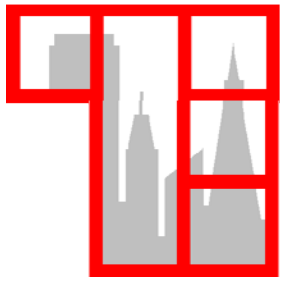
CO_2 Demand Controlled Ventilation Control Strategies



Steven T. Taylor, PE
Taylor Engineering
Alameda, CA

February 2009

Agenda

- **Ventilation Codes**
  - CMC 403 (Standard 62.1-2004)
  - Title 24 Energy Standards Section 121
- **CO_2 DCV Fundamentals**
- **CO_2 Sensors**
- **DCV Control Strategies**
  - Single zone systems
  - Multiple zone (VAV) systems

Tale of Two Ventilation Standards

- **Title 24 Energy Standards Section 121**
  - First issued in 1991
  - Key elements
    - Includes building component (cfm/ft^2) as well as people component (cfm/person) – take larger of the two
    - Allows transfer air to meet 100% of ventilation needs
    - Requires CO2 demand controlled ventilation for densely occupied spaces
  - Proposal to be eliminated from 2008 version squelched by Cal-OSHA
- **CMC Section 403**
  - Based on Standard 62.1-2004
    - Now includes building component (cfm/ft^2) as well as people component (cfm/person) – add the two
    - Includes “multiple spaces effects”
  - Covers all commercial occupancy types including those covered by Section 121

Title 24 Ventilation Rates

- **Larger of**
  - 15 cfm/person * number of people (no less than half the CBC exiting requirement)
  - Table 121A cfm/ft2 * floor area

TABLE 121-A MINIMUM VENTILATION RATES

TYPE OF USE	CFM PER SQUARE FOOT OF CONDITIONED FLOOR AREA
Auto repair workshops	1.50
Barber shops	0.40
Bars, cocktail lounges, and casinos	0.2
Beauty shops	0.40
Coin-operated dry cleaning	0.30
Commercial dry cleaning	0.45
High-rise residential	Ventilation Rates Specified by the CBC
Hotel guest rooms (less than 500 ft2)	30 cfm/guest room
Hotel guest rooms (500 ft2 or greater)	0.15
Retail stores	0.20
All others	0.15

Title 24 vs. Standard 62.1 Ventilation Rates

Occupancy Type	% Difference in Ventilation Rate From ASHRAE 62.1 to Title 24		
	Minimum occupancy from		
	Each Code	Title 24	ASHRAE
Auditoriums	-64%	-64%	-64%
Financial Institutions	-32%	-32%	-32%
Grocery Stores	-7%	-2%	3%
Hotels	-8%	-40%	-8%
Office Buildings	-29%	-29%	-29%
Religious facilities	-23%	-51%	-54%
Restaurants	76%	7%	-16%
Retail and Wholesale Stores	-7%	-2%	3%
Schools	57%	23%	12%
Barber shops	-38%	-76%	-38%
Bars	36%	-24%	-38%

CMC vs. T-24 – which to use?

TABLE 4-1 MINIMUM VENTILATION RATES IN BREATHING ZONE [2,3]

[ASHRAE 62.1:Table 6-1]

Note: *Ventilation air supply requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code.*

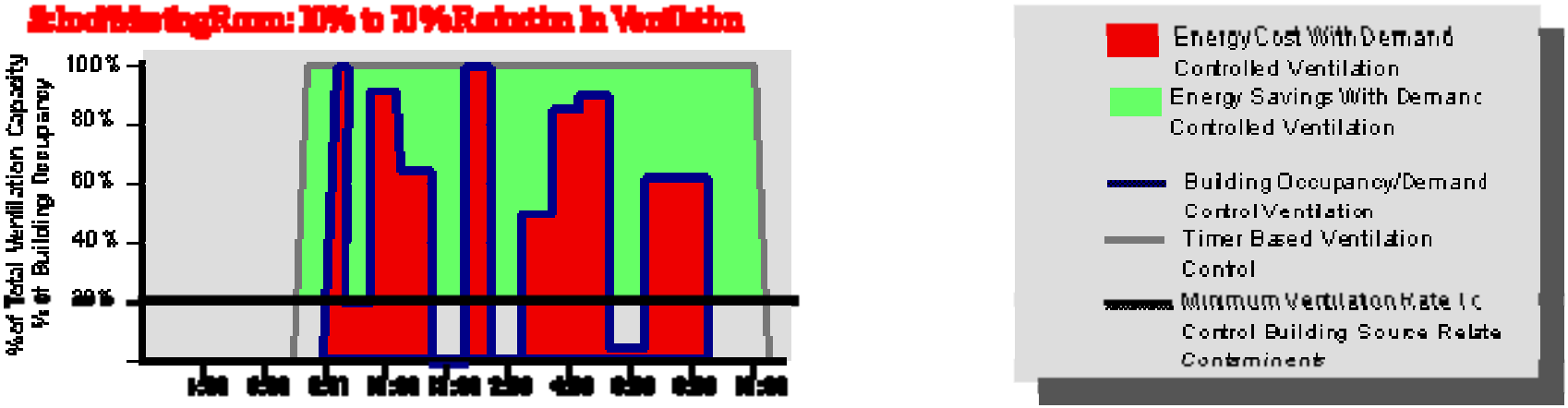
Occupancy Category[6]	People Outdoor Air Rate R_P (cfm/person)	Area Outdoor Air Rate R_A (cfm/ft²)	Default Occupant Density[4] (people/1,000 ft²)
Correctional Facilities			
Cell	5	0.12	25
Day room	5	0.06	30
Guard stations	5	0.06	15
Booking / waiting	7.5	0.06	50
Educational Facilities			
Day care (through age 4)	10	0.18	25
Classrooms (ages 5-8)	10	0.12	25
Classrooms (age 9 plus)	10	0.12	35

