ASHRAE Region VI CRC
Track III: Session 2
Outdoor Air Control and Demand Controlled Ventilation

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Learning Objectives

- Grasp the fundamentals of indoor carbon dioxide generation and measurement
- Recognize different ways to save energy through demand controlled ventilation
- Understand the principles of outdoor air measurement and control

Agenda

- **CO_2 Demand controlled ventilation**
  - CO_2 Fundamentals
  - Single zone systems
  - Multiple zone systems
- **Outdoor airflow measurement**
  - Technology
  - VAV Systems

CO_2 Demand Control Ventilation

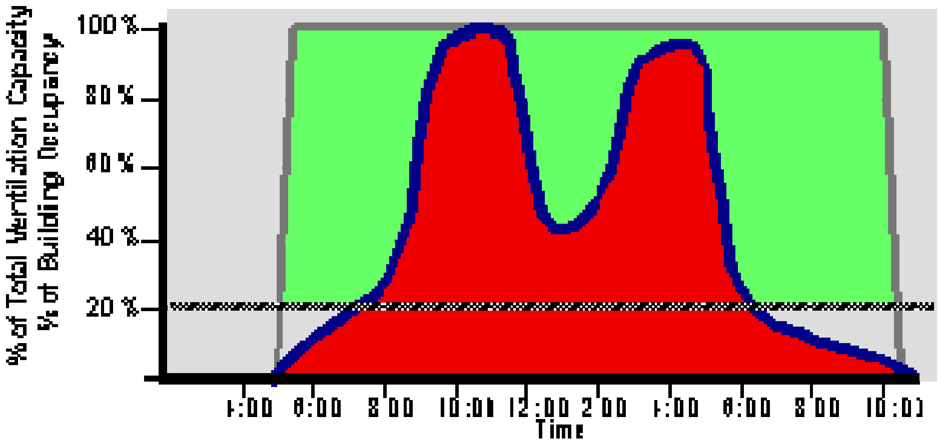
- **CO_2 DCV: CO_2 sensors can be used to reduce the building component of outside air rates during partial occupancy**
  - CO_2 is an indicator of bioeffluent concentration
- **Purpose is to save energy, NOT to improve indoor air quality**
  - IAQ is actually worse since airflow rates are always less than design except at peak occupancy

Standard 90.1-2007 Requirements

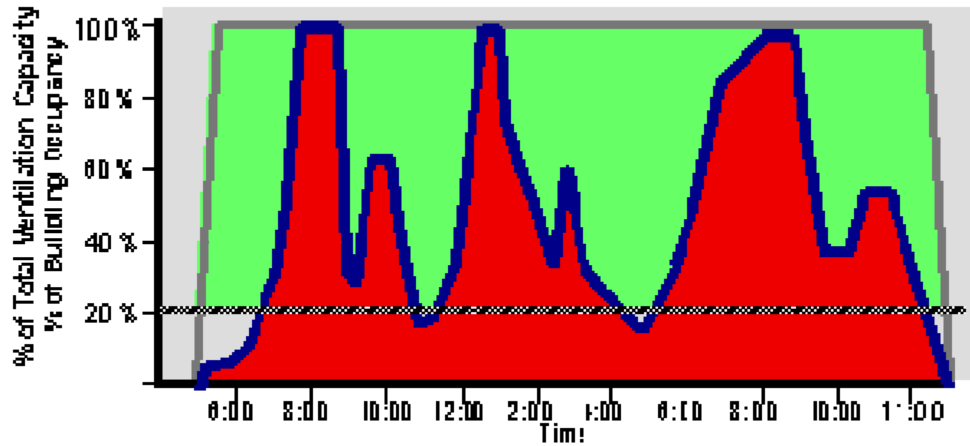
- **6.4.3.8. Demand Control Ventilation (DCV) is required for spaces larger than 500 ft^2 and with a design occupancy for ventilation of greater than 40 people per 1000 ft^2 of floor area and served by systems with one or more of the following:**
  - an air-side economizer
  - automatic modulating control of the outdoor air damper, or
  - a design outdoor airflow greater than 3000 CFM
- **Exceptions to 6.4.3.8:**
  - Systems with energy recovery complying with 6.5.6.1.
  - Multiple-zone systems without direct-digital control of individual zones communicating with a central control panel.
  - System with a design outdoor airflow less than 1,200 CFM
  - Spaces where the supply air flow rate minus any make up or outgoing transfer air requirement is less than 1,200 CFM

Energy Savings

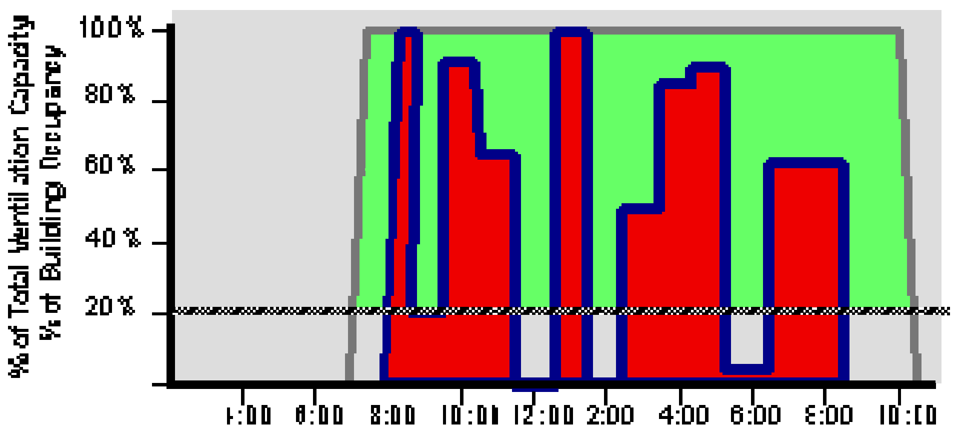
Office Building: 10% to 40% Reduction In Ventilation

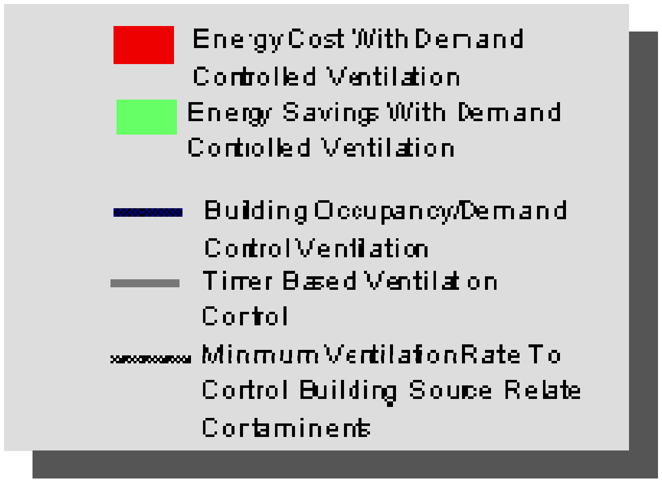


Restaurant/Bar: 30% to 60% Reduction In Ventilation



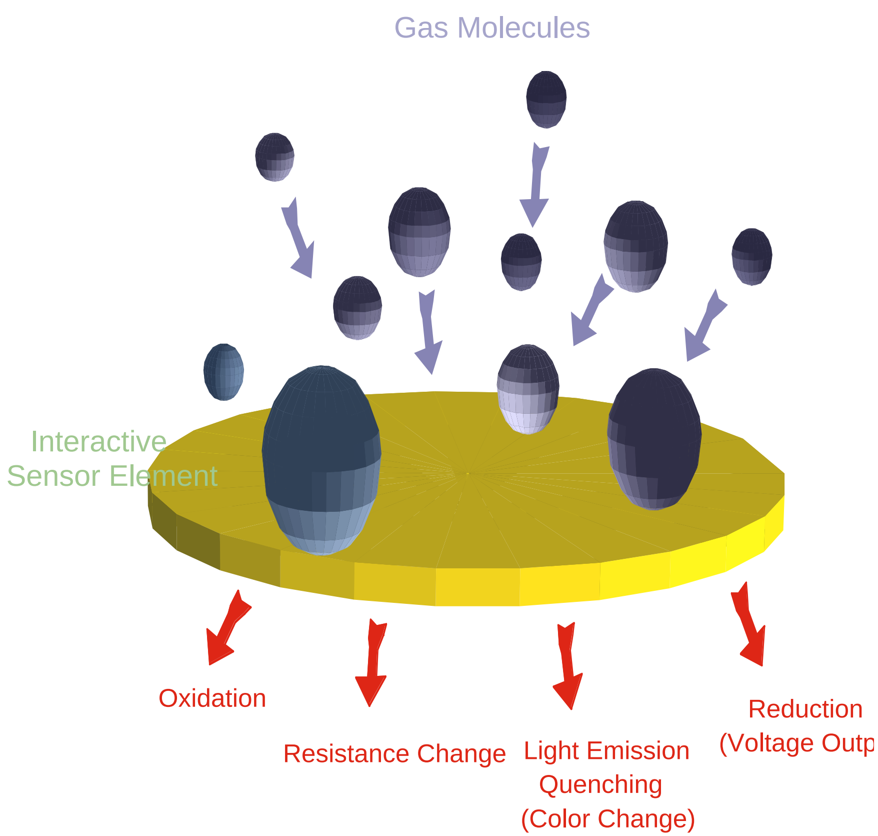
School/Meeting Room: 10% to 70% Reduction In Ventilation



