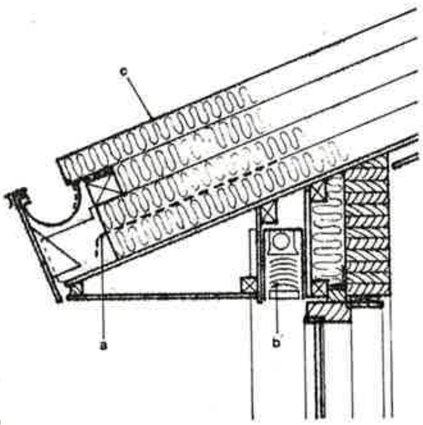
AJ Database CI/SfB (L27)

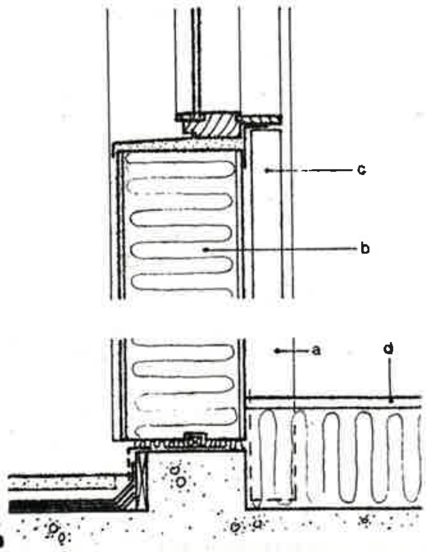
CONSTRUCTION RISKS AND REMEDIES CONDENSATION

Part 2: The remedies

In the first of these two articles on condensation last week, we looked at how and where problems from condensation often arise. This week we explore the remedies and consider in the main part of the text the theoretical approaches to the avoidance, or rectification, of condensation problems. These sections are punctuated by examples which illustrate the implementation of some of these ideas.



1a



1b

1a Eaves detail of Rockwool R and D building: a, membrane to prevent rain penetration, not vapour retarder; blind; c, 300 mm of Rockwool slabs.
1b Wall panel of Rockwool building (on raised concrete deck): a, timber columns; b, 250 mm Rockwool panels with fibre cement facing; c, cable duct; d, flooring chipboard on Rockwool.

1 Condensation avoidance in general

Condensation, or the lack of it, depends on a balance between water vapour content and temperature. The aim is to keep the temperature of the fabric up and the vapour content (vapour pressure) down.

One way to do this would be to wrap the building in an insulating box like a tea-cosy. The vapour resistance of the external envelope would be at a maximum at or very near the internal surface and resistance would decline nearer the exterior.

The thermal resistance (insulation) should rise to a maximum near the outside surface. The idea is to encourage a stable environment with the warmest (in winter) part of the fabric at the highest vapour concentration. Any interstitial condensation that does occur under transient conditions would be able to dry off to the outside later.

The long term experiment at the Rockwool company's Danish research and development building is an example of this approach, the outer part of the roof and walls being mineral wool slabs, *1a, b*.

Ventilation is the other vital ingredient in the anti-condensation recipe. Diffusion through walls and roof is too slow a process to prevent the internal relative humidity rising to 100 per cent as the building's users pump water vapour into the air. To avoid mould growth the r.h. should be no more than 70 per cent for safety, although mould growth is not very active below 80 per cent. Therefore steps have to be taken to remove water vapour as quickly as it is produced.

This can be done by ventilation, replacing the vapour laden air with drier air, or by dehumidifying the air with condensing equipment.

There is a third element in condensation control; the control of water vapour movement. In some types of construction it can be preferable, or unavoidable, to allow parts of the building fabric to be colder than the dewpoint and to prevent significant amounts of water vapour from reaching these parts. Vapour retarders and air flows can do this.

2 Humidity control

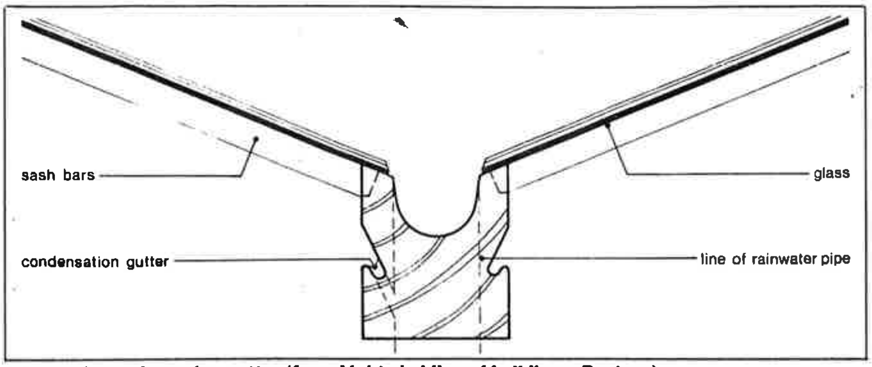
2.1 Dehumidification, controlled condensation

Dehumidification equipment is a standard feature of air conditioned buildings. The chillers remove surplus water vapour as well as surplus heat, so much so that the air often has to be rehumidified.

