

# Saving Energy & Meeting Regulations in Learning Spaces with CO2-based Ventilation Control

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*Building Bulletin 101 provides the regulatory framework in support of the Building Regulations for the adequate provision of ventilation in schools. It deals with the design of school buildings to meet the ventilation requirements of both The School Premises Regulations and the Building Regulations Part F (Ventilation). This Building Bulletin is quoted in Approved Documents F and L2 (amended 2006) as a means of compliance with Regulations F1 and L of the Building Regulations for school buildings. This article sets out to explain a little of the background and other advantages of controlling or monitoring Carbon Dioxide (CO<sub>2</sub>) in the context of the Building Schools for the Future and Primary Capital Programmes.*

## Introduction

The Building Bulletin 101 states that, “Ventilation should be provided to limit the concentration of carbon dioxide in all teaching and learning spaces. When measured at seated head height, during the continuous period between the start and finish of teaching on any day, the average concentration of carbon dioxide should not exceed 1500 parts per million (ppm).”

Using CO<sub>2</sub> concentration as a basis for ventilation control is established in well-quantified principles of human physiology. All humans, given a similar activity level, exhale CO<sub>2</sub> at a predictable rate based on age and activity level. This relationship is described in Appendix D of ANSI/ASHRAE Standard 62-1999.2 As a result, CO<sub>2</sub> can be used as a good indicator of human bio effluent concentration and/or occupancy, as, roughly speaking, doubling the number of people in a space will double CO<sub>2</sub> production.

## CO<sub>2</sub> As A Measure

CO<sub>2</sub> is one of the most common gases found in our atmosphere. As a point of reference, concentrations in the centre of the Pacific Ocean atop Mauna Loa Hawaii have been measured at 366 ppm and are considered to be the benchmark for the lowest concentration found worldwide. In urban areas, outside concentrations generally have been in the 375 to 450 ppm range.

An indoor CO<sub>2</sub> measurement provides a dynamic measure of the balance between CO<sub>2</sub> generation in the space, representing occupancy and the amount of low CO<sub>2</sub> concentration outside air introduced for ventilation. As a result, it is possible to use CO<sub>2</sub> concentration to determine and control the outside air dilution rate in a space on a “per person” basis.

There is evidence to suggest that perceptions of poor air quality associated with elevated CO<sub>2</sub> levels are more indicative of the build-up of other indoor contaminants as a result of reduced “per person” ventilation in a space rather than as a direct effect of CO<sub>2</sub>. For HVAC applications, CO<sub>2</sub> is best used as an indicator for outside air ventilation on a “per person” basis. Another important point to clarify is the relationship between CO<sub>2</sub> production and body odour. CO<sub>2</sub> levels will increase or decrease in relation to human metabolic activity. Since CO<sub>2</sub> is a good indicator of human metabolic activity, it can also be used as a tracer for other human emitted bio effluents.

CO<sub>2</sub> can be used to measure or control any per person ventilation rate, regardless of the perceived level of bio-effluents or body odour in a space. Control levels at 1000ppm generally represent a dilution rate of approximately 10 litres per person per second. This figure is the generally accepted optimum rate.

## The Effect of CO<sub>2</sub> Concentrations on Student Performance

Seppanen and Fisk in 2004 wrote a paper 'Summary of Human Responses to Ventilation Pupils Health & Performance In Regard To CO<sub>2</sub> Concentrations'

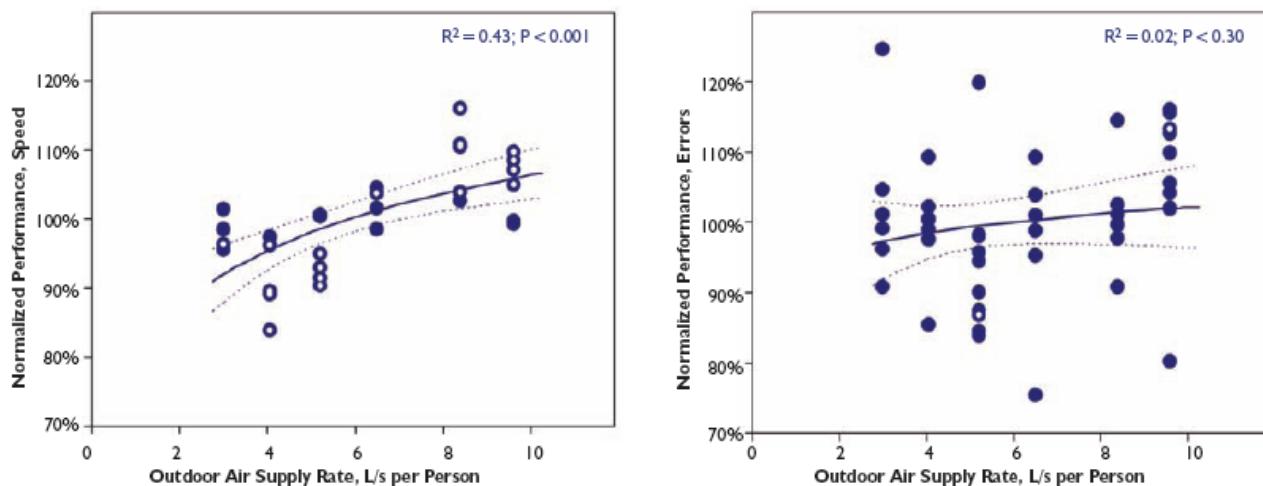
In Summary it showed ventilation has a significant impact on ...

