#3253

Guidance Note EH 22 from the Health and Safety Executive

Ventilation of the workplace

Environmental Hygiene Series EH 22 (revised May 1988)

These Guidance Notes are published under five subject headings: Medical, Environmental Hygiene, Chemical Safety, Plant and Machinery and General.

INTRODUCTION

1 This Guidance Note provides information on standards of general ventilation and fresh air requirements in the workplace. It does not deal with the ventilation of domestic premises or specialised premises such as livestock buildings or mines, nor does it deal with exhaust ventilation, ventilation for the control of smoke and combustion products in the case of fire or ventilation for the control of condensation.

2 A minimum standard of general ventilation is necessary to provide fresh air for people in the workplace and to dilute airborne impurities. General or dilution ventilation is not an adequate alternative to containment or control of an impurity at source by local exhaust ventilation. However, it may be necessary to dilute the impurity to an acceptable level by means of general ventilation where complete control at source is not reasonably practicable.

FRESH AIR REQUIREMENTS

3 Ventilation is the means by which fresh air is introduced to, and circulated throughout, the workplace or building and by which vitiated or stale air is removed or diluted. Fresh air is clean air which has been drawn from a source outside the building and is not polluted by discharges from flues, exhaust ventilation systems and process outlets. In a pure, dry state it typically comprises:-

Oxygen	20.94% by volume
Carbon Dioxide	0.03% by volume
Nitrogen and other inert gases	79.03% by volume

4 Fresh air is required for several reasons:-

(a) for respiration, ie to provide oxygen, and to dilute exhaled carbon dioxide;

(b) to dilute and remove airborne impurities created by the occupants of the room, for example body odour, tobacco smoke;

(c) to remove excess heat and maintain comfortable conditions;

(d) to dilute other airborne impurities present in the room, for example, dust and fume etc, from work processes and machines, products of combustion from heaters and water heaters, traces of matter from the fabric of the room and its contents, cooking and other smells.

Respiration

5 A person's need for fresh air depends on his metabolism, or rate of activity. On average, 0.5 litres per second per person of fresh air will be required to provide sufficient oxygen for respiration but this can range from 0.15 litres per second at rest to 1.0 litres per second per person for heavy work. Approximately 2 litres per second per person will be required to dilute exhaled carbon dioxide to the occupational exposure limit, 0.5%.

6 Lack of oxygen and the presence of high concentrations of carbon dioxide can present an acute danger. However, they are only likely to occur in certain extreme situations, for example, when entering and working in confined spaces. In practice, other criteria need to be used when deciding on the appropriate ventilation rate.

Odour

7 Air requirements for the dilution of personal odours depend largely on the space available per person, on personal cleanliness, and on personal sensitivity. Perception of odour varies and usually diminishes with time as the sense of smell becomes fatigued. It is doubtful whether odour has any directly harmful effect. Odour is unlikely to be a problem at ventilation rates of 9 litres per second per person or more. Figure 1 shows ventilation requirements for respiration and the dilution of odours.

Tobacco smoking

8 Tobacco smoking introduces a number of airborne impurities into the room and there is little doubt that some people may experience discomfort and irritation in smoky atmospheres. Therefore it is necessary that ventilation rates take into consideration factors such as the number of smokers and the number of cigarettes smoked.

9 The Chartered Institution of Building Services Engineers recommends air supply rates ranging from 16 litres/second per person where there is some smoking to 32 litres/second per person for very heavy smoking (CIBSE Guide, Section B2).

Environmental comfort

10 Personal comfort depends on the air temperature, radiant heat and, at higher temperatures, on humidity. The comfort of people in the workplace cannot be

