Badger & Ebtron Practical Sequences of Operation

Who is Jacco

- Established 1968
  - Hudson, Ohio
  - Columbus, Ohio
  - Toledo, Ohio
- Focused on the Engineered Environment
- Systems Knowledgeable
  - HVAC Systems
  - Service & Maintenance
  - Parts

JACCO

Who is Jacco

- Operations
  - –Brenda Homjak
  - –Mike Spangler
  - –Chad Russell
  - –Mike Mueller
  - –Hana Lee
- Contractor Owning Experience
  - –Dan Duignan
  - –Rick Baker
- Engineering Owning Experience
  - –Greg Drensky
  - –Jerry Cohen
- Owning Experience
  - –Beth Plazak
  - –Jeff Watson

JACCO

Outdoor Airflow Control Improves Buildings

Peter Blaha
Product Specialist
ESC

Agenda

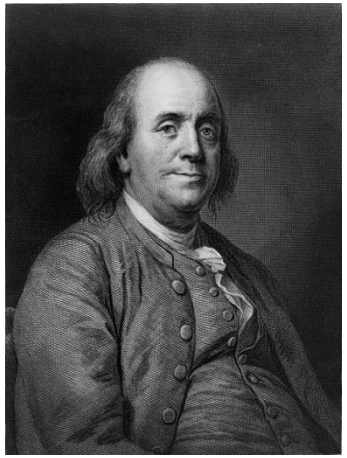
I. Why Measure & Control Outdoor Air Intakes?
II. Analyze Alternatives:
    a. Fixed Outdoor Air Damper Position ≠ Control
    b. Supply Air – Return Air ≠ Outdoor Air
    c. Outdoor Airflow Control Improves CO2 DCV
III. Outdoor Air Delivery Design Guidelines
IV. Selecting Outdoor Airflow Monitors
V. Why Measure & Control Water / Steam & Natural Gas?
VI. Water / Steam / Natural Gas Design Guidelines
VII. Questions/Comments/Open Floor

I. Why Measure and Control Outdoor Air Intakes

Proper Ventilation Helps Ensure a Comfortable, Healthy, & Productive Indoor Environment

Benjamin Franklin

On Fresh Air, 1785



“ I considered (fresh air) as an enemy and closed with extreme care every crevice in the rooms I inhabited.

Experience has convinced me of my error. I now look upon fresh air as a friend. I even sleep with an open window.

I am persuaded that no common air from without, is so unwholesome as the air within a close(d) room that has been often breathed and not changed.”

Letter from Benjamin Franklin to Dr. Ingenhaus physician to the emperor in Vienna

Quote found in Real Estate Law (Thomson/Southwestern) Jennings, 2008 & 2005: pg 229, Chapter 10: Commercial Leases: Condition of the Premises – The Sick Building Syndrome

Code and Standard Compliance

ASHRAE Standards:

- ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*
- ASHRAE Standard 189.1, *Standard for the Design of High-Performance Green Buildings*
- ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*

IMC (*International Mechanical Code*)

IECC (*International Energy Conservation Code*)

LEED (*Leadership in Energy and Environmental Design*)

State Mandates: CA Title 24, Washington Energy Code, etc.

ALL SYSTEMS

ASHRAE 62.1

- **SECTION1.1** - The purpose of this standard is to specify **minimum ventilation rates** to provide indoor air quality that is acceptable to human occupants and that minimizes adverse health effects.
- **SECTION 5.3.1** - All systems shall be provided with manual or automatic controls to **maintain no less than the outdoor air intake flow** *(V_{ot})* required by Section 6, under all load conditions or dynamic reset conditions.
- **SECTION 5.9.2** - Ventilation systems for a building shall be designed such that the total building **outdoor air intake equals or exceeds** the total **building exhaust** under all load and dynamic reset conditions.

ALL SYSTEMS

IMC

- **SECTION 405.1** - Air-conditioning systems that supply required ventilation air shall be provided with controls designed to **automatically maintain the required [outdoor] air supply rate** during occupancy.

VAV Systems

ASHRAE 62.1

- **SECTION 5.3.2** - Systems with fans supplying variable primary-air *(V_{ps}),* including single-zone VAV and multiple-zone-recirculating VAV systems shall be provided with … Outdoor air-intake, return air dampers or a combination thereof that **modulate to maintain no less than the outdoor air intake flow** (V_{ot}).

ASHRAE 189.1

- **SECTION 8.3.1.2.2 -** Each mechanical ventilation system shall have **a permanently installed device to measure the *minimum outdoor airflow*** … **Exception to 8.3.1.2.2:** Constant volume air supply systems that do not employ *demand control ventilation …*

VAV Systems

IMC

- **SECTION 403.6 –** Variable Air Volume Systems. Shall be designed to **maintain the flow rate of outdoor air** at a rate not less than required by SECTION 403.3 over the **entire operating range** of supply air operating rates.

LEED

- **EQ PREREQUISITE** - For variable air volume systems, **provide a direct outdoor airflow measurement device** capable of measuring the minimum outdoor air intake flow.

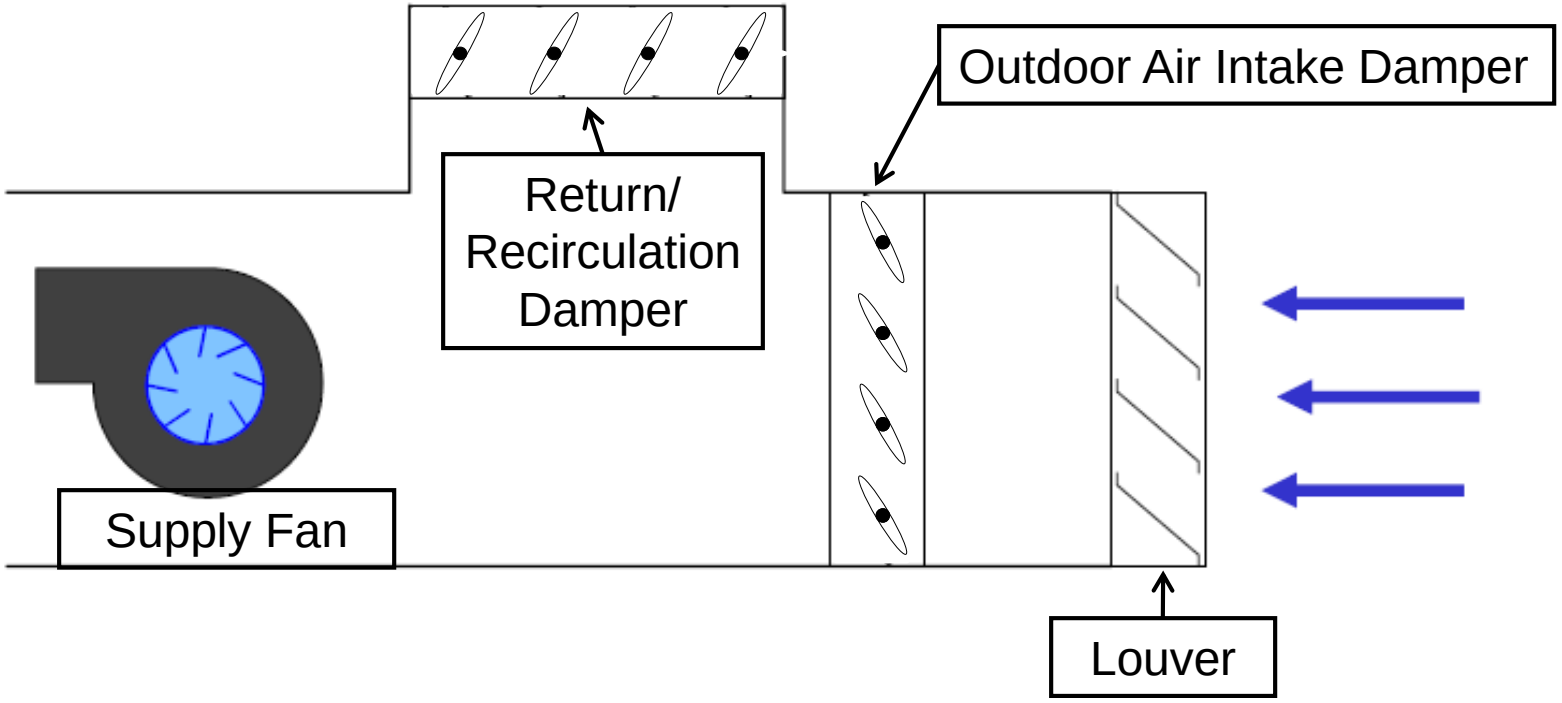
Controlling Outdoor Air Intakes Ensures Compliance to Ventilation Codes and Standards

- Measurement & Verification provides documented proof of compliance
- Cannot control what is not measured
- Outdoor Air Delivery *Monitoring* is required or recommended by:
  - ASHRAE 62.1
  - ASHRAE 189.1
  - LEED v4
  - IMC
  - Local Statutes like Minnesota 123B.71 – Schools

a. Fixed Outdoor Air Damper Position ≠ Control

What is Fixed Outdoor Air Damper Position?

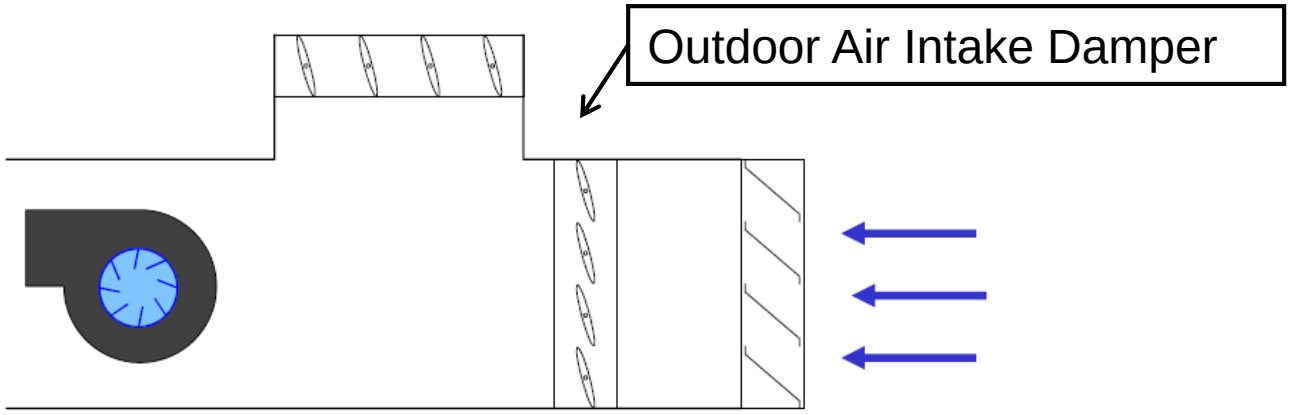
- During ‘Occupied Mode’, the Outdoor Air Intake Damper goes to a pre-determined ‘% Open’
- This method of ‘control’ is unfortunately used by an overwhelming majority of new and existing buildings



Fixed Damper Position ≠ Control

Fixed Damper Setpoint Position is:

- Determined by ‘Test And Balance’ during initial commissioning
- Based on the minimum design airflow (i.e. building codes or ASHRAE 62.1)
- ‘% Open’ kept throughout the building’s life
- Rarely ever re-checked (i.e. retro-commissioned)



