BRE Digest

Digest 398
September 1994

Concise reviews of building technology

CI/SfB (57.6)

IHS bre press

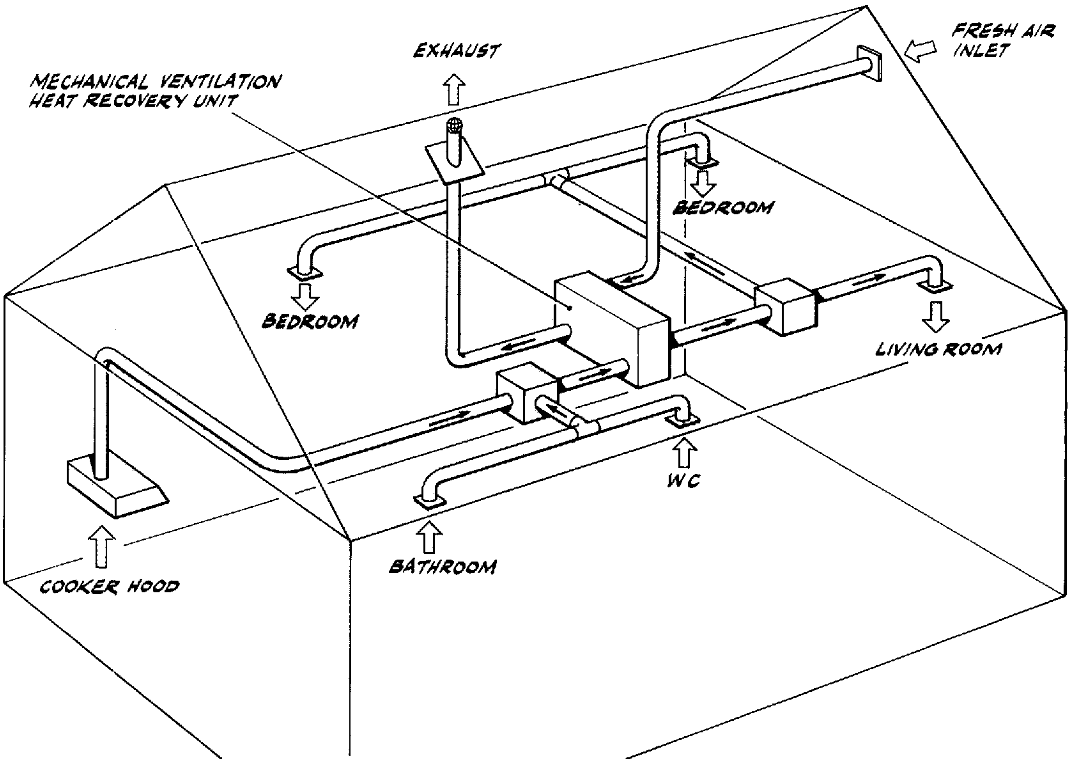
Continuous mechanical ventilation in dwellings:
design, installation and operation

This Digest discusses continuously operated mechanical ventilation systems for typical UK housing. It deals with ducted extract systems and balanced supply and extract systems, with and without heat recovery; it does not include unducted single room units. It considers the characteristics of dwellings and their heating systems, the design of mechanical ventilation systems, controls, fire precautions, installation, and cleaning and maintenance.

This Digest will interest architects, engineers, housing officers and others concerned with the ventilation of dwellings.

MV	Continuous mechanical ventilation
MEV	Continuous mechanical extract ventilation
MVHR	Continuous mechanical ventilation with heat recovery

Fig 1 Typical system for mechanical ventilation with heat recovery



84453

Technical enquiries to:
Building Research Establishment
Garston, Watford, WD2 7JR
Fax 0923 664010

Building Research Establishment

VENTILATING SYSTEMS

The use of continuously operated mechanical ventilation (MV) is becoming more common in dwellings in the United Kingdom. There are two main types:

- balanced supply and extract mechanical ventilation with heat recovery (MVHR)
- mechanical extract ventilation (MEV).

In both, the air is collected or distributed through a duct network.

Figure 1 shows a typical installation of an MVHR system. An MEV system consists essentially of the extract components of an MVHR system and is cheaper to buy and install.

