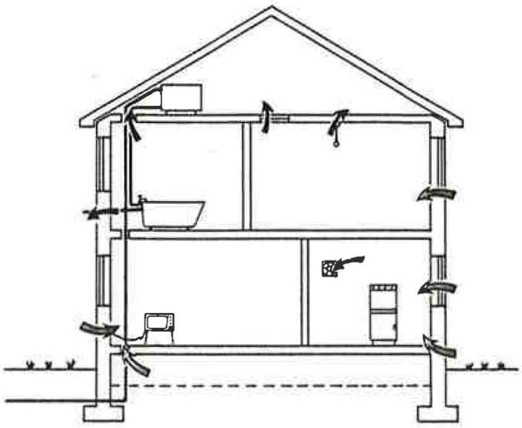
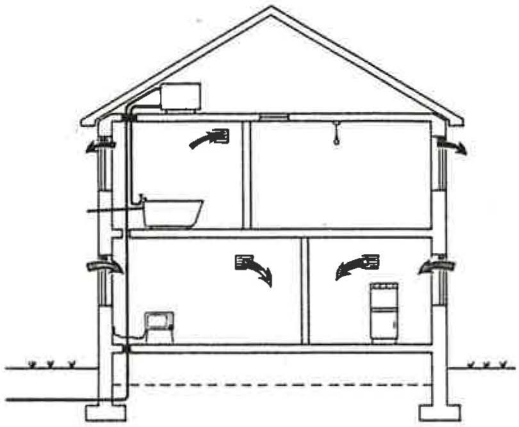
Building Research Establishment Report

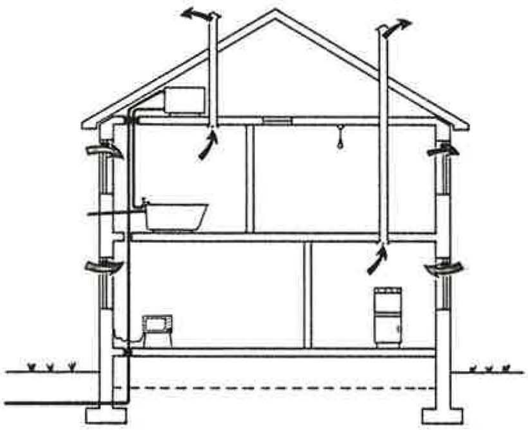
CI/SfB (L2)

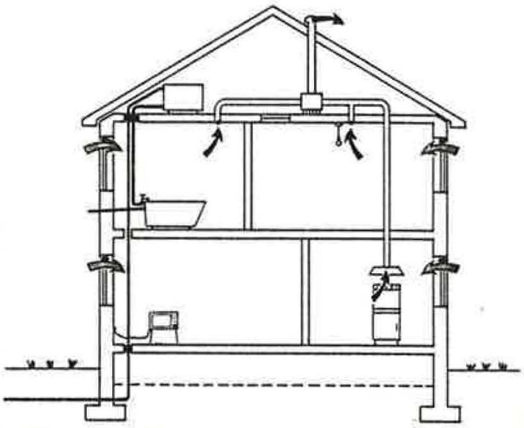
1989



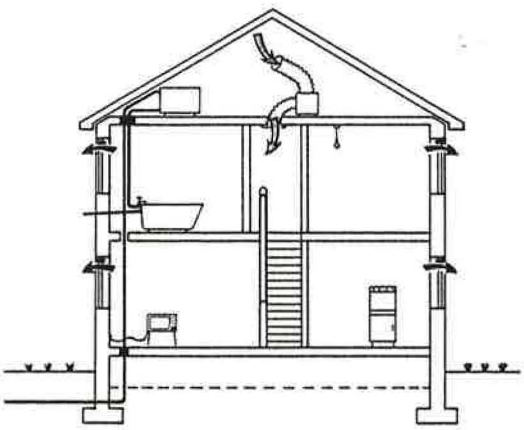


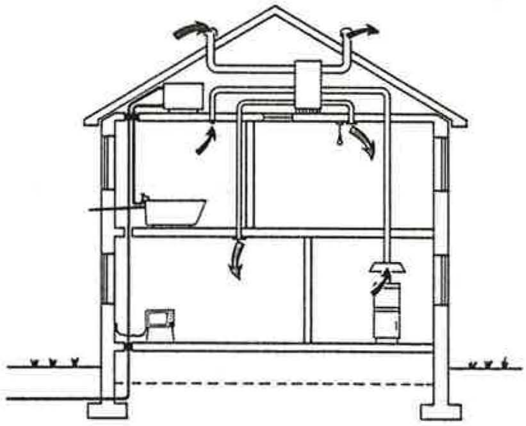
Background ventilation of dwellings: a review





