File 2079

2 of 5

ENERGY EFFICIENT RENOVATION OF HOUSES

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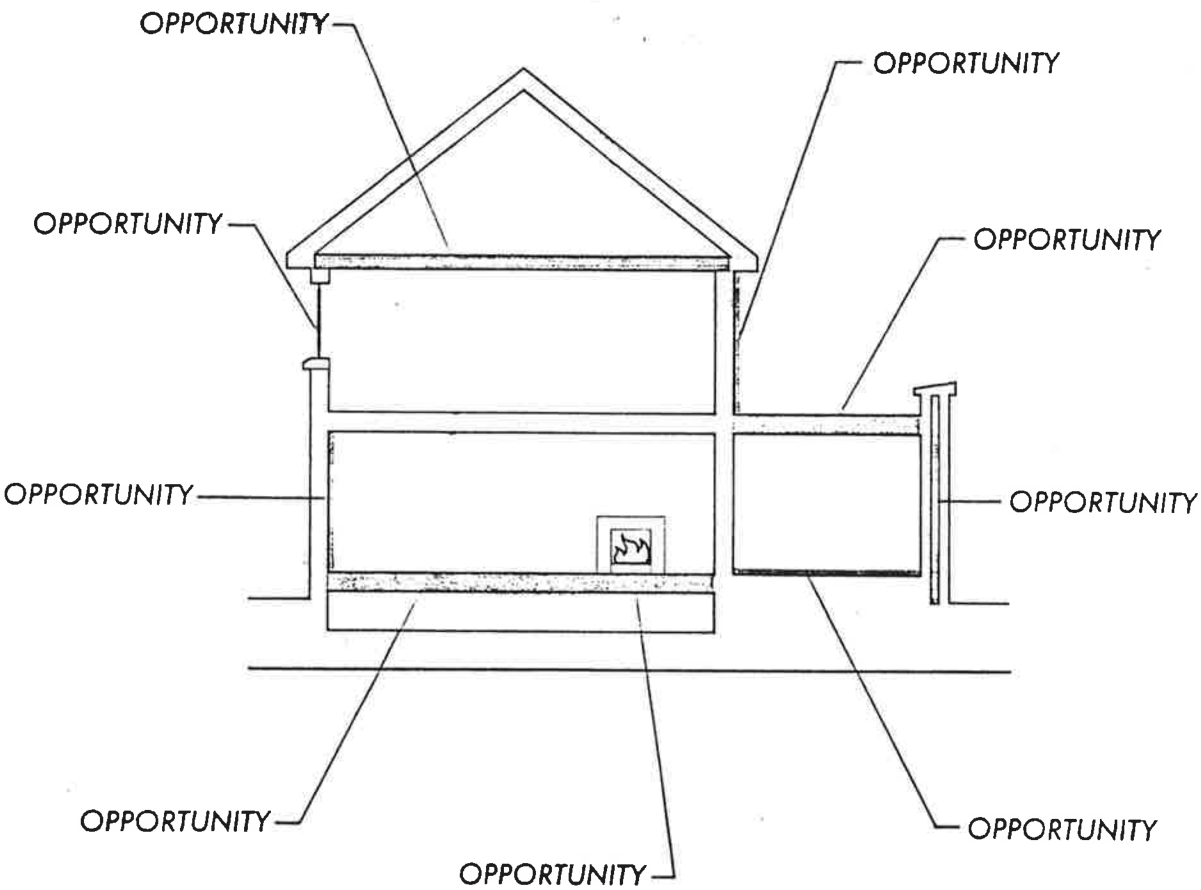
A DESIGN GUIDE



DEPARTMENT OF THE ENVIRONMENT

Contents

Energy Efficient Renovation of Houses has been prepared under the joint sponsorship of the Department of the Environment and the Energy Efficiency Office of the Department of Energy.

Introduction

It is now considered normal to update the energy performance of housing whenever the opportunity arises during renovation. This guide aims to provide sound technical advice for the architects and surveyors responsible for design decisions and to help them assess the opportunities for adopting an energy efficient approach to the renovation of traditionally built housing.

The guide aims to demonstrate to housing managers and property developers that an investment in an energy efficient approach has advantages and represents good value-for-money.

AN OUTLINE OF EACH SECTION

The *strategy for energy efficiency* section promotes a coordinated approach to insulation, ventilation and heating, and describes the design refinements that should be included in housing renovation projects in order to achieve the benefits of energy efficiency and reduced condensation.

On pages 10 to 17 *four typical examples* are used to illustrate the energy efficient approach. A package of energy saving measures is described for each example and a simple comparison of net additional costs and fuel savings is used to give the overall payback period.

The practical details section deals with each of the major elements of the building in turn. For each element (pitched roof, flat roof, etc) there is firstly a description of the alternative energy saving materials and construction techniques which apply, followed by a list of key points to consider in order to ensure that the energy saving measures:

- ☐ are appropriate for the application being considered,
- ☐ do not increase the technical risk, ie have no adverse side effects,
- ☐ are as effective as possible in practice.

Finally, typical specification clauses are used to demonstrate the costs and savings that result from adopting an energy efficient rather than the usual approach to renovation. For each specification, the net extra cost and the corresponding fuel saving, is tabulated, together with the payback period.

There follows a page on *assessing value-for-money* which gives details of the assumptions made in estimating the additional capital costs of the energy efficient approach and the resulting fuel cost savings. Also shown is a procedure for adjusting these savings for different fuels and heating patterns.

The back page lists references to other documents which give more detailed information on some of the technical issues discussed in the guide.

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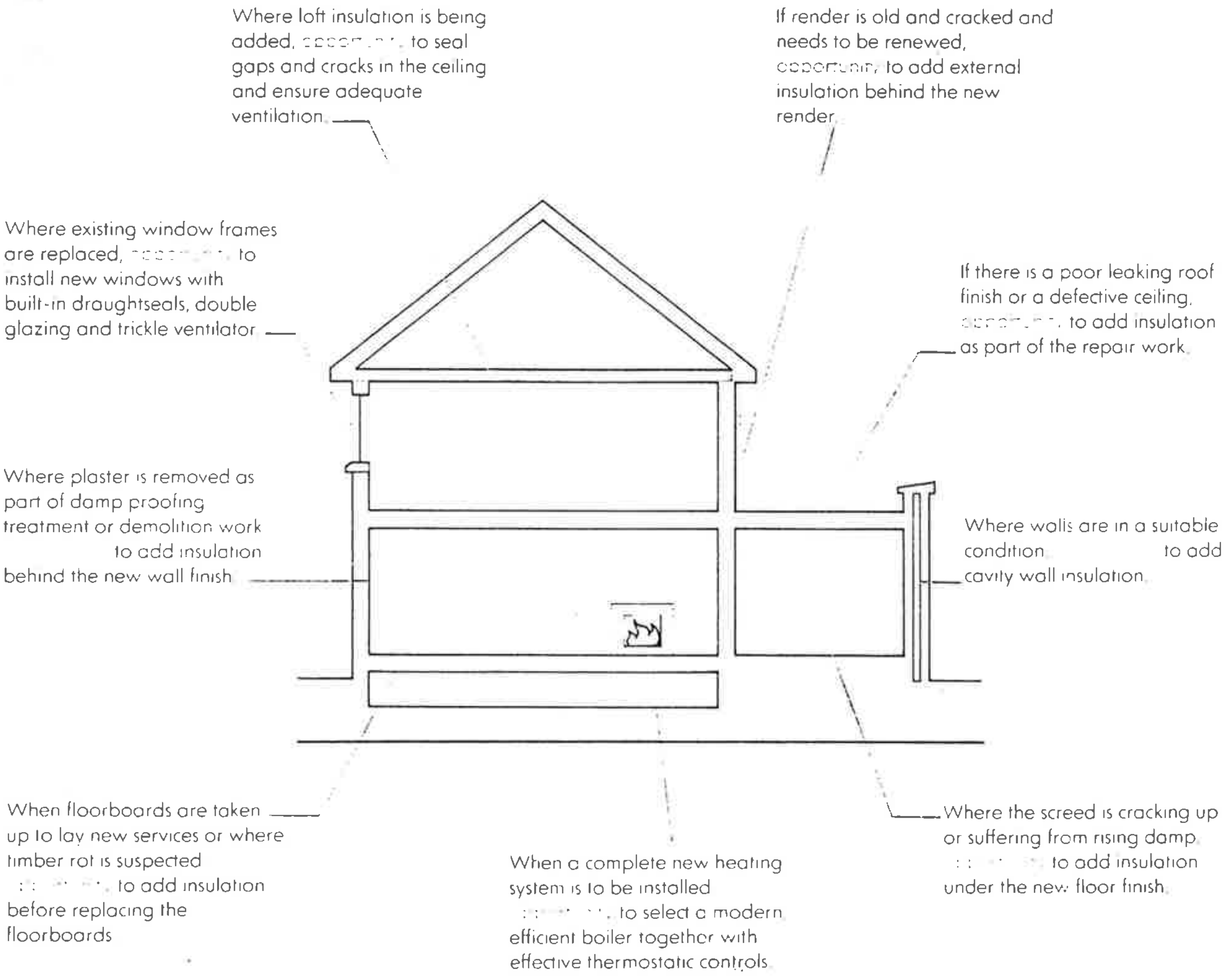
OPPORTUNITIES FOR ENERGY EFFICIENCY

It is less disruptive as well as cheaper to incorporate many energy efficiency measures whilst carrying out renovation work than to add them at a later date. Homes undergoing major improvement and repair offer the ideal opportunity to upgrade insulation levels, provide controllable ventilation and install an efficient, well controlled heating and hot water system. If the opportunity is missed, rising fuel costs will compound the disadvantage that tenants suffer, either in higher fuel bills or, alternatively, cold homes, with the attendant problems of condensation and mould growth.

It is hoped that this guide will encourage all concerned to adopt a more energy efficient approach to housing renovation and so avoid many of the problems associated with earlier rehabilitation work which arose due to a lack of consideration for high running costs and their consequences.



The opportunities for adopting energy efficient measures in house renovation

A STRATEGY FOR ENERGY EFFICIENCY

Objective

One of the objectives of future housing renovation should be to introduce energy efficient measures whenever possible, so that the occupants are able to enjoy an acceptable level of heating at a reasonable cost. It should be noted that measures to improve energy efficiency also help to lessen the risk of condensation.

Energy efficient approach

The energy efficient approach involves:

1 Assessing the extent of repair and improvement work necessary

2 Assessing the thermal characteristics of the dwelling and considering the opportunities for incorporating energy saving measures

3 Selecting a package of measures and checking that there are no adverse side effects

4 Calculating the payback period in order to demonstrate cost-effectiveness. Because of the complexity and high cost of some forms of construction it may not always be judged cost-effective to add insulation.

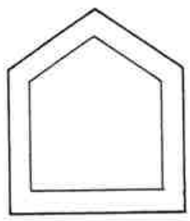
Comprehensive treatment

Making the most efficient use of energy requires comprehensive attention to thermal insulation, ventilation and heating. Concentrating exclusively on any one is unlikely to be successful.

Thermal insulation

As well as cutting down heat loss, thermal insulation helps to raise the internal surface temperatures of the building fabric. This improves internal comfort and reduces the risk of condensation.

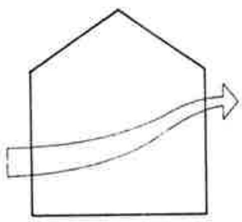
Each renovation project will present different opportunities for adding thermal insulation, depending on the degree of repair and improvement work required. Where there are complexities in construction to add insulation may not always be cost-effective. However, the designer should be alert to the opportunities provided, and aim to insulate the whole fabric where possible, taking particular care to avoid introducing cold bridges.

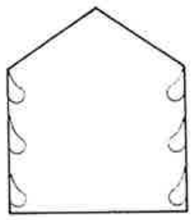


Ventilation

Many older houses suffer from high ventilation rates because doors and windows are not draughtproofed and the multitude of other air leakage paths are not effectively sealed.

High ventilation rates result in uncomfortable draughts and increased heat loss. *Unwanted* air leakage around windows, doors and other gaps and cracks should be reduced and *essential* ventilation maintained by introducing finely controllable ventilators in each room. The designer should make special provision in kitchens and bathrooms to enable the tenant to remove steam close to its source, and so minimise the amount of water vapour that can disperse throughout the dwelling.



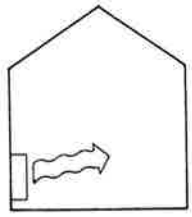


Avoiding condensation

Heating

Adequate heating should be provided of a type which is efficient and economic in use.

It is important that the heating system should operate efficiently, especially at low output and have simple yet responsive controls that are easy for the tenant to understand. Heating reduces the condensation risk because it keeps the surfaces of walls and ceilings warm. Clearly, it costs less to do this when the structure is well insulated.



Thermal Insulation

INSULATION STANDARDS

The standard of thermal insulation adopted for current housing renovation projects is usually well below that required of new housing by the Building Regulations. This can be improved considerably by taking whatever opportunities present themselves to add insulation. The diagram below, which is for a typical 1930's end-of-terrace house of 61 m² with the living room heated to 21°C illustrates how:

[**1**] The well insulated renovated house [**C**] can be heated all day for about the same cost as a thermally unimproved house [**A**] heated in the evenings only. The tenant in the well insulated house can therefore more easily afford a satisfactory standard of heating, while avoiding many of the condensation problems that occur in conventionally renovated dwellings.

[**2**] Because heat is lost slowly, the well insulated house [**C**] has a higher average internal temperature than the others. This is particularly important in preventing condensation. The difference in temperature is most marked when comparing houses that are only heated in the evenings.

[**3**] The addition of an insulated drylining to the external walls of the kitchen [**B**], which is becoming more common in renovation work, makes very little difference to the annual energy consumption. Its main benefit is to reduce the risk of surface condensation in the kitchen.

TECHNICAL SOLUTIONS

Most properties being renovated have solid or cavity brick external walls. Brickwork alone offers very little thermal insulation, but its capacity to store heat should be borne in mind when deciding where to add insulation as this will make a big difference to the way the building responds when heated.

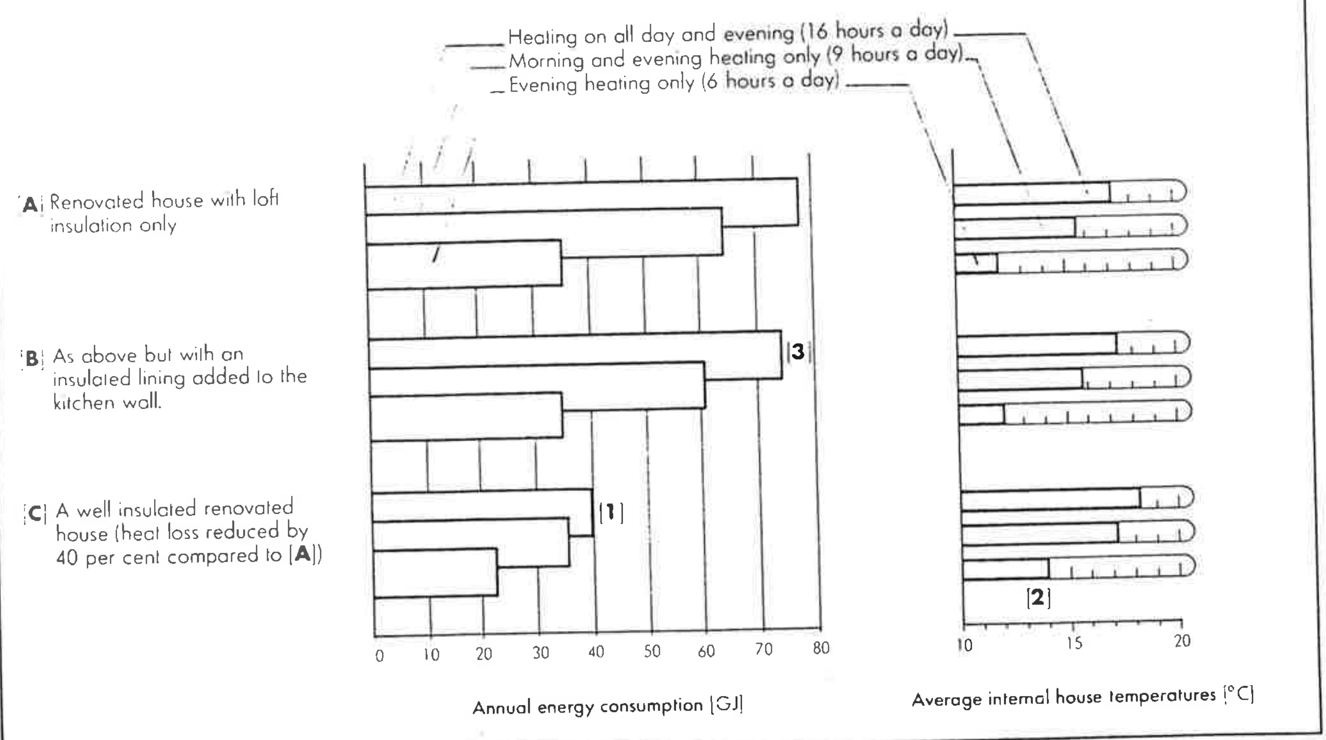
For example, insulation added to the outside of the wall will greatly reduce the rate of heat loss, whilst allowing heat to be stored in the structure. The wall will still take some time to heat up, but will cool down much more slowly.

By adding insulation to the inside of the wall, its behaviour is changed completely. The wall surface will warm up very quickly because of the insulation, but because the heat storage is insignificant, it will cool down quickly when the heating is turned off. However, where a house which is insulated internally has a large area of brick party wall (eg a terraced house) then the internal structure is still able to store heat as before and the house will continue to act as a high thermal capacity building. Solid concrete floors and brick internal partitions also have the capacity to store heat in the same way.

In rooms which are used intermittently and particularly those where moisture is generated, internal insulation enables the wall surfaces to heat up quickly, thus minimizing the risk of surface condensation.

The most appropriate technical solution will depend on the detailed design of the property, the degree of repair work and whether the dwelling is to be decanted whilst the work is carried out. Pay particular attention where heat loss is greatest, such as exposed gable walls and back extensions. Aim, whenever possible, to reduce cold bridges, eg at concrete boot lintels and projecting balconies.

Where new energy saving methods are employed, close site supervision and good briefing of the contractor may be required to ensure he is aware of potential pitfalls and to resolve any technical difficulties.



Ventilation

The strategy for reducing heat loss from excessive ventilation should be to reduce unwanted air leakage, whilst providing controllable ventilation.

The Building Research Establishment estimates that air infiltration accounts for as much as 25 per cent of the total heat loss from a typical British home. Ventilation rates in old houses are often around two air changes per hour. Where windows fit badly, ventilation rates may be even higher. The diagram below illustrates the unwanted leakage paths into and from a typical house and also where it is important to maintain essential ventilation.

