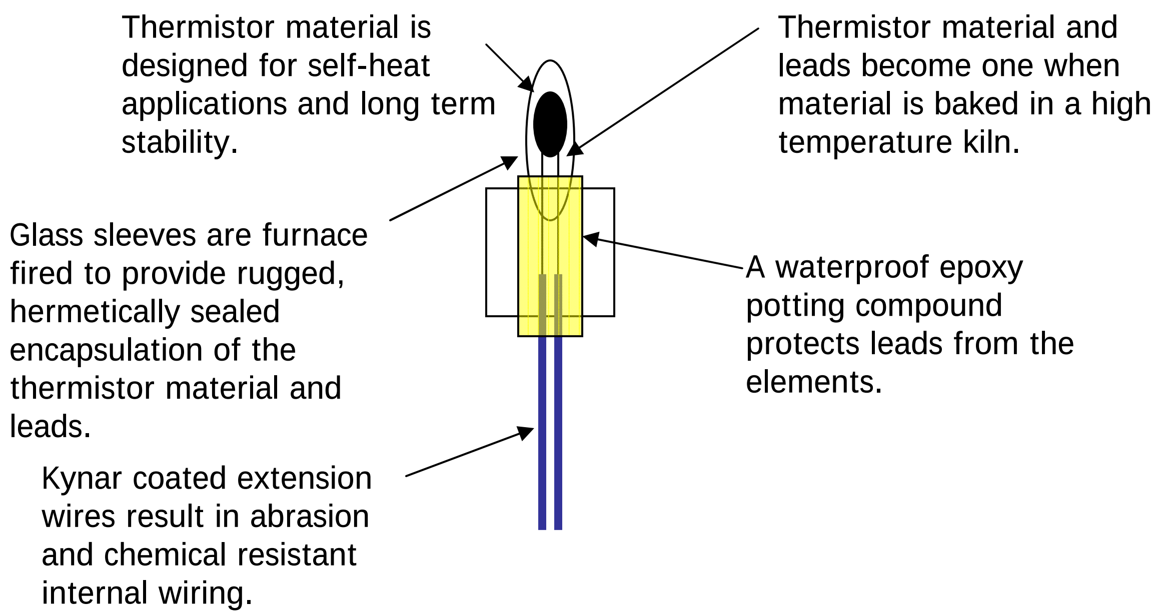


Probe Uncertainty: Stability,

WHEN specific design features are included

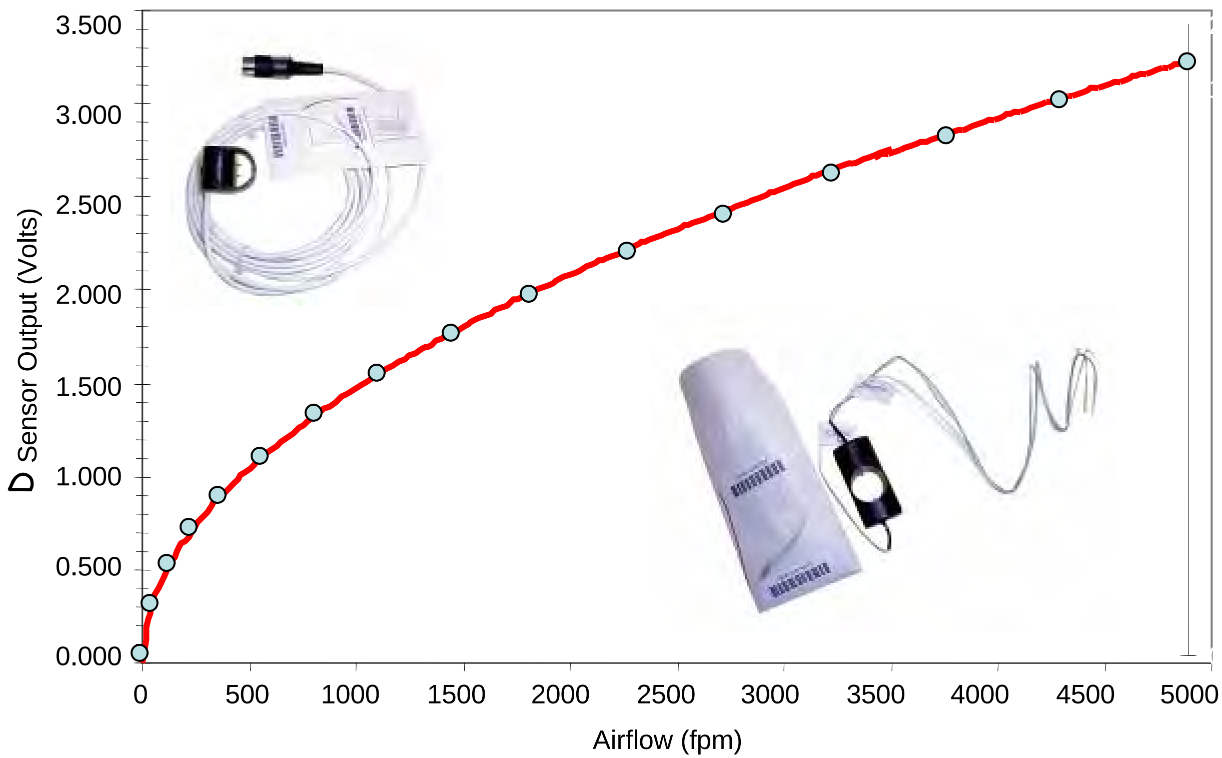
One thermal dispersion manufacturer uses two pre-stabilized bead-in-glass thermistors at each sensor node.

