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Positive pressurisation:

a BRE guide to radon remedial measures in existing dwellings

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INTRODUCTION

This report is one of a series giving practical advice on methods of reducing radon levels in existing dwellings. It is intended to help surveyors, builders and householders who are trying to reduce indoor radon levels by positive pressurisation.

The report is based on a large body of remedial work carried out to advice from the Building Research Establishment (BRE), and on discussions with others working in the field. The measures it describes are applicable, in principle, to all dwellings and similar buildings. However, the success of positive pressurisation measures in reducing radon levels is significantly influenced by the characteristics of the dwelling and the occupants' lifestyle.

Before reading this report, consult *The householders' guide to radon*[1], obtainable from local environmental health officers or from the Department of the Environment. The government recommends that, if the average radon concentration in a dwelling exceeds 200 Bq/m^3 (the 'action' level), measures should be taken to reduce it. This report assumes that radon measurements have been made in the building and that the annual average indoor radon level was shown to exceed the action level.

If it is difficult to decide which is the most appropriate remedial measure for a specific dwelling, additional guidance is available in another BRE report[2].

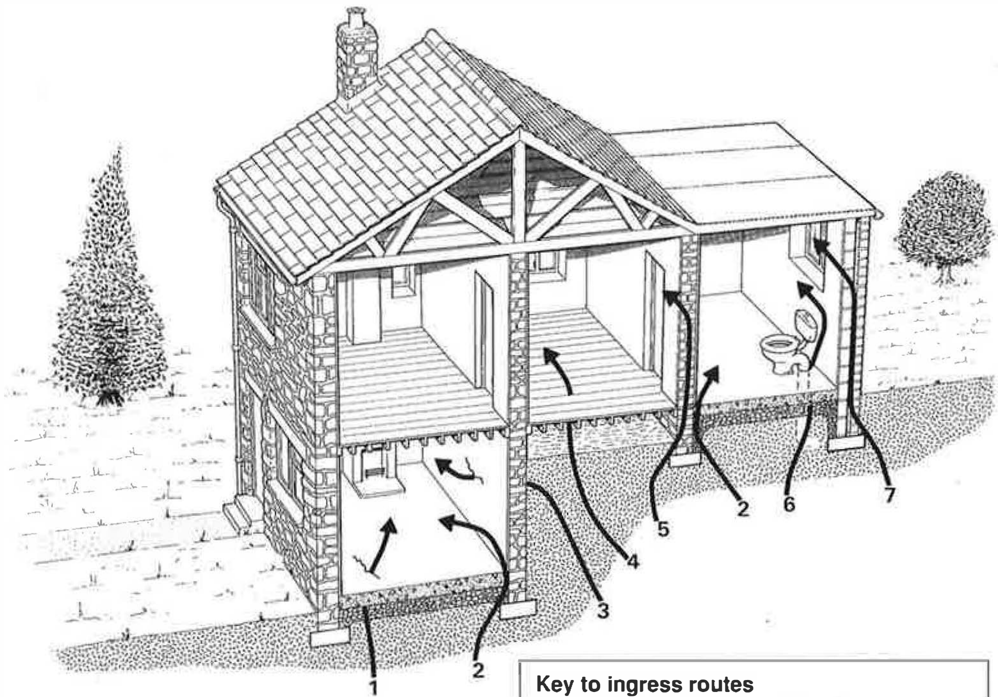
What is radon?

Radon is a colourless, odourless, radioactive gas which comes from the radioactive decay of uranium. Uranium acts as a permanent source of radon and is found in small quantities in all soils and rocks, although the amount varies from place to place (it is particularly prevalent in granite areas). Radon levels vary not only between different parts of the country but even between neighbouring buildings.

Radon in the soil and rocks mixes with air and rises to the surface where it is quickly diluted in the atmosphere. Concentrations in the open air are low, but relatively high concentrations are possible in enclosed spaces, such as dwellings.

The floors and walls of dwellings contain many small cracks and holes formed during and after construction. Radon from the ground is drawn into a building through these cracks and holes (see Figure 1) because the atmospheric pressure inside the building is usually slightly lower than the pressure in the underlying soil. This small pressure difference is caused by the stack (or chimney) effect of heat in the building and by the effects of wind.