Christine E Uglow





BUILDING
RESEARCH
ESTABLISHMENT

Department of the Environment

£10.00 net

Building Research Establishment Report

Background ventilation of dwellings: a review

Christine E Uglow, BSc, MSc

Building Research Establishment
Garston
Watford
WD2 7JR

Price lists for all available
BRE publications can be
obtained from:
Publications Sales
Building Research Establishment
Garston, Watford, WD2 7JR
Tel: Garston (0923) 664444

BR 162
ISBN 0 85125 417 9

First published 1989

CONTENTS

INTRODUCTION

All dwellings need a supply of fresh air, for the health and comfort of the occupants, for the control of condensation and to ensure the safe and efficient operation of combustion appliances. However, ventilation is something which, all too frequently, happens by accident rather than by design, leading to ventilation rates which do not match the needs of the dwelling or the household. This review summarises current thinking on how adequate and appropriate provision for ventilation can be made.

VENTILATION REQUIREMENTS

Domestic pollutants

Fresh air in dwellings is required for breathing, for the safe and efficient operation of combustion appliances and for the removal of pollutants, including moisture and odours. The pollutants which can be found in dwellings are listed in Table 1, with an indication of the relative importance of each.

The control of pollutants can be achieved in a number of ways, including removal at source, restriction of emission rates, removal by filtration and dilution ventilation. It is the latter which is the most common method of pollutant control in housing and the one which leads to the question: 'What level of ventilation is required to control pollutants to an acceptable level?'

Ventilation is also used as a cooling medium in warmer weather. For that purpose copious ventilation capabilities are needed. This review does not address that question, limiting itself to ventilation needs in colder weather.

Basis for a standard

In order to establish the required level (or levels) of ventilation, it is essential to decide which of the pollutants listed in Table 1 form a realistic basis for a standard, ie are found throughout the housing stock, have a relatively narrow range of production rate, have a well defined criterion for control (eg maximum concentration) and are not more readily controlled by another method. Those which emerge as the 'key' pollutants are water vapour and combustion products (in particular carbon monoxide) from fuel-burning appliances. The provision of ventilation openings for dealing with combustion air supply and, for flueless appliances, dilution of combustion products is already documented in appropriate United Kingdom Building Regulations and is not therefore covered in this review.

The presence of water vapour in indoor air is essential for a comfortable environment, but if relative humidity levels exceed 70% for prolonged periods there is a high probability of condensation occurring on cold external walls[1]. If damp conditions persist, conditions may be conducive to the germination of mould fungi, with resultant growth of mould on surfaces and on clothes in cupboards.

Table 1 Relative importance of airborne pollutants in housing

Pollutant	Relative importance
Water vapour	Very important
Carbon dioxide	Not important (indicator only)
Carbon monoxide	Very important
Other combustion products	Marginal
Body odour	Marginal
Formaldehyde	Important in certain situations
Pesticides	Important in certain situations
Other organics	Insufficient knowledge
Radon	Important in certain situations
Tobacco smoke	Important
Asbestos	Important in certain situations
Other non-viable particulates	Possibly important
Micro-organisms	Possibly important

Research at BRE[1] has shown that if realistic assumptions are made about the rates of production of water vapour and standards of heating, then a whole-house average ventilation rate of at least 0.5 air changes per hour will usually suffice to keep relative humidities below 70%, provided that U-values do not exceed 1.0 $W/m^2 °C$ for walls and 0.5 $W/m^2 °C$ for the roof. However, condensation does not necessarily occur in the moisture-producing areas of the dwelling and in fact is more frequently found in areas such as unheated bedrooms, especially when the insulation levels are poor. The optimum solution, to ensure good ventilation during the heating season, is for all rooms to have provision for introducing additional, finely controllable ventilation, without creating a security risk or draughts. (Large openable areas of window are obviously still needed for intermittent, summertime cooling.) For ventilation during the heating season, the current BRE suggestion is for a minimum whole-house average ventilation rate of 0.5 air changes per hour with provision for an additional 30 m^3 of controllable ventilation per occupant per hour in each room. Under typical conditions of occupancy in a dwelling of average size, this allows for up to 3.5 air changes per hour in a lounge, if the additional ventilation is utilised to the full.