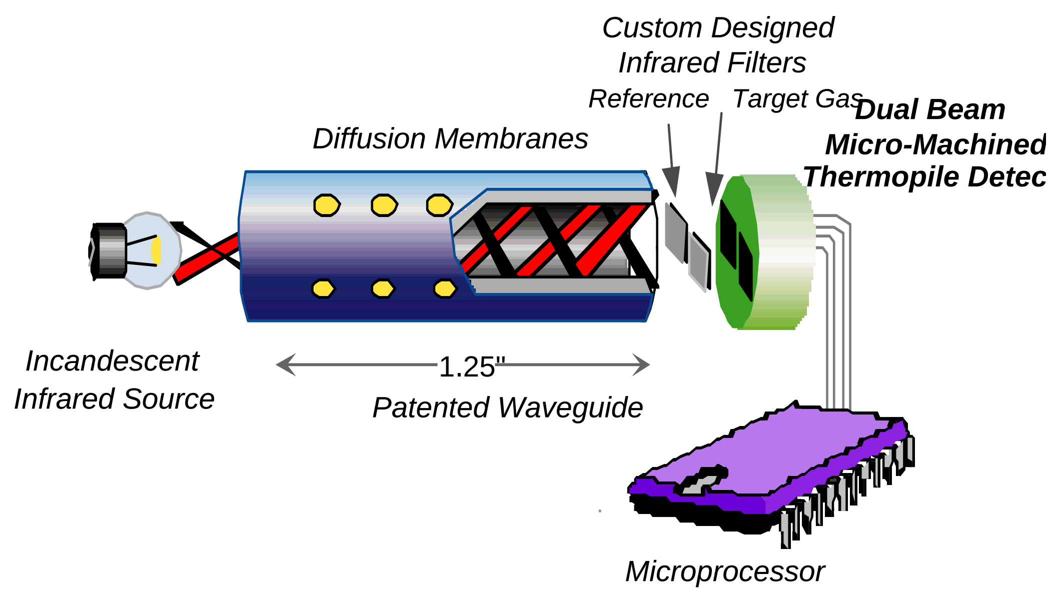


Types of CO_2 Sensors

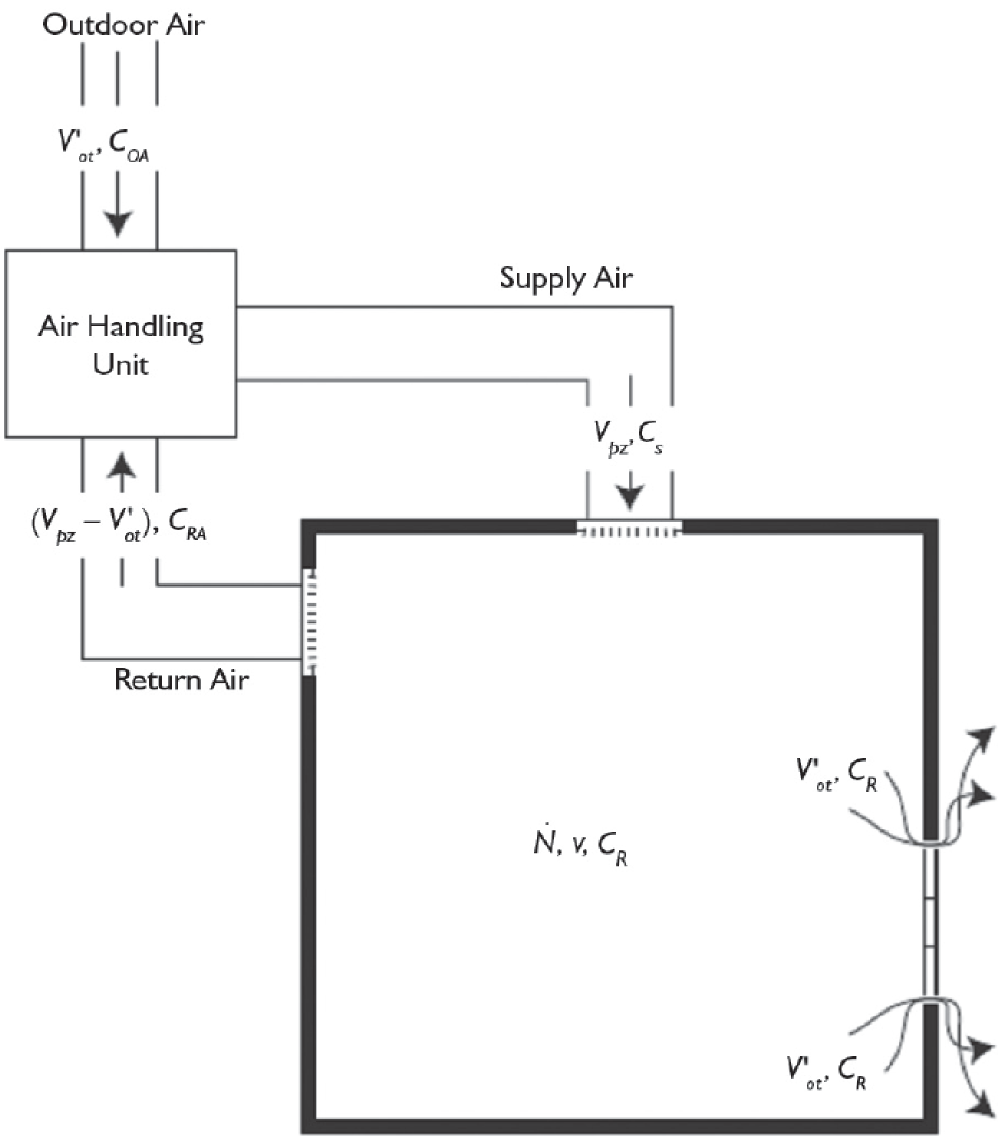
Solid State



Infrared



CO_2 DCV using 62.1



Steady-state CO_2 Concentration

$$C_R = C_{OA} + \frac{8400 E_z m}{R_p + \frac{R_a A_z}{P_z}}$$

Occupancy Category	Activity Level	Steady State CO_2 Concentration
Classrooms (age 9 plus)	1.0 met	1025 ppm
Restaurant Dining Rooms	1.4 met	1570 ppm
Conference/Meeting	1.0 met	1755 ppm
Lobbies/Prefunction	1.5 met	1725 ppm
Office Space	1.2 met	990 ppm
Sales	1.5 met	1210 ppm

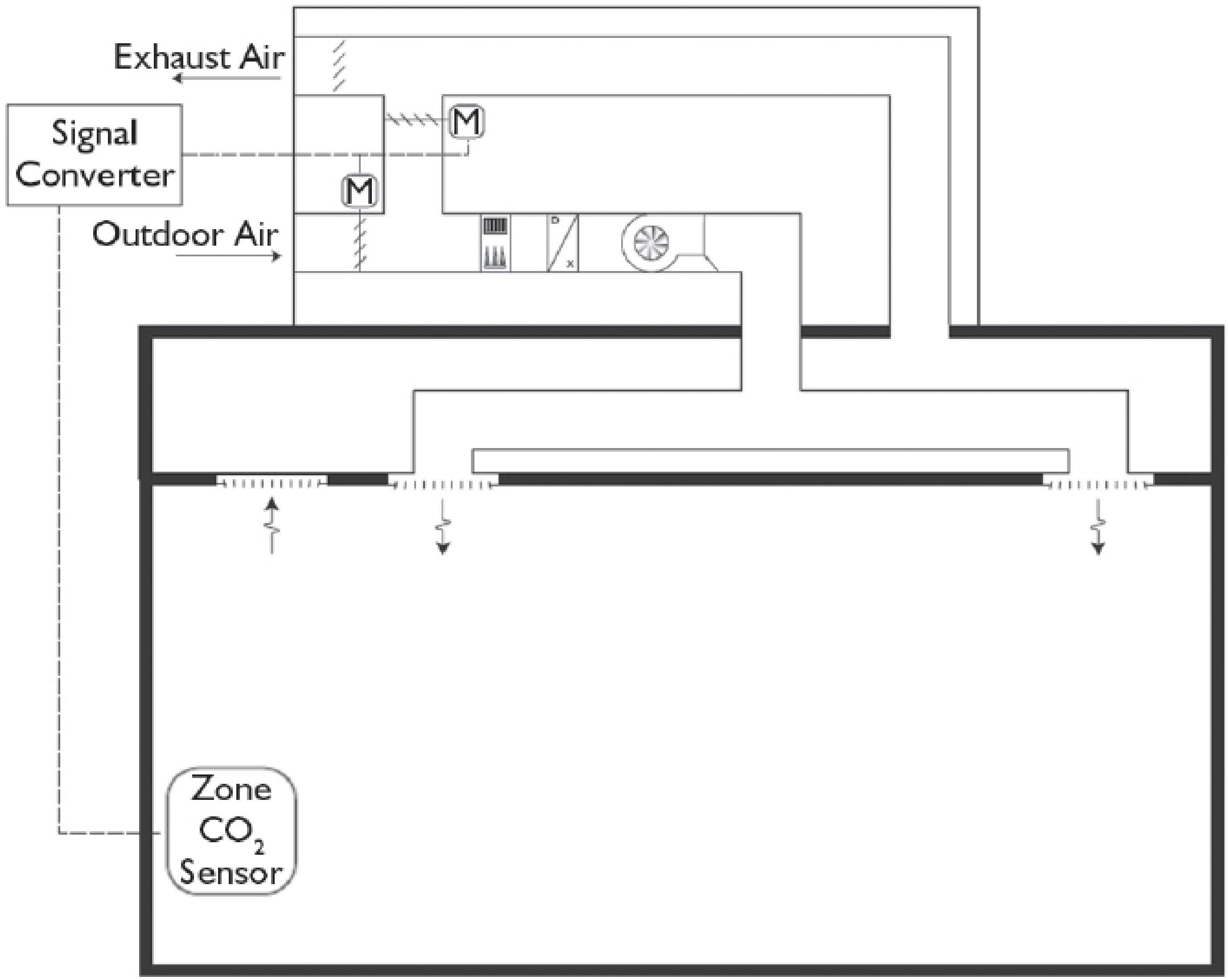
Use of Steady State Equation

- Since building is probably NOT at steady-state, CO_2 concentration cannot be used to determine number of occupants or their pollutant source strength or the actual cfm/person
- However, CO_2 concentration still tracks bioeffluent concentration and it is bioeffluent concentration you are trying to control
- Cfm/person rates were determined based on steady-state chamber studies
- Conclusion: Steady-state equation can be used to determine CO_2 setpoint and actual CO_2 concentration can be used to control actual ventilation rate

Single Zone CO_2 DCV Procedure

- **Calculate the Vot at design occupancy**
- **Using the same equations, calculate the outdoor air rate with no occupants (Vat)**
- **Determine the steady-state CO_2 concentration (CO2max)**
- **Provide a CO_2 sensor/controller adjusted to send**
  - Maximum output signal when room CO_2 is at CO2max
  - Minimum output signal when room CO_2 is ambient (400 ppm)
- **Adjust outdoor air damper so that**
  - At maximum output signal, outdoor air rate = Vot
  - At minimum output signal, outdoor air rate = Vat

Single Zone CO_2 DCV Schematic

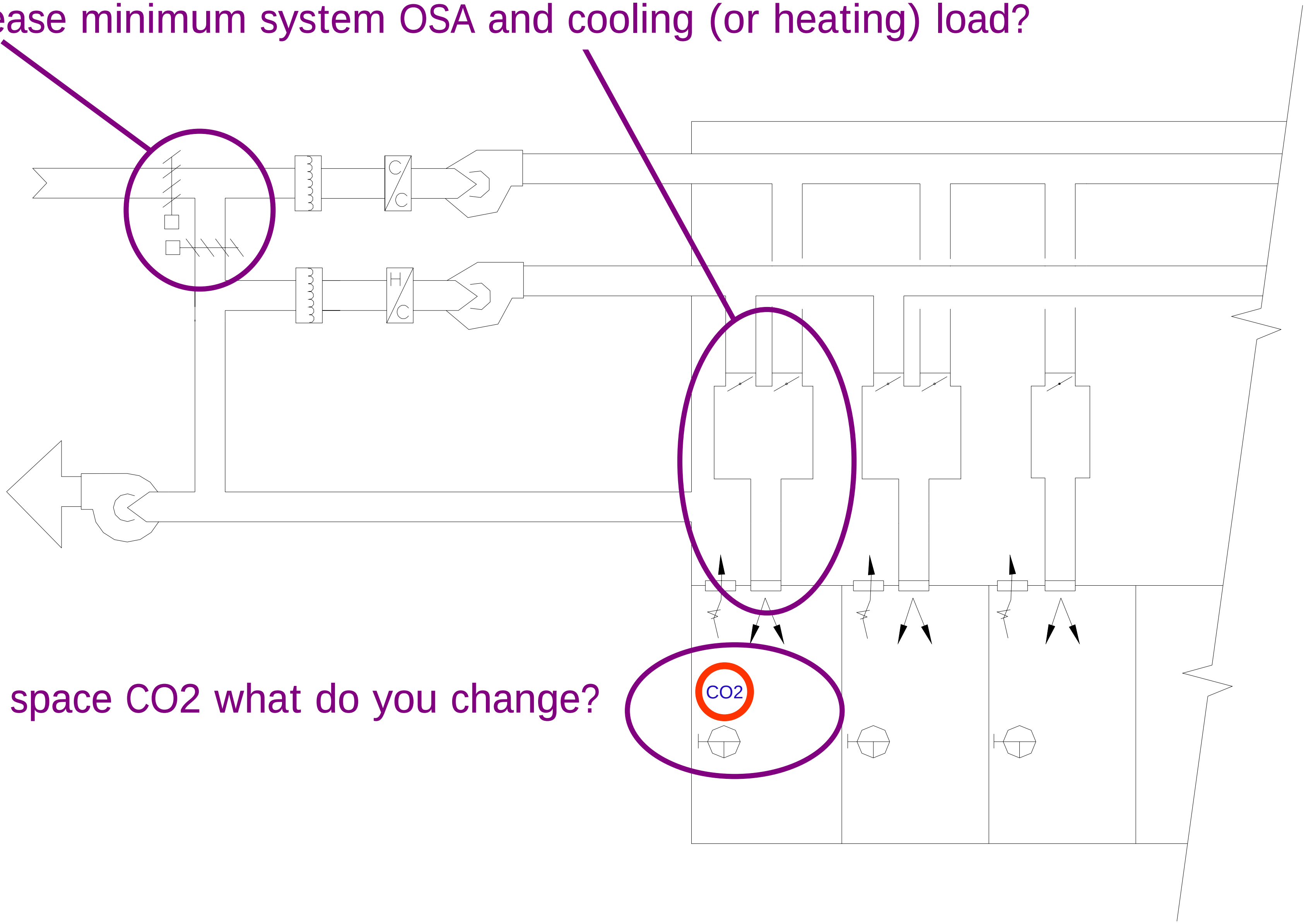


Application Issues

- **Sensor location**
  - In the space at “breathing level”
  - Not in return air duct since leakage and short-circuiting can skew signal
- **DCV in multiple zone systems**
  - Cannot use a single return air CO_2 sensor
  - All densely occupied spaces must get CO_2 sensors
  - Optimum control strategy for VAV systems may vary by system and climate

CO_2 DCV with VAV Systems

1) Increase Zone airflow and reheat?
2) Increase minimum system OSA and cooling (or heating) load?



On rise in space CO2 what do you change?

