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Ventilation for People

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Abstract
The developing trend that Building Regulations in the future will be applied to buildings in use rather than to their design intent on paper has many important implications. It will lead to pressure testing of new buildings to ensure air tightness, low energy bills and the associated absence of draughts. Importantly, it means that for the first time, the ventilation air will enter the building through the air inlet ductwork. This offers the designers the opportunity to control the indoor environment to create refreshing comfortable climate while retaining low energy use. The three critical factors are sufficient air to dilute odours, better filtration to remove particulate matter with the implications of this for health, and controlled humidity for comfort and freshness.

Introduction

Ventilation is the least understood and most abused factor in building services. In the ventilation of a building, there are at least five kinds of problem which can arise.

(1) The designer of a building can sometimes believe that infiltration of air is ventilation. As a consequence, little in the way of planned ventilation is provided in many buildings. Loose-fitting window frames, gaps in the structure, internal duct ways which are open ended and act as chimneys, and unsealed interfaces between wall and floor or roof are all considered breathing routes for the building. Such holes and gaps offer high ventilation rates, albeit of an unknown and variable quantity. This is believed to give protection against damp and mould growth, for which the architect will be blamed if such unhealthy signs appear. The resulting uncomfortable draughtiness and high energy bills are not popular with clients. This also means that the indoor environment directly reflects the outdoor one because the air supply is not properly engineered [1].

(2) The building services engineer may see his ventilation system as supplying a given quantity of air to the built space. The distribution of the air and the effectiveness of its purging pattern in relation to the building occupancy is ignored. Draughtiness and stale air simultaneously within the same space are two of the legacies of a poor air distribution system.

(3) The planner can decide to locate the air inlet in a place which is the least obtrusive without regard to outdoor pollution. This can lead to the air inlets being located in zones of high traffic loads. Modern city buildings often no longer have a rear face which can be used for service

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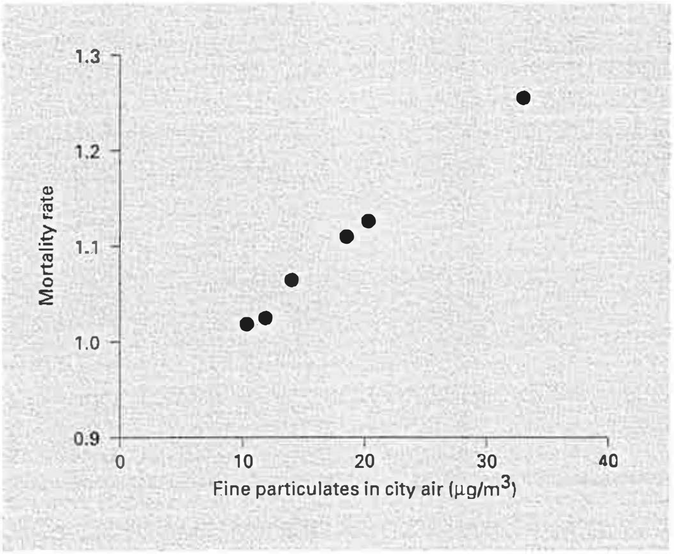

Fig. 1. The relationship between mortality and airborne fine dust concentration. Adapted from Dockery et al. [4].

penetrations. The building must look tidy on all four faces.

(4) The maintenance staff may not realise that present-day HSE guidelines ask for duct cleaning to be undertaken once each year [2]. It is not unusual for the supply from mechanical ventilation to introduce more contamination from debris inside the ductwork collected over the ages rather than reducing contamination by diluting the pollutants generated indoors [3]. Recent surveys in Sweden have shown that the majority of ventilation systems in use in buildings were not in good order.

(5) Changes in use or in the neighbouring buildings can create havoc with the pollution level at the air intake. Reorganising traffic or even changing the car parking spaces may introduce high levels of outdoor contamination to the building. Introducing a chimney on a building in the neighbourhood may permit exhaust gases to enter the air inlet duct [1].

