Demand control ventilation: maximize savings with practical approaches

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May 12, 2015
Acknowledgement

Minnesota Conservation Applied Research and Development (CARD) Grant Program
Today’s topics

- Quality DCV design
- Field study results
- (Re)commissioning
- Program recommendations
Background on DCV

Central and/or Zone Control

VAV Boxes

Sensor

Source: http://i.stack.imgur.com/4WKDC.jpg
Quality DCV design
Choose responsible party

Be complete:

- Specific sequence
  - CO₂ setpoint
  - Outside airflow lower limit
- CO₂ sensor location
- Airflow measurement req.
1. Direct OA flow control
   a. Zone CO₂ sensors

   Slight potential for imperfect IAQ...

   b. Return CO₂ sensor

   More potential for imperfect IAQ...
### Ventilation reset

<table>
<thead>
<tr>
<th>Description</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone outdoor airflow</td>
<td>$V_{oz}$</td>
<td>500</td>
<td>600</td>
<td>700</td>
</tr>
<tr>
<td>Zone primary airflow</td>
<td>$V_{pz}$</td>
<td>1500</td>
<td>2000</td>
<td>1500</td>
</tr>
<tr>
<td><strong>Zone OA fraction</strong></td>
<td>$Z_{pz} = V_{oz}/V_{pz}$</td>
<td>0.33</td>
<td>0.30</td>
<td>0.47</td>
</tr>
<tr>
<td>Average OA fraction</td>
<td>$X_s = V_{ou}/V_{ps}$</td>
<td></td>
<td></td>
<td>$1800/5000$</td>
</tr>
<tr>
<td>System vent efficiency</td>
<td>$E_v = 1 + X_s - \max Z_{pz}$</td>
<td>1 + 0.36 - 0.47</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td>System OA intake flow</td>
<td>$V_{ot} = V_{ou}/E_v$</td>
<td></td>
<td></td>
<td>$1800/0.89$</td>
</tr>
</tbody>
</table>

*Figure and table used with permission from Trane, a business of Ingersoll Rand.*
Ventilation reset

Zone outdoor airflow \( V_{oz} \)
- 500
- 600
- 400
= 1500

Zone primary airflow \( V_{pz} \)
- 1500
- 2000
- 1500
= 5000

**Zone OA fraction**
\[ Z_{pz} = \frac{V_{oz}}{V_{pz}} \]
- 0.33
- 0.30
- 0.27

Average OA fraction \( X_s = \frac{V_{ou}}{V_{ps}} = 1500/5000 \)
- 0.30

System vent efficiency \( E_v = 1 + X_s - \max Z_{pz} = 1 + 0.30 - 0.33 \)
- 0.97

System OA intake flow \( V_{ot} = \frac{V_{ou}}{E_v} = 1500/0.97 \)
- 1550

*Figure and table used with permission from Trane, a business of Ingersoll Rand*
2. Ventilation reset
   a. OA flow reset
   b. Zone, then OA flow reset
   c. Zone, then OA flow reset, with occupancy sensors
Upper limit
Freeze protection
Mitigates failures

Lower limit
Save energy
Maintain press.

Separation between OA lower limit and Design OA drives energy savings
CO\textsubscript{2} setpoint

Setpoint(s) per: \[ C_R = C_{OA} \cdot \frac{8400 E_Z \times \text{met}}{R_P + R_a \times \frac{s_f}{p}} \]

Proportional or single setpoint
Ideally in zone

- At breathing height (3-6 ft.)
- Not below a thermostat

Common return

- Limited situations

Show on drawings!
Use AFMS (not damper position)

Careful layout on dwgs:
- Consider manufacturer requirements

If possible: second intake for economizer
Use occupancy sensors!

- Occ. sensor = VAV savings, aside from DCV

Consider OA diversity in sizing

**DCV: not just a ‘Yes / No’ choice**

- Control portion of zones
- Strategically use common return
- Use 2-way dampers
- Mix approaches
For MN energy code:

- DCV has been required in densely occupied spaces
- New code does NOT change DCV or OA—except buildings older than ~8 years

The new code could lead to big improvement in compliance.

Source: http://www.dli.mn.gov/
Field study results
Characterization of approaches

96 systems around Minnesota:

- **System type:**
  - VAV
  - Single Zone
  - GSHP/DOAS
  - Other

- **Commissioning reported:**
  - None/limited
  - Full
  - Cont./Re-Cx

- **System age:**
  - 0-4 yrs.
  - 5-9 yrs.
  - 10+ yrs.

