Carbon dioxide measurement as a means of ventilation control

M. P. Lyons* looks at the advantages and techniques of relating ventilation rates to varying needs

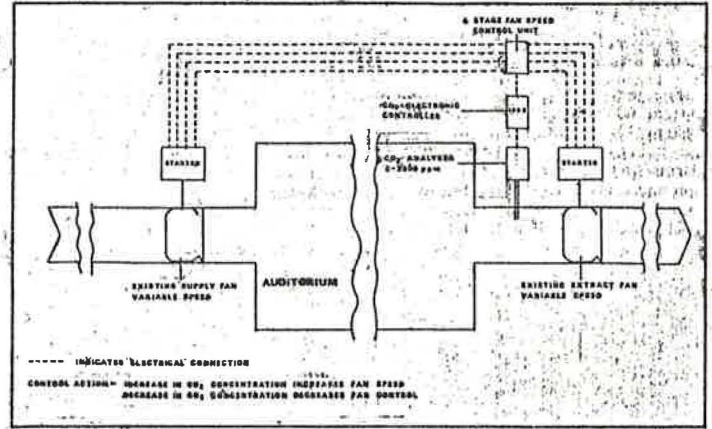
Many mechanical ventilated and air conditioned buildings are over ventilated, ventilation rates usually being based on a fixed number of people which is often considerably in excess of the average occupancy. Over-ventilation also occurs because no allowance can usually be made for infiltration. If ventilation rates could be modulated so that only the requirements of the actual number of occupants was supplied, considerable savings in heating energy could be made.

Occupants exhale carbon dioxide in the course of respiration, and this can provide the basis for a viable control technique. The carbon dioxide concentration in the ventilated space can be related to the ventilation rate per person. By modulating the fresh air flow to maintain a constant concentration of carbon dioxide, a constant ventilation rate per person can be achieved. This control action reduces the total ventilation rates whenever the occupation level is less than the design level. Additional reductions in the total air supplied may also be made by 'holding off' the mechanical ventilation until the carbon-dioxide concentratoin reaches a predetermined value.

In air conditioned and other mechanically ventilated buildings the design fresh air rate is usually determined by assessing the maximum number of occupants. A recommended quantity of fresh air per person is in turn assessed using, for example, the CIBS guide. The personal ventilation rate is normally based on odour control requirements and takes into account the volume of space occupied per person. Ventilation rates solely based on empirical odour criteria are typically five times those required to limit carbon dioxide to acceptable levels.

To summarise, building over ventilation and consequent energy wastage is attributable to three main causes.

- The population of a building may be variable. Actual occupation may vary and be on average well below the design occupancy level. Hour to hour, weekly and even seasonal patterns of occupation are not easily predicted.
- In buildings with a 'fixed' occupancy, air quality takes some time to deteriorate after initial occupancy. The length of this period can vary and, again, cannot easily be forecast.
- Although infiltration of air is notionally assessed for the purpose of determining heating and cooling loads, it is not generally or easily taken into account when deciding the ventilation requirements of a building.

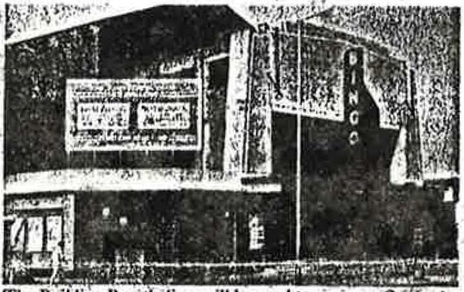


Diagrammatic layout of a typical Building Breathaliser system in a cinema.

In practice, ventilation related waste is attributable to a combination of these three factors. Building owners, however, tend to either accept their excessive energy bills or try to recover some of the exhausted heat or tackle infiltration in isolation. Much effort is applied by energy managers both to justifiable schemes such as simple draught proofing and to arguably less cost effective programmes such as heat recovery. Most approaches do not tackle the root causes of ventilation related wastage, which in a modern building can account for up to 70% of the total annual heating consumption.†

One partial answer is occasionally encountered where full recirculation is applied in the pre-occupancy heating phase. However, once the building is occupied or, more importantly, liable to be occupied, a fixed minimum fresh air supply is initiated. This generally corresponds to the design occupancy of the building in question.

Take, for example, the case of a cinema, lecture theatre or retail store. These buildings may have an outdoor supply for say 500 people yet have a fluctuating average occupancy well below this figure. 20 people watching a week day afternoon performance at the cinema have as much ventilation and thus heating supplied as the 500 watching on Saturday evening. This is highly wasteful and in certain circumstances can even reduce comfort conditions. Even in less obvious situations such as offices, there are daily and seasonal variations in occupancy.



