

DEMAND CONTROL VENTILATION (DCV)

Carbon Dioxide (CO₂)-based demand controlled ventilation (DCV) is increasingly used to modulate outside air ventilation based on real-time occupancy. Measurement and control technology using CO₂ sensors is quickly evolving to a stage of maturity where cost and reliability will likely approach that of conventional temperature measurement and control in the near future. As a result, the use of CO₂ as an indoor comfort, ventilation and air quality control parameter has the potential to become as common as thermostatic control is today. Like any other control system, the success of CO₂-based DCV application is dependent on how it is engineered, installed and maintained.

An indoor CO₂ contaminant level provides a dynamic measure of the balance between CO₂ generation in the space, representing occupancy, measured in part per million (ppm) and the amount of low CO₂ concentration outside air introduced for ventilation. The net effect is that it is possible to use CO₂ concentration to determine and control the fresh air dilution rate in a space on a per person basis.

Carbon Dioxide (CO₂) and Demand Control Ventilation DCV

CO₂ is one of the most common gases found in our atmosphere. As a point of reference, concentration in the center of the Pacific Ocean has been measured at 366 ppm and this considered as the lowest concentration found worldwide. In urban areas, outdoor concentrations have been in the 375 to 450 ppm range,

CO₂ is not considered harmful nor a contaminant at the levels of 400 to 2000 ppm normally found in buildings. Perceptions of poor air quality associated with elevated CO₂ levels are more indicative of the buildup of other contaminants as a result of reduced per person ventilation in a space rather than the direct effect of CO₂. All humans, given a similar activity level, exhale CO₂ at a predictable rate based on occupant age and activity level. This relationship is described in ASHRAE standard 62. For HVAC applications, CO₂ best used as an indicator for fresh air ventilation on a per person basis.

The relationship between CO₂ production and body odor is that CO₂ levels increase or decrease in relation to human metabolic activity. Since CO₂ is a good indicator of human metabolic activity, it could also be used as a tracer for other human emitted bio effluents.

High levels of CO₂ can cause nausea, headaches and dizziness. Adults usually can tolerate CO₂ concentration of 1,000 ppm, and children usually can tolerate 500 ppm. Outside air dampers should open to allow enough air to enter a building to keep the CO₂ level below 1,000 ppm.

As this technology has developed, so have codes and standards. The International Mechanical Code (IMC), the mechanical code of reference for most local building code bodies in the United States, has included provisions for CO₂-based DCV. IMC codes states that "The minimum flow rate of the outdoor air that the ventilation system should be capable of supplying during its operation shall be permitted to be used on the rate per person indicated in their standard and the actual number of occupants present"

Also ASHRAE standard 62 has clarified the use of CO₂ as a parameter that can be used for controlling ventilation based on actual real-time occupancy while still maintaining target cfm-per-person ventilation rates.

BENEFITS OF CO₂ -BASED DEMAND CONTROL VENTILATION DCV

CO₂ – based DCV does not affect the design ventilation capacity required to serve the space; it just controls the operation of the system to be more in tune with how a building actually operates.

- ◆ Excessive over-ventilation is avoided while still maintaining good Indoor Air Quality (IAQ) and providing the required cfm-per-person outside air requirement specified by codes and standards. ASHRAE Technical Committee has observed operational energy savings. This observation has been verified in a recent literature review on CO₂ control that cited studies where energy savings from DCV control approaches ranged from 5% to 80% versus a fixed ventilation strategy. System paybacks can range from a few months to two years and are often substantial enough to help pay for other system or building upgrades.
- ◆ The payback from CO₂ –based DCV will be greatest in higher density spaces that are subject to variable or intermittent occupancy that would have normally used a fixed ventilation strategy (e.g., theaters, schools, retail establishments, meeting and conference areas).
- ◆ In spaces with more static occupancies (e.g. offices), CO₂ –based DCV can provide control and verification that adequate ventilation is providing to all spaces. For example, a building operator may arbitrarily and accidentally establish a fixed air intake damper position that results in over or under ventilation of all or parts of a space. A CO₂ control strategy can ensure the position of the intake air dampers is appropriate for the ventilation needs and occupancy of the ventilated space at all times. This may save additional energy when outside air intakes are arbitrarily set to over-ventilation.
- ◆ In some buildings, infiltration air or open windows may be a significant source of outside air. A CO₂ sensor will consider the contribution of infiltration in a space and only require the mechanical system to make up what is necessary to meet required ventilation levels. The savings are in addition to those quoted earlier.