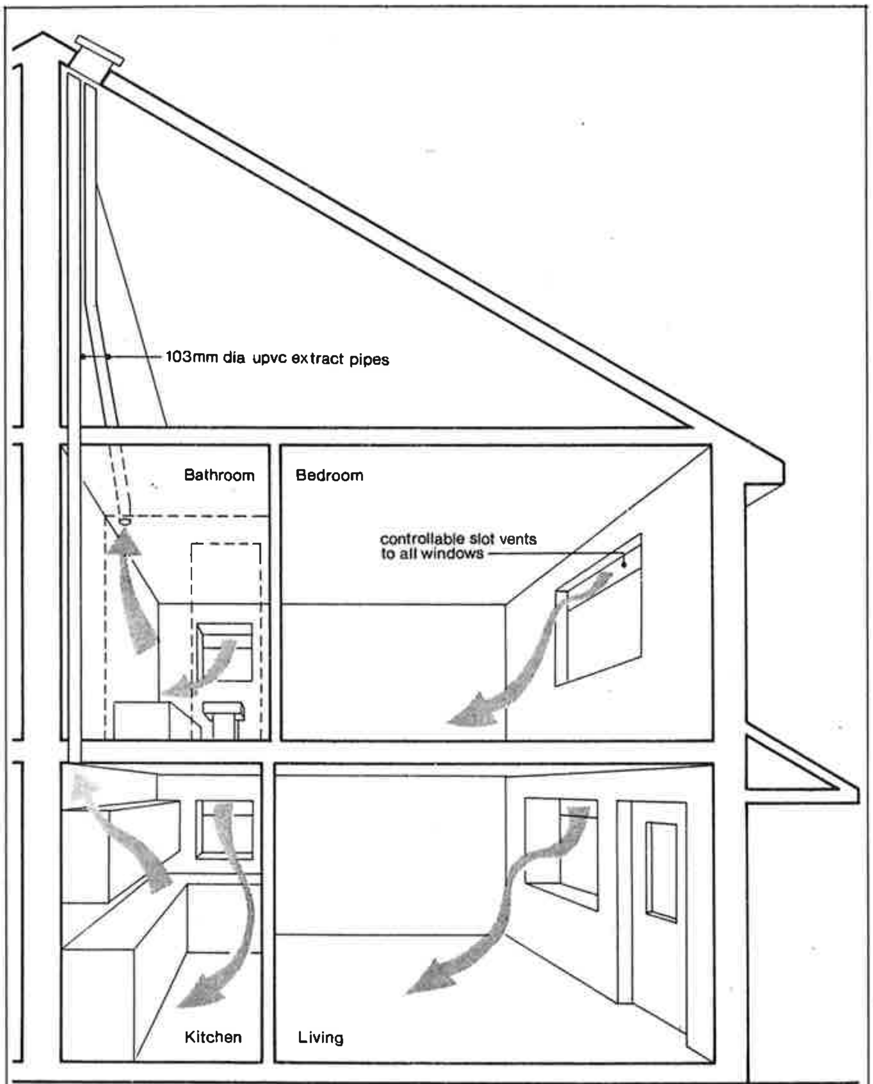
The BRE and others have experimented with dehumidifiers in houses and mobile and built-in electric machines have been on the market for several years. The conclusion so far has been that they will do some good in well heated spaces that have condensation problems, but in cold rooms they have no more effect than a low power heater. Some households found them too noisy, and unless they are plumbed in for the removal of condensation, the chore of emptying the reservoir and the running costs act as a disincentive.

Single glazing can be used as a simple dehumidifier. With a U-value of about 5.6W/m^2 °C condensation can be expected on glazing with internal relative humidity at only 50 per cent, even when the temperature difference inside to outside is only 17°C.

Condensation on the glass can drain into a channel at the sill and thence into a drain to the outside, but



2 Paxton's condensation gutter (from Light cladding of buildings, Rostron).



The stack effect ventilation system.

Stack effect ventilation

A combined development by Trada, Pilkington and John Laing of a simple natural ducted ventilation system for two-storey houses has produced some promising results. The system consisted of 103 mm uPVC pipes from the bathroom ceiling and a point over the cooker, to the underside (close to but not touching) of a tile vent near the apex of the roof.

The stack effect operating over these two ducts 'powers' the ventilation system. The gap at the roof vent reduces the suction of high winds. Titon Trimvents in the main room windows provided air inlets.

Without the ducts or window vents the 'tight' construction gave air change rates of less than one-third per hour. This is important as it ensures that the ducts become the main route for air leaving the house.

Over a range of wind and temperature conditions the system averaged 0·45 ac/h for the whole house, which represented 2·5 ac/h and 2 ac/h respectively for kitchen and bathroom. The pipes are run in as straight a line as possible, with a sleeve of thermal insulation in the roof space to prevent condensation and the loss of drive that cooling could cause. Development of the system continues.

incipient mould growth will still have to be regularly wiped off the glass.

Paxton was aware of the problem at the Crystal Palace. He found that water would not fall off in drops if the glazing was at a slope of at least 2·5:1. By using a ridge and furrow roof and special gutters, *2*, the condensate was collected at the bottom of each pane.

2.2 Water vapour emission

In January the BRE launched a set of papers, slides and a videotape called 'Remedies for condensation and mould in traditional housing'. They include advice about controlling water vapour emission and the tape is particularly good for explaining to householders.

2.3 Removing water vapour at source

Experts agree that removing water vapour at source is one of the best anti-condensation measures. Catering and industrial processes do this via an extract hood over the source.

The same thing can be done in domestic kitchens and bathrooms, which are the main sources of vapour. The BRE has tested extractor fans and found that under automatic humidistat control they might run for 50 hours a week. If control was left to the occupants they were used for much shorter periods and were correspondingly less effective. Noise, running cost and the cost of extra heating to make up the warm air lost, were among the reasons given.

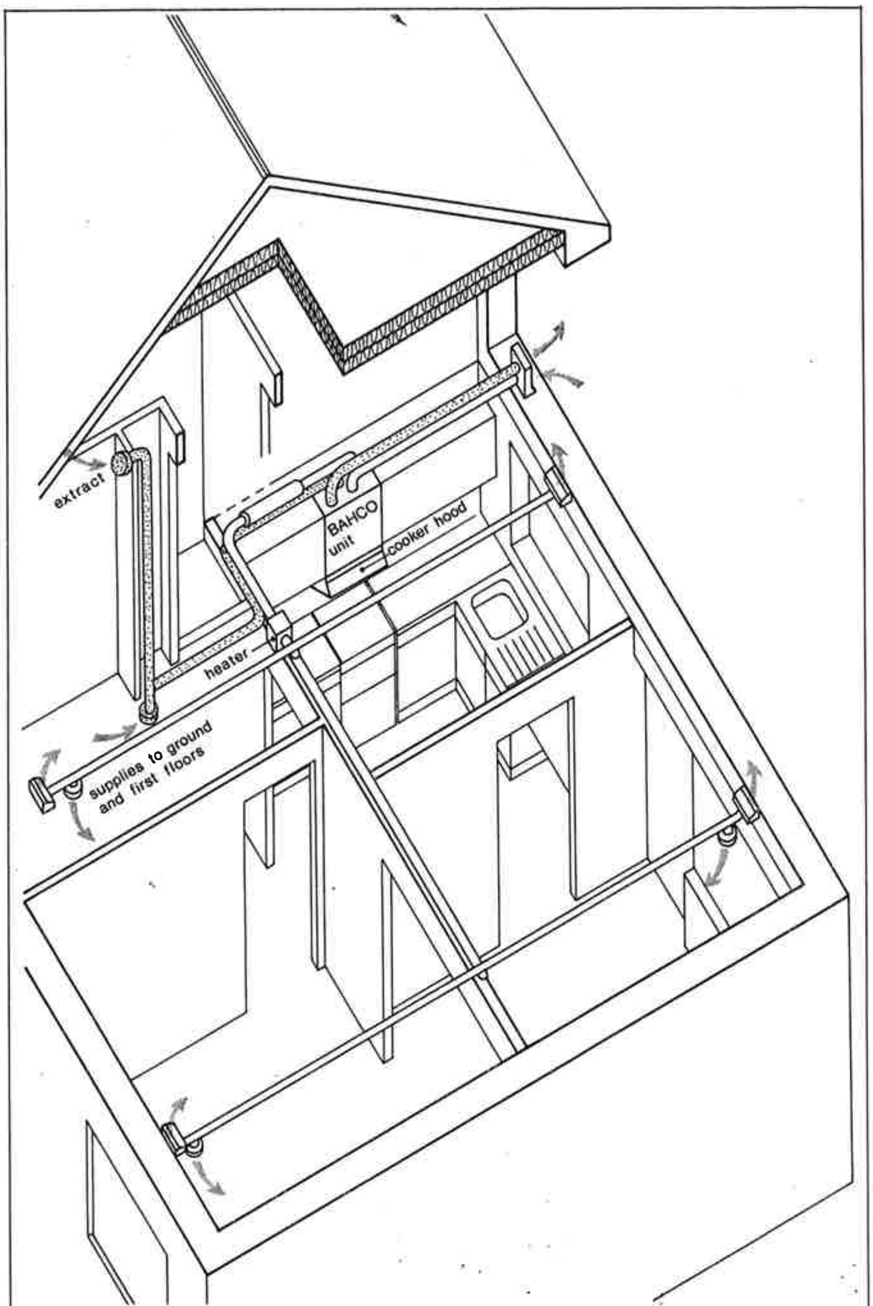
Extractors should either be ducted or positioned near cooker and sink, above door head level if possible. There must be sufficient leakage for make-up air without short circulation or negative pressure on gas appliances. Most tumble driers must be vented to the outside.

