CONSTRUCTION RISKS AND REMEDIES CONDENSATION

Several areas of building design and construction exhibit recurring problems. Construction Risks and Remedies is a new occasional series that focuses on these problem areas. The articles will give examples of the most important problems, and will discuss how they are caused and how they can be avoided or resolved.

We begin with condensation, looking at the risks this week and at the remedies next week. Other articles later in the year will be tackling problems associated with thermal insulation and the subject of timber decay.

Part 1: The risks

Contents: Part 1

Contents: Part 2 (AJ 16.4.86)

We should like to thank the following people for their help in the preparation of this article: Lyall Addleson, consulting architect; Dr William Bordass, consulting building scientist; Professor Peter Burberry, UMIST; Keith Darby, architect, Feilden & Mawson; Ecclesiastical Architects' and Surveyors' Association; Peter Falconer, architect, Falconer Partnership; Kenneth Johnson, Pilkington Brothers Research & Development; Roger Jowett, architect, Bickerdike Allen Partners; staff of the BRE, particularly J. L. Smith.

Any assessment of condensation risk has to start with the question, 'does it matter?' Transient misting of windows and mirrors is usually tolerable. Water collecting at the bottom of a window can be coped with by drain holes, although some occupants will complain of draughts. Condensation in a drained and ventilated wall cavity probably does not matter, although some experts view the long-term effect of saturation of outer brick skin and the freeze-thaw cycle with concern.

Buildings are often more sensitive to condensation now than they were when plaster and brick surfaces were more absorbent. A bit of condensation could be 'stored' in such materials and slowly released when the conditions changed. A thin layer of hard plaster on a concrete wall panel does not do this. Buildings were 'leakier', so there was a higher air change rate, and, for some people at least, there was less concern to save energy. Open fires not only warmed the structure, but ventilated the room.

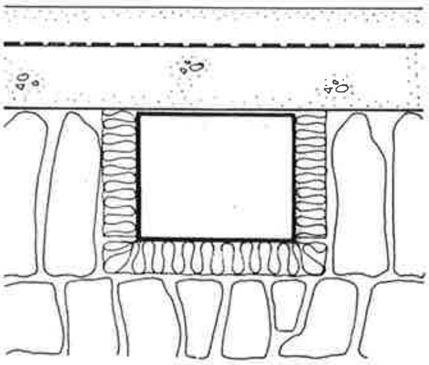
Heating systems now are often used for quick bursts of heat over short periods of the day, which warms the air, letting it take up more water vapour, while having little effect on structural temperature. Condensation risk is greater when the air temperature drops again because of the combination of cold structure and higher dewpoint temperature. Quiet country churches may suffer from this problem just as much as tower blocks.

The acute domestic condensation problem dates from the 1960s, when construction changes were combined with a move to reduce heat lost by ventilation. More recently simple shed-like industrial buildings have been expected to shelter increasingly sophisticated and sensitive operations and equipment without enough being spent on their construction.

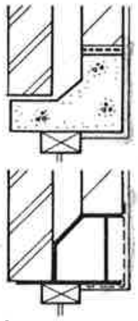
It also depends on an element of informed judgment for which simple adherence to BS codes is unfortunately not an adequate substitute.

RISKS BY BUILDING TYPE

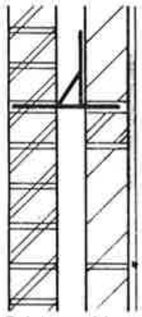
Housing



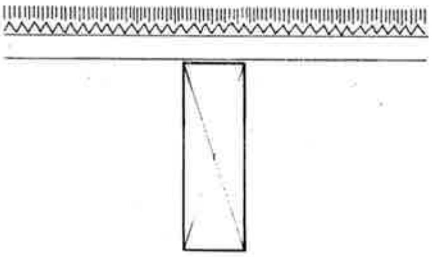
Failure to provide water-protected insulation to underfloor warm air ducts. Condensation caused and water vapour blown round house when system restarts.