- Designed for self-heat applications.
- Ruggedized thermistor probe is ideal for all HVAC applications.
- Aging process results in exceptional long term stability.



Probe Uncertainty: Factory Calibration

16 Point Sensor Calibration to NIST Traceable Standards



No K Factor.

Need for compensation is Calibrated Out under actual airflow.

Probe Uncertainty: Factory Calibration

Example from one manufacturer

Production

NIST Airspeed (VNIST), [fpm]	IUT Output (VIUT), [fpm]	Expanded Uncertainty, [%]
115.92	116.03	1.43
175.58	175.83	1.09
219.59	219.83	0.81
268.35	266.31	1.18
316.32	314.61	1.03
366.59	365.41	0.82
419.39	417.92	0.76
462.72	462.39	0.67
506.95	506.91	0.71
744.49	743.96	0.68
1035.1	1033.5	0.73
1190.7	1187.8	0.67
1438.0	1434.1	0.67
1772.5	1765.7	0.65
2050.1	2040.6	0.64
2488.3	2476.0	0.64
2986.9	2975.0	0.67
3382.5	3367.2	0.68
3984.5	3963.2	0.70
4988.1	4959.6	0.67
5990.8	5965.3	0.88
6979.2	6941.6	0.87
7993.3	7937.7	0.65

Typical Production Unit Calibration Report

	Ref	UUT	Error	Error%
0	0.00	-0.01	-0.011595	
1	116.89	117.18	0.3	0.3%
2	157.40	157.34	-0.1	0.0%
3	227.43	227.89	0.5	0.2%
4	333.64	331.39	-2.3	-0.7%
5	453.03	447.86	-5.2	-1.1%
6	577.73	574.96	-2.8	-0.5%
7	740.80	737.85	-3.0	-0.4%
8	943.69	940.25	-3.4	-0.4%
9	1153.84	1165.31	11.5	1.0%
10	1414.55	1402.48	-12.1	-0.9%
11	1678.59	1687.86	9.3	0.6%
12	2024.89	2008.12	-16.8	-0.8%
13	2409.37	2399.48	-9.9	-0.4%
14	3342.61	3340.49	-2.1	-0.1%
15	4941.23	4923.32	-17.9	-0.4%