DRAUGHTPROOFING

As can be seen from the diagram, there is a multitude of potential air leakage points. Many are impossible to correct in an existing building, although gaps around components (ie doors, windows, roof hatches), are accessible and able to be sealed.

Windows and doors

For most houses and flats the easiest and most cost-effective way to reduce air leakage is to draughtproof the windows and doors. Most replacement double glazed windows and good quality single glazed windows will have built-in draughtproofing.

It is impossible to calculate accurately the savings resulting from draughtproofing measures. The rate of air change in a house varies over the year according to the wind speed and direction, as well as the external temperature, and the effect of sealing cannot easily be measured. However, where field tests have been carried out, draughtproofing the windows and doors has reduced the air infiltration rate by 0.3 to 0.6 air changes/hour.

Suspended timber ground floors

The majority of houses built before 1940 in England and Wales, and nearly all those in Scotland have suspended timber ground floors, many with square-edged floorboards. Air infiltration from the floor void is a significant factor in these houses. Furthermore, as external temperature falls, the increased difference

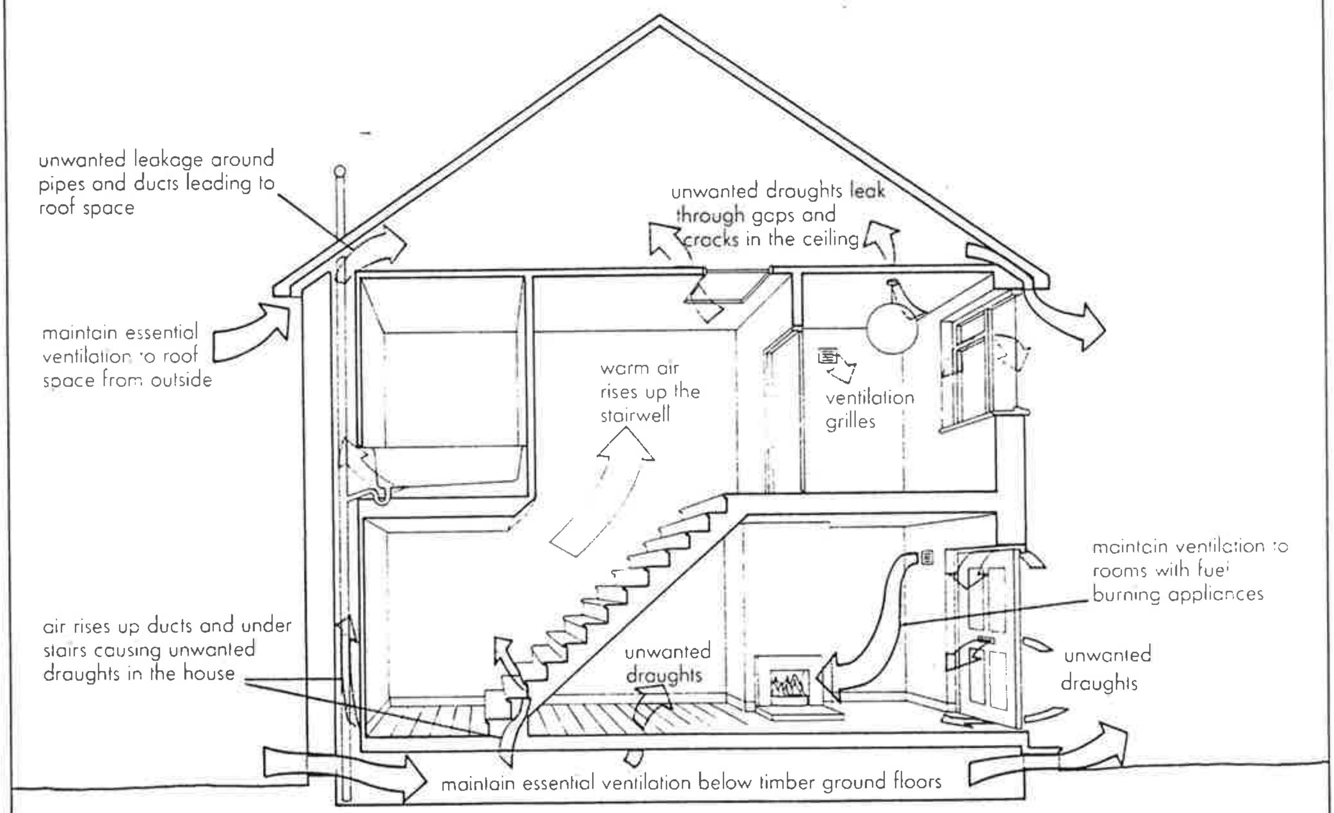
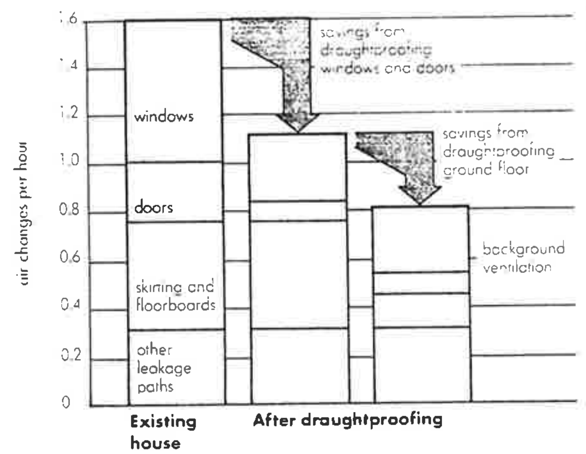


Diagram of unwanted air leakage and essential ventilation.

between the inside and outside air temperature creates a 'stack' effect, causing cold air to enter ground floor rooms.

There have been no field trials to measure the savings from draughtproofing a traditionally constructed suspended timber ground floor. However, theoretical studies indicate that sealing the gap between the skirting and the floor should result in savings of about half those for draughtproofing windows and doors. In houses with square-edged floorboarding, sealing the gaps between the floorboards might save as much again, although laying a continuous floor finish (eg sheet vinyl or fitted carpet) will have almost the same effect.



Typical reductions in the ventilation rate due to draughtproofing.

Gaps and cracks in the ceiling

Holes and cracks in the ceiling below the roof space should be filled to prevent warm moist air passing through, increasing heat loss as well as the risk of condensation in the roof space. This is particularly important where kitchens or bathrooms are below flat roofs. In pitched roofs, the roof access hatch should be draughtproofed and fitted with a means of securing it firmly closed.

PERMANENT VENTILATION

Statutory regulations stipulate that when heating appliances that require fresh air for safe operation are to be used, the room should have a permanent ventilator.

These ventilation openings which are usually fitted in the external wall, often cause unacceptable draughts. Where possible, either select room sealed heating appliances or position the appliance where the necessary fresh air can easily be ducted to it.

Many existing houses have permanent ventilators in rooms which have no heating appliance. These are understandably papered over or sealed up by tenants because of draughts. If, however, controllable ventilators are provided, the original openings can be permanently blocked.

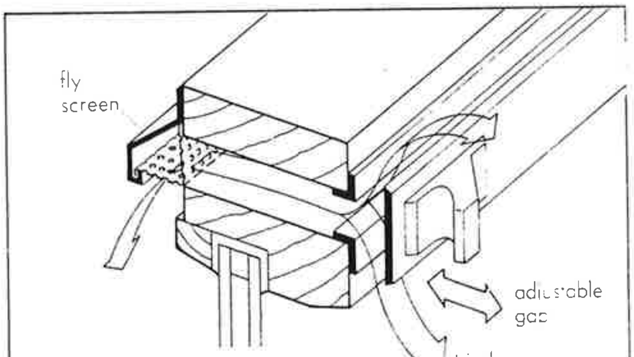
CONTROLLABLE VENTILATION

Draughtproofing significantly reduces air leakage, but usually leaves enough background infiltration to remove odours and prevent the air becoming stagnant. However, the air infiltration is not uniform throughout the dwelling and individual rooms (notably bedrooms) often have very low air change rates. This can cause condensation and mould growth.

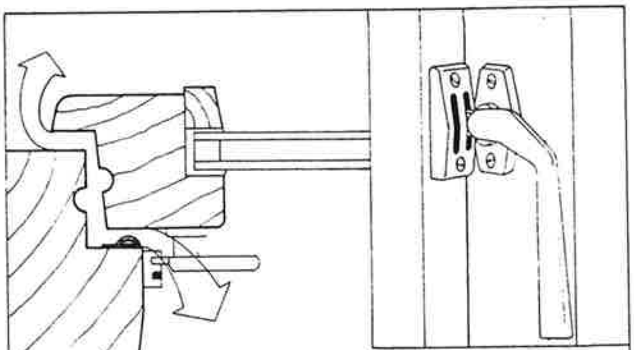
The introduction of controllable trickle ventilation in each room helps to improve the ventilation balance throughout the whole dwelling, thus reducing the risk of condensation. It has been found that following the installation of controllable slot ventilators, windows have been opened less often in Winter, thereby improving the distribution of ventilation without incurring an energy penalty.

Draughtproofing measures should therefore be implemented as part of a total package which includes improving the level of insulation and providing controllable ventilation.

Ventilation control in bedrooms and living rooms is most effectively achieved by trickle ventilation. Where windows are being replaced, it is recommended that controllable slot ventilators are incorporated into the window head to provide 400mm² of free area for each 1m² of room area. Where existing windows are retained, slot ventilators may often be incorporated into the top of the glazing. Alternatively for side hung casements, the fastener can be replaced by one with two keep positions, allowing the window to be secured in a night-vent position. Trickle ventilation offers security without rain ingress or uncomfortable cold draughts.



Example of an adjustable slot ventilator fitted into window head.



Two position window fastener providing trickle ventilation.

Heating

Adding insulation and reducing air leakage can cut the rate of heat loss dramatically and make it easier and cheaper for tenants to afford a better level of comfort throughout the dwelling.

In selecting and designing a heating system the following points should be considered:

☐ **Select a heating system which is appropriate to the dwelling type.** For most family homes, central heating will be the first choice. In smaller dwellings designed for one or two people, easily controlled individual unit heaters should be cheaper to install than central heating and allow just one room to be kept warm. This is preferred by many tenants who need to keep their heating bills as low as possible.

☐ **Aim to provide an attractive focal point heater in the living room,** even where a dwelling has central heating. This is a popular feature. It allows a quick warm up of the principal room and is useful in taking the chill off the room in cold Spring and Autumn evenings, and avoiding the need to switch on the full central heating system. The heater in the living room should ideally have some proportion of radiant heat.

☐ **A reasonable level of background heating provides a safeguard against condensation.** Some heating systems such as electric off-peak storage radiators and solid fuel heaters by their very nature provide good background heating, but are less responsive to thermostatic control than gas or oil fired systems. An alternative adopted for some blocks of flats, is to provide background heating and include the cost in the rent. The background heating is independently controlled to achieve a temperature of around 14°C, which is considered the minimum necessary to avoid serious condensation. A separate 'top-up' heating system is controlled and paid for by the tenant.

☐ **A central heating system should be designed to avoid wasteful boiler cycling.** In a poorly controlled system, the boiler thermostat in a gas or oil fired boiler continues to switch the burners on and off to maintain its pre-set temperature, even when there is no demand for heat. Boiler cycling is readily avoided when the controls consist of a room and cylinder thermostat linked to a motorized valve and programmer. These controls should be wired so that they override the boiler thermostat when there is no demand from the heating or hot water circuits.

☐ **For gas boilers and fires, specify models with spark ignition rather than a pilot light.** This should save on gas consumption, especially where the boiler is used to supply hot water in the summer months.

☐ **It is important to avoid oversizing the boiler** because gas and oil fired boilers are less efficient at low output than at full load. A boiler with an output of 7kW should be adequate to provide space heating and hot water for a dwelling with a design heat loss of up to 5kW.

☐ **For a well insulated house, choose a lightweight, low thermal capacity boiler.** Laboratory tests and field trials by the British Gas Corporation have shown that boilers with a low thermal capacity maintain their efficiency better at lower loads than boilers with a high thermal capacity (ie with a cast-iron heat exchanger). In well insulated houses the boiler operates at low loads for most of the year. Only during initial warm-ups and in very cold weather is it likely to operate at full capacity.

☐ **Where individual unit heaters are specified, they should incorporate their own thermostats.** Some models are also available with a time clock. It may be worth considering these where it is expected that households will be out for much of the day.

☐ **Retain unused chimneys** and thus keep options open for possible future uses.

☐ **The heating system should be cheap to run and simple to control accurately.** There are still many misconceptions among tenants about the workings of a central heating system, particularly how thermostats and programmers work. This can result in unnecessarily high fuel bills because the controls are misused. Each new heating installation should be accompanied by permanent (ie plastic coated and fixed) instructions on how to operate and control the heating system together with general advice on running the system economically and avoiding condensation. At each re-let, the workings of the heating system should be explained to the new tenant.

Refer to *page 35* for more detailed information on heating systems.

Avoiding condensation

Moist air is created as a result of many essential household activities. It is difficult to control its movement around the house and it is often the cause of condensation amd mould growth. However, measures to improve energy efficiency also help to avoid condensation problems. Dwellings that are well insulated and draughtproofed retain more heat and consequently stay warm for longer, allowing ventilation to remove the moist air before the temperature drops to a level where condensation can occur.

In addition to the measures described above under thermal insulation, ventilation and heating, several other steps can be taken to help avoid condensation.

Remove moisture at source

Extracting moisture at source is one of the best ways of preventing condensation.

Moisture in the kitchen is generated when meals are being cooked, dishes washed and, in recent years, when unvented tumble driers are in use. An extract fan, which is switched on when moisture is produced, is desirable for both kitchens and bathrooms.

The designer must decide whether an extract fan is necessary for the dwelling being renovated and if so, how it should be controlled.

BRE studies have shown that when dwellings are well insulated and well heated, it has not been necessary to use an extract fan to avoid condensation problems. But can tenants be relied upon to heat their dwellings to the level necessary?

Dwellings that are poorly heated have been shown to suffer less from condensation problems when kitchen extract fans have been well used. But the BRE evidence showed that when fans were under tenants' control they were operated for less than 3 hours per week. On the other hand, fans controlled by humidistats were found to be in use for considerably longer periods (50 hours per week) and proved very successful in preventing the dispersal of moist air to living rooms and bedrooms. But care should be taken to check the reliability record of any system being considered.

Even where extract fans are installed, it is essential that the kitchen and bathroom have an effective means of natural ventilation which is easily controlled. A small top hung sash is usually suitable (provided the window furniture is within easy reach). Unlike a properly functioning extract fan, an open window can be a route for air to enter, distributing moisture throughout the house. The risk of this happening is greatest where the kitchen window faces the direction of the prevailing winds.

Unvented tumble driers can also be responsible for dispersing large quantities of moist air within the house. Householders should be encouraged to use a flexible hose from their tumble drier directly to the outside.

Provide self-closing doors to the kitchen and bathroom

Draughtproofing kitchen and bathroom doors and fitting them with self-closing devices will help prevent the dispersal of moist air. In flats it is often necessary in any case to have a self-closing kitchen door to comply with fire regulations.

Unflued paraffin and gas heaters

The use of unflued paraffin and bottled gas heaters should be strongly discouraged. Each litre of fuel burnt produces over a litre of water as vapour.

Cupboards on external walls

Enclosed cupboards, particularly those on cold north walls should be vented into the room. A louvred door or holes drilled at high and low level should encourage air circulation and prevent pockets of damp stagnant air forming in the cupboard.

Insulate to reduce cold bridges

Unless cold surfaces are eliminated, condensation is likely to occur. It is therefore important to insulate the complete building envelope and avoid leaving cold bridges (eg at window reveals and boot lintels).

Consider the risk of Interstitial condensation

When insulation is added to a wall, the possibility of interstitial condensation occurring needs to be considered.

With external insulation, interstitial condensation is usually avoided where the insulant and weather protecting finish are both vapour permeable. If the insulant has a high vapour resistance (eg cellular glass) the risk of interstitial condensation is minimal if the thickness of the insulation is at least 25mm. Where an impermeable outer cladding is specified, a ventilated cavity should be introduced behind it.

Where insulation is added internally, a vapour check should be placed on the warm side of the insulation. For maximum effectiveness the vapour check should not be punctured by socket outlets etc and should be sealed at the perimeter and around all openings.

Make provision for condensation on windows

Where wall and roof insulation is added, internal surface temperatures are raised and the incidence of surface condensation is reduced. However, where insulation levels are improved but single glazing is retained, more condensation can occur on the glass than before. Installing an inner pane of glass will reduce window condensation by raising the surface temperature, but this is an expensive solution. A more common alternative is to accept that condensation will occur, but to avoid deterioration of the window frames by using one of the proprietary channel sections which drain the condensate direct to the outside.

Educate tenants

The design aspects should be backed up by education of the tenant. Simply written *permanent* advice should be given on good housekeeping measures to minimise the amount of moisture generated, together with an explanation of how to reduce the risk of condensation by adequate heating and ventilation.

FOUR TYPICAL EXAMPLES

The following examples illustrate the scope for adopting an energy efficient approach to renovation for four dwellings. The dwelling types shown are typical of those which occur in current rehabilitation programmes and have been chosen to illustrate the energy efficient approach by describing a range of energy saving packages in which the opportunity has been taken to upgrade the specification.

The following are examples of the opportunities for energy efficiency that thave been included in the energy saving packages:

☐ When windows are rotten, the replacement windows can be fully draughtproofed, double glazed and incorporate controllable ventilators.

☐ When solid walls need replastering, insulated lining boards can be a substitute for wet plaster.

☐ When floors are opened up for repair or inspection, insulation can be placed between the floor joists.

☐ When render needs extensive repair, external insulation can be applied.

Other measures such as loft insulation, cavity wall insulation and draughtproofing have also been included as an essential part of the energy efficiency packages, but these can if necessary be carried out independently of full renovation work.

The examples differ in age, form of construction and proposed heating system. Each example starts with a description of the dwelling, its form of construction and condition of repair, followed by a statement of the general level of improvement and repair work, insulation and heating which *usually* occurs. In contrast, energy saving specifications are tabulated, together with the net extra cost and the annual fuel cost savings of each. In the case of the heating installation, there is a net saving in cost. Finally, costs and savings are totalled and the overall payback period for the package obtained.

It is suggested that calculations should always be done to assess the cost-effectiveness of an energy saving package, even if cost-effectiveness is seen as less important than reducing heating fuel costs to an affordable level.

Inter-war flat

Description and condition

There were nine different flat plans on each floor of this large block of balcony access flats. The illustration shows a typical three bedroom flat on the third floor.

The external walls were loadbearing brickwork, 335mm thick, supporting a pitched roof. The structural spine wall was 225mm thick brickwork and the partitions 50mm blockwork, with plasterwork in good condition. The floors were in-situ concrete.

