Building airtightness and ventilation - an overview of international practice

Martin Liddament

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1. Introduction

Fresh air is required in buildings both to satisfy the respiratory needs of occupants and to dilute and disperse internally generated pollution. Although an inexhaustible supply of fresh air is almost always available, excessive rates of air exchange can add substantially to a building's space heating, cooling and humidification load. It may also create an uncomfortable, draughty environment. Thus, in general, it is desirable to match the supply of outside air to internal needs. The minimum fresh air supply necessary to meet metabolic needs is estimated to vary between 1.0 and 9.0 l/s/person according to the intensity of activity. On the other hand much higher rates are required to maintain adequate indoor air quality and it is this problem that normally dictates overall ventilation requirements.

Principally for reasons of health and safety, many countries have introduced legislation, codes and standards aimed at ensuring the adequate ventilation of occupied premises. More recently, a number of standards have also been introduced in an attempt to minimise unnecessary energy waste through excessive ventilation. In some countries airtightness requirements governing the entire building structure have been introduced. This report compares and contrasts the background behind some of these standards and practices for the purpose of evaluating their suitability and impact on conditions in the United Kingdom. Although not intended as an exhaustive document on standards, a set of appendices containing a summary of standards from many countries is included for reference purposes.

2. Summary of UK regulations and standards

The relevant Acts of Parliament covering the ventilation needs of buildings are the Offices, Shops and Railway Premises Act[1], the Factories Act[2] and the Building Regulations[3] There are no recommendations covering building airtightness but a number of British Standards deal with the airtightness performance of individual components (Appendix 1). Minimum ventilation rates are not specified by statute but maximum concentrations of indoor pollutants are covered by recommendations of the Health and Safety Executive[4]. The general ventilation requirement of the Offices, Shops and Railway Premises Act is that, "effective and suitable provision shall be made for securing and maintaining by the circulation of adequate supplies of fresh or artificially purified air, the ventilation of every room...". Similar provisions are made in the Factories Act with the addition of the requirement for ventilation" ...for rendering harmless, so far as is practicable, all such fumes, dust and other impurities generated in the course of any process or work carried out in the factory as may be injurious to health".

The ventilation requirements of the UK Building Regulations apply only to dwellings, sanitary rooms and bathrooms. They deal solely with the means of providing ventilation; no specific ventilation rates are given except when mechanical ventilation is used. Additional requirements apply to the use in dwellings of gas cookers and conventionally flued gas or solid fuel fires. The Building Regulations also cover the ventilation of roof voids.

Information on recommended minimum ventilation rates and approaches to ventilation are contained within Part B of the CIBSE Guide [5]. Details cover the avoidance of odour, maximum contaminant concentrations, choosing ventilation systems and calculation techniques. British Standard 5925[6] provides valuable information on designing for natural ventilation. It also contains calculation details for determining the supply rate of outside air necessary to dilute and remove airborne contamination.

3. Airtightness

Approaches to building airtightness have a considerable impact on the suitability of a ventilation strategy. Measures taken to increase the overall airtightness of a building, such as weatherstripping or the use of tight fitting components, reduce the natural ingress of air. This is beneficial in terms of minimising air infiltration heat loss and it may also improve comfort conditions by eliminating cold draughts, yet where natural ventilation is relied upon to meet the fresh air requirements of a building, an adequate number of openings must be provided. The alternative is to effectively seal the building and to provide for ventilation by completely separate means. These alternatives represent two fundamentally different approaches to the problem of ventilation. As a general rule, buildings are constructed to a poorer standard of airtightness in countries which experience a predominantly mild climate than in those which experience a severe climate.

Airtightness standards are frequently formed in terms of the quality of fitting of individual components. The standard is normally expressed as a maximum permitted rate of air flow through the component at a specified reference pressure, typically 100-200 Pa. Compliance with the standard is verified by laboratory testing, in which the reference pressure is developed across the component using a suitably rated fan and the resultant air flow rate is measured. Such testing techniques are widely used by manufacturers and standards authorities. Typical specifications and standards covering testing methods for many countries are referenced in Appendix 1. By selecting components conforming to the relevant standard, some control over total building airtightness may be achieved.

In Sweden and Norway legislation has been introduced concerning the airtightness performance of the entire envelopes of dwellings [7,8]. Thus the performance standard applies to the complete system rather than to individual components. In both countries the legislation prescribes approved maximum air leakage values for all new dwellings in terms of a permissible number of air changes per hour (ach) at an artificially induced pressure difference of 50 Pa. This unit of an "air change per hour" is defined as the displacement of one building volume of indoor air, by an equivalent volume of outdoor air over a period of one hour. The pressure difference of 50 Pa reflects a compromise between the need to be able to conduct the test above naturally occurring pressures but not so high that adventitious openings are forced open or closed during the test. Performance testing is carried out in much the same way as for components but *in situ*, with the complete building being pressure tested as illustrated in Figure 1. This type of testing is very unusual in the United Kingdom although it is used for research purposes. The maximum permitted leakage values for several types of Swedish and Norwegian buildings are presented in Table 1. In practice these represent very airtight conditions in which air infiltration is minimal. As a consequence it is essential to provide for ventilation by alternative means.

