

Code of practice for

Ventilation principles and designing for natural ventilation

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Basic Data and Performance Criteria for Civil Engineering and Building Structures Standards Policy Committee (BDB/-) to Technical Committee BDB/2, upon which the following bodies were represented:

Aggregate Concrete Block Association	Department of the Environment
Association for the Conservation of Energy	(Construction Industries Directorate)
Association of Building Component Manufacturers	Department of the Environment for Northern Ireland
Association of County Councils	Electricity Supply Industry in United Kingdom
Association of District Councils	Eurisol (UK Mineral Wool Association)
Association of Metropolitan Authorities	Flat Glass Manufacturers' Association
Autoclaved Aerated Concrete Products Association	Gypsum Products Development Association
Brick Development Association	Hevac Association
British Board of Agrément	Institution of Civil Engineers
British Cement Association	Institution of Gas Engineers
British Gas plc	Institution of Structural Engineers
British Precast Concrete Federation Ltd.	Lighting Industry Federation Ltd.
Building Employers' Confederation	Ministry of Defence
Building Services Research and Information Association	National House-building Council
Chartered Institute of Building	National Illumination Committee of Great Britain
Chartered Institution of Building Services Engineers	Royal Institute of British Architects
Concrete Society	Royal Institution of Chartered Surveyors
Consumer Policy Committee of BSI	Scottish Development Department
Cranfield Institute of Technology	Society of Chief Architects of Local Authorities
Department of Education and Science	Timber Research and Development Association
Department of Energy (Energy Efficiency Office)	Trades Union Congress
Department of Health	Watt Committee on Energy Ltd.
Department of the Environment (Building Research Establishment)	

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Association of Lightweight Aggregate Manufacturers	Institution of Mechanical Engineers
British Coal Corporation	Medical Research Council
British Concrete Masonry Association	National Council of Building Material Producers
Flat Roofing Contractors Advisory Board	Phenolic Foam Manufacturers' Association

This British Standard, having been prepared under the direction of the Basic Data and Performance Criteria for Civil Engineering and Building Structures Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 31 May 1991

© BSI 01-2000

First published September 1980
Second edition May 1991

The following BSI references relate to the work on this standard:
Committee reference BDB/2
Draft for comment 89/17211 DC

ISBN 0 580 19285 7

Amendments issued since publication

Amd. No.	Date	Comments
8930	December 1995	Indicated by a sideline in the margin

Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
Section 1. General	
1 Scope	1
2 Definitions	1
3 Symbols	2
Section 2. General principles of ventilation	
4 Basic data	3
5 Application	9
6 Provision for ventilation	9
7 Choice between natural and mechanical ventilation	13
Section 3. Natural ventilation	
8 General	15
9 Flow characteristics of openings	15
10 Generation of pressure differences	16
11 Meteorological variables	18
12 Determination of natural ventilation rates	19
13 Other mechanisms of natural ventilation	23
14 Fire ventilation	25
15 Air infiltration	25
16 Normal building practice for natural ventilation in dwellings	26
Appendix A Bibliography	28
Appendix B Calculation of contaminant concentration	29
Appendix C Calculation of ventilation rates to reduce the risk of surface condensation under steady state conditions	33
Appendix D Determination of ventilation requirements	34
Appendix E Calculation of reference wind speed u_r	35
Appendix F Calculation of natural ventilation rates for a simple building	36
Index	39
Figure 1 — Ventilation required to reduce the risk of surface condensation occurring on the inner wall surface for various wall U -values and ambient air conditions	6
Figure 2 — Typical possibilities for inlets and outlets, for both natural and mechanical ventilation systems in dwellings	12
Figure 3 — Correction to the dry resultant temperature to take account of air movement	13
Figure 4 — Pressure difference and flow created by temperature difference	18
Figure 5 — Contours of u_{50} for the UK	20
Figure 6 — Arrangement of openings in a simple building	23
Figure 7 — Variation of $J(\phi)$ with angle opening ϕ for (a) side-mounted casement windows and (b) centre-pivoted windows	26
Figure 8 — Variation of gas concentration c with t and ventilation rate Q for gas leakage rate q	30
Figure 9 — Allowable reduction in minimum fresh air supply rate when the pollutant source is present for a limited period, t_1 , rather than continuously	31