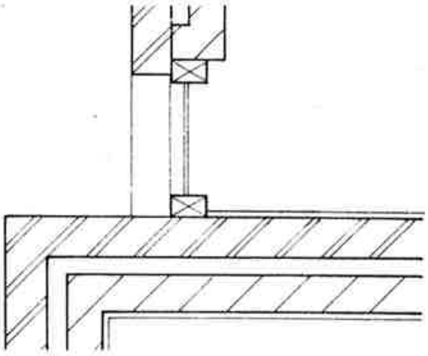
Certain types of lintel act as cold bridge in well insulated walling.



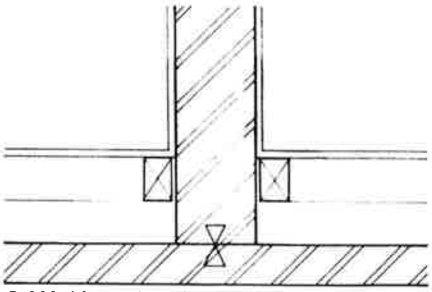
Brick used in blockwork to make up coursing. Local change of U-value results.



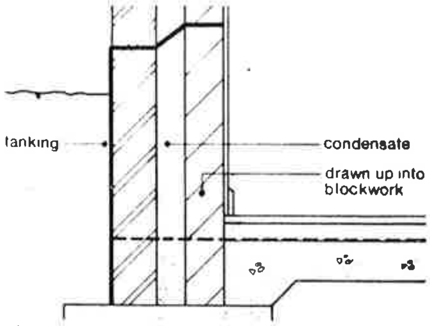
Rubberised carpet underlay prevents stack effect air infiltration through floor construction and forms vapour check. High r.h. caused by construction water or from earth below the floor has caused rot in suspended floor chipboard.



External leaf becomes internal leaf. Mortar bridging cavity or unfilled perpends to blockwork cause condensation staining.



Cold bridge at junction of party wall and external leaf. Structural and fire safety require contact; damp-proofing and insulation require separation.

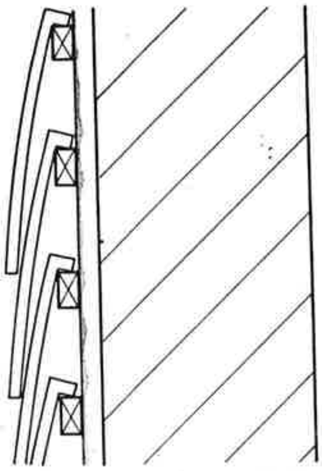


No insulation to the retaining wall. Other examples, for instance failure to continue insulation into eaves, given in BRE Defect Action Sheet No 4, July '85.

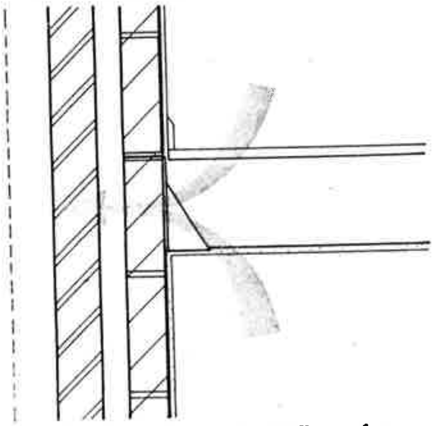
Table I BRE estimate of extent of condensation in English housing*

	Owner occupied/%	*Private rented/%*	*L.A./%*
No condensation/damp	58	48	39
Condensation on windows	33	32	45
Deterioration of paint on sills	9	15	21
Mould or damage to decorations	9	27	23
Damage to floor, carpet, furniture	1	6	3

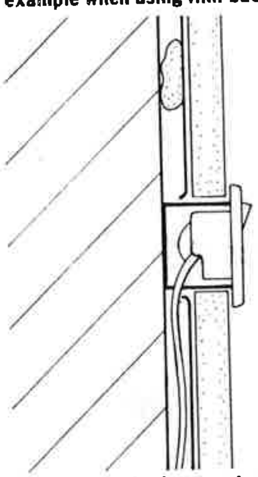
*From BRE Digest 297 May 1985



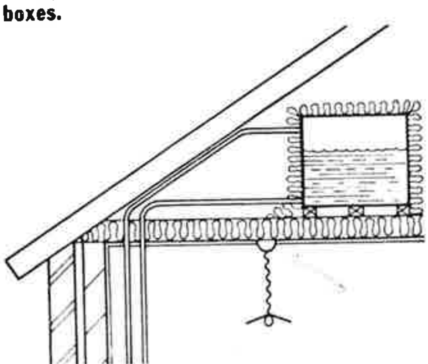
Impermeable material used as sarking behind board or tile cladding. Danger of wall dampness or rot in battens.