It is also important for moisture to be removed at source in kitchens and bathrooms. This is most effectively achieved by the use of extract fans, preferably humidistat controlled, or high rates of natural ventilation (ie open window with internal door closed) during and immediately after periods of moisture generation.

What the above means in terms of the required areas and types of ventilation opening is pursued later in this report.

BUILDING REGULATIONS REQUIREMENTS

In England and Wales, the Requirement (F1) relating to ventilation of dwellings set down in the current (1985) Building Regulations[2] states: 'There shall be means of ventilation so that an adequate supply of air may be provided for people in the building.' The level of performance is deemed to be acceptable if '...ventilation under normal conditions is capable, if used, of restricting the accumulation of such moisture and pollutants (originating in a building) as would otherwise become a hazard to the health of people in buildings.'

The accompanying Approved Document[3], which presents practical advice on how the Requirement can be satisfied, states that ventilation by natural means will meet the required performance if ventilation openings are sized and sited as shown in Table 2.

Table 2 Advised[3] siting and sizing of ventilation openings for natural ventilation to meet Building Regulations requirements

Room or space	Size of ventilation openings to be provided
In dwellings	
Habitable rooms, kitchens and bathrooms	At least one ventilation opening with an area of at least 1/20th of the floor area of the room or space
	Some part at least of the ventilation opening to be at least 1.75 m above the floor level
In buildings containing dwellings	
Common spaces	At least one ventilation opening with an area of at least 1/50th of the floor area of the space
In any building	
Sanitary accommodation	At least one ventilation opening with an area of at least 1/20th of the floor area of the room or space

The Building Regulations for England and Wales are currently being reviewed and it is expected that future Approved Documents will give more detail on how satisfactory ventilation performance can be achieved. In particular, provision for controllable and secure background ventilation in all rooms is proposed in the consultation documents, together with mechanical or enhanced natural ventilation in kitchens and bathrooms. Although the Building Regulations apply only to new dwellings, they tend to be consulted by those involved in all types of refurbishment and improvement work.

In Scotland, Part K of The Building Standards (Scotland) Regulations[4] includes minimum ventilation requirements for dwellings and most other buildings. The Standards, which apply to both new building and alterations, are under review as in England and Wales. A preliminary consultation has indicated a strong desire to retain the wide coverage but with some reduction in the amount of background ventilation opening normally required. The introduction of mechanical extract ventilation in all bathrooms and kitchens is being considered.

NATURAL VENTILATION

This review addresses the question of ventilation provision during the heating season; it is not concerned with ventilation as a cooling mechanism during warm weather.

The principles

Ventilation is the exchange of stale, indoor air with fresh, outdoor air, through purpose-provided openings and through adventitious openings in the fabric of the building. (It has become common practice to refer to air movement through the latter types of opening as 'infiltration'.) Where ventilation is provided by natural means, ie without fans, there are two driving mechanisms: the wind effect, resulting from air moving around and over the dwelling, and the 'stack' effect, resulting from a difference in temperature, and hence density, between the indoor and outdoor air.

Although the wind and stack effects interact, they are not additive in a simple manner. It is suggested in *BRE Digest* 210[5] that a reasonable approximation to the combined effect of wind and temperature difference can be made by considering each effect separately and assuming that the larger air flow rate applies to the combined case.

At any given time, the air flow rate through a dwelling is determined by the following factors:

(a) surface pressure coefficients,

(b) wind speed,

(c) internal and external temperature, and

(d) position and flow characteristics of all openings in the dwelling fabric.

Predicting a ventilation rate for a given dwelling is difficult, because of the complex nature of these factors.

(a) Surface pressure coefficients depend on the wind direction, the built form of the dwelling, the proximity and form of adjacent buildings and obstructions, and the nature of the surrounding terrain. Pressure transducers can be mounted on the dwelling, or scale-model tests can be conducted in a wind tunnel, to obtain an indication of the surface pressure distribution. However both of these techniques are expensive and generally reserved for research use.

(b) Wind speed data for the UK are well documented but tend to be mean values over relatively long time spans. In practice, the turbulent nature of the wind leads to rapidly fluctuating pressures over the surfaces of the dwelling. This in turn leads to momentarily large pressure differences where an analysis based on mean conditions might suggest small or negligible pressure differences.

