engineers newsletter

volume 34–5 • providing insights for today's hvac system designer

CO_2-Based Demand-Controlled Ventilation
with ASHRAE Standard 62.1-2004

from the editor ...
Demand-controlled ventilation, or DCV, can reduce the cost of operating the HVAC system—which is bound to appeal to property owners in light of the recent surge in energy costs. But implementing DCV based on indoor levels of carbon dioxide isn't quite as straightforward under ASHRAE Standard 62.1-2004, *Ventilation for Acceptable Indoor Air Quality* as it was under previous versions. The good news is that DCV remains do-able and practical, especially for spaces like gyms and meeting rooms, where people and their activities are the main sources of indoor contaminants.

In this article, author and Trane application engineer, John Murphy, reviews ASHRAE 62.1's requirements for dynamic reset, and then outlines several methods for using CO_2 sensors to successfully implement DCV.

In Section 6.2.7, "Dynamic Reset," ASHRAE Standard 62.1-2004 (hereafter referred to simply as "ASHRAE 62.1") explicitly permits an HVAC system to "reset the design outdoor air intake flow *(Vot)* and/or space or zone airflow as operating conditions change."

The standard doesn't give details for implementation, but any system control approach that responds to varying conditions must be capable of providing at least the required minimum breathing-zone outdoor airflow whenever the zones served by the system are occupied. The standard goes on to list three examples of dynamic reset strategies:

- **Reset based on occupancy.** First, ASHRAE 62.1 lets you reset intake airflow in response to variations in zone population. This control strategy, often called *demand-controlled ventilation (DCV),* responds to the actual need, or "demand," for ventilation by regulating the rate at which the HVAC system brings outdoor air into the building. There are several ways to assess ventilation demand:

  – *Occupancy schedules,* which allow a building automation system to predict the current population based on the time of day

  – *Occupancy sensors,* which detect the presence or number of people in each monitored zone

  – *Carbon dioxide (CO_2) sensors,* which monitor the concentration of CO_2 that is produced continuously by the occupants and diluted by the outdoor air

  Regardless of which method is used, DCV strategies attempt to vary the outdoor-air intake in response to the current population.

- **Reset based on ventilation efficiency.** ASHRAE 62.1 also lets you reset intake airflow in response to variations in ventilation efficiency.

  In a multiple-zone VAV system, system ventilation efficiency (E_v) depends on the current zone- and system-level primary airflows, and it's always higher at part load than at design (worst-case) conditions. This control strategy, which we call *ventilation reset,* dynamically resets the system's outdoor air intake based on this changing efficiency.

- **Reset based on economizer operation.** Lastly, the standard lets you reset the VAV minimum primary airflow settings at each box in response to variations in intake airflow. For example, when a system is in the economizer (free cooling) mode, the content of the primary air is richer in outdoor air than is necessary to meet minimum ventilation requirements, so the minimum primary airflow settings on the VAV boxes can be reduced and still allow the zones to be properly ventilated. If any zones require reheat during economizer operation, this strategy can reduce both fan and reheat energy.

Let's take a closer look at what may be the most common application of dynamic ventilation reset—that is, *demand-controlled ventilation based on CO_2 readings*—to understand how it works and how ASHRAE 62.1 will affect its implementation.

Applying CO_2-based DCV

"CO_2-based demand-controlled ventilation" refers to the practice of using carbon dioxide concentrations as an indicator for the per-person ventilation rate. In this context, CO_2 is monitored as a byproduct of respiration rather than as an indoor contaminant.

The rate at which people produce CO_2 varies with diet and health, as well as with the duration and intensity of their physical activity. The more exertion an activity entails, the more carbon dioxide we produce.

Appendix C of ASHRAE 62.1-2004 provides the following mass balance equation to predict the difference between indoor (C_s) and outdoor (C_o) concentrations of carbon dioxide at steady-state conditions, given a constant, per-person ventilation rate (V_o) and a constant CO_2 generation rate (N):

$$V_o = \frac{N}{C_s - C_o}$$

where,

V_o = outdoor airflow rate, cfm/person
N = CO_2 generation rate, cfm/person
C_s = CO_2 concentration in the space, ppm
C_o = CO_2 concentration in the outdoor air, ppm

Implementing CO_2-based DCV is a matter of estimating the CO_2 generation rate of the occupants (N), measuring the concentration difference in the space versus outdoors ($C_s - C_o$), and then using this difference to determine the rate at which ventilation air (V_o), on a per-person basis, is delivered to the space.