2.4 Ventilation at potential sites of condensation

Where local extraction is insufficient or not practical general ventilation can be used to replace vapour laden air with drier air.

The amount of vapour removed in this way depends simply on the rate of air movement and the difference in vapour content of the incoming and outgoing air. Failures seem to arise as a result of providing no ventilation at all rather than because someone got their sums wrong.

Condensation in houses was less before 1965 because chimneys to open fires and the vents required in building by-laws ensured a high rate of air change. As fabric heat loss has been reduced by better insulation ventilation losses have become more important, *3*. Ventilators should be controllable and should not lessen security when opened. For winter ventilation they should be high up in rooms so that falling cold air mixes and diffuses, weakening the stream. Draughts are less noticeable than from a low level inlet where cold air forms a stream that does not mix so much with the warmer air.

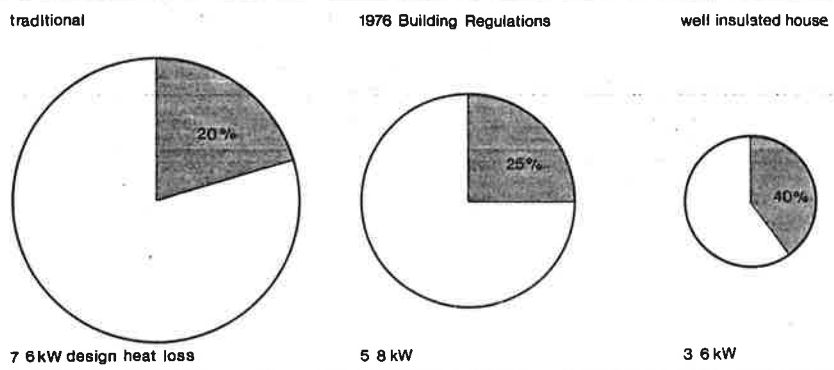


Mechanical extraction of vapour at source comes with heat recovery system at Two Mile Ash.

Mechanical ventilation

Another approach is being tried at Two Mile Ash in Milton Keynes. With funds from the EEC, the Energy Design Group of Bath and the Polytechnic of Central London have designed a group of highly insulated timber-framed houses using the Finlandia system. These houses are very 'tight', although with windows that can open.

Winter ventilation employs a mechanical system, with heat recovery, based on a Swedish (BAHCO) unit, *above*, with ducts in the upper floor to avoid interference with the vapour barrier in the external envelope. A heater from the hot water system provides the space heating needed (2Kw).



3 Ventilation heat losses become more important when houses are better insulated.

The lower limit for ventilation is set by the air needed for combustion and for the removal of odours. These rates are indicated in table I.

Ventilation will do nothing to reduce condensation if the air supplied is no drier than that being removed. One of the problems of the cold profiled sheet roof is that night-time cooling takes it below the dewpoint of ambient air so no amount of natural ventilation under the sheets will stop condensation—in fact it supplies more moist air. One approach is to keep air away from the cold underside with insulation of high vapour resistance that fills the profile, see 4.3. Opinions differ about the risk posed by water vapour in the insulant.

2.5 Pitched roofs and ventilation

Ventilation as a defence against condensation in domestic roofs appeared in the England and Wales Building Regulations (section F2) for the first time in 1985. The document shows ventilation openings along the eaves equivalent to a continuous 10 mm wide strip on both (opposite) eaves of a pitched roof and 25 mm for flat roofs. Tile-vent type openings are shown at high level on lean-to roofs, but the regulations do not otherwise refer to ridge ventilation.

Situations often arise where it is impossible to get the necessary cross ventilation. For example in flats with a central access corridor there is a conflict with the fire separation. This must be horizontal to preserve ventilation but cavity barriers may still be needed because of the width of the roof.

The National House-building Council rules on construction do not permit a vapour barrier at ceiling level so in the majority of houses with 100 mm of more of insulation at ceiling level the roof space will be cold and reliant on ventilation to disperse water vapour.

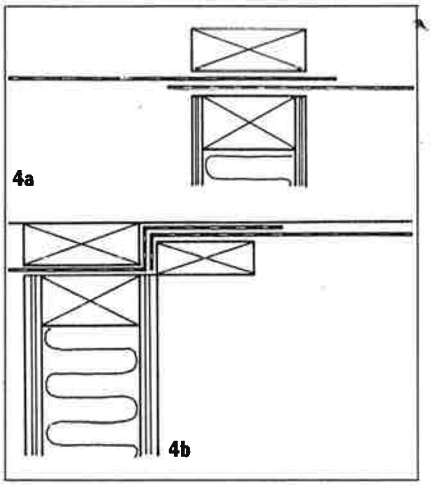
On still nights these cold roof spaces will contain condensation. The 1971 DOE publication *Condensation in dwellings Part 2* advised against eaves ventilation with roofs pitched at less than 20° 'in very humid climates', and it specifies Scotland. It suggests a vapour barrier instead.