There are various ways to prevent radon from entering a building. They include installing a radon sump[3], sealing cracks and holes[4] and ventilating the void under suspended floors[5]. The method described in this report is to make the air pressure inside the building greater than that in the underlying soil by positive pressurisation.



Key to ingress routes
1 Through cracks in solid floors
2 Through construction joints
3 Through cracks in walls below ground level
4 Through gaps in suspended floors
5 Through cracks in walls
6 Through gaps around service pipes
7 Through cavities in walls

Figure 1 Routes by which radon enters a dwelling

POSITIVE PRESSURISATION

What is positive pressurisation?

Positive pressurisation uses a house pressurising fan unit, usually positioned in the roof space, to blow filtered fresh air into the dwelling (see Figure 2). The air usually enters through a special ceiling-mounted diffuser in a central hallway or at the top of a stairway, from where it gently spreads throughout the rest of the dwelling. The fan unit should be left running all the time because radon will quickly return as soon as the unit is switched off. This is also true of any other active radon remedial measure, such as a radon sump or a fan ventilating the space under a suspended floor.

House pressurising fan units were originally developed to combat problems of condensation and mould growth in dwellings with poor ventilation. Householders may therefore find that these units not only reduce radon levels but also have the secondary benefits of giving a fresher indoor environment and reduced condensation.

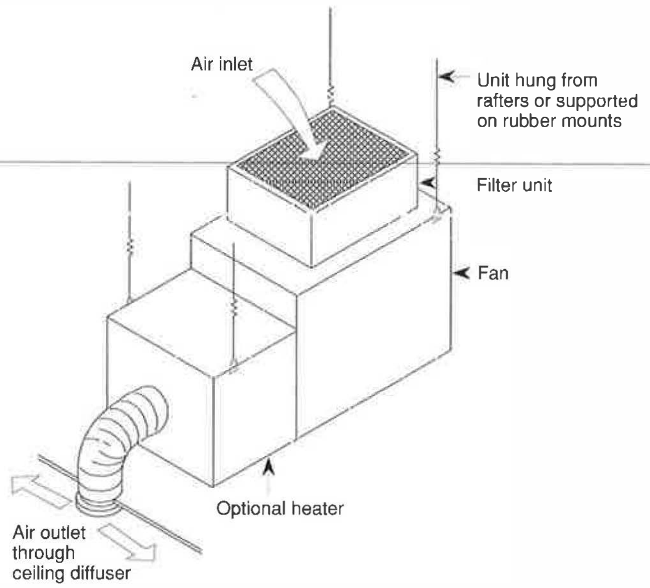


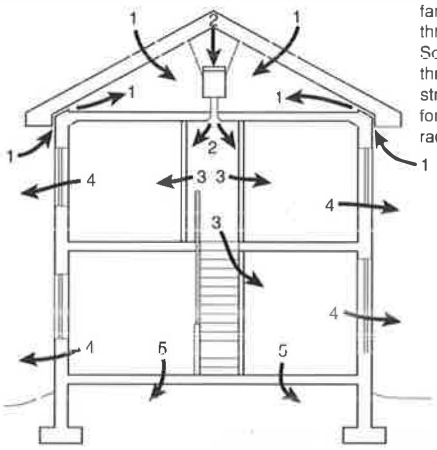
Figure 2 A typical positive pressurisation system

How does it work?

It is often claimed that house pressurising fan units increase the air pressure inside the dwelling such that the pressure difference between the dwelling and the underlying soil is reversed. In this ideal situation, radon would no longer be able to enter through the cracks and holes in floors, cellar walls, etc (see Figure 3).

This result might be possible in a dwelling which was particularly airtight, but in most cases the overall effect of a house pressurising fan is more complicated. In practice, the unit excludes radon to a certain degree by raising the air pressure indoors, but it also dilutes the radon which is still getting into the house (see box opposite for a fuller description of this process).

The pressures generated by house pressurising fans are extremely small (typically between 0.5 and 2 Pascals). On opening a normal size door such pressures would not be noticed.