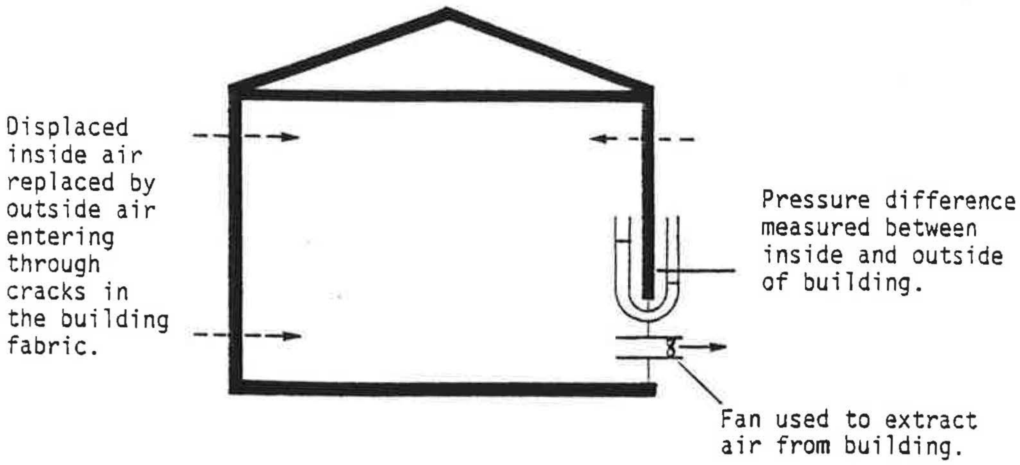

Figure 1: Pressurisation testing

	Sweden	Norway
Single family dwellings (detached, semi detached and terraced)	3	4
Other residential buildings of not more than 2 storeys.	2	3
Residential buildings with 3 or more floors.	1	1.5

Table 1: Airtightness requirements for Swedish and Norwegian buildings (expressed in whole house air change rates (ach) at 50 Pa)

The only other country in which whole building airtightness standards are currently being considered is the United States, where proposed ASHRAE Standard 119P on the airtightness performance of single family dwellings[9] is under discussion. Performance testing is again by pressurization but the permissible air leakage is described in terms of an "effective leakage area" (ELA), rather than the number of air changes at a given reference pressure. This provides an approximate indication of the total area of adventitious openings in the building envelope. Since the United States experiences an extremely varied climate, the energy saving potential of airtightness measures varies on a regional basis. As a result, the prescribed equivalent leakage area in any region has been set according to local degree day values.

An interesting issue raised by this proposed standard is that it does not in itself address the problem of minimum ventilation rates since, it is argued, this is covered by ASHRAE Standard 62 on indoor air quality[10]. However should United States dwellings be constructed to these proposed levels of airtightness, then many would fall within the ambit of the air quality standard. This would mean that it is probable that many homes would need purpose provided ventilation, even in areas where this is traditionally not the practice. Whether or not such a change in practice would become acceptable remains to be seen.

4. Ventilation methods

While the overall philosophy behind the need for ventilation is universally appreciated, each country's approach to the problem can differ markedly. Differences relate to air quality standards, ventilation requirements and ventilation strategy. Perhaps most agreement applies to industrial buildings where the need to remove process heat and pollution normally dictates the choice of ventilation approach. Depending on the amount of heat gain, either mechanical or natural ventilation may be used. In the case of mechanical ventilation, roof mounted extractor fans provide the opportunity to remove warm air which is replaced at a lower level by means of vents or by a complementary mechanical supply system. Natural ventilation for cooling is achieved by using a combination of roof and low level wall ventilators. This promotes the natural displacement of rising warm air by cooler incoming air. The removal of pollution is most efficiently achieved by using local exhaust hoods. On occasions when excess heat is being produced, interest in building airtightness is marginal. However, if only light manufacturing processes are taking place or if the building is being used for storage, then insufficient attention to airtightness will result in excessive infiltration heat loss.

Approaches to commercial buildings and particularly to dwellings are much more varied and tend to depend on climate, building size and national preferences. In Sweden, where domestic energy resources are scarce and the climate is severe, much effort has been devoted to the control of ventilation heat loss. In so doing, considerable attention has been focused on the use of mechanical ventilation, often incorporating heat recovery. In industrial, commercial and large apartment buildings, mechanical ventilation is nearly always mandatory, with even the type of system being dictated according to building use. Two types of mechanical ventilation are recognised by the Swedish Building Code for use in commercial buildings and dwellings; these are extract ventilation and balanced supply/extract methods. In the first, air is extracted from the building via a centrally located fan and a series of ducts connected to individual exhaust points (Figure 2). Make up air enters the building through carefully positioned air inlets. In the case of balanced systems, a separate fan and duct network is used to supply the make up air (Figure 3). Very often the exhaust air is used to preheat incoming supply air by means of an air-to-air-heat exchanger. The exhaust system provides the cheapest alternative but care is necessary in the sizing and positioning of air inlets to avoid draughts or insufficient air flow. Balanced systems can provide a greater degree of control but the building must be well sealed to avoid interference to the ventilation pattern by air infiltration.

