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IP 13/94

July 1994

Passive stack ventilation systems: design and installation

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Passive stack ventilation is a means of removing unwanted moisture from dwellings. The proper design and installation of these systems is vital to their successful performance. This paper gives detailed guidance on this subject and is in support of the 1995 edition of the Approved Document to Part F of the Building Regulations.

INTRODUCTION

All dwellings need a supply of fresh air for the health and comfort of the occupants, to control condensation and to ensure the safe and efficient operation of combustion appliances.

Modern construction practices and the declining use of open fires have resulted in dwellings with fewer ventilation openings which, in many cases, has led to problems associated with inadequate ventilation. One of the most important of these is the removal, preferably at source, of moisture generated by normal household activities.

One solution to the problem of unwanted moisture is to remove it from kitchens, utility rooms, bathrooms and WCs via ducts from the ceiling of each of these rooms to an outlet terminal on the roof. Such ventilation systems are commonly known as passive stack ventilation. They are suitable for houses and blocks of flats of up to four storeys.

OPERATING PRINCIPLES

Passive stack ventilation (psv) systems work by a combination of the natural stack effect, ie the movement of air that results from the difference in temperature between indoors and the outside, and the effect of wind passing over the roof of the dwelling. During the heating season, and under normal UK weather conditions, the ducts will allow warm moist air from the 'wet' rooms of the dwelling to be vented directly outside. The air-flow rate in each duct will depend on several factors, the most important at low wind speeds being the temperature difference between indoors and the outside. As the temperature indoors increases, because of cooking, heating, washing or bathing, the air-flow rate will also increase[1]. Wind speed and direction also influence the rate of air flow but in a relatively complex way that depends on the interaction between factors such as the airtightness of the dwelling, the type and position of air-leakage paths and the position of the duct outlet terminals.

PERFORMANCE IN PRACTICE

The performance of psv systems has been monitored by BRE[1], both in a test house at the BRE site and in occupied dwellings.

Air-flow rates achieved in the test house (under typical weather conditions of a wind speed of 4 metres per second and a temperature difference of 10 °C) ranged from 25 cubic metres per hour (m^3/h) for a 100-mm diameter system with bends, to 75 m^3/h for a 155-mm diameter straight system. The tests in occupied dwellings produced similar air-flow rates for the ducts of the same diameter.

Some of the tests on occupied dwellings were carried out before and after improvements were made to the systems. These included the removal of excess ducting and straightening of twisted bends. There was a significant increase in the air flow after these improvements, underlining the need for good installation.

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DESIGN OF PSV SYSTEMS

Studies carried out in a number of dwellings have shown that the design of psv systems can have a significant influence on their performance[2,3,4,5]. If the guidelines set out in this Report are followed, adequate performance should be achieved. Equally important is the care taken when installation is carried out, since the advantages of good design can frequently be negated by poor installation practices. Guidance on good practice will be given in a later section.

System layout

The psv system should be designed to:

- avoid crossflow between the kitchen and bathroom/WC,
- prevent, as far as possible, air flow in the ducts being adversely affected by the prevailing wind speed and direction, or by sudden changes in these, and
- minimise resistance to air flow by having ducts that are as near vertical as possible.

The layouts shown in Figure 1 are considered to be suitable for the majority of dwellings of up to three storeys. Separate ducts are taken from the ceilings of the kitchen, bathroom, utility room or WC to separate terminals on the roof. A common outlet terminal or branched ducts between these rooms should be avoided as they could (usually in high wind speed conditions) result in air from one room being routed to another.

As Figure 1 shows, there are broadly two suitable positions for the duct outlet terminals.

Ducts with ridge terminals (Figure 1(a))
Placing the outlet terminal at the ridge of the roof is the preferred option for reducing the adverse affects of wind gusts and certain wind directions. This layout does, however, introduce bends into the ducts because of the room configuration.

Sharp bends will cause a resistance to the flow of air and so reduce the effectiveness of the system. Any bends should therefore be of the 'sweep' rather than the 'sharp' type and no more than two in number. In addition, no section of duct should be at an angle of more than 45° to the vertical so that, in general, exhaust grilles should be as close to directly below the ridge as is practicable (Figure 2).