Fixed Damper Position ≠ Control

Sources of Outdoor Air Intake Uncertainty with Fixed Damper Position

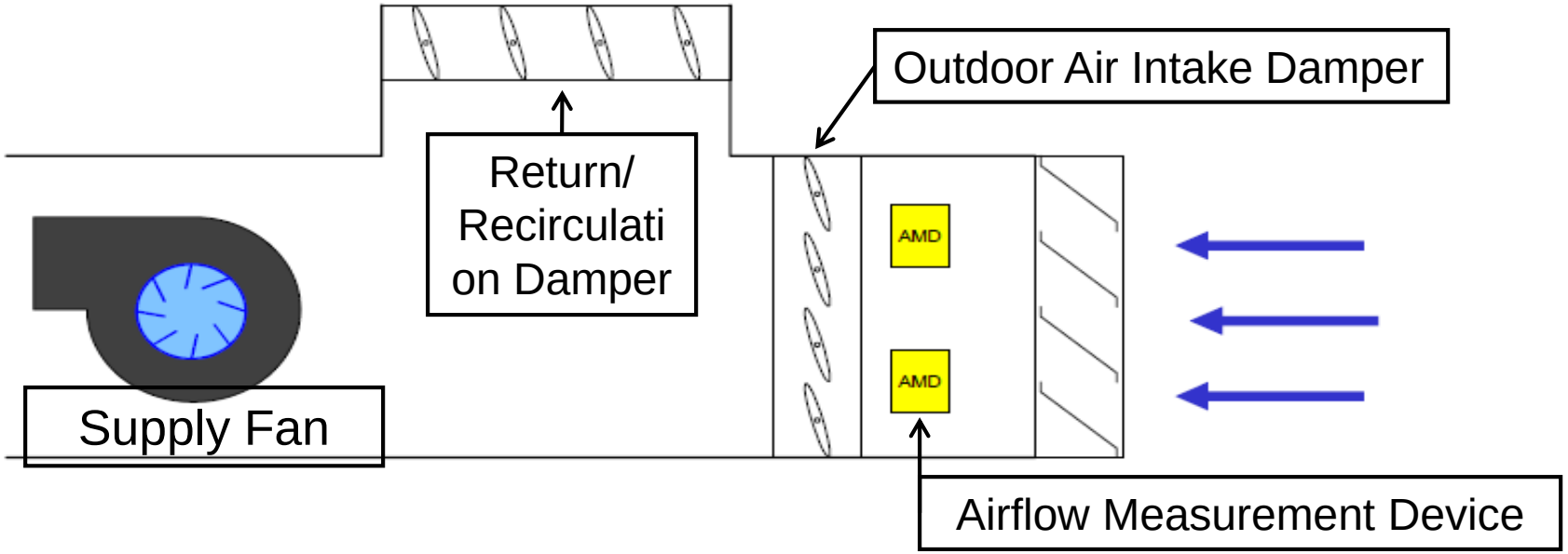
- Damper Hysteresis
  - Damper/Actuators don’t always go back to the exact same position
- Wind Effect
- Stack Pressure
- Conditions at Time of Commissioning

Damper Hysteresis Test:
Damper 'Position' ≠ Desired Airflow

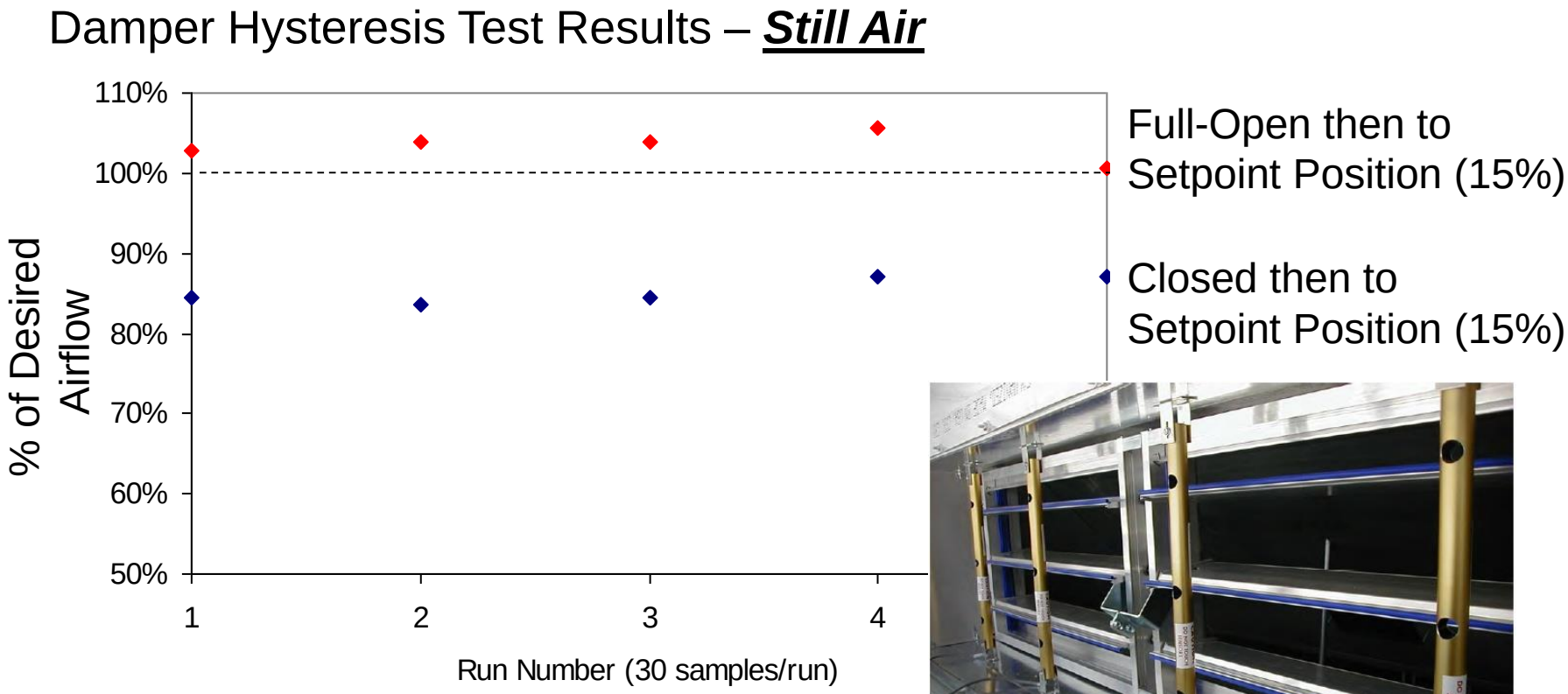
Step 1: A 'Fixed Damper Position' (15% open) was selected and the resulting airflow was recorded. This airflow will be the target (shown as 100% on the chart)

Step 2: Damper was moved fully open, then back to the damper setpoint position (15%) and the airflow measurement was taken (shown in red on the next slide)

Step 3: Damper was closed. Then, moved back to the damper setpoint position (15%) and the airflow measurement was taken (shown in blue on the next slide)



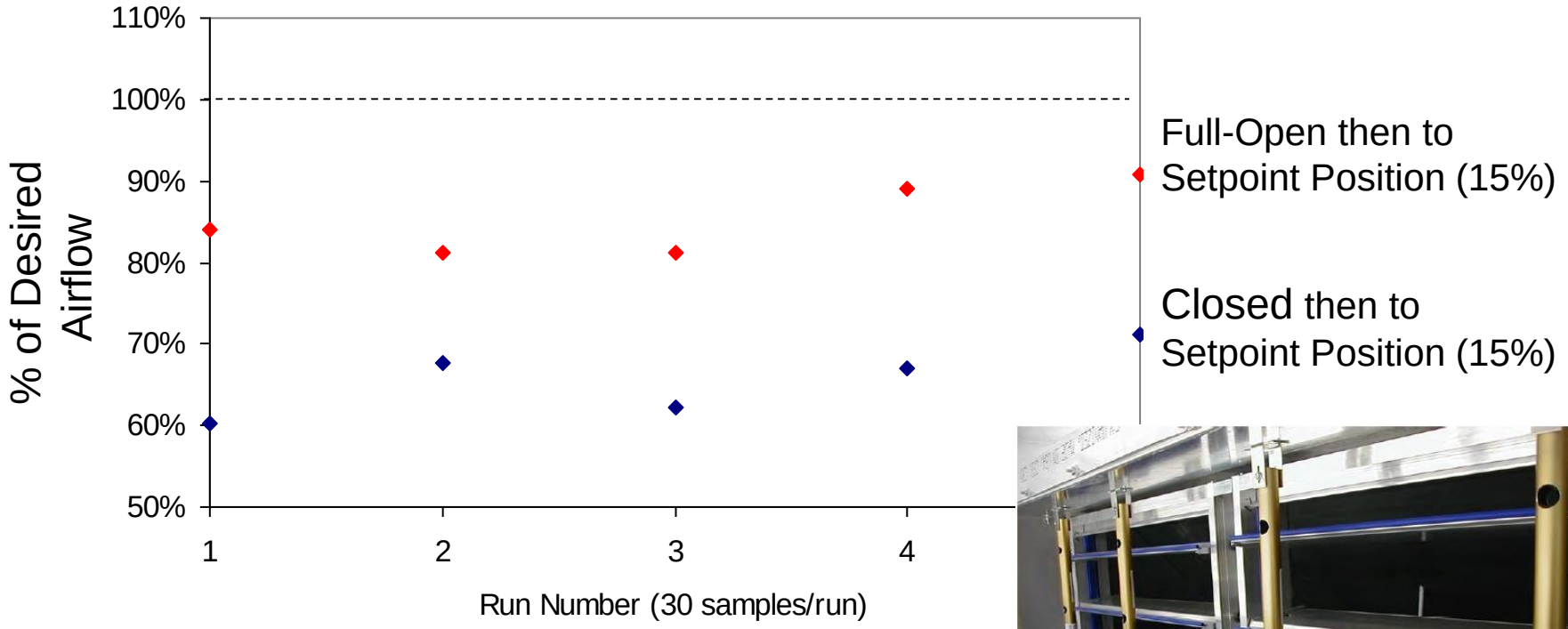
Damper Hysteresis Test Results: Position ≠ Desired Airflow



-Damper/Actuators don't always return to the exact desired position
-What is the airflow on Day 2 of operation (ie after the damper is closed at night)?