Probe Uncertainty: Stability

Maximum Total Uncertainty
of Thermal Dispersion System,
Due to Potential Drift

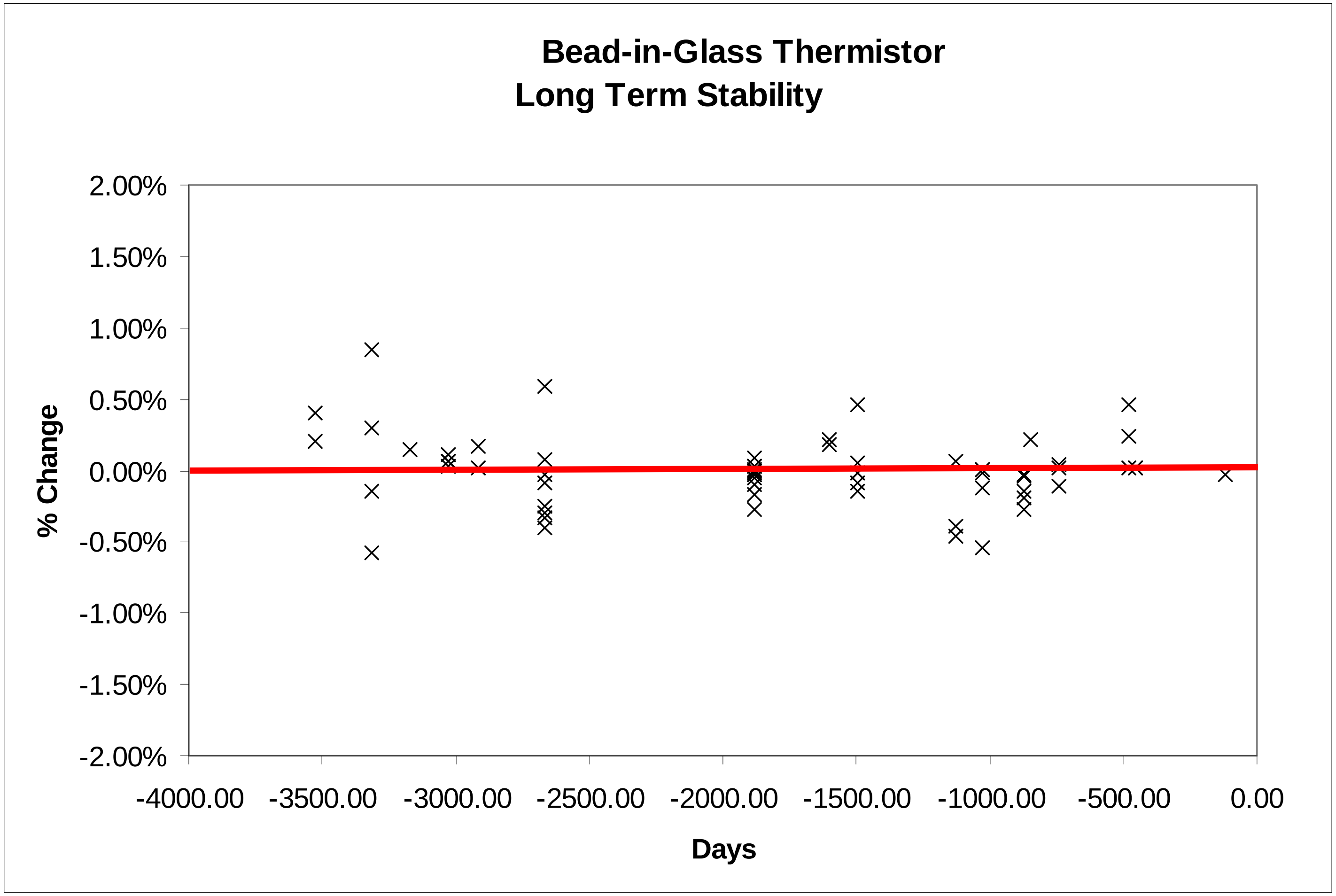
0.76% of Reading

= Uncertainty Range from -0.18% to +0.58%

From 100 – 5,000 FPM, over 10 years

Negligible Drift

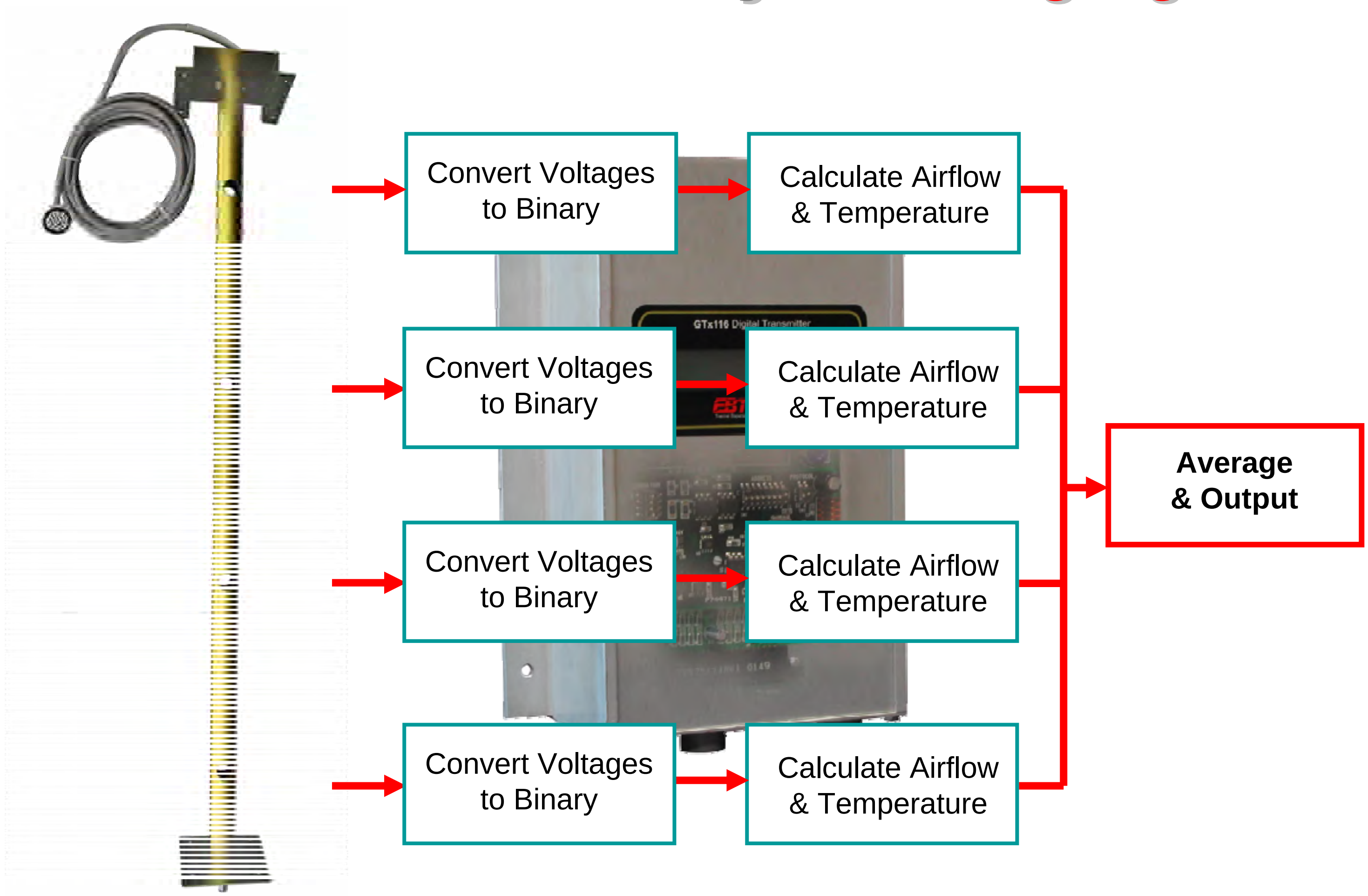
Probe Uncertainty: Stability



Long term empirical testing validated modeling.