CO_2 DCV with VAV Systems

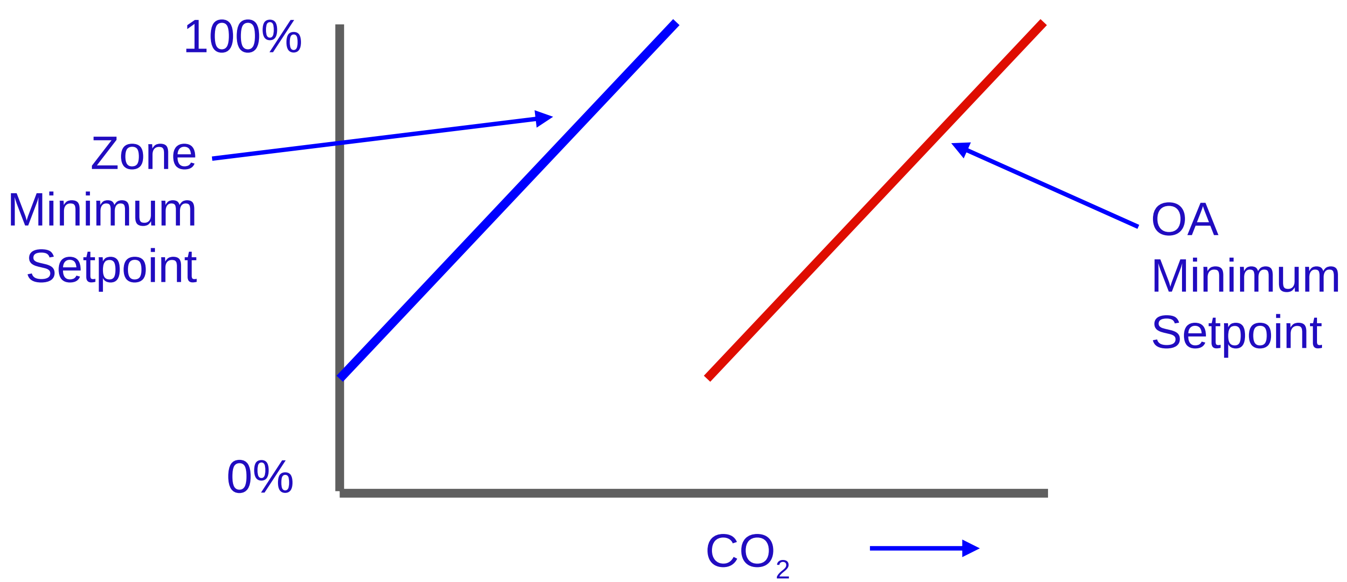
- **Increasing the VAV Box Minimum Airflow Setpoint**
  - Increases simultaneous heat/cool at zone and slightly increases fan energy
  - Works only if other spaces are over-ventilated (diluted recirculated air) but that is likely

CO_2 DCV with VAV Systems

- **Increasing the OSA Minimum Position**
  - If the OAT is below cooling set point this will increase the heating energy
  - If the OAT is above the cooling set point this will increase the cooling energy
  - Non-critical zones are over-ventilated

CO_2 DCV with VAV Systems

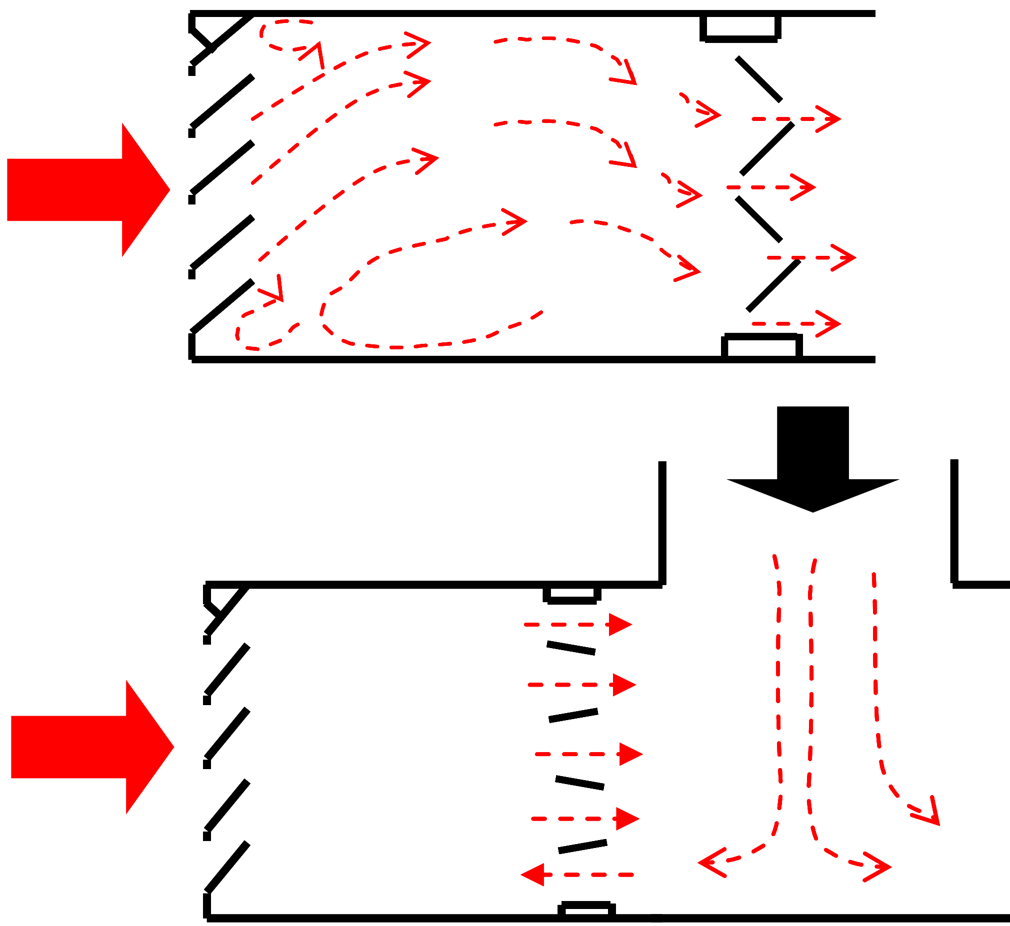
- **Probably Best Bet (See 62.1 User's Manual)**
  - Increase the zone damper up to 100% of zone maximum then stage the OA damper open from unoccupied minimum to design OA minimum
  - Appears to be ideal for systems with outdoor air economizers; study is not complete



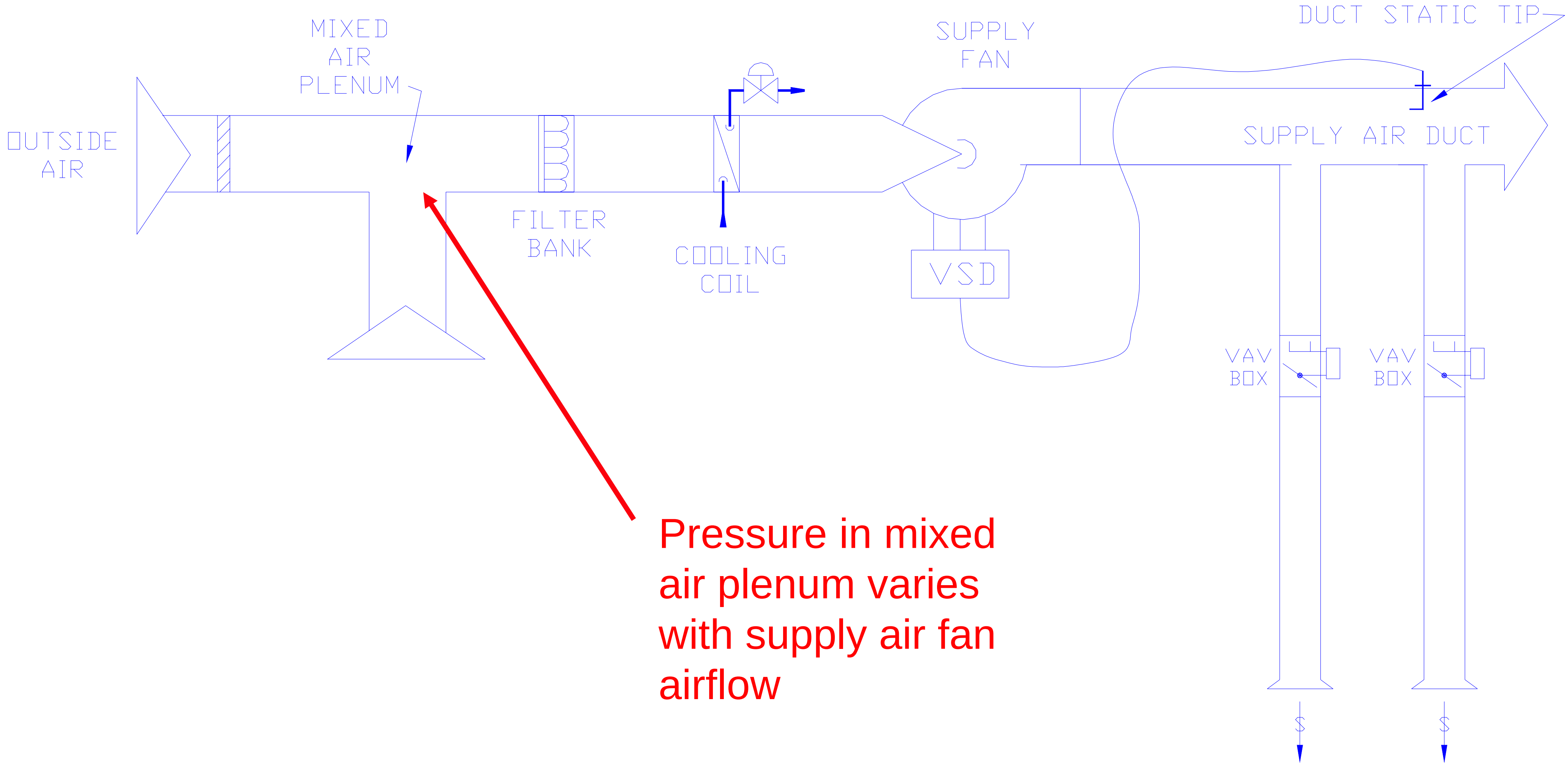
Outdoor Airflow Measurement & Control

Why are OA intake measurements challenging?

- Low air speeds, near detection limits of many sensors
  - Especially at minimum rates of OA supply
- Spatially variable (non-uniform) direction of air flow
- Limited space
- Air flow rates & temperatures vary over time
- Sensors may be exposed to moisture and dust
- Effects of winds



Outdoor Air Intake on VAV Systems



Pressure in mixed air plenum varies with supply air fan airflow

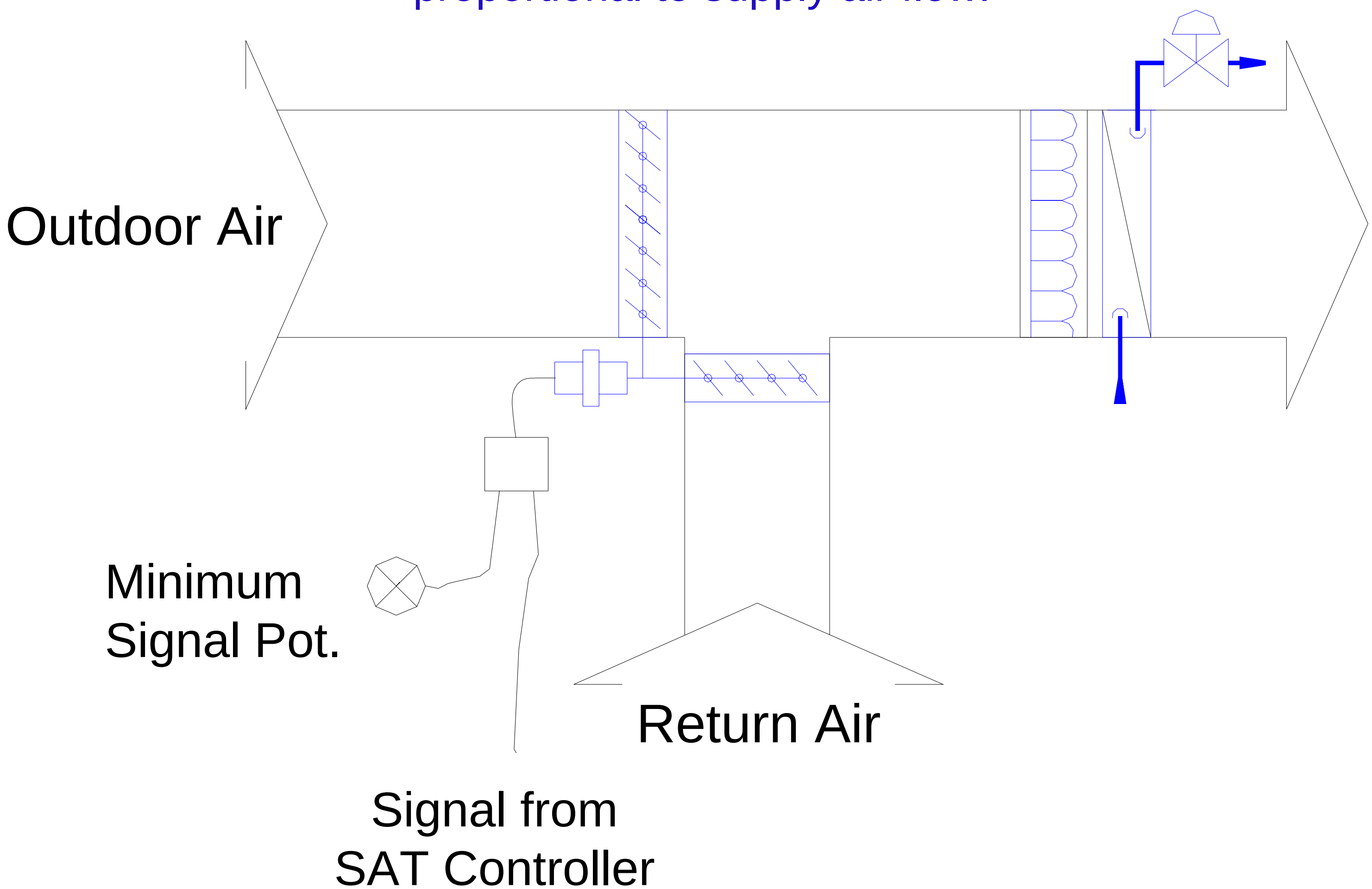
Lab and Field Tests

- **Fisk et al (LBNL 2004, 2005)**
  - Measured performance of 5 measurement technologies in lab and a few in the field
  - Unfortunately only tested a few products – many more available but untested
- **ASHRAE RP-980**
  - Theoretical review and lab tests of several common airflow measurement concepts
- **May be the only two unbiased tests (not performed by manufacturers)**