(c) Internal and external temperatures can be measured with reasonable accuracy, but in estimating a likely ventilation rate it is usual to ignore short-term variations and select a daily, monthly or even seasonal mean value. The errors introduced in this way should not in general be significant but may mask extremes of ventilation rate resulting from brief periods of particularly cold weather.

(d) Determination of the ventilation characteristics of some openings (such as airbricks, trickle ventilators, windows and doors) is not difficult, provided that a purpose-designed test rig is available. The characteristics of adventitious openings cannot normally be measured individually. Their characteristics may be measured collectively using the fan-pressurisation technique discussed later in the text. It is however virtually impossible to predict the characteristics of openings from a visual inspection. In addition, the way in which dwelling occupants use purpose-provided openings will have a significant effect on ventilation rates.

One of the conclusions which must be drawn from the foregoing is that it is not possible, without access to a detailed mathematical model, to predict the ventilation rate likely to be achieved in a given dwelling, under given conditions of temperature, wind, and occupant behaviour (ie window and door opening).

It therefore seems reasonable to propose that general guidance on the provision of ventilation during the heating season should be based on a 'minimum fail safe' approach, which can be applied to large groups of dwellings. This idea is developed further in subsequent sections.

Effects of climate and exposure

It is well understood that the heat losses from a dwelling, by transmission through the fabric and by ventilation, increase with increasing internal-external temperature difference. Ventilation also increases with increasing wind speed and with reducing degree of shelter. There is therefore a significant difference between the average ventilation rate of a dwelling in a city centre in the south of England and an identical dwelling situated on an exposed coast in the west of Scotland. Consideration of mean wind speeds and mean external temperatures over the heating season suggests that in dwellings of equal airtightness, the infiltration heat loss could increase by a factor of two in the colder, more exposed location. The increase would be even more marked if extremes of high wind speed coincided with low external temperature.

However, it is also known that variations in the micro-climate of a particular building can be as large as or larger than variations in average climate from one area of the country to another. The micro-climate of a building depends on factors such as neighbouring buildings and vegetation, which can easily change during the life of the building.

It could therefore be argued that provision for natural ventilation should be less generous in colder, more exposed parts of the UK. However, there are strong and convincing arguments for guidance on the provision of ventilation to be simple and uniform across the UK, ignoring climatic variations. The arguments are based on administrative considerations, ie the need for legislative simplicity, and practical considerations, ie the need for an approach which is easily understood by building professionals.

Whatever approach is adopted, it is imperative to ensure that all dwellings have purpose-provided ventilation openings which are *finely* controllable. Ensuring comfortable conditions within the dwelling can then be argued to be within the control of the dwelling occupants.

VENTILATION OPTIONS IN DWELLINGS

There are at least six different ways of providing ventilation in a dwelling, all of which are used in UK housing. These methods are briefly discussed below with reference to their merits and their drawbacks.

Natural infiltration

Natural infiltration represents the means by which a large number of UK dwellings are ventilated for much of the heating season. Air enters and leaves the dwelling via many small adventitious openings in the building envelope, such as cracks around openable windows and doors, cracks between window frames and reveals, voids around service entries, electrical fittings, joints between walls and floors and numerous other routes through the building fabric.

With a view to improved energy efficiency and elimination of draughts, dwelling occupants often seal infiltration gaps with draughtproofing materials. If infiltration is the only ventilation mechanism available, its reduction could in some cases be undesirable. However, with current conventional construction techniques, draughtproofing of windows and doors alone is unlikely to lead to drastic reductions in air infiltration rate, because of the presence of many other routes for air leakage.

Infiltration is, however, a poor way of providing ventilation because it is not possible to build-in just the right number and size of such openings to achieve a design infiltration rate. This is because infiltration rates vary greatly from hour to hour and from day to day owing to changes in indoor/outdoor temperature difference and wind speed and direction.

Natural ventilation

In this case, natural infiltration is supplemented by air flow through purpose-provided openings in the dwelling fabric. These include: openable windows, fixed and controllable airbricks, and window-head and through-the-wall ventilators. If openings are controllable, the opportunity is given to control ventilation to some extent.

In both natural infiltration and natural ventilation, the various openings act sometimes as air inlet points and sometimes as air exit points, depending on the distribution of surface pressures over the dwelling. Air flow patterns are complex but for a typical two-storey dwelling there are two extremes of behaviour. In calm conditions the stack effect dominates; air tends to enter through openings on the lower floor and leave through openings on the upper floor. When the wind speed is high and the stack effect negligible, air tends to enter through openings on the windward side and leave through openings on the leeward side. Usually, however, the air flow pattern is a combination of these effects.