The main reason for installing some form of MV (with or without heat recovery) is to control condensation and indoor pollutants, such as tobacco smoke, metabolic carbon dioxide and odours. These are difficult to control at source. Reducing air humidity can reduce populations of house dust mites but there is insufficient evidence that this can be achieved in dwellings by simply installing MV (1).

Mechanical ventilation systems are usually designed to extract air from bathrooms, kitchens and utility rooms, so that water vapour is removed from as close as possible to its source, and from WCs to remove odours. When weather conditions are such that natural ventilation rates would be low, an MV system can provide adequate ventilation, even in an airtight dwelling. Pollutant concentrations can be controlled and humidity maintained at an acceptable level; this reduces the risk of condensation damage to the building fabric.

Systems should not be installed without expert advice in dwellings which may have high radon levels. Information and addresses for advice on radon are given in *The householders' guide to radon* (2).

In recent years, MVHR systems have been combined with warm air heating systems. This allows the same duct system to be used for both heating and ventilating and may give the opportunity to recover energy from the products of combustion from the heating source. Although these systems are more complex than ordinary MVHR, design guidelines for ventilation still generally apply.

The features which should be considered in the design, specification and installation of a domestic mechanical ventilation system, with or without heat recovery, are summarised on pages 4 to 7. All the recommendations apply directly to MVHR systems; they are equally applicable to MEV systems unless they specifically refer to the air supply system.

ENERGY SAVING POTENTIAL

Balanced supply and extract mechanical ventilation offers the opportunity to simply recover heat from the extracted air. This was the original intention of MVHR systems but, because the UK climate is mild, their cost effectiveness may not appear encouraging. However, the level of cost effectiveness depends also on several other factors. They include the price of the fuel used for heating the dwelling (and hence the value of the heat recovered), the level of airtightness of the dwelling, the balance between energy saved and energy consumed by fans, and the fact that in a very airtight dwelling some form of continuous mechanical ventilation system may be needed anyway. These factors will influence a decision to include an MVHR system as part of an integrated energy efficient approach.

MEV systems allow recovery of heat by the use of more complex heat pump technologies. The cost effectiveness considerations are similar to those outlined here.

AIRTIGHTNESS OF DWELLINGS

The dwelling should be as airtight as practicable for economic operation of an MEV or MVHR system. Currently, the practical limit is a mean background air infiltration rate of no more than about 0.2 air changes per hour (ach) [3] [4] [5] and somewhat less in timber-frame construction. Since the infiltration rate in a given dwelling is usually unknown, some guidance is needed.

Natural infiltration rates vary widely in the UK, even in apparently identical dwellings. Dwellings with mean natural infiltration rates as low as 0.2 ach are the exception rather than the rule; 0.7 ach is probably typical. Natural infiltration rates cannot be assessed purely by visual inspection; some form of measurement is needed.

Natural infiltration rates are difficult and expensive to measure directly. Air leakage rates, under artificially applied pressure differences, can be measured quickly and easily using fan pressurisation [6]. The air leakage rate may be regarded as a measure of the sum total area of all the cracks and openings in the dwelling structure through which air exchange takes place.

Although air leakage rate cannot be interpreted directly in terms of infiltration rate, it can be used as a good indicator. Generally speaking, a dwelling with a mean natural infiltration rate of 0.2 ach will have an air leakage rate, at an applied pressure difference of 50 Pascals, of about 4 ach. *Although the infiltration and air leakage rate are 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.*

Fan pressurisation is useful in identifying the extent to which dwellings should be sealed when installing MV. However, it is difficult to seal an existing dwelling to achieve a 50 Pascal air leakage rate of 4 ach. Just draughtproofing windows and doors is rarely sufficient. Some of the details that need special attention – see Fig 2 – are service entries, wall/floor junctions, suspended timber floors, boxed-in pipe runs, behind bath panels, around window and door frames and plasterboard dry lining (it must be perimeter sealed and not just dab fixed). Seal these details using appropriate flexible and rigid sealing materials. It can be quite impracticable to seal some potential leakage paths in an existing dwelling, such as where intermediate floor joists penetrate the inner leaf of a cavity wall.

