Indoor Environment Quality (IEQ)

Air Quality Sensors

Rev. 5/03/10

Overview

This paper will prove that the BAPI Indoor Environment Quality (IEQ) sensor is an accurate and reliable way of incorporating Demand-Controlled Ventilation (DCV) into a building's HVAC strategy. It will also show that the IEQ sensor is as good an indicator of space occupancy as a CO2 sensor while also measuring other contaminants which affect human comfort and health. The paper will also describe how the IEQ sensor output signal corresponds to CO_2 level in the space so that system designers can use existing DCV algorithms. Finally, it will detail how proper ventilation from the IEQ sensor improves occupant comfort, health and productivity, and saves money for building owners.

CO_2 and Demand-Controlled Ventilation

Until now, Indoor Air Quality (IAQ) has been defined as proper temperature, humidity and CO_2 levels. According to tenants however, offensive odors, smoke, carpet off-gassing and other Volatile Organic Compounds (VOCs) have just as much or more impact on human comfort, productivity and health.

Then why is Indoor Air Quality so closely linked to CO_2? This is due to one interpretation of The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 62.1. This standard establishes minimum ventilation rates for proper Indoor Air Quality, allowing for Demand Controlled Ventilation (DCV) which saves on heating and cooling costs by bringing in outside air only as it is needed. Standard 62.1 has two procedures for establishing the ventilation rates — one based on VOCs and one based on occupancy. The occupancy procedure, formally called the Ventilation Rate Procedure or VRP, is used most often due to its straightforward math and the vast majority of those users choose CO_2 sensors to determine the occupancy of the space.

The problem with this method of DCV is that it ignores the offensive odors and VOCs that may be present even when the CO_2 levels are low[1].

As stated earlier, Standard 62.1 has two procedures, one based on occupancy and the other based on VOCs. The difficulty with the VOC procedure is that HVAC system designers must use subjective criteria, such as whether the air quality is acceptable to 80% or more of the building's occupants. System designers are not comfortable dealing with these subjective perception-based criteria, so most choose the CO_2 occupancy method, even though it ignores odors and VOCs.

BAPI's IEQ Sensor offers the best of both worlds. It uses the VOC procedure of Standard 62.1 to measure the space, but provides the HVAC system designer with the straight forward mathematics of the occupancy based Ventilation Rate Procedure. The sensor does this by measuring the total VOC level then outputting a signal that corresponds to a CO_2 level of 0 to 2,000 ppm, allowing system designers to use their existing DCV algorithms. More information on this equivalent CO_2 level output is included in the next section, but let's start with the VOCs themselves.

What are VOCs and Where Do They Come From?

Table 1 Typical Indoor Contaminants (VOCs) and Their Source

Contamination Source	Emission Source	VOC
Human Being	Breath	Acetone, Ethanol, Isoprene, CO_2
	Skin Respiration & Perspiration	Nonanal, Decanal, alpha-Pinene
	Flatulence	Methane, Hydrogen,
	Cosmetics	Limonene, Eucalyptol
Consumer Products	Household Supplies	Alcohols, Esters, Limonene
Office Equipment	Printers, Copiers, Computers	Benzene, Styrene, Phonole
Combustion	Engines, Appliances, Smoke	Unburnt Hydrocarbons, CO, CO_2
Building Materials	Paints, Adhesives, Solvents, Carpets	Formaldehyde, Alkanes, Alcohols, Aldehydes, Ketones, Siloxanes
Furniture	**P**oly **V**inyl **C**hloride (PVC)	Toluene, Xylene, Decane

What are VOC’s and Where Do They Come From? continued....

VOCs are chemicals that contain carbon and can be emitted as gases at room temperature. Table 1 shows some typical indoor contaminants and their sources. VOCs evaporate from substances, such as cleaning products, adhesives, paints, dry-cleaning fluids and wood preservatives. VOCs are also emitted from humans and animals in their breath, sweat and directly from their skin. In fact, the largest share of VOCs in an indoor space is generated by humans, and this is the reason that VOCs are an accurate indicator of space occupancy.