For the last 20 years, there has been much lobbying by environmentalists to do away with air conditioning and mechanical ventilation, and design with natural ventilation using wind collectors and indoor ventilation stacks. The result has been customer unhappiness with the current systems, high energy bills in practice and the hope of lower costs unrealised. Unfortunately, many of the buildings designed in this way have not produced the low energy bills nor the customer satisfaction expected.

New Data

Five new research findings are about to change the way in which people think about new buildings.

(1) Particulates in urban air are believed to curtail life expectancy in a dramatic way. The toxic mechanism is unknown, but one possibility involves the adsorbed combustion products on the surface of the particles which may be desorbed in the lung. The commonest source of such particulates is the exhaust from diesel engines, and the finer particles are the most dangerous, in part because they penetrate most deeply into the lung. This effect of particulates has surprised the medical world which previously believed that the key pollutants producing health effects were chemicals such as sulphur dioxide, ozone and the oxides of nitrogen [4, 5]. A number of epidemiological studies relating the level of airborne particulates to morbidity and mortality have been conducted, of which probably the best known is the six-cities study. Data from this US study are shown in figure 1 [4].

(2) One function of ventilation is to dilute the odours generated within the building. This has traditionally meant diluting cigarette smoke and body odours. Now that cigarette smoking is no longer allowed in most buildings, ventilation rates have been cut back appreciably. Customer surveys show that unpleasant odours are still a real problem. Research has found that the building itself can generate unpleasant odours. These come from solvents, plasticisers, copying machines, sealants, paints, in addition to smells from the ductwork and associated equipment. Some allowance needs to be made for building-generated odours [3]. Large-scale studies have shown that around a third of office occupants find indoor air quality unacceptable [6].

(3) Moisture in air has long been recognised as an important factor for maintaining comfortable skin, avoiding eye irritation and minimising electrostatic shocks at the low-humidity end of the spectrum, while avoiding mould and condensation at high humidity [7]. More recently, the freshness of clean air has been clearly shown to be associated with its enthalpy. Reducing the enthalpy of the air results in the perception that it is more pleasant. This means that low-temperature dry air gives the impression of freshness while stuffiness is associated with more humid warmer air. This is attributed to the cooling effect of the air as it passes through the nose. Temperature and humidity control are essential for a refreshing atmosphere [8]. The relationship between temperature, humidity and acceptability of indoor air is illustrated in figure 2.

(4) The effects of pollutants on physical and mental well-being are being recognised at much lower concentrations than previously. Health risks associated with damp, mouldy houses have long been recognised [6]. Careful studies on the health effects resulting from the use of unvented gas cooking in houses show both lung function decrements and increased respiratory symptoms, especially among young women [9, 10]. Sensitive psychological tests on students exposed to low concentrations of carbon monoxide from unvented paraffin stoves revealed a deterioration in memory, a loss of attention and a decrease in visuomotor and tracking skills [11].

(5) The quality of building construction in the UK is such that it permits high infiltration rates, which means that a high proportion of the indoor air enters through unplanned routes, from unknown points and in a variable quantity, depending upon the wind speed and direction, and to a lesser extent upon the ambient temperature. Planned ventilation slots do not always have the expected effect. This means that the indoor pollution levels usually reflect the outdoor ones because the filter system is bypassed by much of the outdoor air [12–18].