- Use T-24 Section 121 for all commercial occupancies covered by Energy Standards
- Use UMC Section 403 for all else, e.g. garages

CO_2 Demand Controlled Ventilation (DCV)

- **Key assumptions:**
  - The per-person ventilation rates required by Standard 62.1 and Title 24 are based on a bioeffluent concentration “with which a substantial majority (80% or more) of the <occupants> exposed do not express dissatisfaction”
  - Bioeffluent generation rate is proportional to number of occupants and their activity level and that the relationship is predictable and fixed
  - CO_2 generation rate is proportional to bioeffluent generation rate

2008 Title 24 CO_2 Demand Controlled Ventilation Requirements



3. **Required Demand Control Ventilation**. HVAC systems with the following characteristics shall have demand ventilation controls complying with 121(c)4:

   A. They have an air economizer; and

   B. They serve a space with a design occupant density, or a maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1000 ft^2 (40 square foot per person); and

   C. They are either:

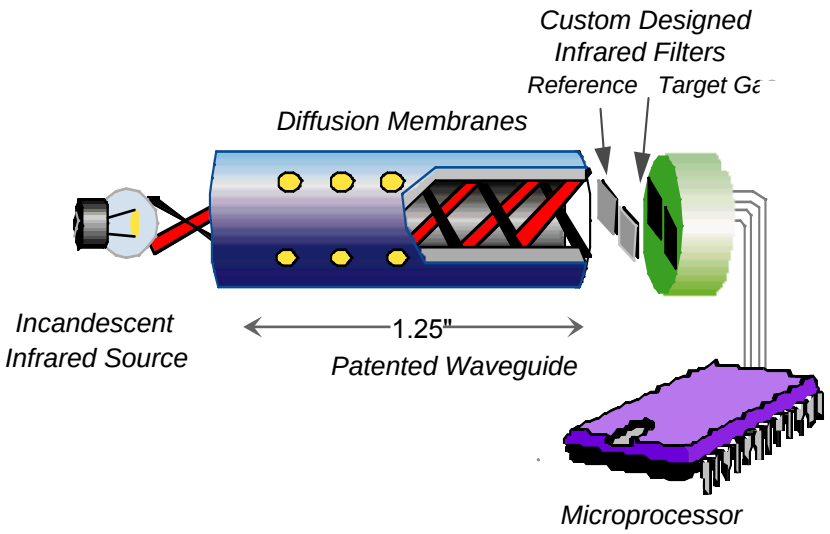
      i. Single zone systems with any controls; or

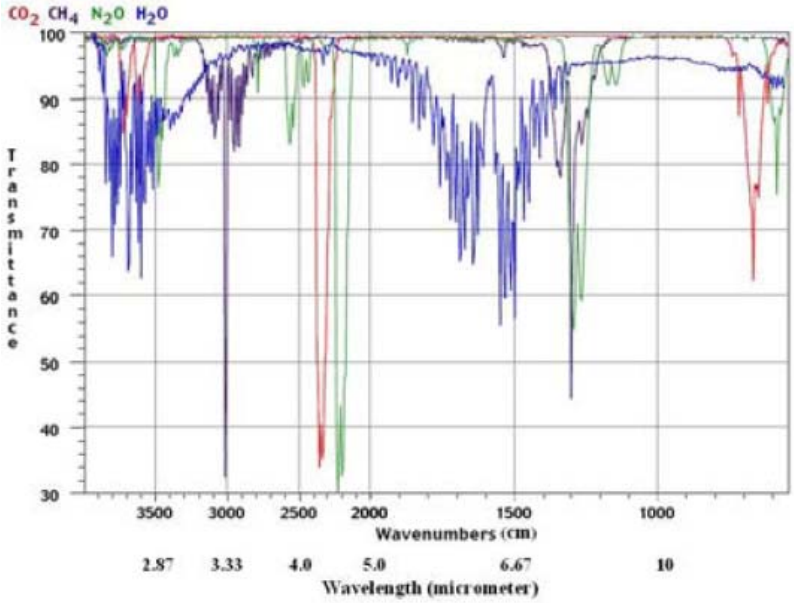
      ii. Multiple zone systems with Direct Digital Controls (DDC) to the zone level.