- **Owner type:**
  - Public
  - Owner occ.
  - Leased

- **% of area controlled:**
  - 20% or more
  - 0-19%
  - Return sensor

- **Prevent. maintenance (private bldgs.):**
  - Regular
  - None

- **Prevent. maintenance (public bldgs.):**
  - Regular
  - None
Approaches (sequences):

1a. Direct OA flow control, return sens. 19%
1b. Direct OA flow control 26%
2a. Ventilation reset 15%
2b. Zone box, then ventilation reset 22%
2c. Zone min. reset, w/ occ. sensors 19%
Measured savings per design OA rate (cfm)

**FIELD STUDY**

**Results**

**Occ. + CO₂ sensing**

With ERV

**Median = $0.50/cfm**

High lower limit

![Graph showing annual cost savings per cfm across different settings.](image-url)
We also scaled the results to a Duluth climate

<table>
<thead>
<tr>
<th></th>
<th>Savings per Design OA Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>therms/cfm</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td><strong>0.80</strong></td>
</tr>
<tr>
<td><strong>Change from MSP results</strong></td>
<td>27%</td>
</tr>
</tbody>
</table>
Savings are heavily weighted toward heating fuel
Deficiencies

Sequence change to reflect design
OA damper schedule
Use of damper position
OA lower limit
OA upper limit
CO$_2$ setpoint
CO$_2$ sensor calibration
Inaccurate airflow measurement

![Graph showing energy savings and no energy savings/improved IAQ]
Half the systems saved more, an average of 54%
### Economics per 1000 cfm of design OA

<table>
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<tr>
<th></th>
<th>CO₂ and Occupancy Control</th>
<th>Typical CO₂ Control</th>
<th>Typical CO₂, Partial Control</th>
<th>Recommissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break-even cost</td>
<td>$16,412</td>
<td>$6,658</td>
<td>$1,643</td>
<td>$2,900</td>
</tr>
<tr>
<td>Simple payback</td>
<td></td>
<td>4 - 5 years</td>
<td>7 - 8 years</td>
<td>&lt;1 - 2.5 years</td>
</tr>
</tbody>
</table>
(Re)commissioning
• Conduct when hot, or very cold outside

• Review CO$_2$ and OA flow trends:
  - CO$_2$ (ppm)
  - OA flow (cfm)

Find lower limit (also look for upper)

CO$_2$ follows occupancy

OA flow increases per sequence

Virtual performance checks
- Determine control: 1) OA damper position vs. 2) OA flow measurement (if available)
- Check for rogue DCV zones
- Check CO₂ sensor reading at unoccupied
- Determine OA damper schedule

Higher Ed PAC

OA not directly ctrld.

= 480 ppm
• Determine control: 1) OA damper position vs. 2) OA flow measurement (if available)
• Check for rogue DCV zones
• Check CO$_2$ sensor reading at unoccupied
• Determine OA damper schedule
• Recognize that savings is from heating (gas)
  - Economizer negates cooling savings
• Verify economizer operation
Meet the operator on-site; discuss system operation

Validate measured points:

- Temperatures: SA, MA, RA, OA (brief traverse)
- Valve positions (visual, temp)
- OA damper position (visual)
- Supply fan speed (VFD)
CO₂ sensors
- Calibrate or replace

*AIRSENSE*
Model 310e

Microprocessor-based, Infrared Environmental CO₂ Sensor

Operator's manual © Copyright 2010

- Auto calibration valid?
• Recalculate setpoint per Standard 62.1

• Check location of sensor

• Areas not being sensed? Leave CO₂ logger behind
Test the AHU

1. Modify CO₂ reading or setpoint
   a) False full occupancy, AND
   b) False no occupancy

2. Determine response

3. Await steady-state if possible

System performance tests

Test individual VAVs; same method
Test OA damper

- Visually verify two positions
- Check for leakage

Test occ. sensor impact on VAV box
Correct deficiencies found in tests

Optimize:

→ OA upper / lower limit, CO₂ setpoint, OA schedule
Report any changes made

Add any needed trending

Complete handover missed at install
- Document the sequence
- Plan for future monitoring
Opportunity #1: New and retrofit DCV systems
- Incentives per OA flow (see report)
- Consider more detailed requirements
- Dependent on heating fuel

Opportunity #2: Recommissioning
- Highly cost-effective for many programs
  - Recommissioning, retrocommissioning, HVAC tune-up
Opportunity #3: Ventilation re-design
- Code changes
- Excessive safety factors
- Poor estimate of occupancy
- Problem AFMS or dampers
- OA damper schedule

Opportunity #4: Trade allies
- Awareness
- Training
Sequences

- **Basic**: EDR 2007
- **Ventilation reset**: Trane 2005

Code requirements

- Code Notes 2012 IECC Demand Control Ventilation
- **AFMS**: Fisk 2009
- **CO$_2$ sensor performance**: Shrestha 2009
Resources

Download the study
Stay tuned for a fact sheet and the full report: seventhwave.org/dcv

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Learn about our work
seventhwave.org/buildings