



CARBON DIOXIDE MONITORING

All buildings are required by building codes to provide either natural or mechanical ventilation. Often the requirements for natural ventilation cannot be met or may not provide adequate ventilation for comfort; therefore, a majority of HVAC designs incorporate mechanical ventilation. Ventilation can be a significant component of equipment heating and cooling load, especially when designing buildings in locations experiencing extreme heating or cooling conditions, or in areas with high humidity. Ventilation rates are typically determined based on a prescribed minimum flow rate of outside air per occupant, defined by building codes. As designers, we realize that a majority of the densely occupied spaces are only occupied to full capacity for a small percentage of the time. The result is excessive ventilation rates a majority of the time. These excessive ventilation rates directly correlate to unnecessary expenditure in operational costs. A potential solution is to allow the ventilation flow rate to fluctuate based on space occupancy monitored by a carbon dioxide (CO₂) sensor.



LEED APPLICATION

The application and use of CO₂ sensors should be considered to conserve energy and decrease an owner's operational costs. There is rising interest in the building industry to design with a more environmentally friendly focus. Some areas of the country are actually requiring that new buildings be registered with the Leadership in Energy and Environmental Design (LEED) program. LEED is a program administered by the United States Green Building Council that uses a Green Building Rating System to register and certify the world's greenest buildings. Use of a CO₂ sensor as a method of monitoring and controlling the ventilation rate to a facility can potentially earn one of the 69 points available in the LEED certification process.

GREEN BUILDING ISSUES

Application of CO₂ sensors in an HVAC system not only has the potential to reduce energy consumption but also may improve indoor air quality (IAQ). Realizing that most of the buildings we design are occupied, our ultimate concern should be for those occupants' health and safety.

Improving and monitoring IAQ through use of CO₂ sensors is one fairly simple and relatively inexpensive option. Based on findings documented in the article, "Building Air Quality: A Guide for Building Owners and Facility Managers" produced in 1991 by the U.S. Environmental Protection Agency, good IAQ results in improved employee productivity, comfort level, and health. If this improvement is not reason enough to encourage an owner to implement a CO₂ monitoring system, the following list of potential consequences related to poor IAQ may serve as sufficient influence:

- employee health problems
- decreased employee productivity
- increased employee absenteeism
- accelerated deterioration of furnishings
- negative publicity of property jeopardizing resale
- potential litigation

Application of a CO₂ monitoring system is only a minor expense compared to the possible penalties listed above.

A CO₂ sensor and additional related control programming will be an additional cost applied to the initial budget of a project. There will also be annual calibration and maintenance expenses that will need to be budgeted. The initial cost for the sensor is \$250-\$500, and it can be expected there will be approximately a \$1000-\$1500 addition to the initial controls contract for each sensor point. At first glance, this increased initial cost could be a deterrent to applying a modulating ventilation system. When examined more thoroughly from a fiscal point of view, this system and its initial cost is something that can be easily justified. The ability to decrease the amount of ventilation air and the annual savings related to not having to heat or cool this air, in most areas of the country, can quickly pay for the additional initial and annual costs of implementing CO₂ sensors. This does not take into account the potential increased profit due to greater employee satisfaction and health or the defense cost from litigation related to IAQ.



DESIGN/CONSTRUCTION APPLICATION

What is CO₂?

CO₂ is an odorless colorless gas that is produced in one of three primary ways:

1. metabolic activity (exhaled by humans)
2. combustion processes
3. motor vehicles

What is a safe level of exposure to CO₂?

Carbon dioxide is not considered dangerous until extreme levels of contamination are reached. This level outlined by OSHA is defined as >5,000 ppm for an extended time period and >30,000 ppm for a period of 15 minutes. These levels are rarely seen in a standard building environment and most CO₂ sensors are limited to a 2,000 ppm reading.

Why does ASHRAE Standard 62- 2001 define the recommended design limit to be 1000 ppm when this level is significantly lower than what is dangerous to the occupant?

ASHRAE 62-2001 recommends that the CO₂ level not exceed 700 ppm above outside conditions. A typical outside CO₂ reading is between 250 – 350 ppm. The standards defined by ASHRAE are not actually developed to address the CO₂ level but rather to monitor IAQ.

How does CO₂ relate to IAQ?

CO₂ is monitored as an indicator to indoor air quality. CO₂ is used because it is unavoidable in a space with living occupants since it is a component of the breathing process, it is predictable, and it is measurable. When CO₂ levels exceed 1000 ppm, it is assumed that other pollutants also exceed safe levels.

How does CO₂ relate to ventilation rates?

All mechanical and ventilation codes require that a prescribed level of outdoor air be added to the supply air stream to a space, based on the number of occupants or the space use. Most spaces will require that 15-20 CFM per person be brought into the building as ventilation. This outdoor air much of the year in most climates will be greater than or less than the desired supply air temperature, requiring that energy be spent heating or cooling this air stream. It is easily seen that if we are able to reduce the amount of ventilation brought into the space, then the amount of energy needed can also be

reduced, helping not only the owner's utility expenditure but also the environment. Without the use of a CO₂ sensor, the ventilation rate is typically determined by the maximum number of occupants and hopefully at least designed with an occupied/unoccupied control setting to attempt to save energy. This complies with code ventilation rates and does reduce load during unoccupied times, but it does not address the fact that excessive ventilation is introduced to the system in the partial load conditions. Many spaces do not function at full occupancy all of the time, especially those that have the most demanding ventilation load due to occupant density, i.e. theaters, ball rooms, and lobbies. Use of a CO₂ sensor in systems serving these types of spaces results in the most significant savings.

How do I design CO₂ into an HVAC system?

The HVAC system must be designed with the maximum occupancy in mind and according to governing code, but a CO₂ sensor will allow the outdoor air rate to modulate based on the actual occupancy. The CO₂ sensor is installed within the space being monitored. When the CO₂ level is similar to outdoor air for the building location (this value varies and will need to be measured), the ventilation damper will be allowed to close (unoccupied conditions). As people enter into the monitored space, the CO₂ level will begin to rise and this increase will be seen by the CO₂ sensor and will signal the damper to open accordingly to maintain the CO₂ near outdoor conditions (occupied conditions). Keeping the CO₂ level near outdoor conditions will allow for maximum comfort in the space while minimizing energy demand.

ADDITIONAL INFORMATION

U.S. Environmental Protection Agency:
www.epa.gov-iaq

U.S. Green Building Council: www.usgbc.org
American Society of Heating Refrigerating and Air
Conditioning Engineers: www.ashrae.org
User's Manual for ANSI/ASHRAE/IESNA Standard
90.1-2001

This GreenBuild Tech Bulletin was developed by Julia Keen, a graduate student and instructor at Kansas State University. As designers and builders of structural, mechanical, electrical, and plumbing systems in buildings, architectural engineers and constructors have a tremendous opportunity and responsibility to address energy and/or environmental impacts in their work.