There are a number of ventilation options which aim to override the natural variability in direction of air flow, either by mechanical means or by optimising natural air flow patterns. They include passive stack ventilation, mechanical extract ventilation, mechanical supply ventilation and balanced mechanical ventilation.

Passive stack ventilation
This is a form of natural ventilation as described above but with an important distinction: the natural stack effect is used to extract air from the moisture-producing rooms of the dwelling through vertical ductwork. If the system is well designed, the air flow rates achieved under average conditions of wind and temperature difference should be sufficient, over the course of a day, to remove moisture at source and achieve good ventilation throughout the dwelling.

Usually, the extract ducts run from the kitchen and from the bathroom to ridge ventilators, or other terminals, on the roof. Air inlet openings must also be provided, unless the house is relatively leaky. There is some evidence[6] that if controllable trickle ventilators are used as the air inlets, occupants can exercise some control over the air flow rates in the passive stack system, provided that the house is relatively airtight (see later section on air leakage characteristics).

Whilst this type of system allows moist air to be extracted from the rooms where water vapour production is greatest, some other ventilation provision (such as additional airbricks or trickle ventilators) may still be required to give adequate whole-house ventilation in airtight dwellings. Research, by BRE and other organisations, on the performance of these systems is continuing. The installation must be designed with considerable care to avoid excessive air flows during particularly windy or cold weather. Experience shows that this would result in many occupants blocking the ducts, rendering the system useless.

Mechanical extract ventilation
In its simplest form, mechanical extract ventilation is achieved by window- or wall-mounted extract fans in the kitchen and/or bathroom. These do not normally operate continuously but can be either manually controlled or used in conjunction with a humidistat sensor and/or speed controller.

In a more complex form, the air extract routes may be ducted and manifolded together, with a single fan to extract the air. These systems are not common in the UK. They are designed for houses which are structurally airtight and should run continuously. In less airtight houses, however, there is no reason why such a system should not run intermittently, on humidistat control.

In principle, mechanical extract ventilation is a reliable system, because water vapour is extracted at source, and the fan can be made sufficiently powerful to provide adequate ventilation in the whole dwelling, whatever the weather conditions outside. By careful design, mechanical extract systems will reduce the spread of moisture-laden air by extracting from kitchens and bathrooms and providing air inlets in the 'dry' rooms of the dwelling.

There are some drawbacks to mechanical extract systems: occupants may choose not to operate manually controlled fans, whilst fans with humidistat control may operate when not required, during warm, humid summertime conditions. In addition, the fan(s) need maintenance and occasional replacement, especially if run continuously. The system components also need regular cleaning so that the fan and extract registers, if installed, do not lose effectiveness due to fouling by dust and grease. The occupants probably need some instruction on what the system does, and how little it costs to run, so that they use any controls properly (eg manual on/off or extract boost) and do not attempt to disable the system in order to save energy.

Mechanical extract ventilation must never be installed in rooms where there are solid-fuel or oil-burning combustion appliances which have a conventional flue. This is because the extract system could affect the combustion process and could draw toxic combustion products back into the room. Extract ventilation *is* permitted in rooms with a gas-burning, conventionally flued appliance, provided that guidance is obtained from the local Gas Board. Balanced-flue-type appliances, if properly installed, should be unaffected by an extract system.

Mechanical supply ventilation
This is similar in design to the extract system described above except that the fan is used to blow air into the dwelling. Fan maintenance is the same as above but cleaning will be needed less often because outdoor air is normally cleaner than indoor air. Occupant instruction is perhaps more important

because the supply air is usually unheated and the occupants may be tempted to disconnect the system to prevent cold draughts.

A supply air system cannot remove excess water vapour directly from the kitchen or bathroom. Water vapour has to find its way to the outside by means of either adventitious openings or purpose-provided openings such as airbricks. Humidity levels are therefore likely to be higher with a supply system than with an extract system, but a supply system *is* compatible with combustion appliances which have a conventional flue.

A possible drawback is that moist, warm air could be driven into the structure of the dwelling. In practice however, this is unlikely to occur because the pressure differences induced by a mechanical supply system are very small and probably less than those induced by natural wind and stack effects in conventional constructions.