Extensive research was conducted on VOCs and CO_2 in 1,500 offices, schools and homes to determine the correlation between CO_2 levels and VOC levels, and this research was used to create the CO_2 equivalent output for the BAPI IEQ sensor. The accuracy of this output as compared to the CO_2 level is shown in the charts in the next section.

The BAPI IEQ output of 0-5 volts or 0-10 volts represents 0 to 100% VOC contamination or a CO_2 equivalent of 0 to 2,000 ppm. So 25% VOC contamination (or 2.5 volts on a 0-10 volt IEQ sensor) is 500 ppm CO_2 equivalent. An output of 50% VOC contamination is 1,000 ppm CO_2 equivalent, and 100% VOC contamination is 2,000 ppm CO_2 equivalent. Using the CO_2 equivalent number, you ventilate to ASHRAE’s Demand Controlled Ventilation algorithm at that CO_2 concentration.

Please note that the IEQ sensor does not directly measure CO_2, it measures the total VOC concentration. If a CO_2 analyzer is placed next to the IEQ sensor, they may not match. The CO_2 analyzer is reading only CO_2, while the IEQ sensor is also reading total VOCs which the CO_2 analyzer is missing.

Space Occupancy — Comparing the IEQ Output to CO_2 Levels

The following three charts show data compiled by the Institut für Bauphysik (IBP), part of the Fraunhofer Institute, a group of academic institutes focusing on applied sciences located in Stuttgart, Germany, near Munich. IBP conducts research and development in the field of building physics including acoustics, lighting, energy conservation, indoor climate, durability, hygrothermics, building chemistry, building biology, hygiene, new building materials and preservation of buildings.

The studies were conducted with standard laboratory grade NDIR CO_2 analyzers and BAPI’s VOC sensor. The tests were used to determine the correlation between CO_2 levels and the output of the VOC sensor as related to space occupancy. The studies used sophisticated instrumentation including Gas Chromatography, Mass Spectrometry (GC/MS) and GC olfaction. GC/MS determines the exact concentration of contaminant that is present while GC olfaction analyzes what odors and aromas are present.

Chart 1 shows the kitchen and serving area in a cafeteria during a 48-hour period. The red line is the measured CO_2 in the zone and the blue line is the output of the BAPI IEQ sensor.

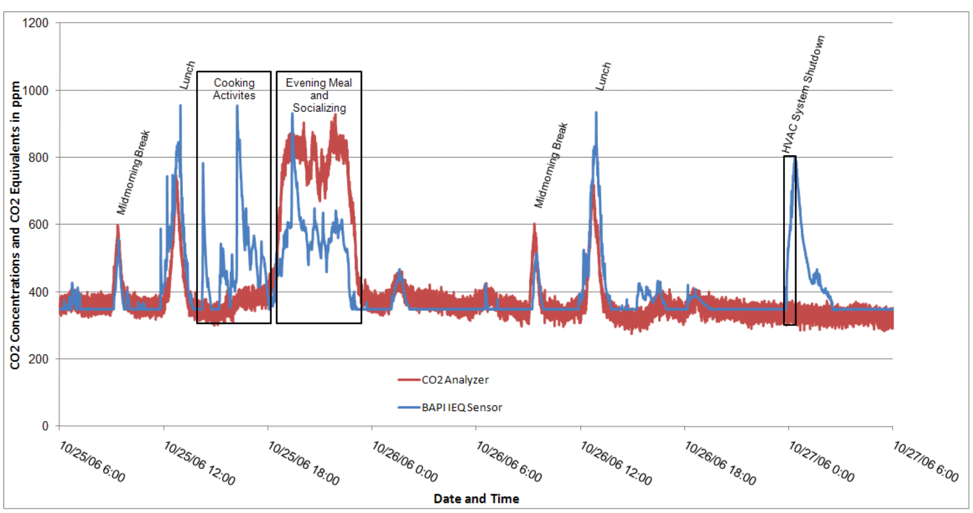

Chart 1: VOCs in a Kitchen and Serving Area
(The red line indicates CO_2 and the blue indicates the output of BAPI’s VOC Sensor)

The VOC levels measured by the IEQ sensor followed the CO_2 levels during the time that the space was heavily occupied ("Midmorning Break", "Lunch" and "Evening Meal and Socializing"). BAPIs IEQ sensor also detected cooking odors and other VOCs during the "Cooking Activities" period that the CO_2 sensor did not detect. The IEQ sensor will therefore ventilate away these odors and VOCs while the CO_2 sensor will not.