Negligible Drift

Probe Uncertainty: Averaging Error

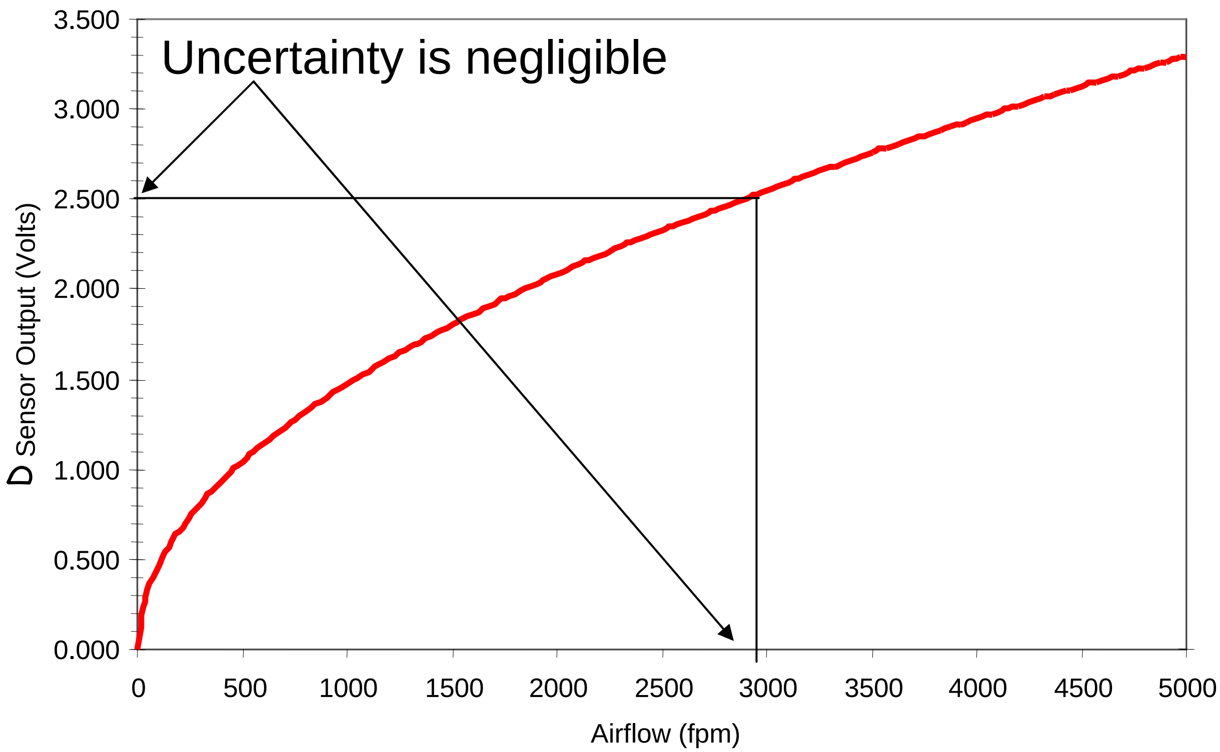


NO AVERAGING ERROR

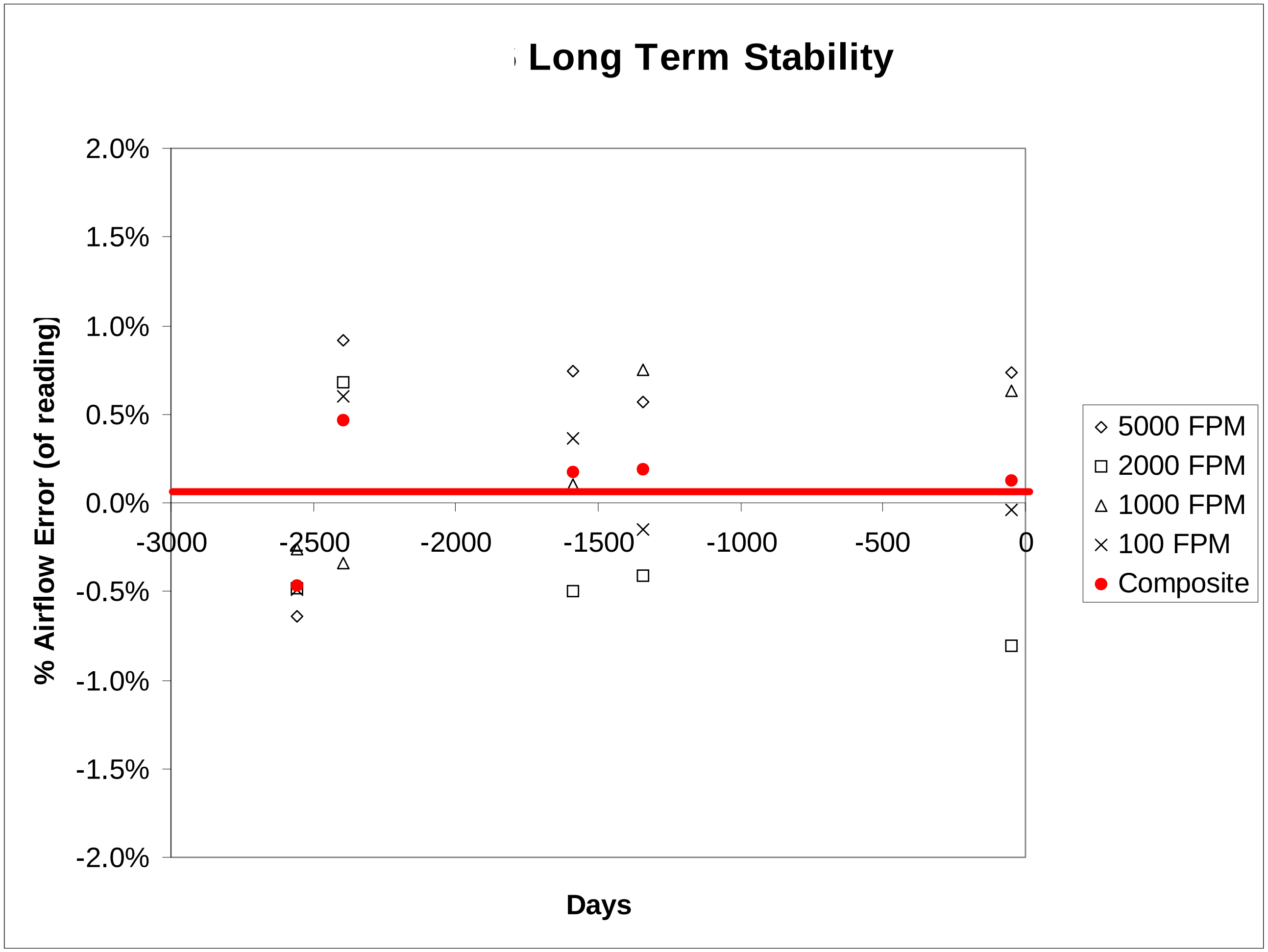
Transmitter Uncertainty