More recent work at BRE has shown that a vapour retarder at ceiling level has little value. It is far more important to see that light drops,

Table I: Individual air requirements† (living room)*

Requirement		*Air supply litres/ second*	*Air changes/ hour*
Open flued appliance (heat input 20 kW)		15	1·3
Respiration	3 people	6	0·55
	6 people	12	1·1
Contamination (odours, tobacco smoke)	3 people	25	2·2
	6 people	80	7·2

†British Gas: *Studies in energy efficiency* No 6; paper one.
*Based on a room volume of 40 m³.



4a,b Joints in vapour retarder pinched tightly.

pipes, and trap doors are sealed. Ventilation then has more chance of coping with the water vapour that does enter the roof.

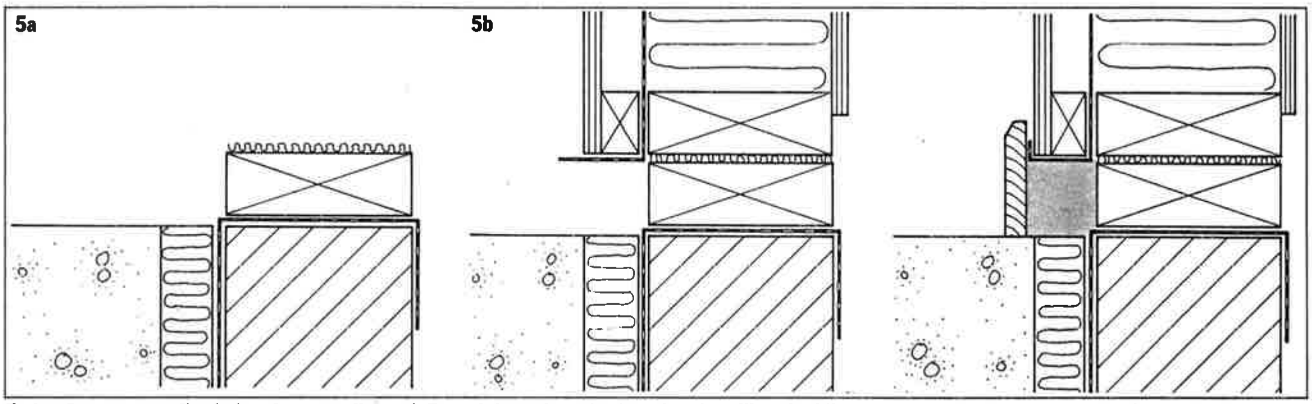
Opinion now favours the warm roof for these situations with the insulation above the rafters, but a steeper pitch with extra vents in the ridge might be a cheaper solution.

Large non-domestic low-pitched roofs should be designed as warm roofs. The practical difficulties of achieving a vapour barrier over a large area of ceiling mean there will be little difference in vapour pressure between the roof space and the accommodation. The geometry of such a roof makes eaves ventilation less effective.

3 Controlling vapour flow

Early advice on vapour barriers underestimated the difficulty of making them work and so the term vapour check appeared. Instead of claiming to stop all vapour penetration the vapour check restricts the 'flow' of vapour so the ventilation that is available in cavities outside the check can disperse moisture as fast as it comes from the inside. Vapour retarder (v.r.) is probably a better term.

Some of the techniques for making a v.r. are illustrated in *4* and *5*. Taped lap joints on their own in a vapour retarder are not very effective. It is better to pinch the retarder between battens, *4*. The assembly sequence is important for ensuring continuity. The example from Two Mile Ash (below) shows how a virtually air tight membrane was built.



5a,b,c Sequence to fix timber-frame wall panel. Foam injected on site (tone) and resilient bedding on sole plate give vapour retarder continuity.

Timber frame v.r.

Two Mile Ash super-insulated houses use the Finlandia system which employs large factory-made timber-frame panels imported from Finland. The size of panel cuts down the number of site joints. The vapour check is fixed to the inner face of the 145 mm wall frame, and 40 mm of further insulation is fixed to the inner face of that. This creates a zone for services.

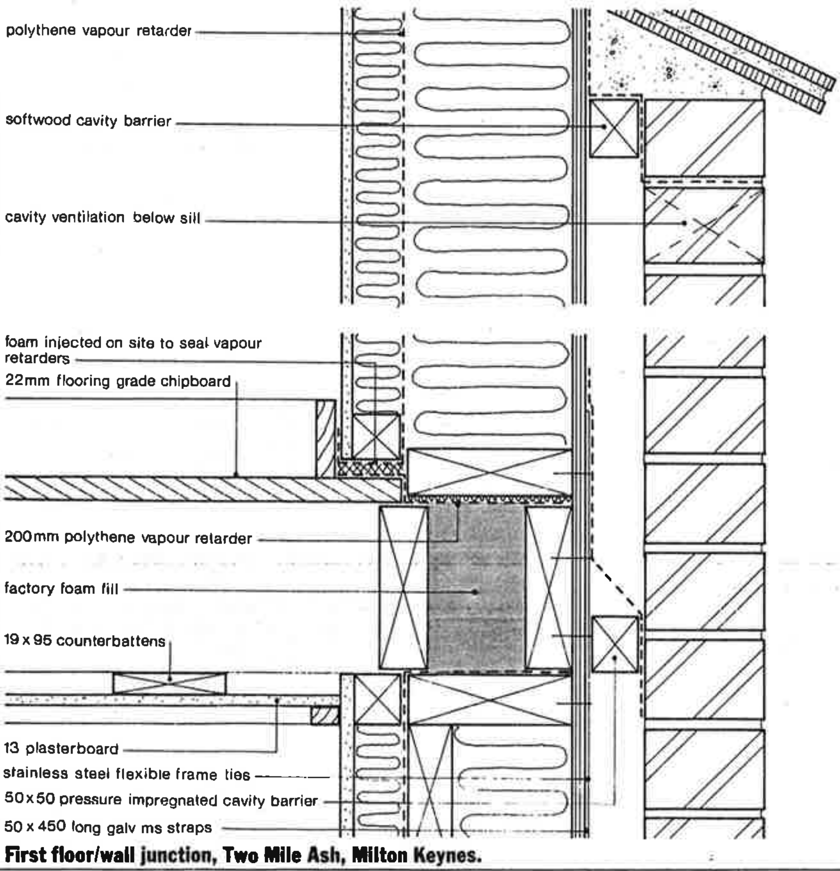
The first floor panel supports the upper wall panels. Cold bridge and loss of v.r. continuity is avoided by factory filling the space between the two trimmers to the floor panel with foam. A 200 mm strip of polythene is fixed to the top of the edge of the floor panel, and over the chipboard floor. A strip of compressible material then forms a base for the wall panel on top of the polythene. The sequence is similar to 5a, b, c, above. A similar foam filling technique is used at the edge of v.r. round window openings, and at vertical joints.