In most locations, the outdoor concentration (C_o) of carbon dioxide seldom varies by more than 100 ppm from the nominal value.* Because of this and in lieu of installing an outdoor CO_2 sensor, most designers use either a one-time reading of the outdoor CO_2 concentration at the building site or a conservative value from historical readings. This simplifies control, lowers the installed cost, and usually increases accuracy because it avoids the potential inaccuracy of an outdoor sensor.

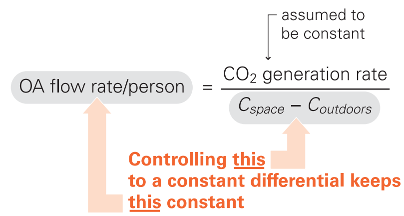
Impact of ASHRAE 62, then and now

ASHRAE 62.1-1989 thru -2001. In the 1989 through 2001 versions of ASHRAE Standard 62, the required ventilation rates were based on either the number of occupants in the zone (cfm/person) or the floor area of the zone (cfm/ft²).

As an example, let's consider the ventilation rate for a lecture classroom with a design population of 65 (Figure 1). ASHRAE 62-1989 through -2001 required 15 cfm of outdoor air per person in this space type. To comply, our example classroom must receive 975 cfm of outdoor air (15 cfm/person × 65 people). If the population drops to 20, the required quantity of outdoor air drops, too, to 300 cfm (15 cfm/person × 20 people).

Assuming that the CO_2 generation rate (N) of the occupants (who are seated, doing light desk work) is a constant 0.0105 cfm of CO_2/person, the mass balance equation establishes that a 700 ppm difference between the indoor and outdoor CO_2 concentrations will correspond to 15 cfm/person of outdoor air, delivered under steady-state conditions (Figure 1).

Figure 2. CO_2-based DCV under ASHRAE 62-1989 thru -2001

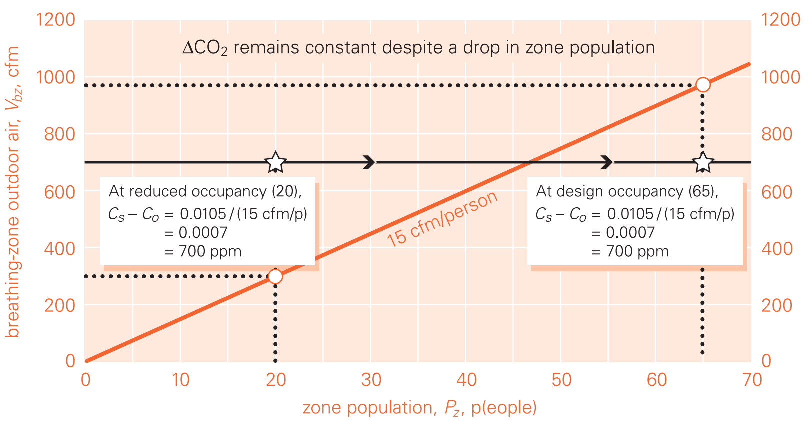


ASHRAE 62-1989 through -2001, required that the breathing zone receive the same rate of outdoor airflow per person, regardless of the number of people actually in the space—15 cfm/person in our classroom example. Therefore, the desired differential between indoor and outdoor CO_2 concentrations remained constant, too, regardless of how many people actually occupied the zone (Figure 1). By controlling to this constant differential, $C_s - C_o$, CO_2-based demand-controlled ventilation maintains the same per-person ventilation rate (V_o) to the space during periods of reduced occupancy (Figure 2).