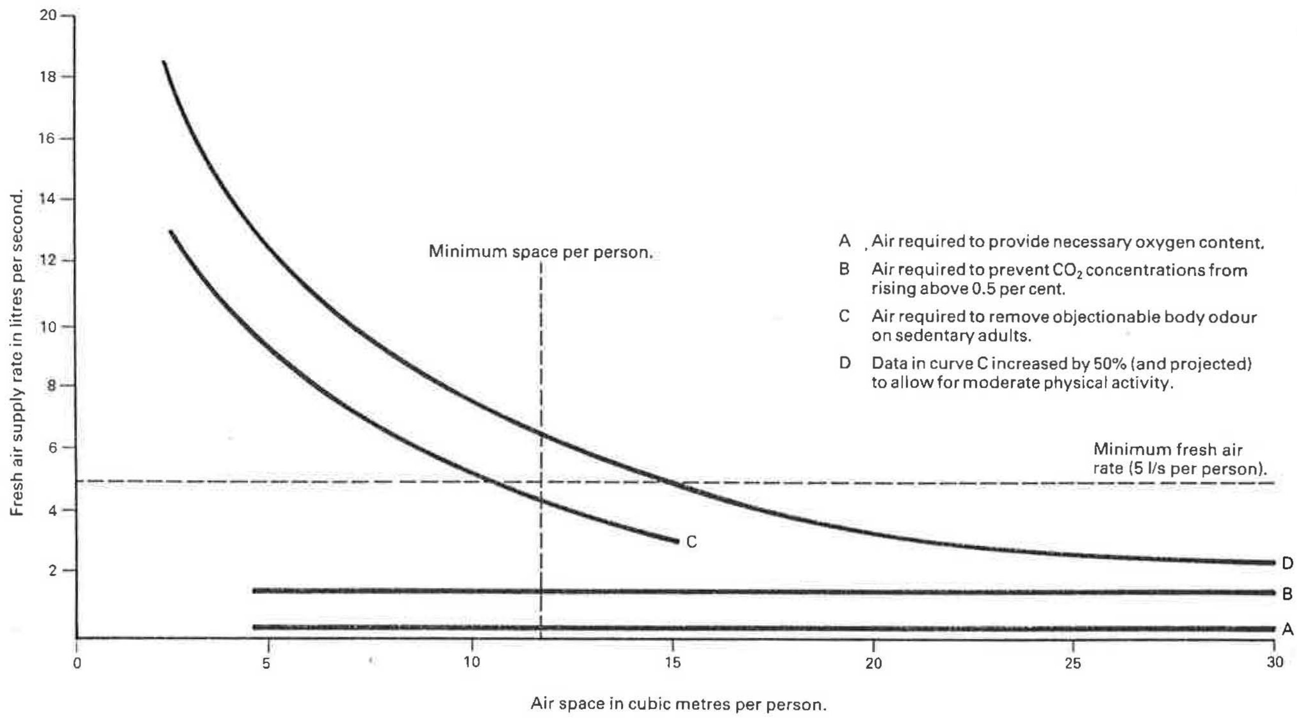

Fig 1 Ventilation requirements

directly related to the ventilation rate. However, if comfort is to be maintained ventilation is necessary to remove and dilute warm, humid air and to provide air movement. Some air movement is also necessary to provide a sense of 'freshness'. At normal room temperatures an air velocity of 0.1 to 0.15 metres per second is recommended. Higher air velocities are likely to lead to complaints about draughts unless the temperature is high or the occupants are engaged in physically demanding work.

Recirculated air

11 Mechanical ventilation and air conditioning systems often treat or condition the extracted air and then return it to the workroom. Treatment normally involves heating or cooling the air, filtering it and, in some cases, adjusting the humidity. Such treatment does not remove gases or very fine particles from the recirculated air and these may accumulate. In extreme cases, impurities may build up to an unacceptable level. Even low concentrations of certain impurities can adversely affect the health of occupants, particularly if they have an allergenic effect.

12 It is therefore important to distinguish between fresh and recirculated air, and to ensure that the building or workplace has an adequate supply of fresh air either as make up air into the ventilation system or from other sources. The incidence of minor illness among occupants of modern, well sealed buildings, especially those with mechanical ventilation or air conditioning, is often higher than in older, naturally ventilated buildings. Although the causes of this problem, sometimes referred to as 'building sickness' or 'sick building syndrome', have not been fully identified it would appear that the incidence and severity of illness is less in buildings which are adequately provided with fresh air.

VENTILATION STANDARDS

13 The need for fresh air in the workplace is influenced by a number of factors; in particular the space available per occupant, the work activity, the habits of the occupants (eg smoking) and the presence of other sources of airborne contamination such as process plant, heaters, etc.

14 The fresh air supply rate to a workplace should not fall below *5 litres per second per occupant.* Higher air supply rates are recommended, especially if some or all of the occupants smoke (see also paragraph 10). BS 5720: 1979 Code of Practice for Mechanical ventilation and air conditioning contains guidance on minimum and recommended fresh air rates for air conditioned spaces based on information contained in Section A1 of the CIBSE guide (this is reproduced in Table 1). These rates may also be used as a general guide to requirements for non air-conditioned spaces. However, if the workplace contains process or heating equipment or other sources of dust, fume, toxic gases or vapours, much higher ventilation rates will be necessary for adequate dilution.