Transmitter can Accurately Resolve to 0.0024 VDC

(<2.5 millivolts or about 1.2 fpm @5,000 fpm FS)

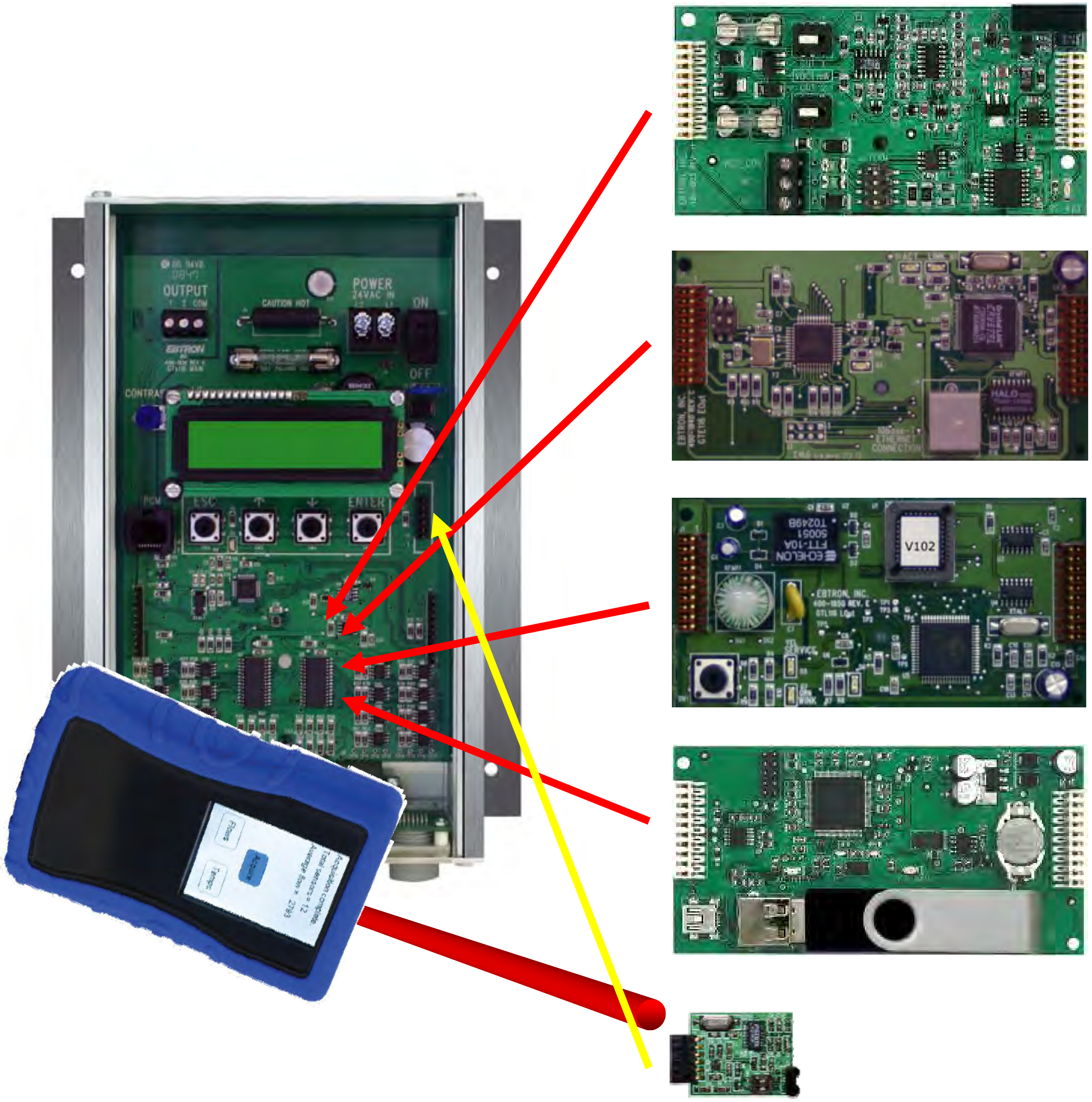


Transmitter Uncertainty: Stability



No Drift in the processor-based transmitters!

