CO_2

MAKING SENSE OUT OF SENSORS

CO_2 and air quality sensors are not interchangeable, but both can be important for building indoor air quality control. Here is a review of what they can and can't do.

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With the growth of the indoor air quality industry, a number of new technologies have burst onto the marketplace. One of these technologies, often called an air quality sensor, volatile organic compound (VOC) sensor, or IAQ sensor has generated great interest as a possible approach to controlling air quality in all types of buildings.

Many have wondered if these sensors can be used the same way as CO_2 sensors. While both sensor technologies can be useful in indoor air quality control, they are not interchangeable. Each has its own particular applications.

AirTest's carbon dioxide controllers are designed to regulate fresh air delivery to a space to ensure that target cfm-per-person ventilation rates for indoor air quality are maintained.

A CLOSER LOOK

Air quality sensors are often called total contaminant sensors, because they measure and react to a broad range of diverse compounds in the air.

These sensors utilize an interactive, chemical-based oxidizing element. When this element is exposed to various compounds in the air, the sensor will vary it's electrical resistance and provide an output signal.

The sensor reaction is nonspecific to any one gas; its output reflects the total effect of a wide variety of compounds in the air on the sensor. The compounds it reacts to can be VOCs, aerosols, hydrocarbons or just changing temperature and humidity.

The biggest drawback of these sensors is that they have no way of distinguishing a potentially harmful air contaminant from a harmless gas (e.g., perfume or after shave).

Because an air quality sensor will react in different ways to different gases and compounds or mixtures in the air, there is no way to calibrate them to a known measure of contaminant concentration or air quality.

Some manufacturers suggest that individual sensors can be tuned to the building space in which they are operating. In such an application, each individual sensor in a building space would be adjusted to provide a low output signal when the building is perceived to have good air quality. The sensor would provide a higher signal when more contaminants are in the space.

While this approach may work in general, it is limited by the inability of this type of sensor to have any defined

Comparison	Broadband Air Quality Sensors	Carbon Dioxide Sensor
Gases Measured	Wide range of non-specific gases.	Carbon Dioxide
Measurement Units	Cannot be referenced to any known measure but can be individually “tuned” to a building space.	parts per million (ppm)
Measurement Range	Typically 0-5 or 0-10 units	0-5,000 ppm
Resolution	1 unit (non-quantifiable)	±20 ppm
Common Interference	Temperature & Humidity- Also, low levels of silicon vapors and other hydrocarbons may cause damage.	None
Calibration	Cannot be calibrated to any referenced standard. Will tend to normalize in the direction of conditions it sees most often over the short term.	Use calibrated gas or recently calibrated instrument as reference.
Type of Technology	Interactive Sensor chemically reacts with pollutants and eventually changes or degrades sensitivity over time.	Non-Interactive Sensor does not come in contact with sampled air. CO_2 concentration determined by infrared light interference of CO_2 gas.
Drift	Unpredictable.	100 ppm per year or less (linear). Can be reduced to 30 ppm annually with self-calibrating software.
Best Application	To measure changes in indoor conditions where unusual non-occupant related pollutant sources are a concern (e.g. occupied printing plants, VOC cleaning materials).	Ventilation control to ensure that target cfm-per-person outside air ventilation rates are maintained at all times in occupied spaces. Energy savings can result where occupancy is variable or intermittent (e.g., schools, meeting rooms, offices).
Correlation to Ventilation Rate	Levels will probably be higher when there is less outside aire ventilation and inside sources of sensor-sensitive pollutants are higher.	The differnce between inside and outside concentrations can ve directly related to the cfm-per-person of outside air delivered (e.g., a 700 ppm differential = cfm/person).
Recognized in the ASHRAE 62-1989 Standard “Ventilation for Acceptable Indoor Air Quality”	No. The “Air Quality Procedure” in the standard allows for control of ventilation based on reducing concentration of specific contaminants. Since the sensor does not sense specific gases in known concentrations, it is impossible to know if acceptable contaminant concentrations have been achieved.	The “Ventilation Rate Procedure” in the standard establishes specific cfm-per-person guidelines for various applications . Appendix D of the standard provides the rationale to correlate CO2 concentration to specific cfm-per-person ventilation rates.