Balanced mechanical ventilation

Balanced mechanical ventilation combines supply and extract ventilation in one system. One fan supplies air to the living-room and bedrooms through one duct system; the other fan extracts air from the kitchen, bathroom and WC through a second duct system. A heat exchanger is generally incorporated in the system to preheat the supply air using heat recovered from the extracted air. This should be the ideal ventilation system because moist air is extracted at source and the supply air migrates through the house to the extract points, giving good air exchange throughout the house. Such a system can provide the required level of ventilation under all weather conditions and is compatible with all types of combustion appliance.

The drawbacks are that there are more components to go wrong, there are more parts to be cleaned and the systems are relatively expensive to buy and install. It is important that the occupants are told how to use the system if they are to get full benefit from it. One further problem is that unless the house is structurally airtight, the combined effect of ventilation provided by the system and natural infiltration may be a total ventilation rate which is in excess of normal requirements for much of the time.

AIR LEAKAGE CHARACTERISTICS OF UK DWELLINGS

Current state of knowledge

Direct measurement of air infiltration or ventilation rates in dwellings relies on the use of tracer gases. The techniques are complex and time consuming which means that, although accurate, such direct measurements cannot be contemplated for large-scale surveys of the housing stock.

A much simpler technique, which can be used to gain a more rapid assessment of the ventilation-related characteristics of a dwelling, is that of fan pressurisation. A portable fan assembly is sealed into a doorway of the dwelling and the air flow rates required to maintain a series of pressure differences in the region of 10 to 60 Pa are measured. (The pressures acting on a dwelling as a result of the natural effects of wind and temperature difference are usually no more than about 10 Pa.) In accordance with international convention, it is usual to express the air leakage rate of the dwelling at a pressure difference of 50 Pa. Figure 1 illustrates the 50 Pa leakage rates of 284 UK dwellings, from the BRE housing air leakage database.

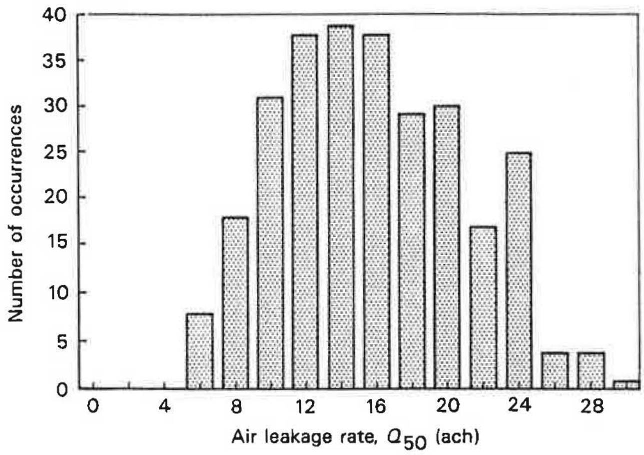


Figure 1 Distribution of air leakage rates (air changes per hour) at 50 Pa applied pressure difference in 284 traditional low-rise UK dwellings

The average 50 Pa air leakage rate of the BRE sample of dwellings was 14.8 air changes per hour. (Note that although air leakage rates and ventilation rates are often expressed in the same units of air changes per hour, they have completely separate meanings because of the different pressure conditions under which they are measured.) In the UK, a relatively airtight dwelling may be taken as one which has a 50 Pa air leakage rate of 10 or less air changes per hour, whilst a relatively leaky dwelling may be taken to be one which has a 50 Pa air leakage rate of 20 or more air changes per hour. The majority of dwellings of conventional construction are likely to fall between these two limits.

The last few years have seen an increasing use of the pressurisation test, with the introduction of the 'house doctor' concept in North America and the availability of mass-produced equipment. In the UK, BRE and its contractors have now carried out pressurisation tests on some 300 dwellings. The results of these tests are being analysed in an attempt to relate air leakage rates to type of construction, age, etc. Recently, commercial organisations in the UK have begun to offer pressurisation testing as a method of 'quality control' in nominally airtight housing or to determine the effectiveness of draughtproofing, but this service is still not widely available.

It is important that organisations using this technique should follow a common site procedure, so that the interpretation of results is meaningful and so that results from different dwellings can be directly compared. BRE has recently published its own recommended procedure[7] for use in UK dwellings.

Implications of variability

The analysis of air leakage rates in dwellings, currently being carried out at BRE, has identified a number of expected trends. For example, air leakage rates increase with the volume or permeable area of the dwelling. However, the relationship which might have been expected between leakage rate and age of the dwelling has not been found. One important factor to emerge is that system-built flats of large panel system construction tend to be much more airtight than traditionally built dwellings.