Note: Assumptions simplify DCV, but they also introduce inaccuracy. Remember that the CO_2 generation rate (N) *varies with occupant activity level, diet, and health; the required ventilation rate* (V_o) *differs by space type under ASHRAE 62-1989 through -2001; and the outdoor CO_2 concentration* (C_o) *can vary from location to location.*†

ASHRAE 62.1-2004. The 2004 standard changes the method for determining the breathing-zone ventilation rate (V_{bz}). Now the required rate is based on the number

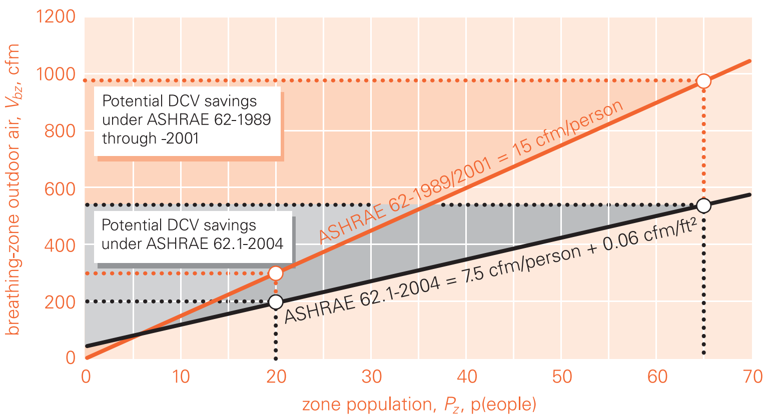
Figure 1. CO_2-based demand-controlled ventilation under ASHRAE 62-1989 thru -2001



* M. Schell, S. Turner, and R.O. Shim, "Application of CO_2-based demand-controlled ventilation using ASHRAE Standard 62: Optimizing energy use and ventilation," *ASHRAE Transactions*, 1998.

† A 2002 *Engineers Newsletter* (volume 31-3, "Using CO_2 for Demand-Controlled Ventilation") provides more detail on the mass balance equation and on implementing CO_2-based DCV to comply with ASHRAE 62-2001.

Figure 3. Comparison of potential DCV savings: ASHRAE 62-2001 versus ASHRAE 62.1-2004



of occupants in the zone (cfm/person) *and* the zone's floor area (cfm/ft²). Therefore, ASHRAE 62.1 prescribes two ventilation rates for each occupancy category: one for people-related sources (R_p) and another for building-related sources (R_a).

$$V_{bz} = (R_p \times P_z) + (R_a \times A_z)$$

where,

R_p = required outdoor airflow rate per person, cfm/person

P_z = zone population, number of people

R_a = required outdoor airflow rate per unit area, cfm/ft²

A_z = zone floor area, ft²

Let's revisit the lecture classroom in our example. ASHRAE 62.1-2004 requires 7.5 cfm of outdoor air per person *plus* 0.06 cfm of outdoor air per square foot of floor area (Figure 3). With a design population of 65 and a floor area of 1000 ft², the 2004 standard requires delivery of 550 cfm of outdoor air (7.5 cfm/person × 65 people + 0.06 cfm/ft² × 1000 ft²). And with only 20 people in the classroom, the required quantity of outdoor air drops to 210 cfm (7.5 cfm/person × 20 people + 0.06 cfm/ft² × 1000 ft²).

The comparison in Figure 3 reveals two important effects of the 2004 standard. First, the required design ventilation rate for this space type is much lower (550 cfm versus 975 cfm). By accounting for people- and building-related sources separately (described by some as "additivity"), ASHRAE 62.1-2004 results in lower breathing-zone ventilation rates for most occupancy categories than ASHRAE 62-1989 through -2001; see Table 1. In densely occupied spaces—those that historically benefited most from CO_2-based DCV, such as auditoriums, gyms, conference rooms, lecture classrooms, and cafeterias (shaded in the table)—the rates dropped dramatically.

Second, Figure 3 shows that as the zone population decreases, the required breathing-zone ventilation rate (V_{bz}) drops less rapidly … in this case, by 7.5 cfm for every person who leaves the zone under the 2004 standard versus 15 cfm/person under ASHRAE 62-1989 through -2001.