USUAL APPROACH

General level of improvement and repair

The layout of flats in this large block was replanned to enlarge the kitchen and bathroom and eliminate bedrooms next to the access balcony. Each flat improvement was carried out within the existing party walls, resulting in equal numbers of one and two bedroom flats. To retain a number of family units in the development, the two lower floors were converted into maisonettes.

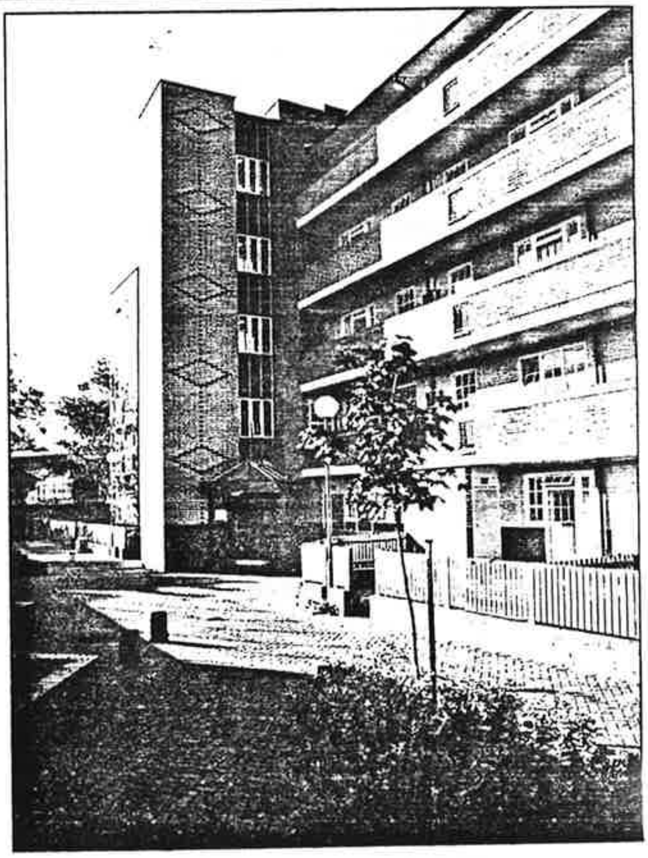
Generally the vertical sliding windows were replaced on the balcony access side of the flat and repaired on the other side.

Insulation and ventilation measures

The measures adopted were:

☐ 100mm mineral fibre insulation added to the loft (top floor flats only).

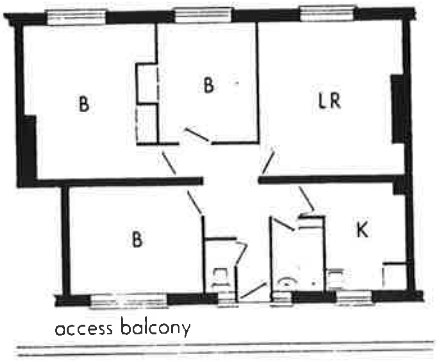
☐ Gable walls lined with 20mm polystyrene/ plasterboard laminate, adhesive fixed to the existing plaster (end flats only).



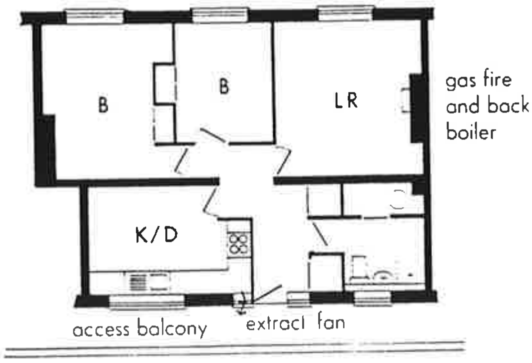
☐ The windows thoroughly overhauled but not draughtproofed.

Heating installation

A new gas fire with back boiler was installed in the living room to serve radiators in all rooms as well as the hot water cylinder. The radiators were fitted with thermostatic radiator valves.



ORIGINAL PLAN



PLAN FOLLOWING RENOVATION

ENERGY EFFICIENT APPROACH

The energy saving package reduces the design heat loss from **3.85kW to 3.35kW** (a 13 per cent reduction). The **payback period** is about **seven years**.

The measures proposed for this flat are modest. Adding an insulating internal lining would reduce the heat loss by a further 20 per cent, but it would be relatively expensive because of the cutting needed around window openings. The payback period would be more than 15 years. Always fairly cheap to heat.

THE ENERGY SAVING PACKAGE

Energy saving measures			**Extra capital cost** [£]	**Annual fuel cost savings** [£/annum]
Insulation and ventilation measures:				
Draughtproof living room and bedroom windows.			52.00	6.00
Replacement windows to bathroom and kitchen to be double glazed, draughtproofed and incorporate slot ventilators.			105.00	8.00
Draughtproof the front door.			25.00	3.00
Add reflective foil behind radiators in the living room and bedroom.			12.00	5.00
	Extra costs and fuel savings		£194.00	£22.00
Heating installation:				
Reduce size of radiators in line with reduced heat loss	saving	£32.00		
	Capital cost saving	£32.00		
Net extra cost and annual fuel cost saving			£162.00	£22.00

The capital costs and annual fuel cost savings are based on the figures in the cost-effectiveness tables in *The Practical Details* section.

For details of the assumptions used in assessing costs and information on how to calculate payback periods, see page 37.

Pre-1919

end-of-terrace house

Description and condition

In its unimproved condition, this small house had a single storey extension containing the kitchen and outside wc. There was no bathroom. The back extension had very poor brickwork and a dilapidated roof. The suspended timber ground floor had square edged boards and was in need of repair.

USUAL APPROACH

General level of improvement and repair

The house was fully rehabilitated. The new work included an injected dpc and associated replastering, rewiring, central heating, and a new extension.

Insulation and ventilation measures

The measures adopted were:

- ☐ 100mm mineral fibre insulation.
- ☐ 25mm polystyrene insulation in the cavity wall to the bathroom extension to comply with a U value of 0.6 W/m²K.
- ☐ The external wall to the kitchen was rebuilt from dpc level in 200mm lightweight concrete blockwork with a rendered finish. (U value 0.7Wm²K).

None of the windows were draughtproofed.

Heating installation

A new combined gas fire and back boiler serving five radiators and the hot water cylinder was located in the dining room.

GROUND FLOOR FIRST FLOOR GROUND FLOOR FIRST FLOOR

ORIGINAL PLANS **PLANS FOLLOWING RENOVATION**

ENERGY EFFICIENT APPROACH

The energy saving package reduces the design heat loss from **6.2kW to 3.4kW** (a 45 per cent reduction). The **payback period** is **eight years.**

The main reductions in heat loss are due to insulating the solid brick walls and draughtproofing. With a house insulated to this standard, it is possible to omit radiators from bedrooms and rely on heat convection from the ground floor. However, to supplement the convected heat, a radiator needs to be added on the top landing. The gas fire in the living room is retained to provide instant radiant heat, top-up warmth and partial heating on cold days or evenings in the Spring and Autumn. Heating costs are then acceptable.

THE ENERGY SAVING PACKAGE

Energy saving measures			**Extra capital cost** [£]	**Annual fuel cost savings** [£/annum]
Insulation and ventilation measures:				
Insulate new solid ground floor by substituting 25mm polystyrene and moisture resistant chipboard for 38mm sand/cement screed. Finish with vinyl tiles.			30.00	4.00
Draughtproof the skirtings with sealant and fit 50mm polystyrene between the joists, while the floorboards are up.			190.00	17.50
New extension walls — substitute 75mm mineral fibre cavity batts for 25mm partial cavity fill.			2.00	4.00
Rebuild wall to kitchen in rendered 140mm lightweight blockwork lined with a 50mm polystyrene/plasterboard laminate internally, instead of 200mm thick lightweight blockwork, rendered externally.			nil	1.50
Following injection of a chemical dpc and replastering, substitute a 50mm thick polystyrene/plasterboard laminate for the skim coat.			285.00	32.00
Adhesive fix a 50mm thick polystyrene/plasterboard laminate to the existing plaster of the first floor external walls, and secure with screw fixings.			415.00	36.00
Draughtproof the two external doors (one new/one existing) and the four sash windows.			120.00	16.00
The new windows to the bathroom and kitchen to have built-in draughtseals, double glazing and slot ventilators.			65.00	4.00
Draughtproof and insulate the roof hatch and fix securing bolts.			15.00	3.00
Add reflective foil behind the radiators on outside walls.			20.00	4.00
	Extra costs and fuel savings		£1142.00	£122.00
Heating installation:				
Reduce size of radiators in line with reduced heat loss	saving	£135.00		
Add thermostatic radiator valves to all radiators	extra	£50.00		
Omit radiators from bedrooms, but add one to top landing	saving	£100.00		
	Capital cost saving	£185.00		
Net extra cost and annual fuel cost saving			£957.00	£122.00

The capital costs and annual fuel cost savings are based on the figures in the cost-effectiveness tables in *The Practical Details* section.

For details of the assumptions used in assessing costs and information on how to calculate payback periods, see page 37

1930's

mid-terrace house

Description and condition

With a downstairs bathroom and a wc opening off an external lobby, this house was typical of early inter-war designs. The passage provided rear access to the house on each side.

USUAL APPROACH

General level of improvement and repair

The existing bathroom was relocated upstairs to allow the small kitchen to be enlarged into a kitchen/dining room.

All existing windows and doors were renewed with timber replacements to match the existing. The house was rewired, the plumbing renewed and a new solid floor laid in the back half of the house. This was finished with a 38mm screed and vinyl tiles.

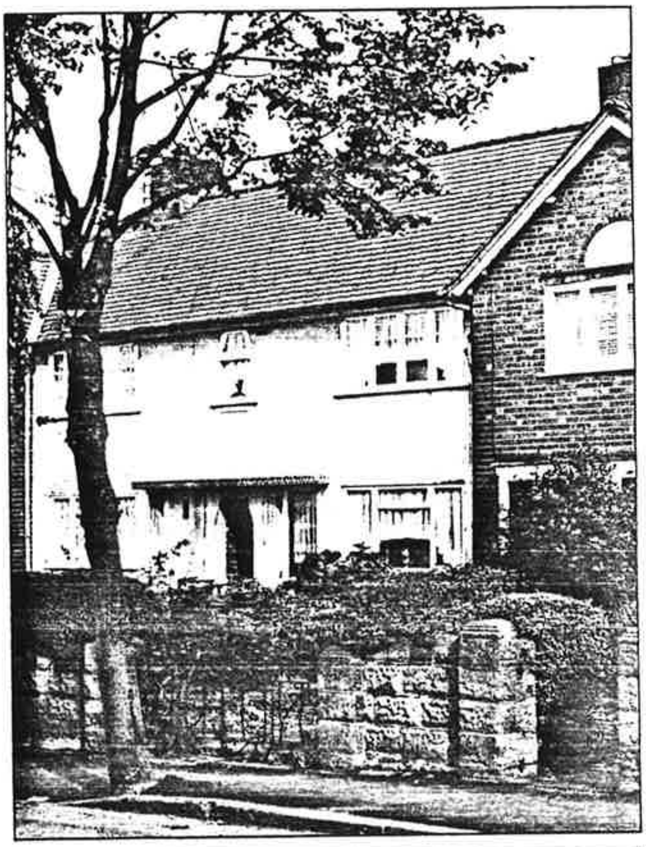
Insulation and ventilation measures

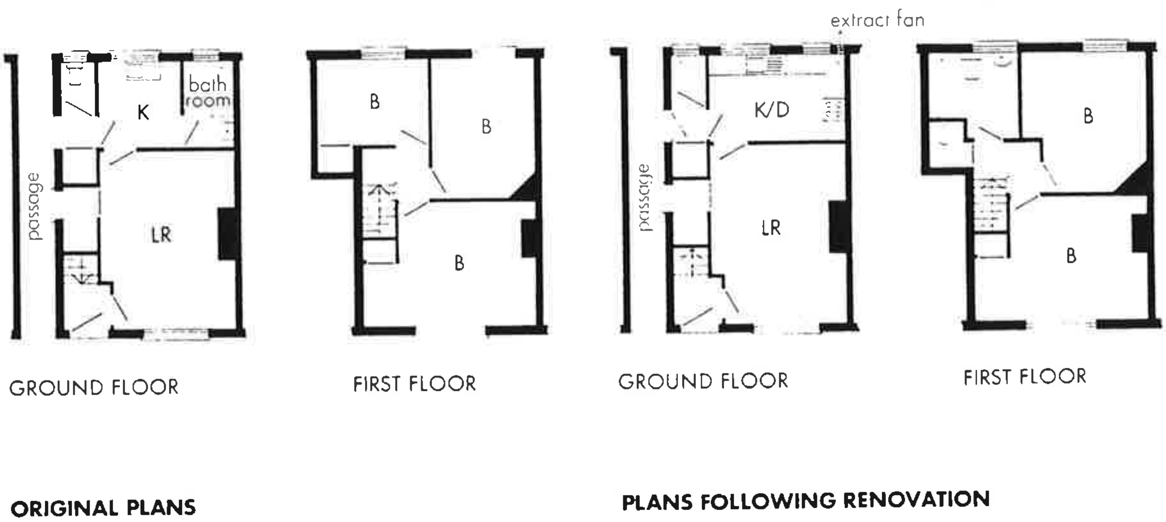
100mm of mineral fibre insulation was added to the loft and a new draught lobby formed to protect the back door. No other insulation measures were taken. The replacement timber windows were single glazed but not draughtproofed.

Heating installation

The house was heated electrically. Off-peak storage radiators were located in the living room, kitchen/diner, hallway and both bedrooms, with a radiant electric fire in the living room and a downflow convector heater in the bathroom.

The hot water cylinder was fitted with dual immersion heaters to take advantage of the off-peak rate.





ENERGY EFFICIENT APPROACH

The energy saving package reduces the design heat loss from **6.0kW to 3.6kW** (a reduction of 40 per cent). The **payback period** is **eleven years.**

The main savings result from adding external insulation and draughtproofing. The payback period is longer than the other examples because external wall insulation is more expensive than other other wall insulation methods used. The combination of external wall insulation and off-peak electric heating should result in very even internal temperatures minimising the risk of condensation. However, the high thermal capacity structure of this house and less controllable output from its heating system are likely to cause a greater proportion of the benefits from increased energy efficiency to be in the form of higher temperatures rather than reduced fuel bills.

THE ENERGY SAVING PACKAGE

Energy saving measures	**Extra capital cost** [£]	**Annual fuel cost savings** [£/annum]
Insulation and ventilation measures:		
Add 50mm external insulation and render (saving £250 on external repair work).	1025.00	62.00
Replacement windows to incorporate draughtseals, double glazing and slot ventilators.	270.00	23.00
Insulate the solid floor to the kitchen, wc and lobby, by substituting 25mm polystyrene insulation and moisture resistant chipboard for the 38mm sand/cement screed.	30.00	3.00
Draughtproof the skirtings to the suspended ground floor with sealant.	20.00	4.00
Insulate the floor over the passage with 100mm mineral fibre quilt laid between the joists.	12.00	4.00
Draughtproof and insulate the roof hatch and fix securing bolts.	15.00	3.00
Draughtproof the two new external doors.	60.00	6.00
Extra costs and fuel savings	£1432.00	£105.00
Heating installation:		
Reduce size of storage radiators in living room and kitchen/diner — saving £70.00		
Replace storage radiators in the hall and bedrooms with a storage radiator on the top landing and top up panel heaters in both bedrooms. — saving £210.00		
Capital cost saving £280.00		
Net extra cost and annual fuel cost saving	£1152.00	£105.00

The capital costs and annual fuel cost savings are based on the figures in the cost-effectiveness tables in *The Practical Details* section.

For details of the assumptions used in assessing costs and information on how to calculate payback periods, see page 37.

1950's
semi-detached house

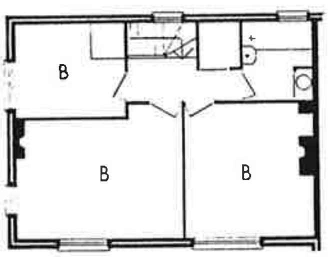
Description and condition
Houses of this date are generally spacious and well planned, but like many of the early post-war designs, this house had a ground floor wc. The external walls were of rendered brick/cavity/brick construction and the ground floor of concrete. The structure was generally in good condition, but the electrical and plumbing services were nearing the end of their useful life.

USUAL APPROACH

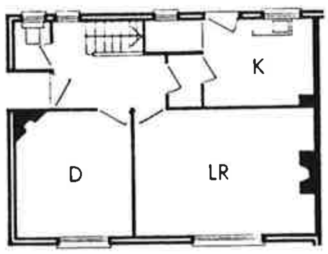
General level of improvement and repair
The tenants remained in residence during the improvement work which consisted of rewiring, adding central heating, replanning the kitchen and bathroom to include an upstairs wc and replacing the windows.

Insulation and ventilation measures
100mm loft insulation was added. The new windows were single glazed and not draughtproofed.

Heating installation
A solid fuel roomheater located in the living room served seven radiators and the hot water cylinder. The radiator in the hall acted as a heat leak radiator. The hot water cylinder was fitted with an off-peak immersion heater for summer use.

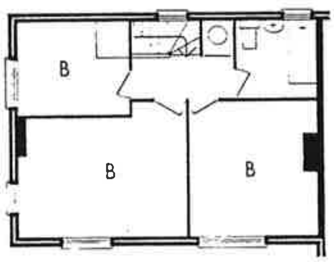


FIRST FLOOR



GROUND FLOOR

ORIGINAL PLAN



FIRST FLOOR

GROUND FLOOR

PLAN FOLLOWING RENOVATION

ENERGY EFFICIENT APPROACH

The energy saving package reduces the design heat loss from **7.4kW to 4.5kW** (a reduction of 39 per cent). The **payback period** is only **three years**.

In this example, the opportunity is again taken to replace bedroom radiators with one radiator on the top landing to help offset some of the increased capital cost. The high level of insulation enables the bedrooms to benefit from convected heat.

The improved insulation standard together with the continuous combustion of the solid fuel heating system may cause more of the benefits of energy efficiency to be taken in the form of higher temperatures rather than lower fuel bills. However, as in the electrically heated example, this should result in a more even internal temperature, minimising the risk of condensation. Heating cost should now be reasonable.

THE ENERGY SAVING PACKAGE

Energy saving measures		Extra capital cost [£]	Annual fuel cost savings [£/annum]
Insulation and ventilation measures:			
Insulate cavity wall with polystyrene beads or granules.		195.00	72.00
Replacement windows to incorporate double glazing, draughtseals and slot ventilators.		380.00	33.00
Draughtproof the two external doors.		60.00	10.00
Draughtproof and insulate the roof hatch and fix securing bolts.		15.00	3.00
Insulate the floor over the entrance porch with 100mm mineral fibre quilt laid between the joists.		8.00	2.00
Adhesive fix 25mm urethene/plasterboard laminate to the 112mm external brick wall in the wc and secure with screw fixings.		38.00	4.00
Extra costs and fuel savings		£696.00	£124.00
Heating installation:			
Reduce radiator sizes in line with reduced heat loss	saving £125.00		
Omit radiators from bedrooms, but add one to top landing	saving £200.00		
Capital cost saving	£325.00		
Net extra cost and annual fuel cost saving		£371.00	£124.00

The capital costs and annual fuel cost savings are based on the figures in the cost-effectiveness tables in *The Practice Details* section.