Although some trends in air leakage rates have been identified, it has also been established that supposedly identical dwellings can exhibit vastly different air leakage rates. Measurements have further shown that the contribution made to total air leakage by various components varies widely. Windows have been shown to account for anything between 5 and 45% of total leakage.

The major implication of this variability is that it is currently impossible, by simple inspection of a dwelling, to make a realistic estimate of its likely air leakage characteristic.

The conclusion which must be drawn is that in all cases a 'fail safe' approach should be taken when making provision for ventilation and that the basic structure of the dwelling should be assumed to provide no more than a minimum background rate of air infiltration. If the additional ventilation provision is finely controllable, the situation should not occur where excessive ventilation, leading to inefficient use of energy and discomfort, occurs. In the event that the dwelling is structurally very leaky, it is likely that occupants will in any case take action to reduce unwanted infiltration.

VENTILATION PROVISION

Approach

From consideration of cost and user acceptability, the ventilation option likely to be used in the majority of UK dwellings is 'natural ventilation', ie controllable ventilation through purpose-provided ventilation openings supplemented by natural, uncontrolled infiltration of air through the dwelling fabric. (During the heating season, the emphasis must be on fine control, whereas during the summer, large openable areas are needed to introduce copious ventilation.)

Ideally, further ventilation provision should be made in kitchens and bathrooms, to remove moisture at source. This can be achieved by opening windows during periods of moisture generation, by the use of a ducted, passive system or, most efficiently, by the use of mechanical extract fans (preferably humidistat-controlled).

In the future, the means of providing ventilation is likely to change more rapidly in new housing than in the existing stock, with a possible increase in the use of whole-house mechanical systems. For the time being however, it seems inevitable that guidance on ventilation provision in 'dry' rooms must focus on simple, passive ventilation openings. The following types are currently available:

- Airbrick or grille — permanently open
- Airbrick or grille — adjustable
- Other types of 'through-the-wall' vent
- Window 'fan' ventilator (wind driven)
- Window ('trickle') ventilator — frame mounted
- Window ('trickle') ventilator — glass mounted
- Ducted passive stack ventilation system

Required characteristics

The different types of opening listed above present various merits and drawbacks from the point of view of user acceptability, performance, etc. The most important characteristic, with regard to ensuring adequate ventilation provision, is the air flow characteristic of the ventilation opening, ie the variation of air flow with applied pressure difference. From such a characteristic it is possible to define an 'equivalent area' which is approximately independent of the applied pressure difference.

At present, such ventilation characteristics are not widely available and in fact few manufacturers of ventilation openings carry out the associated tests. Some unpublished work was carried out at BRE during the 1970s to determine the 'equivalent area' of a number of typical airbricks. This work clearly demonstrated that visual inspection does not permit a realistic assessment of the likely air flow through the opening.

Difficulties can be encountered in specifying ventilators when sound insulation requirements are important, ie close to airports or main roads. Acoustic airbricks are available, but in general the types of ventilator listed above are not designed with sound insulation in mind.

A number of basic requirements for purpose-provided ventilation openings for background ventilation during the heating season are proposed below. These should be installed in all rooms of the dwelling and, in addition, it is recommended that mechanical extract fans should be installed in kitchens and bathrooms:

- 'Free area' of at least 4000 mm^2, when fully open
- Finely and easily adjustable to give a continuous range of opening positions
- Positioned to prevent uncomfortable draughts
- Designed to deflect incoming air in such a way as to avoid draughts
- Secure against illegal entry

Note that airbricks which are required for the provision of fresh air to **combustion appliances** must **not** be adjustable and must **never** be blocked or sealed[8].

For summertime cooling, which is usually intermittent, the current requirement of the Building Regulations (England and Wales) is appropriate: namely, a total opening area at least one-twentieth of the room floor area. It is worth considering whether this requirement should be extended to include one opening light of sufficient size to allow human exit in the event of fire.

Research on ventilation openings

In addition to the studies of air leakage rates discussed earlier, BRE has also carried out a large programme of measurements of air infiltration rates in dwellings, including the effects of opening windows. This work found that the ventilation rate of a room could increase by a factor of three or more when a window was opened to only the first stop.

Under the Energy Efficiency Office's demonstration scheme, trials were mounted in a group of houses in Abertridwr, South Wales, of the effectiveness of 'trickle' ventilators in reducing the incidence and severity of condensation[9]. Whilst there were indications that the ventilators helped to reduce the condensation problem, the site in question was on a severely exposed hillside. Further evidence is needed of how 'trickle' ventilators perform in the majority of UK dwellings, which tend to be in sheltered, suburban locations.