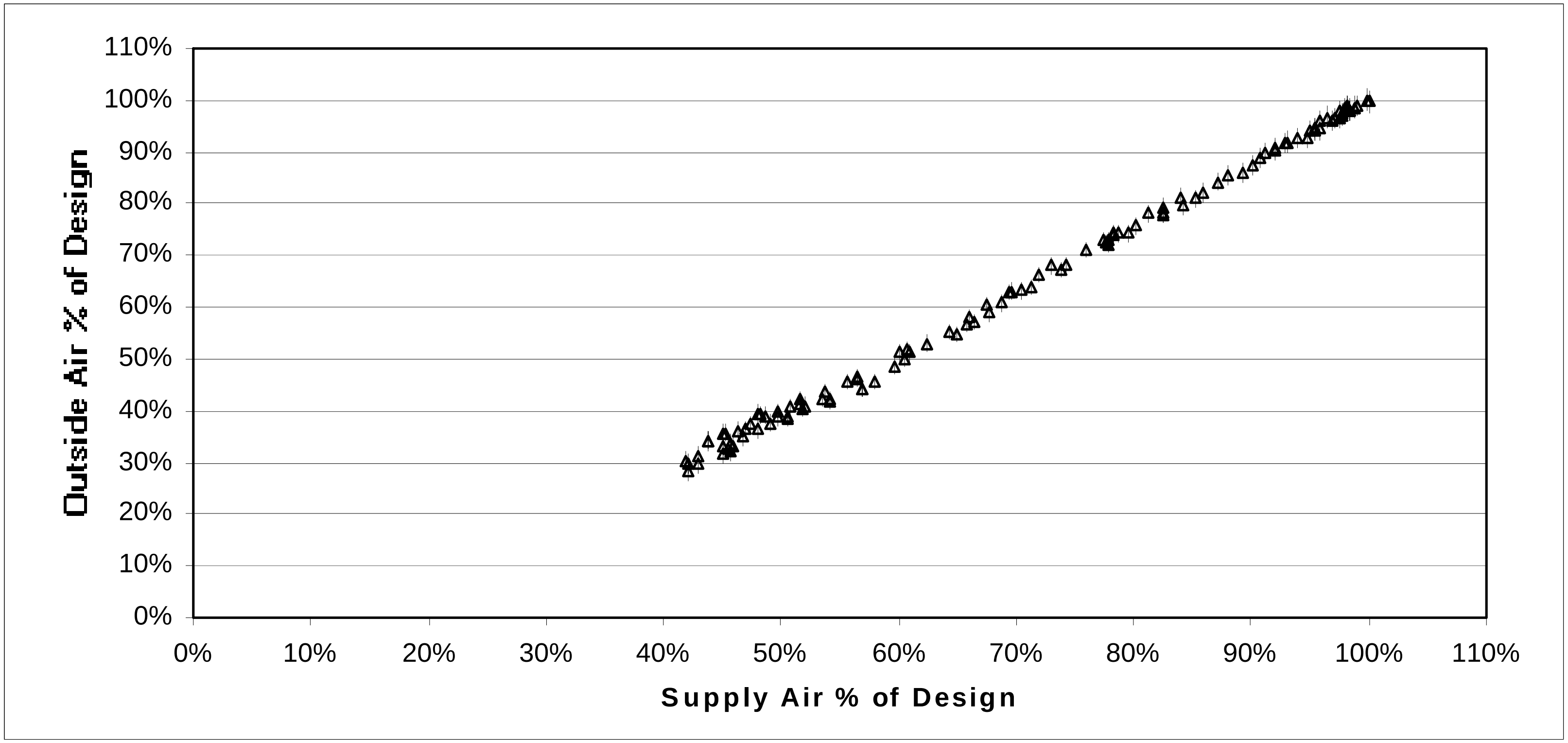
Fixed Minimum OA Damper Position

Most Common Approach

Does NOT WORK since mixed air plenum pressure varies!! Outdoor air flow will vary proportional to supply air flow.



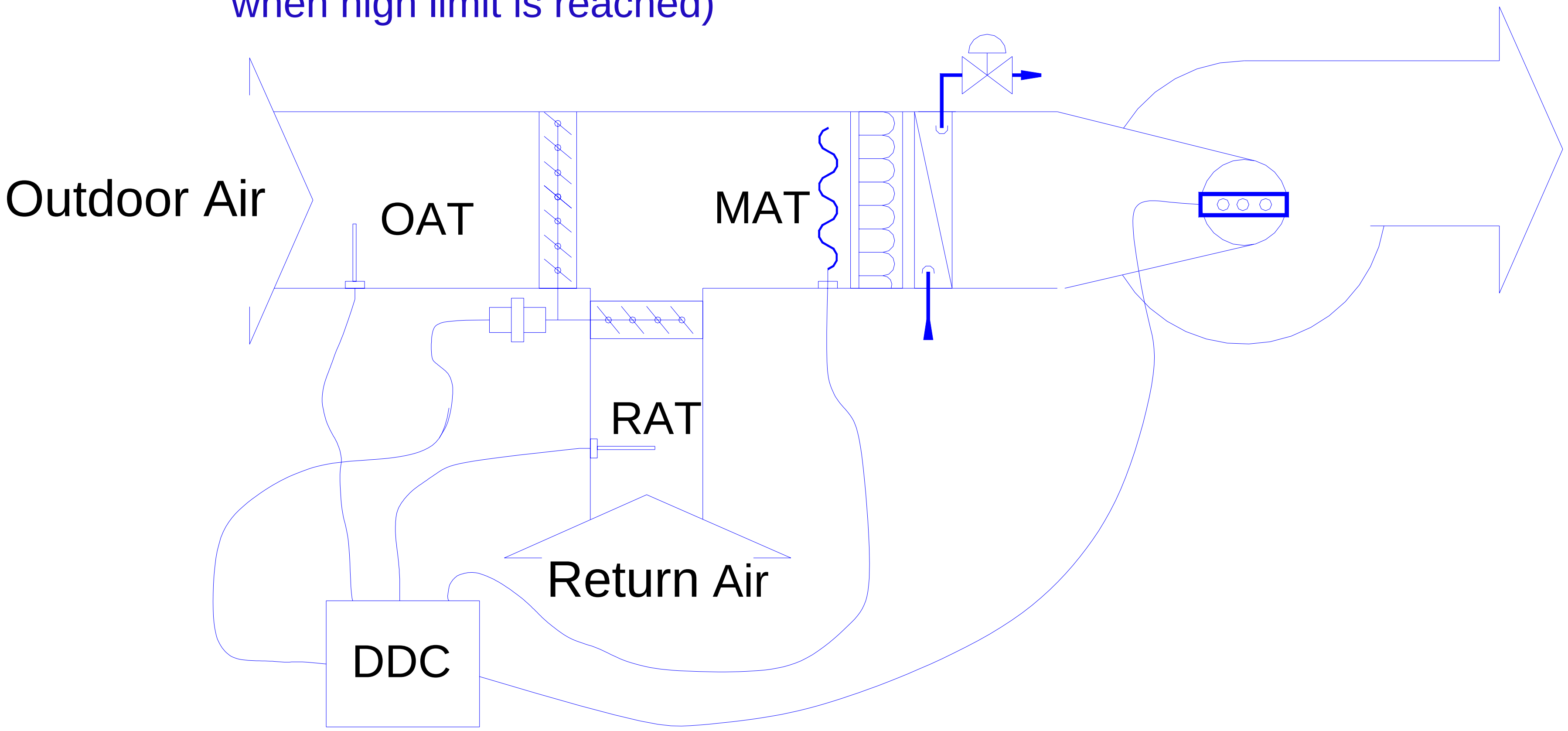
RP980 Lab Results
Fixed Minimum OA Damper



Mitigation: determine multiple minimum positions at varying flow (e.g. full flow, minimum flow) so minimum damper position varies with supply airflow/speed

Energy (or CO_2) Balance

Does NOT WORK when OAT ~ RAT (which it is when high limit is reached)

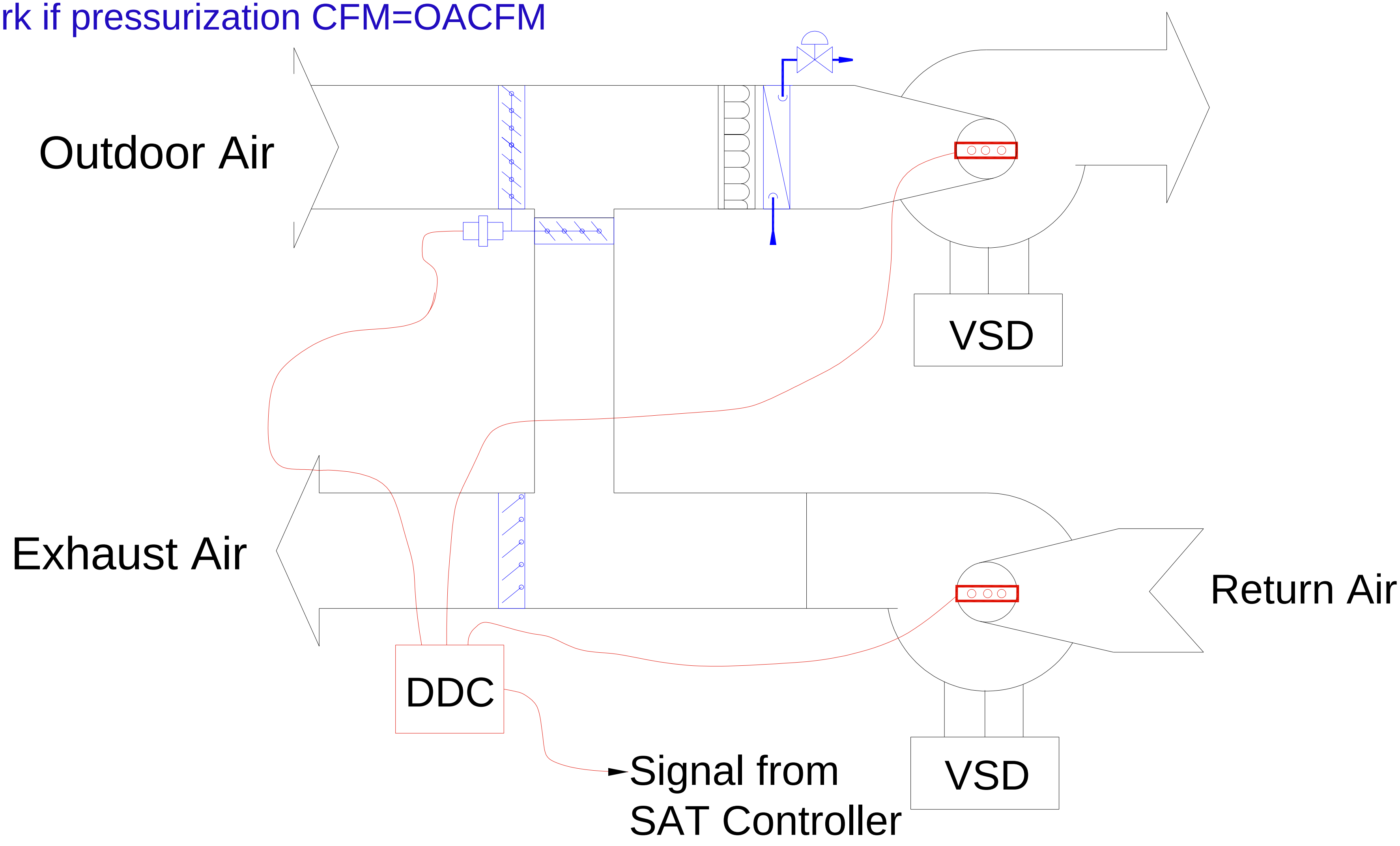


%OA = (MAT - RAT) / (OAT - RAT)