Fresh air enters roof space from outside **1**, passes through house pressurising fan unit **2** and disperses throughout dwelling **3**. Some air escapes to outside through leakage all over the structure **4**; some air is forced through floor, stopping radon entry **5**.

Figure 3 Idealised view of how a house pressurising fan works

The pressurising effect

If a dwelling was made totally airtight, the house pressurising fan would generate a considerable pressure in the dwelling and radon would be excluded by that pressure. However, most dwellings are not very airtight, and it is difficult to make an existing dwelling so.

To make a dwelling very airtight, air leakage routes need to be sealed all over the structure, often in inaccessible places such as behind boxed-in pipework, behind fitted cupboards or kitchen units and even within floor structures. It is very disruptive and quite impractical to try to seal all these air leakage routes. Simply fitting draughtstrips to windows and doors and blocking up vents and chimneys will not normally be sufficient. Thus, in many cases, a house pressurising fan may only *reduce* the pressure difference between the dwelling and the underlying soil, not reverse it. However, even this limited effect can significantly slow the rate at which radon enters the dwelling, and thereby lower indoor radon levels.

The dilution effect

The other effect of the house pressurising fan is to increase the ventilation rate and therefore dilute any radon which still gets into the dwelling in spite of the pressurising effect. For a given rate of radon entry, if the overall ventilation rate is doubled the average indoor radon level is roughly halved. In practice, the ventilation rate can only be increased to a limited extent because it increases heating costs and, if taken to excess, can lead to problems with draughts.

Combined effects

In most dwellings fitted with house pressurising fans there is a combination of reduced radon entry (because of the pressurising effect) and increased dilution of indoor radon (because of increased ventilation). The advantage of positive pressurisation is that it makes indoor radon more dilute without lowering pressure inside the dwelling. By contrast, an extract fan tends to create a negative pressure in the dwelling such that radon is drawn into the house.

Whether the pressurising effect or the dilution effect is the more significant depends upon the rate of air supply, how airtight the dwelling structure is (including the effects of air vents and chimneys), and window opening by the occupants. Whichever effect is dominant, positive pressurisation can be an economical and effective means of reducing indoor radon levels.

When is positive pressurisation a suitable solution?
Whichever type of radon remedial measure is chosen for a dwelling, there is no guarantee that it will reduce indoor radon to an acceptable level. It is therefore impossible to be precise about how much a particular remedial measure will reduce the indoor radon level, but typical reductions are shown in Figure 4. More than one method can be used to treat a particular dwelling, eg sealing around the services that pass through a timber floor combined with positive pressurisation. However, combinations of methods are not addressed in Figure 4.

The experience of BRE and others working in this field has shown that positive pressurisation is generally only likely to be effective at moderate radon levels, ie up to about 700 Bq/m^3. Using this method, it is difficult to reduce radon levels to much less than one-quarter of the original level. Dramatic reductions in radon level have been achieved in some houses with initial radon levels of 1200 Bq/m^3 or more, but these were generally known or suspected to be unusually airtight and should be regarded as exceptional.

Positive pressurisation is likely to be most successful in dwellings which happen to be relatively airtight. Unfortunately, airtightness cannot be reliably assessed by visual inspection, and although airtightness test methods do exist, measurement services are not widely available and can be quite expensive relative to the cost of installing positive pressurisation measures. Clues which combine to suggest a dwelling is relatively airtight are that:

- it suffers from condensation and mould even though the dwelling is fairly warm,
- odours linger rather than disperse, and
- the occupants do not have problems with cold draughts.

However, these clues are no more than a guide and should not be relied upon.

Like all solutions to radon problems, positive pressurisation has both advantages and disadvantages. Most of these are discussed in later sections of this report. However, one advantage worth considering when choosing a solution to a radon problem is that positive pressurisation can be useful in dwellings with moderate radon levels and mixed ground floor types.

A house pressurising fan can be difficult to install in dwellings where there is no roof space, eg in houses with flat roofs, in blocks of flats, and in rooms open to the roof (as with cathedral ceilings). In this type of case it may be advisable to choose a different remedial measure, but by taking the air supply directly from outside it may still be possible to employ the *principle* of positive pressurisation. Where this is done, the design, installation and other factors discussed in this report should be applied wherever possible.