Table 1 Recommended minimum fresh air supply rates for air-conditioned spaces. Reproduced by permission of CIBSE

Type of space	*Smoking*	*Outdoor air supply (litre/s)*		
		Recommended	*Minimum (take greater of two)*	
		Per person	*Per person*	*Per m² floor area*
Factories*	None	8	5	0.8
Offices (open plan)	Some			1.3
Shops, department stores and supermarkets	Some			3.0
Theatres*	Some			-
Dance halls*	Some	12	8	-
Hotel bedrooms	Heavy			1.7
Laboratories	Some			-
Offices (private)	Heavy			1.3
Residences (average)	Heavy			-
Restaurants (cafeteria)†	Some			-
Cocktail bars	Heavy	18	12	-
Conference rooms (average)	Some			-
Residences (luxury)	Heavy			-
Restaurants (dining rooms)	Heavy			-
Board rooms, executive offices and conference rooms	Very heavy	25	18	6.0
Corridors	A PER CAPITA BASIS IS NOT APPROPRIATE TO THESE SPACES			1.3
Kitchens (domestic)				10.0
Kitchens (restaurant)				20.0
Toilets*				10.0

* See statutory requirements and local bye-laws

Rate of extract may be over-riding factor.

† Where queuing occurs in the space, the seating capacity may not be the appropriate total occupancy.

Notes

1 For hospital wards, operating theatres see Department of Health and Social Security Building Notes.

2 The outdoor air supply rates given take account of the likely density of occupation and the type and amount of smoking.

VENTILATION OF PROCESS AND COMBUSTION EQUIPMENT

Industrial processes

15 Wherever possible fume and other impurities from industrial processes should be contained or controlled at source by means of exhaust ventilation. However, exhaust ventilation may not always be reasonably practicable or fully effective. For example, when paints, solvents or adhesives containing volatile hydrocarbons are used, vapours may be released into the work shop atmosphere both during application and when the materials dry or cure. It may be impractical to control all such vapours at source and some may accumulate in the room, exposing the operator and other persons to unacceptable levels. It is therefore necessary to reduce the ambient concentration to an acceptable level by general ventilation in addition to controlling airborne releases from the process itself.

16 The Health and Safety Executive publishes occupational exposure limits for a wide range of substances in guidance note EH 40: *Occupational Exposure Limits.* These exposure limits apply to personal exposure levels, not to background levels or average levels throughout a space. When calculating ventilation rates for a building or workplace, it will be necessary to work to a much lower level to take in to account factors such as localised variations in concentration, direction of air movement, direction of movement of the dust or fume etc, from the source. Appendix 1 gives information on methods of calculating required ventilation rates. Where there is doubt, an occupational hygienist or other suitably competent person should be consulted.

Combustion products

17 A room or workplace containing combustion equipment or plant such as oil or gas fired heaters or furnaces, fork lift trucks with internal combustion

engines etc, will require air for the combustion process and, if the plant or equipment is not flued, to dilute toxic combustion products (carbon monoxide, carbon dioxide and oxides of nitrogen) to an acceptable level.

Gas and oil fired equipment

18 Fresh air requirements for gas and oil fired equipment will depend on whether the equipment is open flued (drawing air from the room and discharging combustion products outside), room sealed (drawing air from and discharging combustion products to outside), or flueless (drawing air from and discharging products to the room).

19 The theoretical combustion air requirements for open flued appliances burning commercially available fuels is 0.25 litres per second per kilowatt. In practice, most appliances require substantially more to provide excess air for complete combustion and, in boiler and engine rooms, to disperse excess heat. Minimum ventilation rates of between 0.9 and 1.1 litres per second per kilowatt, depending on the type of burner and flue connection, are required for plant or boiler rooms with gas fired equipment. More information on standards of ventilation for rooms containing gas and oil fired equipment are given in the British Standards listed in paragraph 41.

20 Room sealed or balanced flue appliances do not require air from the room or workplace for combustion, and are recommended where ventilation is difficult.

21 When unflued gas fired heaters are used, a ventilation rate of at least *10.4 litres per second per kilowatt* will be required to dilute carbon dioxide in combustion products to an acceptable level. Ventilation requirements for other types of unflued gas and oil fired equipment may vary but this figure can be used as a general guide.

22 If ventilation is inadequate carbon monoxide levels in the combustion products can increase rapidly, thus increasing the danger of carbon monoxide poisoning from unflued combustion equipment. Unflued space heaters are not recommended for use in recirculating warm air heating systems.

Internal combustion engines

23 Stationary internal combustion engines are not permitted in factories except in partitioned off areas with provision for conducting exhaust gases from the engine directly to open air. However, exhaust gases may contribute significantly to airborne pollution in motor vehicle workshops, enclosed car parks and in buildings where fork lift trucks are used, necessitating a high standard of ventilation.