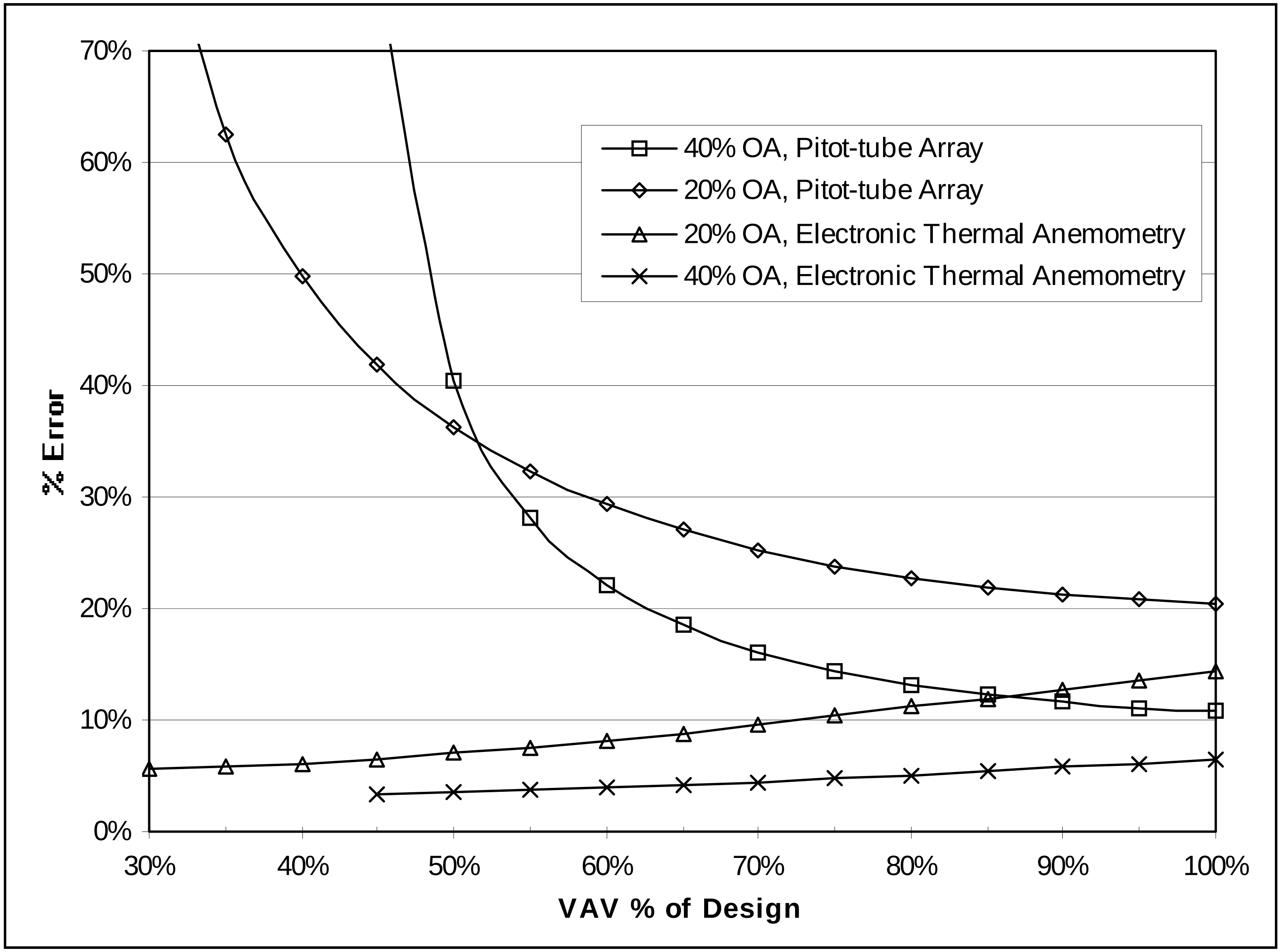
CFM-OA = %OA * CFM-SA

Return Fan Tracking

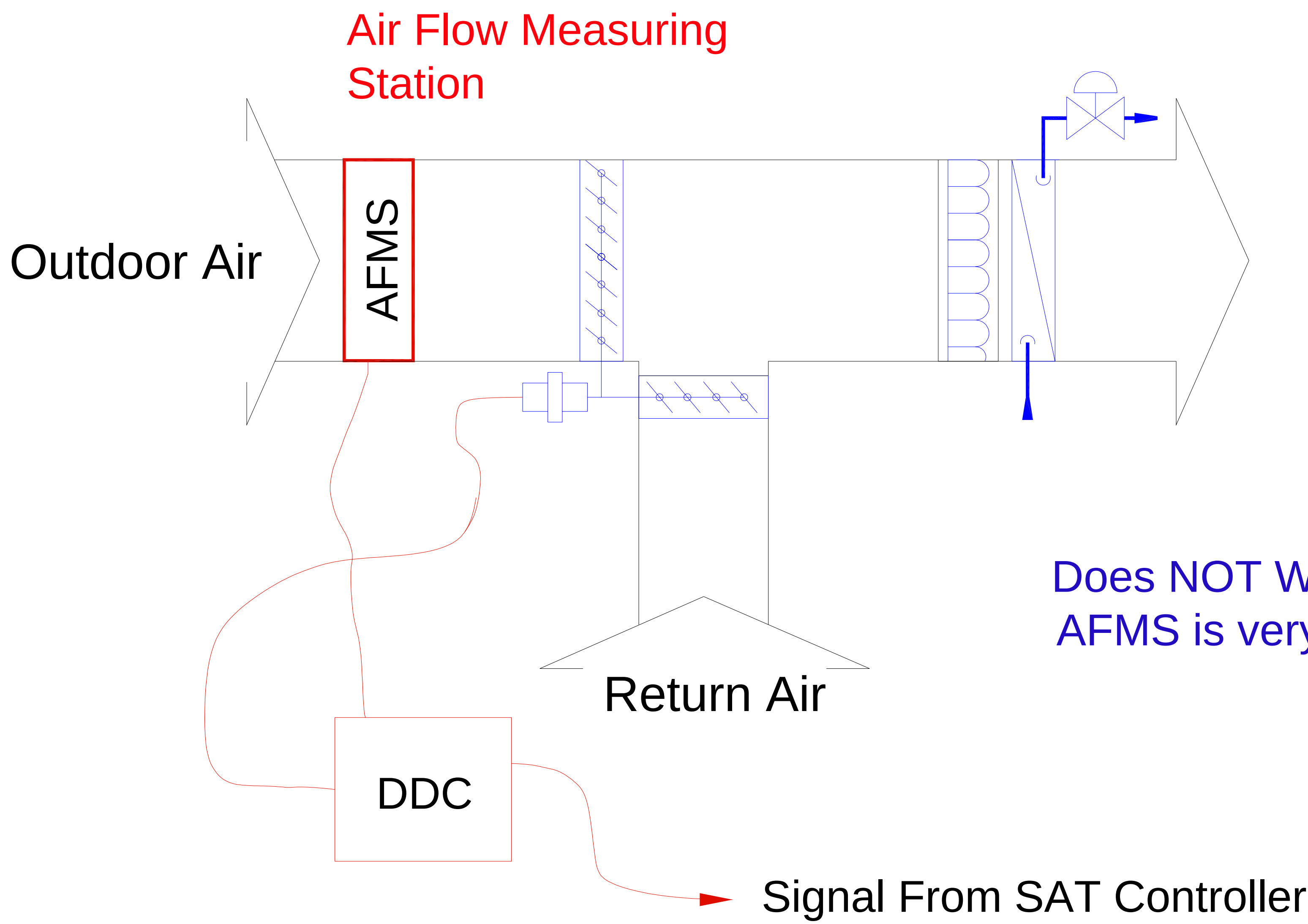
May NOT WORK due to cumulative error in flow sensors and possible flow reversal, and ONLY could work if pressurization CFM=OACFM