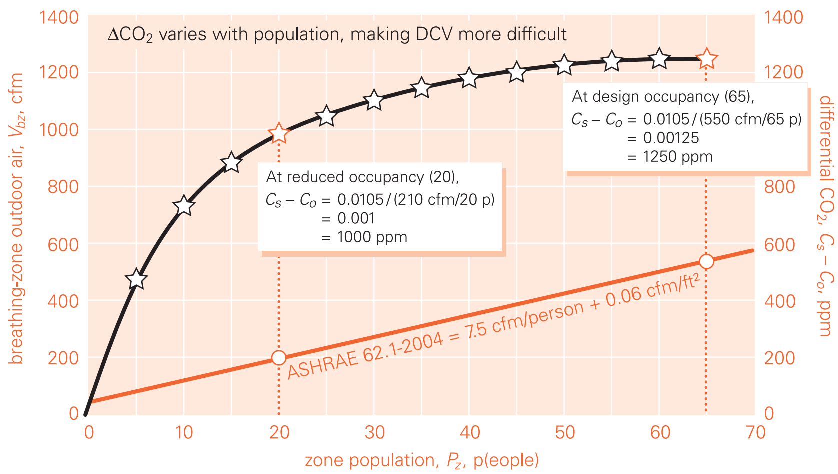
For these two reasons, *CO_2-based DCV under ASHRAE 62.1-2004 provides less potential energy savings for most space types* (Figure 3).

Table 1. Minimum ventilation rates in ASHRAE 62.1-2004 *versus* ASHRAE 62-1989 thru -2001

Occupancy category		Required ventilation, cfm/1000 ft² 62-1989 thru -2001	62.1-2004	Change[a] [(2004–1989)/1989]
Education	Art classroom	300	380	27%
	Classrooms (ages 5–8)	375	370	–1%
	Classrooms (ages 9 and up)	525	470	–10%
	Lecture classroom	975	550	–44%
	Multi-use assembly	1500	810	–46%
	Science labs	500	430	–14%
Food/beverage service	Bars, cocktail lounges	3000	930	–69%
	Cafeterias/fast food dining	2000	930	–54%
	Restaurant dining rooms	1400	705	–50%
General	Conference/meeting rooms	1000	310	–69%
	Corridors	50	60	20%
Lodging	Barracks/sleeping areas	300	160	–47%
Office	Office space	100	85	–15%
	Reception areas	450	210	–53%
Public assembly	Auditorium seating area	2250	810	–64%
Retail	Sales	300	230	–23%
	Supermarket	120	120	0%
Sports and entertainment	Gym, stadium (play area)	600	300	–50%
	Disco/dance floors	2500	2060	–18%
	Gambling casinos	3600	1080	–70%

[a] "Change" compares ASHRAE 62.1-2004 with ASHRAE 62-1989 (through -2001) using the default occupant densities in the 2004 standard.

Figure 4. Implementing CO_2-based DCV under ASHRAE 62.1-2004



Returning to our example and assuming the same CO_2 generation rate (N = 0.0105 cfm of CO_2/person), the indoor-to-outdoor difference in CO_2 concentrations is 1250 ppm at design occupancy. But, as the number of people in the space decreases, the desired indoor-to-outdoor difference in CO_2 concentrations changes because the effective outdoor airflow rate—on a cfm/person basis—is no longer constant. With 20 occupants, the 2004 version requires 210 cfm of outdoor air. This equates to 10.5 cfm/person, compared with 8.5 cfm/person at design occupancy. At 10.5 cfm/person, the desired difference in indoor-to-outdoor CO_2 concentrations drops to 1000 ppm when the zone population is 20 (Figure 4).

In ASHRAE 62.1-2004, the effective cfm/person ventilation rate (V_o) varies with population. Therefore, the desired difference in indoor-to-outdoor CO_2 concentrations, $C_s - C_o$, also varies. Controlling to a constant differential that's based on design occupancy will underventilate the zone at partial occupancy.

Bottom line, *ASHRAE 62.1-2004 makes it more difficult to implement CO_2-based DCV because the effective cfm/person, and (therefore) the desired difference between indoor and outdoor CO_2 concentrations, vary with occupancy* (Figure 4). More difficult … but not impossible.

CO_2-based DCV in a single-zone system

In an application where the ventilation system delivers fresh outdoor air to a single zone, the CO_2 sensor typically is installed on the wall in the breathing zone, just like the thermostat (Figure 5). It's usually expedient to assume that the outdoor CO_2 concentration is constant, so the indoor concentration (rather than the difference between indoors and outdoors) is measured and used to modulate the position of the outdoor-air damper and thereby provide the space with the proper amount of ventilation air on a per-person basis.

Compared to previous versions of the standard, ASHRAE 62.1-2004 requires a more complex control strategy for CO_2-based DCV. Following are two possible strategies—the "proportional control" approach that's described in the ASHRAE 62.1-2004 user's manual‡, and an alternative that requires fewer setpoints.