TABLE 1: A comparison of CO_2 sensors and air quality sensors, also called VOC or IAQ sensors

measure of air quality, as well as the fact that it reacts in different ways to different contaminants.

A critical feature of any good sensor, whether it measures temperature, humidity, or various gases, is that it should have very little drift. Drift is the tendency for a sensor to shift its calibration over time.

Air quality sensors continually drift as chemical compounds react with he sensor surface. Once installed, these types of sensors will tend to zero or stabilize themselves in whatever environments they have been exposed to over the past few days or hours.

The sensitivity of these sensors also is dramatically affected by temperature and humidity. As a result, it is sometimes difficult to determine if the air quality conditions measured from season to season are actually similar, even if the sensor output may be the same.

However, a low reading will still presumably indicate better air quality than a higher reading when compared over a few days.

TESTING REVEALS LIMITATIONS

In a recent article written by Sal Ignello, manager of Indoor Quality Environments at Johnson Controls, he indicated that their testing had found some limitations to IAQ sensors. He stated:

-Sensitivity of these sensors is not sufficient to detect low levels of VOCs that are known to affect building occupants.

One study monitored 240 spaces in 15 buildings. Measurements were made with a single air quality sensor at the same time as a trained human sensory panel made judgment of the space odor level. There was no correlation between the sensor's indications and the panel's perception of the area's IAQ.

-Temperature and humidity often overwhelm the sensor, making it less sensitive to other contaminants.

- Sensors can be heavily biased toward reaction to one compound over another.

Testing showed that an IAQ sensor will have the same response to 5,000 ppm of methane as 250 ppm of carbon monoxide (CO), 90 ppm of acetone, or 50 ppm of ethanol. These tests confirmed that high and dangerous levels of toxic pollutants like CO could be masked or missed in place of much lower concentrations of other harmless gases.

Ignello also noted in his article, "There are virtually no standards stipulating acceptable concentrations of common air contaminants for nonindustrial buildings. Even if sufficiently sensitive IAQ sensors were available, the lack of standards makes a control setpoint quite arbitrary."

MORE EXPLANATION

Because of the drift and non-specific nature of the sensor output, its use as an indoor air quality diagnostic and control tool may be limited.

Air quality sensors are best used as indicators of dramatic short-term changes in contaminant concentrations that might occur within the air. (This is provided the contaminants in the air are the type that actually cause the sensor to react.) As a result, they are best used to indicate unusual sources being released into the air.

In a printing plant, this might occur when the presses begin operation. In a commercial building, it might indicate when the cleaners are using potent detergents or de-waxers. In a new building, it might indicate when furniture or carpets are off-gassing a significant number of contaminants.

Most air quality sensors provide a 1-5 or 1-10 scale of output. It is impossible to determine what a "3' reading means versus a "9," because of the non-specific nature of the sensor. It can tell you something has changed, but it cannot really indicate if the change is significant or quantifiable from an air quality perspective.

Future product development will focus on trying to make sensors more consistent, as well as referencing them to a known standard of air quality, Ideally in a real application, once an air quality sensor is tuned to the space, a control strategy would attempt to keep levels as low as possible.

THE DIFFERENCES

Air quality sensors and CO_2 sensors measure very different things. In fact, because carbon dioxide is an inert gas, it is one of the few elements that will not cause an air quality sensor to react.

Also, most CO_2 sensing technology is quite stable and is not subject to the short-term, random drift found in air quality sensors. Most carbon dioxide sensors only measure CO_2.

People are the principal source of CO_2 in indoor air. Outside levels tend to be at a relatively low level and are fairly constant. An indoor CO_2 measurement can be compared to outside concentrations to provide an indication of the amount of outside air ventilation, on a cfm-per-person basis, that is being provided to an occupied building space.