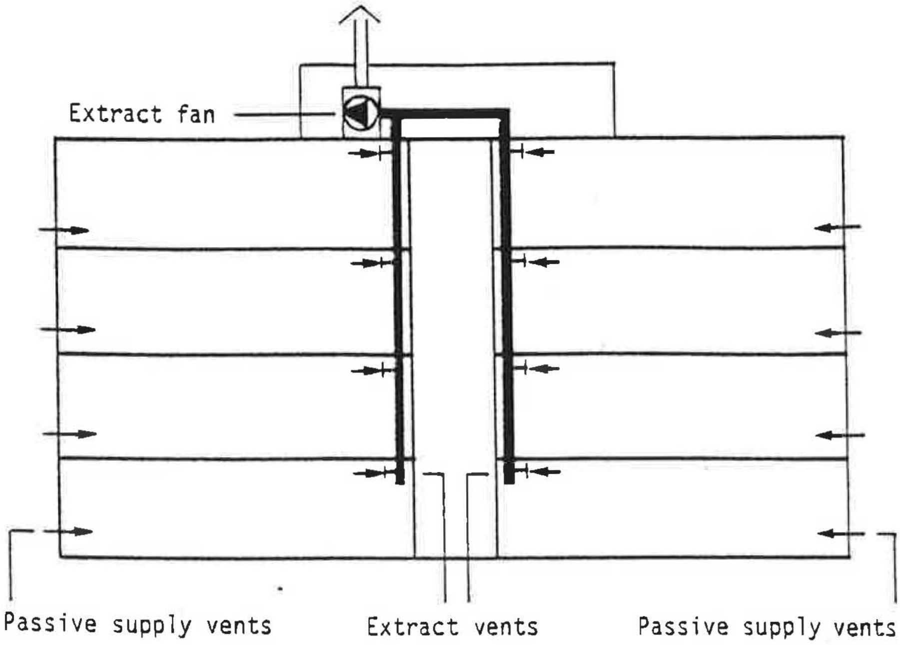

Figure 2: Extract mechanical ventilation

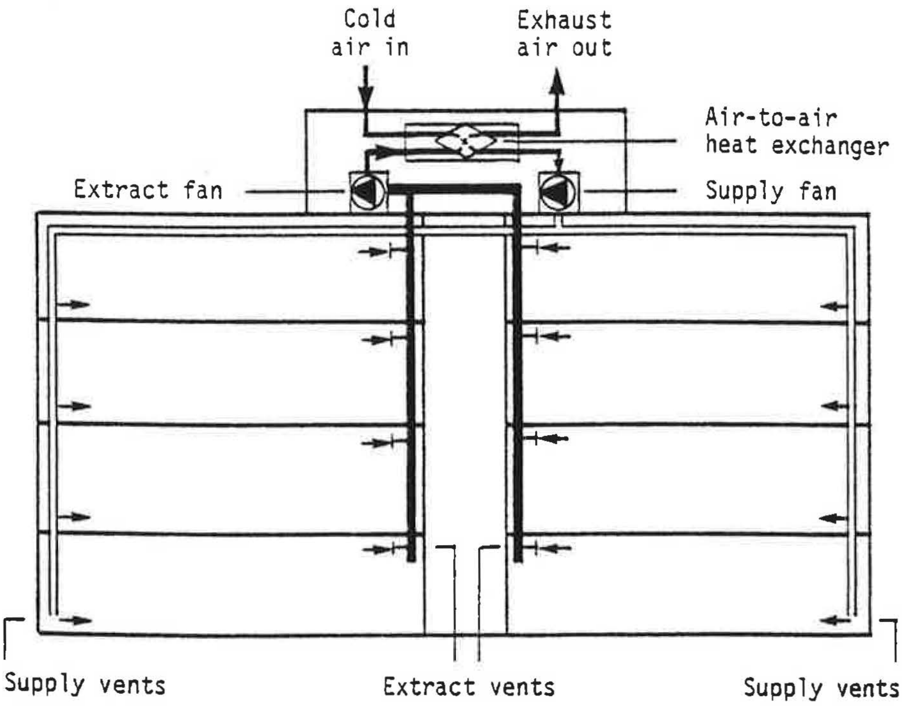

Figure 3: Balanced mechanical ventilation

New Swedish dwellings are usually mechanically ventilated although natural ventilation is permitted. However, if natural ventilation is applied very much more elaborate designs are required than those used in the United Kingdom. These incorporate ventilation stacks, combined with controllable air inlets. The stack passes from the "wet" areas of the dwelling and terminates above the roof within the negative pressure region generated by the interaction of wind with the building (Figure 4). Ventilation is primarily driven by the "stack effect" in which the rate of air flow is proportional to the vertical spacing between the upper and lower openings and to the temperature difference between the inside and outside of the building. It is further enhanced by the negative pressure generated by the wind. Since the consistency of operation is essentially dependent on temperature difference, the performance of these systems is most reliable in cold climates. Outside the heating season, window opening is normally necessary to supplement ventilation needs. This method of stack ventilation is also widely used in the Netherlands and in other parts of Scandinavia.

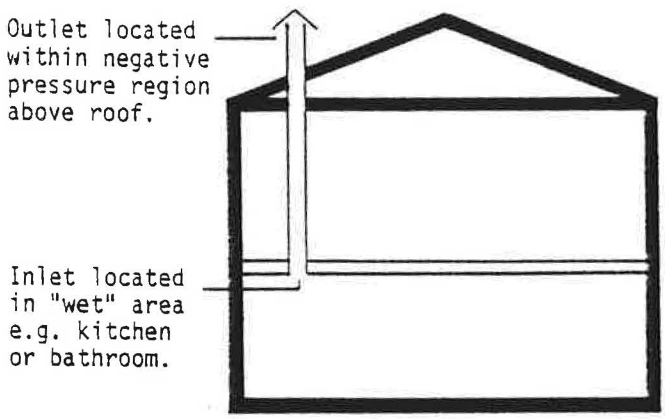

Figure 4: Natural ventilation stack

France has also recently introduced very stringent regulations covering the ventilation of dwellings [11]. These regulations have been introduced partly for reasons of energy conservation and partly to minimise the problems of condensation in the home. In many respects this legislation is similar to that of Sweden and demands the installation of either mechanical ventilation systems or natural stack ventilation. Very precise guidelines are presented on the sizing of the ventilation system and on ventilation requirements. This regulation applies to the construction of new dwellings in all but the mildest regions of France.

In Switzerland, the emphasis has been placed on natural ventilation for all buildings. This is despite the fact that Switzerland, like Sweden and France, has only limited domestic energy resources. It is argued that, except for extreme alpine regions, climatic conditions do not warrant the need for mechanical ventilation or air conditioning. Exceptions include large or deep office spaces, noisy or polluted external environments and industrial areas of high heat load, pollution levels or occupant density. A set of recommendations for mean air change rates under normal climatic conditions have been derived for both dwellings and commercial buildings [12] (see Table 2). Unlike many other standards, a residual air change rate of 0.2 ach is required when all doors, windows and other adjustable openings are closed. This "background" ventilation may be satisfied by means of structural leaks or by the provision of permanent openings. Similar requirements are embodied in French and Swedish regulations, both of which demand that although air inlets may be adjustable, they must not be constructed in such a way that they may be completely closed. The methods by which Swiss ventilation requirements may be satisfied are left entirely to the designer. In this respect Swiss regulations are very similar to those in the United Kingdom. Responsibility is also put on the occupier to satisfy his own needs for ventilation by opening windows or vents.

