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Application Note

# Using $CO_2$ For Zone Ventilation Control In Buildings: Answers To 12 Common Questions/Objections

Ventilation control using $CO_2$ is one of the fastest growing building control strategies being implemented in new and retrofit building projects today. This approach can provide better control of building ventilation, help assure tenant comfort and reduce complaints while reduce operating costs related to ventilation. Outlined below are the answers to 12 of the most common questions that a building owner may ask about using $CO_2$ to control ventilation in buildings. The answers are provided on the following pages.

### 1. Is $CO_2$ a contaminant that must be controlled in buildings?

At the concentrations typically measured in buildings (400-2,500 ppm), carbon dioxide is not considered to be a health threatening contaminant. The real value in $CO_2$ sensing in buildings is to estimate the cfm- per-person ventilation rate in the space. This method of ventilation measurement described in ASTM Guide Standard D6248-98, considers the $CO_2$ concentration difference between inside and outside. Inside $CO_2$ levels are a dynamic measure of the number of people in the space exhaling $CO_2$ and mixing with the amount of lower $CO_2$ concentration air introduced from outside for ventilation. A fairly simple calculation allows the calculation of a cfm per person ventilation rate based on $CO_2$ inside/outside differential.

Some portable hand held $CO_2$ monitors are available that will automatically calculates and displays the cfm/person based on $CO_2$ concentrations.

If a hand held sensor is used to perform a spot measurement to determine ventilation rates it is best performed 2 to 3 hours after occupancy has started. For permanently mounted sensors, the control algorithms used with these sensors constantly measure $CO_2$ concentrations to enable calculation of ventilation rates and control of ventilation.

### 2. What is new about $CO_2$ based ventilation control.

Ventilation control using $CO_2$ is an enhancement of existing ventilation practices in buildings and allows the control of ventilation on a zone-by-zone basis much like we control temperature today. Currently, all commercial buildings with mechanical ventilation provide some amount of outside air for dilution of contaminants and odors. In most systems, dampers are adjusted and set to provide a fixed amount of outside air based on providing a code required ventilation rate (e.g. 15 cfm/person) times the number of occupants in the building (the design ventilation rate). There is no real control in this approach. The system is designed, and a fixed ventilation rate is set or controlled by dampers for the life of a building. In some cases airflow may be measured and regulated to ensure that the fixed amount of outside air stays constant as air movement in the system changes. The designer must take great care to make sure the duct distribution system is designed so it can deliver the right amount of outside air to each zone in the space based on it's intended occupancy. However, until recently there has not been a simple way to measure the ventilation rate in each zone to ensure that the right amount of fresh air is getting to every space.

In buildings that incorporate ventilation control using $CO_2$, the system is designed and sized the same as it always was. The use of ventilation control with $CO_2$ affects how the building is operated rather than how it is designed. What is different is that sensors are placed into each occupied zone to measure the ventilation rate being delivered to the space. Airflow to each zone and at the central air intake is then regulated to ensure the code required ventilation rate per person is provided to each zone based on actual occupancy. This approach is similar to temperature control in that a sensor in each space measures and regulates the delivery of warm or cool air to ensure comfort. Now ventilation can be measured and controlled in the same way.

### 3. So what does zone ventilation control with $CO_2$ mean to a building owner, operator or tenant?

Ventilation control allows measurement and control of fresh air to each space based on its occupancy ensuring adequate air is delivered to each space to ensure comfort and minimize complaints. An often

used saying in quality control is that you cant control something unless you measure it. This approach to ventilation control actively measures ventilation rates in the space and adjusts airflow appropriately. Some advantages of this approach include:

- Building owners can record ventilation levels and monitor the system to ensure the system is operating as designed. Potential problems related to ventilation can be identified quickly and fixed before building occupants become aware of a problem. Maintaining consistent ventilation throughout a building can ensure comfort.
- If occupancy in certain zones varies during the day, ventilation rates can be adjusted up or down to provide the right amount of ventilation per person based on occupancy (e.g. 15 cfm/person). In most buildings adding ventilation control has resulted in energy savings that can payback installation costs in less than a year.
- If usage and density within a space changes from the original design assumptions (i.e. 3 people in a space originally designed for 1) the system will automatically adjust to provide adequate ventilation for additional or less people. Without ventilation control, expensive mechanical changes may be necessary to ensure adequate ventilation.
- If outside air is entering the space via an open window, door or as a result of infiltration, a $CO_2$ sensor will count this air as ventilation air and reduce the amount of mechanical ventilation that has to be conditioned from outside sources. Also if a room is unoccupied and has built up a reservoir of fresh air the ventilation control system will start to use this air before drawing more air from outside.
- Even if occupancy is very consistent throughout the day, ventilation control with $CO_2$ can ensure that just the right amount of outside air is provided for people in the space. By measuring and controlling ventilation unnecessary over or under ventilation is avoided.

