Minimise to maximise

Air quality in urban areas is often poor, creating problems for local buildings forced to ventilate with polluted air. Most of the pollution comes from traffic, with the worst periods during rush hours. What role can the automatic control of ventilation play in reducing the impact of pollutants?

BY JOHN FLETCHER

Traffic pollution is a major problem in urban areas, and is often cited as a reason why buildings must be sealed and air conditioned. However, pollution levels are highly variable, being dependent on factors such as traffic density and weather conditions. An example of this is shown in figure 1, which illustrates an average summer day at one of the UK government's automatic monitoring sites[1].

There are many factors in design, construction and operation that contribute to polluted outdoor air entering a building. Leaky buildings or openable windows provide a path for unconditioned and potentially polluted air. HVAC design is also important, particularly the location of air intakes. Basement plantroom air handling units often have intakes at low level, with most urban buildings located near busy roads.

The operation of hvac systems is also a major factor. Economiser cycles make use of free cooling, which often results in 100% outdoor air. In summer, pre-occupancy purge cycles (as recommended by the International Energy Agency[2]) operate at peak rush hour periods, and if CO_2 or mixed gas sensor controls are used these increase the proportion of outdoor air if the indoor air quality is perceived as being poor.

Fortunately there are potential solutions, such as carbon filters to remove the gaseous pollutants. Another possible solution is to control ventilation in relation to outside pollution levels. Where pollution is variable, for example during the rush hour period, an opportunity exists to effectively cut the pollution peaks through ventilation control (this is currently the subject of a BSRIA research study, sponsored by the DoE's Construction Sponsorship Directorate and industry partners).

The potential effectiveness of ventilation control can be demonstrated by a simple model (figure 2). After only 2·3 air changes (typically 30 minutes) the indoor pollutant concentration is 90% of the outdoor level at full fresh air, demonstrating the speed at which outdoor pollution episodes can affect indoor air quality. At a high air supply rate, this time may be less than 15 minutes.

Conversely, a system operating at minimum fresh air is much less affected, and even after a few hours could still be well below the outdoor level. Since traffic-related pollutant peaks typically last between two to three hours, ventilation control could be an effective technique. Obviously, in actual buildings there are many contributing factors.

The type of ventilation control applied is dependent on the frequency of the pollution episodes. In extreme circumstances, a simple timeclock could be applied to operate minimum outdoor air between selected hours. An analysis of government pollution data indicates that the timeclock could operate from 07.00 h to 10.00 h, and 16.00 h to 19.00 h, unless local conditions dictate otherwise. However, this type of control is only appropriate where air quality is regularly poor.

Alternatively, pollution peaks may be associated with rush hour periods, but of a more sporadic nature. In this case some form of direct measurement may be more suitable.

A third type of pollution episode is more random and could be the result of a nearby bus stop, taxi drop-off point or a lorry unloading. In this case, it may be feasible to determine when a pollution source is present indirectly, and without resorting to direct measurement, for example by barrier operation or opening loading bay doors.

Exposure limits

Any attempt to apply ventilation control must determine which pollutant(s) to measure and the concentration(s) deemed unacceptable. The HSE regulates the maximum permitted exposure to airborne pollutants while at work as defined in occupational exposure standards[3]. These are generally a factor above the other limits, and their application to offices has actually been investigated in a separate study[4]. This study concluded that there were no health-based reasons for different limits, but the expectation and perception of office workers required lower limits.

Sick building syndrome is rarely acknowledged in factories, where heat, noise and high metabolic activity are considered to be the norm. This is not so in offices, and maximum limits based purely on the grounds of health should not apply.

In addition, occupational exposure standard limits are legally permitted maximums and as such should not be used as target levels. Therefore, lower limits, for example those laid down by the WHO, are applicable for ventilation control.

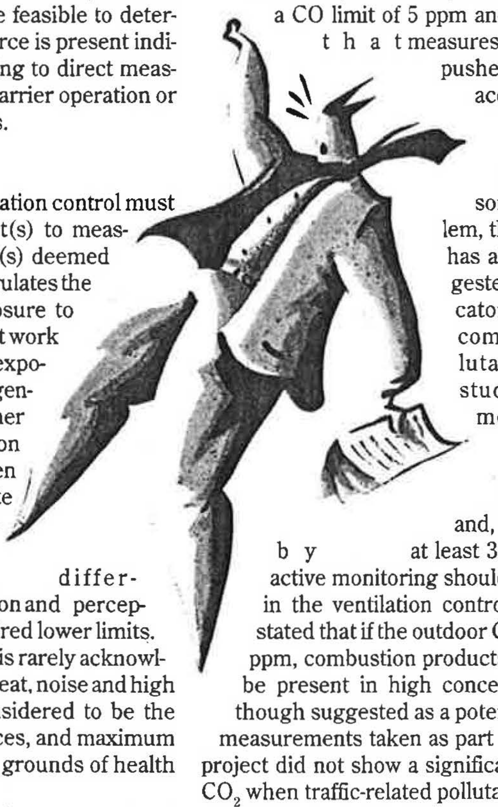
Control sensor options

Exposure limits (other than those expressed by the occupational exposure standards) are given in parts per billion (ppb) for most pollutants, which presents something of a problem for ventilation control.