Vapour retarder interrupted at floors, for example when using film-backed plasterboard.

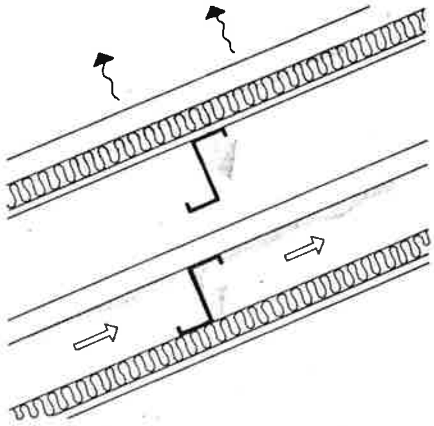


Vapour retarder interrupted in walls, for example by electricity socket and switch boxes.



In roof space over bathroom where pipework penetrates ceiling on way to tanks. Further examples in Defects Action Sheets:
No 1 *Cross-ventilation of roofs* May 1982;
No 3 *Reducing water vapour flow into roof* June 1982;
No 59 *Converting to warm deck flat roof* September 1984.

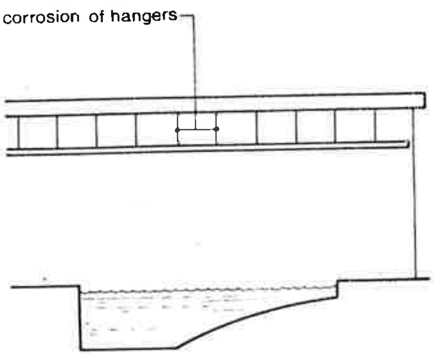
Industrial

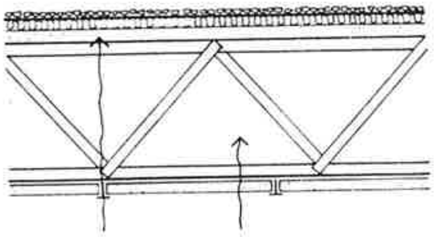


Profiled roof sheeting with insulated or uninsulated lining board. Sheet loses heat by radiation to clear winter night sky, cooling below ambient air temperature. Water vapour condenses, either from factory interior through joints fixings, services and so on or from outside air penetrating from eaves. Ice can form, water collected in/on lining or insulation. Ceiling sags, leaks, falls. Stains may follow line of purlins. Problems from October to April. No obvious difference between steel or aluminium; fibre cement can be affected (see AJ 12.6.85 p73-74), but less so.

Pools

Includes other very humid environments—laundries, knitting and other yarn processing, animal houses.





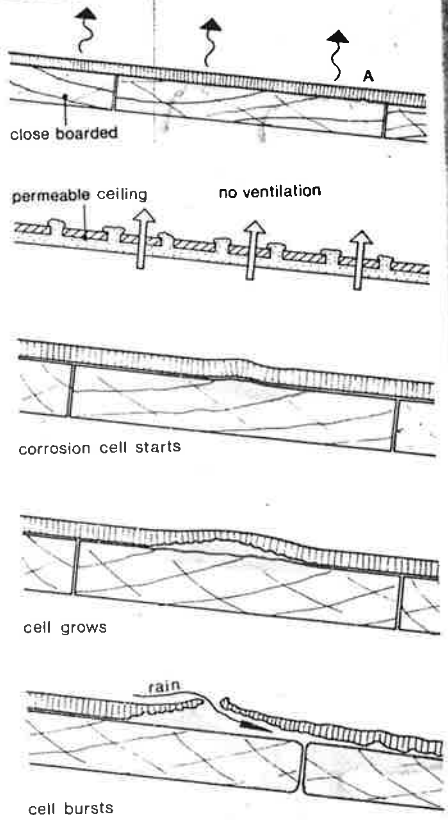
Many failures have occurred in small pools, where conventional built-up felt flat roof relies on natural ventilation. Relative humidity can be 100 per cent inside and condensation occurs on any surface below pool water temperature. Ceiling tiles stain, metal corrodes, chipboard decking and fibreboard insulation sag and rot.