Sealing measures can be incorporated into new dwellings during the building process. In traditional construction, the same sealing materials and techniques are used as in existing dwellings (bearing in mind that some air leakage paths may widen as the structure dries out) but many of the air leakage paths can be sealed whilst they are still accessible. In timber-framed construction, a carefully fitted vapour control layer can also be a very effective air barrier to limit air leakage. The barrier should be impermeable to air, eg polyethylene, and be continuous over the whole dwelling envelope; this can lead to particular problems, such as at the junctions between floor and wall structures. Take special care to ensure that all tears and service penetrations of the barrier are sealed before the interior wall surface is fixed.

The special sealing measures required to achieve a high level of airtightness are not widely recognised in the UK; industry specifications for low energy housing, such as the Electricity Association's Medallion 2000 scheme [7] generally recommend the less onerous air leakage rate limit of 7 ach at 50 Pascals (equivalent to a mean natural infiltration rate of about 0.35 ach). This is only a maximum: better levels of airtightness are desirable and achievable.

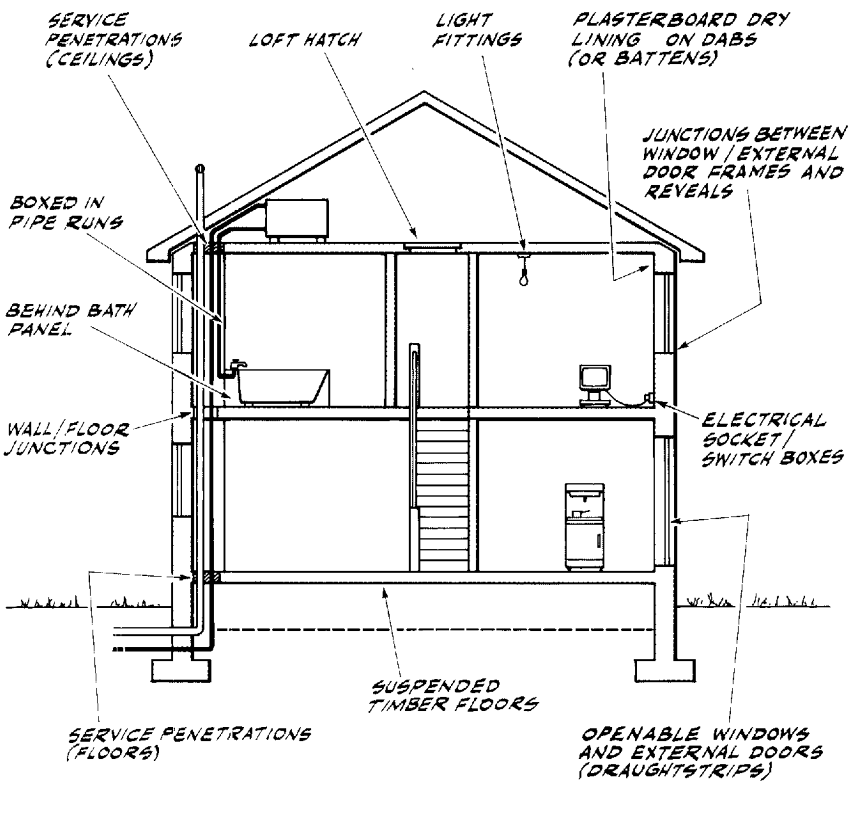


Fig 2 Air leakage routes may need to be sealed

DESIGN, INSTALLATION AND OPERATION

AIR FLOW RATE AND AIR DISTRIBUTION

Ideally, the air supply and extract rates should be tailored to suit the pollutant production rates in the dwelling but pollutant production depends on the number of occupants and their life-style. It is, therefore, difficult to estimate. A whole house ventilation rate of 0.5 ach, with some additional extract ventilation in the wet rooms during moisture production, will generally keep water vapour and other pollutant concentrations below accepted maxima. The total extract air flow rate during normal operation of the MV system should be equivalent to between 0.5 and 0.7 ach based on the whole dwelling volume, less an allowance for background natural infiltration, if desired – see *Airtightness of dwellings* on page 3. Individual room air change rates will be significantly higher, perhaps between 2 and 5 ach in rooms with an extract terminal.

