NIS

#3495

Fresh air for sedentary occupants

Paul Appleby examines the basis of ventilation requirements and recommendations for buildings and compares the imminent ASHRAE Standard with the latest thinking in Scandinavia.

In recent years there has been a tendency to blame many of the complaints from people working in air conditioned office buildings on a lack of fresh air. Investigations have shown that a perception of inadequate fresh air is frequently associated with lack of air movement, stuffiness, or the inability to open windows. There is usually very little correlation between the incidence of this comment and the ventilation rate provided.

Infiltration of outdoor air into naturally ventilated buildings in winter is frequently below recommended quantities, particularly for occupants working 5 or 6 metres from a window, yet ventilation-related problems associated with these free-running buildings would appear to be less common than in the sealed air conditioned buildings. So just how important is fresh air? Should more attention be focussed on other aspects of air conditioned buildings, such as remoteness of some workers from a view or daylight, lack of personal control etc?

ASHRAE will be publishing their new standard *Ventilation for acceptable indoor air quality* later this year. This document has been available for public comment since July 1986 and the final appeal meeting was scheduled for June 1989. Britain does not have such a standard, nor such a procedure. The latest recommendations from CIBSE appeared in *Section B2* of the *1986 Guide* without being considered by a committee, other than the authors, and without public consultation.

Recent laboratory-based work[1] has shown that the minimum ventilation rates for CO_2 control adopted in Britain and North America, of 5 and 2·5 litres/s per person respectively, were inadequate when considering odour levels perceived by people when first entering an already occupied space, and that the density of occupancy has no bearing on fresh air requirements. It is widely thought that the high incidence of complaints in North American air conditioned buildings can be largely attributed to the adoption of the 2·5 litres/s recommendation, leading to their coining of the phrase "tight building syndrome". Minimum fresh air requirements have been increased accordingly in both countries, to 8 and 7·5 litres/s per person respectively.

What is fresh air?

Outside air must reach certain minimum standards to be considered suitable for supply to occupants within a confined space. The new ASHRAE Standard uses ambient air quality standards produced by the US Environmental Protection Agency as a basis for their definition of fresh air. This specifies long and short term limits for common pollutants only. If examination of records shows that these are exceeded then it is recommended that suitable air cleaning apparatus be installed.

Odour control

Odour represents one of the biggest sources of complaint among sedentary workers, and is thought to be a significant contributing factor in many "sick" buildings. There are many sources of odours in a building, including the ventilation or air conditioning system[2].

The recently revised CIBSE recommendations (8 litres/s per person) and new ASHRAE recommendations (7·5 litres/s per person) result from concern over the incidence of ventilation-related problems in air conditioned buildings, and are based on recent work in Denmark[3] and N America[1] which have concentrated on odour perceptions and reducing the percentage of dissatisfied occupants to an acceptable level.

This work showed that there is a difference in perception between people entering a space and those who are acclimatised. Even with no smokers present, up to 40% of people entering a room supplied with 2·5 litres/s of air per person will be dissatisfied.

Up to now, ventilation rate recommendations, have not taken account of ventilation efficiency or odours released by the building and services. Fanger[2] has addressed the first deficiency by devising a unit of odour intensity which he has called the olf, defined as the emission rate of air pollutants (bioeffluents) from a standard person.

Using the subjective assessment of a large group of people subjected to odour levels in a variety of naturally and mechanically ventilated and air conditioned spaces, Fanger has found that for every occupant and associated odour there may be another four to five odour equivalents (olfs) released from building materials, furnishings and the air handling system.

Auditoria are particularly prone to soiling of internal surfaces because of the extent of soft furnishings and acoustically absorbent finishes. The odours emitted from cooling coil drip trays and spray humidifiers were found to be particularly significant.

The new ASHRAE Standard allows the designer to calculate an appropriate ventilation rate from first principles. This *Indoor Air Quality Procedure* involves the calculation of a dilution or displacement ventilation rate, based on limiting concentrations for non-industrial exposure to contaminants and a prediction of the ventilation index[4].

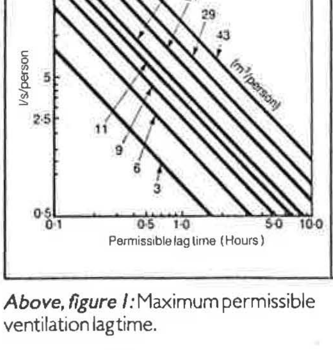
There is, however, a dearth of published limits for non-industrial exposure to contaminants. The World Health Organisation produced a table in 1982[5], which summarises the concentrations of concern at 1982 levels of knowledge for contaminants commonly found in offices and homes. This table covered exposure to passive smoking, CO_2, CO, formaldehyde, radon gas and ozone, among others.