Title 24 DCV Device Requirements

- **Minimum rate = Table 121A cfm/ft^2 * area**
- **Setpoint = ambient + 600 ppm**
- **Ambient can be either**
  - 400 ppm assumed
  - Ambient CO_2 sensor
- **Sensor**
  - Located in the space between 3 ft and 6 ft above the floor
  - ±75 ppm accuracy at 1000 ppm
  - Factory or field calibrated
  - Require recalibration no more frequently than every 5 years
  - Continuous display and “recorded” on DDC systems

Types of CO_2 Sensors

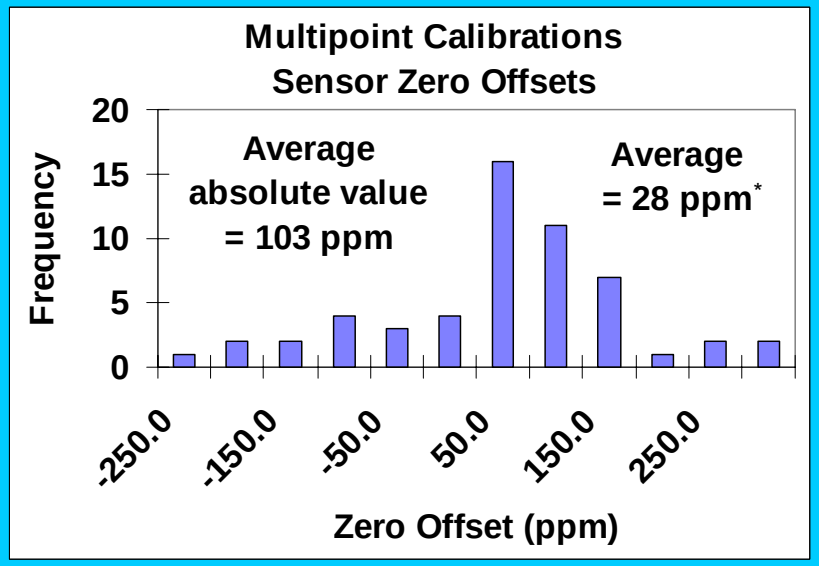




- **Non-dispersive infrared (NDIR) most common**
  - Single Beam – single wavelength
  - Single Beam – dual wavelength
  - Dual Beam – single wavelength
- **Automatic Background Calibration (ABC)**
  - Assumes diurnal swing to ambient (400 ppm)

LBNL Field Tests of CO_2 Sensors

Results – Multipoint Calibration Checks



*Average is +38 ppm if one value of – 534 ppm is excluded

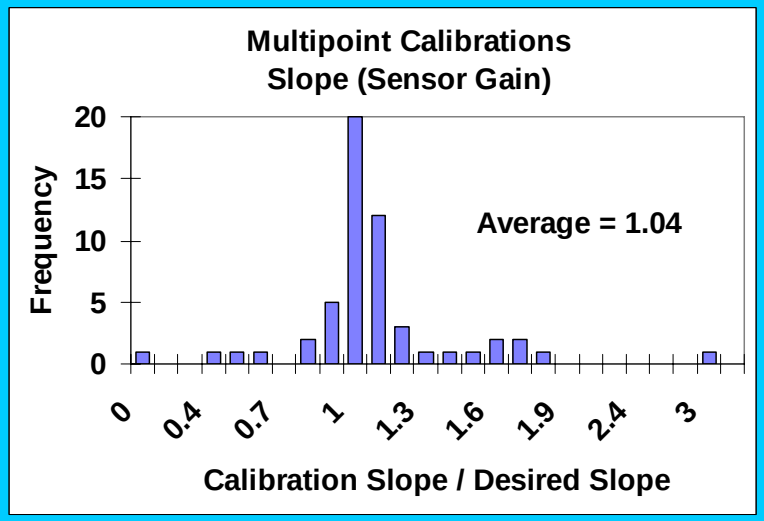
129 sensors

23 buildings

8 “brands”