The first floor ceiling is fixed on 19 mm battens to form a space below the vapour retarder for cables. The polythene is site fixed by stapling to the underside of the trussed rafters. It is lapped at least 100 mm over the v.r. from the walls and taped.

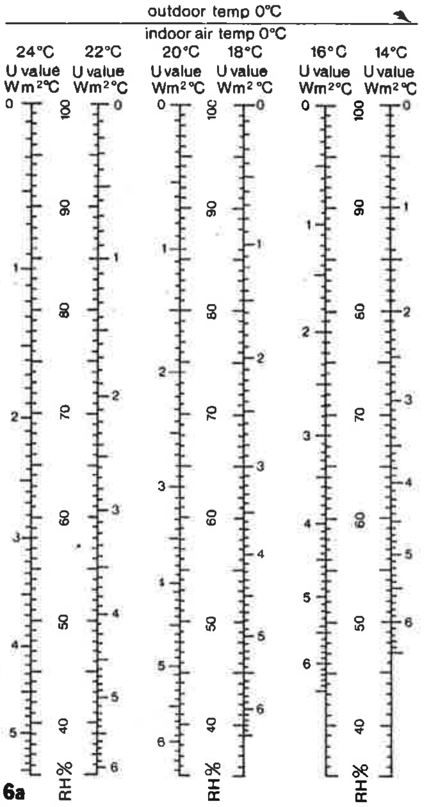
The most difficult points were at partition lines because it was impossible to insert the v.r. between rafters and partitions.

The ceiling was kept virtually intact by persuading the water authority that all the supplies should be direct from the mains.

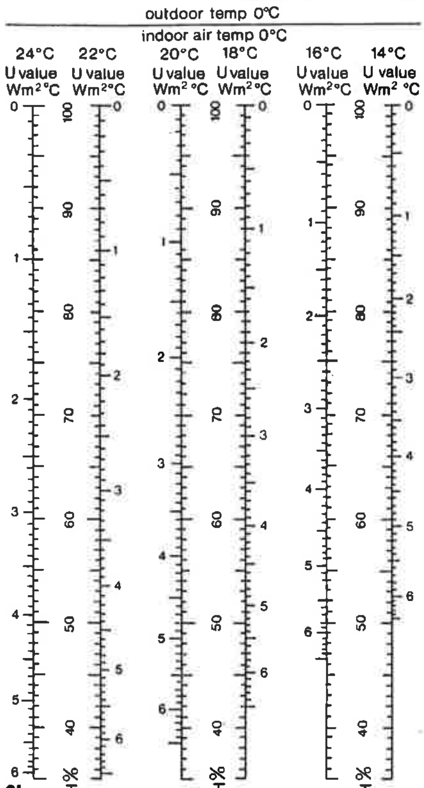
Pipes such as soil vents that did have to enter the roof space were fitted with a sleeve and the skirt of this was taped on to the v.r.



First floor/wall junction, Two Mile Ash, Milton Keynes.



6a



6b

6a,b Rough guide to room air temperature at which condensation begins given, a, wall and, b, roof/ceiling U-value and r.h. of room air. Assumes steady state, normal exposure and 0·12 m²°C/W internal wall surface resistance (0·11 for ceilings). (After Addleson).

4 Adding insulation

While water vapour must be removed to prevent relative humidity being pushed up too high by normal building occupancy, ventilation alone will not always produce satisfactory conditions. For example, in unheated rooms affected by water vapour from other parts of the building, when there is little difference between the temperature inside and outside, when the r.h. is high outside, it is difficult to bring the internal r.h. below the 70 per cent level needed to avoid mould growth, by ventilation with cold outside air.

Raising the internal air temperature in these conditions will make ventilation more effective. Raising the structural temperature will reduce the risk of surface and interstitial condensation. A current test case will say if owners can get away with telling tenants to turn heating up.

4.1 Surface condensation

Any improvement in the U-value will increase the interior surface temperature, no matter where the insulation is located from inside to outside in the structure.