For details of the assumptions used in assessing costs and information on how to calculate payback periods, see page 37.

THE PRACTICAL DETAILS

The introduction of new techniques and products can lead to problems on site due to unfamiliarity. This will be particularly true of small builders of the kind who specialise in rehabilitation work. It is inevitable, therefore, that when new materials or techniques are introduced, there will be a learning period and the supervisory staff should take extra care.

When a modernisation scheme is planned for a large estate, it is recommended that a small pilot project be completed first. This will allow for learning new techniques and enable the work to be programmed accordingly.

Some measures such as cavity wall insulation and external wall insulation should only be carried out by specialist contractors. Most others can be carried out by the general builder or trade sub-contractor. However, it may prove worthwhile to nominate specialist sub-contractors for such work as draughtproofing and dry-lining.

In this section, guidance is given on the practical details of energy efficient construction, the materials to be used and the important points to be considered if adverse side effects are to be avoided.

The constructions dealt with are those most commonly found in housing renovation, eg timber pitched and flat roofs, solid or cavity brick walls, timber or metal windows, doors, suspended timber or solid concrete floors. If renovation is being carried out on forms of construction which differ from those shown below, some of the energy efficient solutions may still apply, but their suitability should be carefully checked.

Pitched roofs

The loft is the easiest and cheapest place to add insulation. The equivalent of 100mm mineral fibre insulation is the minimum that should be installed, even if there is already 25mm in the loft. If the existing loft has no insulation, then it may be worth considering adding up to 140mm of insulation, especially in blocks of flats where some of the well heated rooms, such as living rooms and kitchen/dining rooms, are directly under the roof.

There are three main types of loft insulation material:

Mineral fibre quilt

This is the most readily available loft insulation material. Although 100mm thickness is universally available, 120, 140 and 150mm thickness are becoming more common due to increased demand. In pre-1919 houses, the spacing of rafters will probably not match the width of the insulation, so consider having it cut to width from trade width rolls.

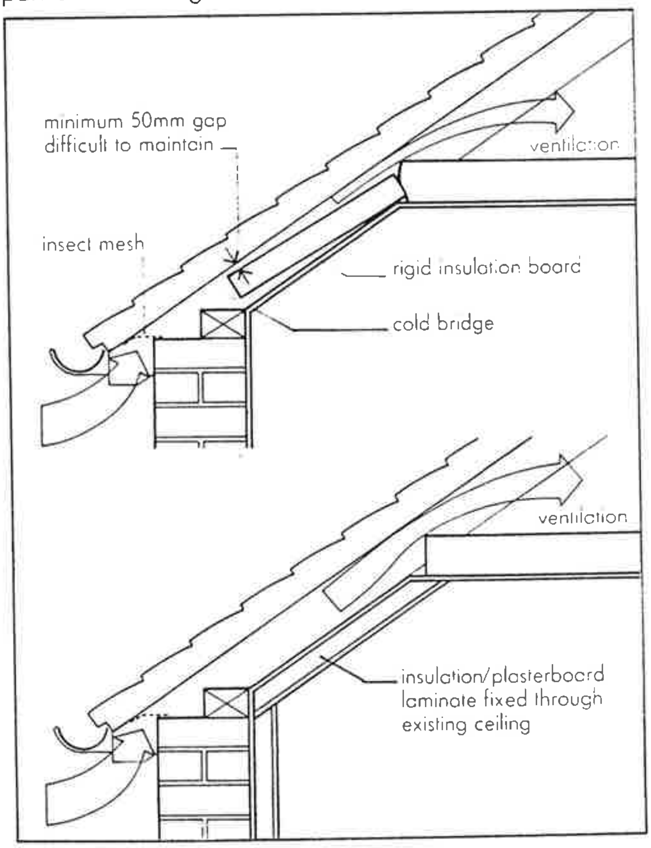
Blown fibre

Several Agrément Certificates have been issued for blown mineral and cellulose fibre insulation. Prices are about the same as for quilt insulation, but more care is needed to ensure that it is installed to a uniform thickness. However, blown fibre may work out cheaper than quilt where the spacing of rafters is irregular.

It is recommended that cellulose fibres should not be in direct contact with chimneys and recessed light fittings — check the relevant Agrément Certificate for details. Blown materials should be checked for depth after installation.

Rigid insulation boards

Rigid insulation boards are not normally used for loft insulation, except where there is a section of sloping ceiling as illustrated. Mineral fibre or expanded polystyrene are the cheapest board materials. Supervision in this position is difficult, in particular ensuring that adequate ventilation has been provided to the loft space. Consequently, some housing authorities prefer to specify that insulation is fixed to the underside of the sloping part of the ceiling.

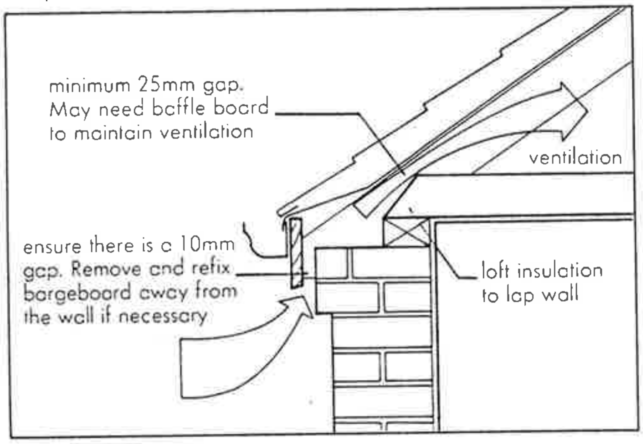


POINTS TO CONSIDER

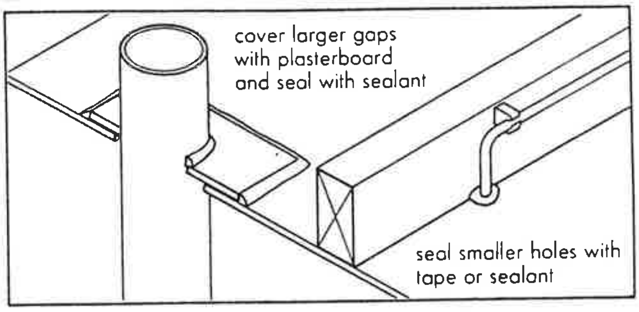
□ The effect of adding loft insulation is to reduce the temperature within the roof space during winter months, thereby increasing the risk of condensation. This is especially so where the roof has been renewed and felt added below the tiles, thus decreasing ventilation.

□ There are three precautions you should take:

1 Ensure the roof space is well ventilated. Do not tuck insulation into the eaves. Make sure that air can ventilate the roof space from eaves level on opposite sides of the roof. Ventilation equivalent to a continuous 10mm gap should be provided at eaves level in pitched roofs. Check BS 5250 for the principles for ventilating more complicated roof shapes.

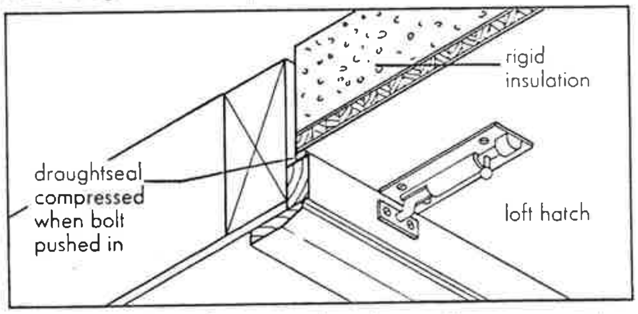


2 Try to reduce the amount of water vapour reaching the roof space. Specify that all gaps and holes between the roof and the rest of the house are sealed. If a new bathroom ceiling is required below the existing roof space, consider providing a vapour check immediately above the plasterboard. Where a vapour check is not specified, the least that should be done is to paint the bathroom ceiling with oil paint. The open top of cavity walls should also be sealed to prevent moisture passing into the roof space.



3 If retiling is necessary, specify a felt that is water vapour permeable. Experience has shown that condensation problems have resulted from the use of some polythene based materials.

□ The roof hatch should be well insulated and draughtproofed. A rigid insulation, such as expanded polystyrene, is less likely to get damaged than a mineral fibre quilt and will not shed fibres into the house. A couple of small bolts correctly fixed will keep the draught seal compressed.



□ Any tanks and pipework in the roof space must be insulated, but omit the insulation from below the cold water tank, unless it is on a raised platform, so that heat from the house can rise and prevent freezing. Specify insulation to *all* pipework, even overflows.

□ Where possible electrical cables should be kept clear of the insulation to avoid the risk of overheating. Alternatively they should be de-rated in accordance with IEE Regulations (see *BRE Defects Action Sheet 62* for details). PVC insulated cables should not come into contact with expanded polystyrene, as this can embrittle the PVC.

PITCHED ROOFS COST-EFFECTIVENESS TABLE

Usual approach	Energy efficient approach		Typical cost (per m²)	Annual savings (per m²)	Simple payback period
Add 100mm insulating quilt to uninsulated loft, (U value = 0.35 W/m²K).			£4.00	£1.40	3 years
	Add 140mm insulating quilt to uninsulated loft instead of 100mm. (U value = 0.25 W/m²K).	extra	£0.75	7p	10 years
	Insulate roof hatch with 75mm rigid board insulation, draughtproof and fix bolts to compress draughtseal		£15.00	£3.00	5 years
	Add 100mm insulation to a loft which already has 25mm insulation (U value = 0.28 W/m²K).		£4.00	48p	8 years

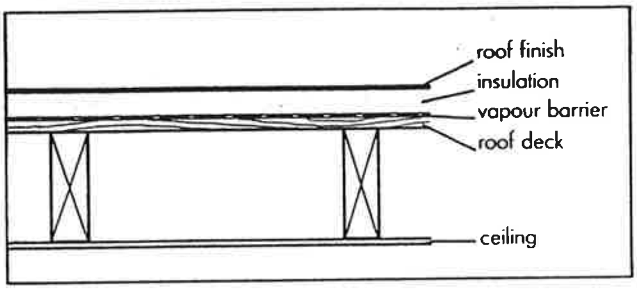
For details of the assumptions used in this table, see page 37.

Flat roofs

Flat roofs are more difficult and expensive to insulate than pitched roofs. The most economical solution will depend on the required repair work.

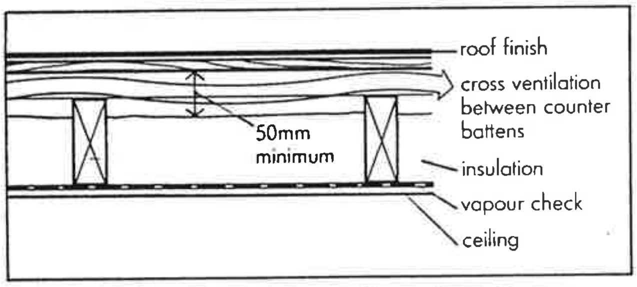
There are two alternative positions to place the insulation:

Above the roof deck ('warm roof' solution)



The best place for insulation is above the roof deck. This keeps the timber structure warm and so lessens the risk of condensation. If the roof finish is in poor condition, consider including insulation in your specification for the re-roofing work. The insulation must be placed above a vapour barrier and be of a board material which will not be compressed by foot traffic.

Between the rafters ('cold roof' solution)



Where the roof finish is in good condition, but the ceiling needs to be replaced, then an insulating quilt can be pushed up between the joists. With insulation in this position, there is a risk of condensation forming on the underside of the roof deck. To minimise this risk take account of the points listed below.

POINTS TO CONSIDER

All roofs

☒ Refer to BS 6229:1982 Code of Practice for flat roofs with continuously supported coverings. The Code details alternative designs and explains how to calculate the condensation risk.

Warm roof

☐ With a warm roof construction, check the height of the perimeter upstand. The extra thickness of insulation may present detailing problems. The waterproof finish should have a reflective surface such as chippings or solar reflective paint to minimise thermal movement.

☐ For the warm roof, there is a wide range of rigid insulation materials available. With some (eg expanded polystyrene) it is necessary to place a layer of fibreboard above the insulation to prevent it being damaged by hot bitumen or asphalt. With others (eg urethene foam) a partially bonded breather felt is required. Check with the manufacturers of both the insulation and roof covering that the materials specified are compatible.

Cold roof

☐ Specify a vapour check between the insulation and the new plasterboard ceiling. Consider using wall lights to avoid puncturing the vapour check. However, if pipes or electrical cables must pass through the vapour check, ensure that the gaps are sealed to minimise the passage of water vapour.

☐ You must ensure that it is possible to ventilate the space above the insulation. There should be a minimum clearance of 50mm between the insulation and the roof deck. Provide ventilation on opposite sides of the roof. The minimum recommended free area is 1/250th the area of the roof. If it is not possible to provide adequate ventilation, then go for a warm roof solution.

☐ Insist the Clerk of Works checks that the ventilation is not obstructed and the vapour check is well sealed before the work is hidden.

FLAT ROOF COST-EFFECTIVENESS TABLE

Condition	Usual approach	Energy efficient approach	Typical extra cost [per m²]	Annual savings [per m²]	Simple payback period
Roof leaks and is in poor condition	Remove existing roof finish and replace with new 3 layer high performance roofing felt on 25mm fibreboard on vapour barrier (£16/m²) (U value = 0.9 W/m²K)	Replace the fibreboard with a 50mm polystyrene/13mm fibreboard laminate. (U value = 0.46 W/m²K)	£3.50	30-40p	9-12 years
Roof finish in reasonable condition but ceiling needs replacing.	Take down existing ceiling and replace with new plasterboard ceiling and decorate. (£10/m²) (U value = 1.2 W/m²K)	Push fit 100mm thick mineral fibre quilt between joists, staple polythene vapour check in place and fix plasterboard ceiling in the normal way. (U value = 0.3 W/m²K)	£6.00	60-80p	7-10 years

For details of the assumptions used in this table, see page 37.

Cavity walls

Cavity insulation reduces heat loss from traditional cavity walls by about two thirds and is relatively cheap to install. Payback periods of about four years show it to be a cost-effective method of reducing heat loss.

EXISTING WALLS

There are three main types of material in use, all are pumped or blown into the cavity through a series of holes drilled in the brickwork from outside.

Urea-formaldehyde (UF) foam

This is one of the cheapest materials, but it tends to shrink and crack as it dries out which can increase the risk of water penetration across the cavity. For this reason its use is restricted to particular climatic zones according to Driving Rain Index — refer to BS 5618 for full details.

Small holes are drilled in the wall at one metre centres. The foam is then generated at the injector nozzle from a mixture of resin, hardener and water. The foam is pumped in fluid form and sets within the cavity, slowly drying by evaporation over a period of weeks. As the foam dries, it gives off formaldehyde which may have a noticeable smell. This has resulted in its use being restricted to masonry cavity walls with a plastered finish internally. At high concentrations, formaldehyde can cause irritation to the eyes, nose and respiratory tract, and a small minority of people suffer serious effects.

If installed in accordance with BS 5618 however, there should be no worries about the safety of using UF foam. Many homes with new furniture record higher levels of formaldehyde than homes with UF cavity foam insulation. This is because formaldehyde resin is used extensively as a glue in making chipboard.

Polystyrene beads and granules

Polystyrene beads are amongst the cheapest of the *dry* cavity fill materials and most are suitable for buildings up to 10 or even 12 metres high, but a few products are restricted geographically. Check the Agrément Certificate for details.

There are two types of beads, those coated with a binding agent and dry beads or granules. With coated beads, complete bricks are removed or holes made in a specific pattern and the material pumped in. Holes are usually 25-45mm diameter and spaced at about two metre centres. When dry materials are used, the pattern of holes is either the same as above, or alternatively holes are formed at about 8 metre centres and directional nozzles used to ensure the cavity is properly filled.

Mineral fibre

Mineral fibres and fibre pellets are usually the most expensive form of cavity insulation. Usually 65mm holes are drilled at 2.5 metres centres, some systems use smaller holes (25 or 32mm diameter) at one metre centres.

POINTS TO CONSIDER

☐ Adding cavity fill can increase the risk of rain that has penetrated the outer leaf moving across the cavity to the inner leaf. In the majority of cases, this risk is small and no problems are encountered. However, Agrément Certificates place restrictions on use according to building height and climatic zone. In addition, walls in an exposed situation may be at greater risk. Check local experience on whether cavity fill has been successful.

☐ Check the size of the cavity. Cavities should be over 40mm wide.

☐ It is important to inspect the external skin and cavity for soundness of construction.

☐ Check that the firm you select is an approved installer.

☐ If you decide on UF foam, the company you use should either be registered by the British Standards Institution as an approved firm or be prepared to give a guarantee that the work complies with the stringent requirements of BS 5618, as amended in November 1982.

☐ For other materials, the work should be carried out to comply with a current Agrément Certificate. The installer should either have an Agrément Certificate for their insulation material or be licensed by a manufacturer who has one.

☐ Air bricks and balanced flues should be sleeved. The top of cavity walls should be closed to prevent insulation spilling into the loft and, if necessary, the inner leaf sealed to prevent insulation escaping from the cavity, eg into floor spaces and ducts.