A suspended concrete ceiling over a Swiss pool collapsed when corroded hangers failed.

More sophisticated designs using pressurisation of the ceiling void with heated air have failed when operators reduce temperature, turn off extract fans or reduce flow rates to save energy. If recirculated air is used for pressurisation it has be dehumidified.

Some recent condensation failures have occurred in multi-purpose sports or leisure buildings where the enclosure of the pool part of the building is incomplete. The problems often develop at roof level, where moisture vapour from the pool condenses in the structure of another part of the complex with insulation and ventilation of a lower standard.

Ecclesiastical



The Ecclesiastical Architects' and Surveyors' Association (EASA) is about to publish a report, *Corrosion of lead roofing*. The following is based on its findings. Metal roof to churches are prone to condensation cooling by radiation to the sky. Sometimes condensation on underside of the metal causes corrosion and sometimes rot of the substrate.

Symptoms
- **pin holes, usually in groups, may cause patchy damp inside**
- **hard white discolouration on underside of lead (lead sulphate)**
- **softer, crystalline, loosely adhering voluminous corrosion product on underside or as soft whitish flakey areas on external, especially vertical, surfaces. Spreads over larger and larger areas, causing leaks.**

The first can be a product of the third or a result of external attack or casting sand in the lead. The second is not progressive and forms a protective coat.

Cause
Acetic acid vapour can be emitted from timber, if it is abnormally wet (over 18 per cent moisture content, for example as result of condensation) rate of evolution is aggressive.

Oak is the most aggressive producer of acetic acid vapour, and lead, copper, aluminium and terne-coated stainless steel are all susceptible to it.

The introduction of heating, especially intermittent heating, increases the condensation risk. There is also less ventilation nowadays and, in the major churches and cathedrals where the worst problems have been found, the moisture input has increased markedly because there are so many visitors. The old heating plant was either much more vigorous, with high air flows induced by the flue, or it was on all the time, and did more to warm the structure.

The EASA report suggests that condensation is a key factor. Lead is vigorously attacked by distilled water in the presence of air low in CO_2. If there is little ventilation below the lead sheet, CO_2 in the air may feed the formation of lead carbonate.

RISKS BY PHYSICAL PROCESSES

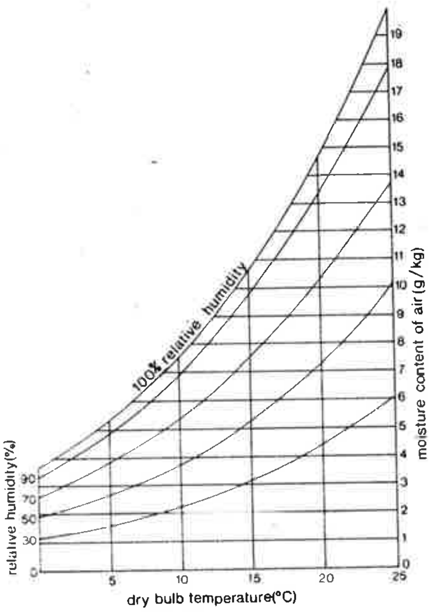
1 Condensation process

1.1 Saturation

There is a limit to the amount of water vapour that air can hold, and this varies with temperature (and barometric pressure, although this is not normally significant). When, because it is cooled, a parcel of air reaches this limit (the saturation point), water may begin to condense. In buildings this is most obvious on visible surfaces, but it can also happen inside materials or in construction cavities. In meteorology the same physical conditions produce mist, cloud, rain, dew, fog and other delightful features of the British climate.

1.2 Dewpoint

From the meteorological world we get the term dewpoint, which is another word for the saturation temperature. The dewpoint temperature is that at which condensation can start to appear. It varies with the ratio of water vapour to air. The excess water vapour is dumped instantly as liquid although in practical terms, since cooling is often a surface phenomenon, large volumes of air are not cooled all at once. The rate at which water then condenses out increases according to how far below its dewpoint temperature the cooling surface is. Condensation continues until the amount of water vapour in the air has been reduced to the new limit applicable to the new temperature. The physchrometric chart, *1*, shows how temperature and water vapour content are interrelated.