For use in building services, sensors must be cheap, robust and reliable. Measuring ppb levels, though, requires an expensive analyser, sensitive to the environment and requiring frequent recalibration. One of the cheapest technologies is electrochemical cells, which measure a range of gases. These sensors are relatively inexpensive, costing between £300-£500, compared to alternative techniques costing between £10 000-£15 000.

Electrochemical cells measure in ppm, which is too high for most WHO pollutant limits (with the exception of CO). CO sensors are generally aimed at occupational exposure standards compliance or to prevent potentially harmful exposure from faulty combustion appliances, and typically have ranges between 0-100 ppm and 0-500 ppm. The WHO one hour limit for CO is 25 ppm.

Several studies have shown a good correlation between CO and other traffic-related pollutants, and that a concentration of approximately 5 ppm of CO indicates that other pollutants may be unacceptable[5,6,7]. Adopting a CO limit of 5 ppm and using a cell that measures up to 100 ppm pushes the sensor accuracy to its limit.



As cheap, reliable sensors are a problem, the use of CO_2 has also been suggested as an indicator of outdoor combustion pollutants. One study[8] recommended that outdoor CO_2 is monitored for a week and, if it fluctuates by at least 300 ppm, then active monitoring should be included in the ventilation control. The study stated that if the outdoor CO_2 is 700-800 ppm, combustion products are likely to be present in high concentrations. Although suggested as a potential solution, measurements taken as part of the BSRIA project did not show a significant change in CO_2 when traffic-related pollutants peaked.

Mixed-gas sensors are a third low-cost option and, although there are problems with calibration, they do react to a wide range of traffic-related pollutants and are already being used by some car manufacturers to control ventilation in vehicles.

There is some evidence that, in certain situations, mixed-gas indoor air quality sensors in buildings may pick up traffic-related pollutants. Figures 3 and 4 show the sensor output from a test building. Air intakes are at low and high level near a busy dual carriageway. In this building peaks did not occur every day, but when they did the peaks coincided with rush hour periods. Also, peaks from areas supplied by rooftop plant were smaller than those from basement plant.

Current sensor technology indicates that, generally, the only cheap, practical option is a CO cell, although in certain circumstances CO_2 or mixed-gas sensors may be feasible.

Sensor location

The effect of different sensor locations has been modelled, and the results are shown in figure 5. Locating a CO sensor in the air intake will cause the control to activate if outdoor air quality is poor and continues as long as the outdoor air exceeds the set-point, regardless of indoor levels. If the pollution episode lasts for an extended period, at some point the indoor concentration will exceed that outdoors, but a sensor in the intake will not recognise this situation.

Again, figure 5 shows that the control continues to operate even when it is no longer beneficial. There are a number of ways to overcome this problem and these will be assessed in future test work.

A CO sensor in the zone or return air could be located in the occupied space or in the return air path. This option recognises when it is beneficial to control, but is slower to react to pollution episodes. CO must build up indoors before the control responds.

The obvious way of overcoming the limitations of sensors in the air intake or return air alone is to use them both. Figure 5 shows that the response to pollution episodes is quick and controls stop when no longer required. However, the model does not assess the limitation of the sensors. The use of one electrochemical CO sensor stretches the technology to its limits, and two would need a deadband sufficiently large enough to account for the accuracy of both sensors.

Control strategies

The most appropriate control is a simple on/off type, the control objective being simply to minimise the effects of a pollution episode. The pollutant set-point is not a limit that can be controlled to, but an indication that action is required. Sensor limitations effectively exclude proportional control as an option.

When the ventilation control has been activated, it can move the dampers to minimum outdoor air or operate on full recirculation for a short period. Full recirculation is preferable because it effectively blocks the ingress of outdoor pollutants, although its use can only be short-term to prevent problems with indoor pollutant sources.

The latest draft of ASHRAE *Standard 62* allows temporary reduction below the design minimum, providing the average rate each hour is at the minimum. This is aimed at systems where ventilation may not be continuous. *Standard 62* also states that levels below the design rate can be used when the outdoor air quality is poor, and that this should be applied for no more than four hours per day. Systems that do not have recirculation can reduce the supply rate or even switch off the ventilation system providing the above are complied with.

John Fletcher is a senior research engineer at the BSRIA BEMS Centre.

References

[1]Air Monitoring Group: Warren Spring Laboratory, *"Air pollution in the UK: 1993-94"*, ISBN 0-85356-422-1.