Connectivity Solutions – Thermal Dispersion



Combination analog/digital

Two field selectable 0-5, 0-10 VDC or 4-20 mA isolated outputs
One RS-485 BACnet MS/TP or Modbus output

Ethernet

Two field selectable 0-5, 0-10 VDC or 4-20 mA isolated outputs
One Ethernet BACnet or Modbus output

Lon

Lonworks

Data Logging

USB thumb-drive datalogger, logs average airflow and temperature plus airflow and temperature readings of individual sensors with time stamp

IR-Reader Option

Add to any transmitter to interface with infra-red PDA

Permanently Installed Instruments

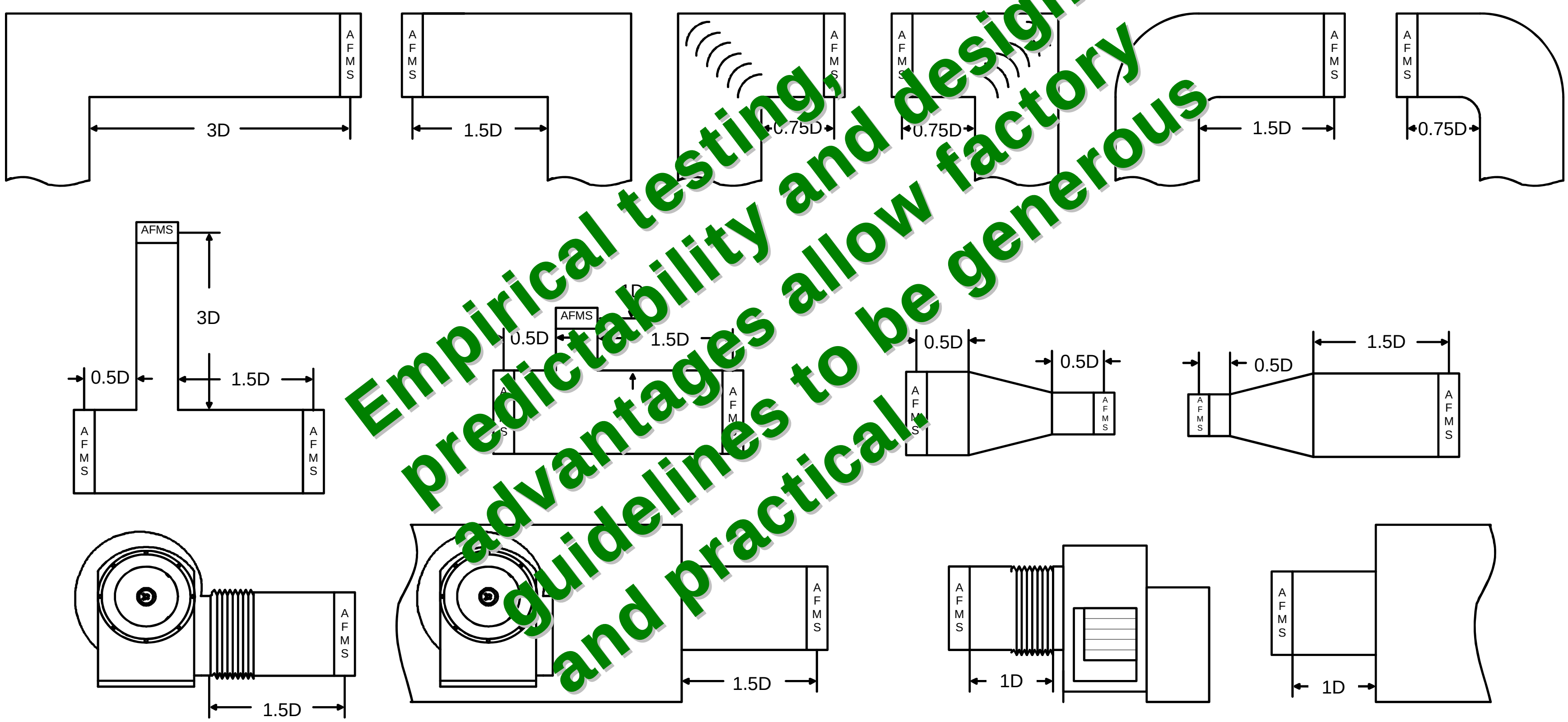
IR and Network Connectivity can allow you to Collect Traverse Data Fast !

- Download **individual sensing point data** directly to your PDA **and totally independent of the BAS system.**
- Increases your efficiency and **SAVES time and money**
- **Directly measure outdoor air intake**
(ASHRAE Std. 62.1-2010, 189.1-2009, CA Title 24, IMC 2009, IGCC & LEED – 2009/2012)

Permanently Installed Instruments

Minimum Duct Placement Conditions

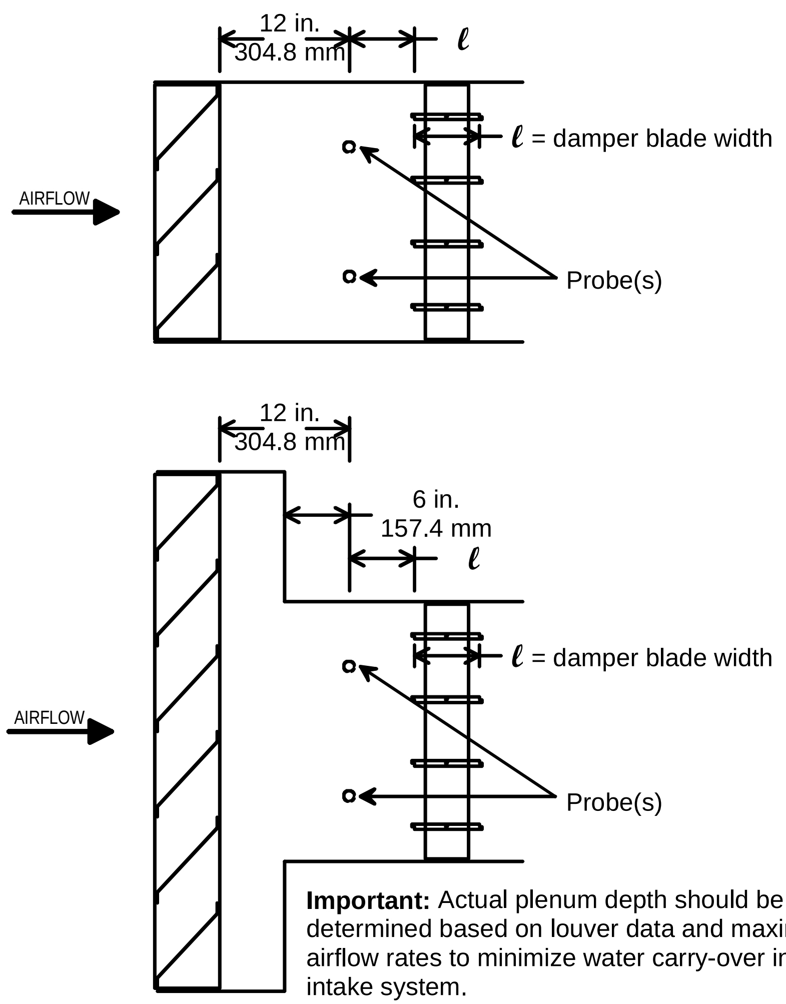
Thermal Dispersion Ducted Probes, ‘C’ Density Only