Ducts penetrating the roof (Figure 1(b))
An alternative layout is to have the ducts running vertically and penetrating the roof away from the ridge with the centre line of the psv within 1.5 m of the ridge. They should extend above the roof level to at least ridge height to ensure that the duct outlet is in the negative pressure region above the roof[6]. While this removes the problem of bends in the duct, there are disadvantages to extending the duct above roof level including the considerable visual impact and the difficulty of insulating this part of the duct.

Ducts that terminate on the slope of the roof (tile vents) should not be used because, under certain wind conditions, air flow will almost certainly be reversed (Figure 3). This would result in moist air being transferred to other rooms in the dwelling and may cause discomfort. Also, such positioning of the outlet leads, particularly in the bathroom, to a significant loss of stack height which is one of the main driving forces of the system.

The positioning of the duct that runs from the kitchen ceiling is usually constrained by the layout of the room(s) above, since the duct needs to run either in a corner, where it can be boxed in, or in a cupboard. Experiments have shown that systems are more effective if they are placed near the cooker, ideally as near to the centre line of the hob as possible. If the inlet is not over the cooker it should preferably be away from the window, on the opposite side of the cooker.

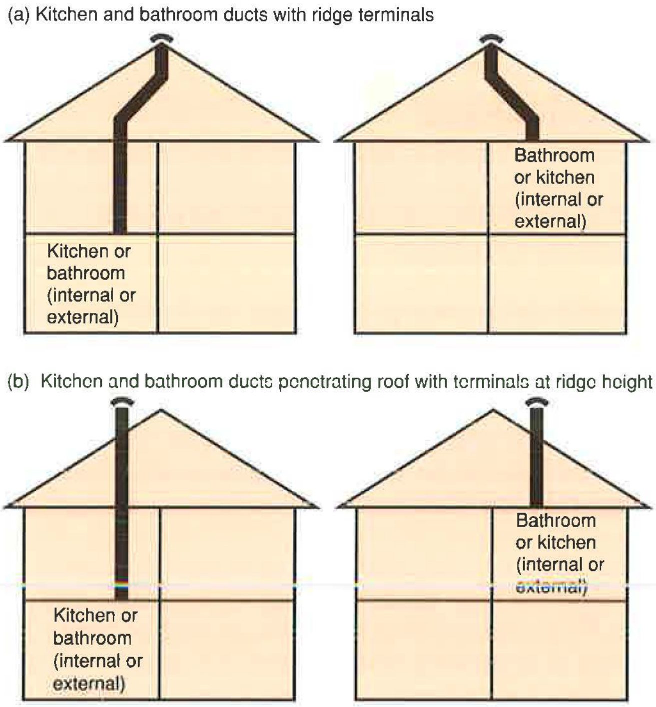


Figure 1 Suitable layouts for passive stack systems

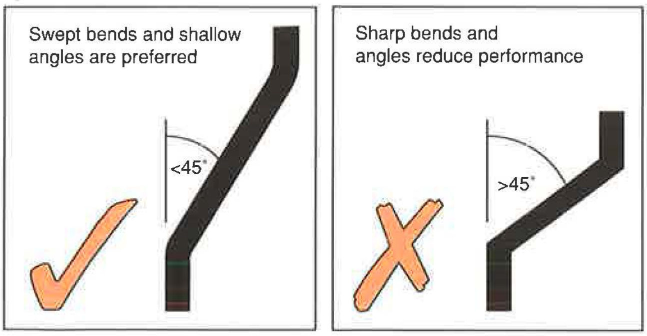
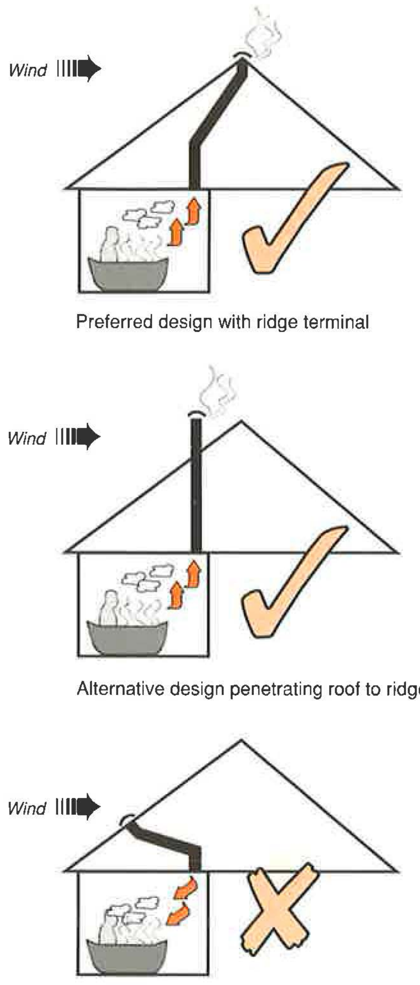


