The challenges of CO_2 sensing

We spend most of our lives indoors – at home, in the office or out visiting shops, restaurants and other public venues. As fresh air becomes a precious commodity, it is important that buildings are properly ventilated. CO_2 levels have long been used as an indicator of indoor air quality, which is why many modern HVAC systems are equipped with CO_2 sensors. However, in order for these sensors to be accurate, there are many factors that must be considered and addressed.

Lack of fresh air

The health benefits of fresh air are irrefutable, and the lack of it affects our health and the ability to focus. Unfortunately, in this busy world, few of us are able to spend as much time outdoors as we might want to. On average, we spend up to 90 % of our lives indoors, and most of that time we reside in our homes. Even though we leave our houses regularly, a lot of the time spent outside the home is in another indoor location, such as an office, restaurant or shop. This clearly shows the importance of high quality indoor air and proper monitoring of CO_2 levels, especially in crowded venues.

Impact on health and productivity

Although high levels of CO_2 and bad air quality are not synonymous, raised concentrations of CO_2 can be a good indication that the room requires additional ventilation. In addition, an increase in CO_2 often comes hand-in-hand with a rise in volatile organic chemical (VOC) concentrations, as both are emitted by humans. It is commonly known that bad air – especially high VOCs – can be detrimental to health and increase the risk of transmission of airborne viruses, such as SARS-CoV-2. Additionally, a lack of fresh air also has a great impact on productivity and the ability to focus – a claim that is backed up by numerous studies.

Demand controlled ventilation

Extremes are never good, and this is also true for ventilation. HVAC systems that are constantly working at maximum capacity will lead to high energy consumption and, consequently, exorbitant electricity bills, especially during very hot or cold periods. It is therefore not a surprise that demand-controlled ventilation is currently seen as the gold standard for HVAC systems, and the CO_2 concentration is often used as a control parameter, as it correlates closely with air quality. This application relies on sensors providing accurate information on CO_2 levels, activating the system when a specified limit has been reached. Although comfort norms vary around the world, there is a consensus that the CO_2 levels should always be kept below 1,000 ppm, and not exceed 1,500 ppm for long periods. A good compromise is to measure and adjust the CO_2 levels every 30 seconds, which keeps the air fresh and the energy bills low.

Dual detector approach

A common CO_2 sensor design consists of a light source and two detectors (Figure 1). As light passes through the measurement chamber, filled with ambient indoor air, it is absorbed by the molecules present. One detector has a filter with a window at around 4.3 µm – which corresponds to a peak in the CO_2 absorption spectra – meaning it only registers extinction of light due to the presence of CO_2 molecules. In contrast, the reference detector measures the unfiltered light intensity, making it possible to determine the CO_2 level by comparing the two measurements. The dual sensor design also helps to counter the drop in light intensity originating from light source degradation or small dust particles. To further enhance the robustness of the sensors, they should be fitted with a dust cover that stops particles from interfering with the detectors.

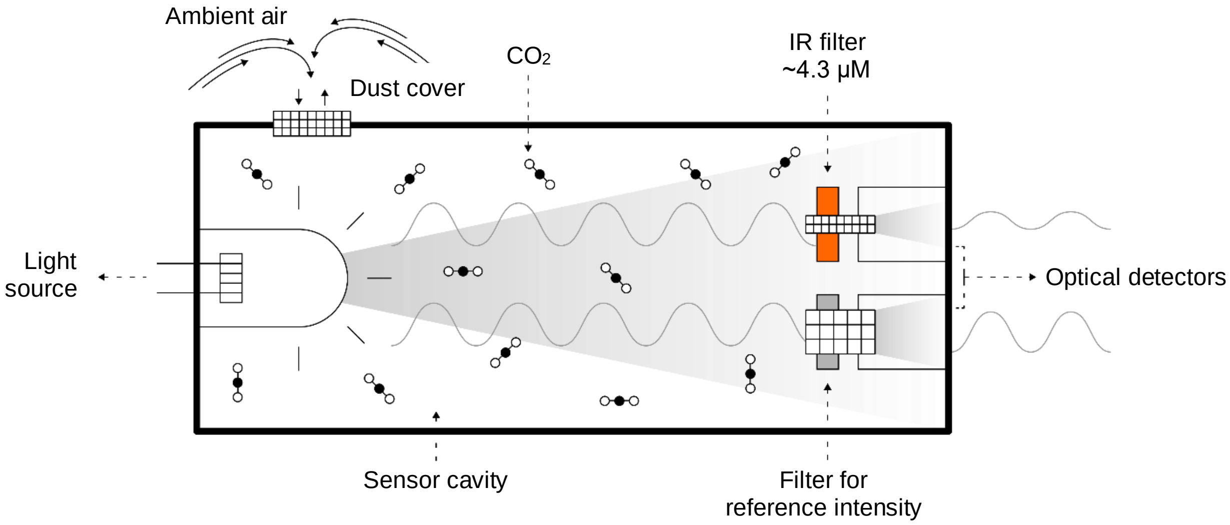

Figure 1: Visualisation of the NDIR dual detector approach

Long-term stability

Although the dual channel approach is considered to be accurate, it alone cannot guarantee stable long-term measurements, as the baseline can start to drift over time due to aging of sensor components. This can be fixed through automatic baseline correction (ABC), which constantly tracks the sensors lowest reading, and corrects for any drift that is detected. This approach works well for buildings that are unoccupied for periods of time such as offices that are closed during the weekend. However, this drift is not as easy to identify and address in venues that are occupied 24/7, for examples hospital emergency rooms, logistic centres or factories. It is therefore crucial to use robust sensors that provide accurate long-term measurements without the need for constant calibration, allowing them to be used in all applications, regardless of occupancy patterns.

