VAISALA / APPLICATION NOTE

DCV Savings through Well-Chosen Technology

Optimizing demand-controlled ventilation (DCV) contributes to an enhanced indoor environment with lower operating costs. DCV systems can only be optimized using accurate carbon dioxide (CO_2) sensing.

Humans spend 90% of their time indoors. Studies indicate that indoor air quality (IAQ) is directly linked to human well-being and productivity. Indoor CO_2 levels can be used as an indicator of human presence. A high CO_2 level is a sign of poor ventilation and often an indication of other unpleasant odors in the air. As many as 30% of buildings have poor IAQ.

The most economical way to determine how much ventilation is needed is to measure carbon dioxide levels as these increase in relation to the number of humans present. By controlling ventilation according to CO_2 levels rather than according to the assumed maximum number of people occupying the space, indoor air can be kept fresh without over-ventilating and wasting energy.

Industry Drivers

Limits for maximum CO_2 levels in indoor air differ slightly from one country to another. For example, ASHRAE (www.ashrae.org) Standard 62.1 “Ventilation for Acceptable Indoor Air Quality” states that CO_2 levels should not exceed 700 ppm above outdoor ambient levels of about 400 ppm. According to the International Energy Conservation Code (IECC), DCV shall be provided for spaces larger than 500 square feet (50 m^2) with an average occupancy of 25 people per 1000 square feet (93 m^2) of floor area.

Similar requirements are set by the ASHRAE 90.1-2010 standard. The EU Commission has issued an Energy Performance in Buildings Directive (2002/91/EC) that is aligned with these maximum permissible CO_2 concentrations and specifies that energy savings should not have a negative impact on indoor air quality.

The Energy Technologies and Indoor Air Quality (ETIAQ) project coordinated by Rehva – the Federation of European HVAC Associations – reports energy savings of 20-50% in public buildings using DCV, and an even greater savings potential in buildings with varying occupancy.

One of the forerunners in improving indoor air quality is the State of California, where the Building Standards Code not only requires CO_2-based DCV in some spaces with high-density occupancy, but also defines the required measurement accuracy and long-term stability: "CO_2 sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 and 1000 ppm concentration when measured at sea level and 25°C, factory calibrated or calibrated at start-up, and certified by the manufacturer to require calibration no more frequently than once every 5 years".

Linking CO_2 Performance to DCV Systems

Green building initiatives, such as LEED (www.usgbc.org) rating systems, specify actions to be taken when CO_2 conditions vary by 10% or more from the user-specific set point. Either the building automation system should generate an automatic alarm and adjust the ventilation accordingly or an alert must be generated to building occupants.

The stability of the ventilation system is typically checked and adjusted during commissioning only. Once in place, CO_2 transmitters are expected to operate continuously for at least five years. Therefore, the choice of CO_2 technology is important not only for initial accuracy specifications, but also for stability. Maintaining IAQ standards can be challenging while simultaneously striving for energy efficiency.

Most CO_2 sensor manufacturers will offer an initial accuracy specification in the range of ±50 to 100 ppm at concentrations of 1000 ppm. Some technologies on the market rely on the assumption that background CO_2 concentrations are 400 ppm and adjust the sensor reading accordingly. However, depending on the season, as well as whether the location is rural or urban, background levels may vary by tens of ppms. On the other hand, in premises with round-the-clock occupancy, CO_2 levels may never reach the outdoor levels assumed by such calibration schemes, although DCV is applied to optimize air quality and reduce energy consumption.

These uncertainties in the true minimum concentration set a tough challenge for such methods to comply with the strict accuracy requirements set by, for example, the California Building Standards Code. For example, if the system is set to maintain a CO_2 level of less than 800 ppm in the space and the sensor has a margin of error of 80 ppm, the deviation could lead to false alarms. If the CO_2 level indication is too low, it will limit the amount of fresh air; if the CO_2 level indication is too high, it will be introducing more unconditioned outdoor air to the space than is required. The situation is also likely to deteriorate over time if the sensor has poor long-term stability.

How CO_2 Relates to DCV

- Measuring CO_2 is the most economical way to monitor both air quality and human presence with one sensor
- Inadequate ventilation results in an elevated CO_2 level, causing drowsiness and decreased productivity
- Good indoor air quality can be achieved based on occupancy levels
- Energy is saved by minimizing the use of unconditioned outside air

CO_2 Information

- CO_2 is measured in parts per million (ppm)
- Typical outdoor ambient CO_2 concentrations: 350 – 450 ppm
- Acceptable indoor air quality (IAQ) CO_2 concentrations: 600 – 800 ppm
- Tolerable IAQ CO_2 concentration: 1000 ppm

Maintaining IAQ without False Alarms

Every technology has some component that is depleting or changing, which makes it difficult to maintain the required accuracy specifications. The most common technology available for measuring CO_2 is non-dispersive infrared (NDIR) technology. The problems with this technology are that the required light source will lose its intensity over time, and the inability to identify when the light path has been contaminated.

The Vaisala CARBOCAP® sensor has a unique ability to measure at alternating dual-wavelengths: one wavelength to measure CO_2 and a second reference wavelength to determine the light source intensity and contaminant levels. The result is accuracy that lasts for years without having to rely on any assumptions regarding background CO_2 concentration when performing light-source calibration.

One Technology for All HVAC Applications

By eliminating the need for self-calibration, Vaisala CARBOCAP sensor can be used in a wider variety of applications, including those with variable outdoor CO_2 levels or in facilities with round-the-clock occupancy like hospitals, workplaces, residential buildings, or homes for the elderly.

The robust CARBOCAP technology allows the sensor to be located inside the duct for highly accurate measurement in single-zone systems. Other CARBOCAP benefits include tolerance to water condensation and good temperature tolerance, allowing it to be used in refrigeration applications.

Structure of the CARBOCAP sensor.

Visit www.vaisala.com/CO2 to learn more about our complete CO_2 offering.

Guidelines for Placing CO_2 Transmitters

- Avoid locations where people may breathe directly onto the sensor and don't place near intake or exhaust ducts, windows, or doorways.
- Wall-mounted sensors are preferable to duct-mounted sensors as they provide more accurate information on the effectiveness of the ventilation system.
- Concrete carbonation creates a CO_2 drain near surfaces so, in order to avoid anomalously low CO_2 sensor readings, cabling from poorly ventilated spaces like cable conduits should be properly sealed in the vicinity of CO_2 sensors.
- Wall-mounted sensors should be located 1 - 6 ft (0.3 – 1.8 m) above the floor.
- Duct-mounted sensors are suitable for single-zone systems and should be installed as close to the occupied space as possible, with easy access for maintenance.
- For multiple rooftop units, one CO_2 sensor per zone is recommended.
- For variable air volume (VAV) systems, one sensor per major zone is recommended.
- For common areas with multiple VAV boxes, a single CO_2 sensor is acceptable if the occupancy pattern is evenly distributed throughout the common area.
- For a constant volume single rooftop unit serving multiple zones, one sensor per zone or space is recommended, with ventilation control based on the highest CO_2 reading.

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