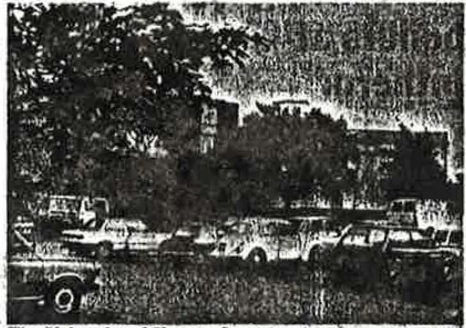
The Building Breathaliser will be used to measure CO_2 in the Top Rank bingo and social club in Hounslow.

What is needed to reduce these losses is a constant monitoring technique to assess the quality of the air in a building space, related to occupancy, and a suitable method of variable control. A suitable technique recently developed is based on the carbon dioxide released in the course of respiration. Much study worldwide has been concentrated on this potential control method. In the United Kingdom, studies have been carried out in the building science section in the school of architecture at Newcastle University which indicate the potential savings of this technique.

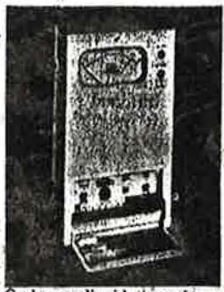
My company became involved in 1982 with Newcastle University in developing a commercially viable system based on infra-red absorptiometry. This was dubbed 'building breathaliser' during development work. The name was later adopted for commercial use. Our own work confirmed Newcastle University's research that carbon dioxide analysis offered a very good basis for the control of ventilation systems. It was also noted that infiltration had a direct effect on the level of carbon dioxide present. Carbon dioxide exhaled by occupants was diluted, and thus the system automatically made allowance for its impact.

The application of the system to real buildings was much easier than anticipated and was not restricted to buildings with a provision for recirculation. Cinemas, for example, generally have a 'total loss' fixed volume ventilation system. This can be controlled by using dampers to throttle the air flow by up to 75%. This is sufficient to satisfy the heating load of the space without excessive heating losses.

At present Rank Leisure is applying this technique to a number of its buildings, some under an ETSU Demonstration Scheme. Provisional results from the monitoring body, Energy Conscious Design, indicate minimum daily savings of 22%. Bill Taylor, Rank's Energy Executive, reckons the cost of the system and associated work in these more complex retrofit schemes will be recovered in about 12 months. Mecca Leisure, under Energy Manager Harry Smith-Hampshire, is encouraged enough to be installing its own systems, initially in the South East.



The University of Kent at Canterbury's Cornwallis lecture theatre.



Carbon dioxide analyser used as part of the Building Breathaliser system.

The system is equally capable of controlling fan speed units, and in many variable volume systems power as well as heating savings are made. The University of Kent at Canterbury was one of the first to take this route in its Cornwallis Lecture Theatre during 1983. The University considers that 'The Building Breathaliser has achieved considerable economies in the Cornwallis Lecture Theatre and we expect a rapid payback.' In a separate project, we have been working with Ralspeed, the Accrington fan speed control company, to offer a comprehensive and fully automated package for both new and retrofit schemes. Peter Schaffel, managing director of Ralspeed, says, 'the future for variable volume systems is even brighter given that we can now relate volume to real need at any moment in time.'

The Building Breathaliser has also found a place in British Home Stores' energy strategy. Last year BHS commissioned ABBA Consultants of Byfleet to conduct field trials in its Kingston Branch over several months. Their report endorsed the technique and the system is being adopted in BHS's new buildings where it complements temperature based controls in minimising the admittance of outdoor air. In practice, this means that a signal comparator is used. If either the Building Breathaliser or other controls call for more outdoor air, the dampers respond accordingly. Minimum fresh air has been replaced by an infinitely variable system, and there is no need to establish an arbitrary minimum value during commissioning.

Several variants of the basic system have evolved. Possibly of most interest is its application to the control of direct gas fired heating units. These previously had to operate on 100% outdoor air. Where it is suitable, a modulated mix of fresh and recirculated air is supplied producing substantial savings. Pilot work supervised by Alexander Hardy & Associates at the Sleepeeze factory at Wakefield indicted savings of 30% on applying the technique to Dravo Heating Units.

The Building Breathaliser technique is rapidly coming of age, consultants and end users alike finding it comparatively simple and highly cost effective. If the interest from abroad alone is an indication of potential, carbon dioxide based ventilation controllers may well become as common as optimisers over the next decade. □

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†J. Kusuda. Control of ventilation to conserve energy while maintaining acceptable indoor air quality. ASHRAE Transactions, 82, Part 1, 1169-1181 (1976).