24 Ventilation requirements will vary greatly, depending on the type of fuel, condition of the engine and pattern of use. Table 2 gives minimum ventilation rates to dilute combustion products to an acceptable level; higher rates may be required if vehicles are poorly maintained or if air circulation is poor. Conversely, if vehicles are used intermittently or are fitted with pollution control equipment, lower rates may be sufficient. Note that the figures refer to brake horsepower, not total horesepower of the engine, so it will be necessary to estimate the load on the engine, taking into account its usage.

Table 2 Ventilation requirements to dilute exhaust gases from internal combustion engines

Fuel	*Main toxic constituent of exhaust gas*	*Minimum dilution air requirement (litres/second/ brake horsepower)*
Petrol	Carbon monoxide	700
Liquefied Petroleum Gas	Carbon monoxide	230
Diesel	Oxides of nitrogen (nitric oxide and nitrogen dioxide)	70

Emergency ventilation

25 Emergency ventilation systems are often provided for plant rooms handling toxic gases, for example, ammonia in refrigeration systems. Such ventilation is primarily intended to control the escape of gas from the plant room in the event of a major release, and not to maintain a safe atmosphere inside the room; other emergency measures will be necessary to protect persons in the room. The ventilation system should therefore be designed to maintain the plant room at a lower pressure than surrounding areas in order to prevent the flow of toxic gas into occupied areas in the event of a release and should discharge in a safe place.

26 Air conditioning and recirculating ventilation systems should not take air from rooms such as plant rooms where dangerous gases or fumes could be released to avoid the danger of spreading such fumes and gases.

27 In situations where it is not possible to site the air intake to a room or building in a safe place, for example if the building is sited in the emergency plan area for a hazardous installation, there should be a suitable means for immediately shutting off the system in case of emergency.

METHODS OF VENTILATION AND AIR MOVEMENT

28 Air may enter and leave a building by one or more of the following means:-

(a) Infiltration through the fabric of the building, for example through gaps around door and window frames or between roofing panels or tiles. Many traditional industrial buildings have infiltration rates of between 0.5 and 2 air changes per hour. In modern offices and buildings which are well sealed for energy conservation purposes, infiltration rates may sometimes be very much lower.

