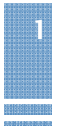


Outside Air and Demand Control Ventilation Systems

Best Practice Method - Conclusions

- Exterior Hot Wire and Velocity Matrix measurements are best performers
  - Velocity matrix not appropriate for flows nominally less than 250 fpm
  - Use hot wire for flows below 250 fpm
  - Interior measurements may still be necessary due to AHU configuration

Outside Air and Demand Control Ventilation Systems

Best Practice Method - Conclusions

- Rule out flow hood due to added pressure drop
- Rule out temperature split due to reliance on large ΔT and error stacking of supply flow measurement

Outside Air and Demand Control Ventilation Systems

In Situ Testing - Results

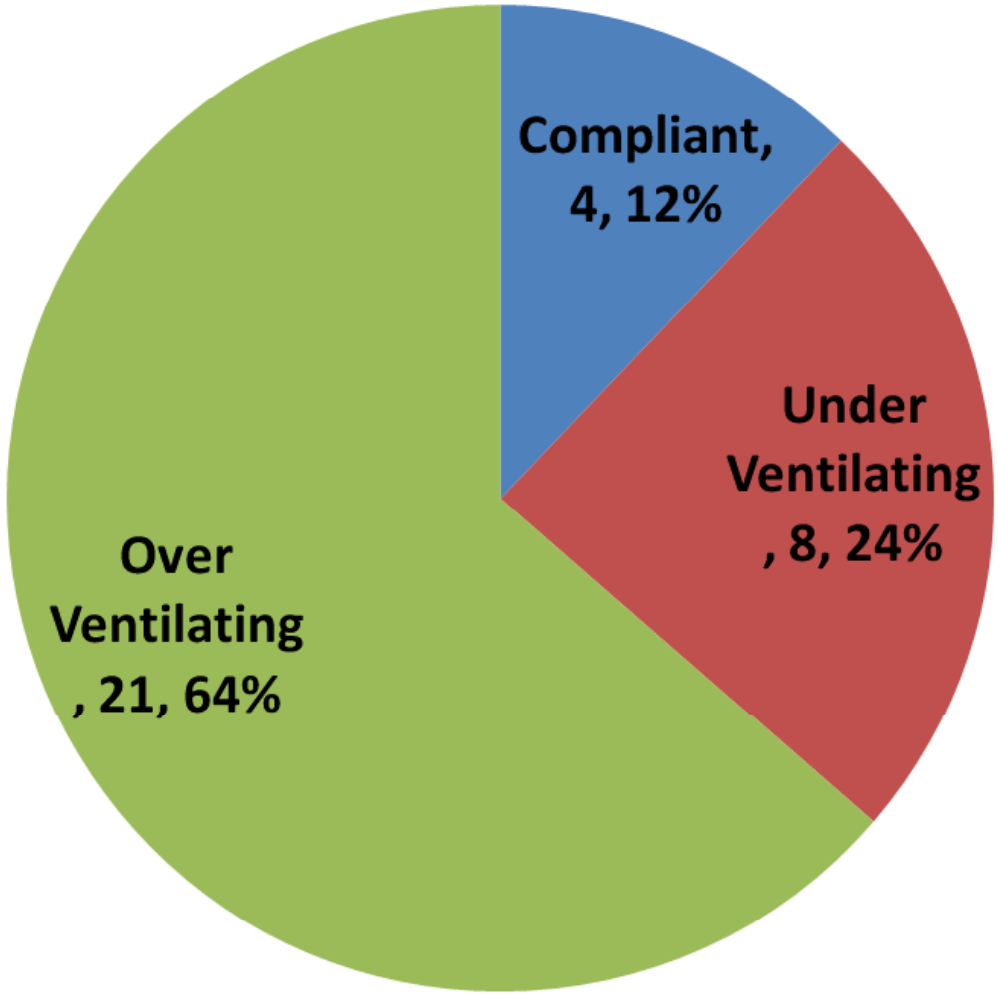
- In general, systems are significantly over-ventilating

System Type	Average % Relative Deviation from Title 24 OA Requirement	Average % Absolute Deviation from Title 24 OA Requirement
Built-Up	**84%**	**89%**
Multi Zone	**84%**	**89%**
OA Control: Dynamic	11%	40%
OA Control: Fixed Min Damper	98%	99%
Packaged	**50%**	**70%**
Multi Zone	**21%**	**36%**
OA Control: Dynamic	-1%	23%
OA Control: Fixed Min Damper	25%	38%
Single Zone	**108%**	**138%**
OA Control: Fixed Min Damper	108%	138%
Total	**62%**	**77%**

Outside Air and Demand Control Ventilation Systems

In Situ Testing - Results

- Systems are compliant if measured air flow is within 10% of the Title 24 requirement *(per acceptance testing requirements of MECH-2A)*