	Page
Figure 10 — Allowable reduction in minimum fresh air supply rate when the pollutant source is intermittent, being present for a length of time, t_1 , with a return period, t_2 ($r = t_1/t_2$)	31
Figure 11 — Interconnecting spaces	32
Table 1 — Fresh air requirement values for respiration	3
Table 2 — Moisture generation rates	5
Table 3 — Flueless appliances: carbon dioxide production rates and air supply rates	8
Table 4 — Recommended outdoor air supply rates	10
Table 5 — Values of k for windows	15
Table 6 — Equivalent area of ventilation openings	16
Table 7 — Typical magnitudes of pressure created by wind and temperature difference	17
Table 8 — Factors for determining mean wind speed at different heights and for different types of terrain from the Meteorological Office wind speed, u_m , measured at 10 m in open country	19
Table 9 — Values of the ratio of mean wind speed exceeded for a given percentage of time to the 50 % mean wind speed u_{50}	19
Table 10 — Mean daily air temperatures for 12 sites in the UK, 1941 to 1970	21
Table 11 — Natural ventilation of a simple building	22
Table 12 — Natural ventilation of spaces with openings on one wall only	24
Table 13 — Mean surface pressure coefficients for vertical walls of rectangular buildings	38
Publication(s) referred to	Inside back cover

Foreword

This British Standard has been prepared under the direction of the Basic Data and Performance Criteria for Civil Engineering and Building Structures Standards Policy Committee. It supersedes BS 5925:1980, which is withdrawn. This revision takes into account research on ventilation and indoor air quality that has taken place since the publication of BS 5925:1980. In particular, under section 2, the ventilation requirements for the dilution and removal of airborne pollutants have been updated and account taken of the guidance given in BS 5250. Under section 3, a new clause dealing with air infiltration has been introduced.

Recent increased awareness of the need for efficient use of energy in the design and management of buildings, as recommended in BS 8207, has led to greater insulation levels and reduced ventilation rates in both new and existing buildings. However, it is essential that a balance is struck between the needs for low ventilation rates commensurate with saving energy and the needs for higher ventilation rates required to ensure good indoor air quality and to reduce the risk of mould growth. Ventilation rates in different parts of a building may differ, depending on both the levels of occupancy and the occupant's activities in those parts. It is important to remember the complex interrelationship of factors affecting condensation and to take particular care when designing new buildings or considering changes or attempting to remedy problems in existing buildings. A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 40, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This British Standard gives recommendations on the principles which should be observed when designing for the natural ventilation of buildings for human occupation. The standard is in three sections, as follows:

Section 1. General

Section 2 outlines the main reasons for the provision of ventilation and, where possible, recommends quantitative air flow rates. It is shown that these form the basis for air supply recommendations for different types of buildings and rooms characterized by usage. The basis for the choice between natural and mechanical ventilation is given. The design of mechanical ventilation systems is dealt with in BS 5720.

Section 3 gives recommendations on the design of natural ventilation systems and on the estimation of air infiltration rates in housing.

Appendix A is a bibliography and reference to publications listed in it are shown as: (see Appendix A [15]).

Appendix B gives recommendations on evaluating contamination risks.

Appendix C gives recommendations on calculating ventilation rates to reduce the risk of surface condensation under steady state conditions.

Appendix D gives recommendations on determining ventilation requirements.

Appendix E gives recommendations on calculating reference wind speed.

Appendix F gives recommendations on calculating natural ventilation rates for a simple building.

This standard does not attempt to address thermal comfort aspects of ventilation such as indoor air movement, temperature stratification, exact position of ventilation openings etc.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard the definitions given in BS 5643 and BS 6100 apply, together with the following.

2.1

absolute temperature

temperature measured with respect to absolute zero

2.2

discharge coefficient

coefficient which relates the volume flow rate through an orifice to its area and the applied pressure difference

2.3

equivalent area

area of a sharp-edged orifice through which air would pass at the same volume flow rate, under an identical applied pressure difference, as the opening under consideration

2.4

input rating

heat available for liberation by combustion within an appliance, based upon the gross calorific value of the fuel

2.5

kerosine

petroleum oil fuel suitable for appliances with small vaporizing and atomizing burners; classified as class C in BS 2869

2.6

open-flued appliance

appliance designed to be connected to an open flue system; its combustion air being drawn from the room or internal space within which it is installed

2.7

premium grade kerosine

kerosine suitable for flueless space heaters, complying with the requirements of the specification for class C1 petroleum oil fuels in BS 2869

NOTE The non-preferred term is paraffin.