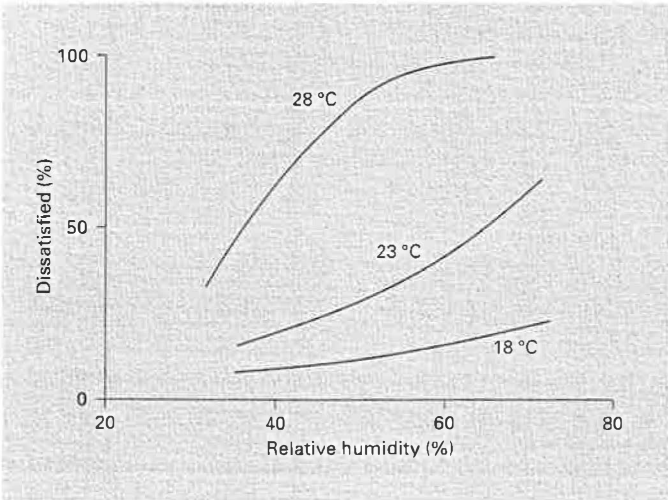

Fig. 2. Perceived air quality as a function of temperature and humidity. Adapted from Fang et al. [8].

Present Position

The UK has an international obligation to reduce its carbon dioxide emissions, half of which come from servicing buildings. Unfortunately, the low energy designs intended to deal with this are not always successful. In part, this is because our Regulations only require us to deal with the thermal insulation properties of the building at the paper design stage. We have minimal design regulations for ventilation and none at all on air quality.

Part L of our Building Regulations deals with energy matters, and the whole is in the process of revision. To assist the Government in this, public consultation took place, and two major changes were proposed. The first was that the Regulations should apply to the finished building and even to existing ones including Crown property. The second was that all new buildings should be assessed for air tightness. The work on pressure testing for air tightness was initiated by the superstores. They found that it saved considerable amounts of energy, minimised the amount of frost forming on frozen food packages and inhibited the amount of air entering the building in windy weather which created draughts.

Most field experience of pressure testing for infiltration has been carried out by the Building Services Research and Information Association (BSRIA), supported by data from the research testing by the Building Research Establishment and the investigative testing of factory premises by the University of Cardiff. BSRIA have produced practical guidelines which are being considered by the Chartered Institution of Building Services Engineers (CIBSE) for inclusion in the CIBSE Technical Memorandum on pressure testing. The proposed values are:

for an office	10 $m^3 \cdot h^{-1} \cdot m^{-2}$ at 50 Pa pressure (5 if air conditioned)
for a factory	10 $m^3 \cdot h^{-1} \cdot m^{-2}$ at 50 Pa pressure
for a cold store	1 $m^3 \cdot h^{-1} \cdot m^{-2}$ at 50 Pa pressure
for a house	10 $m^3 \cdot h^{-1} \cdot m^{-2}$ at 50 Pa pressure

The initial results showed the UK to possess some of the leakiest buildings amongst those measured in Europe and North America [16]. Devices in the UK for user-controlled intervention had a negligible effect on the overall air change rate [17].

Since the superstores led the way, others have followed closely behind. Those developers who retain the building and lease to clients have a strong motivation to build to a high standard to maintain low infiltration. Architects say they are asked for a wide variety of specifications on infiltration and were pleading for one standard for each building type. The pressure testers say that the work of most builders fails the pressure test for the first one or two buildings, but once they understand about the weak points in their construction, they quickly learn to rectify the defects. Eventually, the architects specify the required detailing and include air barriers to minimise air leakage.

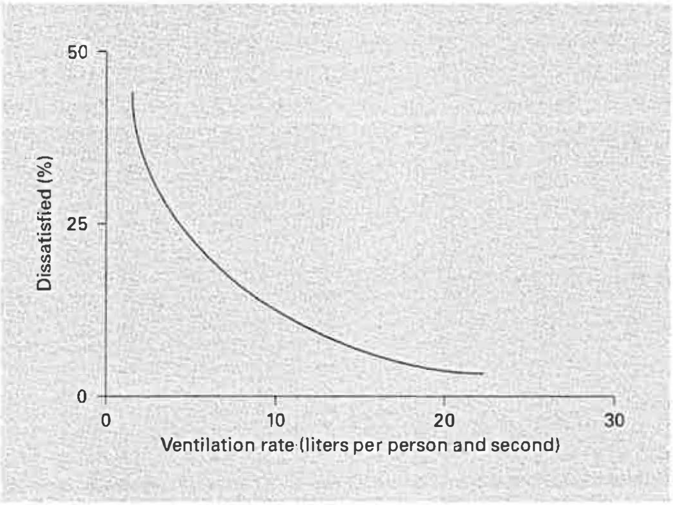

Fig. 3. Dissatisfaction decreases with increasing ventilation [20].