Proportional control. Appendix A of the ASHRAE 62.1-2004 user's manual discusses a method for implementing CO_2-based DCV in a single-zone system. A paraphrase of that method follows:

1 Find the required intake flow of outdoor air for the design zone population, P_z.

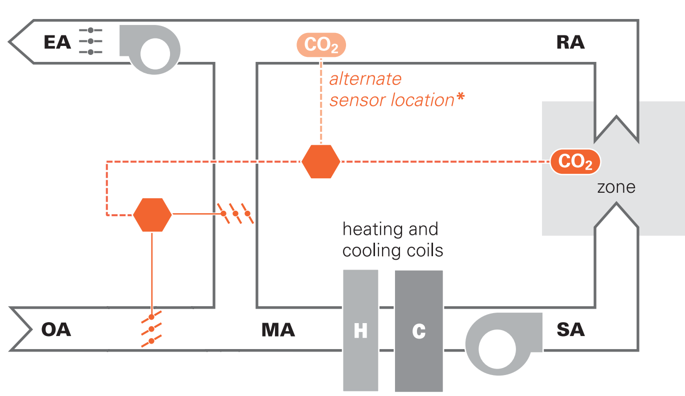
$$V_{ot\text{-}design} = V_{oz} = \frac{(R_p \times P_z) + (R_a \times A_z)}{E_z}$$

$$= \frac{(7.5 \times 65) + (0.06 \times 1000)}{1.0}$$

$$= 550 \text{ cfm}$$

‡ The *ASHRAE Standard 62.1-2004 User's Manual* is scheduled for release in October 2005. Visit ASHRAE's web site, http://www.ashrae.org, for availability and pricing.

Figure 5. CO_2-based DCV in a single-zone HVAC system



Because the recirculated air returns from only one zone, some designers prefer to place the CO_2 sensor in the return-air (RA) duct. But if any supply air bypasses the breathing zone, the sensor in the RA duct may register a less-than-actual indoor CO_2 concentration.

Figure 6. "Proportional control" strategy for CO_2-based DCV per ASHRAE 62.1-2004

Outdoor-air intake flow (V_{ot}) and CO_2 are proportional (or linear) to each other, but neither is linear with respect to zone population. The controller adjusts intake airflow (V_{ot}) in proportion to the percentage of the CO_2 signal range. But when the controller changes outdoor airflow, the indoor CO_2 concentration changes, too. So, the controller must adjust V_{ot} in small increments until the indoor CO_2 reaches a stable value. When plotted in relation to zone population, the results of these control actions are curves for both V_{ot} and indoor CO_2.

2 Find the required intake flow of outdoor air when the zone is unoccupied, that is, $P_z = 0$.

$$V_{ot\text{-}min} = \frac{(7.5 \times 0) + (0.06 \times 1000)}{1.0}$$
$$= 60 \text{ cfm}$$

3 Find the target indoor CO_2 concentration at $V_{ot\text{-}design}$.

$$C_{s\text{-}design} = C_o + \frac{N}{(V_{ot\text{-}design} / P_{z\text{-}design})}$$
$$= 350 \text{ ppm} + \frac{0.0105}{(550 \text{ cfm} / 65 \text{ people})}$$
$$= 1600 \text{ ppm}$$

4 Set the target indoor CO_2 concentration at $V_{ot\text{-}min}$ equal to the outdoor CO_2 concentration, C_o.

$$C_{s\text{-}min} = 350 \text{ ppm}$$

When the indoor CO_2 concentration equals $C_{s\text{-}design}$ (1600 ppm for our example), V_{ot} should equal $V_{ot\text{-}design}$ (550 cfm). When the concentration of CO_2 indoors equals $C_{s\text{-}min}$ (350 ppm), V_{ot} should equal $V_{ot\text{-}min}$ (60 cfm). When the indoor CO_2 concentration is between $C_{s\text{-}min}$ and $C_{s\text{-}design}$, a controller should adjust outdoor-air intake flow V_{ot} proportionally between $V_{ot\text{-}min}$ and $V_{ot\text{-}design}$:

$$V_{ot} = \frac{C_{s\text{-}actual} - C_{s\text{-}min}}{C_{s\text{-}design} - C_{s\text{-}min}} \times (V_{ot\text{-}design} - V_{ot\text{-}min}) + V_{ot\text{-}min}$$

As Figure 6 shows, the "proportional control" approach yields an outdoor-air intake flow (V_{ot}) that equals or exceeds the requirement of the 2004 standard. This control strategy is easy to implement, but it does overventilate the zone somewhat at partial occupancy. It requires a modulating outdoor-air damper, and a controller with two CO_2 limits ($C_{s\text{-}design}$, $C_{s\text{-}min}$) and two OA damper limits that correspond to intake airflows ($V_{ot\text{-}design}$, $V_{ot\text{-}min}$).