Figure 2 Suitable and unsuitable bends for passive stack ducts



Preferred design with ridge terminal

Alternative design penetrating roof to ridge height

Bad design with tile terminal – **should not be used**

Figure 3 Examples of good and bad design of passive stack ventilation

Outlet terminals

For duct systems that terminate on the ridge of the roof, ridge terminals with appropriate adapters are suitable. If the alternative configuration with the duct extended above the roof is used, flue or soil pipe terminals should be used. Wind tunnel tests carried out by BRE on various terminal types have shown that those least adversely affected by wind are the 'H' pot terminal and the multivane type that revolves with the wind. Further guidance on these and other suitable terminals is to be given by BRE[7].

The outlet terminal should have a free area of not less than the duct cross-section area and should be designed so that rain is not likely to enter the duct and run down into the dwelling. It should neither incorporate a flow restrictor nor require a flow restrictor in the duct for fitting. The guidance given in Table 1 is based on ridge vents and is therefore somewhat conservative. If more efficient terminals are used, it may be appropriate to modify this guidance on the basis of data to be published by BRE[7].

All outlet terminals should be so designed that they do not allow ingress of insects or birds, and should incorporate a condensation cap to allow runoff of any condensation to the roof.

Exhaust grilles

Grilles or terminals placed on the inlet ends of the ducts do not contribute to the operation of the psv system, unless they are control devices, but are there for aesthetic purposes. These grilles should have a free area of not less than the duct cross-section area and be easy to clean. Grilles that have some manual adjustment and those operated by humidity control must have a free area of not less than the duct cross-sectional area when in their fully open position. In the case of humidity controlled inlet grilles, it is recommended that controls are set to start opening the grill when the relative humidity rises to 40%.

Duct sizes and materials

To achieve an adequate, but not excessive, air-flow rate, the diameter of the ducting should be chosen in accordance with the figures given in Table 1. 'Off the shelf' PVC-U pipes and fittings, of the type used for soil pipes, are suitable and have the advantages of being inexpensive, widely available and, to some extent, self-supporting. Flexible ducting has the advantage of being easier to install where a completely vertical duct is not viable. It is also available in a pre-insulated form. There is, however, the disadvantage of the need to support any bends in a smooth curve. Tests have shown that flexible ducting and rigid ducting have similar resistance to air flow at the flow rates found in typical psv systems[1].

Table 1 Recommended duct sizes

Room	Duct diameter (mm)
Kitchen	125
Utility room	100
Bathroom with or without WC	100
WC	80

Note: these figures refer to circular ducts. Non-circular ducts of equivalent cross-sectional area and flow resistance may be used

Duct insulation

The ducts should be insulated in the loft, or other unheated spaces, with the equivalent of at least 25 mm of a material having a thermal conductivity of 0.04 W/mK. Where the duct extends above roof level, as in Figure 1(b), the section above the roof should also be insulated. This helps to maintain the stack effect and reduces the risk of condensation forming inside the duct and running back down into the dwelling.

Air inlet to the dwelling

If the psv system is to work effectively as an extract system, there must be an inlet supplying air to the rooms it serves. This can be achieved by using controllable, purpose-provided ventilators, eg trickle ventilators of 4000 to 8000 mm^2 in area, in all habitable rooms including those which contain the psv system.

Proximity of tall buildings
If a dwelling, in which psv is proposed, is situated near a significantly taller building (ie more than 50% taller), it should be at least five times the difference in height away from the taller building. For example, if the difference in height is 10 m, psv should not be installed in a dwelling within 50 m of the taller building.

Controlled psv systems
For the purposes of energy conservation, controlled psv systems should be provided so that they can be closed when the moisture has been removed. This may be achieved by means of manual and/or automatic sensors or controllers. Both of these have been found to operate satisfactorily in practice.

Alternative design solutions
Any alternative design solutions should be shown, for example by experimental or field data, to perform in an equivalent manner to systems described in this guide.