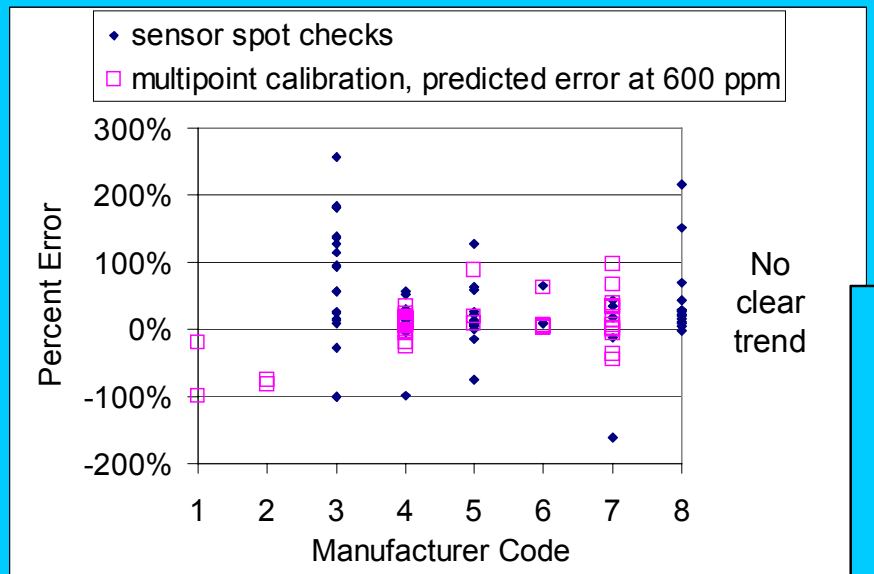
Results – Multipoint Calibration Checks

Error in Sensor Gain



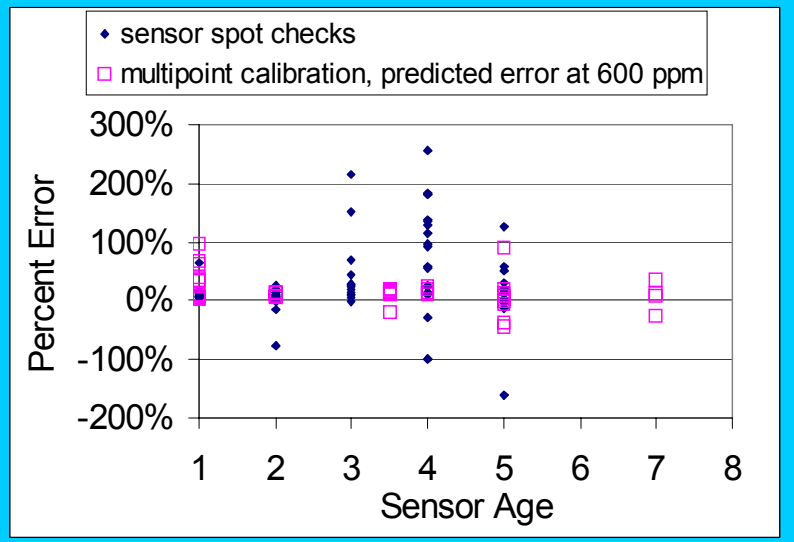
LBNL Field Tests of CO_2 Sensors

Results – All Data



No clear trend

Results – All Data



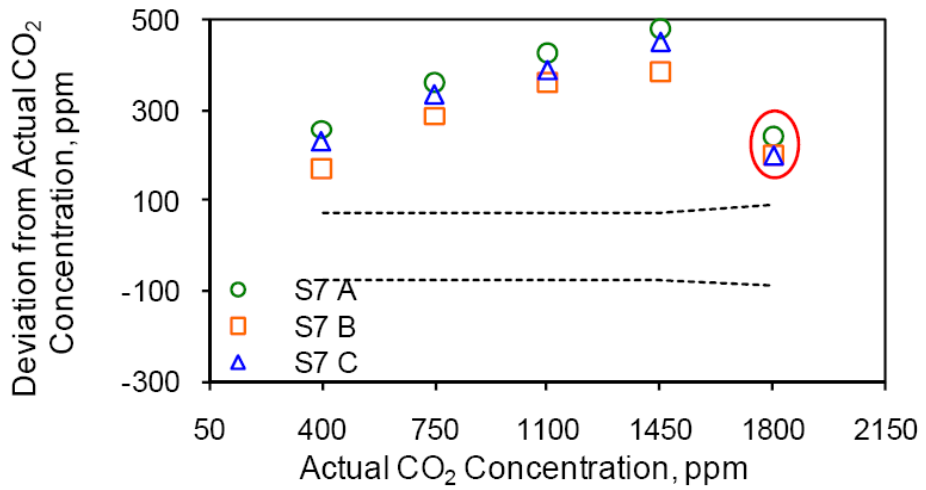
Newer sensors not clearly more accurate

- **Conclusions**
  - Many very poorly performing sensors
  - No clear trend of brand or technology or age