Pilkington R&D Laboratories, in conjunction with the Timber Research and Development Association (TRADA) and Laing, have conducted tests on 'passive stack' ventilation ducts installed in a test house and in a number of occupied 'starter' homes[6,10]. The results were encouraging and confirm that, in conjunction with purpose-provided air inlets, these ducts can enhance air flow rates in the most critical zones of the dwelling.

British Gas have conducted tests to determine the free area of a range of air vents used by their installers[11].

Future developments

It seems clear that there is a need for an agreed test procedure on determining the air flow characteristics of ventilation openings of all types, with a requirement for manufacturers to make the information freely available. Only then will it be possible to make a direct comparison of the likely performance of ventilation openings of different types in different situations.

A programme of work to develop a simple test procedure is now virtually complete at BRE, in collaboration with the industry. In the test, measurements are made of the rate of air flow through the ventilator over a range of applied pressure differences. A value is then determined for the 'effective free area' of the device.

SECURITY CONSIDERATIONS

Illegal entry to dwellings is often by way of windows which have been left open or can easily be opened with the aid of a crowbar. By careful design of components, it is possible to make it very difficult for the would-be burglar to break in through a closed window or door. BRE has recently published Defect Action Sheets on designing against illegal entry[12,13].

Traditionally, the small top-hung opening window has been used as a means of providing low levels of ventilation, particularly for night-time ventilation in bedrooms. Although efficient in fulfilling this role, the top opening light has, in recent years, fallen from favour and it is often claimed that top lights are vulnerable to illegal entry.

In the context of security, there are three types of ventilation provision to be considered:

1 Finely controllable ventilation for use when the dwelling is unoccupied or at night-time. This must be secure and must avoid opportunities for leverage with a crowbar or similar instrument. It is best provided by through-the-wall ventilators or appropriate hardware fitted into the window or frame, rather than by opening the window itself.

2 Slightly larger ventilation openings for use during the heating season when the dwelling is occupied and security is not a consideration. The traditional top-hung opening window is probably the most suitable for this purpose, provided that it can be locked in a secure position.

3 Large openable areas of glazing for intermittent summertime cooling and/or escape in the event of fire. Security cannot be a consideration in this context.

ECONOMIC CONSTRAINTS

Cost is the overriding issue in the provision of windows and other ventilation components in dwellings. Boulton & Paul, a major window manufacturer, estimate that of the 22 000 or so windows sold each week by them, only about 11% are supplied with 'trickle' ventilators. The reason for this low take-up of what can be an effective and inexpensive means of providing additional controllable ventilation is the pressure to keep costs to a minimum.

A further constraint on incorporating ventilation provision into the window frame is the tendency towards window sashes of smaller cross-section, again to reduce costs. Window-head ventilators of smaller section can be manufactured to overcome this constraint but if the length of ventilator required to achieve the desired free area becomes too great, the window frame will inevitably be weakened. An

6 **Johnson K A, Gaze A I and Brown D M.** A passive ventilation system under trial in UK homes. *Proceedings 6th AIC Conference, Netherlands, September 1985.*

7 **Stephen R K.** Determining the airtightness of buildings by the fan-pressurisation method: BRE recommended procedure. *BRE Occasional Paper.* Garston, BRE, 1988.

8 **Department of the Environment and The Welsh Office.** Heat producing appliances. *Approved Document J, The Building Regulations 1985.* London, HMSO, 1985.

9 **Energy Efficiency Office.** Trickle ventilators in low energy houses. *Energy Efficiency Office Expanded Project Profile* 109. London, EEO, 1985. (Copies available from Building Energy Efficiency Division, BRE, Garston.)

10 **Johnson K A and Pitts G.** Experiments with a passive ventilation system. *Proceedings 3rd AIC Conference, London, September 1982.*

11 **British Gas.** Airvent requirements for gas appliances. British Gas Services Department, July 1978.

12 **Building Research Establishment.** Wood entrance doors: discouraging illegal entry — specification. *Defect Action Sheet* 87. Garston, BRE, 1986.

13 **Building Research Establishment.** Windows: discouraging illegal entry. *Defect Action Sheet* 88. Garston, BRE, 1986.

Printed in the UK for HMSO. Dd.8245004, 11/89, C10, 38938.