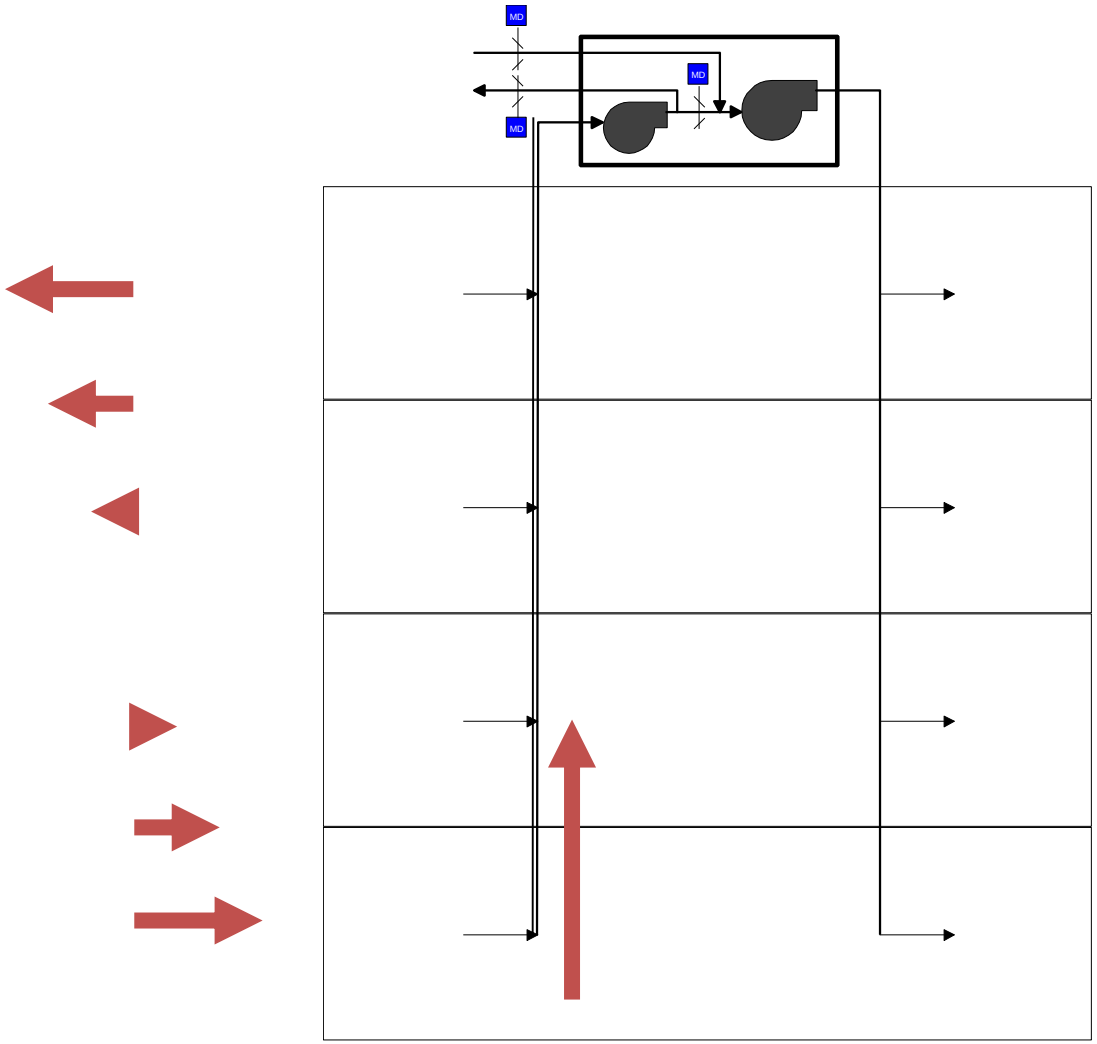
Wind Effects Outdoor Air Intakes

Damper Hysteresis Test Results – ***15 mph Cross Wind***



What if the wind blows directly at the damper?

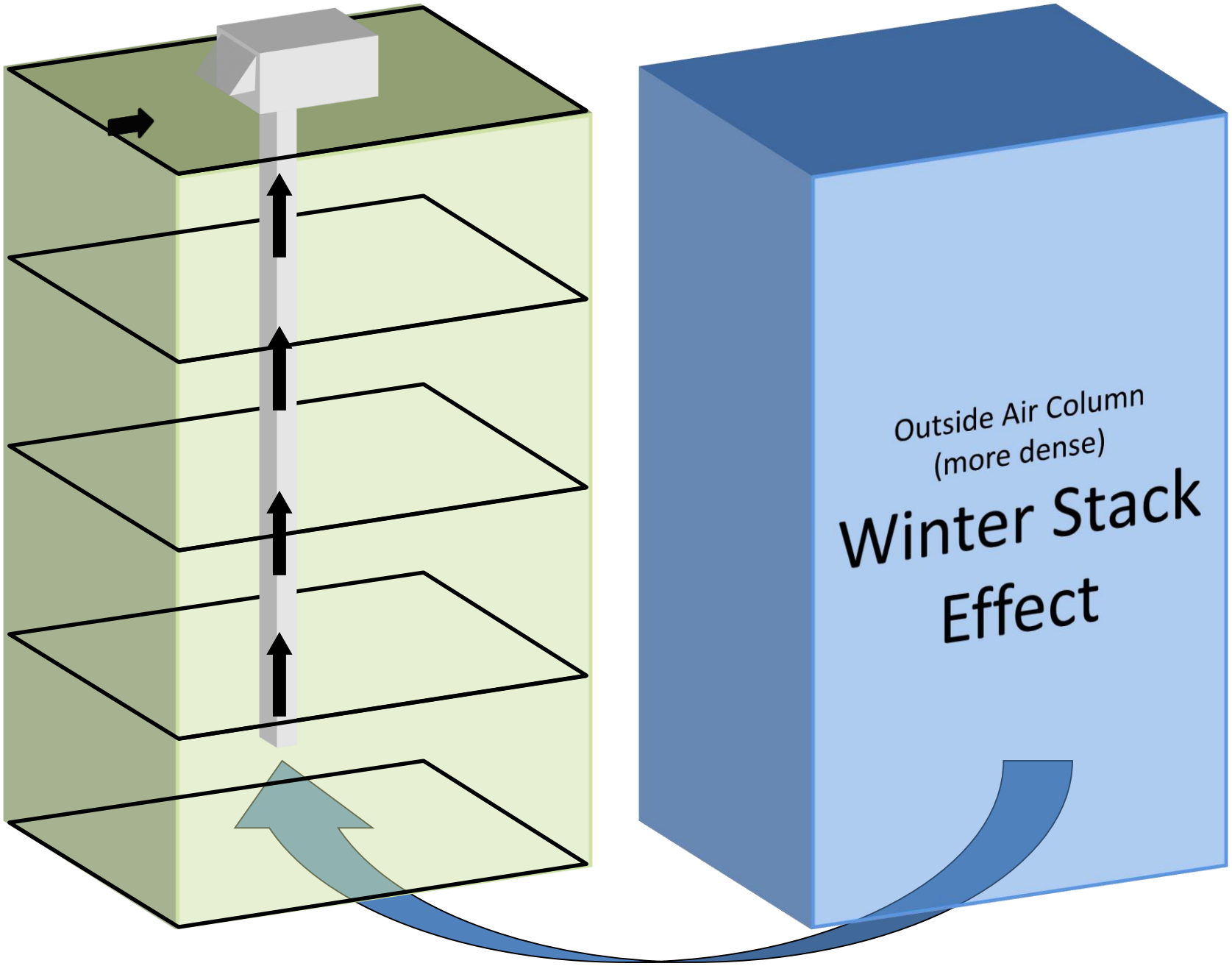
Stack Pressure Effects Outdoor Air Intakes



Stack Effect in Winter

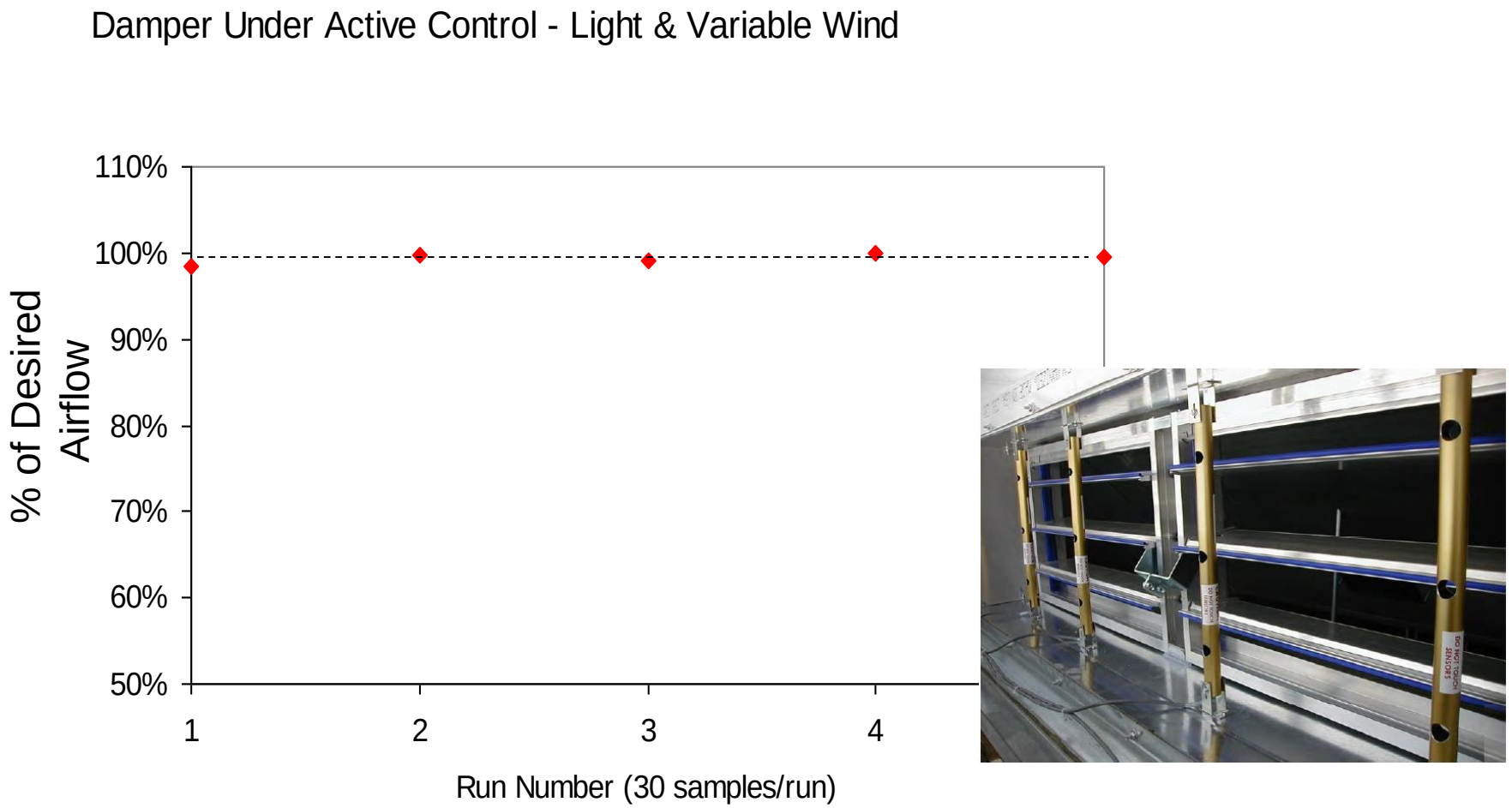
Warm air in the building rises pushing out on the outdoor air damper

Question:
Will a damper setpoint position selected in the winter be valid in the summer?