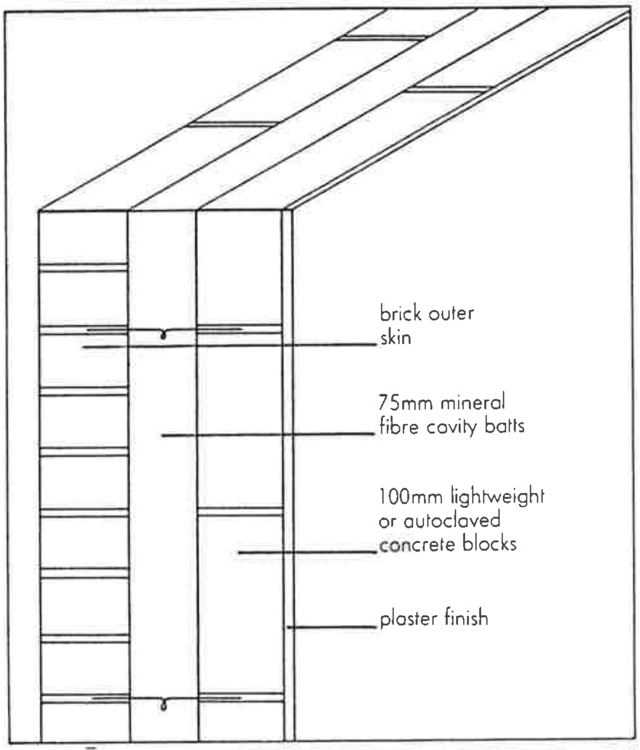
CAVITY WALL COST-EFFECTIVENESS TABLE

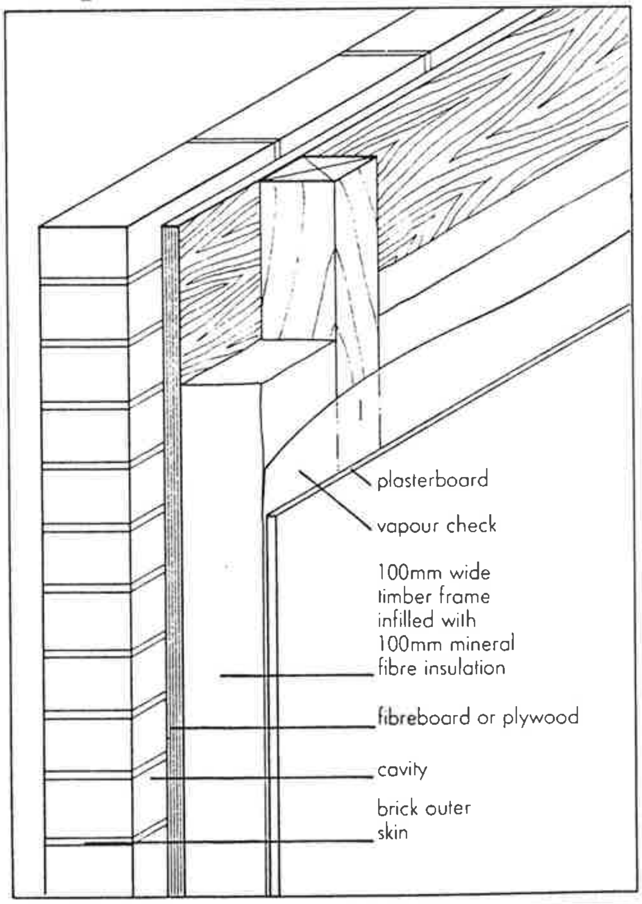
Usual approach	Energy efficient approach	Typical cost (per m²)	Annual savings (per m²)	Simple payback period
Generally little work necessary.	Fill the cavity with:			
	UF foam	£3.00	80p	4 years
	Polystyrene or polyurethane beads or granules	£2.75-£3.50	80p	3-4 years
	Blown mineral fibre	£3.50	80p	4-5 years

For details of the assumptions used in this table, see page 37.
Costs are for four or more houses in one contract.

WALLS TO NEW EXTENSIONS

Walls to new extensions need to have a U value of 0.6W/m²K to comply with the current Building Regulations. This can readily be achieved by partial or full cavity insulation. However, the two constructions below have a U value of about 0.3W/m²K, yet their construction costs are only fractionally more than a wall which just complies with the Building Regulations.





Solid walls

Where dwellings are constructed with solid brick walls, heat loss through the walls is likely to be responsible for a large proportion of the overall heat loss and any opportunity to add insulation should be considered. Solid wall insulation can be carried out in two alternative ways:

☐ By adding insulation externally and protecting it by a render or other cladding, or

☐ By insulating the walls internally using a lining which includes insulation.

Adding 50mm of insulation to the inside or outside of a solid brick wall reduces the U value from 2.1 W/m^2K to under 0.6 W/m^2K. Adding insulation to a solid wall can be very expensive, costing at least £25/m^2 for external insulation and £16/m^2 for internal insulation. However, if the external walls are in poor condition and need rendering, or if replastering is necessary, then the additional cost of adding insulation is much less. The cost-effectiveness tables list the opportunities where adding insulation may be worthwhile.

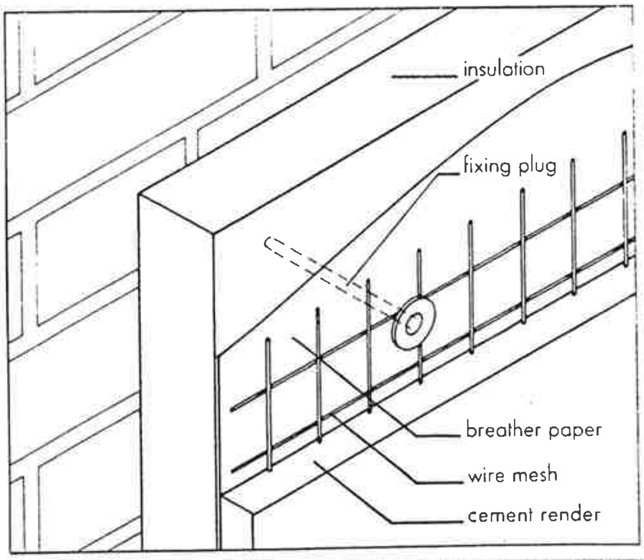
EXTERNAL INSULATION

The high capital cost of external insulation prevents it being cost-effective on energy saving grounds alone. However, where the external wall requires extensive remedial action to combat dampness due to driving rain for example, the additional cost of incorporating insulation may be worthwhile especially taking into account the reduced risk of condensation and mould growth, greater comfort and improved appearance.

There are several proprietary systems on the market which fall into three broad categories:

Metal carrier system

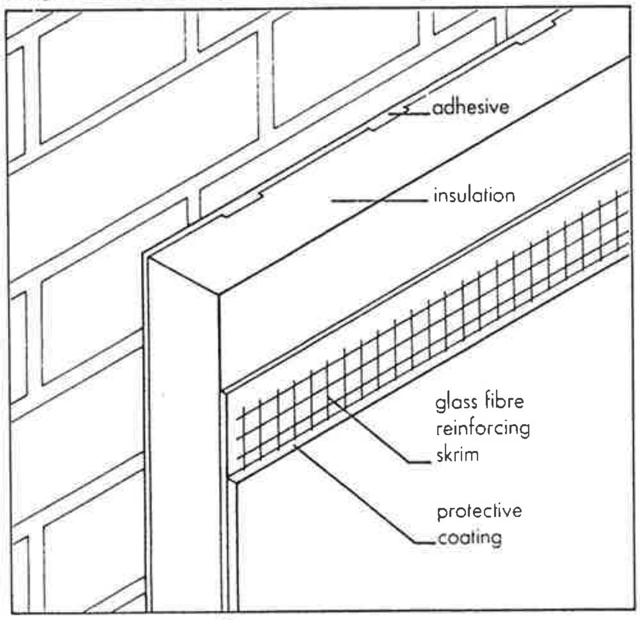
A composite panel of mineral fibre insulation is bonded to a carrier system (comprising a breather paper and mesh reinforcement), which is fixed to polypropylene plugs hammered into pre-drilled holes in the wall. The panels are then rendered with a sand/cement render, the wire mesh forming the key. A 50mm thickness of mineral fibre reduces the U value of a 225mm brick wall to under 0.6 W/m^2K.



Rigid insulation boards

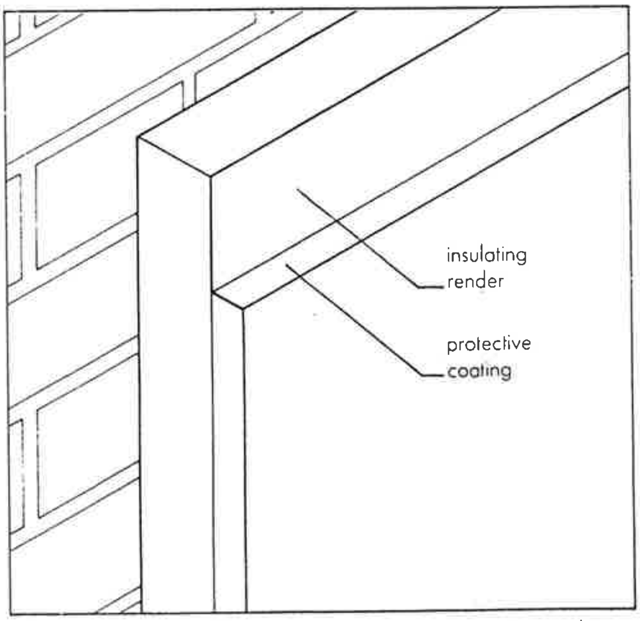
The insulation is in the form of rigid slabs which are fixed either by adhesive, mechanically, or a combination of both. A protective resin based render, usually reinforced with metal lathing or a glass fibre scrim, is then applied, followed by a thin decorative render.

Expanded polystyrene is the most commonly used insulation, but polyurethane foam, mineral wool and cellular glass are also suitable. Thermal performance and cost differ significantly between materials as does their vapour permeability. The boards are usually square edged, but some systems use boards with tongued-and-grooved or rebated edges.



Insulating render

A lightweight insulating render incorporates expanded polystyrene beads and is finished with a protective, decorative coating. Its insulating effect is less than the other two methods, eg a 50mm render only reduces the U value of a 225mm brick wall to about 0.95 W/m^2K.



The *External Wall Insulation Association* will send you a list of their members and descriptions of the systems they offer.

POINTS TO CONSIDER

☐ **Appearance** Unless the property is already rendered, there will be a dramatic change in its appearance. If the existing brickwork or render has deteriorated or is badly weathered, adding external insulation will make a considerable improvement. Avoid smooth rendered finishes as these tend to develop hairline cracks and show surface damage and weather staining more readily than a textured finish. A painted finish will need regular maintenance to retain its smartness.

☐ **Ornamental detail** External insulation is not suitable where there is fine architectural detailing and moulding.

☐ **Weather protection** If the walls are in poor condition or if there is evidence of dampness from driving rain, then external insulation should make the wall drier and warmer. A good overhang at roof level will help protect the new wall finish. In areas of severe exposure, if the existing overhang is minimal and re-roofing is necessary, consider extending the roof overhang particularly at gable ends.

☐ **Openings** Unless windows are being replaced, window sills will need to be extended to shed water clear of the new wall finish. This can be expensive, especially where there are many window openings. Cutting the insulation around obstructions will also increase costs, as will removing and refixing items such as rainwater and water pipes, balanced flues, telephone cables, etc.

☐ **Cold bridging** External insulation is generally more effective at reducing cold bridges than internally applied insulation. In external window reveals, however, it may be necessary to reduce the thickness of the insulation if existing windows are being retained. Where a narrow window frame wholly prevents the reveal from being insulated, then an acute cold bridge will be created. Some projections, such as bay windows, porches and balconies, can present difficulties and need careful attention to detail.

☐ **Condensation** High thermal capacity helps even out fluctuations in the internal temperature, greatly reducing the rate of cooling. Placing the insulation on the outside creates a high thermal capacity structure which cools down slowly when the heating has been switched off, thus helping to avoid surface condensation. There is no need for a vapour check to control interstitial condensation when the insulation is more than 25mm thick.

☐ **Impact resistance** Most external insulation systems are vulnerable to impact damage and should not be used adjacent to public areas.

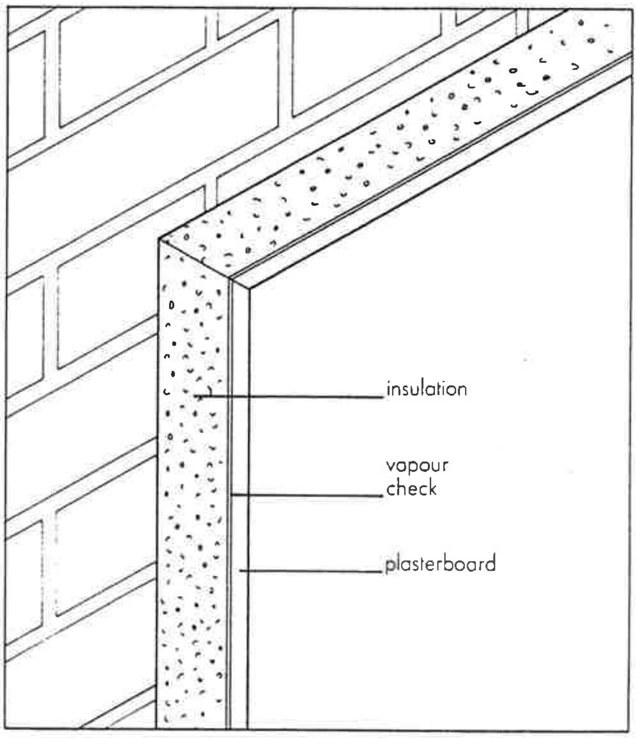
☐ **Decanting** External insulation can be applied without decanting tenants.

INTERNAL INSULATION

There are two principal methods of insulating the inside of solid walls.

Insulation/plasterboard laminates

These are ready-made boards of plasterboard backed with insulation. Some also include a vapour check between the insulation and the plasterboard. Most boards are supplied with tapered edges and the joints between them are filled using normal drylining techniques.



EXTERNAL INSULATION COST-EFFECTIVENESS TABLE

Condition	Usual approach	Energy efficient approach		Typical extra cost (per m²)	Annual savings (per m²)	Simple payback period
Brickwork or rendered finish in poor condition needing extensive remedial work	Apply a sand/cement render with a pebbledash finish to protect poor condition of wall (approx. £13.50/m²	Replace render with an external wall insulation system, comprising expanded polystyrene insulation, bonded and mechanically fixed to the wall, reinforcing mesh and render.				
		Insulation thickness	25mm	£12.00	94p	13 years
			50mm	£13.50	£1.20	11-12 years
			75mm	£15.00	£1.30	12 years

For details of the assumptions used in this table, see *page 37*.

There are several insulation materials available as a backing to the plasterboard:

☐ **Expanded polystyrene** offers a good level of vapour resistance and may, therefore, be preferred for use in kitchens and bathrooms.

☐ **Phenolic foam** has low flamability and smoke emission characteristics.

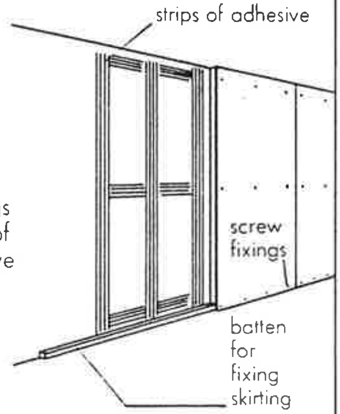
☐ **Foamed polyurethane** or **polyisocyanurate** has a very low thermal conductivity. This means that thinner insulation boards can be used to produce a given U value.

☐ **Mineral wool** provides good acoustic and fire performance with negligible smoke emission.

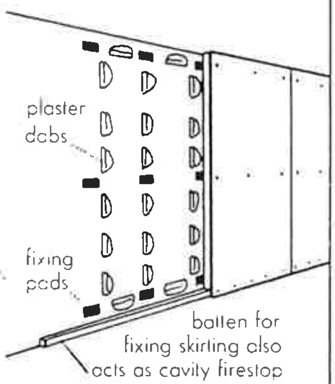
Plasterboard laminates are available with different thicknesses of insulation ranging from about 13mm to 50mm.

Three methods of fixing the board to the wall are available. The most appropriate choice will depend on the condition of the existing plaster or brickwork.

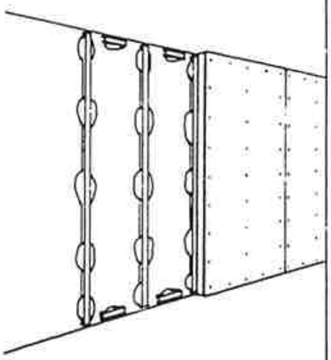
Adhesive fixed direct to plaster in addition to nine fixings for each board. Suitable only where the existing plaster surface is even and in good condition. The screw fixings secure the board in case of fire. Laminated boards have a tendency to bow and their intermediate fixings need to be strong.



Bonding with plaster dabs also with nine mechanical fixings per board, plugged and screwed to the wall. This is used where the existing wall has been stripped of plaster. The screw fixings secure the board in the event of a fire.

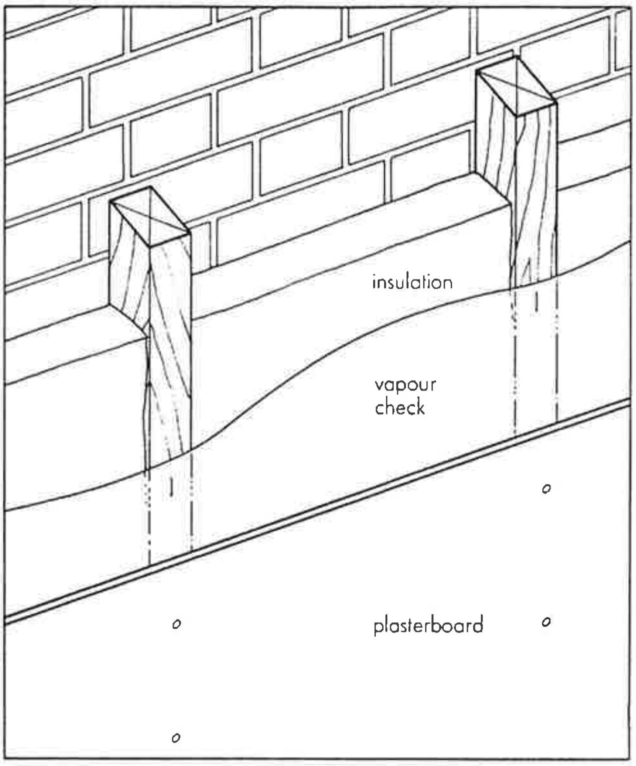


Screwed to metal firrings bonded to the wall This method is suitable for uneven brickwork or walls with damp proofing treatment. It is more expensive than plaster dabs, but there are no fixings to penetrate the damp proofing treatment.



Timber battens infilled with insulation

Vertical timber battens the thickness of the insulation are fixed to the wall at centres determined by the size of the plasterboard. The battens should be pressure impregnated to prevent timber rot. The insulation, if in rigid board form, is friction fitted between the battens or if in quilt form, is stapled to them.



Although more expensive than laminated plasterboard, this method can accommodate a greater thickness of insulation.

A vapour check should be positioned on the warm side of the insulation. This is usually a 125g polythene sheet stapled to the battens. The staples should be rustproof. The joints can be either welted, or lapped and taped at a batten position.

Avoid puncturing the vapour check if possible, eg by not locating socket outlets on external walls. Where this cannot be avoided., eg at waste pipes or if damage occurs by accident, ensure that the integrity of the vapour check is maintained by sealing or taping over any holes.

POINTS TO CONSIDER

☐ Internal insulation does not change the external appearance of the house, but it does slightly reduce the size of rooms. This may be critical in a small room such as a bathroom.

☐ Window boards will either need to be replaced by deeper ones, or extended to suit the thickness of the new lining.

☐ Decorative skirting boards will need to be removed and refixed so that they match the rest of the room.

☐ Plan the location of radiators and other heavy fixtures so that support battens can be appropriately positioned behind the plasterboard lining.

Expanded polystyrene insulation should not come into direct contact with PVC insulated electrical wiring, as in time, the PVC sheathing will become brittle, making the wiring unsafe.