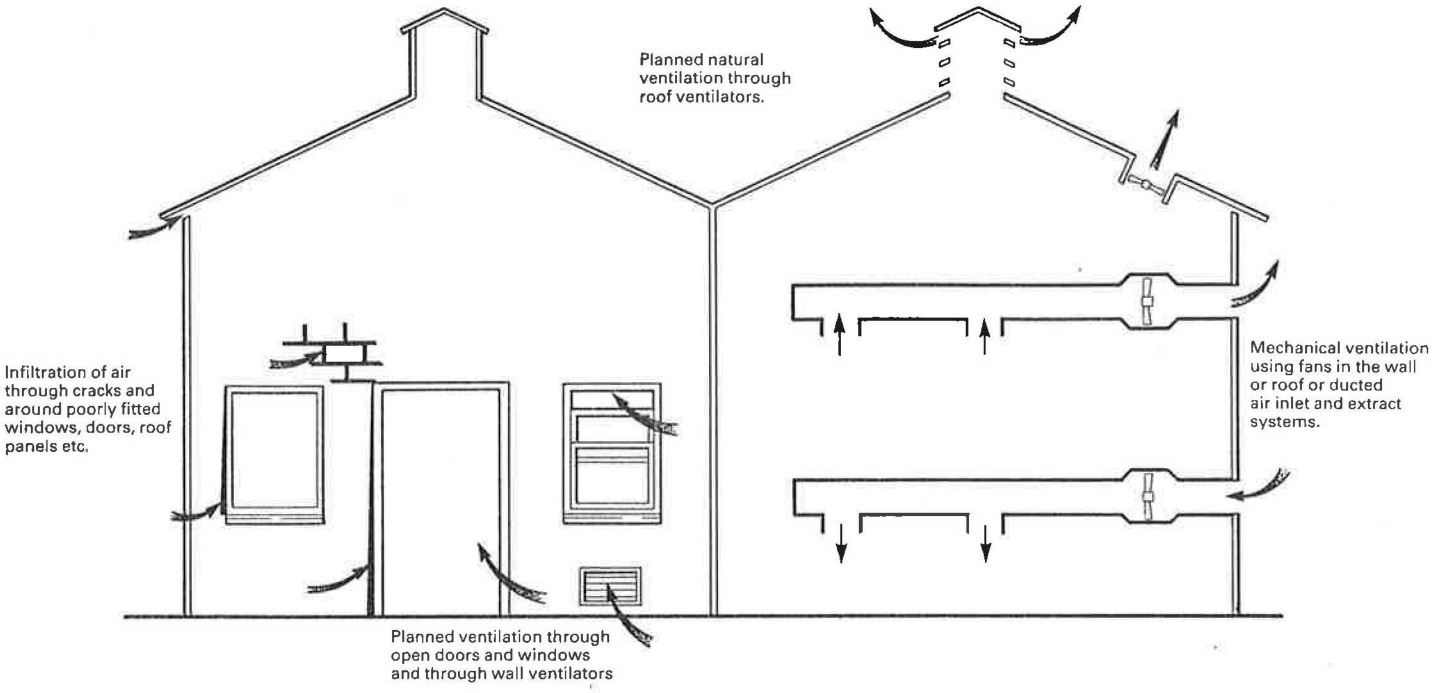

Fig 2 Building ventilation

(b) Planned natural ventilation, either through fixed openings or vents, or through windows or doors.

(c) Mechanical ventilation, using either extract fans in the wall or roof, or more complex ducted ventilation of air conditioning systems.

29 The method of ventilation, and the design of the ventilation system requires careful consideration. If the workplace is to be ventilated adequately, fresh air should not only be supplied in sufficient quantity but it should also be effectively circulated to all parts of the workplace.

30 Natural ventilation and infiltration rates are governed by wind pressure on the building and by internal temperature differences which create an upward movement of warm, buoyant air. These will vary according to the weather conditions, and natural ventilation rates are not always predictable or reliable. In particular, infiltration cannot be regarded as a suitable method for ventilating the workplace. Where doors or windows provide ventilation, it must be possible to maintain the minimum required rate even when these are closed.

31 The method of ventilation will be determined by the type and size of the building and its use. Natural ventilation by means of fixed or adjustable openings, vents, grilles, roof ventilation etc, is usually satisfactory for industrial buildings or for single rooms with outside walls. Opening windows may also be acceptable and they allow building occupants to alter the rate of ventilation as required. Mechanical ventilation is necessary for large or wide buildings, especially where such buildings are divided into many units such as offices, and for buildings where a high or consistent ventilation rate is necessary. The use of mechanical ventilation allows more control than natural ventilation although some types of extract fan are affected by changes in wind speed and direction.

Air movement within the workplace

32 Air movement within the workplace is influenced by the design and position of air inlet and extract openings, by temperature differences within the room or building, by the movement of people and equipment and by obstructions such as furniture, machinery and partitions. These influences are constantly changing and it is often difficult to predict air flow patterns unless the room and its ventilation system have been carefully designed as, for example, in a laminar flow clean room.

33 The design and position of air inlets, including inlet terminals in mechanical ventilation systems, vents, windows and other openings in the building are particularly important. Air movement from inlets is directional, maintaining high velocities for a considerable distance, whereas air movement into extract openings is not directional, so air velocities close to extract openings are generally low, as illustrated in figure 3. The fast moving airstream from the inlet therefore has more influence on air movement in the room or workplace, entraining air and causing turbulence over a wide area.