In Scandinavia the total supply air flow rate in an MVHR system is normally set at 90 to 95% of the total extract air flow rate to depressurise the dwelling slightly. This reduces the risk of interstitial condensation. In practice this effect is very small, even in airtight dwellings, and is easily overcome by the effects of the wind. In UK dwellings, supply and extract air flows should be nominally balanced, except when extract boost is operating.

A facility to boost the air extract rate from the kitchen during periods of cooking, and perhaps from the bathroom during washing, is highly desirable. Many systems increase the total extract air flow rate by higher fan speeds but there are several other methods. They all have their merits and it is difficult to give definitive guidance on the amount of boost required. However, it is suggested that an increase in extract air flow rate of 50% in a single room, or 25% for the whole system, would be a reasonable minimum.

With the facility to boost the air extract rate from the bathroom/shower room, take care that the make up air entering the bathroom does not cause unacceptable draughts to the occupant.

Supply air is normally ducted to all 'dry' (habitable) rooms: bedrooms, dining rooms, living rooms, studies etc. There are normally no extracts in these rooms. Total supply air flow rate is usually distributed in proportion to the room volumes.

Air is normally extracted from the 'wet' (service) rooms: kitchens, bathrooms, shower rooms, utility rooms, and from WCs to remove odours. There may be an extract terminal in a larger dry room to help avoid excessive extract rates in wet rooms; this is typical where a dwelling has one kitchen and one bathroom but many dry rooms. Total extract air flow rate during normal operation is usually distributed in proportion to room volumes. Recirculation by the system of moist air from the wet rooms to the dry rooms should be avoided in dwellings.

DWELLING CHARACTERISTICS

Dwellings which are not airtight will have a combination of controlled ventilation, provided by the MV system, and uncontrolled infiltration through air leakage paths all over the structure. Because the infiltration part is uncontrolled and highly variable, it is undesirable but difficult to eliminate. For optimum economic operation of the MV system, the dwelling must be as airtight as practicable. This means a background air infiltration rate of about 0.2 ach. If this is achieved, the bulk of the dwelling ventilation will be provided in a controlled way through the MV system. However, some 'energy efficient house' specifications [7] call for the equivalent of about 0.35 ach so as not to be too onerous.

Air transfer grilles to allow the passage of air between rooms within the dwelling are essential only if MVHR is combined with a warm air heating system but may be fitted if desired. If the bottom edges of internal doors clear the floor surface by 5 to 8 mm, there is likely to be a sufficient opening for air movement. Transfer grilles are usually positioned not more than 450 mm above the floor. If positioned higher, such grilles could, in the event of fire, allow the rapid movement of toxic combustion products and the spread of fire throughout the dwelling.

With MEV, outdoor air must be admitted into the dwelling to replace extracted air. With an leakage rate of 4 ach at 50 Pascals, it is probably sufficient to rely on structural air leakage. In more airtight buildings, small openings, such as trickle ventilators, are needed in each room to avoid excessive depressurisation by the ventilation system. These openings are unnecessary with MVHR systems.

Balanced flue (room sealed) combustion appliances are preferred in dwellings fitted with MV because their operation is not affected by any pressure difference between inside and outside the dwelling and they do not have any permanently open air leakage paths. Exceptions are some combined warm air heating and ventilating systems which may incorporate an open-flued heat source with a fan driven combustion air supply – see BS 5864. Flueless appliances may be used but, apart from cooking appliances, are not recommended because of their high production of water vapour and other pollutants.

PRECAUTIONS NEEDED WITH OPEN-FLUED COMBUSTION APPLIANCES AND CHIMNEYS

Open-flued combustion appliances (any appliance which draws some or all of its combustion air from the living space) are not recommended in dwellings fitted with MEV or MVHR where the MV system might interfere with the operation of the appliance and combustion products could be drawn back into the room. For most types of appliance, regulations require that an air supply is provided by means of air vents of specified sizes in an outside wall of the dwelling. These vents, and the open chimney or flue, reduce the airtightness of the dwelling and, therefore, its suitability for MV.