One family housing	0.4 h^{-1}
Multi family housing	0.6
Offices, commercial	0.8
Airtightness of entire building*	0.2

* *with all doors, windows and other openings closed*

Table 2: Swiss recommended standard-occupancy - air change rates

A selection of standards and regulations applying to the airtightness and ventilation requirements of industrial and commercial buildings and dwellings is presented in Appendix 2. Details covering measurement and calculation standards are presented in Appendix 3.

5. Ventilation heat recovery

Ventilation heat recovery is an essential aspect of Scandinavian ventilation policy and this has attracted much attention elsewhere. This technique provides a method for extracting the heat from waste exhaust air for re-use within the building. In dwellings the most popular approach is to use a balanced supply/extract system in which supply air is distributed to the living and bedrooms and extract air is taken from the kitchen and bathroom areas. The warm exhaust air is passed over the plates of a plate heat exchanger, across which separately ducted fresh supply air is passed. The process is very efficient with as much as 70% of the waste heat being transferrred to the incoming air. Some varieties of heat recovery system are also able to condense water vapour in the exhaust air and recover the latent heat. A similar approach is being used in Canadian housing where, again, a severe climate makes controlled ventilation desirable and where this form of heat recovery enables the incoming fresh air to be preheated before entering the occupied space.

An alternative method of heat recovery for extract only ventilation systems is to absorb the heat from outgoing air by means of a heat pump. In large buildings this may take the form of an air-to-air heat pump in which the recycled heat is used directly for space heating, whereas in dwellings, air-to-water heat pumps are becoming increasingly popular. These use the heat from the waste air to pre-heat the domestic hot water supply.

Whichever approach is adopted, heat is only recovered from air ducted to the heat exchanger or pump. Exfiltration losses through adventitious openings will, therefore, reduce the overall performance of these systems. It is for this reason that very airtight building design is needed.

For heat recovery systems to be cost effective, the annual saving in energy cost must outweigh the combined yearly operating and payback cost of the ventilation systems. This gives the colder countries an advantage since there is greater potential for energy savings. In the comparatively mild climate of the United Kingdom, it is difficult to envisage, at current prices, sensible pay back periods for heat recovery installations in dwellings, even if they are constructed to Swedish standards of airtightness. The use of these techniques in buildings not specifically designed for the purpose is unlikely to offer any energy advantage whatsoever. Similar conclusions are supported by recent German research [13]. On the other hand, for larger buildings or for those in which there is waste heat (e.g. from industrial processes, occupants and high electrical loads) ventilation heat recovery may prove to be an extremely worthwhile consideration. The necessary knowledge and calculation skills needed to evaluate the potential cost effectiveness of heat recovery are available to the designer.

6. Air quality

An important aspect of ventilation is the need to prevent unnecessary risks to health as a result of poor indoor air quality. The quality of air depends on many factors including the rate of air change, the efficiency of the ventilation system in removing contamination and the presence of sources of contamination.

Very often odour is regarded as a good indication of indoor air quality, especially in densely occupied environments. Hence many standards and guidelines have been based on the perception of odour. Other important contaminants to be found in the office and home are carbon dioxide, moisture and particulate matter. In some countries formaldehyde and radon gas have become major health concerns while in others the high risk of condensation in dwellings has become an important problem.

In general, each pollutant present in the building requires a different rate of ventilation to ensure sufficient dilution. The minimum ventilation rate must at all times exceed the rate necessary to disperse the pollutant requiring most ventilation. Guidelines on calculating minimum ventilation rates for several common contaminants are published in British Standard 5925[6]. There is, however, little uniformity between countries on acceptable indoor air quality standards. In industrial environments, threshold limit values are widely used to provide guidance on acceptable levels of pollutant concentration for many contaminants. Although these originated in the United

States [14], they have been widely accepted as a basis for air quality standards in other countries including the United Kingdom[4]. Threshold limit values (TLV) are expressed as either eight hour time weighted averages to which healthy adults may be exposed repeatedly without adverse effect, or as short term exposure limits to which individuals may be exposed for periods of up to 15 minutes. In most cases the level of irritation and discomfort which is accepted by the threshold limit values would be unacceptable for residential or office conditions. ASHRAE Standard 62 on indoor air quality [10] currently suggests that, unless otherwise stated, a safe margin for these environments would be concentrations not exceeding 1/10 of the TLV. British Standard 5925[6] recommends maximum concentrations for continuous indoor exposure should not exceed 1/5 of the TLV, while Swedish Standards suggest maximum concentrations of 1/10 of the TLV for carbon dioxide and carbon monoxide and 1/20 of the TLV for the remaining chemicals.

Japan has introduced some of the toughest indoor air quality requirements especially in relation to carbon dioxide which is set at a maximum of 1000 ppm. This compares with current ASHRAE requirements of 2500 ppm and a UK requirement of 5000 ppm. To achieve such a low concentration in heavily occupied buildings, demand controlled ventilation is used. Typically, carbon dioxide monitors are used to measure the carbon dioxide concentration in the return air duct of the ventilation system and an electrical output from the device is used to regulate the fresh air supply. Such systems can be very cost effective and are being introduced in the United Kingdom for use in transiently occupied buildings. However, the relatively high cost of these systems restricts their use to the office and other densely occupied environments.