2.8

reference static pressure

static pressure in the free wind, away from any interference with the flow

2.9

static pressure

pressure which would be recorded by a pressure gauge moving with the flow, i.e. static relative to the fluid

2.10

wake

region of disturbed flow which persists some distance downstream of a building or similar structure exposed to the wind

3 Symbols

For the purposes of this British Standard the following notation applies. Commonly used abbreviations for units of measurement are not listed.

A	Equivalent area of an opening	p	Surface pressure
A_1, A_2	Equivalent area of specific openings denoted in the text	$\bar{p}$	Mean surface pressure
A_3, A_4		p_o	Static pressure in undisturbed wind
A_b		Q	Volume flow rate of air
A_w		Q_b	Volume flow rate of air due to the effect of temperature only
a	Exponent relating wind speed to height	Q_w	Volume flow rate of air due to the effect of wind only
C_d	Discharge coefficient for an opening	Q^r	Reduced air flow rate for intermittent contaminant emission
C_p	Surface pressure coefficient	q	Input volume flow rate of contaminant
$C_{\bar{p}}$	Mean surface pressure coefficient	R	Ventilation rate
c	Concentration of contaminant in air by volume	r	Return period of an intermittent pollutant source
c_e	Concentration of contaminant in outside air	t	Time
c_o	Concentration of contaminant at time $t = 0$	U	Thermal transmittance
c_E	Equilibrium value of contaminant concentration	u	Wind speed
g	Acceleration due to gravity	u_m	Wind speed at 10 m, exceeded for a given proportion of time
H_1	Vertical distance between the centres of two openings in a wall	u_r	Reference wind speed
H_2	Vertical distance between top and bottom edges of a rectangular opening in a wall	V	Room volume
h	Vertical distance between ground and the eaves or parapet	w	Width of building
J	Function relating ventilation rate through an open window to the angle of opening, ϕ	z	Height
K	Factor relating wind speed to height	α	Angle made by wind relative to building
k	Window leakage factor	Δ	Difference between two values of the same quantity, e.g. $\Delta C_{\bar{p}}$
L	Length of a crack	ε	Area ratio
l	Length of a building	θ	Absolute temperature
M	Metabolic rate	θ_e	Absolute temperature of outside air
n	Exponent relating flow rate through crack to applied pressure difference	θ_i	Absolute temperature of inside air
		$\bar{\theta}$	Average of inside and outside air temperatures
		ρ	Air density
		ϕ	Angle made by an open window with the plane containing the wall of a building.

Section 2. General principles of ventilation

4 Basic data

4.1 General

A supply of fresh air is required for one or more of the following:

- a) provision for human respiration;
- b) dilution and removal of airborne pollutants, including odours and tobacco smoke;
- c) control of humidity;
- d) provision of air for fuel-burning appliances;
- e) control of thermal comfort;
- f) clearance of smoke resulting from an accidental fire.

In 4.3 to 4.8 each of these is discussed and guidance given on quantitative requirements.

4.2 Composition of outside air

In ordinary engineering practice fresh air means air from outside. The usually accepted composition of dry air by volume is:

oxygen	20.94 %
nitrogen	79.03 %
carbon dioxide	0.035 %
inert gases	traces

The carbon dioxide content is variable and may be lower than 0.035 % in country areas and higher in built-up areas, due primarily to fuel combustion for transport, heating and industrial purposes. Outside air may also contain particulate matter and other combustion products such as sulphur dioxide and nitrogen oxides. These are currently limited by European Council Directives (see Appendix A [1]).

The main variable constituent of outside air is water vapour. In the UK this ranges from approximately 2 g/kg to 12 g/kg dry air over the year, with typical ranges of relative humidity, in winter of 80 % to 95 % and in summer of 55 % to 75 %.