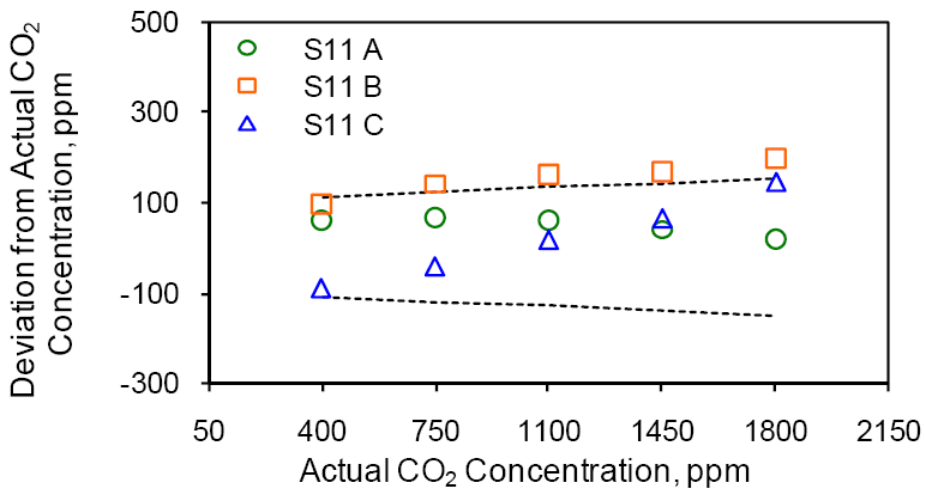
NBCIP CO_2 Sensor Study
sponsored by Iowa Energy Center, NSTAR, and CEC

- **15 sensor types**
- **Tested for**
  - Accuracy
  - Linearity
  - Repeatability
  - Hysteresis
  - Sensitivity to humidity, temperature, pressure
  - Aging
- **Final Report this Spring**

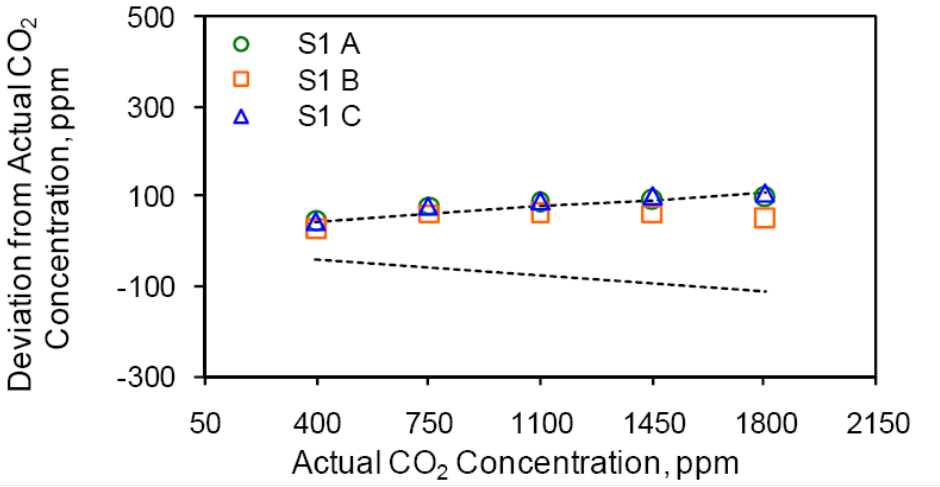
Accuracy Tests



Single-lamp single-wavelength Sensor with Automatic Baseline Adjustment Algorithm.