Acceptable winter relative humidity levels also vary between countries. In many parts of Canada for example indoor humidities between 20-30% would be regarded as acceptable, whereas in the United Kingdom humidities below 40% would be regarded as too low. These differences are largely a factor of climatic influences, which result in the moisture content of outside air in Britain being up to four times greater than in Canada. In many countries, demand controlled ventilation based on indoor relative humidity levels are being increasingly used in dwellings to control moisture problems.

7. Lessons for the United Kingdom

In formulating airtightness and ventilation standards many factors need to be considered. These include climate, sources and severity of indoor pollution, comfort, ventilation needs, existing practices, cost and the overall impact of such controls on both indoor air quality and energy conservation. Airtightness and ventilation requirements are therefore extremely diverse and solutions appropriate to one particular type of building or climatic region need not necessarily be satisfactory elsewhere. It is therefore essential that the full implications of any future requirements are thoroughly evaluated before changes are made to present regulations. Nevertheless current ventilation and airtightness practices in the United Kingdom are generally very haphazard with legislation being limited and with a tendency to support only the most basic of health needs. No energy conservation aspects of ventilation are covered by current requirements. Undoubtedly total ventilation heat loss is considerable but if increased airtightness measures are to be introduced, specific guidance on satisfying ventilation performance must also be given. Following recent trends towards energy conservation, some of the airtightness and ventilation technology of other countries is being introduced. When this is undertaken in a piecemeal fashion or when introduced without a clear understanding of the possible ramifications, many problems may occur. The result, especially for dwellings, is very often manifested in terms of poor ventilation control and increased condensation risks with, perhaps, only marginal savings in energy.

In the area of domestic ventilation, other European Standards and approaches tend to be much more demanding than those applying to the United Kingdom. These requirements appear to stem from concerns over condensation and poor air distribution, in addition to the need for energy conservation. Current UK building regulations for dwellings do not take sufficient account of modern building trends. New construction methods can often be much more airtight than traditional methods, yet guidelines for providing for ventilation have not kept pace with these developments. Where previously a margin of safety may have been present as a result of general "background" porosity, this can no longer be relied upon to be the case today. Several studies have indicated that insufficient ventilation is common. Coupled with our mild, damp climate, this can exacerbate the problem of condensation in buildings in addition to providing an unhealthy environment for occupants. Much can be learnt from the practices of other countries, especially in relation to the use of non closable air inlets coupled with the provision of proper exhaust points (e.g. high level vents, extractor fans or flues).

It is most probable that ventilation in UK housing will continue to be satisfied by natural means, therefore airtightness design approaches must reflect this need. The more widespread use of building pressurisation techniques to determine the airtightness performance of dwellings would provide much valuable data on optimum building airtightness levels for natural ventilation. These methods are now in common use in North America and parts of Scandinavia; reliable equipment is commercially available and the test can be performed without major upheaval or difficulty. While the implementation of mechanical ventilation with heat recovery appears to give very attractive energy savings, the installation and operating costs are unlikely to be recovered in UK single family housing.

Very few airtightness and ventilation studies have been undertaken in large industrial buildings but the results of measurements that have been made show them to be generally very leaky. It is therefore very likely that in many instances Standards covering the airtightness performance of the structural elements used in the construction of these buildings would improve overall energy efficiency without detriment to indoor air quality. Little airtightness information is available from other counties, although the results of a limited number of tests carried out in Sweden show that their industrial buildings are constructed to a much greater degree of airtightness than those in the UK. There has recently been a considerable advance in the development of measurement techniques for determining airtightness performance and ventilation rates of industrial units. This is improving the database of available information and enabling much better judgements to be made on the viability of airtight building design. Much more stimulus in this area is required in order that the necessary design codes can be formulated.

Similar design uncertainties apply to commercial buildings where measurement data are again scarce. It is difficult to make judgements on the airtightness of these buildings or to quantify the benefits of any proposed airtightness measures. Good design requires a much greater understanding than is available on air movement within large office buildings and on the efficiency of ventilation systems in dispersing pollution. This subject is currently attracting much interest in several countries. From the point of view of energy efficiency, an airtight construction coupled with mechanical ventilation presents an ideal opportunity to recover waste heat from lighting, electrical equipment and occupants. On the other hand recent research shows that this type of building is at most risk to "sick building" and indoor air quality problems.

8. Recommendations for future research

While the approaches of individual nations to airtightness and ventilation tend to be soundly based, they reflect the specific needs of the climate and environment concerned. It is therefore unlikely that a uniform approach to ventilation will be achieved or is even desirable. It is suggested that future research and activities convering UK buildings should address the following:

1. Quality control of construction practices.

   Much greater uniformity of building construction is required to ensure consistent airtightness performance. This can be achieved by the introduction of basic quality standards and it represents the first step in ensuring reliable, energy efficient ventilation. The airtightness performance of alternative construction methods must be understood so that the most appropriate ventilation strategy can be introduced. Failure to grasp this problem could result in a serious deterioration in indoor air quality. This problem is not sufficiently addressed by the current approved document of the building regulations, yet it has important health implications.

2. Guidelines on airtightness levels.

   Specific information on safe levels of airtightness for both new and existing buildings should be devised. Current recommendations tend to be vague and the research rests with a much more intensive investigation into the airtightness performance of various building types over a range of age groups. The value of weather stripping and other measures can then be more accurately assessed and guidance on optimum measures can be presented. With the introduction of relatively inexpensive pressurisation test equipment, this approach is becoming feasible.

3. Approaches to ventilation.

The continued use of natural ventilation in most UK buildings is envisaged. However design approaches and requirements must improve in order to reflect changing patterns of building construction and comfort expectation. A structured approach to ventilation with reduced reliance on air infiltration is needed. The provision of safe ventilation must be based on careful judgement regarding the size and location of openings and needs to be supported by the experience of measurement data. This might be expected to reduce the risks of condensation and other indoor air quality problems that tend to afflict a substantial number of British buildings.