Under pressure

A room sensor needs to be able to accurately measure CO_2 levels under any conditions, which means it needs to have a good resistance to both gradual and acute changes in pressure, temperature and humidity.

The pressure differences at different altitudes also need to be accounted for, as even an elevation of 400 m above sea level results in a 70 ppm offset in the measured CO_2 concentration. Considering that some regulatory bodies – for example several state governments in the USA – only allow a tolerance of ±75 ppm, this leaves almost no margin for error. Any high performance CO_2 sensor should therefore include absolute pressure compensation (Figure 2).

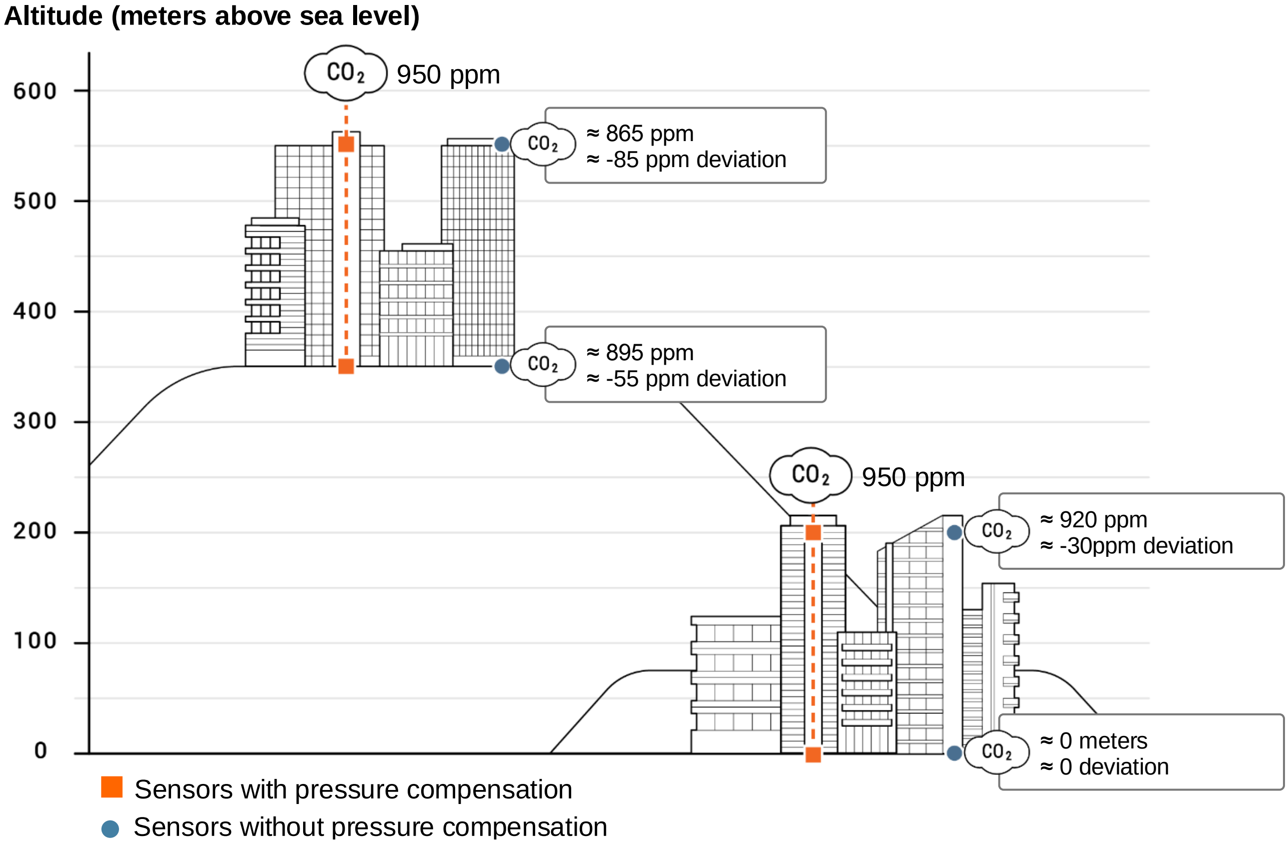

Figure 2: Comparison of sensors with and without absolute pressure compensation at different altitudes.

Testing and verification

Extended testing should be performed to ensure that the sensor can operate under various conditions in order to guarantee long-term stability and function. Sensors should therefore be tested for an extended period – spanning a number of weeks – covering all possible weather conditions and focusing on those known to put a lot of stress on the device. For example, non-condensing wet heat performance can be tested at 95 % relative humidity and 35 °C to ensure the sensor exhibits corrosion resistance and can maintain its performance. On the other hand, dry heat measurements should be performed at higher temperatures – 60-70 °C – to confirm that no drift occurs due to the difference in expansion coefficients of the materials. As internal temperature gradients can also play a role in the overall device performance, the sensor elements must be built in a way that minimizes self-heating.

Summary

As we spend more and more time indoors, it is becoming increasingly important to monitor indoor air quality, which can successfully be done by surveying the CO_2 levels. Many organisations are therefore choosing HVAC systems that regulate airflow based on the levels of CO_2. However, in order to deliver the correct amount of air without over-ventilating, these systems need to be equipped with reliable sensors. Even though most sensors are accurate initially, they can prove to be unstable in the long run, requiring frequent re-calibration. This approach can be effective in some settings, but does not work in constantly occupied venues. It is therefore beneficial to choose robust sensors that can provide correct measurements without constant adjustments. Belimo sensors are designed with all these considerations in mind, and can provide long-term accurate measurements of CO_2 under virtually any condition for indoor air quality applications.

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