- ◆ When integrated with the appropriate building control strategy, ventilation can be controlled zone by zone based on actual occupancy. This allows for the use of supply air from under-occupied zones to be redistributed to areas where more ventilation or cooling is needed.
- ◆ A CO₂ control strategy can be used to maintain any per-person ventilation rate. As a result this approach is highly adaptable to changing building uses and any changes that may occur in future recommended ventilation rates.

DESIGN/INSTALLATION RECOMMENDED GUIDELINES

**** General guidelines**

- ◆ The objective of a CO₂ control strategy is to modulate ventilation to maintain target cfm/person ventilation rates based on actual occupancy. The strategy should allow for reduced overall ventilation during period of occupancy that are less than full occupancy and as a result save energy. Typical control approaches have used a proportional control algorithm to modulate ventilation between a base ventilation rate established non-occupant-related sources and the design ventilation rate for the space. Modulation of outside air above base ventilation begins when indoor CO₂ is above the high limit set by the CO₂ sensor. The outdoor damper OA modulates above the minimum setting of the OA damper.
- ◆ Duct mounted CO₂ sensors are best used where a single space or multiple spaces with common occupancy patterns are being ventilated. The most common area of installation is directly in the return air ductwork or inside the return air plenum.
- ◆ Wall mounted CO₂ sensors are recommended for multiple units installation where the return air may not be representative of what is actually happening in the particular space.
- ◆ In setting the minimum outdoor damper, ventilation rates should not be reduced below 20% to 50% of design. Maintaining this minimum rate supplies sufficient ventilation air to dilute building contaminant sources, even at low occupancy levels.
- ◆ Most of the CO₂ sensors have analog output of 0-10 VDC or 4-20mA correspond to 0-2000 ppm CO₂ concentration. Setting value of the CO₂ level on the economizer/IAQ controller should be based on the difference between the maximum designed outside air and the minimum setting on the OA damper.

**** When to Use Outdoor Air CO₂ Sensing**

CO₂-based demand controlled ventilation is based on the principle that the differential between inside and outside concentrations can give an indication of the ventilation requirement rate in the space. As a general rule of thumb, an inside/outside differential of 700 ppm is indicative of a ventilation rate of 15cfm/person (7 L/s). An inside/outside differential of 500 ppm is indicative of a 20 cfm/person (9 L/s) ventilation rate.

For most applications, outside air can be assumed to be at 400±50 ppm. As a result most control strategies will work well if the designer or installer assumes outside levels are at 400 ppm. Even if outside concentrations are higher than 500 ppm, and 400 ppm is used as the assumed outside level, the only impact will be that the space will be slightly over ventilated by about 2 cfm/person (0.9 L/s) during those periods when outside levels are elevated. Since the lowest levels are approximately 366 ppm, a conservative maximum under-ventilation effect of assuming a 400-ppm outside level is less than 1 cfm per person (0.47 L/s).

Elevated outside CO₂ levels are generally due to the presence of localized combustion sources such as vehicles, power plants, or building exhausts. If elevated levels are measured, it may be a function of the location of outside air intakes related to localized combustion sources. In these applications and if deemed necessary by the designer, CO₂ sensors are installed outdoor to ensure that ventilation rates are controlled based on real-time differential between inside and outside CO₂ concentrations.

**** Setting of the outdoor air damper for the minimum outside air**

By knowing the temperature of the outside air and the temperature of the return air, you can determine the temperature of the mixed air that enters the inlet side of the supply blower. Use the following equation:

$$\text{MAT} = (\text{OAT} \times \% \text{OA}) + (\text{RAT} \times \% \text{RA})$$

Where

MAT = mixed air temperature
OAT = outside air temperature
%OA = % of outside temperature
RAT = return air temperature
%RA = % of return air volume

Let's say that the temperature of the return air is 80°F, and that the temperature of the outside air is 40°F. Assume that you're working on a building that requires a mixture of 10% outside air and 90% return air. Then:

$$\begin{aligned} \text{MAT} &= (40^\circ\text{F} \times 0.1) + (80^\circ\text{F} \times 0.9) \\ &= 4 + 72 \\ &= 76^\circ\text{F} \end{aligned}$$

Now you know that the temperature of the mixed air should be 76°F.

If you are commissioning a 10-ton unit that moves 4,000 cfm of air, you also know that you want about 400 cfm of outside air (10% of 4,000).

Measure the temperature of the air at the blower inlet. If the mixed air temperature is above 76°F, then the amount of outside air is less than 10%, or 400 cfm. If the mixed air temperature is below 76°F, then the amount of outside air is more than 10%, or 400 cfm. In either case, you can adjust the dampers accordingly. Within a short period of time, you can take another temperature reading to determine whether the dampers have been adjusted properly.