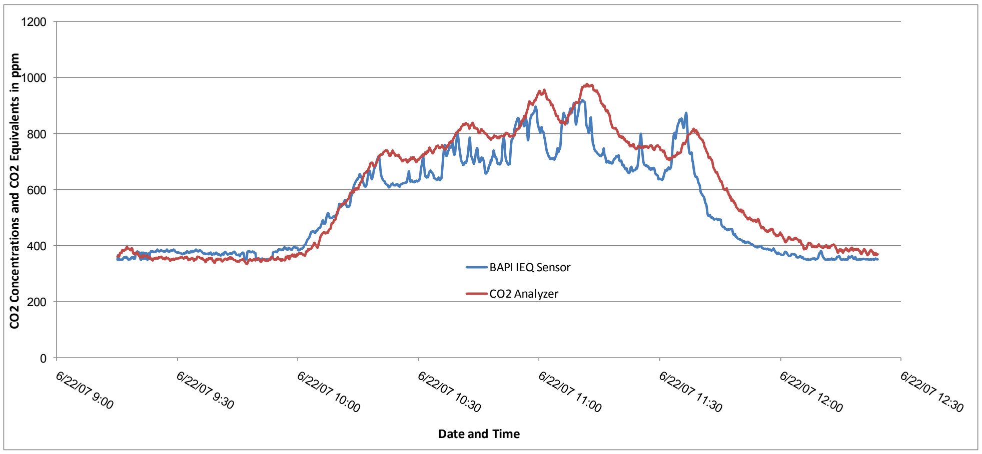

Chart 2: VOCs in a conference room

Switching from a cafeteria to a large conference room, **Chart 2** above again shows a direct correlation between the VOCs and CO_2. Seventy people come and go from the conference room during the 95 minute period between 10:00 AM and 11:35 AM. BAPI's IEQ sensor is nearly an exact match to the CO_2 sensor.

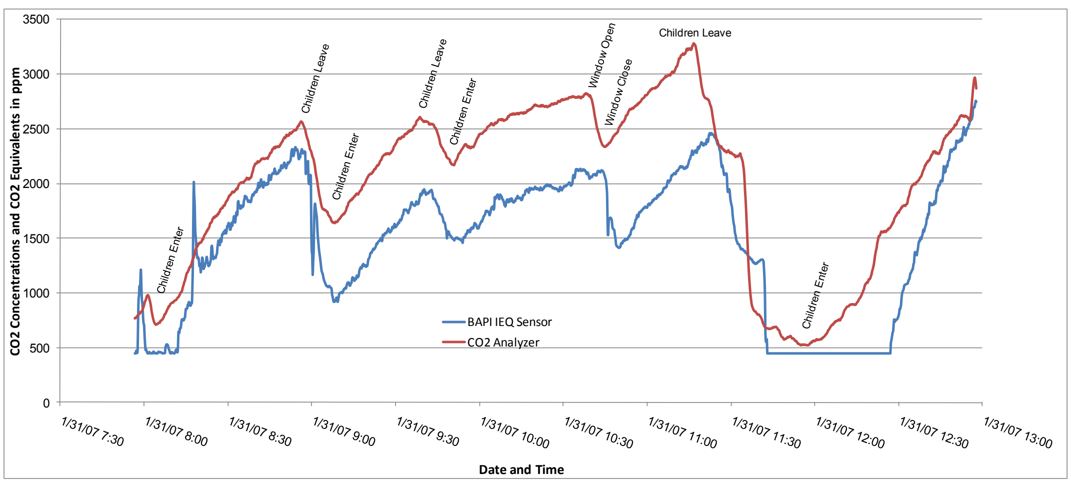

Chart 3: VOCs in an elementary school classroom

Chart 3 shows the VOC and CO_2 levels in a 6,000 cubic foot elementary school classroom with one teacher and 30 students. BAPI's IEQ sensor output tracks the CO_2 level; however it is slightly lower because elementary school children do not wear aftershave lotion, cologne and perfume. Even without the VOCs from lotion, cologne and perfume, the IEQ sensor output on the chart above is a direct indication of occupancy and can easily be set up for Demand Controlled Ventilation.