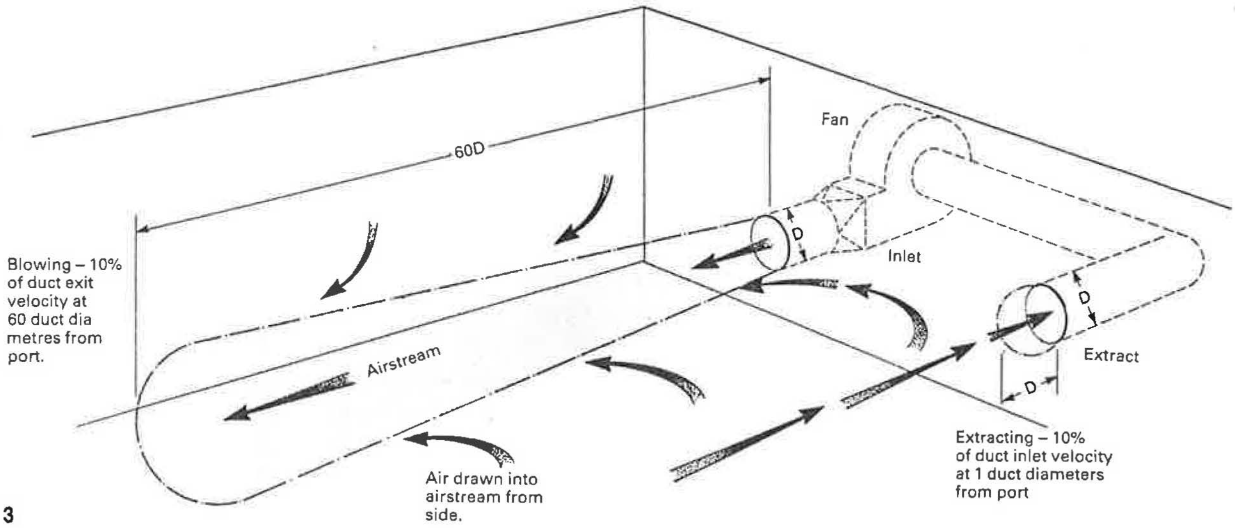

Fig 3

34 This principle will sometimes permit inlet and extract ports to be positioned close to each other or incorporated in combined air handling terminals as illustrated in figure 4. Such terminals are only effective over a limited area.

35 In larger industrial buildings, temperature differences encourage the upward flow of air. If the building contains hot processes, dust and fumes are carried rapidly up to be discharged through roof ventilators or fans. If ventilation is not sufficient to discharge the warm air quickly, it may collect in the roofspace or drift back down in areas away from the hot process, as illustrated in figure 5. Replacement cold air enters the building at low level, for example through open doorways. In some circumstances when upward air velocities equal the settling velocity of a suspended fine dust or fume, it may stratify at an intermediate level.

36 Modifications to a room or workplace, particularly the installation of internal partitions, may affect the circulation of air and reduce the effectiveness of ventilation. Where part of a workplace is blocked or partitioned off, for example, to create internal offices, it is important to ensure that the ventilation system extends to all areas and that suitably sized air grilles are incorporated in the partition walls or doors if necessary. In some cases, supplementary fans may be required to promote air movement and prevent localised stagnation.

37 Displacement ventilation, as illustrated in figure 6, is an alternative to conventional methods of dilution ventilation. Fresh air at, or slightly below, the desired room temperature is introduced at low level through diffusers to replace rising warm air. Because inlet air velocities are low, air disturbance and mixing in the room is small and the cool air displaces the warmer room air rather than diluting it. An independent source of heat may be required if there is no process or other heat source in the room, and warm air heating cannot be used because the ventilation system may be disturbed by high velocity air streams. However, this system is claimed to be more effecient than dilution ventilation because contaminated air is displaced and removed rather than diluted.

Assessment

38 Various techniques can be used in the assessment of building ventilation systems and their effectiveness. These include:-

(a) Measurement of air velocities, either in the ductwork to enable air flows to be calculated, or in the room to detect air movement. Measurement in the room is often difficult because velocities are low, typically less than 0.3 metres per second.

(b) The use of visualisation techniques, for example, smoke generators, to show the pattern of air movement.

(c) The use of tracers, either gases such as sulphur hexafluoride or particles such as potassium iodide to detect and trace air movement through a building. Tracer gases can also be used to measure actual ventilation air change rates in the building. This is done by releasing the tracer once and then measuring the rate of decay (ie fall in concentration) or by continuously releasing tracer gases at a known rate and measuring the equilibrium concentration.

(d) Monitoring for airborne contaminants from a process or combustion equipment, or monitoring for carbon dioxide from building occupants.

Monitoring for tracers or for airborne contaminants is a specialised technique and should be carried out by competent people with suitable equipment.

LEGAL REQUIREMENTS

39 The Health and Safety at Work etc Act 1974 (Section 2(2)(e)) requires the provision and maintenance of a working environment that is, so far as is reasonably practicable, safe and without risk to health.

The Factories Act 1961 (Section 4) requires the circulation of fresh air in each workroom in order to provide adequate ventilation of the room.

The Offices, Shops and Railway Premises Act 1963 (Section 7) requires the ventilation of every room in which employees work by the circulation of adequate supplies of fresh or artificially purified air.

It should be noted that these Acts require that ventilation should be adequate but do not specify ventilation rates or the means by which ventilation should be achieved, whether natural or mechanical.