Note: A simple improvement to this approach is to use a value other than zero for minimum population ($P_{z\text{-}min}$). *In most cases, this results in actual intake values that more closely approach the minimum values required by the standard (less overventilation) than the approach described in the ASHRAE 62.1-2004 user's manual.*

Single setpoint. Following is an alternative control strategy that may result in less overventilation for some occupancy categories:

1 Pick a reasonable value (other than zero) to represent the minimum occupancy for the zone, $P_{z\text{-}min}$, and find the required intake flow of outdoor air for that population.

$$P_{z\text{-}min} = 25 \text{ people}$$
$$V_{ot\text{-}min} = \frac{(7.5 \times 25) + (0.06 \times 1000)}{1.0}$$
$$= 250 \text{ cfm}$$

2 Find the target indoor CO_2 concentration at $V_{ot\text{-}min}$.

$$C_{s\text{-}min} = C_o + \frac{N}{(V_{ot\text{-}min} / P_{z\text{-}min})}$$
$$= 350 \text{ ppm} + \frac{0.0105}{(250 \text{ cfm} / 25 \text{ people})}$$
$$= 1400 \text{ ppm}$$

Intake flow V_{ot} is adjusted to maintain the indoor CO_2 concentration at $C_{s\text{-}min}$ (1400 ppm) for any population. If the OA damper reaches $V_{ot\text{-}min}$ and the population in the zone continues to drop, the OA damper remains at $V_{ot\text{-}min}$. This overventilates the zone, so the indoor CO_2 concentration drifts downward. Conversely, as the current population nears design, the zone will be overventilated.

As Figure 7 (p. 6) shows, the "single setpoint" approach results in an outdoor-air intake flow (V_{ot}) that equals or exceeds the ventilation rate required by ASHRAE 62.1-2004. It's simple to implement; and, depending on the characteristics of the zone, it may result in less overventilation at partial occupancy than the "proportional control" method. It also requires a modulating outdoor air damper, but the controller needs only one OA-damper setpoint ($V_{ot\text{-}min}$) and one CO_2 setpoint ($C_{s\text{-}min}$) rather than two limits for each.

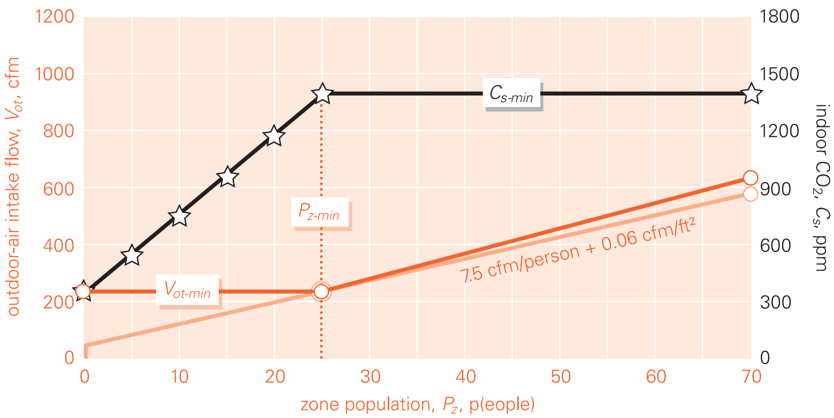


Figure 7. "Single setpoint" control strategy for CO_2-based DCV per ASHRAE 62.1-2004

CO_2-based DCV in a multiple-zone VAV system

In a multiple-zone VAV system, the ventilation system delivers fresh outdoor air to several, individually controlled spaces.