4.3 Human respiration

The body requires oxygen for the production of energy at a rate approximately proportional to metabolic rate. This in turn is proportional to body surface area and to activity level. Metabolic rates are listed in Appendix A (2) and Appendix A (3) for a wide range of activities.

Expired air contains about 16 % oxygen and 4 % carbon dioxide and is fully saturated with water vapour. Human beings, in good health, can adapt to a range of oxygen concentrations with a minimum concentration, at typical ambient pressures, of approximately 12 %. The main limiting factor is, in practice, the build-up of carbon dioxide. Although higher levels of carbon dioxide can be tolerated with no serious health effects, a useful guide is the occupational exposure limit (see Appendix A [4]) of 0.5 %. Air flow rates necessary to accomplish this and a lower concentration of 0.25 % carbon dioxide are given in Table 1 for a range of activity levels.

4.4 Dilution and removal of airborne pollutants

4.4.1 General

A wide range of airborne pollutants is generated by sources within buildings. These pollutants may include gases, vapours, biologically inert particulates, such as dusts and fibres, and viable particulates, such as fungal spores, viruses, and bacteria. Such pollutants may have the potential to harm the health or comfort of occupants or may lead to damage to the building fabric.

Table 1 — Fresh air requirement values for respiration

Activity (adult male)	Metabolic rate (<i>M</i>)	Flow rate to maintain room CO ₂ at given level assuming 0.04 % CO ₂ in fresh air	
		0.5 % CO ₂	0.25 % CO ₂
	W	L/s	L/s
Seated quietly	100	0.8	1.8
Light work	160 to 320	1.3 to 2.6	2.8 to 5.6
Moderate work	320 to 480	2.6 to 3.9	5.6 to 8.4
Heavy work	480 to 650	3.9 to 5.3	8.4 to 11.4
Very heavy work	650 to 800	5.3 to 6.4	11.4 to 14.0

NOTE These values are based upon a production rate of carbon dioxide of 0.00004*M* L/s per person, where *M* is the metabolic rate in watts.

The Health and Safety Executive sets limiting concentrations for airborne pollutants in the form of occupational exposure limits (see Appendix A [4]). These, however, apply to occupational situations and are primarily concerned with healthy adult workers. They cannot, therefore, necessarily be applied to buildings in which the occupants may include other groups, such as children, the elderly or those in poor health. At present, there is no consistent approach to setting acceptable indoor concentrations of pollutants in such circumstances. The factors which determine the concentration of an indoor air pollutant are set out and discussed in Appendix B. These lead to the following methods of control:

- a) source removal;
- b) source control;
- c) extract ventilation close to source;
- d) removal from air by filtration etc.;
- e) dilution ventilation.

Choice of method of control depends upon a number of factors, including the nature of the pollutant and its sources, capital and running costs and practicability. Ventilation will affect the concentration of any pollutant and is the most appropriate means of control where both the production rate and the limiting concentration of pollutant are well defined and where no other method can be as readily used. In practice production rates are best known where the source is combustion or where the pollutant results from the presence or activities of occupants. Production rates are less well defined where the source is related to the fabric or furnishings of the building.

4.4.2 Odour

The human olfactory system is sensitive to a wide range of airborne substances. The characteristics of odour, such as intensity and quality, and its acceptability, cannot be measured directly by instrumentation and have to be assessed by psycho-physical methods using human judgement.

Occupants of buildings are rarely exposed to individual odorants but to complex mixtures, characterized by their source, the most common being body odour, tobacco odour, cooking odours and toilet odour. Control of body odour has formed the basis of standards for fresh air supply in many types of buildings for many years. Based upon the most recent research (see Appendix A [5, 6 and 7]) the minimum requirement to restrict annoyance to persons entering the space from outside is 8 L/s per person, where the occupants are sedentary.

4.4.3 Tobacco smoke

Tobacco smoke consists of “main-stream” smoke, inhaled by the smoker, and the remainder which is termed “side-stream” smoke. Environmental tobacco smoke consists primarily of the latter, augmented by the proportion of main-stream smoke which is exhaled by the smoker. It is a complex mixture of particles, gases and organic vapours, varying with the type of tobacco and mode of smoking.