4. Introduction of technologies from other countries

The rationale behind technologies of other countries should be understood so that, wherever possible, full advantage can be taken of these methods. The where the potential for heat recovery is high. Advanced ventilation systems including automatic demand control and air quality monitoring present important areas of technology which could have a major impact on improving air quality and energy efficiency in the office environment. Bearing in mind the relatively mild British climate, the use of this technology in the home is unlikely to be cost effective at present prices.

5. Commercial and industrial buildings

Perhaps least is known about the ventilation performance of industrial and commercial buildings. Available data show that industrial buildings are excessively leaky and would benefit from an improved quality of construction. This especially applies to buildings which are used for storage or in which only light manufacturing processes take place. There is insufficient data to draw any conclusions about commercial buildings although the uncomfortable environment being experienced in some office buildings may probably be due to either poor ventilation or poor air distribution.

6. Calculation methods

Calculation techniques offer an inexpensive method for pin-pointing potential problems before costly errors are made. It is envisaged that these techniques will become much more widely used. The calculation skills necessary to analyse complex ventilation problems are available and can be expected to provide a framework for future design methods. The dissemination of these skills is most important.

7. Air quality

Indoor air quality has a vital impact on ventilation needs. As yet there is little international agreement on acceptable pollutant concentrations and minimum ventilation rates. An international comparison of air quality requirements, combined with an epidemiological study, will provide much valuable data on ventilation needs.

9. Conclusion

While it is difficult to imagine a movement towards full mechanical ventilation with heat recovery in buildings in the United Kingdom, it is thought that some forms of specific ventilation requirement will eventually be introduced. Requirements covering the overall airtightness of buildings and the method of ventilation are necessary to cope with the demands being placed on fresh air needs by occupants. The need to remove moisture at source is particularly important, especially when clothes are dried in the house or in locations where flueless portable heaters are in use. Studies have also shown that many modern buildings are simply inadequately ventilated. It is envisaged that these problems will be tackled by introducing requirements covering the need for fixed ventilators and the installation of local extractor fans. Market trends show that over the last 5 years the use of extractor fans has grown by over 30% to 650,000 units each year. This trend is almost certain to continue, with many future installations probably incorporating moisture sensors for automatic operation.

In the planning of future requirements and regulations it thought that calculation techniques will play an important role. Such techniques have now reached the point where accurate assessments can be made of the performance of alternative ventilation and airtightness approaches.

It is essential that future requirements keep pace with modern building practices.

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Appendix 1: Standards and specifications covering building component airtightness

Country	Standard	Windows	Doors	Other (specify)
Australia	AS 2146 (1978) Performance of timber window assemblies. Covers test requirements for air infiltration.	✓		
Austria	ONORM B5300 (1980) Windows. Requirements and test specifications (Fenster und forderungen und prufbestimmungen)	✓		
Belgium	NBN B62-003 Leakage through doors and windows.	✓	✓	
	STS 52.0 (INL Draft 1983) External joinery - general principles. (Menuiseries exterieures - generalites)			External joinery
	Building Code STS 52 Menuiseries exterieures en bois - fenêtres, portes fenêtres et façades légère.	✓	✓	
	Building Code STS 36 Menuiseries métalliques - fenêtres, façades légères et huisseries.	✓		
Bulgaria	BDS 10588 (1972) Windows - testing methods.	✓		
Canada	19-GP-23 (1980) Guide to the selection of sealants on a use basis. Canadian General Standards Board.			Sealants
Denmark	DS 1094.3 (1978) Determination of airtightness for sealed glazing units.	✓		
France	CSTB Directives commune pour l'agrément de fenêtres. (Joint directives for the acceptance of windows).	✓		
	NF P20-302 Characteristics des fenêtres.	✓		
	NF P20-501 (1972 + amendment 1974) Test methods for windows.	✓		
Finland	SF6 4487 (RT 42-10089) (1980) Door. Functional requirements. Classification and testing.	✓		

continued/...

Appendix 1: Standards and specifications covering building component airtightness (continued)

Country	Standard	Windows	Doors	Other (specify)
Germany	DIN 18 055 (1981) Windows. Air permeability of joints, water tightness and mechanical strain. Requirements and testing.	✓		
	E EN 42 TI (1974) Versuchsmethoden an Fensten; Luftdurchlassigreit. (Methods of testing windows; air permeability)	✓		
Hungary	MS Z 9384/2-18 (MNOS 1980) Performance characteristics of windows. Performance grades and general requirements.	✓		
Italy	UNI 7519 (ENUI 1976) Methods of test for external windows. Check list of performance requirements.	✓		
	UNI 7520 (ENUI 1976) Methods of test for external windows. General principles for the assessment of performance based test methods.	✓		
	UNI 7979 (ENUI 1979) Building. External windows (vertical) classification based on air permeability, water proofing and wind resistance.	✓		
Japan	JIS A 1513 (JSA 1982) General rule for test methods for windows and doors.	✓	✓	
Netherlands	NEN 3660 (NNI 1975) Windows. Air permeability, water tightness, rigidity and strength; methods of test.	✓		
	NEN 3661 (NNI 1975) Windows. Air permeability, water tightness, rigidity and strength. Requirements.	✓		
New Zealand	NZS 4211 (SANZ 1979) Specification for performance of windows.	✓		

continued/...