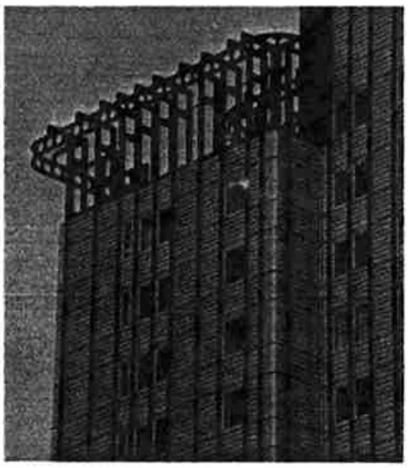
The charts of U-value against ▶ 77

Rainscreen cladding

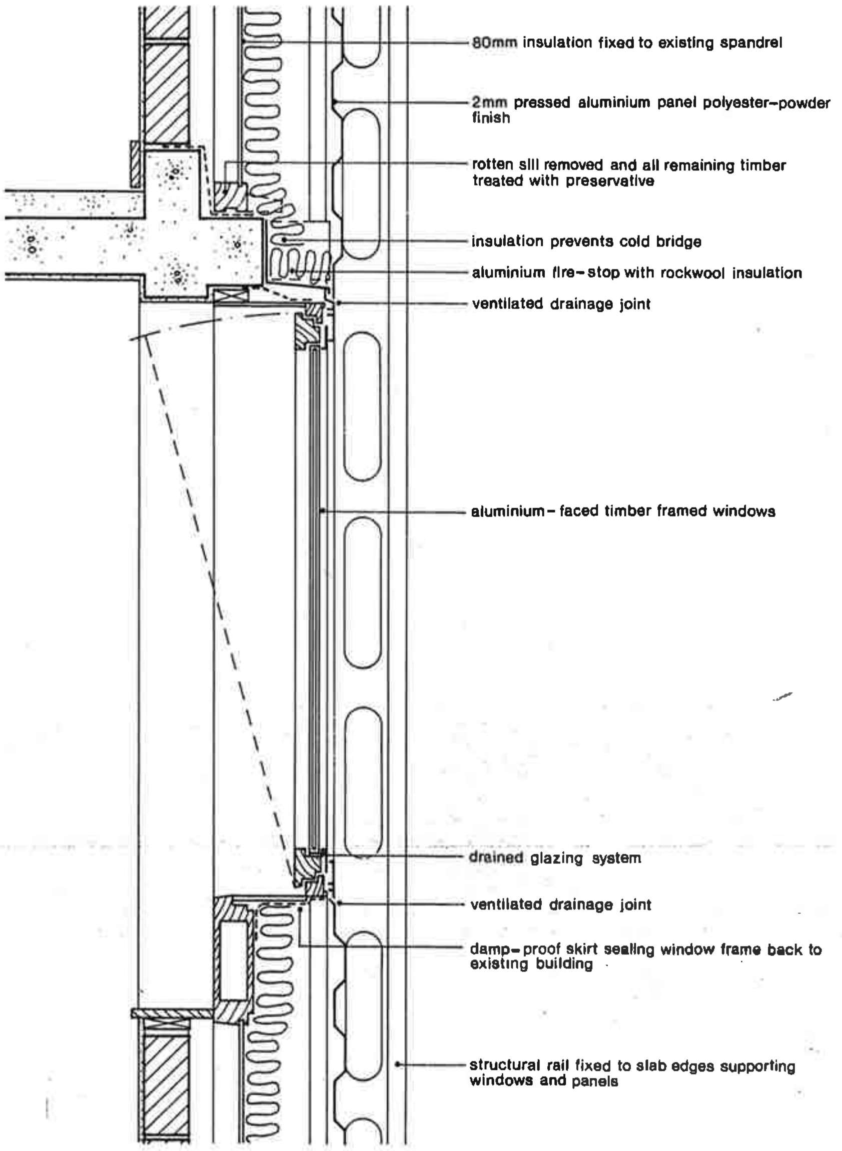
Parson's House is a 20-storey block of flats on the Edgware Road in the City of Westminster. The section shows the construction. The old infill panels were poorly insulated and accumulated condensation was blamed for the rot in their timber sills.

Instead of replacing windows and repairing the rot Peter Bell and Partners, architects for the remedial work, proposed overcladding the complete facade with an aluminium skin incorporating new windows with double glazing and thermal breaks.

The estimated annual fuel saving, at September 1985 prices, was £17 600. The work cost £268 530 which was about the same as the estimate for making good the original form of construction without recladding.



Parson's House overcladding nearly complete (above). Section through new cladding—note ventilation/drainage to cavity (right).



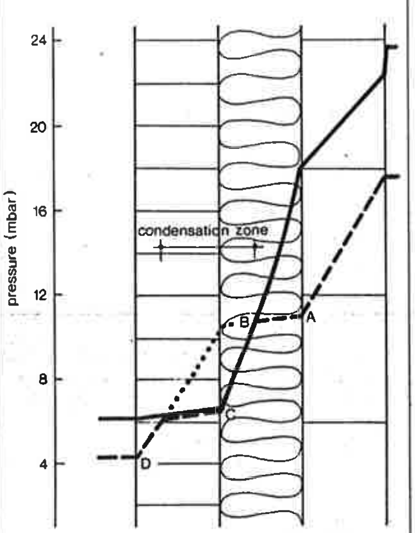
Alternative to BS 5250

BS 5250: 1975 gives the widely accepted method for assessing the risk of interstitial condensation. Temperature and water vapour distribution are worked out (Burberry gives a graphical method in AJ 3.10.79 p736) and one or other of these profiles is converted so a comparison is made either between structural and dewpoint temperatures, or between the corresponding vapour pressures.

Where the structural temperature drops below the dewpoint temperature (dotted line) there is held to be a risk of condensation. Ken Johnson of Pilkington R and D Laboratories argues that this does not happen.

He points out that the dewpoint temperature cannot rise above that of the structural without the air being supersaturated. For various reasons he believes that, in materials such as fibrous insulation, it is more likely that the two profiles follow each other closely, as in ABCD, until the next interface with a different material. Condensation may occur at this point, especially if the next material has a high vapour resistance. If condensation is likened to an agglomeration of water molecules, there is a greater likelihood of this happening on a surface than in free space. The presence of nuclei therefore aids condensation.

It is also easier for agglomeration to take place on a flat surface than a curved one, such as a fibre of insulation. On a larger scale the suction of a porous surface, such as brick or block, probably tends to draw condensate into itself rather than into adjoining glass fibre. Therefore, if condensation is predicted, (and that is less likely using Johnson's method than BS 5250) under most conditions it will only occur on surfaces adjacent to the cold side of relatively low vapour resistance materials.



Insulated cavity wall condensation risk. Pecked line=saturated vapour pressure. Dotted line=BS 5250 s.v.p.

r.h., *6a, b*, give a rough guide to the insulation needed to prevent the onset of surface condensation, with any given internal r.h. and inside-outside temperature difference. *6a*, applies to walls and assumes an internal surface resistance of 0·12 m^2°C/W. It is easy to see why condensation frequently occurs on single glazing (U-value 5·6 W/m^2°C). The charts assume steady state conditions and surfaces of high emissivity (which is true for most building materials except unpainted metals). Use only for preliminary estimates.

Steady state conditions may not be reached where there are cold bridges, or when the heating is not continuous, section 5.3 on intermittancy.

4.2 Interstitial condensation

In contrast to surface condensation, the risk of interstitial condensation depends very much on the location of the main insulating layer in the construction. This risk is minimised if the insulation is concentrated at the external surface. Even in cavity brick or blockwork with inner surface insulation, the condensation risk zone usually falls in the outer leaf or in the cavity and is regarded as harmless, although some authorities feel there may be long term frost damage.

In timber frames the insulation tends to be thicker, 80-100 mm c.f. 25-50 mm, and it is near the inside face of wall panels. This increases the risk of condensation within the construction, and to counter it the cavity between frame sheathing and outer cladding needs to be ventilated. Note the perpend ventilator slots in the Two Mile Ash houses.

A sound vapour retarder on the warm side of the insulation, in conjunction with permeability and ventilation on the cold side, will reduce the amount and seriousness of this condensation. Work at Pilkington Brothers' Research and Development laboratories suggests that the risk of interstitial condensation, at least in glass fibre, is less than suggested by the BS 5250 method of calculation. However, experts do not agree on the conclusions to be drawn from the Pilkington work. (See box left).

In lightweight cladding of the curtain wall type the potential for interstitial condensation is high with an impermeable material such as metal or glass on the outside, and the insulation near the inside. High temperatures in the cavity behind the outer surface, and rapid swings to low night-time temperatures are also ideal for condensation.

The special case of volatilisation in the spandrel panels of all-glass curtain walls was described in AJ 6.3.85, p71-72. The best defence against the effects of condensation in lightweight cladding is to ventilate the cavity to the outside, and design drainage from it to cope with the rapid release of water associated with the melting of ice formed there on cold clear nights.