To minimise the risk of interstitial condensation, consider placing a vapour check on the warm side of the insulation. This is essential where a mineral fibre or other vapour permeable insulation is used, or where the surface of the existing wall has a high vapour resistance, eg gloss paint, ceramic tiles or a dense vitrified brick.

Cold bridging is common where partitions, walls and floors connect with the external wall. It may also be difficult to maintain an even level of insulation at window and door reveals. Cold bridging should be avoided where practicable by continuing insulation into window and door reveals and returning the insulated lining a short way along internal walls and partitions.

The table shows that where a 225mm external brick wall needs replastering, the additional cost of adding an insulating lining would give payback periods of less than nine years. Insulating a plain wall in good condition, such as a gable wall, should also be worthwhile. However, the insulation should be returned to overcome the cold bridge at an external corner.

REBUILDING AN EXISTING WALL

In many pre-1919 houses, it is sometimes necessary to partially rebuild external walls, particularly in back extensions. Unless the wall is rebuilt from new foundations, its thickness is limited to the thickness of the existing wall — usually 225mm. Solid 225mm brickwork to match the existing wall is the usual specification.

However, if a rendered finish is acceptable, one alternative would be to rebuild the wall in lightweight concrete blockwork with a rendered finish. This would be cheaper and would achieve a U value of about 0.8W/m²K. Another would be to rebuild with 140mm thick blockwork and 50mm insulation, either behind the external render or as an internal lining. This would have a U value of only 0.4W/m²K and should still be cheaper than rebuilding in solid brickwork — a very cost-effective solution.

INTERNAL INSULATION COST-EFFECTIVENESS TABLE

Condition	**Usual approach**	**Energy efficient approach**	**Typical extra cost** (per m²)	**Annual savings** (per m²)	**Simple payback period**
Solid 225mm brick wall with plaster finish in good condition.	Remove old wallpaper, fill holes and cracks, clean down and decorate. (U value = 2.1 W/m²K)	After removing old wallpaper, adhesive fix 50mm thick expanded polystyrene/ plasterboard laminate and secure with nine screwed fixings, take off and refix skirting, decorate. (U value = 0.64 W/m²K)			
		Plain wall (no windows)	£11.50	£1.26	9 years
		Wall with window*	£17.00	£1.26	13 years
Plaster in such poor condition that the wall needs replastering.	Remove existing plaster and replaster. Take off and refix skirting, architraves, etc., decorate. (U value = 2.1 W/m²K)	Remove plaster and take off skirting. Batten out wall and infill with 60mm mineral fibre quilt. Line with vapour check and 12mm plasterboard, refix skirting, and decorate. (U value = 0.6 W/m²K)			
		Plain wall (no windows)	£6.75	£1.29	5 years
		Wall with window*	£11.00	£1.29	9 years
Wall has rising damp.	Remove existing plaster and skirtings. Apply new 13mm render with waterproof additive and 3mm skim coat, fix new skirting and decorate. (U value = 2.1 W/m²K)	As usual approach, but replace 3mm skim coat with 50mm thick expanded polystyrene/plasterboard laminate. (U value = 0.6 W/m²K)			
		Plain wall (no windows).	£8.00	£1.26	6 years
		Wall with window*	£12.25	£1.26	10 years

*Includes the additional cost of cutting around a window, extending the window board and either forming new reveals or blocking out behind the architraves.

For details of the assumptions used in this table, see page 37.

Windows

Single glazed windows lose more heat per square metre than any other element. In addition, the windows and doors are probably responsible for a large proportion of the air leakage to and from the house.

Heat loss through a single glazed window can be halved by installing double glazing and air infiltration can be considerably reduced by efficient draughtproofing. However, before deciding on what measures to take, it is necessary to assess the condition of the existing windows.

If the windows are sound, then adding draughtproofing should prove worthwhile. Reglazing with stepped double glazed units, or adding secondary glazing cannot be justified on energy saving grounds alone, but may be worth considering where there is a noise nuisance from traffic or a requirement to reduce window condensation and cold downdraughts.

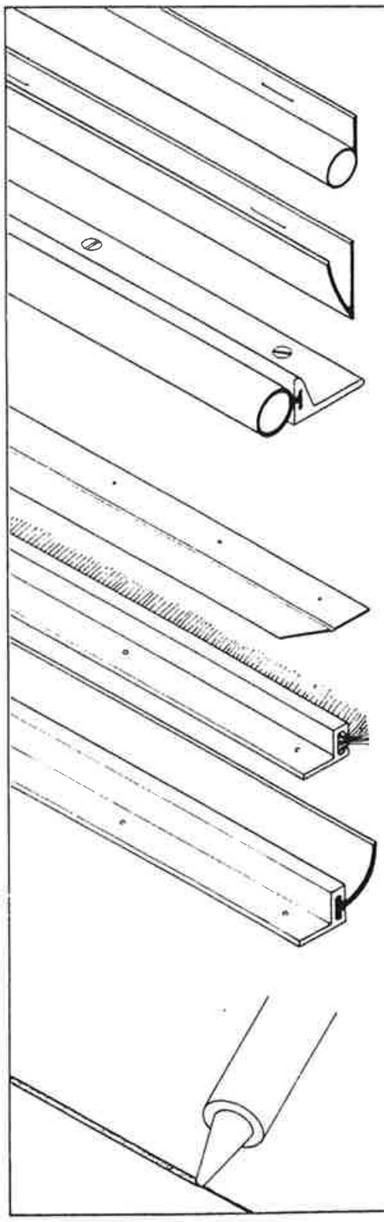
If the main window frame is sound, but the sashes or opening lights need replacing, draughtproofing should again be worthwhile. Consider, also, glazing the new sashes with sealed double glazed units. This package, incorporating a trickle ventilator, has a payback period of 10-15 years depending on the type of window and by how much air infiltration is reduced.

Where the windows have deteriorated to such an extent that they need replacing, consider specifying new double glazed windows with good quality built-in draughtproofing and trickle ventilation. Avoid specifiying metal windows unless they incorporate a thermal break.

DRAUGHTSEALS

Draughtproofing is a relatively cheap and cost-effective method of reducing heat loss due to uncontrolled air leakage.

The following selection of draughtseals are amongst the more durable and can provide an effective seal against draughts:



Compression seals Tubular section stapled in place	Tubular seals of silicone rubber were amongst the most durable and effective in recent trials at BRE Princes Risborough Laboratory. □ The thin walls of the section require little effort to compress the seal. □ Can be painted over without affecting performance. □ Also available for gluing in place with silicone sealant.
Angle section stapled in place	Angle strips are only slightly inferior to tubular trips in performance.
Aluminium holder	Seals with an aluminium holder are more expensive but give a good seal and can be fixed to allow for warped and twisted frames. □ Visible when the window or door is closed. □ Also available with cheaper PVC holders.
Wiper seals Bronze or plastic sprung strip	This is the cheapest type of wiper seal. □ Bronze strips are durable but are less effective on rough or uneven surfaces when the sealing edge becomes wrinkled. □ Can be difficult to fit in small openings.
Brush seal in holder	Available in plastic or aluminium holders. □ Can be fixed to suit warped doors. □ Should not be painted over. □ Several proprietary products are available which have been specially designed for vertically sliding windows.
Wiper fin seal in holder	Available in a variety of sizes to suit different gap widths. □ Durability is dependent on the material used for the wiper blade.
Silicone seals Silicone rubber	A high quality sealant which is especially useful on metal windows. □ Very durable and good at filling gaps of varying widths. □ Poor flexibility compared to other seals.

Feedback from earlier conservation programmes strongly suggests that only good quality materials should be specified. Some of the cheaper materials which have a self adhesive backing tend to lose adhesion and have not proved very durable. This is because to prepare the surface of an existing window sufficiently well to accept self adhesive materials is very difficult and the work is not easy to supervise on site. It is probably better to specify a draughtseal which can be stapled, nailed or screwed in place. Several firms offer a supply and fix draughtproofing service and it may be fruitful to seek their advice before making a final decision.

POINTS TO CONSIDER

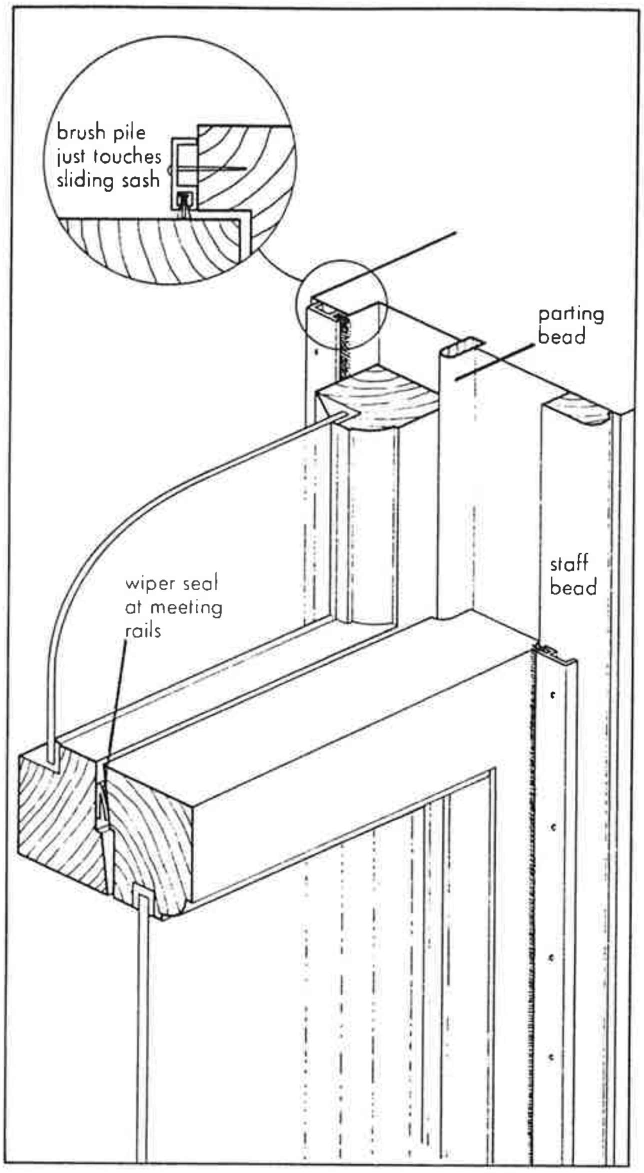
- ☐ Surfaces for self adhesive seals and silicone sealants must be clean and dry before application. Freshly painted surfaces must be left at least a week to dry.
- ☐ Specify draughtseals which compress using the minimum of force. This is especially important for sheltered housing and similar schemes. Thin walled tubular seals of silicone or *EPDM* rubber, silicone rubber sealant and brush seals generally offer the least closing resistance. Wiper fin seals and strips of *PVC* foam or cellular *EPDM* rubber generally require more force to compress them to the same extent.
- ☐ Except for brush seals and open-celled foams, most seals can be painted over without affecting their performance. However, because paint is very slow to dry on *EPDM* rubber, it should not be painted.
- ☐ Consider how to maintain continuity of the seal at corners and junctions (eg with carefully mitred joints).
- ☐ With casement windows, it is important to choose a draughtseal to suit the gap size. Manufacturers normally give recommended gap sizes. To avoid excessive closing pressure, tubular and angled sections should not be compressed by more than 50 per cent of their original thickness.

DRAUGHTPROOFING DIFFERENT TYPES OF WINDOW

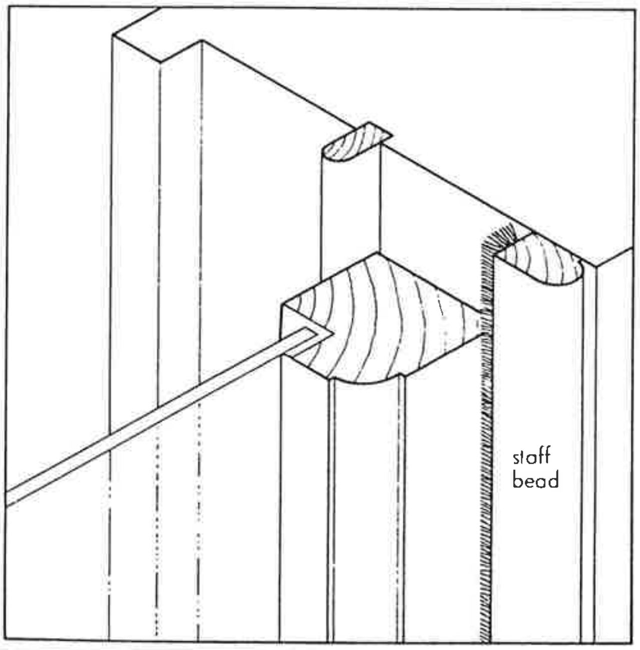
Vertical sliding timber windows

These are generally the most leaky type of window and also the most difficult to draughtproof. Compression seals are normally used at the top and bottom of the window, with brush seals for the sides and meeting rails. Some manufacturers produce special plastic sections which incorporate a brush pile and which are designed to replace the staff or parting bead.

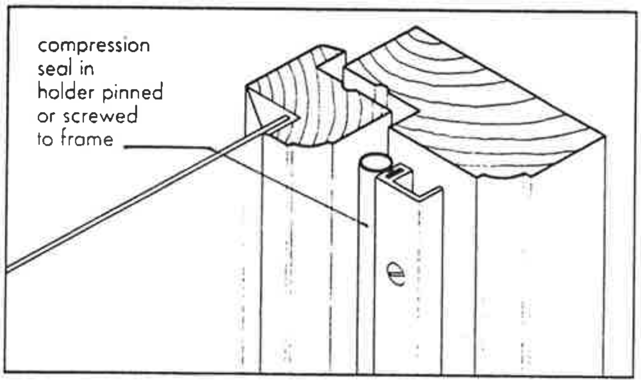
The brush seals are relatively easy to fix, but are visible when the window is closed. For the upper sash, the draughtseal should be fixed to the outside of the frame so that the brush pile just touches the sliding sash. For the lower sash, it should be fixed to the vertical staff bead on the inside.



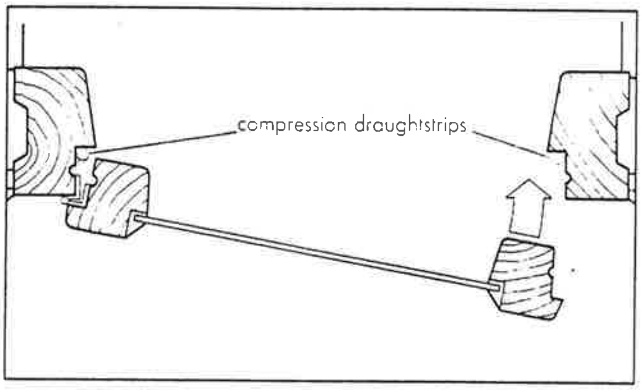
A less obtrusive alternative for the inner sliding sash is to fix a brush seal behind the staff bead.



Hinged wooden windows
If the window is not warped, and the gaps are of uniform size, adding one of the many types of compression seal is the best way of draughtproofing this type of window. Where the draughtseal is concealed within the rebate, it may be necessary to adjust the hinge to enable the window to be closed easily whilst still ensuring that the seal is adequately compressed. Rehanging is avoided where the compression seal is in a holder, but this type looks more obtrusive.



The type of compression seal should be chosen to suit the size of gap. It should be fitted to the main frame, not the opening casement, and towards the inside where it is better protected from the weather. The draughtseal should be positioned on the rebated edge of the frame, except on the hinge side where it should be applied to the *side* of the frame.

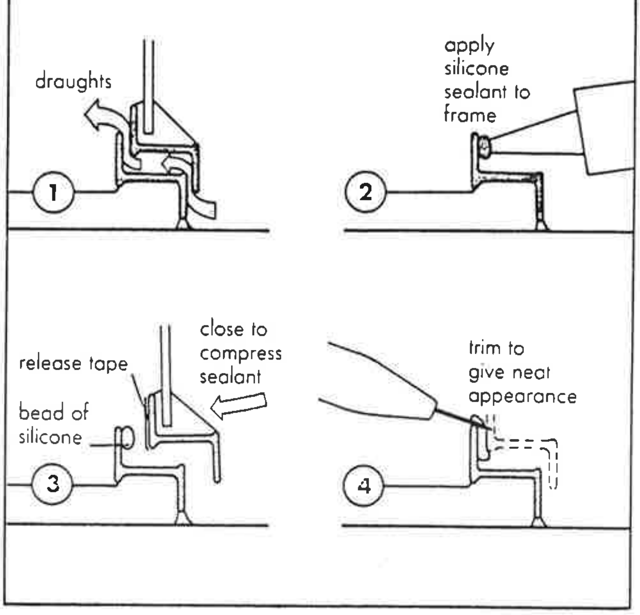


Where the gap width varies, silicone rubber tubing or a wiper seal should give better results. Silicone rubber tubing needs little force to compress and is probably the best type of draughtseal to use here. Silicone sealant can also cope with gaps of varying width, but cannot so easily accommodate later changes in the gap size due to seasonal movement of the timber.

Hinged metal windows
Self adhesive compression seals can be fitted to metal windows but the gap between casement and frame is often too small. The most successful material for metal windows is silicone rubber.

The sealant is squeezed onto the main frame and a special release tape is attached to the opening frame. When the window is closed, the sealant is squeezed into shape and only sticks to the main frame. After 24 hours the sealant will have cured. The release tape is then removed and the excess sealant trimmed. The whole operation requires some skill and is often carried out by a specialist contractor.

Applying silicone sealant to metal windows



POINTS TO CONSIDER

☐ **Brickwork around windows** With all types of window, ensure that the junction between the window and the brickwork is sealed with caulking.

☐ **Controllable ventilation** Having taken steps to cut out unwanted draughts, make specific provision for controllable ventilation. The advantages are set out in the *Strategy for Energy Efficiency* on page 7. Controllable ventilators are usually incorporated into the window head.

DOUBLE GLAZING

Installing double glazing will reduce the amount of heat lost through windows by about half, but it can be very expensive. It is only likely to be cost-effective where existing glazing needs to be replaced. Adding secondary glazing to existing windows is unlikely to be justifiable in terms of energy saving alone. However, double glazing has other advantages:

☐ **Noise** Double glazing can reduce noise transmission through windows. The heavier the glass and the larger the gap between the two panes the better. A gap of at least 100mm, with acoustically absorbent materials lining the reveals, gives the best results.

☐ **Window condensation** With a second pane of glass, it has to be very cold outside before condensation forms on the surface of the glass facing the room.

☐ **Comfort** In winter, when room air is cooled by coming in contact with the cold surface of a single pane of glass, it sinks to the floor, chilling feet and ankles. With double glazing the pane facing the room is warmer, alleviating this downdraught. The warmer a surface, the less heat the body loses to it by radiation. Because the surface of double glazing is warmer than single glazing, people feel more comfortable near the window and better use can be made of the space in the room.