The True Meaning of Air Quality

VOCs are known to cause eye, nose and throat irritations, headache, drowsiness, dizziness, nausea, difficulty concentrating and fatigue; all summarized under the term SBS (Sick Building Syndrome).

The importance of detecting the presence of VOCs in indoor air goes beyond these immediate health concerns. People judge the quality of the air not just by how it feels (temperature and humidity), but also by how it smells. Unfortunately, offensive odors in offices, kitchens, gymnasiums and restrooms have no impact on CO_2 levels. A tuna fish sandwich left in a desk drawer over a weekend may not be life threatening, but may smell like it by Monday.

These obnoxious odors reduce everyone's productivity until the odor is eliminated. In retail settings, customers may leave and never come back. Even small amounts can have a very immediate effect. A single person entering or passing through a space may deteriorate the air quality due to heavy amounts of aftershave lotion, cologne, perfume, hand soap, laundry detergent residue, fabric softeners or residual cigarette smoke.

In these cases a CO_2 sensor will not correct the problem. For instance, a Circuit Court Judge in Tennessee was plagued by migraine headaches causing him to suspend proceedings until his headaches went away. An IEQ sensor installed in the courtroom discovered that the Judge's headaches were caused by support staff's cosmetics. Proper ventilation reduced the VOCs to acceptable levels and the judge's migraines stopped.

In another example, a plastic injection molding company's staff was plagued by persistent minor upper respiratory ailments. An IEQ sensor was installed and the customer thought it was faulty because the output stayed at maximum no matter how much outdoor air was admitted to the building. Subsequent troubleshooting revealed that a recently installed molding machine had its exhaust vented into the building's fresh air intake duct by mistake. Within two weeks of rerouting the exhaust, all occupant respiratory symptoms disappeared. A CO_2 sensor would not have sensed the contaminant from the molding machine.

The Financial Benefits of Appropriate Ventilation

One of the arguments used against VOC sensors is that because they sense odors and contaminants along with occupancy, that the building will be over-ventilated and therefore waste energy. According to ASHRAE Standard 62.1 however, VOC sensors allow the building to be appropriately ventilated, not over-ventilated, and this appropriate ventilation will save building owners and tenants money in the long run[2].

The Building Owners and Management Association (BOMA) stated in a 1999 report that typical building operating costs are 83.3% personnel salaries, 13.5% rent, 2.1% repair and maintenance and 1.2% total energy costs (Heat, Air Conditioning, Lighting, Business Equipment Power, Water Heating, etc). Clearly, the cost of employees is by far the greatest expense to the tenant or owner/employer.

"It has now been shown beyond reasonable doubt that poor indoor air quality in buildings can decrease productivity as much as six to nine percent," stated Professor David Wyon of the Technical University of Denmark's International Centre for Indoor Environment and Energy.

Numerous domestic and international studies support Wyon, showing that appropriate ventilation leads to increased worker productivity, increased worker accuracy, higher morale, less absenteeism and lower health insurance costs from fewer and less costly claims. For a tiny increase in total operating costs to ensure appropriate ventilation, owners/occupants can experience significant increases in employee productivity and significant decreases in employee expenses.

Because complaints about comfort are the number one reason tenants choose to leave a space, assuring indoor air quality with appropriate ventilation means that building owners will lose less tenants. They may even be able to increase rents by showing increased tenant productivity and comfort.

Please call a BAPI representative at +1-608-735-4800 for more information on how an IEQ sensor can enhance your next DDC installation.

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