4.3 Condensation in sheeted roofs

The problems of the insulated sheet roof (described in section 5.2 of Part 1) were known 30 years ago when the National Building Studies Research Paper 23 was being written.

A remedial solution for existing buildings (AJ 12.6.85 p73-74) uses injected foam insulation beneath the sheeting to separate the cold sheet from water vapour in the cavity.

The equivalent to this for new work is to lay the sheeting on preformed insulation of low permeability, so that there is no air space between sheet and insulation. The alternative, suggested by some authorities, is to lay a vapour permeable but waterproof membrane on top of the overpurlin insulation, to shed condensate to the eaves. This does nothing, however, to stop condensation from ambient air, and the fixings appear to be a weak spot leading water to the inside. It is also doubtful that the lap jointed membrane is truly waterproof.

One of our consultants felt that there was no real solution at the level of expenditure developers of this kind of industrial unit would entertain. In his view the sheeting should be used to support external insulation.

The example on the next page shows some of the details developed from Scandinavian practice where highly insulated profiled aluminium roofs are widely used. They minimise the number of vapour retarder penetrations, and pinch these between two flat surfaces.

4.4 Lead roofs

One of the examples in the first part of last week's article was the perforated lead roofs.

The Ecclesiastical Architects' and Surveyors' Associations work in conjunction with the Lead Development Association found two primary factors and several secondary ones:

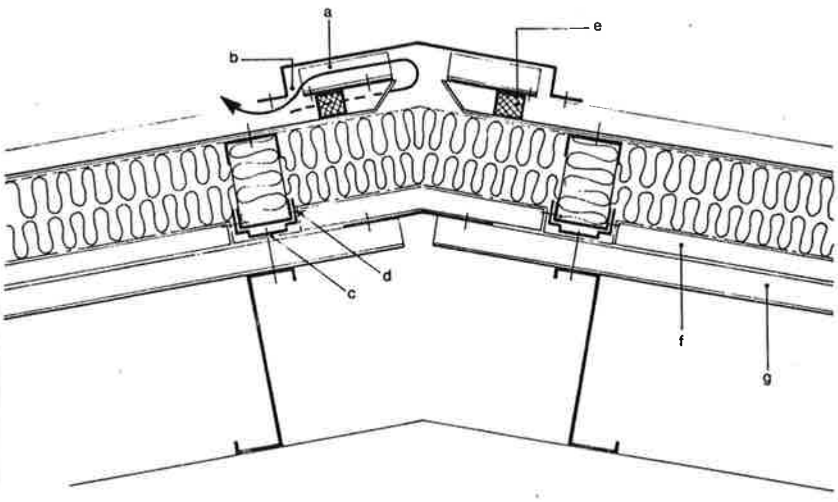
- corrosion of the underside of lead sheet only happens in the presence of moisture
- corrosion can be aggravated by the presence of rotten softwood or sound hardwood, especially oak, which release acids
- the harmful progressive corrosion that produces lead oxides and hydroxides is encouraged by pure water (condensate is distilled water) and air low in CO_2. Without these factors the corrosion is non-progressive producing lead sulphate.

The best defence measures are therefore:

- not to use oak or other hardwood decking
- to specify gap boarded decking and arrange ventilation of the soffit to remove condensate and avoid low CO_2 levels. EASA suggest that by ducting to spaces that are closed off it may be possible to produce natural circulation even there, since mechanical ventilation is expensive and its purpose may be forgotten.

TECHNICAL

18a



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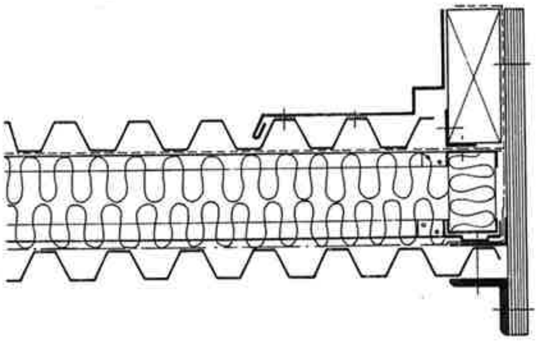

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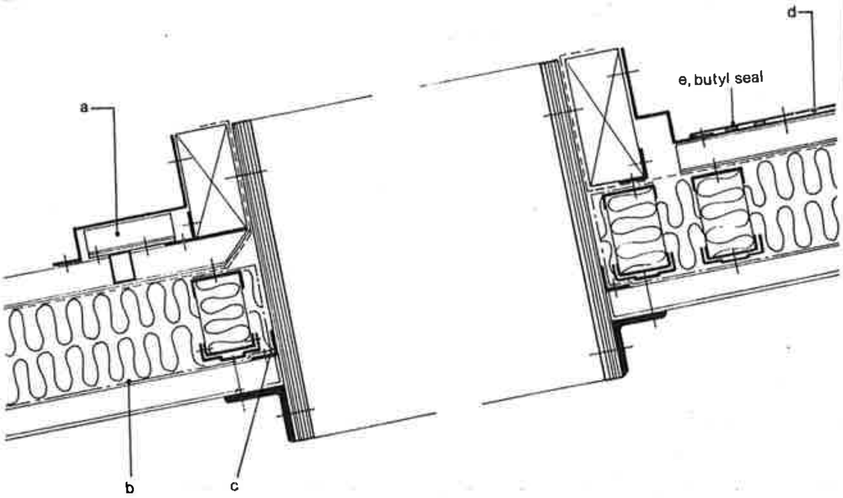


Avoiding sheet roof problems

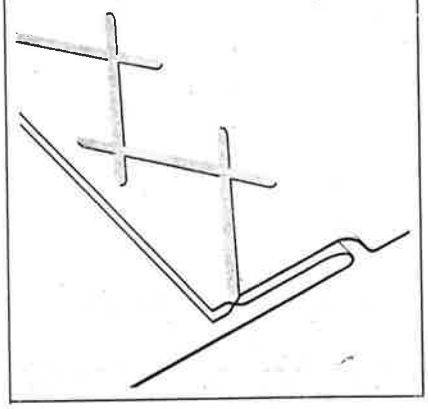
The degree of care needed to avoid the kind of condensation problems with profiled cladding described in section 5.3 last week is illustrated by these details. They were supplied by Design & Construction, a wholly owned subsidiary of Korrugal UK.