The possible effects of exposure to environmental tobacco smoke include:

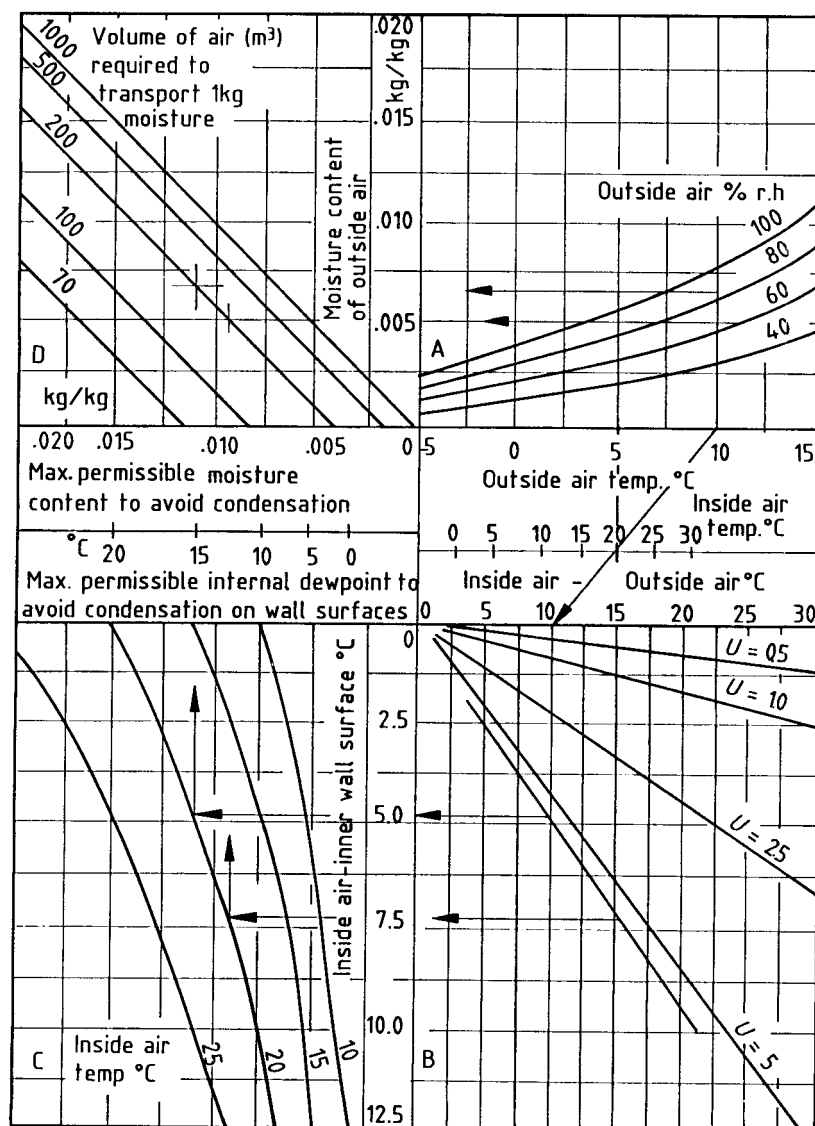
- a) odour annoyance;
- b) irritation of the mucous membranes in the respiratory tract and especially the eyes;
- c) increased susceptibility to respiratory infection and reduced lung function;
- d) toxic reaction to certain components; and
- e) increased risk of lung cancer.

The dominant criteria when assessing the required control of tobacco smoke are odour (based upon the response of non-smokers entering a space in which smoking may occur) and the level of respirable, suspended particulates (based upon standards set for particulates in the ambient air [see 4.2]). These criteria indicate that the dilution air requirement is 120 m³ per cigarette smoked. A lower air supply rate, 30 m³ to 60 m³ per cigarette smoked, should obviate mucous membrane irritation.

Rate of smoking varies with individuals and circumstances but as a guide the average rate of smoking is approximately 1.3 cigarettes per h per smoker. This figure, together with an estimate that approximately one-third of the adult population are regular smokers, yields on the basis of odour considerations a value varying between approximately 15 L/s per person in a large space in which the proportion of smokers is typical of the population at large to 40 L/s per person in a space in which all occupants are assumed to be smokers.