1 Psychrometric chart.

1.3 Vapour content and structural temperature

Basically condensation risk arises in buildings because the air inside contains more water vapour than that outside, as a result of people or processes inside the building.

Unless this vapour is carried away by ventilation and replaced with drier air, the air in the interior will become saturated, and moisture will condense in and on the fabric and contents of the building wherever the temperature is below dewpoint. Vapour may also diffuse through the envelope to the exterior, although this is a slow process. It can lead to condensation within the cooler parts of the fabric. Air carrying vapour can be drawn through cracks by wind or stack effect pressures into cold parts of the construction.

Thermal insulation, in the right places, can reduce this risk and the likelihood of condensation on internal surfaces by raising the temperature of the fabric. In the wrong place insulation can exacerbate the problem by making parts of the fabric colder. Space heating plays a dual role. By raising the structural temperature, condensation risk can be reduced. However, warmer air can absorb and transport more water vapour to cooler parts of the building and intensify condensation there.

As a rule, naturally ventilated buildings that do not house a moisture producing material or process are not subject to condensation. Condensation *can* happen in these buildings, simply as a result of changes in weather conditions, but in most cases this is a transient and fairly unusual phenomenon (however, see night sky radiation, 5.2 below).

The basic principles are therefore quite simple. Unfortunately, as one moves away from these broad generalisations towards a quantitative analysis of the processes, complexity and uncertainty increase.

2 Water vapour input

On a typical winter's day, outside air at 90 per cent relative humidity (r.h.) and 5 °C contains about 5 g/kg of water vapour. Bring this air into a building and heat it to 20 °C and its r.h. will drop to about 35 per cent. At 20 °C it can hold about three times as much water vapour. Table II shows some estimates for the rate of water vapour emission of a range of (mostly domestic) activities. In non-domestic buildings the main sources of water vapour will be people and any particular (industrial) processes that are carried out inside.

One other major source of water vapour is the mixing water used in many construction materials. A new house may contain 4000 litres of water (see Table I). This is released over a year or more and can upset anti-condensation measures.

The energy required to dry construction water out, in the form of latent heat of evaporation, can absorb a significant part of a heating system's output. Lower room and structural temperatures resulting from this may also add to the condensation risk.

It has to be emphasised that these figures are only estimates, and wherever they are related to the behaviour of the individual there can be wide variations. Figure 4 shows how different values for the moisture content of the air can affect the prediction of condensation risk.

Particularly in houses, where the volume of rooms is small, it is important to try out a range of values for vapour input, and thus relative humidity, when doing condensation risk calculations.

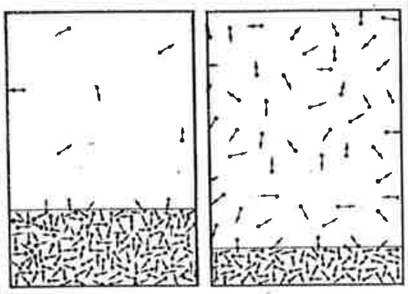
BS 6229, the code for flat roof design, was criticised by all the experts we spoke to, and one of their objections was too close a reliance on specific moisture input rates.

Table I Construction water

Material	*Water in litres/m²*
105 mm brickwork	33
100 mm blockwork	40
150 mm in-situ concrete	30

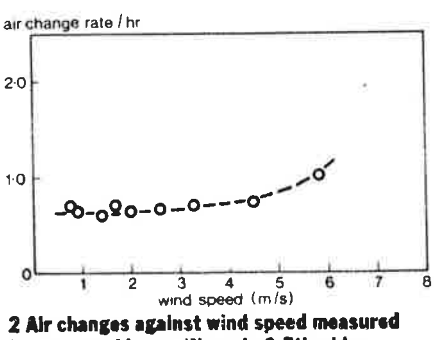
Box 1: Physics and terminology

On the kinetic model, molecules are in constant motion and as the temperature is raised this activity increases. The more energetic molecules in a pool of water can escape into the air above, evaporate, where they contribute to the total atmospheric pressure by an amount called the water vapour pressure. The warmer the system is, the more molecules there are that are active enough to enter the vapour phase, and the water vapour pressure increases. The overall activity of the system—its temperature—determines the maximum number of water molecules that can exist in the vapour phase, and air that is holding this maximum number is said to be saturated. The vapour pressure at that point is the saturated water vapour pressure.