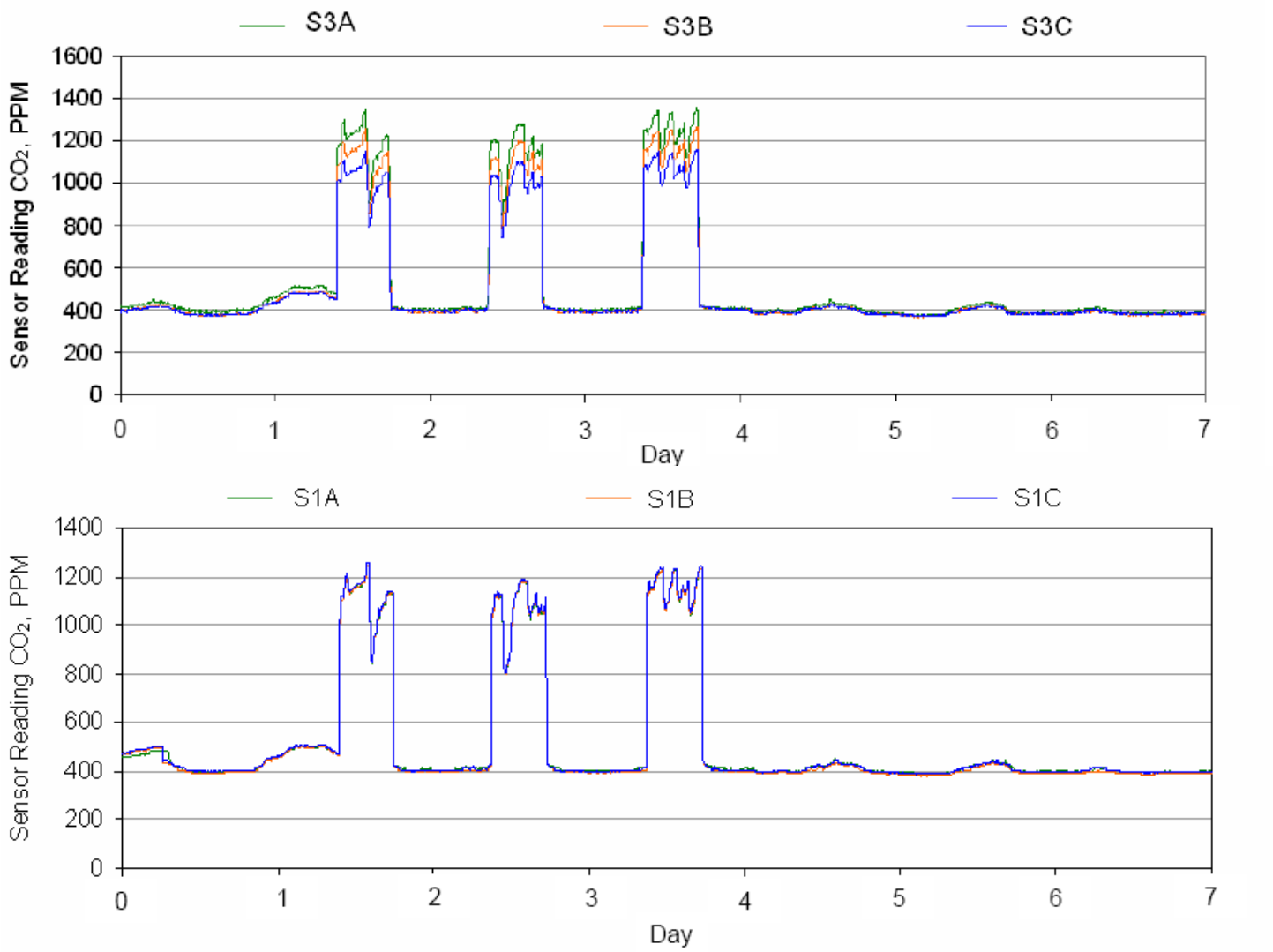


Dual-lamp single-wavelength Sensor.