CO_2-based DCV alone. One approach for implementing CO_2-based DCV in multiple-zone VAV system is to install a CO_2 sensor in every zone. A building automation system (BAS) monitors all the sensors, determines how much outdoor air must be brought in at the air handler to satisfy the critical zone (and thus overventilate all other zones), and then repositions the outdoor air damper accordingly.

However, it's costly to install a CO_2 sensor in every zone. Especially when you consider that most of the zones will always be overventilated, regardless of operating conditions. Installing a sensor in those "non-critical" zones offers no added value. In some applications, you may know that only a handful of zones will ever be "critical," and you could choose to locate CO_2 sensors only in those potentially critical zones. The user's manual for ASHRAE 62.1-2004 discusses this approach further.

Alternatively, some designers opt to install a single CO_2 sensor in the return-air duct of a multiple-zone system, and then use this single sensor to vary the amount of outdoor air brought in at the air handler. However, this CO_2 sensor measures the *average* CO_2 concentration, so it's likely that some spaces will be underventilated while others are overventilated. Whether this approach provides adequate ventilation is a matter of debate among designers.

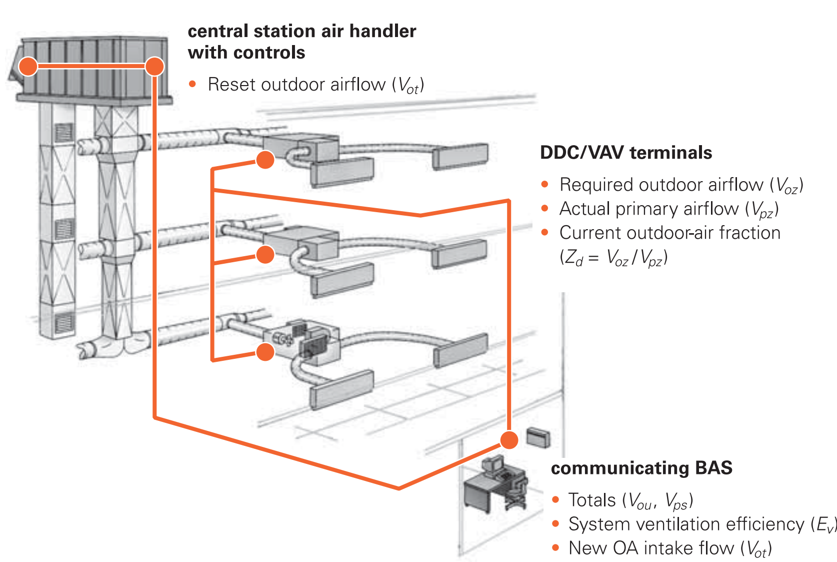
Ventilation reset alone. Another control strategy for multiple-zone VAV systems—called *ventilation reset*—resets intake airflow in response to variations in system ventilation efficiency.

Each VAV box controller senses the current primary airflow (V_{pz}) and calculates its outdoor-air fraction (Z_d). The building automation system totals the primary airflows and required outdoor airflows from all boxes, and determines the highest outdoor-air fraction reported. Then it solves the equations from Appendix A of ASHRAE 62.1-2004, calculating the system ventilation efficiency (E_v) and the system-level intake flow of outdoor air (V_{ot}) that's required at the current operating condition. The new intake-flow setpoint is communicated to the air handler controller, which then adjusts the OA damper accordingly to bring in the required amount of outdoor air (Figure 8).

In DDC/VAV systems, this strategy is fairly easy to implement because all of the necessary real-time information is already available digitally (so no new sensors are required). All of the equations are defined in Appendix A of the standard and can be solved dynamically to find the outdoor-air intake flow that's currently required.

CO_2-based DCV combined with ventilation reset. In most multiple-zone VAV systems, the best approach often combines CO_2-based DCV with ventilation reset. Using this strategy,

Figure 8. Control points for ventilation reset in a multiple-zone VAV system



CO_2 sensors are installed only in those zones (conference rooms, for example) that are densely occupied and experience widely varying patterns of occupancy.

The sensors in these zones are used to reset the ventilation requirement (V_{oz}) for their respective zones. The other zones—which either are not densely occupied or do not experience significant variations in occupancy—are assumed to require their design ventilation rates whenever they're occupied. The BAS then uses the ventilation reset equations to determine how much outdoor air must be brought in at the air handler to satisfy all of the zones served.

