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Making sense of Demand Control Ventilation

When occupancy varies in buildings, good indoor air quality can be maintained using CO_2 as the control parameter. In fact, the quality of the CO_2 measurement can be considered an indicator for the quality of the whole ventilation system.

For nearly 20 years now the HVAC industry – Heating, Ventilation, and Air Conditioning – has been talking about the use of Demand Control Ventilation (DCV) as a means of controlling ventilation in buildings. Essentially this is a process in which the amount of outside air entering a building is varied based on the amount of carbon dioxide inside that space. Carbon dioxide levels are a reliable indicator of indoor pollution originating from a building's occupants.

Co_2 levels indicate ventilation rate

Most people spend 90 percent of their time in different indoor environments. Therefore the quality of indoor air is vital for our wellbeing. The ventilation system takes care of introducing adequate amounts of fresh air into the building spaces – a process that needs to be accomplished as energy efficiently as possible these days.

Demand-controlled ventilation improves the energy efficiency of the ventilation system by optimizing fresh air supply based on true need. For example, a meeting room in an office facility can be crowded for a couple of hours in the morning and empty for the rest of the day, thus increasing the need for fresh air during the morning hours.

The indoor CO_2 level has shown to be a good general indicator for poor air exchange in a building. As it also serves as an indicator for human presense and unpleasant or unhealthy pollutants, it can be used to determine if increased ventilation rate is required.

The National Institute for Occupational Safety and Health in the United States suggests that indoor air CO_2 concentration exceeding 1,000 ppm is a marker for inadequate ventilation. Increased CO_2 levels cause a feeling of stuffyness, tiredness, headache, and as a result of these, lowered concentration and working efficiency.

Accurate measurements top priority

Given the undoubted benefits of DCV, both in terms of energy savings and human wellbeing, it is not surprising that the DCV market has shown years of steady growth. However, concerns persist about the accuracy of the sensor technologies, which the DCV systems use to monitor carbon dioxide concentrations.

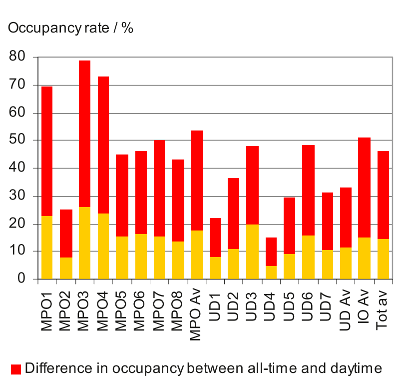
Such sensors are based on Non-Dispersive Infra Red (NDIR) technology, which essentially involves an Infra Red (IR) light source and an IR detector. However NDIR sensors are prone to drift. Too high carbon dioxide readings can lead to costly over-ventilation, and too low readings to underventilation

and unhealthy concentrations of carbon dioxide and other indoor air contaminants within occupied spaces.

The poorest performance is offered by single-beam single-wavelength devices, which are based on one optical channel and one wavelength. Many of the devices on the market are fairly unstable, as aging of the lamp, contamination or changes in the reflecting properties of the optical path easily affect their stability. Moreover, temperature changes have an adverse affect on their short-term stability. On the plus side, the structure of the single-beam single-wavelength devices is simple, and they are mechanically reliable and inexpensive.

Dual-beam single-wavelength configurations utilize one lamp for measurements and a second one for a reference. The first lamp typically pulses at a rate of 3 Hz, whereas the other pulses at a much lower rate, for example once a day. The second lamp ages more slowly and can therefore be used as a reference for light intensity.

Dual-beam dual-wavelength devices have two optical channels, two detectors and two interference filters. These devices are more accurate and stable than the single-beam single-wavelength or dual-beam single-wavelength solutions, but they are also more expensive. Moreover, the detectors must form a perfectly matched pair to achieve good performance over a larger temperature range.



Occupancy patterns in three different office buildings (Johansson, D. Modelling Life Cycle Costs for Indoor Climate Systems, PhD Thesis, Lund University 2005).

One beam, two wavelengths – increased accuracy

Single-beam dual-wavelength sensor technology behind Vaisala CARBOCAP® sensors eliminates the drift problem and provides very accurate real-time CO_2 measurements.

The Vaisala CARBOCAP® sensor comprises a light source, an IR detector and an interferometer. The light source is positioned to shine at the IR detector in such a way that the light travels a fixed distance to the detector, where the light intensity is measured. A Fabry-Perot Interferometer (FPI) positioned just in front of the IR detector acts as a tuneable filter.

The FPI only allows certain wavelengths of light to pass through to the detector. As carbon dioxide absorbs certain wavelengths of light and not others, the FPI is designed to pass light both at a carbon dioxide absorption wavelength of 4.26 µm and – crucially – at a nearby, non-absorbing wavelength, too.

When the sensor is operating, the FPI is regularly tuned back and forth between the measurement and reference wavelengths. At the carbon dioxide absorption wavelength, the intensity of detected light is reduced in proportion to the concentration of the gas in the optical path. In this way, the light intensity measured at the non-absorbing wavelength serves as a baseline for comparison.

As the concentration of carbon dioxide varies, the difference in detected light intensities also varies. The exact relationship between IR light intensity and carbon dioxide volume concentration is determined when the instrument is calibrated using pure nitrogen and a known concentration of carbon dioxide during manufacturing.

Stable solution with simple and robust design

As the Vaisala CARBOCAP® sensor includes only three main components, its design is simple and robust. This eliminates errors caused by slight differences in the multiple components used in competing dual-beam sensor designs. In addition, because the FPI used in the sensor is micro-machined from silicon and has no moving parts, it is more reliable than traditional mechanical 'chopper wheel' designs.

Performing the measurements using two different wavelengths, as described above, make the Vaisala CARBOCAP® solution vastly more stable than other NDIR solutions, which only measure on the carbon dioxide absorption wavelength, trying to manage the drift by adding corrective actions in the software.

The problem with software corrections is that they necessitate the assumption that the background carbon dioxide concentration remains constant, when in reality the background level is not always ventilated to the atmospheric background level. Correcting the sensor reading level to an assumed background level in an environment where the actual concentration could be higher results in under-ventilation and lowered human comfort.

Further information:
www.vaisala.com/instruments/products/carbondioxide