Table 2 — Moisture generation rates

(a) Typical moisture generation rates for household activities			
Household activity		Moisture generation rate	
People:			
Asleep		40 g/h per person	
Active		55 g/h per person	
Cooking:			
Electricity		2 000 g/day	
Gas		3 000 g/day	
Dishwashing		400 g/day	
Bathing/Washing		200 g/day per person	
Washing clothes		500 g/day	
Drying clothes indoor (e.g. using unvented tumble drier)		1 500 g/day per person	
(b) Typical moisture generation rates from heating fuels			
Heating fuel		Moisture generation rate	
		g/h per kW	
^a Natural gas		150	
^a Manufactured gas		100	
Kerosine		100	
Liquefied petroleum gas		130	
^a Coke		30	
^a Anthracite		10	
(c) Daily moisture generation rates for households			
Number of persons in household	Moisture generation rates		
	^b Dry occupancy	^c Moist occupancy	^d Wet occupancy
	kg/day	kg/day	kg/day
1	3.5	6	9
2	4	8	11
3	4	9	12
4	5	10	14
5	6	11	15
6	7	12	16
^a Most heating appliances using these fuels are ventilated to the outside air. consequently the water vapour produced by combustion is not released directly into the dwelling.			
^b Dry occupancy, i.e. where there is proper use of ventilation; includes households unoccupied during the day; results in an internal vapour pressure up to 0.3 kPa in excess of the external vapour pressure.			
^c Moist occupancy, i.e. where internal humidities are above normal; likely to have poor ventilation; possibly a family with children; water vapour excess is between 0.3 kPa and 0.6 kPa.			
^d Wet occupancy, i.e. ventilation hardly ever used; high moisture generation; probably a family with young children; water vapour pressure excess is greater than 0.6 kPa.			



NOTE The method of use of this nomograph is explained in Appendix C. The two examples shown relate to Appendix C.

Figure 1 — Ventilation required to reduce the risk of surface condensation occurring on the inner wall surface for various wall U -values and ambient air conditions
(Reproduced from reference [9] by permission of the Institution of Gas Engineers)

4.5 Control of internal humidity

The relative humidity of air is equal to the ratio of the moisture content of the air to the moisture content of saturated air at the same temperature. Low relative humidities can give rise to respiratory discomfort and nuisance from electrostatic effects. High relative humidities incur the risk of condensation and mould growth on surfaces that have temperatures that fall below the dewpoint temperature of the air. Reference should be made to BS 5250 which deals with factors affecting condensation and mould growth in dwellings, including the thermal properties of the structure, the temperature and humidity of the outside air and the heat and moisture input. The contribution made by ventilation is to lower the moisture content of the internal air by dilution with outside air which normally has a lower moisture content. For any required moisture level the flow rate will depend upon the moisture level in the outside air, and the rate of moisture input from such sources as respiration, cooking, washing and flueless combustion of certain fuels. Table 2(a), Table 2(b) and Table 2(c) give some guidance on the likely moisture input rates and, given the temperature and relative humidity of outside air, which for design purposes should be taken as 95 %, required flow rates should be obtained using equation 9 in Appendix B. It should be noted that in newly constructed buildings large quantities of moisture are released from the fabric as the building dries out. Consideration should be given during this drying-out period to the question of whether additional ventilation should be provided (see Appendix A [8]).

For the particular case of steady state heat transfer, Appendix C gives a simple method using a nomograph (see Appendix A [9] and Figure 1) for estimating the ventilation rates necessary to reduce the risk of surface condensation occurring. BS 5250 deals in more detail with the ventilation rates required to avoid surface condensation.

4.6 Provision of air for fuel-burning appliances

4.6.1 General provisions

An air supply to a fuel-burning appliance is required for one or more of the following purposes:

- a) to supply air for combustion and correct flue operation;
- b) to limit the concentration of combustion products within the spaces to an acceptable level (this is normally taken to be 0.5 % CO₂);
- c) to prevent overheating of the appliance(s) and its surroundings.

4.6.2 Air supply

The supply rate necessary to provide air for typical open-flued domestic fuel-burning appliances, both for combustion and for adequate operation of the flue, is in the range of 0.4 L/s to 30 L/s per kW output of the appliance according to the appliance efficiency. (For gas appliances see BS 5440-2. For oil-burning appliances see BS 5410-1 and BS 5410-2. For solid-fuel-burning appliances see BS 8303.)