REPLACEMENT WINDOWS

When specifying replacement windows look out for the following features:

- ☐ Good quality built-in draughtproofing
- ☐ A means of providing trickle ventilation
- ☐ A rebate large enough to accept double glazing with a gap between the panes of at least 6mm, and preferably 12mm
- ☐ A thermal break (if you decide on aluminium or steel) to avoid condensation forming on the surface of the frame.

SAFETY

If you specify secondary glazing, check that it can be easily and quickly removed or opened in an emergency.

Replacement windows to upper floors should have an opening light through which people can escape (see BS 5588: Section 1.1:1984).

Glass at low level should comply with BS 6262:1982, which may involved replacing existing ordinary glass with toughened or laminated glass.

WINDOW COST-EFFECTIVENESS TABLE

Condition	**Usual approach**	**Energy efficient approach**	**Typical extra cost** (per house)	**Annual savings** (per house)	**Simple payback period**
Good	No energy saving measures are normally included in rehabilitation work.	Draughtstrip windows with good quality materials.			
		Small terraced house (windows $9m^2$)	£85	£10-20	4-8 years
		Small detached house (windows $13.5m^2$)	£125	£12-24	5-10 years
		For comparison Fix secondary glazing (the savings assume that adding secondary glazing also reduces leakage).			
		Small terraced house (windows $9m^2$)	£850	£20-25	34-43 years
		Semi-detached house (windows $13.5m^2$)	£1300	£27-33	39-48 years
Rot in sashes, but frames sound.	Replace sashes, cords and beads, single glaze and decorate (cost £975 for a small terraced house with $9m^2$ of vertical sliding timber windows).	As usual approach, but glazed with stepped double glazed units; provide larger balancing weights and add draught seals.	£375	£24-34	11-15 years
Poor, windows need replacing.	For a small terraced house with $9m^2$ or vertical sliding timber windows. Replace existing windows with new timber box framed windows. (Cost perhaps £1900 for our typical house.)	Provided their appearance is acceptable, an energy efficiency alternative is to install double glazed, draughtproofed uPVC windows.	The Energy efficient alternative would probably be cheaper than new timber box frames.		
	For a semi-detached house with $13.5m^2$ of window. Install replacement single glazed windows to match existing windows (cost £900).	As usual approach, but with stepped double glazed units, windows to be draughtproofed and include slot ventilators:	£550	£33-45	12-16 years
		For comparison Install 'high performance' timber windows with sealed double glazing integral draughtproofing and trickle ventilators:	£950	£33-45	21-28 years
		Install uPVC replacement windows with sealed double glazed units, and integral draughtproofing.	£2800	£33-45	60-90 years

For details of the assumptions used in this table, *see page 37*

Doors

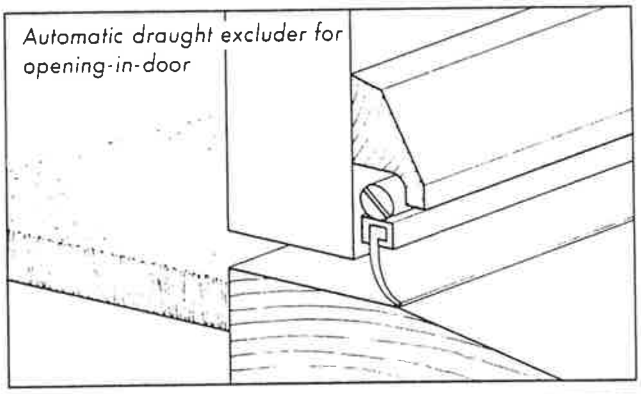
Field trials have demonstrated that the entrance hall and staircase are responsible for about half the air leakage in a typical two storey house. The front door accounts for a large proportion of this air leakage and is a prime candidate for draughtproofing.

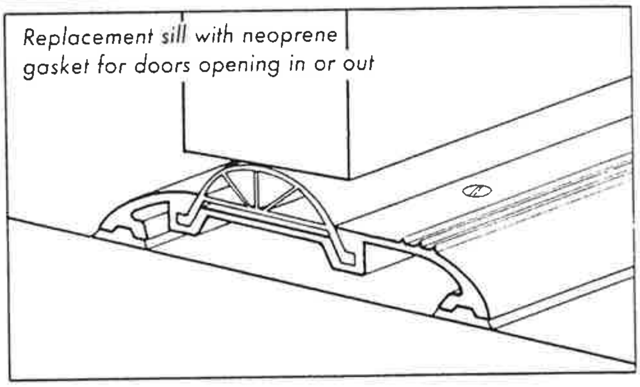
DRAUGHTPROOFING

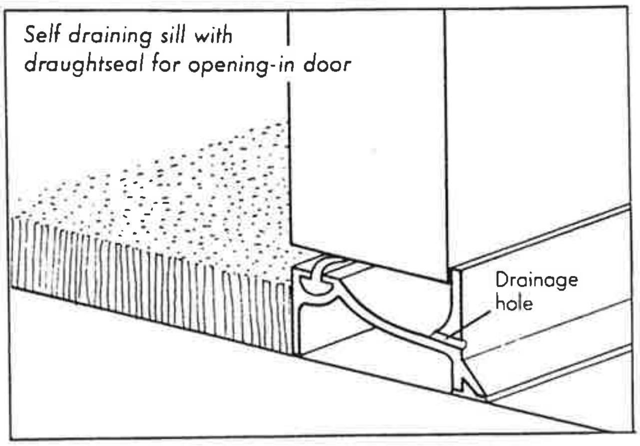
Ideally the plan of the renovated dwelling should incorporate a draught lobby, but where this is not feasible, draughtproofing is even more important. The draughtseals illustrated for windows are equally suitable for the head and jambs of door frames.

Remember that timber doors are susceptible to warping, especially if they are new or where central heating has been added. Specify a draughtseal that will remain effective after a change in the gap size. A thin-wall tubular section or one of the wiper seals is probably the best bet (see page 27).

The bottom of the door should also be fitted with a draught excluder. There are several types available. The most suitable type depends on the design of the threshold.


Automatic draught excluder for opening-in-door


Replacement sill with neoprene gasket for doors opening in or out


Self draining sill with draughtseal for opening-in door

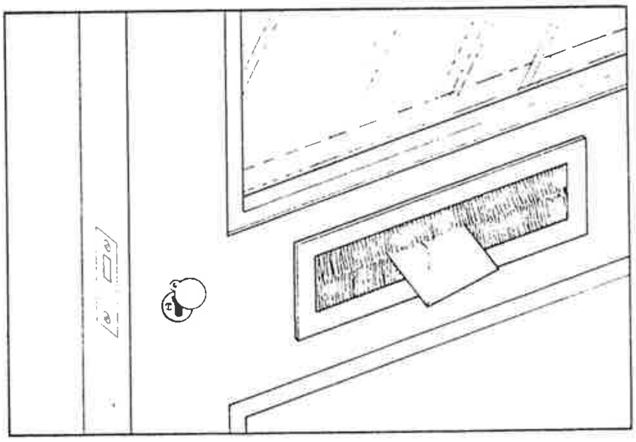
REPLACING THE DOOR

Where a replacement door is specified, its insulation value is rarely considered. Most architects and surveyors specify a replacement door because of its appearance, not its insulation value. However, good looking, highly insulated doors are on the market, although they are relatively expensive. Constructed from two sheets of steel infilled with urethene foam, they are available complete with door frame, threshold and draughtseals. The seal is magnetic and works like a fridge door. If a draught lobby cannot be incorporated, this type of door may be worth considering.

SEALING OTHER FITTINGS

Letter boxes can let in a large amount of cold air, especially if newspapers and letters are left there all day. Internal covers consisting of two nylon brush seals are probably the best solution.

Keyholes are easily dealt with by fitting a covered escutcheon plate.



DOOR COST-EFFECTIVENESS TABLE

Condition	Usual approach	Energy efficient approach	Typical extra cost (per door)	Annual savings (per door)	Simple payback period
Sound but needs repainting.	Repaint door. No draughtseals added.	Add draughtseals and a new threshold.	£25-35	£3-6	4-12 years
Door needs replacing.	Replace existing door with new timber framed door — no draughtproofing.	Replace existing door with highly insulated door, draughtseals and new threshold.	£80	£6-9	9-13 years

For details of the assumptions used in this table, see page 37.

Floors

Ground floors contribute to the heat loss of the house in two ways:

☐ by conduction through the floor

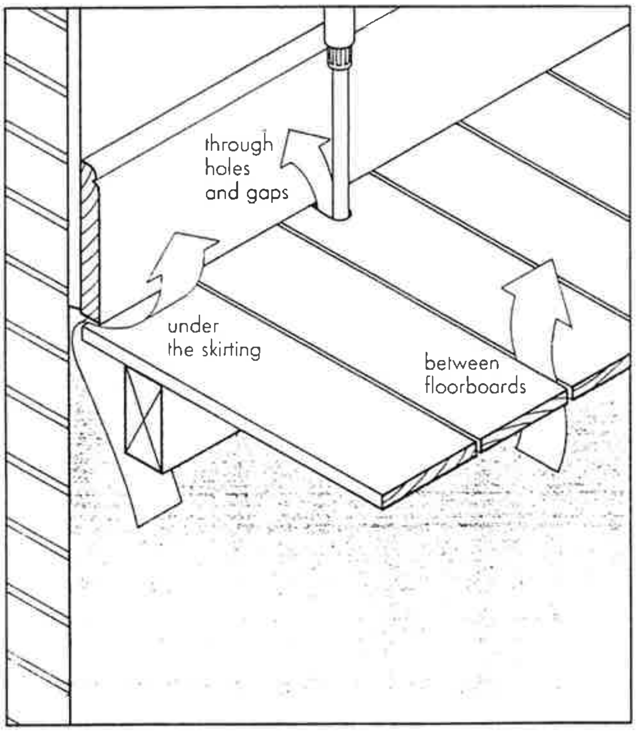
☐ by allowing cold draughts to percolate through gaps and cracks into the room. This can be especially troublesome in older houses with square-edged floor boarding.

The most effective way of reducing this heat loss depends on the construction of the ground floor and the degree of repair work needed.

SUSPENDED TIMBER FLOORS

Draughtproofing the floor

Most houses in Scotland, and the majority in England and Wales built before 1940 have a suspended timber ground floor. Cutting down draughts should be the first priority.



With old square-edged floorboards, laying hardboard over the whole floor will eliminate draughts from between the boards.

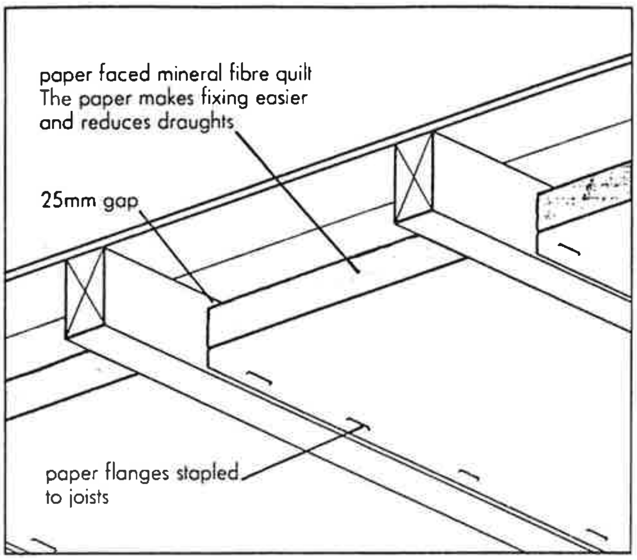
The gaps between skirting and floor can be sealed with a sealant, combined if necessary with a timber bead.

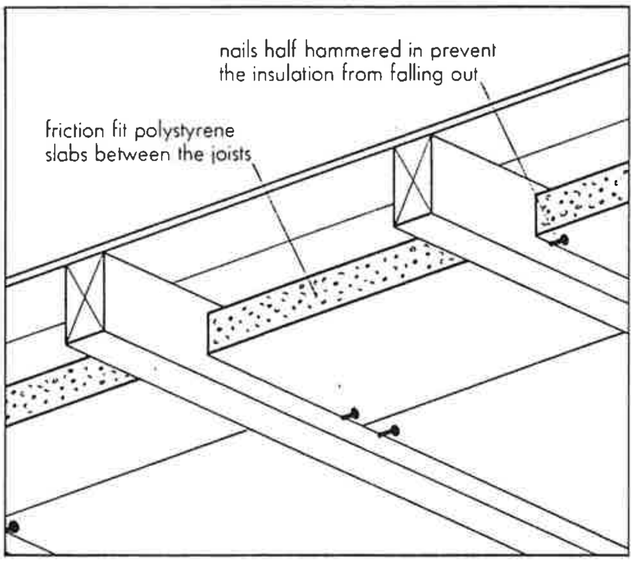
Gaps and holes in the floor where pipes, wires and cables rise from below should be packed with insulation. Foamed polyurethane, available in aerosol cans, is good for filling large awkward shaped gaps and holes, but requires skill.

Insulating the floor

Adding insulation to a suspended timber floor is worthwhile, provided it can be carried out easily. Where it is necessary to take up the floor just to lay insulation, it is unlikely to be cost-effective.

Fixing insulation from below





Where insulation is fitted from above, polystyrene boards can be pushed down between the joists and held by friction. In addition, the floor can be draughtproofed by placing a layer of building paper over the insulation before relaying the floorboards, if possible tucking the paper up behind the skirting.

POINTS TO CONSIDER

☐ The ventilation below a suspended timber floor must be maintained.

☐ If central heating is added for the first time, the wood will gradually dry out and shrink over the first one or two heating seasons. This will be particularly pronounced where new wood has been used — for skirtings and floorboards for example. Draughtproofing measures should allow for future movement.

☐ Avoid putting central heating pipes below the ground floor if at all possible. Where this is unavoidable, the pipes should be insulated.

☐ Where it is proposed to lay vinyl tiles or sheet, it will be necessary to lay hardboard or thin plywood to provide a smooth surface, thus saving energy at no extra cost.

SOLID CONCRETE FLOORS

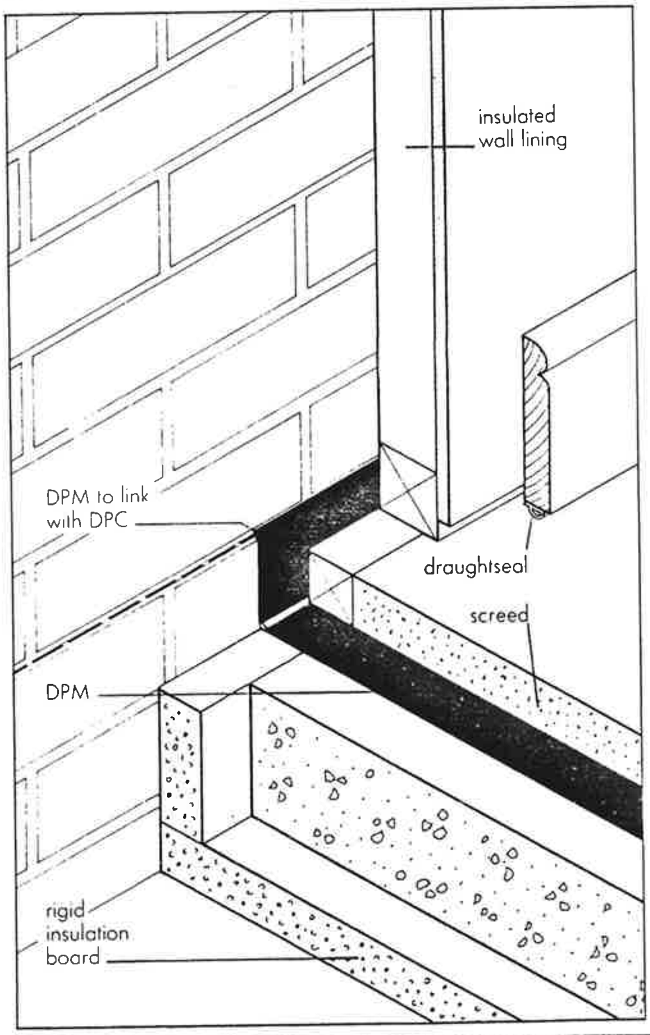
The opportunities for reducing heat loss through concrete floors are much more limited compared with suspended timber floors. The main opportunities for adding insulation are when a solid floor is suffering from rising damp, or the screed is breaking up. Before replacing the existing screed, consider substituting a combination of rigid insulation with either flooring grade chipboard or tongue and grooved hardboard.

Insulating a new concrete floor

In some situations it is necessary to lay a completely new concrete floor. For example, where a basement timber floor has extensive rot, it is common to replace it with a new concrete floor, especially where it is difficult to maintain adequate cross ventilation to the space beneath. The cost of adding insulation to a new concrete floor is little more than the cost of the material, but the cost of adding insulation at some future date is likely to be prohibitive. Any new concrete floor should incorporate insulation as the opportunity will probably never occur again.

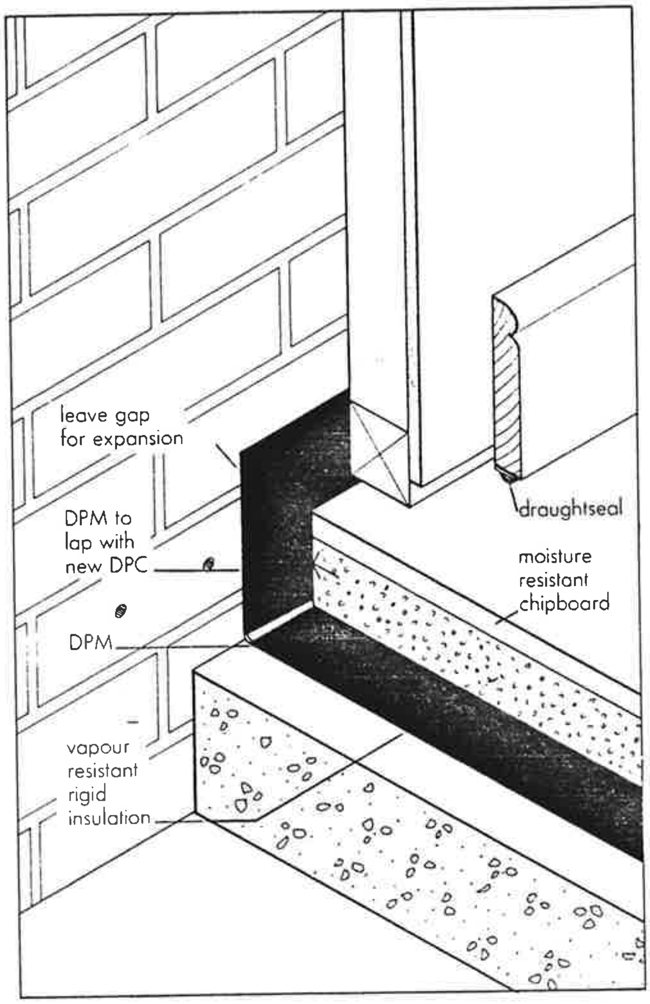
There is a choice of two positions for the insulation:

☐ **Under the concrete slab** This is the preferred position where the new floor is in a south-facing room. The large mass of concrete will usefully absorb heat from the sun's rays during the day and act like a large low temperature radiator during the evening. The optimum combined thickness of concrete and screed is around 125mm.