Outside Air Column
(more dense)
Winter Stack
Effect

Solution:

Control Outdoor Intakes With Airflow Monitors



Requires Accurate & Stable Airflow Measurement

c. Outdoor Airflow Control Improves CO2-based Ventilation Control Systems

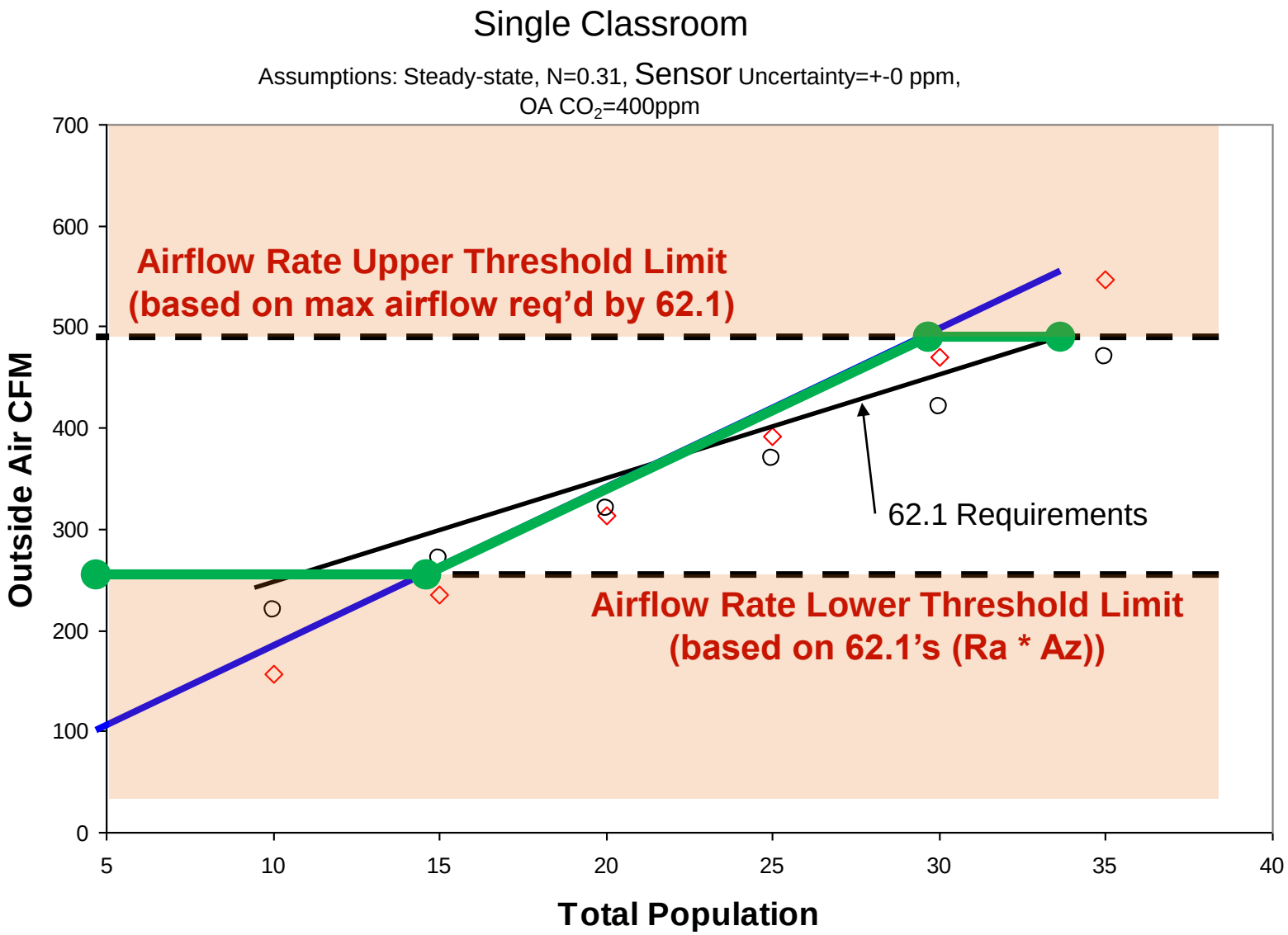
ASHRAE 62.1-2016
Ventilation Rate Procedure (VRP)

6.2.2.1 Breathing Zone Outdoor Airflow. The outdoor airflow required in the breathing zone of the occupiable space or spaces in a *ventilation zone*, i.e., the breathing zone outdoor airflow (V_{bz}), shall be no less than the value determined in accordance with Equation 6.2.2.1.

$$V_{bz} = R_p \cdot P_z + R_a \cdot A_z \quad (6.2.2.1)$$

where
R_p = outdoor airflow rate required per person from Table 6.2.2.1
P_z = the CURRENT population of the ventilation zone (as per 6.2.7.1.1)
R_a = outdoor airflow rate required per floor area from Table 6.2.2.1
A_z = zone floor area

Use Airflow Monitors to put ‘Bounds’ on CO2-based DCV’s Airflow Adjustments



IV. Outdoor Air Delivery Design Guidelines

Outside Air Intake Guidelines

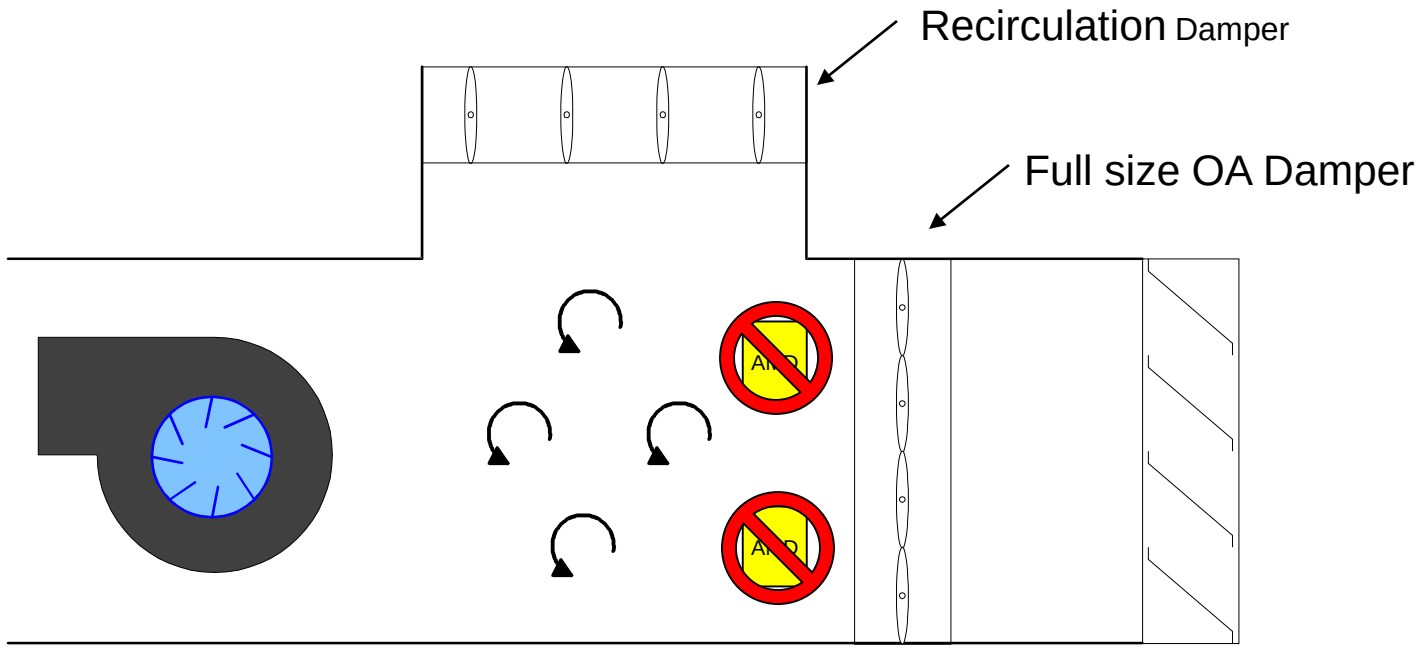
Follow these basic rules for success:

- Select and **apply** airflow measuring devices suited for the measurement of intake flow rates.
  - Make certain the flow meter can measure the outdoor air intake flow rates
  - **Make certain that the flow rates are high enough to control and are not affected by transient wind gusts (> 150 FPM at minimum [200 FPM preferred])**
- Select and size quality control dampers.
  - Use high quality, extruded aluminum blades, with long-lasting and non-binding linkage
- Implement a control strategy that optimizes the performance of the system
  - **Use the right sequences and slow it down!**

Outside Air Intake Guidelines

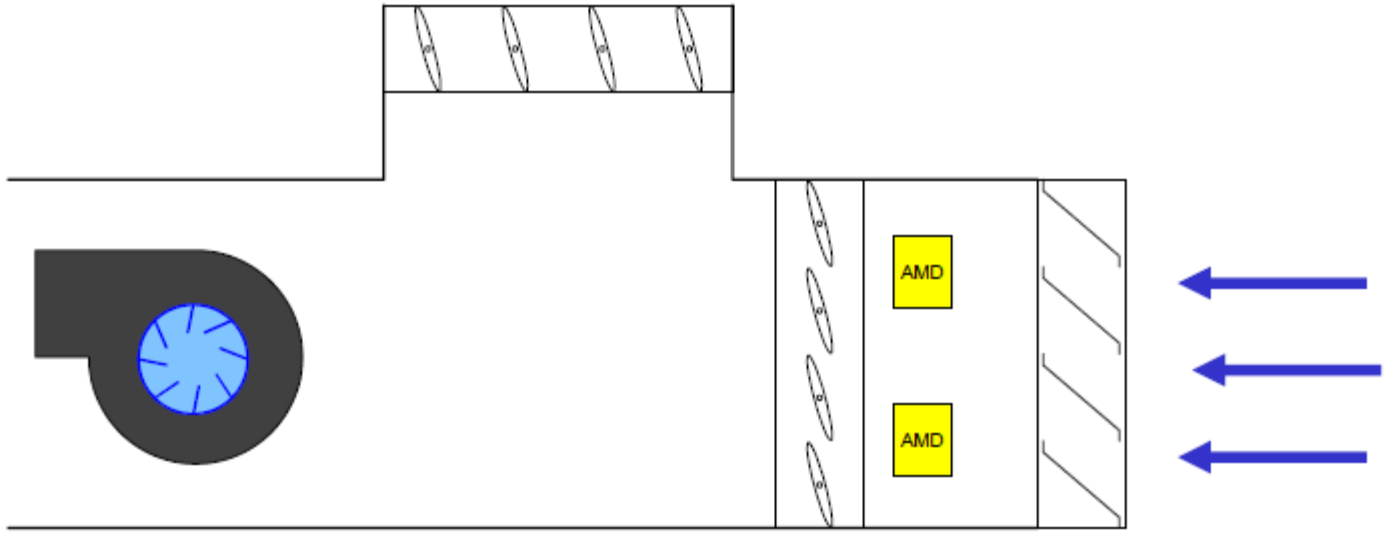
Turbulence in the mixed air plenum from fans and dampers can result in false airflow readings.

Do NOT measure airflow rates downstream of the intake damper or near the mixed air plenum!