Take care with open-flued appliances; the appliance, its flue and its air supply must satisfy the relevant regulations and standards: for example, the Building Regulations for England and Wales [8], Scotland [9] and Northern Ireland [10] and BS 5440. Treat all extract points as if they were extract fans, and carry out a combustion product spillage test – see IP 21/92 and BS 5440: Part 1 – with the MV system operating so as to generate the maximum achievable pressure difference across the appliance. In very airtight dwellings the operation of an appliance might be affected by extract points in other rooms.

Block off unused chimneys or flues so that they cannot be used easily but ensure that they are ventilated.

DUCTWORK

Size ventilation ducts to give air velocities below 4 m/s during normal operation to minimise noise. Greater air velocities are usually acceptable for boost operation. Further guidance is in the CIBSE Guide [11] and in manufacturers' literature.

Ducting of 100 mm diameter circular cross section is normally adequate for air distribution/collection in smaller dwellings. Some sections of the duct system may need to be 125 mm or 150 mm diameter to keep air velocities below 4 m/s. Non-circular ducting of equivalent cross-section may also be used.

Size the duct system and terminal fittings, taking into account the air flow rate and pressure performance available from the MHVR unit or MEV fan.

All joints should be sealed properly to avoid air leaks into or out of the ducts.

In unheated areas, ducts should be insulated with the equivalent of at least 25 mm of insulating material with a thermal conductivity of 0.04 W/(mK). Cold air ducts should be wrapped additionally with a vapour barrier outside the insulation.

The air supply duct between the fresh air intake and the heat exchanger should be insulated and wrapped with a vapour barrier where it passes through heated areas.

Vertical exhaust ducts should be fitted with condensate traps. Horizontal exhaust ducts should slope away from fans to prevent condensate running back and so reduce the risk of contacting live parts.

Where ducts pass through an outside wall or attic floor, they should be carefully sealed to the building envelope to maintain the airtightness of the dwelling.

DUCT TERMINAL FITTINGS

The duct terminal fittings should be capable of passing the required air flow rate, at the available pressure drop, without generating excessive noise.

The terminal fittings should be durable and easy to clean. Extract grilles should incorporate a dust filter and, if fitted in a cooker hood, a grease filter.

Supply grilles should give good mixing with air in the room without causing draughts. Site them as far as practicable from the internal door, at high level and directed across an area of unobstructed ceiling.

Position extract grilles so that they clear air from as much of the room as possible, ideally as far as possible from the internal door and as high as possible; above a shower cubicle or bath is a good place in the bathroom.

The fresh-air intake and extract-air outlet should always be outside the building (for example through a roof, wall or soffit) and away from any noise-sensitive areas such as bedroom windows. Intake and outlet ducts must not terminate inside the roof space because this would increase the risk of high humidity levels.

On exposed sites, it may be better to position the intake and the exhaust on the same side of the building. This helps to reduce the effect of wind-generated pressures on the building which can unbalance the system air flow.

The extract-air outlet fitting should be installed away from the fresh-air intake to minimise 'short circuiting'. A separation distance of 2 m should be adequate. Combined intake and outlet fittings may be used if they keep the two air streams separate.

The fresh-air intake fitting must be installed away from boiler and chimney or flue outlets, foul and surface water drain vents and contaminated air outlets. Normal practice for separation between drain vent pipes, chimneys, etc and windows/air bricks should be followed [8] [12] and see BS 5440. However, in the case of wall mounted flue outlets (eg balanced flue terminals) the separation distances are currently under review. The present minimum vertical separation distance of 300 mm is likely to be increased. In the meantime, it is advisable not to locate the intake above a wall-mounted flue outlet.

Intake and outlet fittings should have a louvre, cowl or similar device to prevent rain, birds, large insects and rodents from entering the duct system.

FAN AND MVHR UNIT SITING

The MVHR fans and heat exchanger (usually combined in a single insulated unit) or MEV fan may be sited anywhere in the dwelling provided there is adequate access for cleaning and maintenance, and that any noise produced by the system will not disturb the occupants or their neighbours.

If the MEV fan or MVHR unit is installed in a heated area, the risk of condensation on cold casing surfaces can be reduced by insulating and then wrapping with a vapour barrier (many units are factory insulated).