Appendix 1: Standards and specifications covering building component airtightness (continued)

Country	Standard	Windows	Doors	Other (specify)
Norway	Romstad, T.O. Doors performance specification. (Døser, ytebesbekrivelse). Oslo, 1976, 23pp Norwegian Building Research Institute, Direction 14. Includes requirements for airtightness.		✓	
	Joint Nordic Building Regulations for Curtain Walls, 1965. NKB Publication No.5, Oslo, 1965. Includes criterion for air leakage.			Curtain walls
	NS 3206 (NSF 1974) Methods for testing windows. Airtightness.	✓		
	NS 3209 (NSF 1977) Determination of airtightness for sealed glazing units.	✓		
	NS 3220 (NSF 1977) Windows. Methods of test. Wind resistance tests.	✓		
	NS 3221 (NSF 1977) Windows. Methods of test. Form of test report.	✓		
Spain	UNE 85-208 (IRANOR 1981) Windows. Classification according to air permeability.	✓		
Sweden	Building Code SBN 75 Supplement 1 (1975) Specifies air leakage through windows at various pressure differences.	✓		
	SIS 36 71 10 (1979) Weatherstrips for doors and windows. Tests.	✓	✓	
	SIS 81 81 03 (1977) Window. Classification with regard to function.	✓		
	SIS 81 81 26 (1977) Windows. Airtightness test.	✓		
	SIS 81 81 28 (1977) Windows. Wind force resistance tests.	✓		
	SIS 81 81 29 (1978) Windows. Thermal resistance tests.	✓		

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Appendix 1: Standards and specifications covering building component airtightness (continued)

Country	Standard	Windows	Doors	Other (specify)
United Kingdom	BSI 4255 Preformed rubber gaskets for weather-stripping buildings.			Weather-stripping
	BS 4315 Part 1 (1968 - amended 1976) Windows and structural gasket-glazing systems. Amendment 1917.	✓		
	BS 4873 (1972) Specification for aluminium alloy windows.	✓		
	BS 5368 Part 1 (1976) Methods of testing windows. Part 1. Air permeability test.	✓		
	BS 6181 (1982) Air permeability of joints in buildings.			Joints in buildings
	BS 6375 Part 1 (1983) Performance of windows. Part 1. Classification for weathertightness.	✓		
United States	ASTM E 783.81 (1981) Field measurement of air leakage through installed exterior windows and doors. 1982 Annual Book of ASTM Standards, Part 18, 1494-1499pp	✓	✓	
	ASTM E 283-73 (1976) Standard test method for rate of air leakage through exterior windows, curtain walls and doors. 1982 Annual Book of ASTM Standards, Part 18, 1026-1030pp	✓	✓	Curtain walls
Yugoslavia	JUS D.E.8.193 (JZS 1977) Building joinery; internal windows and balcony doors. Requirements for air and rain-water tightness.	✓	✓	
	JUS D.E.8.235 (JZS 1977) External windows. Requirements for air and rain-water tightness.	✓		
European	EN42 Methods of testing windows; air permeability tests.	✓		
	EN77 Methods of testing windows; window resistance tests.	✓		
	EN78 Methods of testing windows; form of test report.	✓		

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Appendix 1: Standards and specifications covering building component airtightness (continued)

Country	Standard	Windows	Doors	Other (specify)
International Standards Organisation (ISO)	ISO 6589 (1981) Joints in buildings. Method of test for air permeability of joints.			Joints in buildings
	ISO 6612 (1980) Windows and door-height windows. Wind resistance tests.	✓	✓	
	ISO 6613 (1980) Windows and french windows. Air permeability test.	✓	✓	

Appendix 2: Standards and regulations covering airtightness and ventilation requirements

Country	Standard	Building Type		
		All	Dwellings	Other (specify)
Australia	AS 1668 Part 2 (1984) Draft Australian Standard for the Use of Mechanical Ventilation and Air-Conditioning in Buildings (known as the SAA Mechanical Ventilation and Airconditioning Code) Part 2 - Ventilation requirements	✓		
Austria	ONORM M7600 Teil 1 (1978) Ventilation: basic rules, terms and definitions. (Luftungstechnische anlogen: grand regein, begriffe und definition)	✓		
Canada	The National Building Code of Canada (Associate Committee on the National Building Code, National Research Council of Canada), Ottawa, 1980.	✓		
	Residential Standards, Canada (Associate Committee on the National Building Code, National Research Council of Canada), Ottawa, 1985.		✓	
Denmark	The Danish Building Regulations (Bygnirgsreglement 1982) Chapter 8 - Thermal insulation. Chapter 9 - Ventilation.	✓		
	DS 447 Ventilationsanlag 1 udgave December 1981	✓		
Finland	National Building Code D2 (1978) Ventilation in buildings. Regulations and guidelines.	✓		
	National Building Code D3 (1978) Energy conservation in buildings. Regulations and guidelines.	✓		
France	Ventilation Regulations 1982 (Dispositions relatives a l'aeration des logements)		✓	

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Appendix 2: Standards and regulations covering airtightness and ventilation requirements (continued)

Country	Standard	Building Type: All	Dwellings	Other (specify)
Germany	DIN 1946 Part 2 (1983) Room ventilation; technical health regulations.			
	DIN 1946 Part 4 (1978) Ventilation plants (VDI ventilation rules). Ventilation in hospitals.			Hospitals
	DIN 1946 Part 5 (1967) Ventilation in schools.			Schools
	DIN 4108 Part 2 (1982) Heat conservation in tall buildings.			Tall buildings
	DIN 18017 Part 1 (1983) Ventilation of bathrooms and shower rooms without outside windows. Single duct without ventilator.			Bathrooms and shower rooms
	DIN 18017 Part 2 (1984) Ventilation of bathrooms and shower rooms without outside windows, with ventilator.			Bathrooms and shower rooms
	VDI 2088 (1976) Ventilation installations in dwellings.		✓	
	VDI 2052 (1984) Ventilation techniques for kitchens.			Kitchens
	VDI 2071 Blatt 1 (1981) Heat recovery in ventilation systems.	✓		
	VDI 2082 (1976) Ventilation of commercial buildings and shops.			Commercial buildings and shops
India	NO 15 3103 (ISI 1975) Code of practice for industrial ventilation.			Industrial buildings
	IS 3362 (ISI 1977) Code of practice for natural ventilation of residential buildings.		✓	
Ireland	IIRS IS 168 (1973) Ventilation of caravans and mobile homes.		✓	
Italy	Law 30/4/1976 n.373 Rules for the restraint of energy consumption for thermal uses in buildings.	✓		
	DM (Ministerial decree) 18/2/1975 Guzzetta Afficiale No.29 2.2.1976 Technical standards for schools.			Schools
Japan	Draft Standard. Methods for measuring equivalent leakage areas of dwellings.		✓	