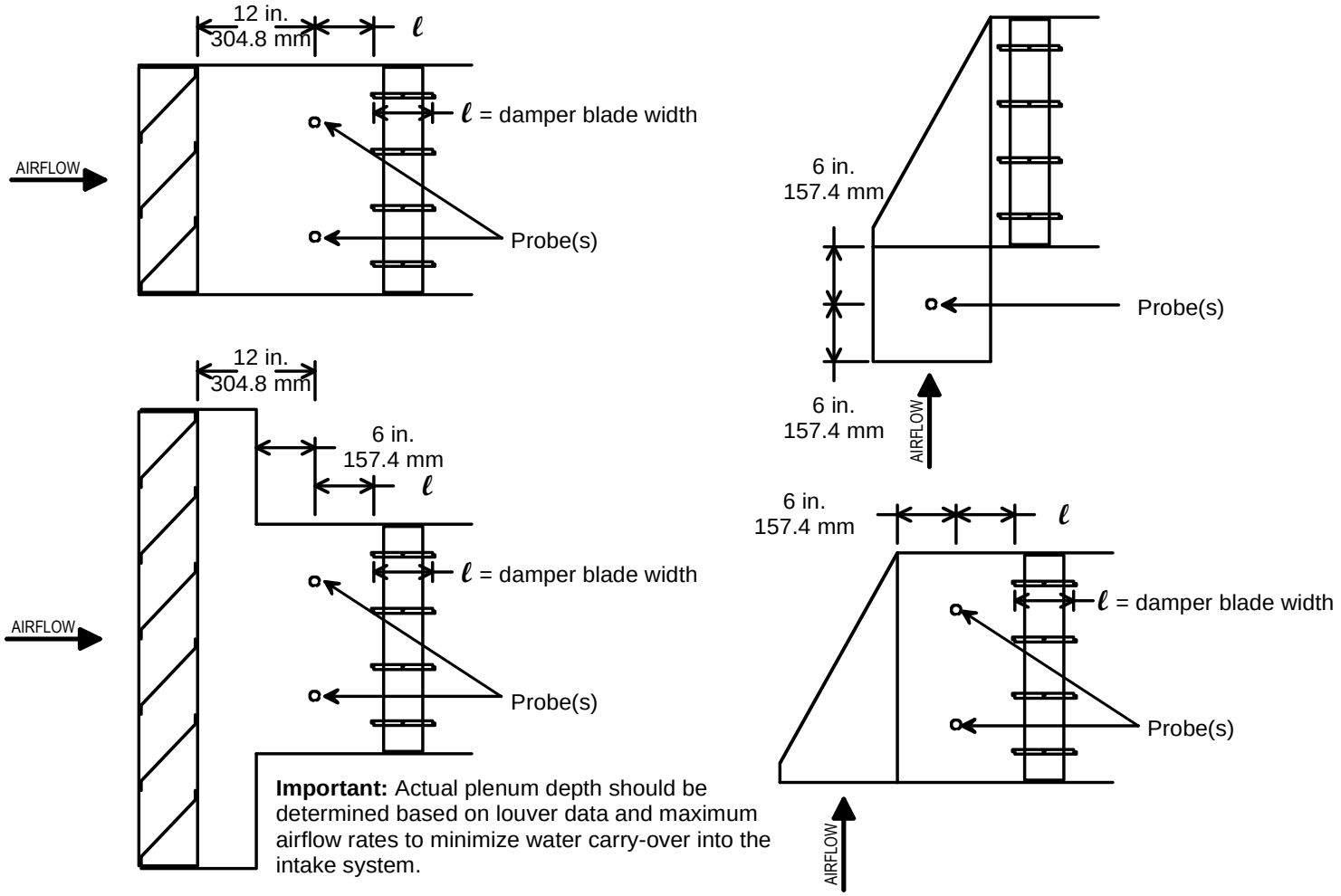


Outside Air Intake Guidelines

Always place the airflow measuring station UPSTREAM of the intake damper



Outside Air Intake Placement Guidelines



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

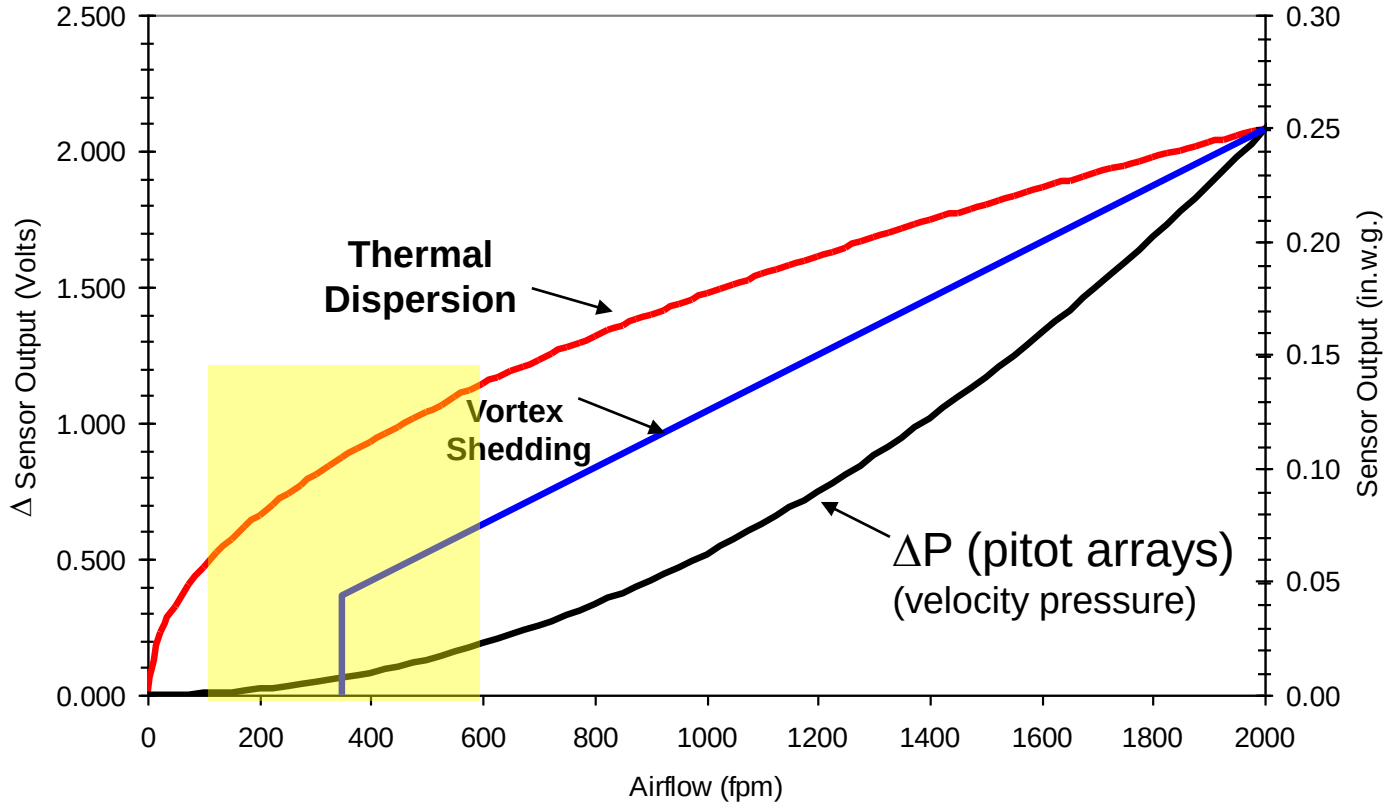
V. Selecting Outdoor Airflow Monitors & Technology Comparison

What’s important?

1. Suitability for Application
   a) Desired Airflow
   b) Minimum Placement Guidelines
2. Total Installed Accuracy
3. Repeatability (i.e. Long-Term Stability)
   a) Long-Term Drift
   b) Recommended Calibration Interval
4. Application Support
5. Cost
6. Reliability
7. Ease of Installation
8. Service and Support

Technology Comparison

Thermal Dispersion vs. DP vs. Vortex Shedding



Thermal Dispersion has the Best Sensitivity at Low Airflows

Outdoor Air Intakes typically 150 to 600 fpm velocity

ASHRAE HANDBOOK

Measurement Means	Range, fpm	Precision	Limitations
Thermal dispersion (microcontroller–based) using thermistors to independently determine temperatures and velocities	20 to 10,000	±2 to 10% of reading	Cost increases with number of sensor assemblies in array. Honeycomb air straighteners are recommended by some manufacturers. Accuracy verified only to -20° F. Not suitable for abrasive or high-temperature environments.
Pitot array, self-averaging differential pressure, typically using equalizing manifolds	600 to 10,000	±2 to >40% of reading	Performance depends heavily on quality and range of associated differential pressure transmitter. Very susceptible to measurement errors caused by duct placement and temperature changes. Nonlinear output (square-root function). Mathematical averaging errors likely because of sampling method. Must be kept clean to function properly. Must be set up and field calibrated to hand-held reference, or calibrated against nozzle standard.
Piezometer and piezoring variations, self-averaging differential pressure using equalizing manifolds	600 to 10,000	±5 to >40% of reading	Performance depends heavily on quality and range of required differential pressure transmitter. Very susceptible to measurement errors caused by inlet cone placement, inlet obstructions, and temperature changes. Nonlinear output (square-root function). Must be kept clean. Must be field calibrated to hand-held reference.