Lower temperature. Higher temperature.

The figures above demonstrate the effect (after Burberry). Some other terms and their units are:
Absolute humidity (or moisture content)—weight of water vapour per kilo of dry air: unit kg/kg or g/kg.
Mixing ratio—ratio of mass of water molecules to mass of air molecules in the sample (essentially the same as absolute humidity).
Relative humidity, r.h.—the quantity of water in air as a percentage of the maximum which could be contained in air at that temperature: units: percentage r.h. at temperature °C.
Vapour diffusivity— the rate of vapour transmission through unit thickness of material under unit pressure differential: units, kgm/MNs or gm/Ns. In practice it is often easier to work in diffusance which is the rate for any stated thickness of material.
Vapour resistivity, r_v—reciprocal of vapour diffusivity: units MNs/kgm or MNs/g.



2 Air changes against wind speed measured in a terraced house (Nevrala & Etheridge, British Gas).

Table II Water vapour emission rates*

Source	*Rate*	
People (respiration):		
resting or asleep	0·04 kg/hr/person	
sedentary activity	0·05 kg/hr/person	
active, sweating	0·2 kg/hr/person	
Combustion in flueless appliances:		
gas	0·81 kg/m³ of gas or 0·64 kg/hour of use for a typical domestic cooker	
paraffin heater	1 kg/litre of fuel	
Laundry:		
clothes washing	2 kg/day	
clothes drying	12 kg/day	
Washing:		
bath	0·05 kg/bath taken	*roughly* 1 kg per day in a five-person house
shower	0·23 kg/shower taken	
dishwashing (3 meals/day)	0·5 kg/day	
Cooking and preparation (excluding combustion)	2·5 kg/deg	
Kettle, boiling	0·03 kg/minute	
Pot plant, respiration and watering	0·84 kg/day	
Wetted surfaces*, pools or tanks: 16 × wetted surface area (m²) × (SVP at water temperature − VP of surrounding air) gives evaporation rate in g/hr		

*after Millbank of BRE.

3 Water vapour movement

Bulk air movement is the main means by which water vapour is distributed. Besides mechanical air-handling, air movement results from pressure effects caused by the wind or by 'stack effect' differences of air density.

Water vapour is not emitted uniformly throughout a building and absolute humidity will vary from room to room. These differences mean that the water vapour pressure (see box 1) is different from place to place. The imbalance creates a driving force, causing diffusion of the vapour. Diffusion is akin to heat conduction and is relatively easy to explain under steady state conditions. A vapour pressure difference causes vapour molecules to move at a rate which depends on the pressure gradient and the permeability of the medium. The movement does not require air movement, as only the water vapour moves.

Work by British Gas and others including Trada, John Laing and Pilkington Brothers, has shown that, in winter, the stack effect is a very important means of ventilation in houses, *2*. Its absence in flats is one reason why they may suffer more serious condensation than maisonettes or houses.

Although design calculations for condensation risk and its removal need figures for ventilation rate and diffusion rate, there is still a great deal of uncertainty in this area. Computer programs and design methods are available, for example in BS 5250 (the code on condensation in dwellings) and BS 6229 (the code for flat roof design), but they are based on assumptions that might not be appropriate to the problem.

3.1 Diffusion: the uncertainties

The accuracy of BS 5250 calculations to check the risk of condensation is very limited. A good computer program based on the BS may help, not because it is more accurate, but because it allows several 'what if' calculations to be done to test the sensitivity of the design. Very few programs are based on more sophisticated principles of calculation.

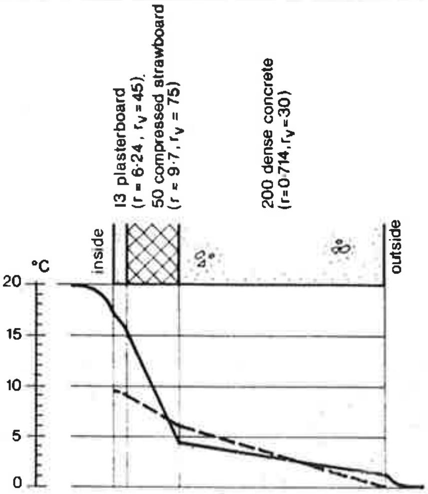
Consider some of the potential inaccuracies in just one factor—the vapour pressure differential across a piece of construction, a roof or external wall that is used for condensation risk calculations. It assumes:

- interior design temperature
- water vapour content of interior air
- exterior temperature and r.h.