### 4. Do current ventilation codes and standards permit $CO_2$ based ventilation control?

If a code requires ventilation to be provided to a space in terms of cfm/person, $CO_2$ based ventilation measurement can be used to verify compliance to the code or to control ventilation rates to code required levels (e.g. 15 cfm/person). All local codes and standards draw recommendations for ventilation from one of two references: ASHRAE Standard 62- 1999 “Ventilation For Acceptable Indoor Air Quality” or the International Mechanical Code (IMC). It is these documents that have established the target cfm/person ventilation rates included in all codes today.

In the ASHRAE Standard 62, $CO_2$ based ventilation control is applied under the prescriptive Ventilation Rate Procedure. In this procedure there is a provision for intermittent and variable occupancy that allows the total ventilation rate to a space to be varied as long as the target cfm/person ventilation rate is maintained for the actual occupancy of the space. ASHRAE interpretation IC 62-1999-33 provides further details specific to ventilation control with $CO_2$ and recommends that a base ventilation rate should be provided to provide a minimum level of ventilation when the space has low occupancy. In practice this base ventilation rate is typically 20-30% of the design ventilation rate or about 5% of total ventilation capacity.

In the International Mechanical Code (2000) section 403.3.1 “System Operation”, the code states that: “the minimum flow rate of outdoor air that the ventilation system must be capable of supplying during its operation shall be permitted to be based on the rate per person indicated in table 403.3 and the actual number of occupants present”. In the commentary to the code which provides examples and explanations for the IMC, $CO_2$ based ventilation control is cited as an ideal technology that could use this section of the code. It is important to note that the IMC titles this section System Operation indicating that this approach is not a design approach but more an operational strategy for ventilation control.

In summary the two most important ventilation references to local codes and standards clearly establish that ventilation rates should be provided in terms of a specified ventilation rate per person. While traditional practice has been to provide a fixed rate of ventilation assuming maximum occupancy, both references clearly enable systems to be operated to provide the target cfm/person ventilation rate based on actual occupancy. This is how $CO_2$ ventilation control is properly applied. If a local code has a provision for providing a cfm/person ventilation rate in a space, $CO_2$ based ventilation control can be applied.

It is interesting to note that the U.S. Green Buildings Council encourages the use of $CO_2$ based ventilation control as part of its LEEDs certification program for green and sustainable buildings.

### 5. I have heard that $CO_2$ is not a contaminant in buildings (as mentioned above) but it is linked to other bio-effluents given off by people. I have also heard there is no link between $CO_2$ and other sources of contaminants in a building like furnishings and equipment. If this is the case how can we use $CO_2$ for control of ventilation?

$CO_2$ based ventilation control does not consider $CO_2$ as a contaminant. $CO_2$ sensors in building allow measurement and control of ventilation on a per person basis as established by codes and standards. These cfm/person rates, as established in ASHRAE Standard 62 have been designed to consider all contaminants within a space. This is why ventilation rates are different for different applications in many codes and standards. For example

in ASHRAE Standard 62 ventilation rates for school classrooms are typically 15 cfm/per person because it is considered that with the high densities in a classroom people will be the major source of contaminants that require ventilation. In a office space the ventilation rate has been established a 20 cfm per person because it is assumed that in addition to people, there will be other sources like carpets, furnishings and equipment that will also be a source of indoor air contaminants. In areas where smoking is permitted, ventilation rates have been raised to 30 cfm to take into account the need for additional ventilation to control for additional smoke and odors. When used to control ventilation $CO_2$ is only used to measure ventilation rate. $CO_2$ can be used to measure and control any cfm/person ventilation requirement.

**6. I am certain that $CO_2$ is an air quality parameter. I have been in rooms where when $CO^2$ levels are high and the air quality appears low. People are tired, lethargic, some may even have headaches and the air seems stale. $CO_2$ must have something to do with this!**

What you have observed is the relationship between ventilation and $CO_2$ levels. When $CO_2$ levels are elevated it indicates low ventilation rates. When ventilation rates are low, all the other gases and contaminants in a space build up along with $CO_2$ concentrations. The physical reactions you are feeling and observing are a result of the low ventilation levels and higher exposure to other contaminants. Like the canary in the coal mine, $CO_2$ is an indicator, not the cause.

**7. Since calculation of ventilation rates is based on the difference between inside and outside $CO_2$ levels, wont changing outside levels affect the accuracy of the ventilation measurement?**

Daily or seasonal variations in any one location may vary by 20 to 30 ppm, which is not enough to significantly affect the ventilation calculation. Outside concentrations throughout the world typically range from a low of 380 ppm up to 500 ppm. System designers should take a few outside measurements to determine what outside levels are in their area and take these readings into consideration when setting up a ventilation control system based on $CO_2$. $CO_2$ sensors can also be permanently installed in outside air to provide real time calculation of ventilation based on inside outside $CO_2$ differences. This may be overkill however. If a designer assumes outside levels are 400 ppm and the actual outside concentration is 500 ppm, the effect on the ventilation control strategy is that ventilation rates will be higher by about 2 cfm/person than the design. This error is in the occupant's favor and will only have a slightly negative affect of energy usage.