FIRE PRECAUTIONS

A single house is a single fire compartment; therefore in a family house of one or two storeys psv may be treated like any other service, with no special fire precautions required. However, where the dwelling extends to three storeys or more, additional precautions (eg encasing the duct in $^1/_2$-hour fire retardent board) should be provided to ensure that the escape route is not prejudiced. Where psv systems are installed in blocks of flats (up to four storeys), the psv duct should run in a service duct that complies with the guidance in the Building Regulations[8]. It should be noted that the reduced standard enclosure of drainage or water supply pipes in the Building Regulations will not be appropriate for psv ducts.

INSTALLATION

It is important to recognise that the performance of a well designed system can be ruined by bad installation. Field studies by BRE on installed psv systems using flexible ducting have shown that some of the most common faults are as follows:

- the ducting is too long (ie longer than necessary to join the exhaust grille to the roof terminal) causing the duct to have too many bends,
- the ducting is not properly supported causing it to sag or become detached, and
- the supports are too tight around the duct causing restrictions to the air flow.

To enable a system to work effectively the ducts must not have excessive bends or restrictions to flow. This is not usually a problem when rigid ducting is used because the bends are preformed and sagging is less likely to occur. More support is needed for flexible ducting (Figure 4).

In all installations upper terminals and lower grilles should be fixed in such a manner that there is no reduction in the cross-sectional area of the complete system. All ducts should be insulated where they pass through the roof and sealed with mastic (or equivalent) where they pass from one room to another (Figures 5 and 6).

In addition there are installation requirements specific to straight ducts and to those with bends, and to flexible and rigid systems. These are listed next.

Figure 4
Badly installed flexible ducts with excessive length of duct work and tight bends

Straight duct installation (Figure 5)

Rigid system

- Measure the length of duct to be used carefully to ensure that the outlet terminal will be level with, or higher than, the ridge.
- Use preformed pieces to make any joins to give stability to the duct,
- Where the duct penetrates the roof covering, seal with a traditional flashing, as in Figure 5(a), or a prefabricated flashing unit, as in Figure 5(b).
- Ensure that the vent cowl, where provided, is suitably secured to the duct.

Flexible system

- Carefully measure the length of duct to be used to fit between the inlet grille and the roof slope so that the duct does not sag or wrinkle. The duct material should be fully extended but should not place any strain on terminals or fixings.
- Use a rigid duct for that part of the duct outside of the roof to give it stability. It should start from far enough inside the roof to give adequate support, and extend to the height of the ridge or above.
- Where the duct penetrates the roof covering, seal with a traditional flashing, as in Figure 5(a), or a prefabricated flashing unit, as in Figure 5(b).
- The flexible ducting should be securely joined to the rigid section by means of a jubilee clip and waterproof tape, ensuring that there is no restriction of cross-sectional area.
- Support the duct where it passes through a room or the attic by attaching it to a suitable wall or a wooden strut in such a manner that it will not be squashed or distorted.

Installation with bends (Figure 6)

Rigid system

- Use preformed bend sections so that any angle formed with the vertical is 45° or less.
- Support the duct so that it does not put undue strain on the join with the ridge terminal.
- Ensure that the roof structure is suitably strengthened to allow for installation of the ridge terminal.

Flexible system

- Cut ducting to approximately 300 mm longer than the distance between inlet grille and outlet terminal to give sufficient material to make smooth bends for connection to the terminals.
- Where there is a straight section of duct (eg passing through an upstairs room), support it by attaching it to a suitable wall or a wooden strut so that it will not be squashed or distorted. In the attic, because the duct bends, it should be supported on a wooden strut that is fixed securely at both ends. The duct should be allowed to curve gently at each end to attach to the inlet grille and ridge terminal.