It is important to remember that, for any radon remedial solution to be completely effective, it must be acceptable to the householder. Some householders — particularly the elderly — are less tolerant of draughts than others, and so positive pressurisation may not be the best solution for them. On the other hand, this measure may be an ideal solution for householders unwilling to accept great disruption inside the house during installation. In every case, the key to finding the appropriate remedial measure is to discuss the different options with the householder, setting out the short-term and long-term implications of each.

DESIGN OF HOUSE PRESSURISING FAN UNITS

Air flow capacity
Perhaps the most important aspect of the design of the house pressurising fan unit is the rate at which it blows air into the dwelling. Clearly, the larger the dwelling, the greater the air flow rate likely to be required to reduce radon to an adequate level. In large dwellings, or those which have an unusual room layout, it may sometimes be better to use two small capacity units rather than one high capacity unit.

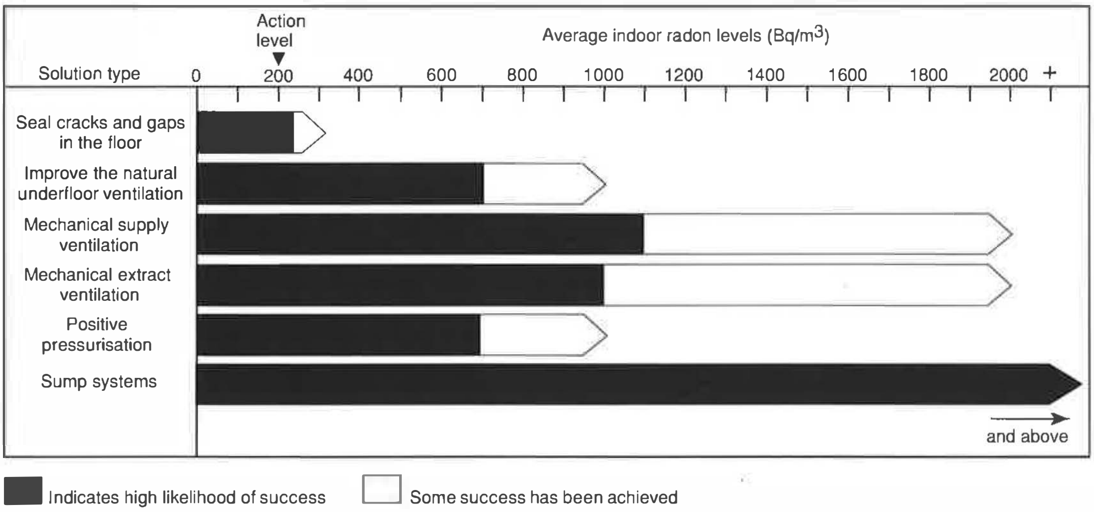


Figure 4 Guide to the likely effectiveness of different radon remedial solutions

The unit should generally supply air at a rate of between 0.5 and 1 air change per hour. For example, if the total volume of a house is, say, 250 m^3 the fan air flow rate should be between 125 m^3/h and 250 m^3/h. It is not wrong to have greater air flows than this — indeed, it would help to reduce radon levels — but it would also result in greater heat loss and could cause draughts.

To cope with dwellings of different sizes, commercial house pressurising fan units usually have two or more air flow rate settings (some have as many as ten). The flow setting is usually set by the installer according to the size of dwelling and the initial radon level.

Air flow rate controls

The most sophisticated units have elaborate air flow control devices which generally respond to the temperature of the air being blown into the dwelling. Typically, these units reduce the air flow rate when the external air temperature is low. The aim is to prevent cold draughts and the development of a 'cold zone' in the hallway. To avoid overheating, the air flow might also be reduced when air temperature is high. The air is normally drawn from roof spaces, which can get quite hot on sunny days: this can be of benefit in the winter, but the warm air can contribute to overheating in the summer.

Provided the radon level is reduced to an acceptable level, ie well below the action level of 200 Bq/m^3, this form of control is perfectly acceptable. However, the lower air flows are less effective in reducing radon levels. In some cases, particularly where the original radon levels were relatively high, there may be more chance of success using a unit with a fixed air flow rate.