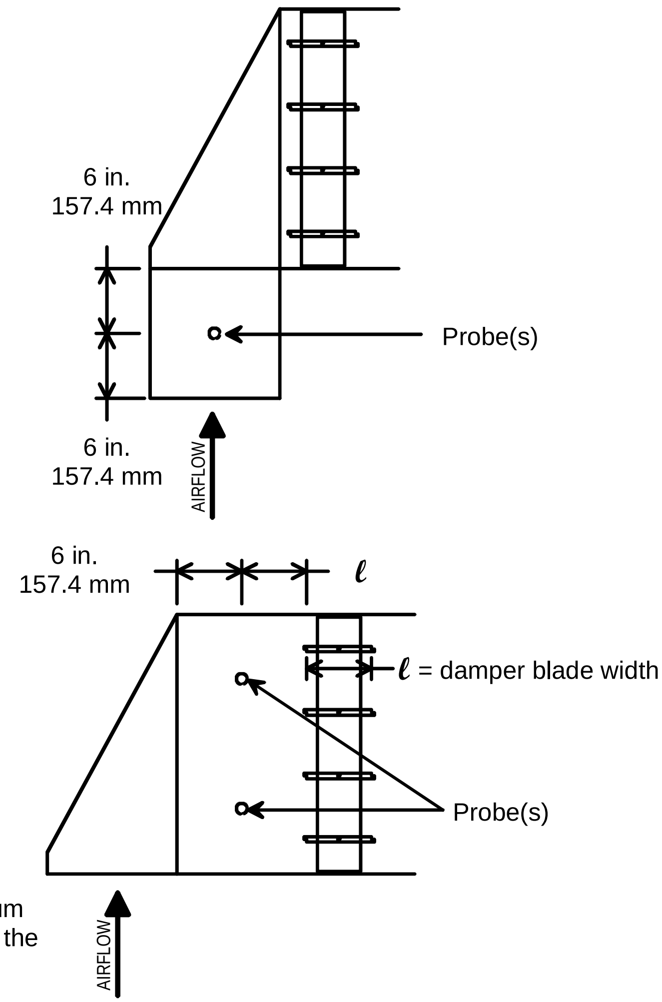


Empirical testing, predictability and design advantages allow factory guidelines to be generous and practical.

Permanently Installed Instruments

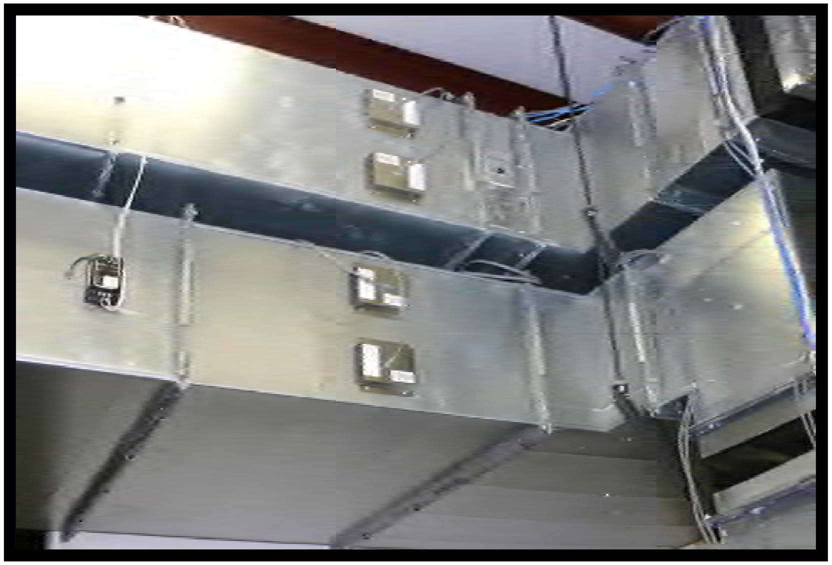
OA Intake Placement

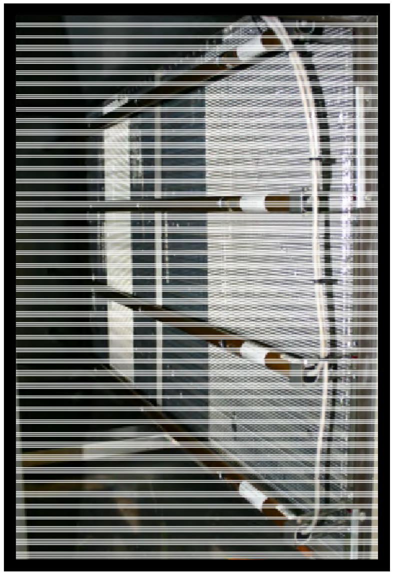




Important: Actual plenum depth should be determined based on louver data and maximum airflow rates to minimize water carry-over into the intake system.