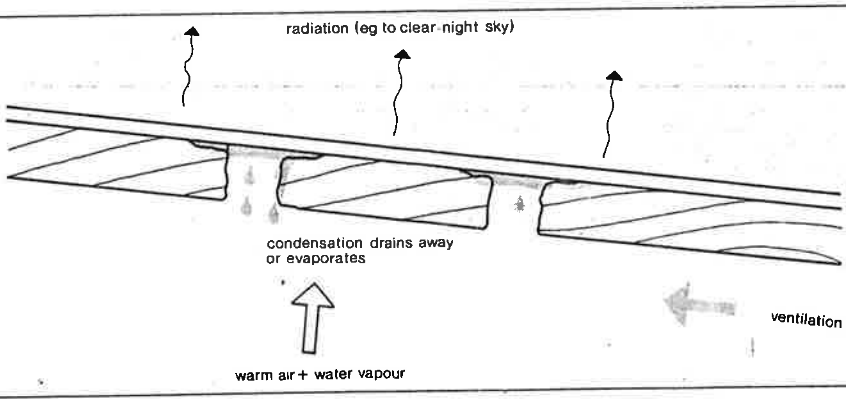
Bottom right, herringbone pattern used for welding polythene v.r. is more reliable than an end-to-end weld.

Below, welding machine for heat sealing the sheets of polythene.

Top left, ridge detail. The ridge cap is supported by a narrow section of profile sheeting, a, to prevent foot traffic deforming it. The ventilation rate can be influenced by the degree of obstruction to the air path, b. The only vapour retarder penetrations are where it is sandwiched between the spacer shoe and the inner sheet, c.
Spacers are fixed to their continuous shoes through the sides, d.

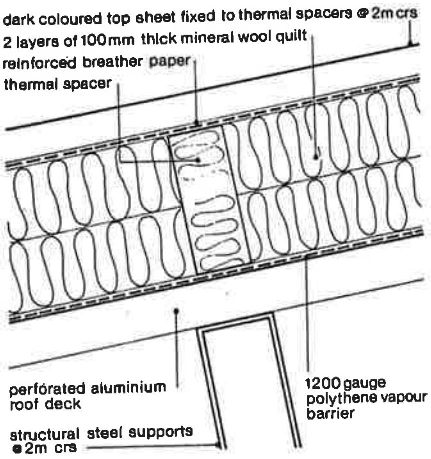
Left and below left, opening to receive a ventilation fan. Ventilation of the top sheet is maintained, a, as in the ridge detail. Vapour retarder, b, is all around opening, c.
A flashing, d, is taken up to and under the ridge cap.





Lead roofs

The Ecclesiastical Architects' and Surveyors' Associations report on the internal corrosion of lead roofs found that gapboarded decking allows air to circulate more freely helping to disperse condensation. It also makes it less likely that air pockets remain depleted in CO_2 next to the metal, as a result of chemical action. Low CO_2 gives progressive corrosion products. Hardwood decking, especially oak, should not be used.



7 Detail of pool roof in 8.

5 Heating

There are two aspects of heating system design to consider in connection with the condensation problem: temperature and intermittancy.

5.1 Design temperatures

As a rule design temperatures are set by comfort considerations rather than by the avoidance of condensation. One exception is ceiling voids and plant spaces above swimming pools. These spaces are often 2-3°C above the air in the pool hall simply to avoid condensation. They are frequently at a positive pressure to the pool space too.

5.2 Heating and insulation: housing

The recommendations of the BRE *Remedies for condensation and mould in traditional housing* on the balance between heating and insulation can be summarised as follows:

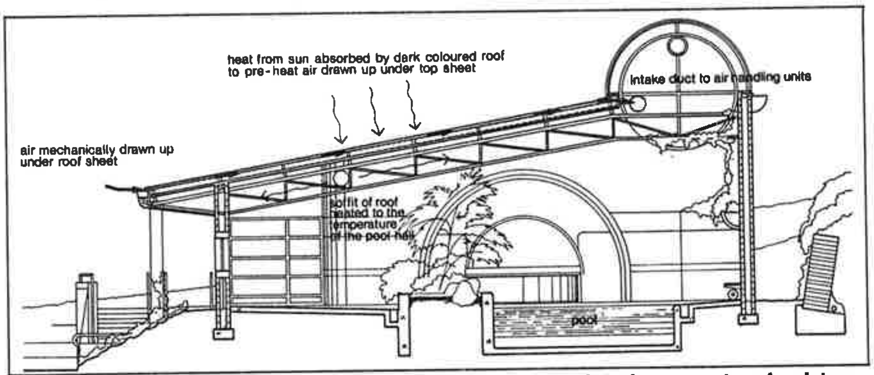
- in two-storey houses or maisonettes with bedrooms over heated living areas, insulation without extra heating may be enough
- in flats and bungalows extra insulation has little effect in unheated bedrooms, and background heating of the room works better
- heating improvements alone can control condensation but at higher fuel costs

5.3 Intermittancy

The problems caused by failure to reach the steady state design temperatures were outlined in section of Part 1, section 4.3.

Buildings that are not occupied all the time are likely to be heated only intermittently. If it is known that this will be the pattern there is a case for making the fabric quick to respond (low thermal inertia). This tends to mean lightweight construction probably with insulation at the inner surface.

Buildings with solid floors, and masonry for external and internal walls have high thermal inertia. Lining the outside walls with insulation will only partly offset this because the floors and partitions remain as surfaces unresponsive to intermittent heating. They should be heated continuously.



8 Dursley Pool roof draws outside air under top sheet to pre-heat it and sweep out pool moisture. Night condensation may still be a problem (Faulkner Brown Watkinson Hendy Stonor).

6 Mould

Mould growth can be permanently removed only by curing the damp conditions that allow it to flourish in the first place.

The latest BRE research findings are reported in Information Paper 11/85. It includes guidance on the specification of cleaning and redecorating processes.

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BRE

Defect action sheets
- *Slated or tiled pitched roofs: ventilation to outside (design)* May 1982
- 3 *Slated or tiled pitched roofs: restricting entry of water vapour from the house (design)* June 1982
- 4 *Pitched roofs: thermal insulation near the eaves (site)* June 1982
- 6 *External walls: reducing the risk from interstitial condensation (design)* December 1982
- 14 *Wood windows: preventing decay (design)* January 1983
- 16 *Walls and ceilings: remedying recurrent mould growth (design)* January 1983

Digests
- 110 *Condensation*
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- 210 *Principles of natural ventilation*
- 218 *Cavity barriers and ventilation in low pitched roofs*
- 270 *Condensation in insulated domestic roofs*
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- 297 *Surface condensation and mould growth in traditionally built dwellings*

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