Sweden reports that pressure testing was done there for several years until the builders became good at building low-infiltration designs. The new buildings in Sweden are not routinely tested, but when they are tested for research purposes, they all have very low infiltration rates.

There is, therefore, a strong possibility that the next generation of Building Regulations will be more searching in their requirements than those in the past. They will apply to all buildings, and they will contain performance testing and low infiltration designs and checks.

The next stage in such a development is to use the control of the incoming air to filter and clean it and possibly even change its moisture level to enhance occupant satisfaction.

Actions Required

There are a number of important actions for designers to take:

(1) Incorporate air infiltration barriers into the design detail of a building. Experience from other countries shows that low infiltration in a building is initially achieved by sealing gaps and cracks around the fabric until the required air tightness is achieved. Eventually, it was realised that it is more convenient to establish air tightness at the design stage rather than rely solely on remediation on site.

(2) Choose low-odour materials for the construction process. This includes the paints, the floor covering, the sealants and the furnishings. When domestic or industrial buildings are in use, containment of pollution at source is strongly recommended. This means, for example in houses, that cooker hoods must be fitted or at least kitchens and bathrooms must be ventilated.

(3) Choose the location of the air inlet to minimise street pollution entering the air duct. Some wind tunnel modelling may be required because the complex nature of shapes and sizes of neighbouring buildings makes analytical prediction difficult. Local flues may be nearby and could create unduly heavy pollution with certain wind directions [1]. Research is active in this area, and the existing knowledge is summarised in a CIBSE Technical Memorandum sponsored by the Department of the Environment, Transport and the Regions [19].

(4) Re-examine the filter characteristics to ensure that the filter quality is sufficient to stop, so far as is possible, the ultra-fine exhaust particulates from entering the building.

(5) Check that the ductwork has a sufficient number and size of inspection hatches to enable both monitoring and cleaning to be undertaken easily.

(6) Consider the degree of occupant satisfaction required. This will determine the amount of clean air supply needed. The conventional design target is for no more than 20% of the occupants to be dissatisfied with the building odour on entering the building. More clean air is needed for greater levels of satisfaction (fig. 3). Then consider the quality of the indoor environment and introduce humidity control when improvement in the 'freshness' of the interior is needed.

Conclusion

Low-infiltration buildings have proved very successful in many different ways for those clients who have demanded them. This has often been the supermarkets, who have sophisticated and skilled building purchasers, or the more knowledgeable of the developers who build to rent. At the present time, the construction industry is pressing for Government control through a revision of the Building Regulations, asking for pressure testing to check the infiltration rate, and not only to incorporate such testing into new buildings, but possibly existing buildings as well.

The main consequence for the designer of constructing a low-infiltration building is that they will have to make provision for an adequate amount of ventilation with air of suitable quality. This means understanding the need for the right amount of air depending upon the scale and nature of activities within the building. It also means an education process to explain to the occupants the nature of the problem and the need for the solution. Fortunately, once the inlet air comes only through a recognised designed duct, then the engineer can treat it, clean it and temper it to his wishes. Recent epidemiological studies suggests that a reappraisal of filter criteria may be appropriate. Fine-particle filters could have an effect on the long-term health of the occupants. A planned ventilation system also enables heat recovery in those environmentally friendly buildings intended to have low energy use.