Eliminating Averaging Errors Expands Placement Options





Averaging Error Comparison

2 R 1

3

4

Thermal Dispersion	Ref Error
R = 960 FPM	0.0 %
1 = 957 FPM	-0.3 %
2 = 933 FPM	-2.9 %
3 = 938 FPM	-2.4 %
4 = 992 FPM	3.4 %

6 independent sensors vs 14 dP pickups

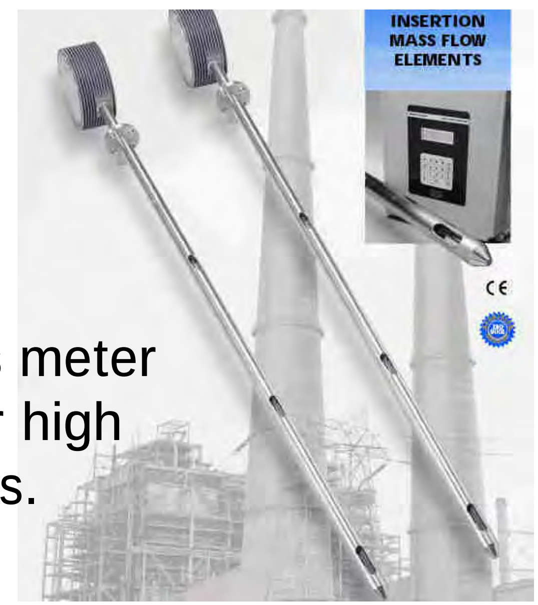
3

4

Pitot Array	Ref Error
R = 872 FPM	0.0 %
1 = 1097 FPM	25.8 %
2 = 864 FPM	-0.9 %
3 = 1250 FPM	43.2 %
4 = 1155 FPM	32.4 %

What thermal-based velocity meter designs are available for permanent mounting?

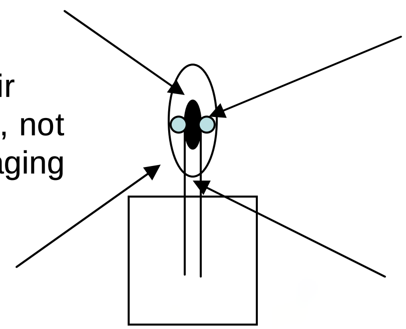
- **5 vendors** have introduced and/or are selling thermistor-based velocity meters during the past 5 years.



  - This excludes the industrial and process meter manufacturers that use RTD designs for high temperature and corrosive environments.

Thermistor Selection is Pivotal !

- **One notable product uses two epoxy coated chip thermistors.**
  - NOT designed for self-heat applications.
  - NOT a ruggedized thermistor probe. Epoxy coating can absorb water. Leads can separate from thermistor substrate. Exposed leads can corrode.
  - Limited aging process results in very poor long term stability.

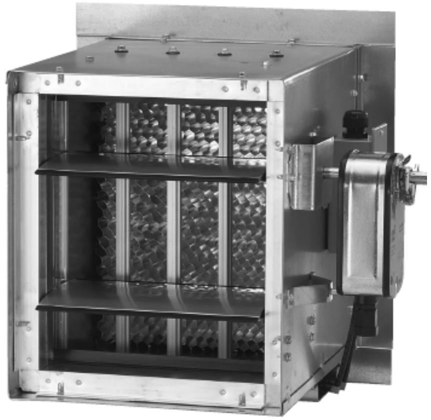


Combination Damper / AFMS

At least **4 vendors** offer combination products.

Only one manufacturer uses Thermal Dispersion technology. All others use variations of the Pitot array.

AHU manufacturer's Intake damper option



calibrated to operate across a specific operating range.

intended to maintain a single pre-determined airflow set point and includes a controller

10 of 16 Minimum TAB Air Procedures can be Satisfied with Qualified Permanent Instruments, already on site

Test and adjust fan speed to design requirements.

Test and record outside air, mixed air, and discharge temperatures

Set adjustments of automatically operated dampers to operate as specified.

Test and adjust air handling and distribution systems to provide required or design quantities for supply, return, outside, and exhaust air.

Make air quantity measurements in ducts by Pitot tube traverse entire cross sectional area of duct.

Measure air quantities at air inlets and outlets.

Vary total system air quantities by adjustment of fan speeds. Provide drive changes recommendations to installing contractor.

Adjust outside air automatic dampers, supply, return and exhaust dampers for design conditions.

Measure temperature conditions across supply, return and exhaust dampers to check leakage.

Where modulating dampers or economizers are provided, take measurement at full design flow - return air, minimum outside air, and 100 percent outside air mode of operation.

Airflow Measurement Devices

Devices having substantially greater, verifiable performance can provide superior TAB field results, reduce TAB labor costs and time investments.

In locations difficult to measure with a Pitot, these devices can provide a superior basis for set up or field verification – the key for the technician is product knowledge, understanding and confidence.

Materials, research, time and travel costs required for the preparation and presentation of this seminar were provided by:

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