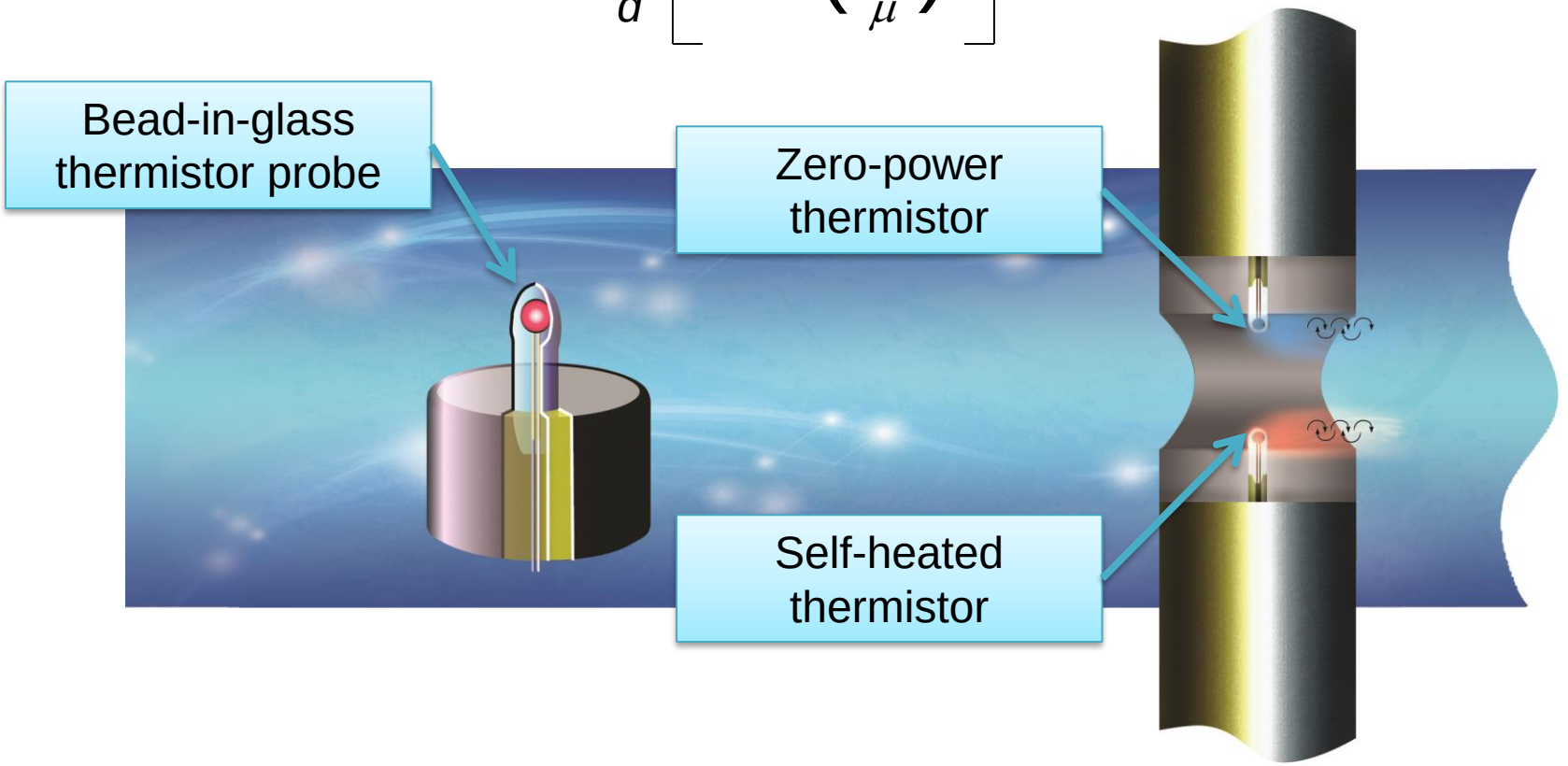
Thermal Dispersion Technology

Power

Velocity

ΔT

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



Water Flow Control Design Guidelines

Design and Installation Requirements Setup / System Verification

- Applications:
  - Water Systems
  - Steam Systems
  - Natural Gas Systems

Flow Meter Selection
Turndown Ratio

- Describes the accuracy range of the flow meter as a ratio of maximum flow/minimum flow
- Typical turndown ratios:
  - Magnetic Flow Meter: 300:1 (min)
  - Turbine flow meter: 10:1
  - Ultrasonic flow meter: 40:1
  - Recordall Disc Meter 25:1

Water Flow Application Quick Select Guide

	Water Flow					Energy			
Meter Series	Turbine Meter		Disc Meter	Electromagnetic Meter	Ultrasonic Meter	Turbine Meter		Electromagnetic Meter	Ultrasonic Meter
Meter Model	SDI	250	M25-M170	M2000	TFX-500W TFXB Ultra	SDI with RTD's and FC-5000 Monitor	380 with FC-5000 Monitor	M2000 with RTD's and FC-5000 Monitor	TFX-5000
Installation Type	Insertion	Inline	Inline	Inline	Clamp-On	Insertion	Inline	Inline	Clamp-On
Size Range	1-1/2" - 36"	1/2" - 1-1/2"	5/8" - 2"	1/4" - 54"	1/2" - 24" 1/2" - 96"	1-1/2" - 36"	3/4" - 2"	1/4" - 54"	1/2" - 96"
Accuracy (% of reading)	1%	1%	1.50%	0.25%	1%	1%	2%	0.25%	1%
Bi-Directional Flow Capability	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes
Requires System Shutdown to Install	No	Yes	Yes	Yes	No	No	Yes	Yes	No
Overall Flow Range	0.5-20 FPS	0.3-15 FPS	0.25-170 GPM	0.1-39.4 FPS	1-40 FPS	0.5-20 FPS	1.0-15 FPS	0.1-39.4 FPS	0.1-40 FPS

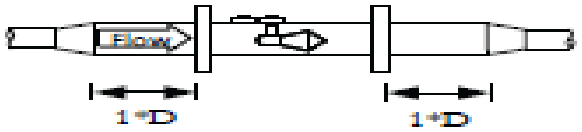
Flow Application

Chilled Water	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hot Water	✓	✓		✓	✓	✓	✓	✓	✓
Hot Water > 280°F				✓	✓				
Condenser Water Closed Loop	✓	✓		✓	✓	✓	✓	✓	✓
Condenser Water Open Loop				✓	✓				
Domestic (Potable) Water	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grey Water / Surface Water				✓					
Make-Up Water	✓	✓	✓	✓	✓				
Steam Condensate (Pumped)	✓			✓	✓	✓	✓	✓	✓

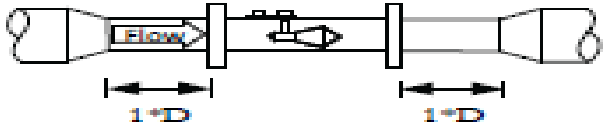
Application Quick Select Guide

Steam				Natural Gas and Compressed Air				
Meter Series	Vortex Meter		Δ P Meter	Meter Series	Thermal Mass Meter			
Badger Meter Model	VN2000 Hot Tap	VN2000 Compact	Preso Gemini	Sage Meter Model	5100 Series SIP	5100 Series SRP Remote Display	5200 Series SIP	5200 Series SRP Remote Transmitter
Installation Type	Insertion	Insertion	Inline	Installation Type	Insertion	Inline	Insertion	Inline
Size Range	2" - 36"	2" - 24"	1/2" - 24"	Size Range	1 1/2"- 8"	1" - 4"	1 1/2"- 8"	1" - 4"
Accuracy (% of reading)	1%	1%	0.5%	Accuracy (% of reading)	1%	1%	1%	1%
Pressure Range	Up to 1000 psi	Up to 1000 psi	Up to 6000 psi	Turndown	100 to 1	100 to 1	100 to 1	100 to 1
Std. Temperature Range °F	400 °F	400 °F	655 °F	Resolution	1000 to 1	1000 to 1	1000 to 1	1000 to 1
Requires System Shutdown to Install	No	Yes	Yes	Low End Sensitivity	5 sfpm	5 sfpm	5 sfpm	5 sfpm
				Flow Conditioner	Optional	Standard	Optional	Standard

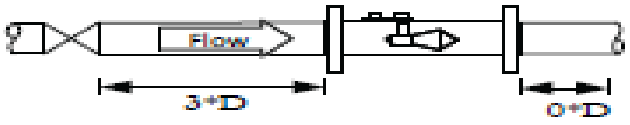
Steam – Gemini



Expansion

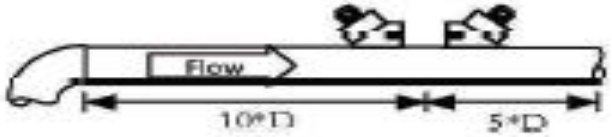


Reduction

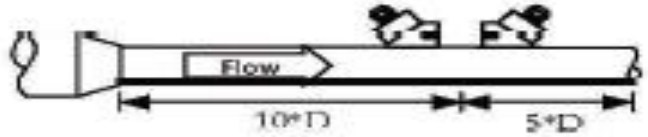


Gate/Globe Valve Fully Open

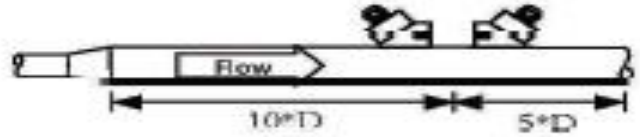
Ultrasonic – TFX, TFX-500w, DXN Portable



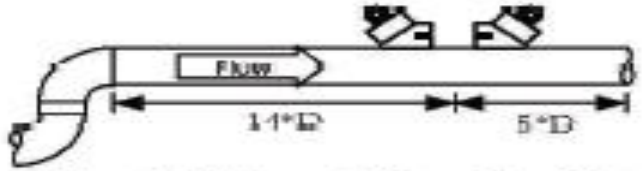
90° Elbow Before Flow Meter



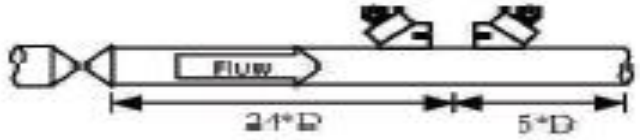
Reduction Before Flow Meter



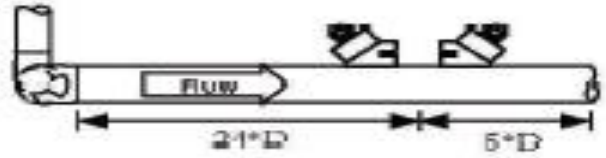
Expansion Before Flow Meter



Two 90° Elbows Before Flow Meter



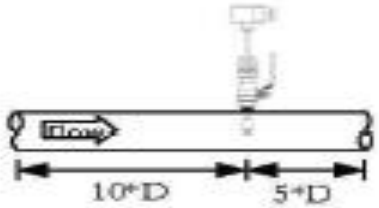
Regulator, Valve, or Header Before Flow Meter



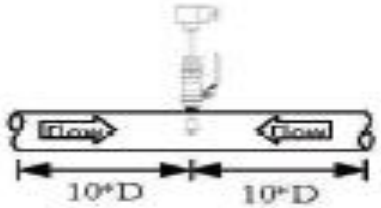
Two 90° Elbows Out of Plane Before Flow Meter