RP 980 Return Fan Tracking Predicted Error

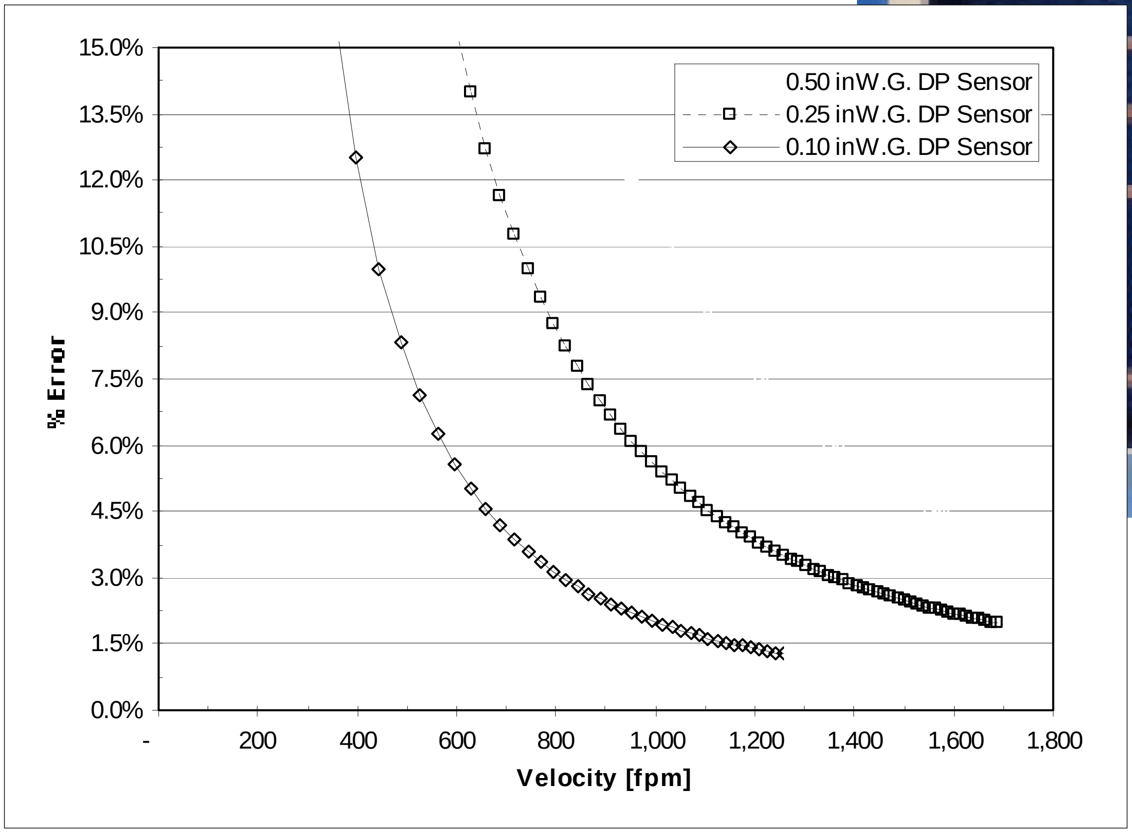


Air Flow Measurement of 100% OA

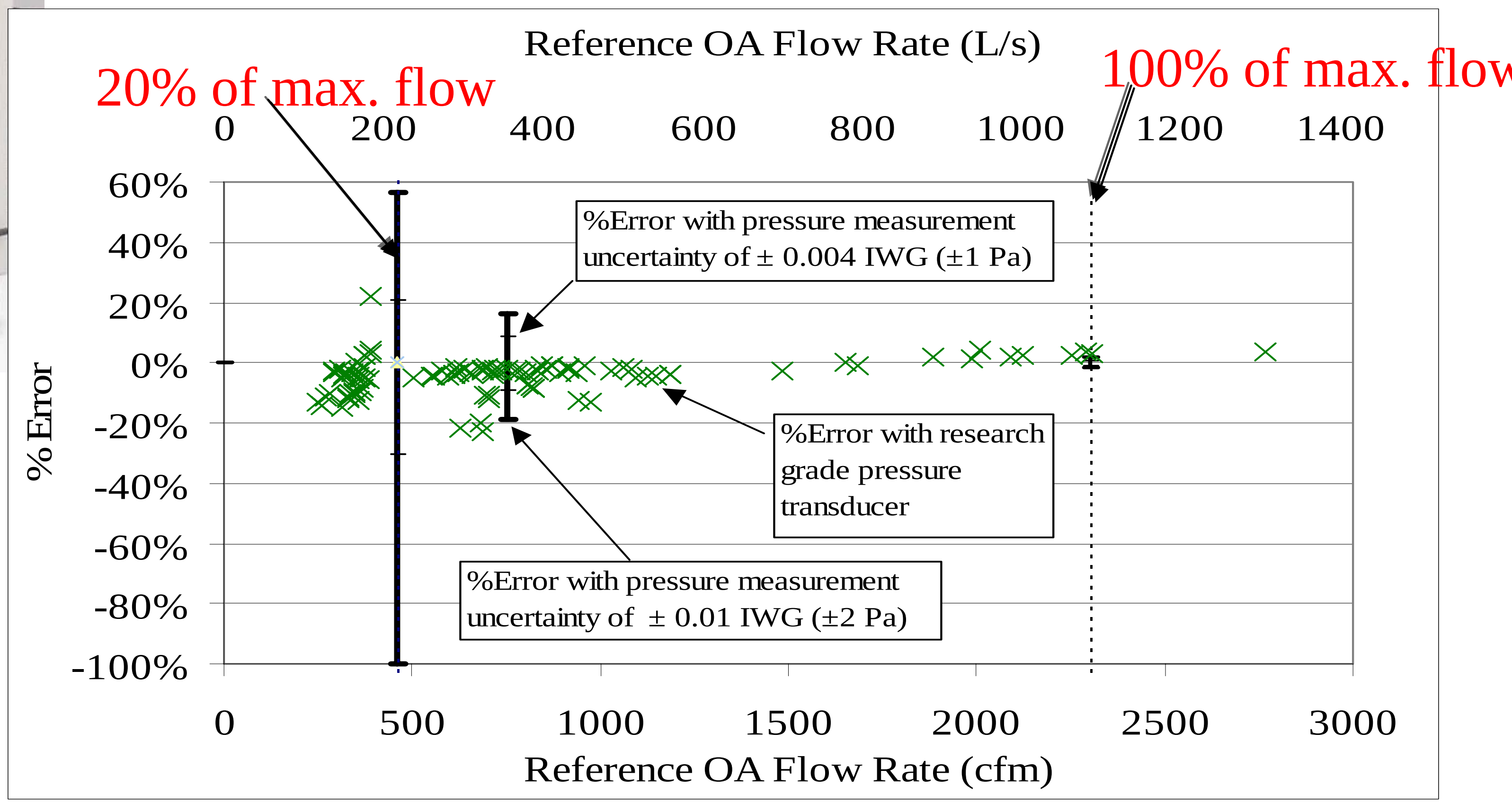


Does NOT WORK unless AFMS is very accurate at low flow

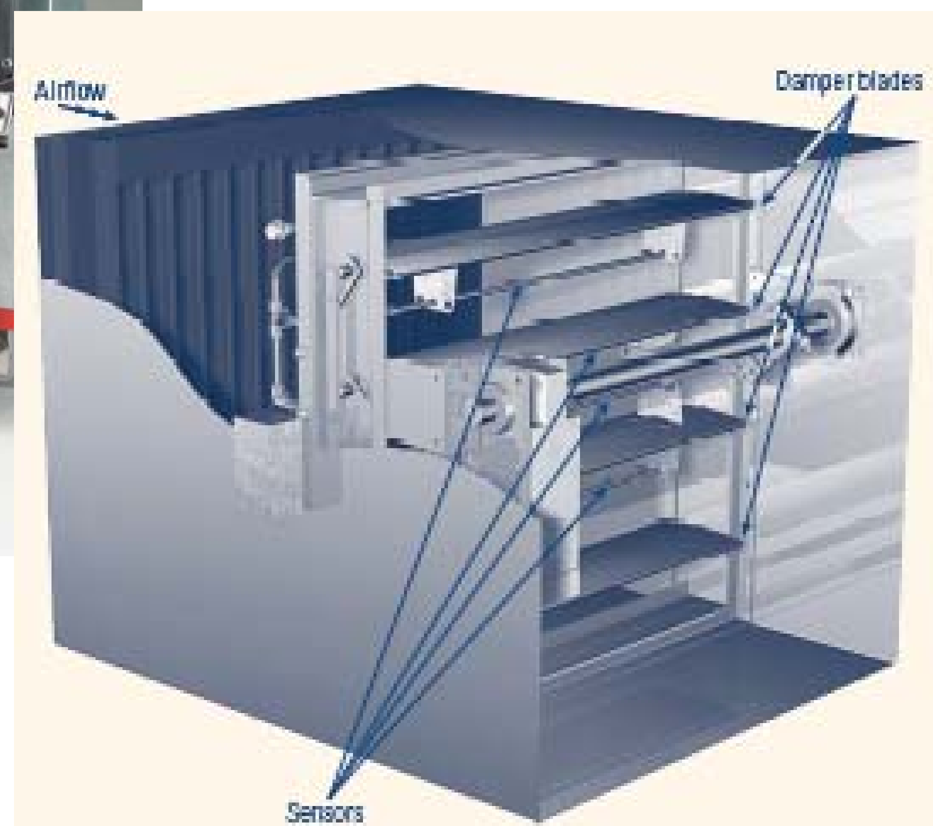
Typical Pitot Array



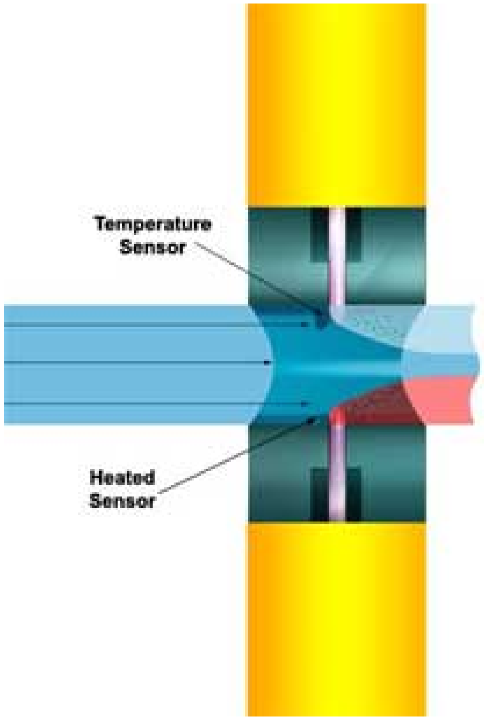
VP Grid in Special Louver



Other Systems: Minimum 300-400 fpm

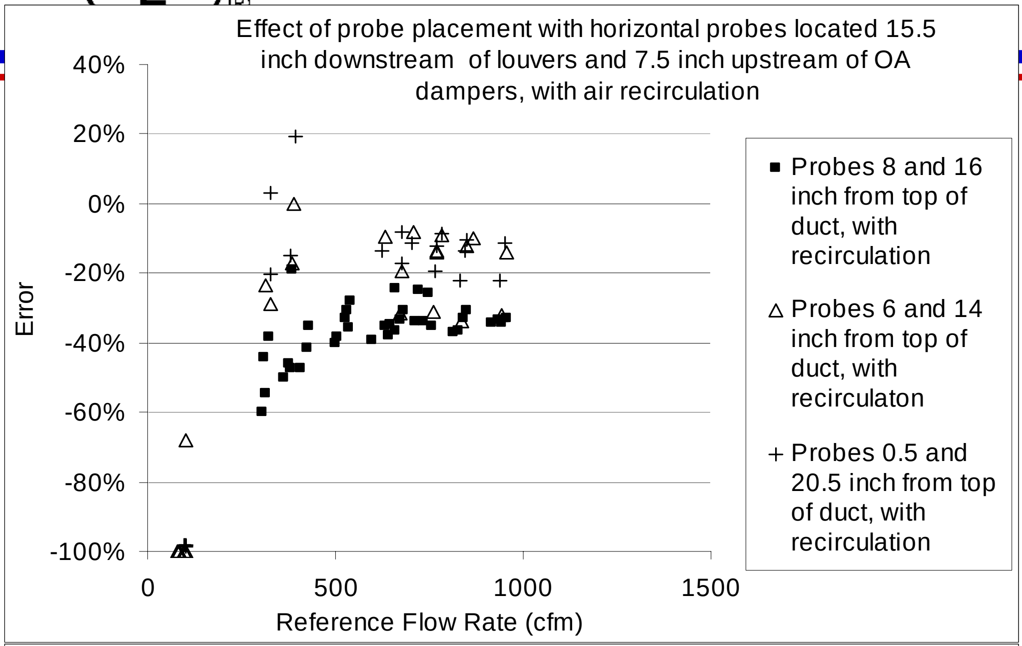


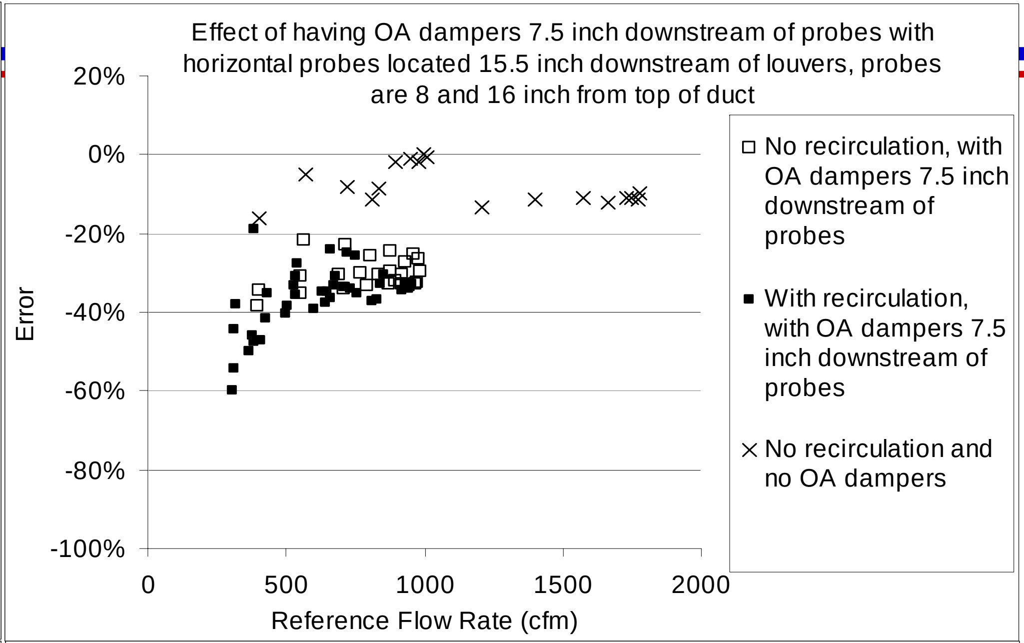
Thermal Dispersion Anemometer

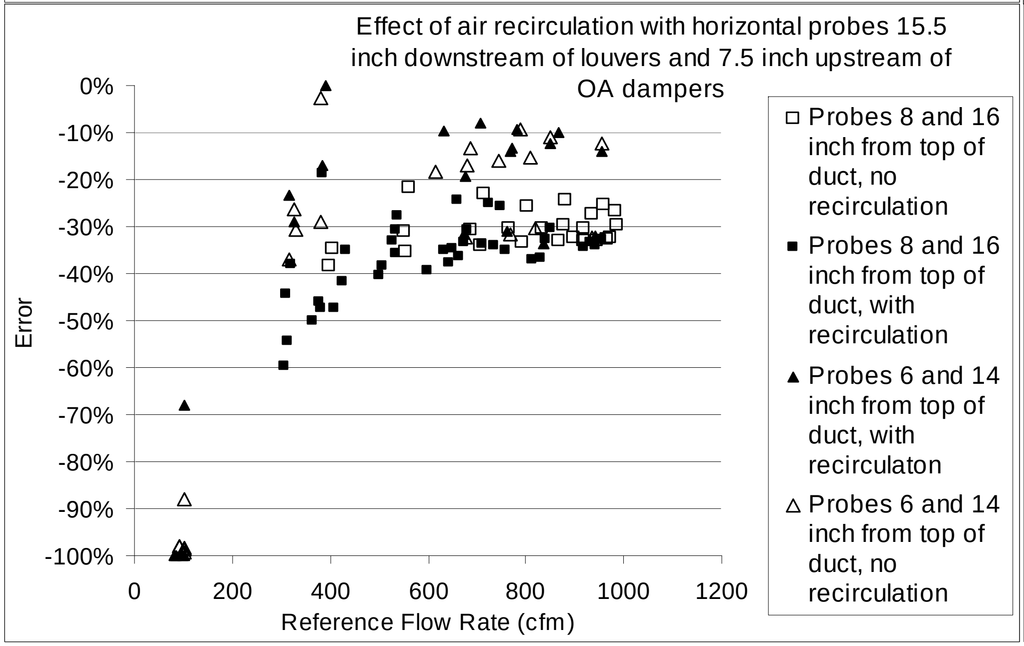


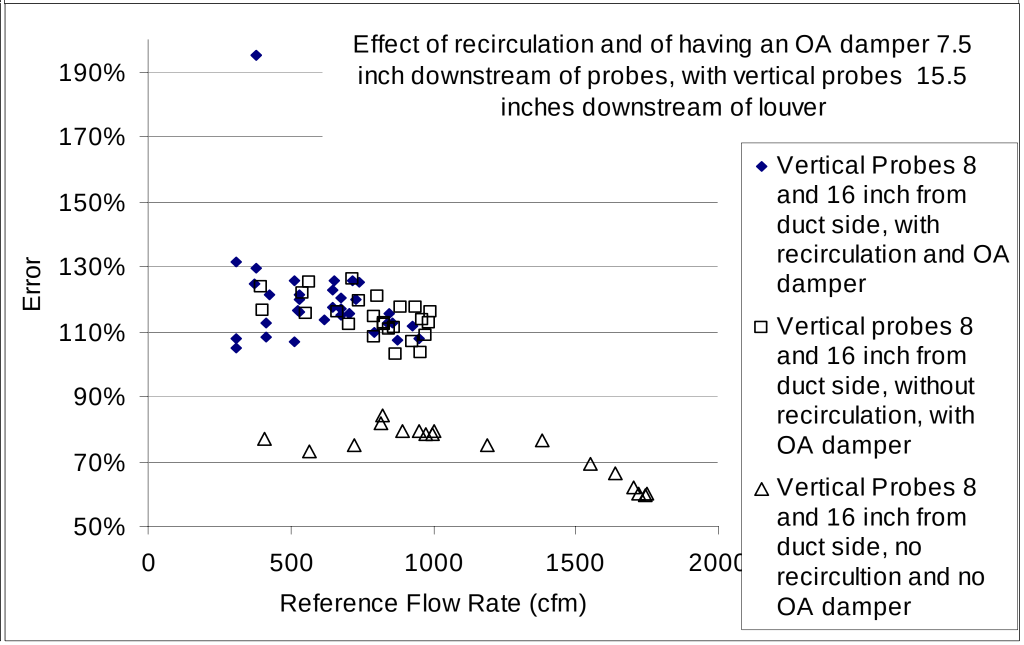
Manufacturer: ±2% of reading over 0 to 5000 fpm range!