The relationship between CO_2 concentrations and ventilation rates is well documented and used extensively throughout the world. The current ventilation standard is ASHRAE Standard 62-89, which specifically details bow CO_2 concentrations can be related to ventilation rate.

The new ASHRAE Standard 62, which was not finalized at the start of this year, is scheduled to provide guidance on how to use CO_2 to control ventilation based on occupancy. An air quality sensor cannot be used to determine the ventilation rate of a space.

A CO_2 measurement cannot indicate if outside air quality is good, although a high outside CO_2 level (over 600 ppm) can indicate the outside air is quite polluted. A CO_2 sensor controls the ventilation rate in occupied spaces.

If a space is unoccupied, a CO_2 controller is typically designed to set air intake volume at a minimum setting; it cannot sense the buildup of other contaminants within a space. Carbon dioxide (CO_2) should not be confused with carbon monoxide (CO), a highly toxic byproduct of combustion of furnaces, fireplaces, and automobiles.

Carbon dioxide sensors are best used to identify and control outside air ventilation rates in non-industrial buildings where cfm-per-person ventilation rates, as mandated by codes and standards, must be maintained.

Measurement and control of CO_2 in a building can ensure that outside air is being circulated in the right proportion to the distribution of people within the building. If the space is subject to intermittent or variable occupancy, costly and unnecessary over-ventilation can be avoided.

So, air quality sensors are best used in applications where unusual, non-occupant-related sources periodically may be present. As a control, the sensor can activate an alarm or mitigation strategy (activate filters or ventilation).

An air quality sensor cannot indicate ventilation rate. It also cannot necessarily indicate whether safe or harmful concentrations of contaminants are present. It can indicate a general change in the concentration of contaminants.

Both approaches can be applied to a demand-controlled ventilation strategy, but the results may be very different. In the case of CO_2, energy savings can result because ventilation is based on actual occupancy of the space rather than the design occupancy of the space.

Code-established per-person ventilation rates can be maintained while reducing over-ventilation when spaces are partially or intermittently occupied. Typically, this type of control is applied in conjunction with a minimum ventilation rate or purge strategy to ensure that other building-related contaminants do not build up during occupied periods.

In the case of IAQ sensors, ventilation is regulated based on the actual presence of some pollutants sensed by the air quality sensor. This may or may not conflict with established ventilation codes.

Energy is saved when pollutant loads are low and ventilation can be reduced, which may occur during or after occupied hours. Where a CO_2 sensor would specifically reduce ventilation during unoccupied periods, an air quality sensor may actually maintain ventilation rates during unoccupied periods if there is a significant pollutant level in the building.

As mentioned before, these sensors can also be used to sense periodic episodes of high pollution that might occur when special equipment is being used, or when potent chemicals from cleaners are released into the air.

COMBINED STRATEGY

In many applications, an air quality sensor and a CO_2 sensor can actually complement one another.

Consider a commercial building in which the ventilation system is controlled by CO_2 During evening hours, occupancy and ventilation rates are very low because only a few cleaners and guards are present in the building.

If the cleaners begin to use com pounds or chemicals that are sensitive to the sensor, a higher level of ventilation can be activated by the sensor until the unusual sources present are fully exhausted from the building.

All air quality sensors are basically the same. Some manufacturers of air quality sensors are now providing an output in "CO_2 equivalent units." This measure is considered misleading and may confuse many new to the indoor air quality industry.

There is currently no recognized procedure to directly quantify the output of these sensors to carbon dioxide or the differential between inside and outside concentrations that is used to determine ventilation rate. Combining the output of the sensors diminishes the usefulness of each type of sensor if used individually.

To summarize, sensors measure different things and have different applications. Make sure that the proper sensor is being applied to the proper application. (Table 1. compares the two technologies.)

CO_2 sensors are used to reglate ventilation based on actual occupancy of a space. IAQ sensors can regulate ventilation based on sensor specific contaminants in the space. Each approach will result in radically different ventilation strategies and energy impacts. **ES**

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