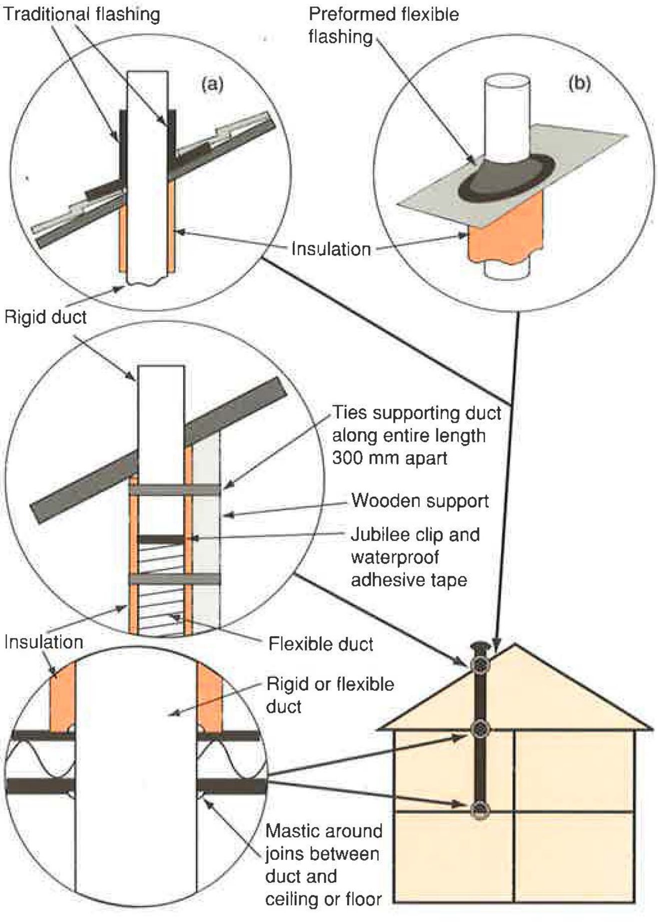


Figure 5 Installation details of straight systems

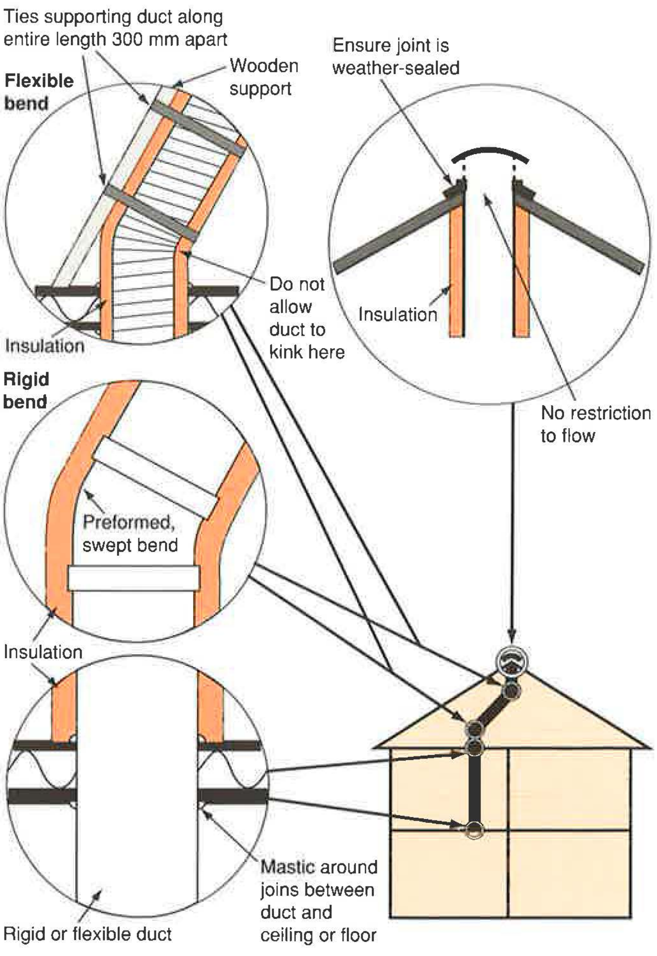


Figure 6 Installation details of systems with bends

NOISE

When a simple psv system was installed in the kitchen of a test house at BRE it was noticed that the duct admitted some noise from a motorway (about 250 m away) and from aircraft. There did not appear to be a noise nuisance in the bedroom through which the exposed duct passed.

Tests have shown that rigid ducts transmit more noise from outside than do flexible ducts[9].

Clearly, in situations where external noise is likely to be intrusive (eg near busy roads and airports) some sound attenuation in the duct is desirable. However, the degree of attenuation required is uncertain because it depends on a number of factors, including the attenuation provided by the duct system itself. It is suggested that, where external noise is likely to be intrusive, fitting an 'off-the-shelf' sound attenuator (essentially a straight length of highly perforated duct wrapped in mineral wool) where the psv duct passes through the roof space is likely to be effective.

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Printed in the UK for HMSO. Dd.8433876, 7/94, C80, 38938