Outside Air and Demand Control Ventilation Systems

Recommended Code Changes

- Eliminate field calibration option for CO2 sensors
- Add field verification of CO2 sensors to acceptance testing
- Confirm dynamic control of outside air
- Confirm pre-occupancy purge for all system types

Outside Air and Demand Control Ventilation Systems

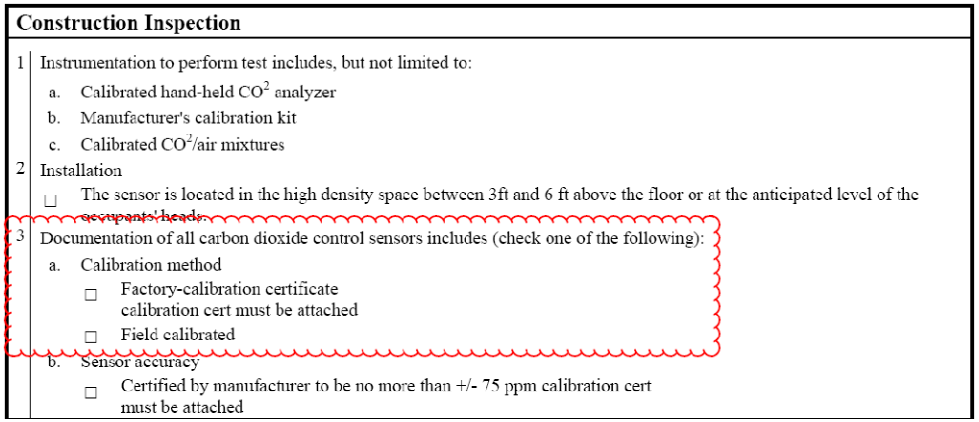
Recommended Code Changes

- Verify proper location of OA ducts in plenum systems
- Add guidance for measuring OA flow
- Correct CO2 sensor mounting height in compliance manual

Outside Air and Demand Control Ventilation Systems

Eliminate CO2 Sensor Field Calibration

- Changes to MECH-6A, Construction Inspection Block
  - Existing Block →



Construction Inspection

1 Instrumentation to perform test includes, but not limited to:
- a. Calibrated hand-held CO^2 analyzer
- b. Manufacturer's calibration kit
- c. Calibrated CO^2/air mixtures

2 Installation
- ☐ The sensor is located in the high density space between 3ft and 6 ft above the floor or at the anticipated level of the occupants' heads.

3 Documentation of all carbon dioxide control sensors includes (check one of the following):
- a. Calibration method
  - ☐ Factory-calibration certificate calibration cert must be attached
  - ☐ Field calibrated
- b. Sensor accuracy
  - ☐ Certified by manufacturer to be no more than +/- 75 ppm calibration cert must be attached

  - Modify language of Item 3 under the Construction Inspection section to read:
    - ***"Documentation of all carbon dioxide control sensor includes factory-calibration certificate (calibration certificate must be attached)"***
  - Remove field calibration option.

Outside Air and Demand Control Ventilation Systems

Eliminate CO2 Sensor Field Calibration

- Changes to Nonresidential Compliance Manual, Section 10.6.13, Construction Inspection
  - "CO2 sensor is either factory calibrated or field calibrated. A calibration certificate from the manufacturer will satisfy this requirement. ***Field calibration of CO2 sensors does not comply with Title 24.*** ~~In order to perform a field calibration check, follow the calibration procedures provided by the manufacturer. Some sensor manufacturers may require using equipment-specific calibration kits (kits may include trace gas samples and other hand-held devices) whereas others may be calibrated simply by using a pre-calibrated hand-held CO2 measuring device and making proper adjustments through the sensor or ventilation controller.~~"

Outside Air and Demand Control Ventilation Systems

Add Field Verification of CO2 Sensors

- Require field verification of factory calibrated sensors
- CO2 sensors can be unreliable, even with factory calibration
- Changes required to MECH-6A and nonresidential compliance manual

Outside Air and Demand Control Ventilation Systems

Add Field Verification of CO2 Sensors

- Changes to MECH-6A, Functional Testing Block
  - Existing Block

A.	Functional Testing	Results
a.	Disable economizer controls	
b.	Outside air CO^2 concentration (select one of the following)	
	☐ Measured dynamically using CO^2 sensor	_____ ppm
c.	Interior CO^2 concentration setpoint (Outside CO^2 concentration + 600 ppm)	_____ ppm

  - Recommended Block

A. Functional Testing	Results
a. Verify in the field that all CO_2 sensors at both zone and system level are accurate to within +/- 75 PPM. All CO_2 sensors must be verified, no sampling is allowed. Indicate PASS/FAIL for all CO_2 sensors.	
b. Disable economizer controls	
c. Outside air CO_2 concentration (select one of the following)	
☐ Measured dynamically using CO_2 sensor	_____ PPM
☐ Interior CO_2 concentration setpoint (Outside CO_2 concentration + 600 ppm)	_____ PPM