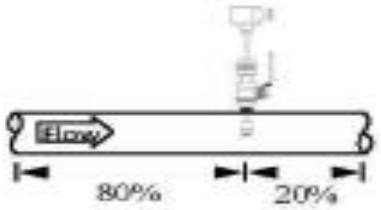
SDI Insertion

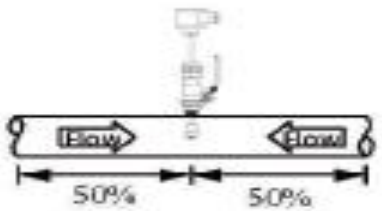
Uni-Directional



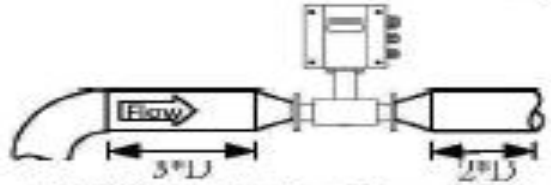
Bi-Directional



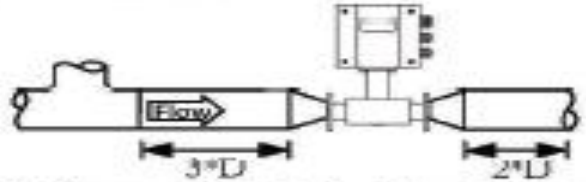




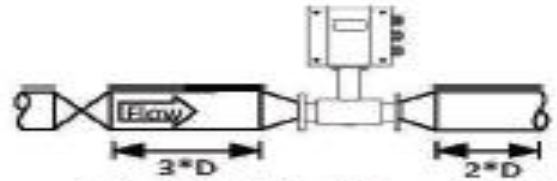
Electromagnetic Meters – M2000



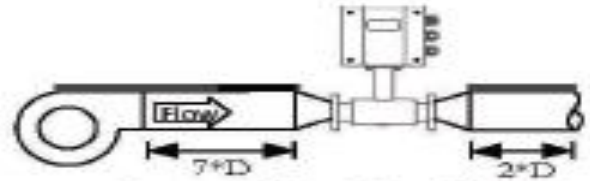
90° Elbow Before Flow Meter



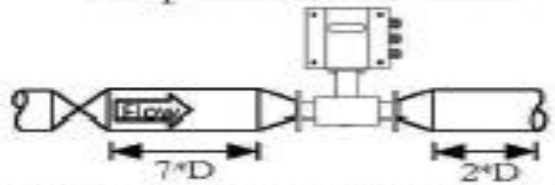
T Connection Before Flow Meter



Check/Globe/Butterfly Valve Before Flow Meter

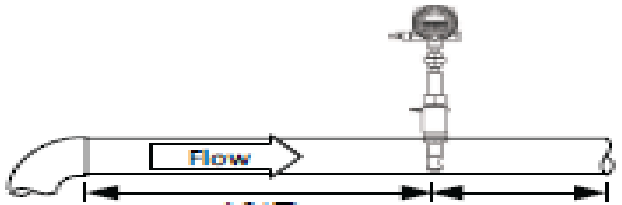


Pump Before Flow Meter

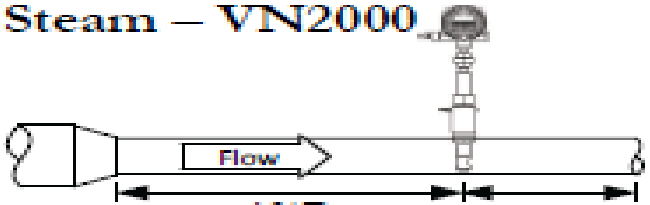


(Fully Open) Gate Valve Before Flow Meter

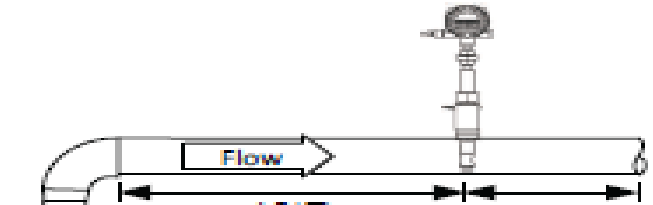
Steam – VN2000



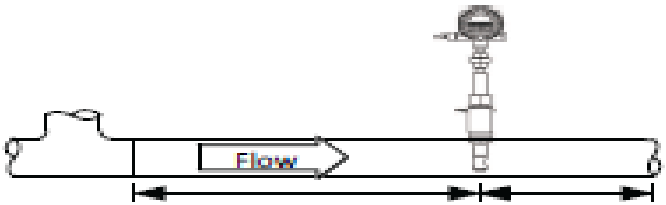
90° Elbow



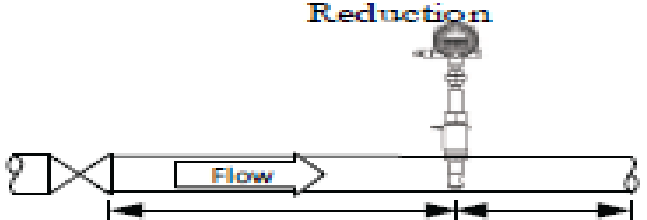
Reduction



Two 90° Elbows



T Connection



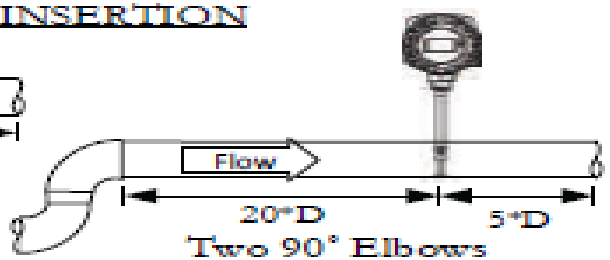
Regulator, Valve, or Header

Two 90° Elbows Out of Plane

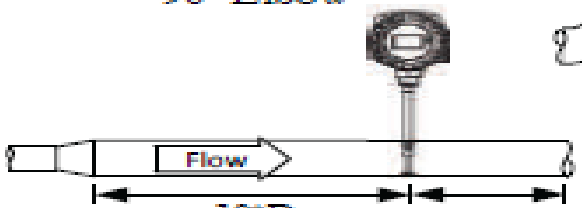
Natural Gas & Compressed Air – 5100 & 5200

INSERTION

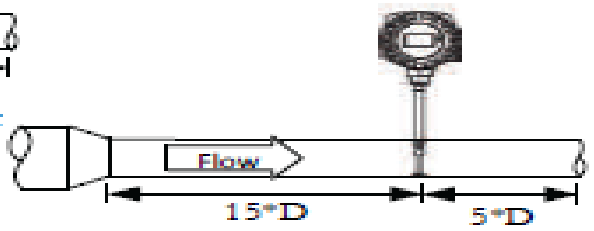
90° Elbow



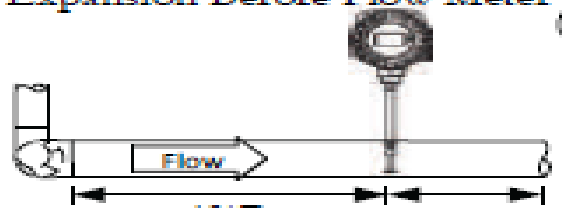
Two 90° Elbows



Expansion Before Flow Meter



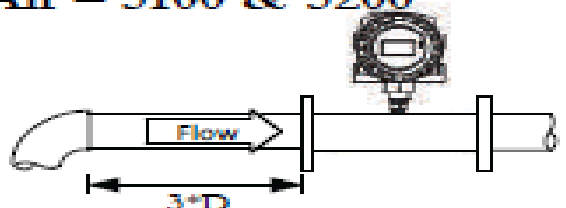
Reduction Before Flow Meter



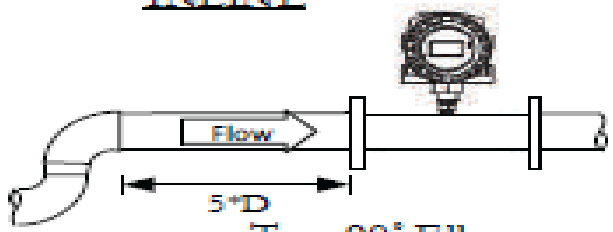
Two 90° Elbows Out of Plane

*Note: Insertion Meters With Flow Conditioning Have Same Minimum Requirements As Inline Meters

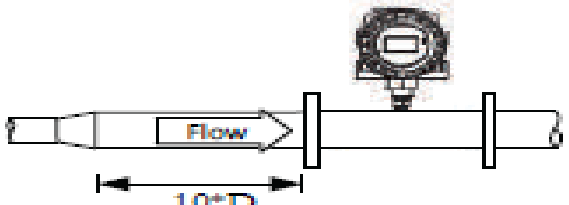
INLINE



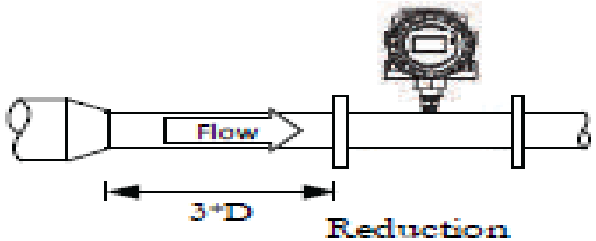
90° Elbow



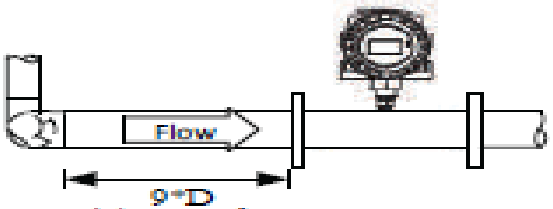
Two 90° Elbows



Expansion



Reduction



Two 90° Elbows Out of Plane

Selecting & Specifying Outdoor Water & Natural Gas flow Monitors

What's important?

1. Suitability for Application
   a) Desired Water / Steam / Natural Gas Flow
   b) Minimum Placement Guidelines
2. Total Installed Accuracy
3. Repeatability (i.e. Long-Term Stability)
   a) Long-Term Drift
   b) Recommended Calibration Interval
4. Application Support
5. Cost
6. Reliability
7. Ease of Installation
8. Service and Support

Agenda

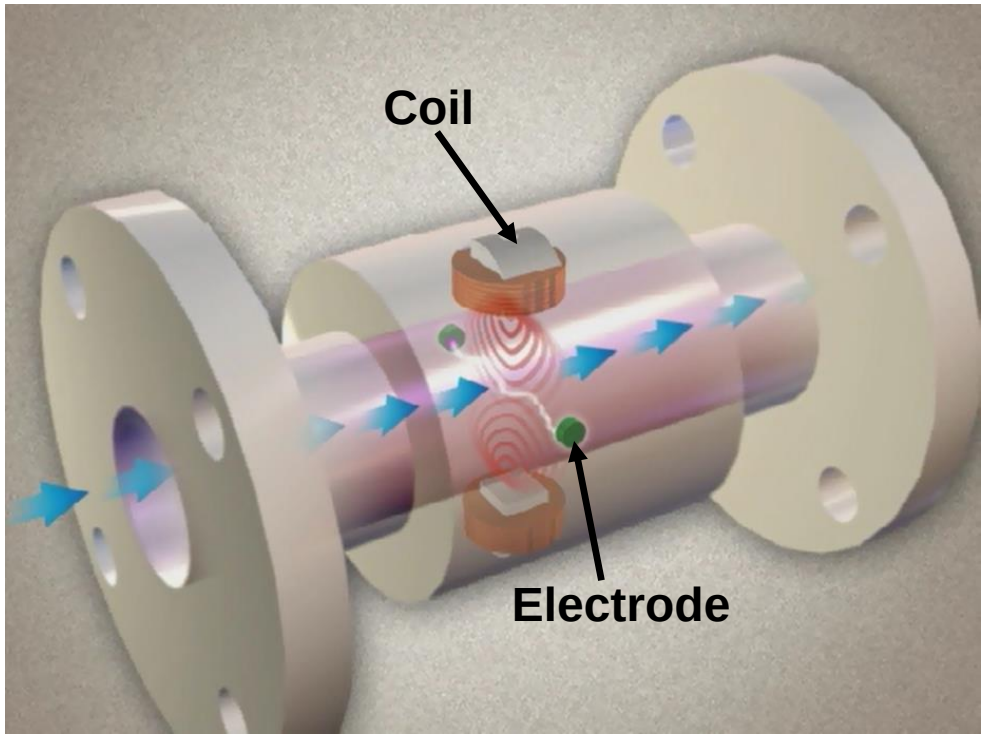
- Industry Updates and Recommendations
  - ASHRAE
  - LEED v4.1