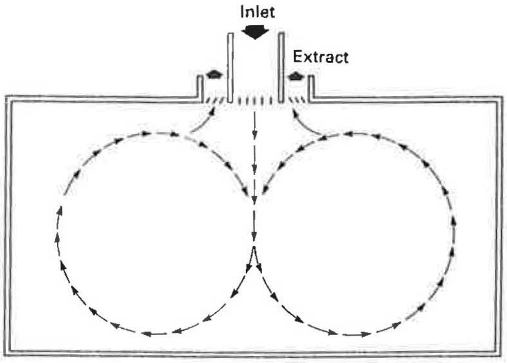

Fig 4 Airflow patterns from adjacent inlet and extract ports

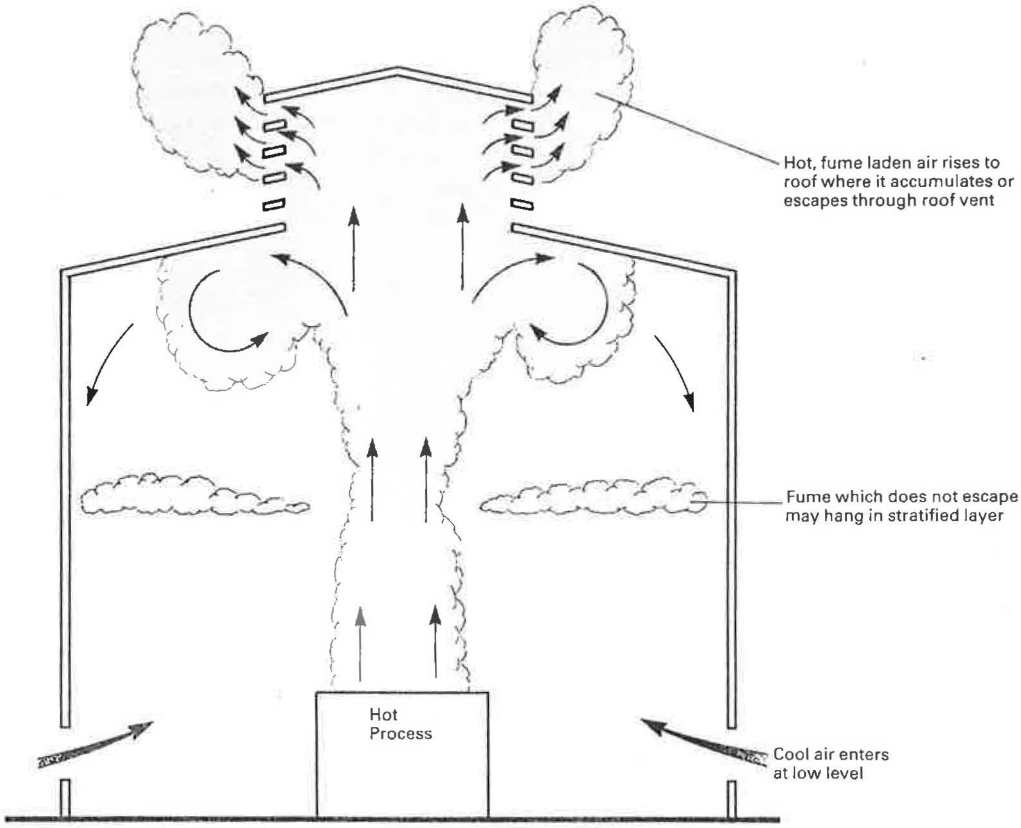

Fig 5

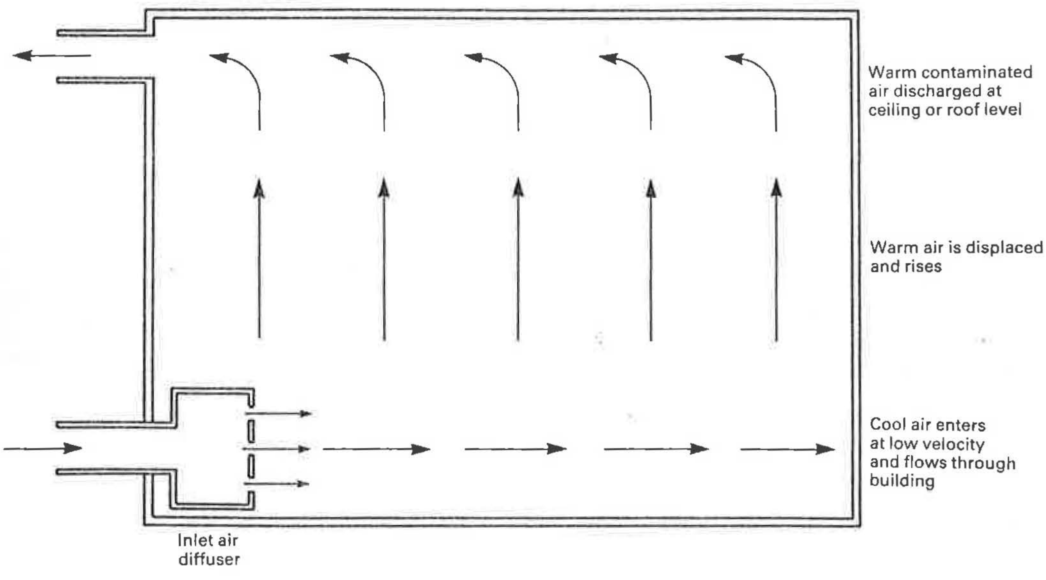

Fig 6 Displacement ventilation

BIBLIOGRAPHY

Further information is available in the following publications:-

i) British Standards Institution Publications

BS 5720: 1979 Code of Practice for mechanical ventilation and air conditioning in buildings.

BS 5925: 1980 Code of Practice for design of buildings: ventilation principles and designing for natural ventilation.

BS 5440: Code of Practice for flues and air supply for gas appliances of rated input not exceeding 60 Kw (1st and 2nd family gases) (Under revision).

BS 5482: Code of Practice for domestic butane and propane gas burning installations.

BS 6230: 1982. Installation of gas-fired forced convection air heaters for commercial and industrial space heating of rated input exceeding 60 Kw (2nd family gases).

BS 6896: 1987. Installation of gas-fired overhead radiant heaters for industrial and commercial heating (2nd and 3rd family gases).

BS 5410. Code of Practice for oil firing.

ii) Health and Safety Executive Publications.

Guidance Note EH 40: Occupational Exposure Limits.

iii) Chartered Institute of Building Services Engineers (CIBSE) Publications

CIBSE Guide, Volumes A, B and C.

iv) Building Research Establishment Papers.

BRE Digest 206: Ventilation requirement.

BRE Digest 210: Principles of natural ventilation.

BRE Current Paper CP 36/74. Ventilation in relation to toxic and flammable gases in buildings.

v) Department of Health and Social Security.

Hospital Building Notes.

vi) The American Society of Heating, Refrigeration and Air Conditioning Engineering Inc (ASHRAE).

Standards for Natural and Mechanical Ventilation.

APPENDIX

Dilution of airborne impurities: calculation of ventilation rates and airborne concentrations

The equations given below may be used to calculate required dilution ventilation rates and concentrations of airborne impurities in the workplace.

1 If toxic vapours or gases are released into the workplace at a constant, known rate then the ventilation rate required to maintain an acceptable, target concentration (C_T) can be calculated from equation 1.