Outside Air and Demand Control Ventilation Systems

Add Field Verification of CO2 Sensors

- Changes to MECH-6A, Testing Results Block
  - Existing Block

B. Testing Results	PASS / FAIL	
Step 1: Simulate a high CO^2 load (check box complete)		
Step 2: Simulate a low CO^2 load (check box complete)		

  - Recommended Block

B. Testing Results	PASS/FAIL	
All CO_2 sensors verified to be are accurate to within +/- 75 PPM		
Step 1: Simulate a high CO_2 load (check box complete)		
Step 2: Simulate a low CO_2 load (check box complete)		

Outside Air and Demand Control Ventilation Systems

Add Field Verification of CO2 Sensors

- Changes to Nonresidential Compliance Manual
  - Section 10.6.12 – Estimated Time to Complete
    - Existing Text
      - "Functional testing: 1 to 2 hours (depending on how ambient CO2 concentration levels are manipulated, system response time to variations in CO2)"
    - Recommended Text
      - "Functional testing: 1 to ~~2~~ ***3*** hours (depending on ***number of CO2 sensors to be verified and*** how ambient CO2 concentration levels are manipulated, system response time to variations in CO2)"

Outside Air and Demand Control Ventilation Systems

Confirm Dynamic Control of Outside Air

- Section 10.6.3 of the compliance manual indicates that confirmation of dynamic controls is intended to be part of acceptance testing, but this protocol is currently omitted on MECH-2A
- Changes required to MECH-2A and nonresidential compliance manual

Outside Air and Demand Control Ventilation Systems

Confirm Dynamic Control of Outside Air

- Changes to MECH-2A, Construction Inspection Block
  - Existing block does not mention dynamic controls

Construction Inspection

1 Instrumentation to perform test includes, but not limited to:
   a. Watch
   b. Calibrated means to measure airflow

2 Check one of the following:

☐ Variable Air Volume (VAV) - Check as appropriate:
   a. Sensor used to control outdoor air flow must have calibration certificate or be field calibrated
      ☐ Calibration certificate (attach calibration certification)
      ☐ Field calibration (attach results)

☐ Constant Air Volume (CAV) - Check as appropriate:
   ☐ System is designed to provide a fixed minimum OSA when the unit is on

Outside Air and Demand Control Ventilation Systems

Confirm Dynamic Control of Outside Air

- Changes to MECH-2A, Construction Inspection Block
  - Add the following verifications to the VAV portion of Item 2.

b. ☐ Fixed Minimum Damper Setpoint is NOT being utilized to control OSA.

c. One of the following dynamic controls is being utilized to control OSA.

☐ Dual Minimum Setpoint Design
☐ Energy Balance Method
☐ Return Fan Tracking
☐ Airflow Measurement of the Entire Outdoor Air Inlet
☐ Injection Fan Method
☐ Dedicated Minimum Ventilation Damper with Pressure Control
☐ Other Active Control, Describe _____

Outside Air and Demand Control Ventilation Systems

Confirm Dynamic Control of Outside Air

- Nonresidential Compliance Manual
  - Section 10.6.2 – Purpose of the Test
    - Existing Text
      - "This test ensures that adequate outdoor air ventilation is provided through the variable air volume air handling unit at two representative operating conditions. The test consists of measuring outdoor air values at maximum flow and at or near minimum flow."
    - Recommended Text
      - "This test ensures that adequate outdoor air ventilation is provided through the variable air volume air handling unit at two representative operating conditions. The test consists of ***confirming dynamic control methods and*** measuring outdoor air values at maximum flow and at or near minimum flow."

Outside Air and Demand Control Ventilation Systems

Confirm Dynamic Control of Outside Air

- Nonresidential Compliance Manual
  - Section 10.6.2 – Acceptance Criteria
    - Add the following acceptance criteria.
      - "***Variable air volume systems use some form of active controls to modulate outdoor air rates. Fixed minimum damper setpoint CANNOT be used***."