☐ **Above the concrete slab** This is the preferred position for basements and north-facing rooms. Where rooms do not benefit from solar gain, placing the insulation above the slab means that the floor surface warms up quickly when the heating is switched on. A vapour barrier should be placed between the chipboard flooring and the insulation.

Experience of placing insulation under screeds has not always been successful. A combination of bad workmanship and inadequate supervision has resulted in a number of screeds failing after only a few months.



POINTS TO CONSIDER

☐ Insulation and chipboard can be walked on immediately after laying and are ready to receive any floor finish. This can reduce handover times as there is no need to wait for the screed to dry out.

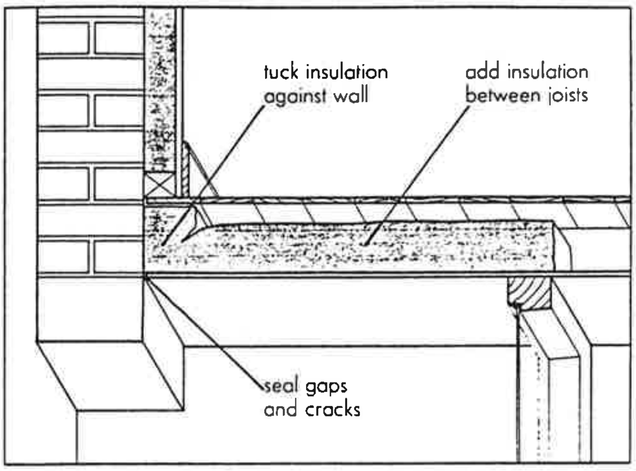
☐ The thickness of the insulation should be chosen to ensure that the finished floor is level with any adjoining floor.

☐ Ordinary flooring grade chipboard must not be used in kitchens or bathrooms. Moisture-resistant chipboard must always be used in kitchens, bathrooms and wherever water is likely to be spilled (type 11/111 to BS 5669, sometimes referred to as V313 chipboard).

☐ Insulation boards that are placed beneath the concrete slab must be strong in compression or settlement of the slab may occur.

UPPER FLOORS

Where the floors of upper rooms are exposed to the outside air on the underside, the floor should be insulated. This is easily done by taking up the floorboards and placing mineral fibre insulation between the joists. If there are any gaps or cracks in the soffit, these should be sealed to prevent draughts.



FLOORS COST-EFFECTIVENESS TABLE

Type of floor	Energy efficient measures	Typical extra cost	Annual savings	Simple payback period
Suspended timber floor	Draughtproofing a suspended timber floor:			
	Seal the gap between skirting and floorboards with sealant.	£40/house	£5-8	5-8 years
	Alternatively, seal the gap with timber quadrant or cove.	£65/house	£5-8	8-13 years
	Insulating a suspended timber floor:			
	Insulate from below with 60mm thick paper backed mineral fibre quilt stapled to the joists.	£4.00/m²	48-64p/m²	6-8 years
	Insulate from above by taking up the floorboards and friction fitting 50mm thick boards of polystyrene between the joists. Lay building paper over the floor and tuck up behind skirting boards before relaying the floorboards. Seal the skirting with sealant. (The cost assumes that about half the floorboards need to be taken up anyway to carry out repairs).	£7.50/m²	55-85p/m²	9-14 years
Laying a new concrete floor	Insulating a new solid floor:			
	Instead of the usual 38mm screed and vinyl tiles, lay 50mm thick extruded polystyrene and moisture resistant flooring grade chipboard.	0-£1/m²	32-64p/m²	0-3 years
	Alternatively, add 50mm thick extruded polystyrene insulation boards before the concrete slab is laid.	£5.75/m²	32-64p/m²	9-18 years
Existing concrete floor with defective screed	Instead of the usual 38mm screed and tiles, lay 20mm thick extruded polystyrene and moisture resistant flooring grade chipboard. The price includes separating the new floor from the brushed liquid dpm with a layer of building paper.	£1.75/m²	15-44p/m²	4-11 years

For details of the assumptions used in this table, *see page 37.*

Heating, controls and hot water

A good standard of insulation and controllable ventilation is only half way towards the efficient use of energy. To take full advantage of the lower energy demand, the heating system must be able to operate efficiently at low output. Make sure tenants understand the heating controls and how to use them effectively. Tenants can misuse good controls due to misconceptions about how they work.

SAVINGS IN CAPITAL COST

As the examples on pages 10 to 17 show, insulation measures can reduce the design heat loss by about 40 per cent. With such a large reduction in the demand for energy, rethinking the normal central heating installation can result in significant savings in capital cost, eg by reducing radiator sizes, eliminating some radiators, and installing a smaller boiler or unit heaters.

The table illustrates the potential savings.

POTENTIAL COST SAVINGS

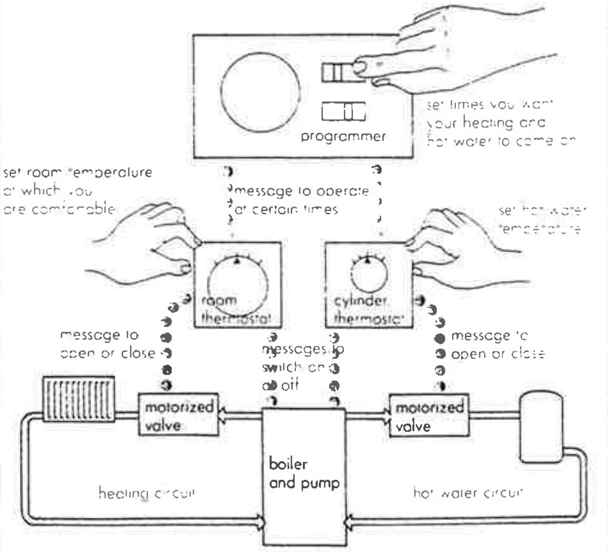
	Savings	Typical installation cost
Usual approach: Install full gas central heating consisting of roomheater with back boiler (new stainless steel flue lining) serving radiators and controlled by a room thermostat, cylinder thermostat, motorized valve and programmer.		£1,650
Energy efficient approaches A CENTRAL HEATING SCHEME Saving on radiator size due to 40% reduction in design heat loss.	£130	
Omit radiators and associated pipework to three bedroom radiators, but add a new radiator on the top landing.	£300	
	£430	£1,220
B UNIT HEATERS As an alternative to central heating, install unit heaters, for example: • gas fire in living room • gas circulator for hot water • two gas convectors in the kitchen/dining room and hallway • electric oil-filled towel rail in bathroom		£800

The ideal heating system to choose will depend on the characteristics of the dwelling and the particular needs of the householder. However, the following principles should be considered when designing a heating system.

Full or partial central heating
In a well insulated house, it is not essential to install full central heating in order to ensure an adequate distribution of heat. Evidence from the DOE's Better Insulated House programme suggests that in a well insulated house, sufficient heat finds its way upstairs by natural air movement and conduction through the floor to provide an acceptable 'balance' temperature in bedrooms, without them needing their own heat emitters. In flats and bungalows, where the 'stack' effect is absent, a full central heating system is desirable, or at least some minimal bedroom heating.

Controls for central heating
A room thermostat controlling a complete central heating system provides the absolute minimum control of temperature. Control within each room can be achieved economically by installing thermostatic radiator valves (TRVs) on each radiator. TRVs are particularly suitable for well insulated houses in which the contribution from incidental gains can usefully reduce the demand for space heating. However, as TRVs are non-electric, they cannot shut down the boiler and prevent boiler cycling. This tends to cancel out some of the advantages of TRVs, but a common compromise is to retain a room thermostat in the living room (wired to prevent boiler cycling), with TRVs in the remaining rooms. Room thermostats and TRVs should not be mixed in the same room. Steps should be taken to relieve pressure build-up in systems controlled by TRVs.

A well controlled central heating system — how the controls work together.



Condensing gas boilers
Condensing gas boilers have just started to appear on the market. The condensing boiler is the most efficient type of gas boiler available as it maintains high

efficiency even at low loads. Its seasonal efficiency is close to 90 per cent compared with 70-75 per cent for a new conventional gas boiler. To achieve the increase in performance, the waste flue gases are cooled by the water returning from the radiator circuit, releasing not only sensible heat due to cooling, but also the latent heat when the water vapour in the flue gases condenses.

Because of its higher installation cost, the condensing boiler is only likely to be cost-effective for houses with 3 or more bedrooms. For smaller houses and flats with design heat losses below about 4kW a conventional low water content boiler is likely to be more suitable.

The cooler the return water temperature, the more efficient the boiler will be. The return water temperature can be noticeably reduced by oversizing the radiators by about 10 per cent. The boiler requires a drainage connection to allow the condensate to drain away.

Domestic hot water

With central heating, hot water is most economically provided by a hot water storage cylinder. The primary circuit should be pumped to provide a quick recovery time.

When space heating is by unit heaters, a hot water storage cylinder heated by off-peak electricity, or a gas circulator can be economical for most households. If hot water demand is likely to be small and infrequent, an instantaneous water heater may be preferable.

POINTS TO CONSIDER

☐ **Simple controls** Good control of temperature and heating periods is important. Simple and easily understood controls are best. For a central heating system, the control should include a programmer, a thermostat to govern room temperatures and a hot water cylinder thermostat. To prevent wasteful boiler cycling, the boiler thermostat should be under the control of the room and cylinder thermostats.

☐ **Existing central heating** When a house with an existing central heating system is insulated, either TRVs must be fitted, or the radiators rebalanced. Otherwise the existing controls may be insufficiently sensitive to realise potential fuel savings.

☐ **Pipe insulation** Pipes leading from the hot water cylinder and all central heating pipes that are hidden under floors, in ducts, etc, should be insulated. The pipe insulation should have a thickness of 13mm or more.

☐ **Reflective foil** A simple, cheap and effective way of increasing the efficiency of radiators located on outside or party walls is to fix aluminium foil on the wall behind. This reflects heat back into the room that would otherwise be lost through the outside wall.

☐ **Radiant heat** Many householders prefer a radiant heat source in the living room. For intermittently heated houses, this can provide instant warmth until the room warms up. A radiant heater can be used at the beginning and end of the heating season without the need to heat the whole house.

☐ **Electric heating** When installing electric off-peak storage radiators, consider models which can be controlled by an outside temperature sensor. This automatically adjusts the amount of heat stored overnight according to the prevailing external temperature.

☐ **Solid fuel heating** For solid fuel heating, modern roomheaters and boilers are much more efficient than their open fire predecessors and they maintain high efficiency even at low levels of output. With some models, thermostatic controls and programmers can be used to give improved control, but seek advice on the provision of a heat leak radiator to avoid boiling.

☐ **Unit heaters** For individual unit heaters, appliances should have integral thermostatic controls. Ideally controls should be positioned at the top of the appliance unless they are easily reached. Consider specifying a time clock to the living room heater to provide an overall level of control comparable to a central heating system.

☐ **Cylinder jacket** Insulating the hot water cylinder is probably the most cost-effective measure you can take. Specify an insulation jacket to BS 5615, or a cylinder with factory applied urethane foam insulation.

☐ **Showers** Consider installing a shower. Showers use less hot water than baths.

☐ **Future systems** Heat pumps and solar panels may play an important role in the future, but at the present stage of development neither are cost-effective for domestic use, although heat pumps may be viable soon.

HEATING AND HOT WATER COST-EFFECTIVENESS TABLE

Usual approach	Energy efficient approach	Typical extra cost	Annual savings	Simple payback period
Add an 80mm thick jacket to an uninsulated h/w cylinder, or buy one with foam insulation.		£15	£10-16	1-2 years
	Add an 80mm thick jacket on top of a cylinder with factory applied foam insulation	£15	£2-4	4-7 years
	Add reflective foil behind radiators (cost for five radiators)	£20	£4-11*	2-5 years

* Savings are greatest for solid brick walls with no insulation, and lowest for well insulated walls.

For details of the assumptions used in this table, see page 37.

ASSESSING VALUE-FOR-MONEY

The benefits to the housing authority of adopting an energy efficient approach (eg improved housing stock, reduced maintenance, easier lettings) are not readily subject to simple value-for-money analysis. However, it is necessary to have some way of assessing whether individual measures offer value for money. The guide uses the simple payback method for comparing alternative measures.

The simple payback method — what it does

It works out how long it will take for the value of the energy savings resulting from a particular measure or package to equal their net extra capital cost.

How to calculate

Divide the net extra capital cost by the annual energy savings. This gives the payback period in years.

Correcting the savings for alternative heating patterns

Many tenants run their heating systems for shorter periods than we have assumed. The table below gives correction factors for different heating patterns.

Heating regime: Weekdays	Heating regime: Weekends	Correction factor
6 hours/day	6 hours/day	0.4
6 hours/day	9 hours/day	0.55
6 hours/day	16 hours/day	0.65
9 hours/day	9 hours/day	0.9
9 hours/day	16 hours/day	1.0
16 hours/day	16 hours/day	1.25

6 hours a day assumes only evening heating (eg. 4pm-10pm).
9 hours a day assumes only early morning and evening heating (eg 6am-9am and 4pm-10pm)
16 hours a day assumes continous daytime and evening heating (eg 6am-10pm).

The following assumptions have been used in calculating the figures in the cost-effectiveness tables:

Capital costs

The costs are for the second quarter of 1985 and reflect typical figures for small contracts of £50,000-£250,000. The economies of scale for contracts of 40 houses or more will probably result in prices being some 10 per cent lower than those shown.

Fuel savings

The savings assume that a gas fired central heating system is operated in winter for 9 hours a day during the week and 16 hours a day at weekends. The figures assume that *all* the savings are taken in the form of reduced heating costs. Savings given are averages over a number of houses and cannot be relied upon to occur in any particular house. The savings were calculated using a method developed by BRE which is soon to be published as *'BRE Domestic Energy Model: Background Philosophy and Description'.*

The method is based on a demand temperature in the living room (in this case 21°C) and assumes some increase in temperature due to slower cooling down periods. It also takes account of the thermal capacity of dwellings.

When, prior to renovation, the condition of the dwelling was such that tenants could not afford to heat to the level assumed in this guide, it is likely that the benefits of the energy saving measures will be taken as much in the form of higher internal temperatures as energy savings.

Fuel prices

The payback period calculations assume no rise in fuel prices. Any rise in fuel prices will shorten the payback period.

The effect of inflation will gradually make the costs look out of date. However, unless there is a significant divergence between rises in construction costs and fuel costs, payback periods and the relative cost-effectiveness of the measures should remain valid.

The effects of using other fuels

Where more expensive fuels than gas are used, savings will be up to 25 per cent greater. In reality, the higher fuel costs of off-peak electric and solid fuel systems are largely offset by the higher standing charges for gas and the cost of regular boiler maintenance. These extra costs associated with gas heating cause off-peak electricity and solid fuel to become competitive in smaller, well-insulated dwellings.

EXAMPLE

A block of flats is to be converted for use as a sheltered housing scheme where the occupants are likely to be at home during the day as well as the evening. Check whether it is economic to increase the loft insulation above 100mm thickness.

Fuel

Off-peak electricity. Off-peak electricity can be up to 25 per cent more expensive than gas.
Assume a correction factor of 1.25

Heating pattern

The heating is on 16 hours/day
Assume a correction factor of 1.25

Calculating

From the cost-effectiveness table on *page 19*:
Use 140mm loft insulation instead of 100mm
Annual saving = 7p/m²
Typical extra cost = 75p/m²
Corrected annual saving = 7p × 1.25 × 1.25 = 11p/m²

$$\text{Payback period} = \frac{75p}{11p} = 7 \text{ years}$$

The payback period is reduced from 10 years in the table to 7 years in the example.

REFERENCES

The following documents contain more detailed information and advice on many of the aspects outlined in this guide, and are recommended for further reading.

British Board of Agrément

Information Sheet No 198: *Agrément Certificates for loft insulation materials, 1982.*

Cavity insulation of masonry walls-dampness risks and how to minimise them, 1983.
Jointly prepared with the Building Research Establishment, Building Employers Confederation, and the National House-Building Council (England and Wales).

British Standards Institution

BS 5250: 1975 Code *of basic data for the design of buildings: the control* of condensation in dwellings. Amendments AMD 3025, June 1979 and AMD 4210, March 1983. (under revision)

BS 5617: 1985 *Specification for urea-formaldehyde (UF) foam suitable for thermal insulation of cavity walls with masonry or concrete inner and outer leaves.*

BS 5618: 1985 *Code of practice for thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with urea-formaldehyde (UF) foam systems.*

BS 5925: 1980 *Code of practice for design of buildings: ventilation principles and designing for natural ventilation.*

BS 6229: 1982 *Code of practice for flat roofs with continuously supported coverings.*

BS 6232: Part 2: 1982 *Code of practice for installation of blown man-made mineral fibre in cavity walls with masonry or concrete leaves.*

BS 8202: *Guide to assessment of suitability of external cavity walls for filling with thermal insulants,* Part 1: 1985 *Existing traditional cavity construction.*

Building Research Establishment

Digests
110 *Condensation*
180 *Condensation in roofs*
221 *Flat roof design and technical options*
236 *Cavity insulation*
270 *Condensation in insulated domestic roofs*
297 *Surface condensation and mould growth in traditionally built dwellings*

Information Papers
IP10/79 *Field studies on the effects of increased thermal insulation in some electrically heated houses*
IP16/81 *The weatherstripping of windows and doors*
IP25/82 *Formaldehyde vapour from urea-formaldehyde*

Defect Action Sheets
This continuing series sets out advice and information for design and site supervisory staff of ways of avoiding common defects in Local Authority housing.

Cement and Concrete Association

Technical Report 538 *The impact resistance of external wall insulation systems,* 1980.

External insulation: *Improving dwelling walls* (Reprint 4/80).

Department of Energy

Energy efficient domestic wet central heating systems: Guidance notes for installers, 1982.

Energy Efficiency Demonstration Projects Scheme.

A scheme to encourage the efficient use of energy by demonstrating new methods and techniques which have been used in housing, commercial and industrial buildings. The results of several demonstration projects have been published, and more are in the pipeline.

Department of the Environment

Domestic Energy Note 2 *Condensation in domestic pitched roof spaces,* 1978.

Newman, Whiteside, Kloss and Willis

Full-scale water penetration tests on twelve cavity fills, *Building and Environment,* Volume 17, No 3, 1982.

Property Services Agency

Flat roofs technical guide: Second edition, 1981.

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London Borough of Islington, Architects' Department.
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