Heat exchangers should be provided with a condensate drain. This can be run direct to outside if protected from freezing but it is often convenient to connect it to a sink waste outlet; in this case it must not be fitted to the sewer side of the water trap. A water trap in the condensate drain is unnecessary because the drain can often dry out.

NOISE

Noise generated by continuous MV should be controlled; suggested reasonable levels are given in *Sound control for homes* [13] and shown in Table 1. See also CIBSE Guide [11]. These levels are for normal operation; they do not apply to systems under boost operation. They should not be exceeded anywhere that is normally accessible to occupants. The noise should be steady and contain no distinguishable tonal or impulsive characteristics.

Free-standing MEV fans and MVHR units should be mounted on vibration isolators to reduce noise transmission to the dwelling structure. For small installations, mounting the MVHR unit or MEV fan housing on a 50 mm thick mineral wool slab, laid on a sturdy board, may be adequate.

Wall-mounted MEV fans and MVHR units can normally be mounted directly on masonry walls. However, vibration transmission problems can occur, both within the dwelling and with adjoining dwellings, when they are mounted on timber or other lightweight walls. These problems can be difficult to cure because ordinary acoustic isolators are unlikely to be effective.

It may also be necessary to fit flexible couplings between the ductwork and the MVHR unit or MEV fan to prevent transmission of vibration.

A sound absorber may be needed in the air supply duct but this becomes less likely if long lengths of flexible ducting are used.

Noise caused by air flowing in the ductwork (regenerated noise) can be reduced by minimising velocities and pressure drops across duct components and by having duct terminals, branches and bends well spaced.

MV SYSTEM CONTROLS

A master on/off switch should be mounted on or near the MVHR unit or MEV fan to isolate the system electrically during cleaning and maintenance. The electrical installation must conform to the relevant regulations.

A variable fan-speed control and/or variable damper control will permit air extract boost during periods of cooking, showering or washing.

Control devices are available which respond to internal humidity, air quality, occupancy, etc. Such devices may be suitable as a substitute for, or in addition to, fan or damper air extract boost controls.

FIRE PRECAUTIONS

Ducting within the kitchen and connected to a cooker hood should be made of steel. A fire damper is essential in all installations to close off the cooker hood's air extraction opening; it should be as close as possible to the hood. Fire dampers are desirable in other kitchen extract terminals. Quick-acting fire dampers, such as a spring loaded or gravity operated flap with thermal release, are preferred.

If metal extract ducting is used, a fire damper and/or thermal fan cut-out switch should be fitted in the air extract system upstream of the MEV fan or MVHR unit. If plastics ducting is used, for supply or extract, fire dampers must, in addition, be fitted wherever the duct passes through any floor and through those ceilings and internal walls which are required to be fire resisting.

Fire regulations may impose requirements additional to those given here.

Table 1 Background noise levels from mechanical services

Room classification	Suggested design background noise level db(A)
Sensitive rooms	
Bedrooms	below 30
Living rooms	below 35
Dining rooms	below 35
Less sensitive areas	below 45
Kitchens, bathrooms, utility rooms, internal and communal circulation areas	

CLEANING AND MAINTENANCE

Cleaning intervals depend largely upon the location and effectiveness of the system's air filters. Air filters and air supply and extract grilles will probably need to be cleaned at least two or three times a year; the heat exchanger in MVHR systems annually. Fan impellers can be inspected, and cleaned if necessary, when the heat exchanger is cleaned. The inside of the ductwork rarely needs cleaning.

Cooker hood grease filters may need cleaning monthly to prevent contamination of the ductwork and heat exchanger.

The main source of information on cleaning and maintenance is the manufacturers' instructions.

WINDOW OPENING AND SUMMER OPERATION

MV systems are usually operated continuously because they provide most of the ventilation in the dwelling. There is normally no need to open the windows during the heating season. Windows may be opened in summer while the system is operating; in hot weather, this may be necessary to keep the dwelling cool. The windows may provide an escape route in case of fire.

All habitable and service rooms on an external wall (except sanitary accommodation separate from a bathroom) should have one or more rapid ventilation openings, such as an openable window. For England and Wales, the relevant provisions are set out in Approved Document F1, 1995 edition (14).