**8. Should ventilation control be considered a competitive technology to other energy saving technologies such as fresh air economizers and energy wheels?**

All these technologies are complimentary. If outside air can be used for free cooling a economizer control should be designed to override $CO_2$ control in a building. When outside air is not suitable for free cooling $CO_2$ control can ensure that just the right amount of air to meet the building ventilation requirements is heated, cooled or dehumidified. When one system is not operational the other is depending on outside conditions. Combined both technologies will work year round to provide good ventilation and energy savings.

Energy wheels are a terrific way to reduce the cost of preconditioning outside air before it is heated or cooled. However, ventilation control with $CO_2$ can be used to vary ventilation rates based on the demands in the space. If less air is required at certain times of the day then the amount of energy used by fans and air conditioning equipment can be reduced. An energy wheel will reduce the cost of heating or cooling air coming into a space. Ventilation control with $CO_2$ will ensure that the fresh air entering the building is distributed to where it is required. Again both technologies serve different purposes, both save energy and their use complements each other.

**9. I have heard that $CO_2$ sensors are fragile and difficult to maintain often requiring frequent calibration. Is this still true?**

The sensor technology for measurement of $CO_2$ for ventilation control has been around for over ten years. When the technology first appeared there were some problems with sensor drift and reliability. Today all major building control and equipment companies offer $CO_2$ based ventilation control and most sensors are designed to operate for five or more years without any maintenance. Like any product you should choose a brand name you trust when you want reliable $CO_2$ based ventilation control.

**10. Where should $CO_2$ sensors be placed? Can I place them in the return air ducts of my building or should I put them in the space?**

The use of duct sensors for ventilation control with $CO_2$ is discouraged for the same reason that space temperature is not controlled by in-duct temperature sensors. Return air ducts draw air from a number of different spaces that may have different concentrations of $CO_2$. A duct concentration only represents an average of conditions and not the actual conditions within a space. The goal of ensuring each space has the right amount of ventilation can only be accomplished by placing sensors within the space. Duct sensing would only be acceptable if an air handler served a single zone.

Many manufacturers are now offering combined $CO_2$ and temperature, wall-mount sensors that are inexpensive and provide sensing for both temperature control and ventilation control.

**11. There are a number of systems on the market that measure and regulate outside airflow as it enters a building. Do these devices provide the same type of ventilation control as a $CO_2$ based system?**

Airflow monitoring stations are typically used on heating and air conditioning systems that utilize Variable Air Volume Systems (VAV) where the total air delivered to the building varies based on the total need for heating or cooling in all building zones. These airflow measurement and control systems are intended to ensure that a fixed rate of outside air is provided as total airflows within the system vary. This type of device cannot regulate or measure airflows to each zone within the space. All this equipment does is ensure that enough air to meet the ventilation requirements for full occupancy are provided at all times at the air intake. These systems have nothing to do with measuring and controlling ventilation in various building zones. In fact in many cases these systems will tend to unnecessarily over-ventilate a building as the system tries to ensure that fresh air is delivered to every zone under all operating conditions. If $CO_2$ control is utilized there is no need for this expensive type of air monitoring and flow control equipment.

**12. Can ventilation control using $CO_2$ be retrofitted into existing buildings?**

If equipment is being changed out as part of the retrofit, integrating $CO_2$ control is relatively easy if a DDC (direct digital building control system is being installed as part of the retrofit). Depending on the system manufacturer, the control algorithms may already be incorporated into their building control system. In some cases some custom programming may be necessary if provisions for $CO_2$ control are not already in the package you are purchasing. It is important to note that the cost savings related to integrating $CO_2$ control can be significant enough to help pay for other building upgrades.

If your building already has a DDC system, adding $CO_2$ may be as simple as placing the sensors in the space and wiring them to the existing system. The Ventilation signal from the $CO_2$ sensor can be used to regulate individual VAV boxes or fresh air introduced at each floor. Again some custom programming may be required to ensure the proper ventilation control algorithms are applied. Check with you controls or building contractor to find out how to perform this type of upgrade.

When contemplating upgrading to $CO_2$ based ventilation control , the most important factor is how is the delivery of fresh air regulated to the space right now. If the space you want to provide control in is served by a rooftop air handler with an economizer control the installation can be as simple as running wires from the $CO_2$ sensors to the rooftop unit. The signal from the $CO_2$ sensor can provide a direct control signal to adjust the air intake dampers. If multiple zones are involved, one $CO_2$ sensor should be placed in each major zone. The output of all zone sensors should be passed through a transducer that takes all the signals and passes through the highest value. That way the system is controlling the space that needs the most amount of ventilation air. This approach can be applied to retail space, schools, and other common low rise building applications.

For a $CO_2$ ventilation retrofit in large buildings, it is necessary to understand how air is delivered to the building and to each floor. If $CO_2$ sensors are to be installed they must be able to control something. In this type of application an ability to modulate ventilation at the air intake and at each floor plate is important. If you do not have this capability it will have to be installed as part of the ventilation control upgrade. Sensors would be placed in each major occupancy zone on each floor. Much like the rooftop example discussed above, the fresh air introduced at each floor should be regulated by the sensor providing the highest reading on the floor. Some control feedback from each floor should be provided to the central air intake to open or close depending on overall demand for fresh air in the building. Your building controls contractor should be able to design a ventilation control system to accommodate the control system you already have.

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