Tobacco smoke

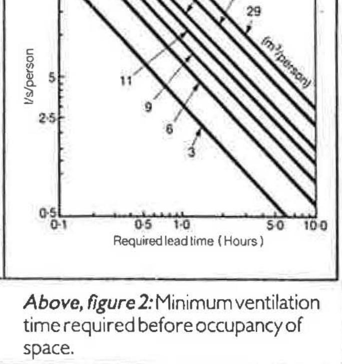
CIBSE recommendations are based on Leaderer and Cain's, with a view to attaining 80% satisfaction among non-adapted occupants. They refer to rooms in which there is "some", "heavy" and "very heavy" smoking, corresponding with ventilation rates of 16, 24 and 32 litres/s per person respectively.

The new ASHRAE Standard uses a different approach[6]. It is based on a lower smoking rate than used by Leaderer, to account for the change in US smoking habits, and satisfying 80% of adapted occupants. This results in a minimum ventilation rate for dilution of tobacco smoke equal to that required for odour dilution, ie 7·5 litres/s per person. However the fresh air rate proposed for office space, having a maximum occupancy density of one person per 14 m^2, is 10 litres/s per person.

The areas listed as requiring the minimum rate, such as auditoria, reception areas and clas-



Above, figure 1: Maximum permissible ventilation lag time.



Above, figure 2: Minimum ventilation time required before occupancy of space.

Table 1: recommended outdoor air flow rates (abridged from ASHRAE Standard *62-1981R*)

Application	*Est max occupancy P/100m²*	*Required l/s person*
Auditoriums	150	8
Bars, cocktail lounges	100	15[a]
Dining rooms	70	10
Hotel bedrooms		15 (per room)
Office space	7	10
School rooms	50	8
Smoking lounges	70	30[b]
Waiting rooms	100	8
Residences		0·35 ach[c]

[a]Air cleaners may be needed.
[b]Local exhaust recommended.
[c]Not less than 7·5 l/s/person.

srooms, are either of a transitory nature or less likely to contain smokers. Table 1 gives selected recommendations extracted from the proposed ASHRAE *Outdoor requirements for ventilation*.

The issue is complicated by the fact that smoke evolves at a rapid rate and there may be high local concentrations which depend on room air movement.

For low level supply systems smoke may rise vertically into the high level extract and dilution will occur at the central air handling unit. The plume will be very sensitive to cross-draughts from opening doors, to wakes generated by moving people, and to other disturbances.

Fanger[2] found that a further two olfs were contributed to the emission of odours by cigarette smoking: this is with 30% of his observers being smokers, although he provides no information on smoking rates.

Intermittent and transitory occupancy

Some new buildings and furnishing materials emit solvents used in their manufacture and treatment for a few years. High surface area materials may adsorb contaminants from the room air and release them later. However, in rooms with mainly hard surfaces, sparse furnishings or where potentially contaminating building products are avoided, there may be insignificant release of contaminants when the building is unoccupied.

For applications in which odours are likely to accumulate it is useful to provide predilution by bringing in the ventilation plant some time before the occupancy arrives. For the second category it may be possible to hold back fresh air provision until the odour levels are approaching unacceptable levels.

The new ASHRAE Standard provides a technique for determining the lead and lag times (see figures 1 and 2), depending on the room volume per person and their fresh air allowance.

Control methods are available which can be used to adjust fresh air rate according to the prevailing contamination levels. CO_2 or odour (air quality) sensors can be installed in the space or in extract ductwork and arranged to adjust the mixing dampers or switch fans accordingly. These methods can be used to provide automatic control over lead and lag operation and adjust fresh air volumes for transient and intermittent occupancy. However Fanger[2] found no correlation between CO_2 concentrations and odour perception, a finding which may throw some doubt on the validity of using CO_2 sensors for the control of ventilation systems.

At perhaps an eighth of the cost of a CO_2 sampling based system, the air quality sensor based controller is a relatively cheap system. The air quality sensor uses the same principle as an adsorption filter to attract gases to the porous surface of a semi-conductor, the conductivity of which changes with the amount of gas adsorbed. Gases are alternately adsorbed and desorbed (by heating the sensor). This system will respond to changes in concentration of a wide range of contaminants, although little is known about the way it responds to mixtures.