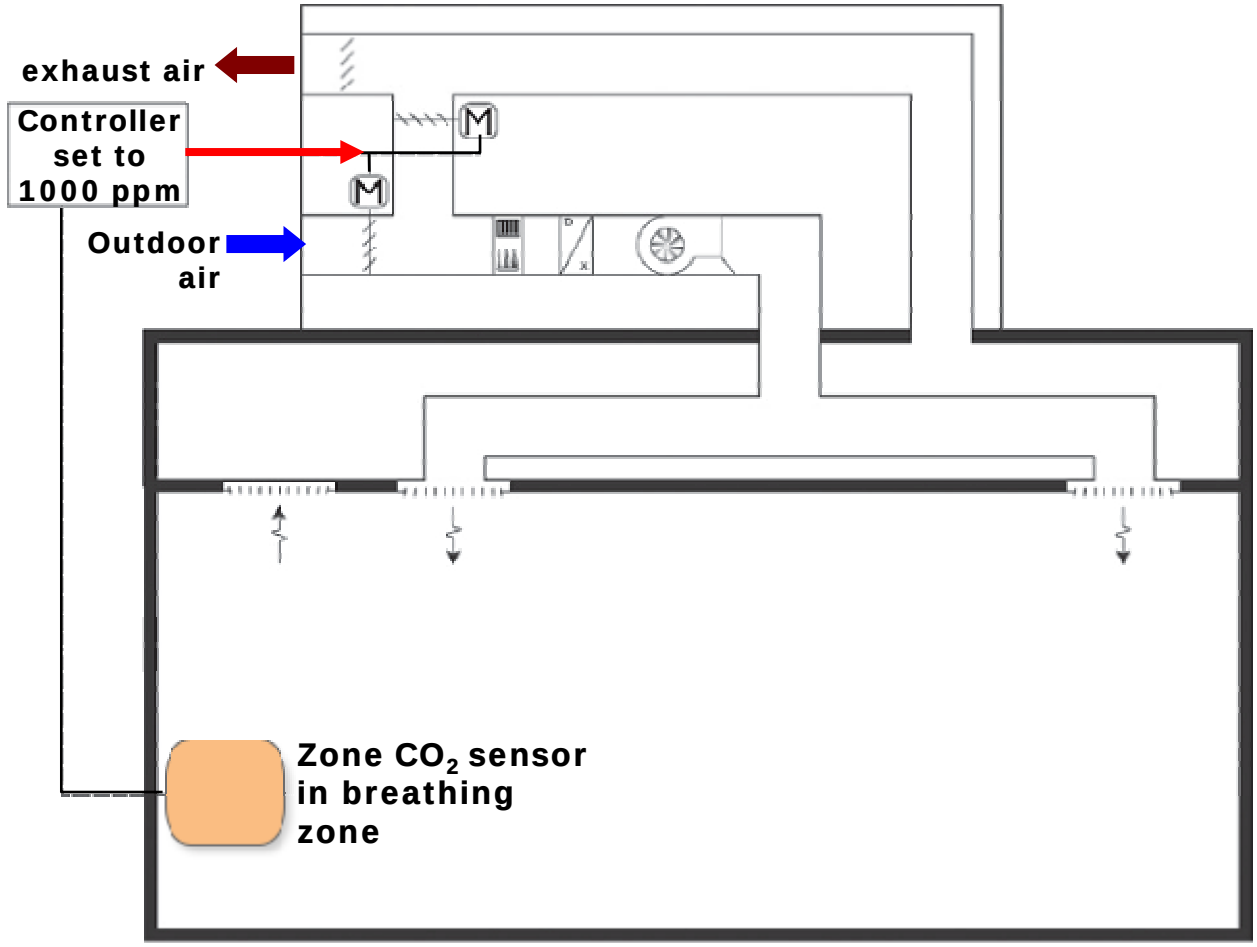


No Clear advantage for one technology over another

Long Term Tests



Single Zone CO_2 DCV Control Schematic

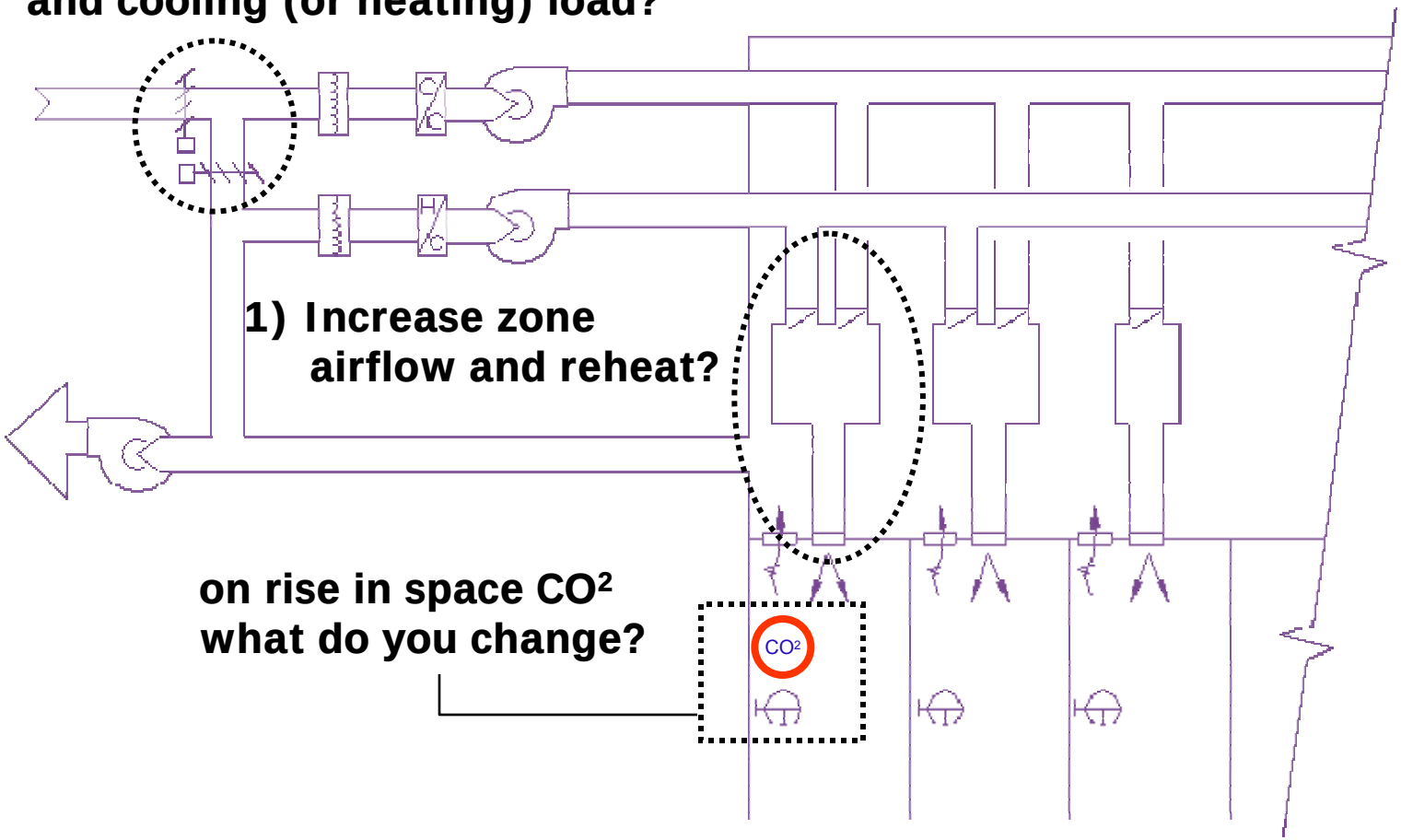


Controller Configuration

- **Use Proportional-only (not PI or PID)**
  - At minimum signal (e.g. 4 mA), balance minimum position to area-based rate only
  - At maximum signal (e.g. 20 mA), balance minimum position to design minimum outdoor air rate (15 cfm/p)
- **Recommended**
  - Wide proportional band to deliver
    - Area-based rate at 400 ppm CO_2
    - Design minimum rate at 1,000 ppm CO_2
  - Conservative but prevents over-shoots
  - Logic matches Standard 62.1 DCV approach

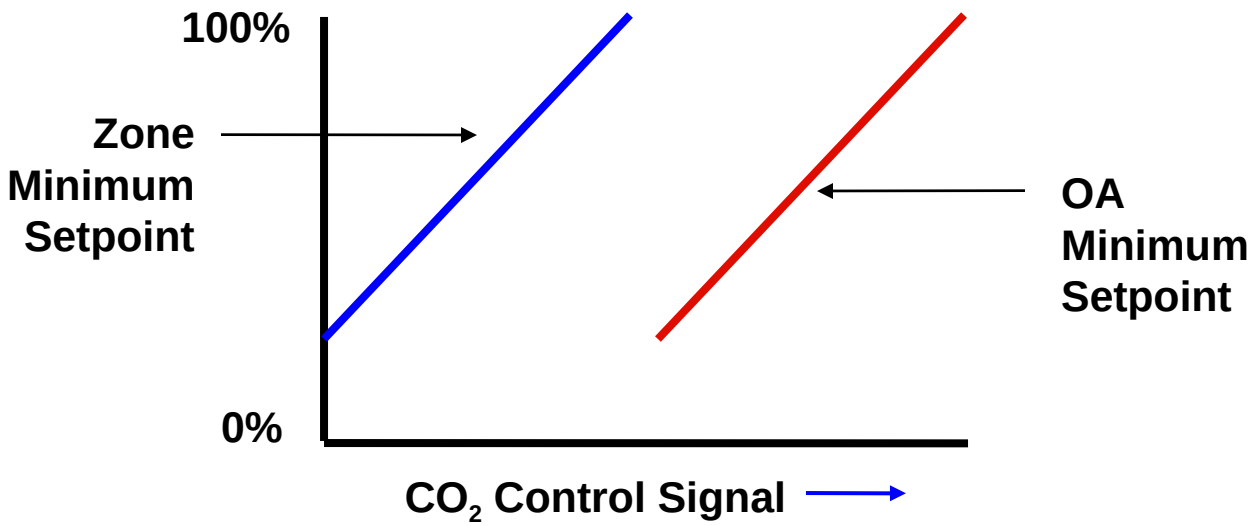
CO_2 DCV with Multiple Zone Systems

2) Increase minimum system OA and cooling (or heating) load?



Multiple Zone System CO_2 DCV

- **One Approach (TBD by ASHRAE RP 1547)**
  - First: Increase the zone damper up to 100% of zone maximum based on zone CO_2 signal
  - Then: Increase the minimum OA setpoint from unoccupied minimum rate to design minimum rate based on maximum zone CO_2 signal



Summary

- **Ventilation Codes**
  - Use Title 24 ventilation rates for almost all commercial occupancies
  - CO_2 DCV require in densely occupied spaces
- **CO_2 Sensors**
  - Significant range in quality – need to spec the right sensor
- **Control Strategies**
  - Single zone – direct control of damper minimum position setpoint. Recommend wide proportional
  - Central VAV − first increase zone supply air minimum rate then cascade up to system minimum airflow rate