Once air is drawn through the inlet duct, and only the inlet duct, then the location of the duct becomes important. The location should minimise pollutants entering the building. Guidelines exist, but more research is actively examining the complex nature of urban pollution, particularly from traffic. Further to that, the designer must also allow provision for easy duct cleaning, even in domestic buildings. It should not be forgotten that the designer is responsible for the equipment which provides the health, safety and comfort of the occupants.

The provision of such controlled internal conditions can most easily be achieved by mechanical ventilation and careful co-operation between client, engineer and architect.

References

1 Kukadia V, Palmer J, Littler J, Wooliscroft R, Watkins R, Ridley I: Air pollution levels inside buildings in urban areas: A pilot study. CIBSE/ASHRAE Joint Conference, Harrogate, UK, September 29 to October 1, 1996, vol 1, pp 322–332.

2 Health and Safety Commission: Workplace Health, Safety and Welfare. Approved Code of Practice. London, HMSO, 1992.

3 Fanger PO, Lantidsen J, Bluyssen P, Clausen G: Air pollution in offices and assembly halls quantified by the olf unit. Energy Buildings 1998;12:7–19.

4 Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG, Speizer FE: An association between air pollution and mortality in six US cities. N Engl J Med 1993;329:1753–1759.

5 Holdgate ST: Chmn, Committee on the Medical Effects of Air Pollutants. Handbook on Air Pollution and Health. London, Department of Health, The Stationary Office, 1997.

6 Bluyssen PM, de Oliveira Fernades E, Groes L, Clausen G, Fanger PO, Valbørn CA, Bernhard CA, Roulet CA: European audit study in 56 office buildings: Conclusions and recommendations. Proc Healthy Buildings 1995;3:1287–1292.

7 Brundrett GW: Criteria for Moisture Control. London, Butterworths, 1990.

8 Fang L, Clause G, Fanger PO: The impact of temperature and humidity on perception and emission of indoor air pollutants. Indoor Air 1996;4:349–354.

9 Brauer M, Kennedy SM: Gas stoves and respiratory health. Lancet 1996;347:412–413.

10 Leynert B, Liard R, Bosquet J, Mesbah H, Neukirch F: Gas cooking and respiratory health. Lancet 1996;347:1052–1053.

11 Amitai Y, Zlotogorski Z, Golan-Katsav V, Wexler A, Gross D: Neuropsychological impairment from acute low level exposure to carbon monoxide. Arch Neurol 1998;55:845–848.

12 Perera MDAES, Stephen RK, Tull RG: Use of BREFAN to Measure Air Tightness of Non-Domestic Buildings. BRE Information Paper 6/89. Watford, Building Research Establishment, 1989.

13 Walker RR, Perera MDAES: The BRESIM Technique for Measuring Air Infiltration Rates in Large Buildings. BRE Information Paper IP 11/90. Watford, Building Research Establishment, 1990.

14 ISO 9972: Thermal Insulation – Determination of Building Air Tightness – Fan Pressurisation Method. Geneva, ISO 9972, 1996.

15 Lamb MJ: Ventilation and Building Air Tightness: An International Comparison of Standards, Codes of Practice and Regulations. AIVC Technical Note 43. Coventry, Air Infiltration and Ventilation Centre, 1994.

16 Perera MDAES, Turner CHC, Scivyer CR: Minimising Air Infiltration in Office Buildings. BRE Note 265. Watford, Building Research Establishment, 1994.

17 Potter IN, Jones TJ, Booth WB: Air Leakage in Office Buildings. BSRIA Technical Note TN8/95. Bracknell, Building Services Research and Information Association, 1995.

18 Potter IN: Air Infiltration Specifications. BSRIA Specifications 10/98, Bracknell, Building Services Research and Information Association, 1998.

19 Irving S: Minimising Pollution at Air Intakes. CIBSE Technical Memoranda TM21. Chartered Institution of Building Services Engineers, 1999 (sponsored by the Department of the Environment, Transport and the Regions).

20 CEC: Commission of the European Community, Report 11, EUR 14449 EN 1992.