[2]International Energy Agency, *"Demand-controlled ventilating systems D2:1993"*, ISBN 91-540-55 13-X.

[3]*Occupational Exposure Limits for 1995, EH 40/95.*

[4]Lunau F W, "Air quality standards in offices: should they be health or comfort-based?", *Indoor Air*, Vol 2, 1993, pp213-216.

[5]Kruger U, *"Location of air intakes to buildings situated in urban environments"*, pp374-388.

[6]Minister of Supply and Services, Canada, 1995, *"Indoor air quality in office buildings: a technical guide"*, ISBN 0-662-23846-X.

[7]Ekberg L E, "Concentrations of NO_2 and other traffic-related contaminants in office buildings located in urban environments", *Building and Environment*, Vol 30, No 2, 1995, pp293-298.

[8]Schell M, *"Guidelines for the use of carbon dioxide for demand-controlled ventilation"*.

HEVAC ON INDOOR AIR QUALITY

Launched in May 1996 and sponsored by the Heating, Ventilating and Air Conditioning Manufacturers' Association (HEVAC), the building services division of FETA, the Indoor Air Quality Initiative aims to promote the benefits of good indoor air quality by providing objective, guiding information on topics such as sick building syndrome and global warming.

A fact sheet was issued in August 1996, examining the relationship between indoor air quality and productivity in the workplace. Among the issues discussed were the possible consequences for employers and the workforce if indoor air quality issues are overlooked, and the ways in which employers can improve indoor air quality.

Funding is being gathered together from member companies for phase two of the initiative, where the HEVAC plans further worksheets and the formation of working associations to bring its members closer to current indoor air quality research projects. A planned third phase will include a series of seminars and workshops.

Copies of the first fact sheet and further details of the Indoor Air Quality Initiative are available from the HEVAC on 01628 531186.

Figure 1: Cromwell Road, London – average summer day

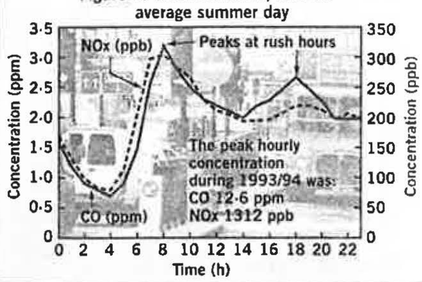


Figure 2: Change in internal pollutant concentration resulting from a fixed external source

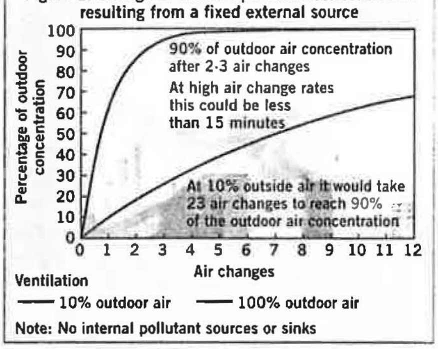


Figure 3: Indoor air quality sensor output from an urban building – morning peak

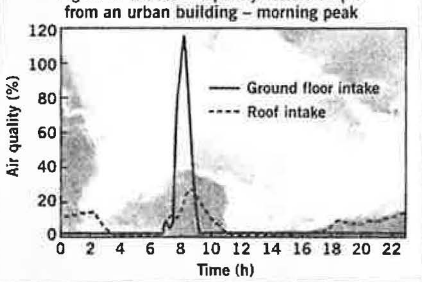


Figure 4: Indoor air quality sensor output from an urban building – evening peak

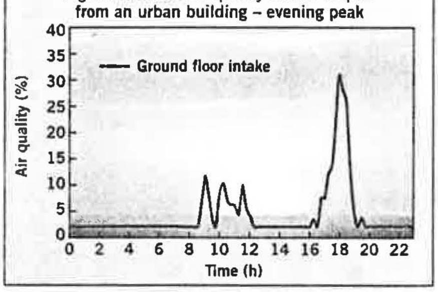
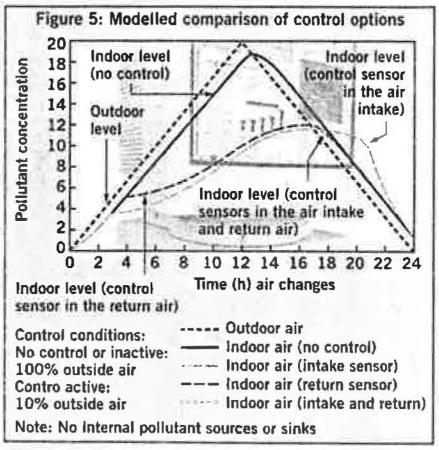


Figure 5: Modelled comparison of control options



Air quality in urban areas is variable, with pollutant levels increasing during rush hours. Automatic control of ventilation can help reduce the impact of pollutants.