Outside Air and Demand Control Ventilation Systems

Confirm Dynamic Control of Outside Air

- Nonresidential Compliance Manual
  - Section 10.6.3 – Construction Inspection
    - Existing Text
      - "There are a number of means to dynamically control minimum OSA. A survey of common methods is presented in Chapter 4 of the Nonresidential Compliance Manual. After validating that the sequence of control will dynamically control outdoor air check the "System is designed to dynamically control minimum OSA" box in the "Construction Inspection" section of MECH-2A."
    - Note: check box for confirming dynamic controls does not currently exist on the MECH-2A form

Outside Air and Demand Control Ventilation Systems

Confirm Dynamic Control of Outside Air

- Nonresidential Compliance Manual
  - "There are a number of means to dynamically control minimum OSA. A survey of common methods is presented in Chapter 4 of the Nonresidential Compliance Manual. ~~After validating that the sequence of control will dynamically control outdoor air check the "System is designed to dynamically control minimum OSA" box in the "Construction Inspection" section of MECH-2A."~~ **Furthermore, fixed minimum damper setpoint, which is common industry practice, is not compliant with Title 24. After validating that the sequence of control will dynamically control outdoor air check the "Fixed Minimum Damper Setpoint is NOT being utilized to control OSA" box in the "Construction Inspection" section of MECH-2A. Also, indicate in this section what type of dynamic control is being used."**

Outside Air and Demand Control Ventilation Systems

Confirm Pre-occupancy Purge for all systems

- Confirm pre-occupancy purge for all system types as required in 121(c)2.
  - No significant cost to verify schedule
  - Low barriers to adoption
  - Current compliance issues
- Currently, verification only completed for single zone and unitary systems in NA7.5.2.
- Modifications needed to the MECH-2A acceptance form and Nonresidential Compliance Manual

Outside Air and Demand Control Ventilation Systems

Confirm Pre-occupancy Purge for all systems

- Changes to MECH-2A, Construction Inspection Block
  - Add the following confirmation to the end of the existing block.

3. Programming, check the following:

☐ Pre-occupancy purge has been programmed to meet the requirements of Standards Section 121(c)2.

Outside Air and Demand Control Ventilation Systems

Confirm Pre-occupancy Purge for all systems

- Changes to Compliance Manual Section 10.6.3 (VAV) AND Section 10.6.5 (CV)
  - Add the following text to the end of the existing Construction Inspection text.
    - ***" Confirm that pre-occupancy purge has been programmed to meet the requirements of Standards Section §121(c)2. This is most easily accomplished by scheduling the unit to start one hour prior to actual occupancy."***

Outside Air and Demand Control Ventilation Systems

Add guidance for measuring OA flow

- Outdoor air flow measurements can be very inaccurate if not done properly
- Add guidance for
  - Choosing instrumentation
  - Avoiding turbulence
  - Measuring free area
  - Averaging multiple measurements

Outside Air and Demand Control Ventilation Systems

Add guidance for measuring OA flow

- Change to Nonresidential Compliance Manual
  - *Intent: add mention of multi-point velocity pressure probes (i.e. velocity matrix)*
  - Section 10.6.2 - Instrumentation
    - Modify existing list of instrumentation to read:
      - ***"An airflow measurement probe (e.g. hot-wire anemometer or single/multi-point velocity pressure probe)"***

Outside Air and Demand Control Ventilation Systems

Add guidance for measuring OA flow

- Change to Compliance Manual
  - Add the following text to the end of the existing "Verify and Document" portion of Section 10.6.3 and Section 10.6.5
    - "Follow the best practice guidelines below in order to increase accuracy of outdoor air flow measurements:
      - Traverse measurements taken in supply, return or outdoor air ducts should be located in an area of steady, laminar flow. If possible, take measurements at least six to eight duct diameters away from turbulence, air intakes, bends, or restrictions.

Outside Air and Demand Control Ventilation Systems

Add guidance for measuring OA flow

- If using face velocity measurements to calculate outdoor air flow, care should be taken to accurately measure free area dimensions of intake. If velocity measurements are taken at the plane of the intake between damper blades where flow is restricted (i.e. to achieve faster flows), free area should be measured as the actual open space between dampers and should not include frames or damper blades.
- Hot wire anemometers are more appropriate than velocity pressure probes for measuring low speed flows (i.e. less than 250 feet per minute).
- Take multiple measurements and average results in order to minimize affects of fluctuations in system operation and environmental conditions (i.e. wind).

Outside Air and Demand Control Ventilation Systems

Verify location of OA ducts in plenum systems

- MECH-2A
  - Add the following confirmation item

3. Outside air supply (check one of the following)

☐ Return air plenum is used to distribute outside air to a zonal heating or cooling unit – Check as appropriate:

a. Confirm that outside air supply is connected either:

☐ Within five ft. of the unit

☐ Within 15 ft. of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 ft. per minute.

☐ Return air plenum is used NOT to distribute outside air to a zonal heating or cooling unit.

Outside Air and Demand Control Ventilation Systems

Verify location of OA ducts in plenum systems

- Compliance Manual Section 10.6.3 (VAV) and Section 10.6.5 (CV)
  - Add the following text to the end of the existing Construction Inspection text.
    - "For systems where return air plenum is used to distribute outside air to a zonal heating or cooling unit, confirm that outside air supply is connected either:
      - Within five ft. of the unit
      - Within 15 ft. of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 ft. per minute."