NOTE 1 Modern gas-burning condensing boilers typically require around 0.4 L/s per kW output whilst gas-burning decorative fuel effect appliances may require up to about 30 L/s per kW output. Other appliances with open flues tend to have air supply requirements in the range 0.8 L/s to 3.5 L/s per kW output.

NOTE 2 The air supply required for appliances burning solid fuel is usually in the range given in 4.6.2. However, the requirement is more commonly specified in terms of the free area of a ventilator in the room or space containing the appliance. A solid-fuel-burning open appliance requires an air entry opening with a free area of at least 50 % of the appliance throat-opening area as defined in BS 8303. Other solid-fuel appliances require an air entry opening with a total free area of at least 550 mm² per kW of rated output above 5 kW. Where a draught stabilizer is used the total free area should be 300 mm² for each kW of rated output.

4.6.3 Control of concentration of combustion products

This applies to flueless combustion appliances where the products of combustion pass into the room or space containing the appliance. Flueless appliances are categorized as:

- a) continuous, such as kerosine or gas space heaters;
- b) intermittent, such as gas water heaters and cookers.

The criterion most usually applied in assessing their ventilation rate is the need to maintain the concentration of carbon dioxide below 0.5 %. For continuously operating appliances this leads to the specifying of an air supply rate derived from equation (9) in Appendix B and a knowledge of the production rate of carbon dioxide. Table 3 shows the rates of production of carbon dioxide and the derived air flow rates for kerosine, liquefied petroleum gas and natural gas.

Table 3 — Flueless appliances: carbon dioxide production rates and air supply rates

(a) Carbon dioxide production rates		
Fuel	CO ₂ production rate	
	L/s per kW	
Natural gas	0.027	
Manufactured gas	0.027	
Liquefied petroleum gas	0.033	
Kerosine	0.034	
Solid fuel	0.048	
(b) Air supply rates		
Fuel	Air supply rate	Basis
	L/s per kW	
Natural gas	5.4	CO ₂ < 0.5 % (V/V)
Manufactured gas	5.4	CO ₂ < 0.5 % (V/V)
Liquefied petroleum gas	6.6	CO ₂ < 0.5 % (V/V)
Premium grade kerosine	6.8	CO ₂ < 0.5 % (V/V)
Premium grade kerosine	1.2	SO ₂ < 5.0 Vppm
Premium grade kerosine	6.0	SO ₂ < 1.0 Vppm

NOTE 1 For kerosine, another criterion should be applied, which is the need to maintain the concentration of sulphur dioxide below a recommended level. The value for air supply rate based on this criterion is also given for a premium grade kerosine (class C1) containing 0.04 % sulphur and with a limiting sulphur dioxide concentration of 5.0 Vppm (the short-term exposure limit) and 1.0 Vppm (for continuous exposure of the general population). There is a standard grade kerosine available (class C2), with sulphur content up to 0.2 %, which should not be burned in flueless domestic heating appliances.

For gas appliances which are likely to be operated intermittently for limited periods of time, a lower outside air supply rate is permissible since it is only necessary to ensure that the level of carbon dioxide concentration does not exceed 0.5 % during the period of operation of the appliance. Manufactured gas and natural gas produce 0.027 L/s of carbon dioxide per kW heat input. Thus, equation (7) in Appendix B should be used in order to determine the ventilation rate, given the length of the period of operation of the appliance. It will be noted that room volume is required for this calculation. For a given heat output the ventilation requirement will increase with decreasing room volume.

NOTE 2 Direct-fired air heaters are covered in BS 6230.

4.6.4 Appliances in confined spaces

Consideration should be given to the provision of an air supply to heating appliances in confined spaces, to prevent overheating of such appliances and of their surrounding enclosures.

NOTE For further guidance reference should be made to BS 5410-1 and BS 5410-2, BS 5440-2 and to Appendix A (10).