- Communicable respiratory illnesses
- Sick building syndrome symptoms
- Task performance and productivity
- Perceived air quality
- Respiratory allergies and asthma

Taking this further, the effect CO<sub>2</sub> concentration has on performance and cognitive behaviour was studied much earlier in this paper "Indoor Environment in Schools – Pupils Health & Performance in Regard to CO<sub>2</sub> Concentrations" Myrvold, Olsen & Nielson 1996 , and is arguably the grand daddy of the research in this area.

The research was conducted in several schools in Norway, and found significant differences in performance with differing levels off CO<sub>2</sub>. The output was designed to measure the effect of a renovation project, but discovered the correlation between performance and health was directly proportional to CO<sub>2</sub> concentrations and ventilation rates.

Further studies Like "Effects of HVAC on Student Performance" Wargocki and Wyon, ASHRAE Journal, October 2006, attempted to prove numerically what Myrvold, Olsen & Nielson had found in 1996. As can be seen from the graphs, there is a demonstrable increase in both the speed and accuracy of performance as the ventilation is increased. These results have been confirmed by other studies.



That proper ventilation is an important factor in maintaining a comfortable, healthy, productive environment for students and faculty has been the conclusion of various private and government-funded studies about the environment within the classroom. Even so, a study published in 2002 by Coley & Beisteiner, entitled 'Carbon Dioxide Levels and Ventilation Rates in Schools' found that some classrooms had incidences of CO<sub>2</sub> levels in excess of 4,000ppm. This approaches the HSE long term exposure limits and is much higher than any recommended or comfortable level!



## Control the CO<sub>2</sub> Concentration, Control the Ventilation

People breathe in oxygen and exhale CO<sub>2</sub>. Outdoor air or ventilation has a very low and typically constant CO<sub>2</sub> content and when introduced into a room, dilutes the CO<sub>2</sub> exhaled by people. High indoor CO<sub>2</sub> levels mean there is not enough ventilation entering the room; and conversely low CO<sub>2</sub> levels indicate over-ventilation.

So, how do we control this? Indoor carbon dioxide (CO<sub>2</sub>) levels form the basis of ventilation control. There is a clearly defined relationship between indoor CO<sub>2</sub> levels and “per person” ventilation rates. This relationship is recognized by all the relevant design guidelines of CIBSE, ASHRAE, VDE and others

CO<sub>2</sub>-based ventilation control (also called demand controlled ventilation or DCV) is the accepted solution. This building control strategy optimizes the outside air intake based on the CO<sub>2</sub> levels within the space. Optimization means that the building will not be under- or over-ventilated. The result of under-ventilation can be poor indoor air quality. Over-ventilating wastes energy because the outside air must be conditioned before being sent into the building. It should be stressed that it is the minimum outside air volume that is modulated, a strategy incorporating temperature or enthalpy comparison should also be incorporated to maximise the efficiency of any ventilation plant. Where automatic windows are used, CO<sub>2</sub> control can also be incorporated into their operational control strategy.

The indoor CO<sub>2</sub> reading allows the HVAC system’s outdoor air intakes to modulate based on the building’s actual load. Maintaining the proper indoor CO<sub>2</sub> level ensures required ventilation rates are met. As an aside it also compensates for any unintentional or unmeasured ‘leakage’ to the measured space, for example an open door or uncontrolled building leakage.

Both BREEAM and LEED sustainability schemes recognise the benefits of DCV control, to the extent both offer points in their respective certification programmes.

## Today's Technology For Demand Controlled Ventilation

A whole range of wall mount and duct mount CO<sub>2</sub> sensor solutions is currently available to meet the needs of the BSF programme and Demand Controlled Ventilation schemes. A monitoring solution specially designed with the UK Schools market in mind is the new T8012 Telaire® Airestat™, from GE Sensing & Inspection Technologies. This is a low-cost, wall mounted CO<sub>2</sub> sensing solution for ventilation control, which offers end-users an easy-to-understand display of ventilation status. It has been developed to allow occupiers a simple way to maintain air quality, without the need to understand complex displays. It provides a relay output to operate small ventilation fans and is the first wall-mounted CO<sub>2</sub> sensing unit on the market which can accept a direct 230 Vac supply, with no need for intermediary transformers.

The essence of this new sensing solution is its Visual Level Indicator (VLI). This is an LED array that indicates increasing or decreasing CO<sub>2</sub> concentrations based on pre-determined thresholds. The CO<sub>2</sub> concentration is a direct indication of the air quality and is also a measure of whether the enclosed space is under-ventilated or over-ventilated. The Visual Level Indicator of the Airestat™ features a sequence of lamps, which pass from blue to red through green and yellow. A red light shows under-ventilation when the air quality is poor. Green and yellow lights indicate optimal operating conditions, and a blue light translates to over-ventilation, where too much energy is being used for heating or cooling. In rooms where heating only is utilised and windows are opened to provide cooling, the blue light can be ignored.

## Conclusions

The incorporation of CO<sub>2</sub> control into a building control strategy not only meets the requirements of the regulations, it also increases the cognitive powers of students, decrease health risks and contamination, and creates a more comfortable environment. In fact, an all-round win/win situation!

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