Fisk Tests of Thermal Dispersion Anemometer

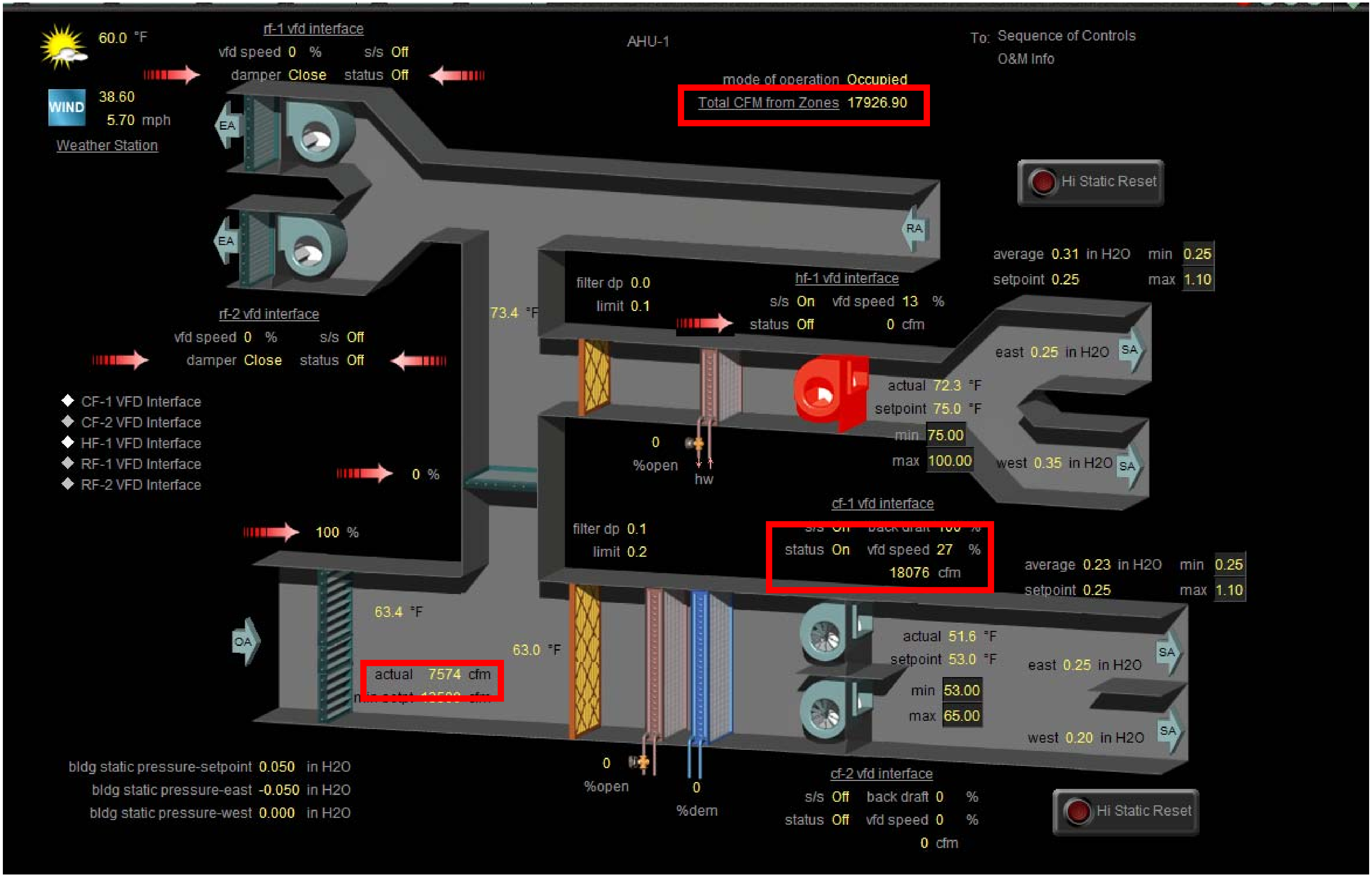








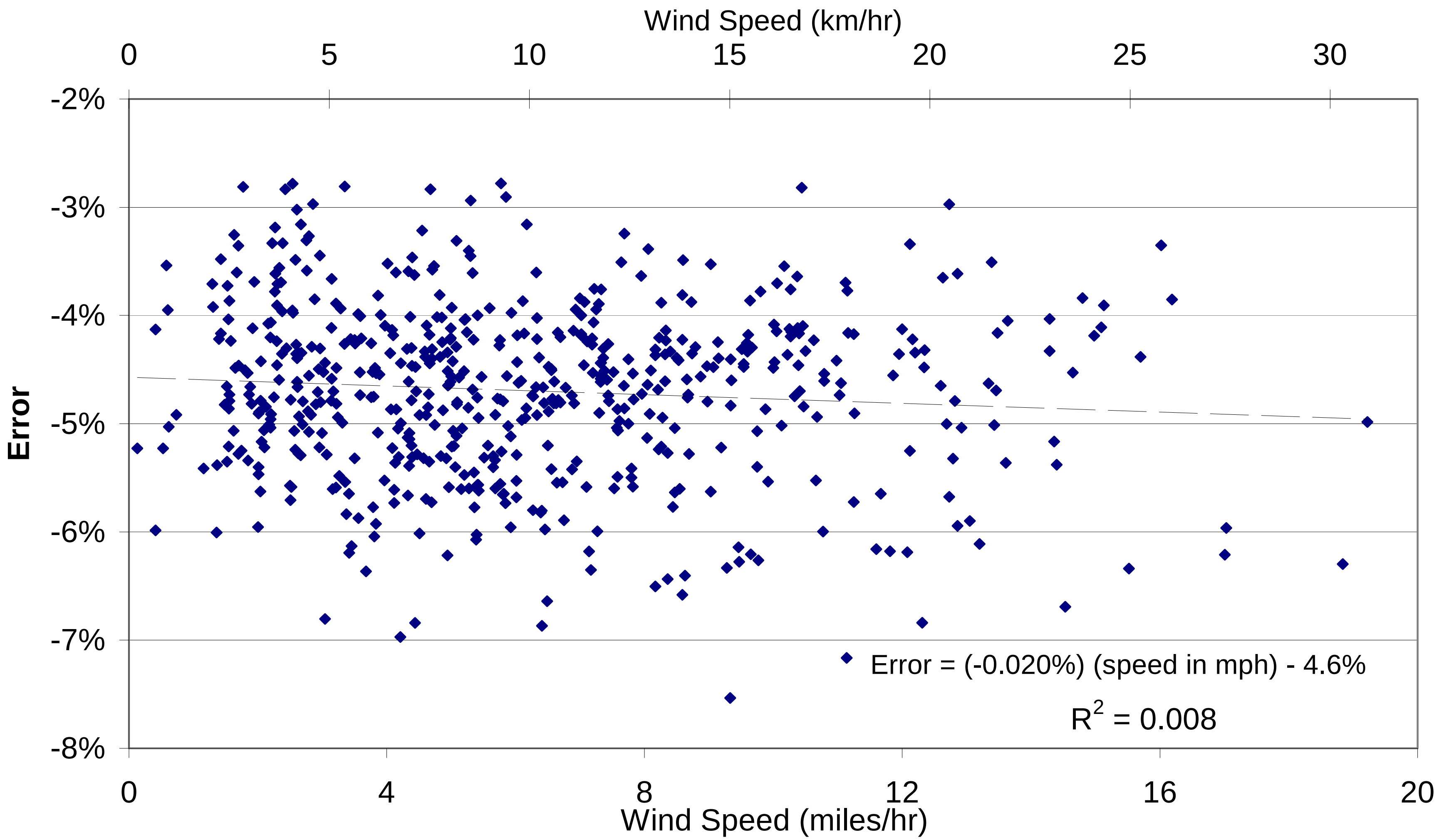
Thermal Dispersion Anemometer in Real Application



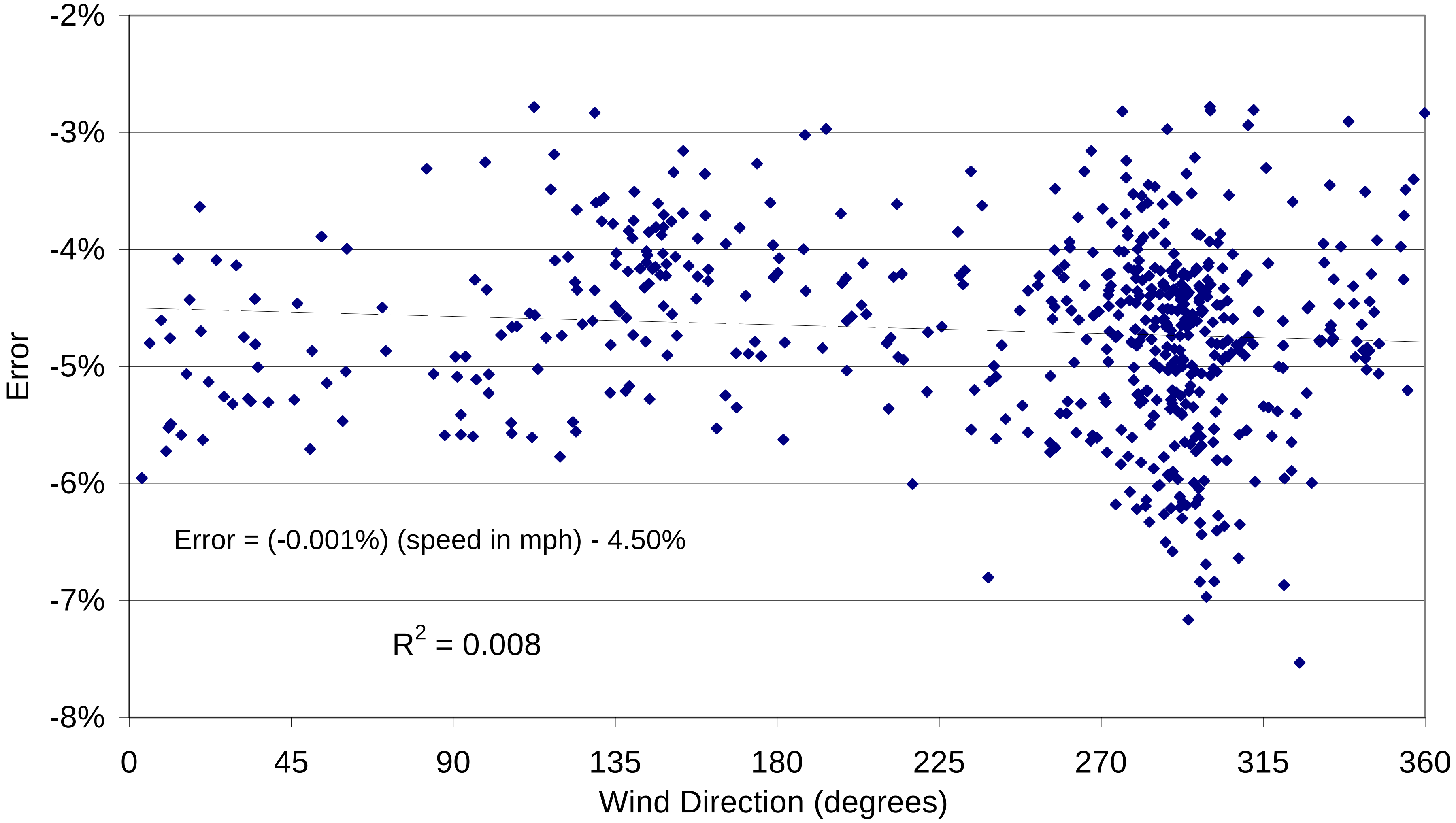
Another Thermal Anemometer Option? Not yet tested