Air heaters

Preheating the air blown into the dwelling is another way to prevent cold draughts and the development of cold zones. House pressurising fan units are available with a built-in heater element and a controller to ensure the heater only switches on when needed. This can certainly work, but the heaters are usually electric and use peak-rate electricity for most of the time: householders will need to be prepared for the running costs involved.

Filters

Most house pressurising fans draw their air from the roof space. This space can be dusty, so the unit should incorporate an air filter, which will also exclude insects and other foreign objects from the unit. Units are also available which remove pollen from the air, and use activated charcoal filters to remove other pollutants and odours.

Ceiling diffusers

The ceiling diffuser has a decorative function: it hides the air delivery duct from direct sight. Its other use is to direct or spread the jet of air entering the dwelling in such a way that the air does not cause the occupants discomfort. Most diffusers direct the air in two or more directions parallel to the ceiling surface, although some simply spread out the air in all directions.

INSTALLATION

Positive pressurisation is one of the least disruptive radon remedial measures to install. In most dwellings it involves cutting a hole in the ceiling of a hallway or stairway area, the rest of the installation being in the roof space. There is no need to lift carpets and little, if any, furniture need be moved. However, the installation needs to be done with care if the house pressurising fan unit is to perform acceptably.

Location of fan unit and diffuser

The main thing to decide is the location of the house pressurising fan unit and the ceiling diffuser. These usually have to be quite close together, with only a short length of flexible duct between them. The location can be affected by the proximity of fixtures and fittings in the roof space, eg water pipes, water tanks, flues and structural timbers.

If possible, the diffuser should be positioned so that the air travels across the ceiling for a distance of 1 m or more before striking a wall. If the diffuser directs the air straight at a nearby wall, there are more likely to be problems with cold draughts (see Figure 5).

It may be very difficult to find a suitable location for the fan unit and the ceiling diffuser in dwellings with no roof space, eg those with flat roofs or rooms open to the roof. It is not advisable to locate the ceiling diffuser in living rooms or bedrooms: cold draughts, and sometimes noise, from the diffuser may lead the occupants to switch off the fan unit.

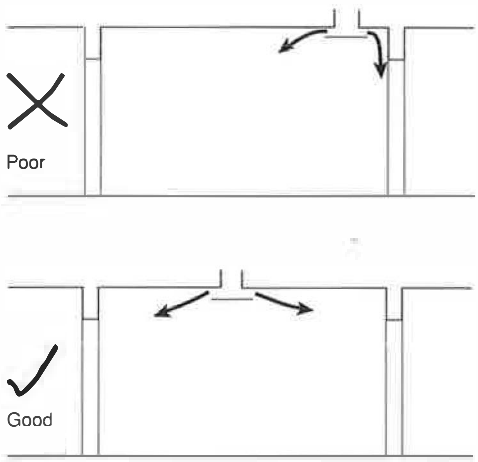


Figure 5 Locating a ceiling diffuser to reduce the risk of cold draughts

Noise and vibration

To avoid the transmission of noise and vibrations through the ceiling or roof structure, the house pressurising fan unit is normally mounted on special vibration isolating mountings (rubber feet) or suspended from suitable roof timbers on kinked wires, elastic shock cord or springs (see Figures 6 and 7). Suspension on wires may be preferable where the fan unit is sited above a bedroom. With the same aim of avoiding transmission of noise and vibrations, the connection between the fan unit and the ceiling diffuser is usually made with a section of flexible duct.