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Appendix 2: Standards and regulations covering airtightness and ventilation requirements (continued)

Country	Standard	Building Type		
		All	Dwellings	Other (specify)
Netherlands	NEN 1087, 1e druk, Normalisatie-Institunt, Nederlands, December 1975 (NNI 1979 + amendment 1981) Ventilatie von woongebouwen. Ventilation in dwellings. Requirements.		✓	
	NPR 1088 Ventilation in dwellings. Indications and examples for constructional performance of ventilation supplies.		✓	
	Ontio 1089 (NEN) 1982 Ventilation in school buildings. Requirements (draft)			Schools
New Zealand	NZS 1900 Model building bylaw SANZ	✓		
	Factories and Commercial Premises Act 1981. Dept of Labour, Wellington.			Factories and commercial premises
Norway	Building Regulations of 1 August 1969. Ch 54: Covers thermal insulation and airtightness. Ch 47: Covers ventilation.	✓		
Poland	PN-74/B 03430 Natural ventilation in dwellings and general building.	✓	✓	
	B 01411 (PKN 1968) Ventilation: terminology and classification.	✓		
	PN-67/B 03432 Natural ventilation in industrial buildings.			Industrial buildings
	PN B-03433 (1980) Mechanical exhaust ventilation in apartment buildings: specification.		✓	
Sweden	Svensk Bygg Norm PFS 1982:3 Starens Planverks Forfattningssamlug. Direct electric heating in one- and two-family dwellings, low temperature heating systems in buildings.		✓	
	Swedish Building Regulations - Update SBN 1980 Ch 33: Thermal insulation and airtightness. Ch 35: Thermal internal climate. Ch 36: Air quality. Ch 39: Energy conservation.	✓		

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Appendix 2: Standards and regulations covering airtightness and ventilation requirements (continued)

Country	Standard	Building Type		
		All	Dwellings	Other (specify)
Switzerland	SNV 271010 (1977) Guidelines for ventilation installations in underground garages.			Underground garages
	SNV 271020 (1975) Boiler room ventilation.			Boiler rooms
	SIA 380/1 (1984) Swiss performance standard for energy conservation in buildings.	✓		
United Kingdom	The Building Regulations 1985 Approved Document F		✓	
	Factories Act Part 1.4 1961			Factories
	Offices, Shops and Railway Premises Act 1963. Section 7.			Offices, shops
	BS 5925: 1980 Code of Practice for the design of building: ventilation principles and designing for natural ventilation.	✓		
	BS 5250: 1975 Basic data for the design of buildings: the control of condensation in dwellings.		✓	
	BSI 14255 Draft Code of Practice on energy conservation in buildings.	✓		
United States	Model Energy Code 1983 Council of American Building Officials.	✓		
	Minimum Property Standards 1979 US Dept of Housing and Urban Development.		✓	
	ASHRAE Standard 62-1981 Ventilation for acceptable indoor air quality.	✓		
	ASHRAE Draft Standard SPC 119P Air leakage performance for residential buildings.		✓	
	ASHRAE Standard 100.6-1981 Energy conservation in existing buildings. Public Assembly.			Public assembly buildings
	ASHRAE Standard 100.5-1981 Energy conservation in existing buildings. Institutional.			Institutional buildings
	ASHRAE Standard 100.2-1981 Energy conservation in existing buildings. High rise residential.		✓	
	ASHRAE Standard 90-80 Energy conservation in new building design.	✓		

Appendix 3: Standards covering testing, measurement and calculation methods

Canada	CAN2-149.10-M84 Determination of the equivalent leakage area of buildings by the fan depressurization method. CGSB Standard 149-GP-10 Ottawa 1981 Determination of airtightness of buildings by the fan depressurization method.
Czechoslovakia	CSN 06 0210 Concerning infiltration heat loss calculations in buildings.
Germany	DIN 4701 (1983) Rules for the calculation of the heat requirements of buildings (Regeln für die Berechnung des Wärmebedarfs von Gebäuden) DIN 18017 Bl.4 (1974) Ventilation of bathrooms and shower-rooms without outside windows, with ventilators. Rules for the calculation of air flow requirements. DIN 1946 Part 1 (1979) Room ventilation; fundamentals. Defines concepts, units, symbols. DIN 4710 (1982) Meteorological data for the calculation of the energy demand by heating and ventilation systems. VDI 2080 (1984) Measuring techniques and instruments for ventilation systems.
Italy	UNI-CTI 7357-74 (1974) Rules for the computation of heat requirements in building heating.
Japan	JIS A 1431 (1974) Method of measurement of air quantity for ventilation and airconditioning system.
Norway	NS 3031 (1981) Energy and power demand for heating of buildings. Calculation rules. NS 8200 (NSF 1981) Airtightness of buildings. Test method.
Poland	PKN B-03431 (1973) Mechanical ventilation in buildings. Specifications. Tests.
Sweden	SS 02 1551 (1980) Thermal insulation determination of airtightness of buildings.
United States	ASTM Standard E 741-80 (1980) Measuring air leakage rate by the tracer dilution method. 1982 Annual Book of ASTM Standards Part 18 1426-1435pp ASTM Standard E 779-81 (1981) Standard practice for measuring air leakage by the fan pressurization method. 1982 Annual Book of ASTM Standards Part 18 1484-1493pp
International	ISO/TC 59/SC 3 N178 (1982) Airtightness of buildings. Test method. First draft proposal.

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