If the system is switched off, windows should be opened freely to keep indoor pollutants at low levels, even in summer when the risk of condensation is low. This is most important in airtight dwellings.

INSTRUCTIONS

The MVHR unit and MEV fan must be supplied with comprehensive instructions for the installer. These instructions should clearly state what components will be required to complete the system, how all the components should be assembled and installed, how the finished system should perform and how to make sure that it does so.

Each MVHR unit and MEV fan must be supplied with comprehensive instructions for the occupants. The instructions should clearly and concisely state what the system is intended to do, why it should not simply be turned off and ignored, how to use any controls provided, and how and when the system should be cleaned and serviced/maintained. It is also essential that the summer and winter operation of the MV system, and the effects of opening windows, are explained. Some guidance on how to spot when something has gone wrong, such as a fan failure, is useful.

REFERENCES AND FURTHER READING

1 **McIntyre, DA.** Ventilation and humidity: weather data for the United Kingdom. Report R3000/T. Capenhurst, EA Technology, November 1993.

2 **Department of the Environment.** The householders' guide to radon (Third edition). London, DoE, 1992. (Available from DoE, Room A518, Romney House, 43 Marsham Street, London, SW1P 3PY)

3 **Lowe, RJ, Curwell, SA, Bell, M and Ahmad, A.** Airtightness in masonry dwellings:laboratory and field experience. *Building Services Engineering Research and Technology,* 1994, **15** (3).

4 **Scivyer, CR, Perera, MDAES and Webb,BC.** Build tight: the Orkney experience. *Building Services,* July 1994.

5 **Oliver, O.** A low Watts house. *Building Services,* July 1994.

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

7 **The Electricity Association.** Medallion 2000 Builders' Guide. EA1029/7.90. London, EA, 1990.

8 **Department of the Environment** and **The Welsh Office.** The Building Regulations 1991. Approved Document J: Heat producing appliances (1992 edition). London, HMSO, 1992.

9 **The Scottish Office.** The Building Standards (Scotland) Regulations 1990. Technical Standards for compliance with the Building Standards (Scotland) Regulations 1990. Edinburgh, HMSO, 1990.

10 **Department of the Environment for Northern Ireland.** The Building (Amendment) Regulations (NI) 1991. Technical Booklet L: 1991. Belfast, HMSO, 1991.

11 **The Chartered Institution of Building Services Engineers.** CIBSE Guide: volumes A, B and C. London, CIBSE, 1986.

12 **Department of the Environment and The Welsh Office.** The Building Regulations 1991. Approved Document H. H1 Sanitary pipework and drainage (1992 edition). London, HMSO, 1992.

13 **BRE and CIRIA.** Sound control for homes. Joint BRE and CIRIA report. BR 238, CIRIA Report 127 1993.

14 **Department of the Environment and The Welsh Office.** The Building Regulations 1991. Approved Document F: F1 Means of ventilation (1995 edition). London, HMSO, 1994.

Building Research Establishment

Other BRE Digests

238 Reducing the risk of pest infestation
270 Condensation in insulated domestic roofs
297 Surface condensation and mould growth in traditionally-built dwellings
306 Domestic draughtproofing: ventilation considerations
319 Domestic draughtproofing: materials, costs and benefits
337 Sound insulation: basic principles

Information Paper

IP 21/92 Spillage of flue gases from open-flued combustion appliances

British Standards Institution

BS 5864: 1989 Installation in domestic premises of gas-fired ducted-air heaters of rated input not exceeding 60kW

BS 5440:— Installation of flues and ventilation for gas appliances of rated input not exceeding 60kW (1st, 2nd and 3rd family gases)
Part 1: 1990 Specification for installation of flues
Part 2: 1989 Specification for installation of ventilation for gas appliances

Printed in the UK and published by the Building Research Establishment
Available by subscription. Current prices from:
BRE Bookshop, Building Research Establishment, Garston, Watford, WD2 7JR (Tel: 0923 664444).
Full details of all recent issues of BRE publications are given in *BRE News* sent free to subscribers.

ISBN 0 85125 641 4

Printed in the UK for HMSO Dd.8433892, 9/94, C90, 38938