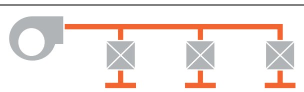
For the example VAV system represented in Table 2, Zone 1 is a conference room (which is densely occupied and has a widely varying population), and Zones 2 and 3 are general office spaces (which are more sparsely and more consistently occupied). The top section of the table shows the system operating at part load, when ventilation reset is used to reduce the outdoor-air intake flow (V_{ot}) and thereby account for the current system ventilation efficiency. For this case, it is assumed that all zones, including the conference room, require their design zone outdoor airflows (V_{oz}), regardless of actual population.

The lower section of Table 2 represents the same system, but a CO_2 sensor is installed only in Zone 1 to reduce the required zone outdoor airflow (V_{oz}) from the design value of 500 cfm to 200 cfm when the actual population in the conference room is less than design. Zones 2 and 3 still require their design outdoor airflows. While sensing CO_2 and finding the current value for Zone 1 V_{oz} lowers the average outdoor-air fraction (X_s), it increases system ventilation efficiency (E_v) and lowers the required intake airflow (V_{ot}) from 2370 cfm to 1530 cfm.

Combining CO_2-based DCV with ventilation reset provides two benefits:

- It can assure that each zone receives the proper amount of ventilation without requiring a CO_2 sensor in every zone. CO_2 sensors are used only in those zones where they will bring the most benefit. When the other zones are unoccupied, time-of-day schedules or occupancy sensors are used to reduce ventilation.
- It enables documentation of actual ventilation-system performance by communicating the ventilation airflows for every zone to the BAS.

Table 2. Effect of ventilation control strategies in a single-duct VAV system at part load



		Zone 1	Zone 2	Zone 3		Total OA intake flow, V_{ot}
Ventilation reset only						
Primary airflow, cfm	V_{pz}	1000	3000	3000	= 7000 cfm	**2370 cfm**
Zone outdoor airflow, cfm	V_{oz}	500	600	700	= 1800 cfm	
OA fraction	Z_d	0.50	0.20	0.23		
Zone ventilation efficiency	E_{vz}	0.76	1.06	1.03		
	X_s = 1800/7000 = 0.26, E_v = 0.76, V_{ot} = 1800/0.76 = 2370					
Ventilation reset *plus* CO_2-based DCV in Zone 1						
Primary airflow	V_{pz}	1000	3000	3000	= 7000 cfm	**1530 cfm**
Zone outdoor airflow	V_{oz}	**200**	600	700	= 1500 cfm	
OA fraction	Z_d	0.20	0.20	0.23		
Zone ventilation efficiency	E_{vz}	1.01	1.01	0.98		
	X_s = 1500/7000 = 0.21, E_v = 0.98, V_{ot} = 1500/0.98 = 1530					

Closing thoughts

Demand-controlled ventilation can reduce the cost of operating the HVAC system—especially in applications where contaminant levels result primarily from people (or their activities) and where population varies significantly. The most common applications include gymnasiums, meeting rooms, and auditoriums.

ASHRAE 62.1-2004 explicitly allows the use of demand-controlled ventilation based on CO_2 to reset intake airflow in response to variations in zone population. However, it also reduces the value of implementing CO_2-based DCV in most space types by reducing the required design ventilation rates. For densely occupied spaces (those that historically benefited most from using CO_2-based DCV), the ventilation rates are dramatically lower.

The 2004 standard also complicates implementation of CO_2-based DCV. That's because the effective cfm/person, and (therefore) the desired indoor-to-outdoor difference in CO_2 concentrations, vary as the zone population changes.

CO_2-based DCV is most commonly used in single-zone systems that serve densely occupied spaces with varying populations. In multiple-zone VAV systems, combining CO_2-based DCV with ventilation reset—using CO_2 sensors only in densely occupied zones with widely varying populations—provides a cost-effective, reliable, and energy-efficient system. •

By John Murphy, application engineer, and Brenda Bradley, information designer, both of Trane. You can find this and previous issues of the *Engineers Newsletter* at http://www.trane.com/commercial/library/newsletters.asp. To comment, e-mail us at comfort@trane.com.

Trane
A business of American Standard Companies
www.trane.com

For more information, contact your local Trane office or e-mail us at comfort@trane.com

ADM-APN017-EN (November 2005)