Electromagnetic (Mag) Meter

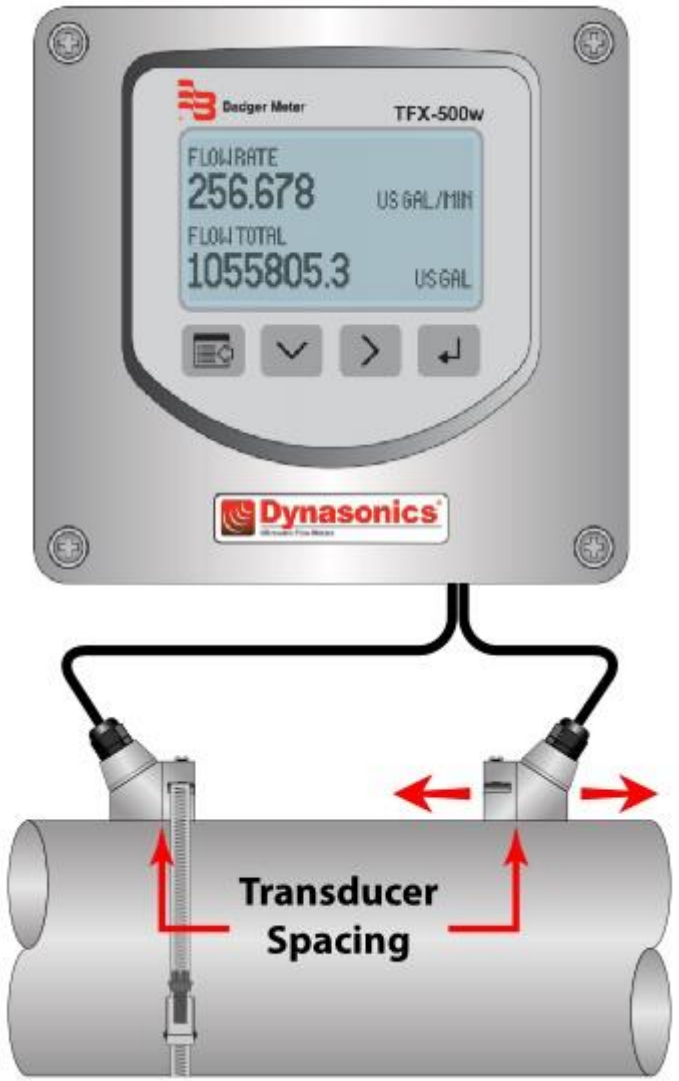
- Basic principles
  - Uses an electromagnetic field to measure flow
- Key advantages
  - No pressure drop
  - No moving parts
  - Accurate with reduced pipe runs
- Applications
  - Water and other conductive fluids
  - Relatively low maintenance costs

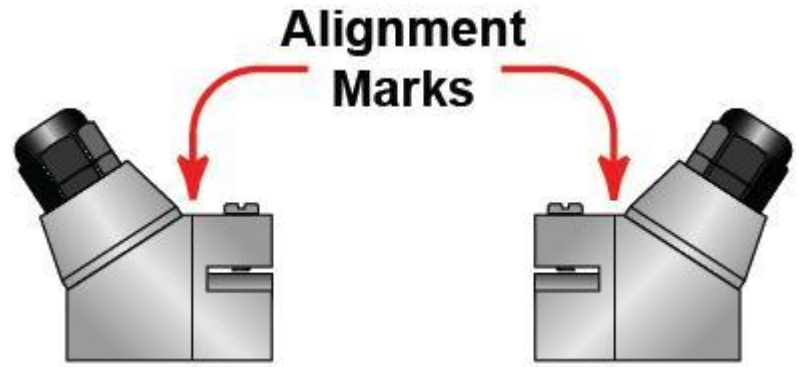
Electromagnetic

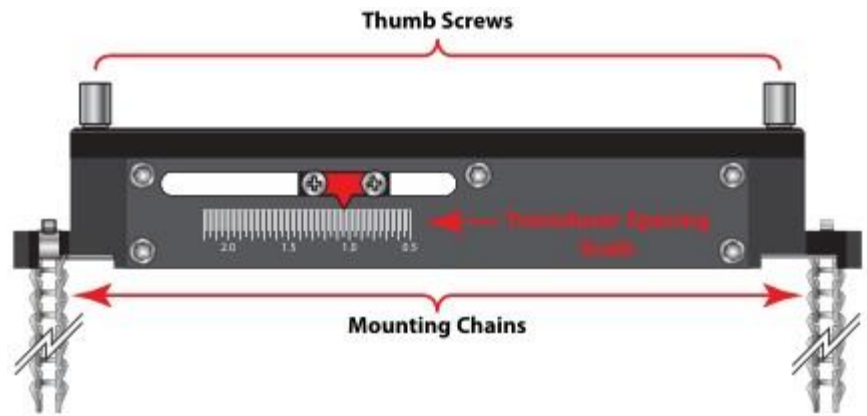
- Measurement principle



Ultrasonic Meter Installation: Transit-Time





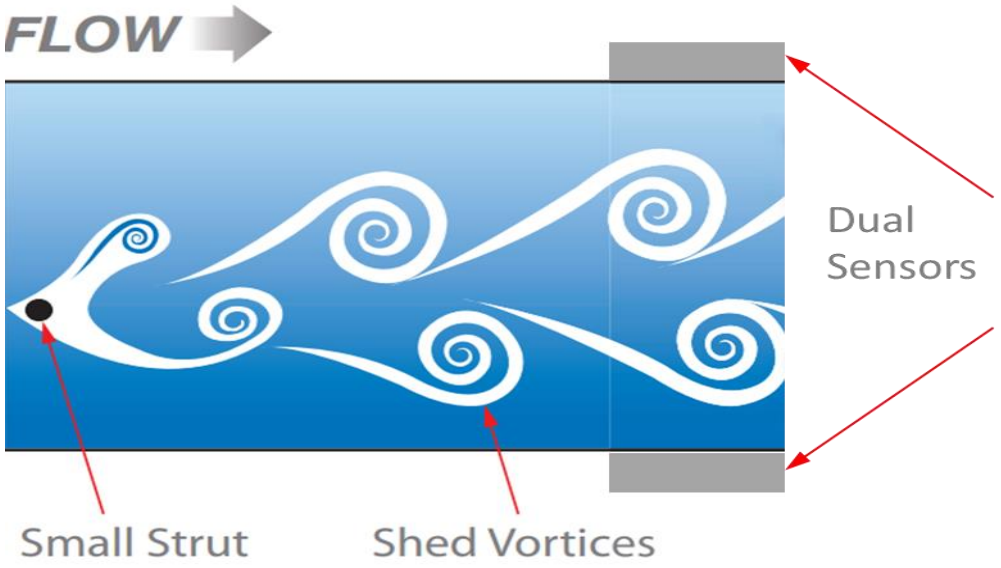


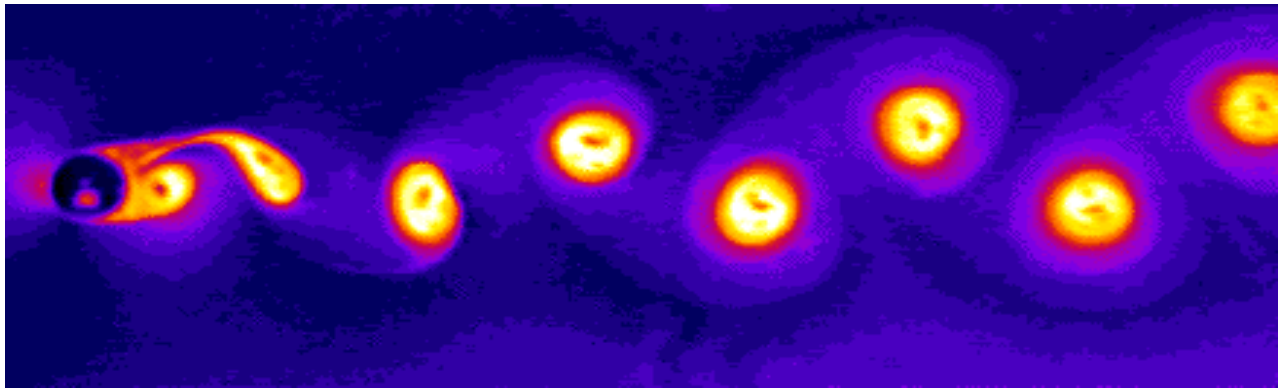
Vortex Flow Measurement

Technical Advantages

- No moving parts to maintain
- Solid one-piece element design
- Dual Sensors have NO leak paths
- Welded construction
- Self cleaning element
- One piece element design
- Horizontal shedder bar

Vortex Flow Measurement





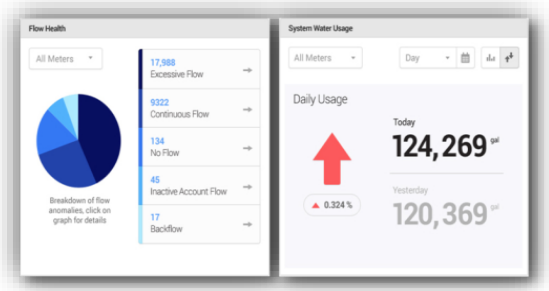
Disc & Sub-metering Series Meters

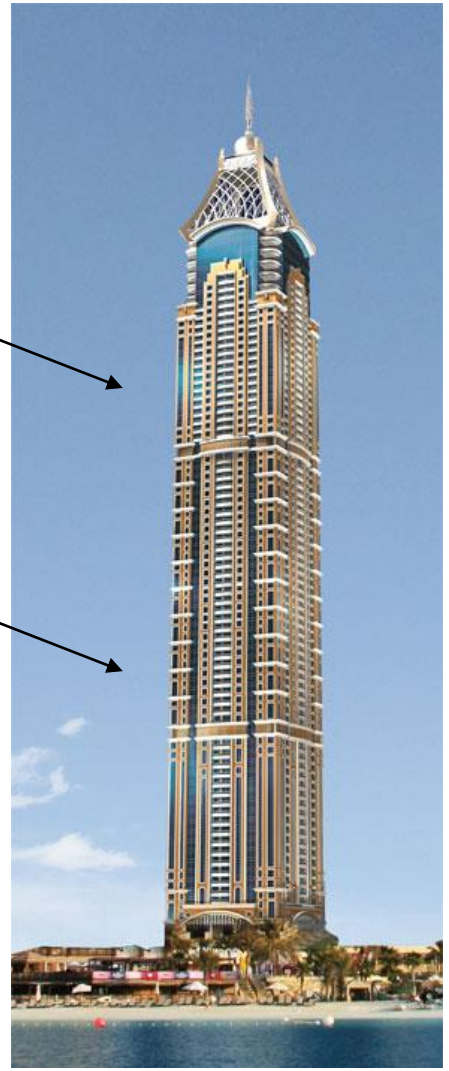
Potable Water Meters

- AWWA Certified
- Lead Free
- Perfect for Tenant Billing
- Trusted by Utilities
- Encoded outputs
- Can connect to AMR systems
- Very low flow measurement

+

Flow Measurement Manager





Natural Gas / Compressed Air

Questions

- Do you need to provide an airflow station on outside air for VAV Applications?
- Does an airflow station provide a point certification or is it a prerequisite in LEED 4.1
- What type of airflow technology has the best overall accuracy for outside air application?
- What water flow technology has the best overall accuracy?
- Does a water flow BTU Meter provide a point certification or is it a prerequisite in LEED 4.1?
- What type of water flow technology has the best overall accuracy for outside air application?

Questions?

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Course ID: 0090007822

Thank You!