For the system to make an appropriate response to the gases and vapours found in tobacco smoke an adjustment to its sensitivity is required which renders it inaccurate in its response to the contaminants which indicate air purity during non-smoking occupancy.

In tests carried out in an existing auditorium in Sweden, Sødergren[7] observed that air quality sensors continued opening the fresh air dampers for some hours after the hall emptied. He suggests that this was the result of the sensor responding to contaminants released from seating and other adsorbent internal surfaces. In contrast the CO_2 controller closed the dampers and switched off the fans under the same conditions.

The complexity, cost and questionable accuracy of the control of mixing dampers can be overcome by the use of full fresh air plant with air-to-air heat exchangers transferring heat between the exhaust and outdoor air streams.

There are a number of devices on the market, some with efficiencies as high as 70-80%. Transfer of both sensible heat and moisture with very little transfer of contaminants is possible if a hygroscopic thermal wheel is used. However, most other arrangements, such as the plate heat exchanger, provide sensible heat transfer only, but introduce a complete physical barrier between exhaust and outdoor air streams.

For the penalty of a lower efficiency, run-around coils transfer heat from an exhaust air system in one part of a building to an outdoor air intake elsewhere in the building, using conventional finned-tube coils with pumped water/glycol circulation between.

Swedish codes may soon reflect the trend which is already prevalent in some Scandinavian countries, for full fresh air ventilation plant, with heat transfer by air-to-air heat exchanger. This follows the widespread adoption of displacement ventilation in those countries, which requires 100% outdoor air to maintain stratification of contaminated air above head level[4].

The new ASHRAE Standard allows for the reduction of outdoor air rate, provided particulate and gaseous contaminants are removed from the air by filtration, so that the level in the space is equivalent to that which would be obtained if the recommended fresh air rates were employed. It also allows provision for a reduction in the outdoor air rate to account for uneven contaminant emissions in multiple room buildings, thus allowing for the air returning from low contamination zones to help with dilution in contaminated regions.

Conclusions

The American approach to ventilation, which allows the designer to minimise outdoor air supply, is no doubt born from concern about the massive amounts of energy required to ventilate their buildings. Floor areas are commonly in the tens of thousands of square metres, and are very difficult to ventilate efficiently, particularly with the widespread use of variable air volume air conditioning and the close proximity of supply and extract air terminals.

If a ventilation or air conditioning system is not adequately maintained, it may contaminate the air more than the room-based sources. Perhaps this is one of the answers to why, in general, naturally ventilated buildings produce fewer complaints than air conditioned buildings.

References

[1]Leaderer, B P & Cain, W S (1983) *Air quality in buildings during smoking and nonsmoking occupancy*. ASHRAE Trans. 89, 2A & 2B, pp 601-623.

[2]Fanger, P O, Lauridsen J, Bluyssen, P & Clausen, G (1988) *Air pollution sources in offices and assembly halls, quantified by the olf unit*. Energy and Buildings, 12, pp 7-19.

[3]Fanger, P O (1986) *Body odour and carbon dioxide, minimum ventilation rates*. IEA energy conservation in buildings and community systems programme, Annex IX final report.

[4]Appleby, P H (1989) *Displacement ventilation - a design guide*. Building Services, 11(4), pp 53-56, April 1989.

[5]Ashley S. (1986) *Sick buildings*. Building Services, pp 25-30, February 1986.

[6]Janssen, J E (1988) *Control of indoor air quality through ventilation*. Proc. 5th Canadian Building and Construction Congress, Montreal, Quebec, Nov. 1988. NRC of Canada.

[7]Sødergren, D & Dahlgren, B (1985) *Requirement-controlled ventilation of an auditorium*. Proc. Int. Symp. Control and Operation of Buildings HVAC Systems. CIB/SINTEF. Trondheim.

Paul Appleby CEng MCIBSE is a consultant engineer, based in Norwich and md of London-based Building Health Consultants Ltd.

We would like to draw the readers attention to the following errors in the equations in the article "Displacement ventilation: a design guide", published in the April issue of *Building Services*. The first should read as follows:

$$Q = 0{\cdot}005 H^{1/3}(X + X_p)^{5/3}$$

and the second as:

$$Q_E = 0{\cdot}00292 (t_Y - t_R)^{0.4} y^{1.2} w$$

We would also like to point out that there was a value missing off the diagram on p65. This should read 0·15 m/s.