4.7 Control of thermal comfort

For detailed discussion of the factors which determine the thermal comfort of occupants reference should be made to the CIBSE Guide (see Appendix A [11]). Thermal comfort is also discussed in reference Appendix A (12). Indoor temperature is a prime determinant of comfort and this depends upon a number of factors including the use of heating (or cooling) plant, adventitious thermal gains, the thermal characteristics of the building and the ventilation rate. A range of methods, largely computer-based, is available (see Appendix A [13]) which allow ventilation rate to be related to comfort for any particular building and conditions. A simplified approach is given in CIBSE Guide (see Appendix A [14]).

4.8 Removal of smoke resulting from an accidental fire

A fire can generate large quantities of combustion products, namely hot gases carrying smoke particles and containing toxic or noxious and irritant products (usually referred to as “smoke”). In the event of a fire within a building, ventilation by natural or mechanical means can be used to limit the spread of these products which could otherwise hinder or prevent escape and thus endanger the lives of the occupants, and restrict or prevent effective rescue and fire fighting by the fire brigade.

For certain kinds of building, provision should be made for:

- a) the removal of smoke from escape routes;
- b) the control of the spread of smoke and the general removal of smoke and heat.

Requirements regarding fire ventilation can arise from statutory regulations, government circulars, conditions of licence, insurance, etc.

Fire ventilation may be required to operate either immediately (i.e. openings automatically operated upon the actuation of a heat- or smoke-sensitive device) or be available for operation as and when required by the fire brigade (e.g. breakable pavement lights or manually operated openings).

The requirements for ventilation in the event of fire may, on occasion, be incompatible with those for normal ventilation. In most cases, larger flows of air or gases have to be allowed for, in directions sometimes different from those required for normal ventilation.

NOTE Refer to BS 5588 and Appendix A (15) for specific recommendations concerning fire ventilation requirements and practice.

5 Application

5.1 General

Clause 4 sets out basic data in relation to the main reasons for providing a supply of outside air. In order to determine the required air supply rate for a specific building, or room within a building, these data should be combined with a knowledge of the use to which the building or room is to be put. Table 4(a) taken from the CIBSE Guide, Volume A 1986, Section A1, lists recommended outdoor air supply rates for a range of building types and these may be used in the initial design process. Table 4(b) taken from the CIBSE Guide, Volume B 1986, Section B2, has somewhat greater outdoor air supply rates for sedentary occupants, based on recent research which reflects changes in occupants' tolerances of tobacco smoke. Where possible, the designer should calculate outside air requirements on a room-by-room basis in order to obtain a more efficient design. An example is given in Appendix D for a domestic living room. In general, the largest rate calculated for the purposes set out in clause 4 defines the required air supply rate. In all cases, however, any calculated rates are subject to the overriding need to satisfy statutory or similar regulations.

It was noted in 4.4.1 that many pollutants may be better controlled by methods other than ventilation, in particular by restricting source emission.

However, in setting standards for this form of control a basic level of ventilation may be assumed and, for this reason, even unoccupied spaces require some degree of ventilation although this is generally lower than that required when they are in normal use.

5.2 Special applications

The provision of ventilation is required in some types of buildings for special applications, examples of which include:

- a) in factories and industrial processes, to remove hot air, toxic and unpleasant contaminants, smoke and products of combustion in the event of a fire;
- b) in garages or enclosed car parks and vehicle tunnels, to remove exhaust gases (particularly carbon monoxide), petrol vapour and smoke in the event of a fire;
- c) in hospitals, to control cross-infection in special care units and to reduce the level of airborne bacteria in operating theatres;
- d) in large commercial kitchens, to remove excess heat, steam and cooking odours;
- e) in underground rooms and floor areas above ground not provided with normally openable windows, to remove smoke in the event of a fire;
- f) in internal common access lobbies and corridors in blocks of flats and maisonettes, to remove smoke resulting from a fire.

NOTE See Appendix A (16) for specific requirements.

6 Provision for ventilation

6.1 General considerations

6.1.1 *Methods of ventilation*

In order to supply the air flow rates referred to in clause 5, either natural or mechanical ventilation systems can be employed. This clause describes briefly the main characteristics of each system. Factors affecting the choice of system are set out in clause 7.

Section 3 deals in detail with the design of natural ventilation systems, while the general design, planning and installation of mechanical systems is covered by BS 5720 and Appendix A (17) and (18).