Can be calibrated to be accurate at 40 fpm per manufacturer

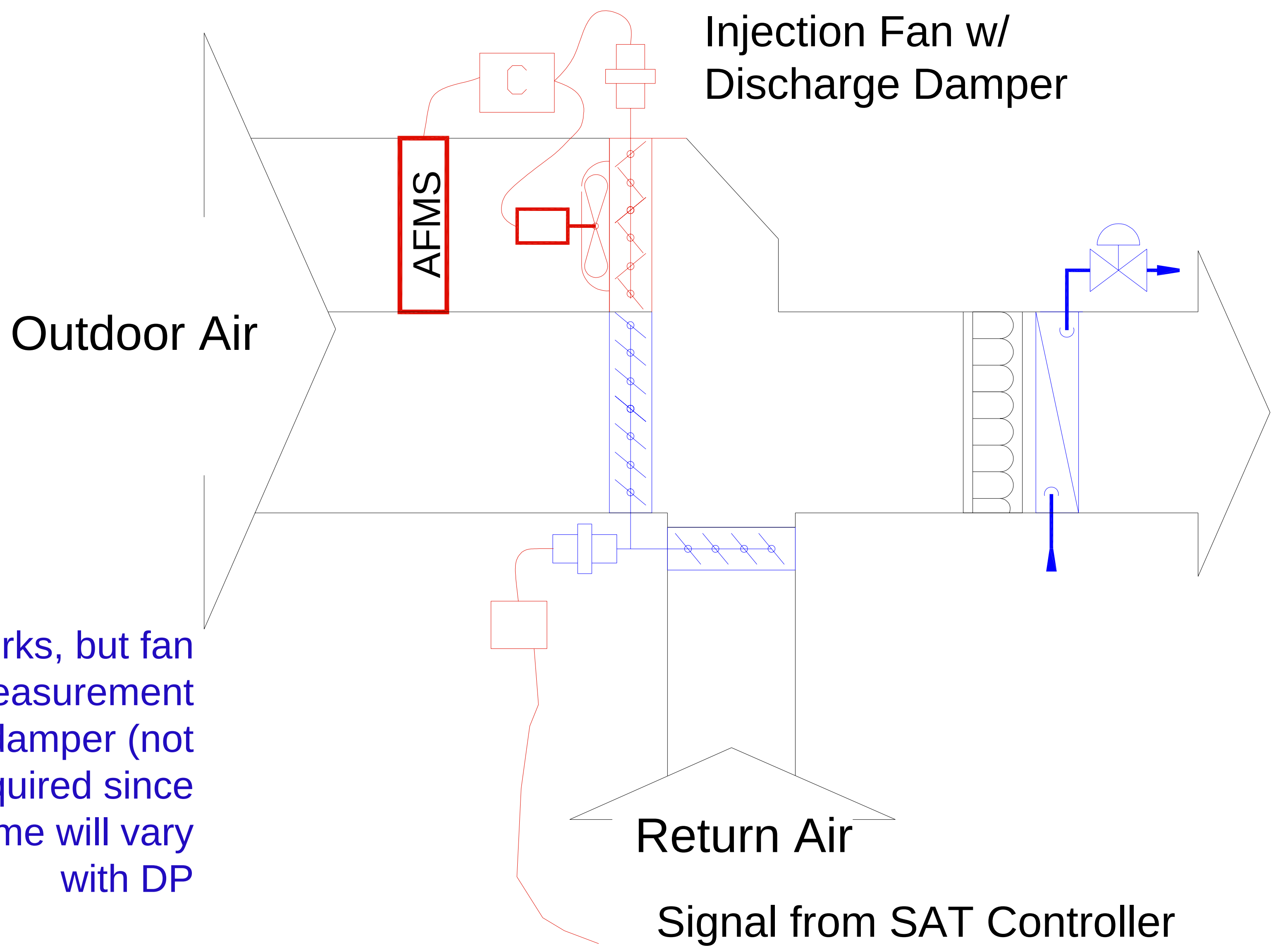
Influence of Wind Speed



Influence of Wind Direction

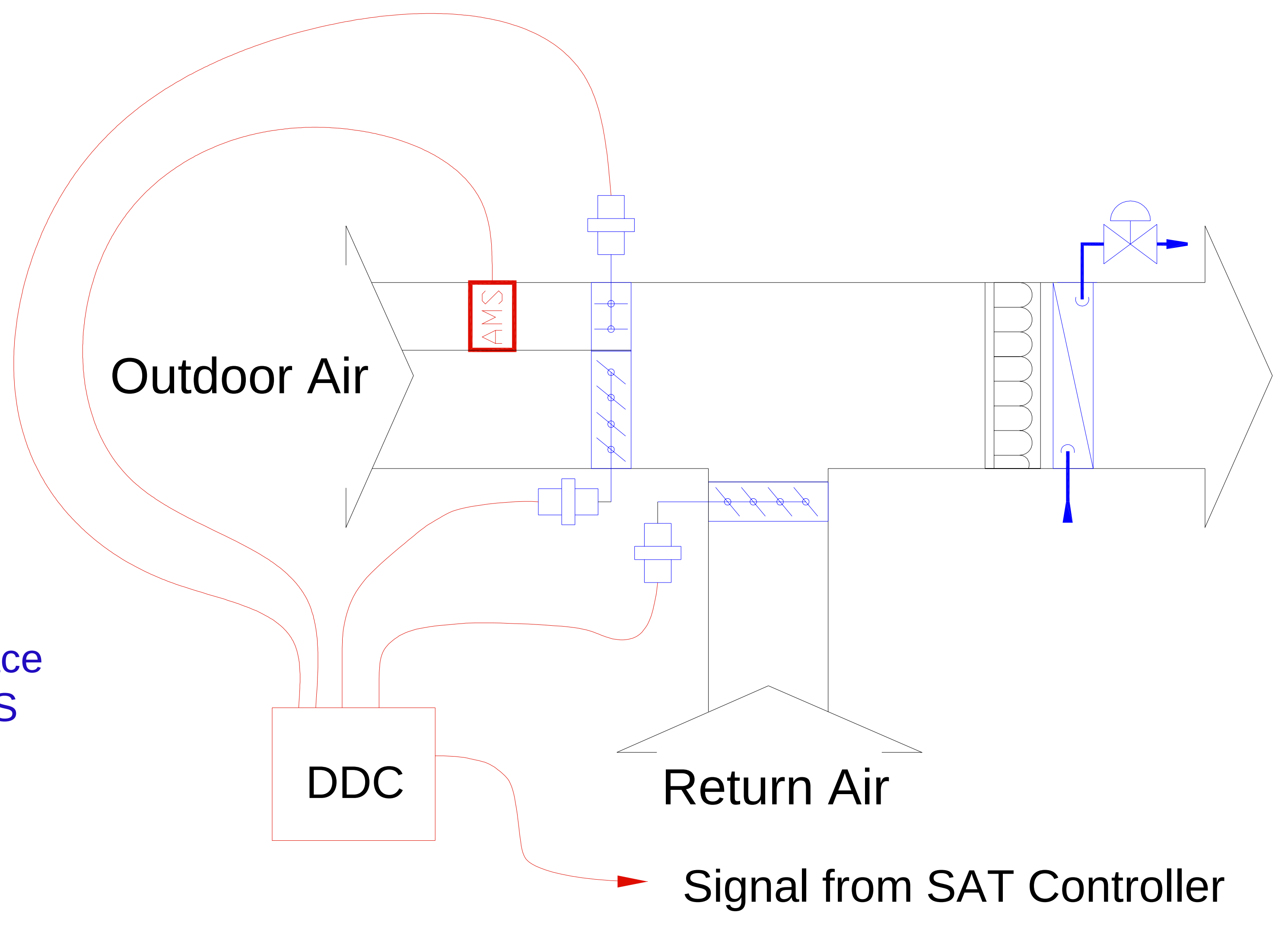


Injection Fan



Works, but fan airflow measurement and damper (not VFD) required since fan volume will vary with DP

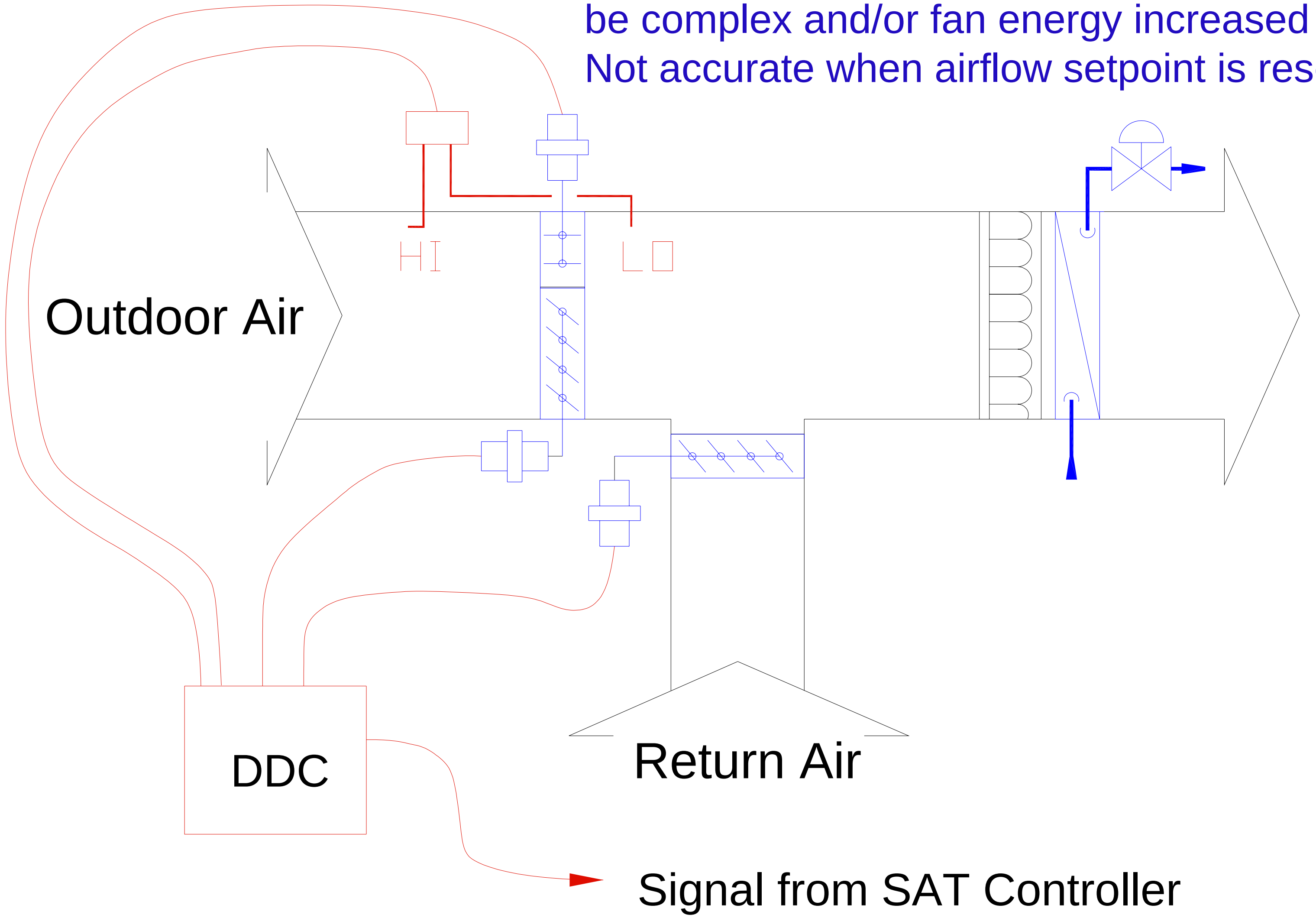
Dedicated Minimum Outdoor Air Section



Works! But space needed for AMS

Fixed Minimum OA Damper w/ Plenum Pressure Control

Works, and lowest cost, but control sequence can be complex and/or fan energy increased slightly. Not accurate when airflow setpoint is reset



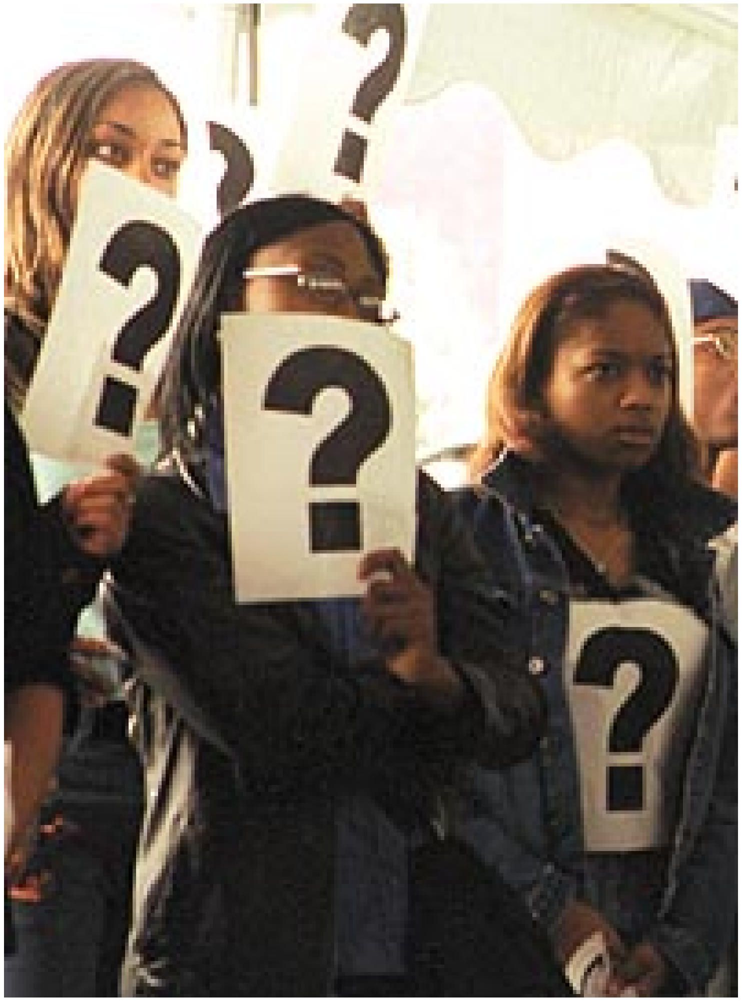
Summary

Option	Advantages	Disadvantages
Minimum position reset by fan speed	•Least expensive •Available on some packaged VAV systems as standard •No additional AHU length required	•Inaccurate (may not meet code) •No compensation for wind and other effects •Field calibration required •Does not work well with CO_2 DCV
100% Outdoor Air AFMS with thermal anemometer	•Total outdoor airflow rate always known •Can be used for CO_2 DCV •Does not require return air damper pressure control	•Questionable accuracy of anemometer •Expensive •Requires extra AHU length
Injection Fan and dedicated minimum AFMS	•Does not require return air damper control	•Most expensive •Requires extra AHU length
Dedicated minimum AFMS	•Can be used for CO_2 DCV	•Requires extra AHU length •Requires return air damper control
Plenum pressure control	•Very inexpensive •No additional AHU length required	•Field calibration required •Does not work well with CO_2 DCV •Requires return air damper control for best efficiency

Summary

- **Demand controlled ventilation**
  - Required by Standard 90.1 for dense occupancies
  - Different equations now for Standard 62.1-2004 rates
  - Sequences for central VAV systems not yet optimized
- **Outdoor airflow measurement**
  - Required by Standard 62.1 and code for VAV systems
  - Not all airflow measurement systems work!

Questions?



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