$$Q\ req = Q_S \left[\frac{C_S - C_T}{C_T - C_e}\right] \qquad 1$$

2 If for a given release rate and ventilation rate the actual concentration is higher than the target concentration then the required ventilation rate may be calculated from equation 2.

$$Q\ req = Q \left[\frac{C_S - C_T}{C_T - C_e}\right]\left[\frac{C - C_e}{C_S - C}\right] \qquad 2$$

3 Equations 1 and 2 assume that equilibrium conditions have been reached. In practice, there will be many situations where the impurity is released for a limited time only and, if the workplace is large, the maximum, equilibrium concentration may not be reached. In these circumstances, if it is necessary to calculate the actual concentration after a known period of time from the start of release, equation 3 may be used.

$$C = \left[\frac{Q\,C_e + Q_S\,C_S}{Q + Q_S}\right]\left[1 - e^{\frac{-(Q + Q_S)t}{V}}\right] \qquad 3$$

The symbols used in equations 1, 2 and 3 are:-

Q req	=	Required ventilation rate
Q	=	Actual ventilation rate
Q_S	=	Total release rate of source. (See note 2 below)
C_S	=	Concentration of contaminant in source. (See note 2 below)
C_T	=	Target concentration of contaminant in workplace. (See note 3 below)
C_e	=	Concentration of contaminant, if any, in outside air/replacement air
C	=	Concentration of contaminant in workplace air
V	=	Volume of workplace
t	=	Time from the start of emission of the contaminant.

Notes

1 Consistent units should be used throughout. For example, if Q req is in cubic metres per second then Q and Q_S should also be in cubic metres per second, V should be in cubic metres and t should be in seconds; if C_S is in parts per million then C_T, C_e and C should also be in parts per million.

2 If the concentrations are expressed in terms of mass per unit volume (eg mg/m^3) then Q_S C_S will be the mass released per unit time (eg mg/second) and Q_S will be negligible compared with Q. Where the contaminant is released as an undiluted gas, Q_S C_S will be the volume of gas released per unit time (eg cubic metres per second).

3 The target concentration will normally be a fraction of the occupational exposure limit or control limit, as discussed in paragraph 18 of the guidance note.

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