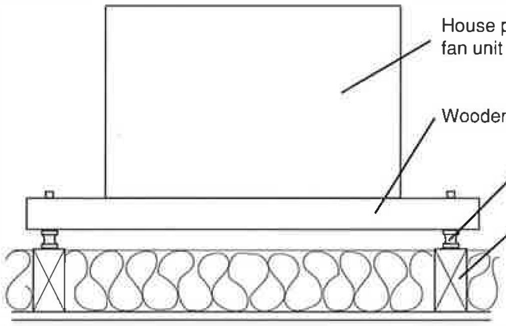


Figure 6 Mounting of fan unit on ceiling joists (typical arrangement)

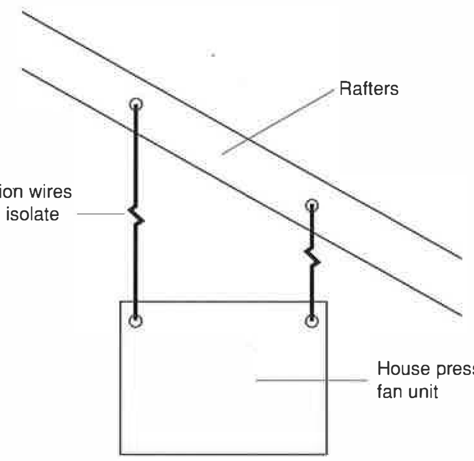


Figure 7 Fan unit suspended from roof structure (typical arrangement)

Air supply to roof space
Is the roof adequately ventilated?
The air drawn from the roof space by the fan unit must be replaced with fresh air from outside, so it is essential that the roof space is adequately ventilated. If the roof space is airtight, radon-rich air could be drawn up into the roof space through the wall cavity or rubble fill and then blown into the dwelling by the fan unit (see Figure 8). It is impractical to seal the top of the walls.

In dwellings built since 1985 this is unlikely to be a problem because roof vents should have been provided in the eaves. Likewise, dwellings with no sarking boards or underfelt under the tile (or slate) roof covering will have adequate ventilation through gaps between the tiles (or slates), unless there is a cement or bitumen wash over the upper surface of the roof or spray-applied foam on the underside.

In other dwellings the amount of roof ventilation will be uncertain. One way to judge is to turn off the lights in the roof space and to look for signs of daylight getting in along the eaves. If daylight can be seen clearly in several places, the air supply to the fan unit is probably adequate.

Is radon-laden air being drawn up into the roof space?
Radon can also be drawn into the roof space by way of boxed-in services. It is common for services — particularly soil pipes for WCs — to run right up through the dwelling, from the ground floor to the roof space. They are usually concealed from view by plasterboard or timber boxing around the pipe. The gap between the boxing and the pipe can sometimes provide a direct route for radon-rich air to reach the roof space from below the ground floor (see Figure 8).

Where the pipe is accessible in the roof space, check for this flow of air with the loft hatch closed and the house pressurising fan running. The flow can be detected using a smoke puffer, or it may be felt as a draught on the moist back of the hand.

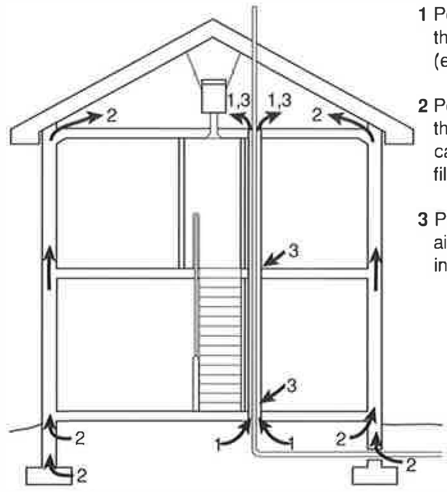


Figure 8 Possible routes for radon entry into the roof space

Boxed-in services may also allow indoor air to 'short circuit' back into the roof space, thus reducing both the pressurising and diluting effects of the house pressurising fan unit (see Figure 8). Indoor air may get into the boxing in a number of places, eg within intermediate floors, under kitchen worktops and around bath panels.

In older semi-detached and terraced houses with linked roof spaces, the house pressurising fan could draw radon-laden air into the roof space from the house next door. This is *possible*, but it is probably rare. The problem can be resolved in one of two ways (see below), and preferably in co-operation with the neighbours.

If radon-laden air is being drawn into the roof — from the ground or inside the house or from next door — there are two solutions to the problem:

- Seal the gap between the boxing and the pipe at top floor ceiling level using a suitable sealant, eg expanding foam. This is the **preferred** solution, but it can prove difficult to achieve because soil pipes are often very close to the eaves, where headroom in the roof space is minimal
- Alternatively, improve the roof space ventilation

Air supply direct from outside
If a roof space is not available, or if air supply from the roof space is not acceptable because of odours or overheating, air can be taken direct from outside. However, this will make problems with cold draughts more likely.

Electrical connections

Simple house pressurising fan units without a heater can usually be connected to an existing lighting circuit in the roof space. However, units fitted with an electric heater may draw too much power for this existing circuit, and should then only be connected to a suitable power circuit. The electrical installation must conform to the relevant regulations.

OTHER FACTORS TO CONSIDER

Costs

House pressurising fans may be cheaper to buy and install than some other remedial solutions, although this depends on what materials and work is required. Overall running costs (including the cost of the electricity used by the fan, and the additional space heating costs caused by increased ventilation) are likely to be broadly similar to those associated with a radon sump or a fan ventilating the space under a suspended floor. However, electric heaters can add significantly to the running costs of the fan unit.

Open-flued combustion appliances

An open-flued combustion appliance, such as an open fire, draws air from the room in which it is sited. Extract fans in kitchens and bathrooms, or those associated with radon sumps and extract ventilation under floors, can sometimes cause the air supply to be restricted and combustion gases to spill into the room. **This is potentially hazardous and should always be avoided.**

This problem does not arise with positive pressurisation because, if anything, it assists the flow of combustion gases up the chimney (or flue). However, it is worth noting that the effectiveness of positive pressurisation in reducing radon levels may be improved if unused chimneys and flues are blocked up. Note that, if chimneys and flues are blocked up permanently, it is important to prevent moisture from building up inside the chimney: a BRE publication[6] is available which deals with this topic in detail.

Condensation

Secondary benefits of positive pressurisation may include a fresher indoor environment and reduced condensation in winter. This is because the fan unit will tend to expel from the building more of the water vapour given off by household activities such as cooking, bathing and drying clothes. Odours may also clear more quickly.

Householders may also find that they no longer need to open windows as often. This is useful because windows left open for long periods, particularly upstairs, may reduce the effectiveness of positive pressurisation.

Odours and pollutants in the roof space

Some householders have noticed the smell of tar when the house pressurising fan is operating. This is caused in some dwellings by the release of vapours from bituminous felts which are often used under the roof tiles or slates. Some roof spaces may be polluted by chimney smoke which gets into the roof space from outside through gaps between roof tiles or slates. There is no easy solution to this problem, but improving roof space ventilation may help. Alternatively, the air supply could be taken directly from outside.

When the timbers in a roof space are treated with solvent-based wood preservatives, it is advisable to switch off the house pressurising fan to stop solvent vapours being drawn into the dwelling. In properly ventilated roof spaces the solvents normally disperse within about a week, and the fan unit can then be turned on again.

Heat loss

By increasing the ventilation rate, positive pressurisation inevitably increases the heat loss of the dwelling. In a 'leaky' dwelling this extra ventilation may be undesirable, and therefore some attempt should be made to make the dwelling more airtight when installing a house pressurising fan.

RETESTING FOR RADON

Once remedial measures have been installed, it is important that the dwelling is remonitored for radon. Ideally this should be done over a three-month period using two etch-track (plastic) detectors located in the same rooms as were used for the original monitoring.

For further information on detectors and monitoring, contact the National Radiological Protection Board (see box below).

MAINTENANCE

Maintenance requirements of house pressurising fan units are minimal. As with most other domestic appliances, the fan motor bearings are usually of the 'sealed for life' type and require no further lubrication. Normally all that is required is that the air filter is cleaned or replaced at the intervals specified by the manufacturer (typically every one to two years). The ceiling diffuser may need to be cleaned occasionally.

FURTHER INFORMATION

Research into radon is continuing and further reports in this series are planned. Help with radon-related problems of all kinds is available from the BRE Radon Hotline (telephone: 01923 664707). BRE publications on the subject of radon can be obtained from Construction Research Communications Ltd, 33–39 Bowling Green Lane, London EC1R 0DA.

Advice on radon risks and monitoring is also available from The Radon Survey, National Radiological Protection Board, Chilton, Didcot, Oxon OX11 0RQ (telephone: 01235 831600).

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