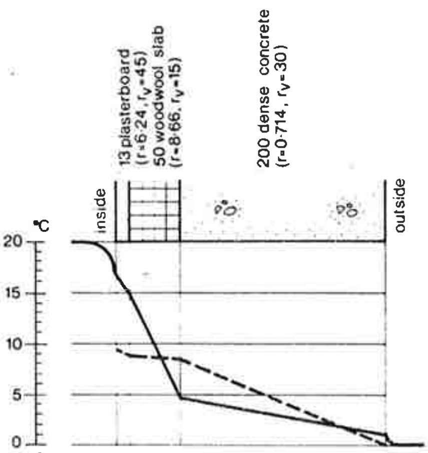
Temperature
Design temperature and actual temperature may differ because of inaccuracies in heat loss calculations, heating system control performance, building occupants' use of the controls, occupants' activities differing from design assumptions, or differences between design and construction. The steady state assumption that internal and external temperatures are constant is also inaccurate.

Water vapour content
The water vapour content of the interior air depends on vapour emission rates which are highly variable both in the short term and over longer periods, according to occupants' behaviour. It also depends on the ventilation rate and the way vapour moves around the building. These factors vary tremendously according to wind speed and direction, whether windows and doors are open, and on the background leakiness of the building (the small cracks and openings that are not designed), *5*.

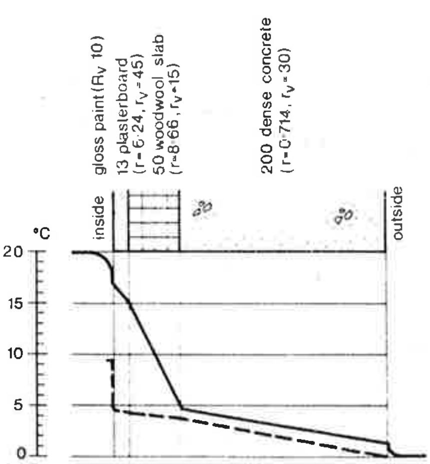
Permeability
The permeability of the construction is another factor on which information is



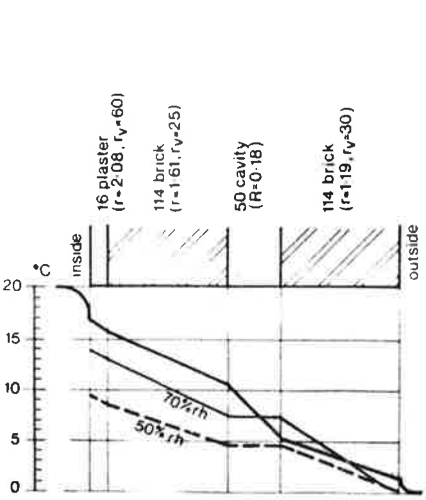
3a Condensation risk example.



3b Effect of more permeable insulation on 3a.



3c Effect of gloss paint vapour retarder on 3b.



4 Effect of different r.h. assumptions.

scarce, divergent and probably inaccurate. The standard permeability tests were devised for use on packaging materials, and the conditions and size of sample may not be appropriate to the environment of buildings. Cracks, openings and variations in material porosity combine with these uncertainties to make it pointless to rely on the accuracy of calculations involving permeability (or resistivity, see box 1). One expert we spoke to said that where low permeability seemed to be important—where a vapour retarder was needed, for example—he tested the calculation to see what was the effect of reducing the resistance of the supposed 'barrier' by a factor of 10. The Swedish-Finnish Timber Council has used the same factor to represent a poor or damaged vapour check. However the methods available are able to sort out the safe from the totally unsafe designs. Figures *3, 4* show how condensation risk assessment is sensitive to some of these factors.

3.2 Diffusion rate

Bearing these qualifications in mind, it is possible to make an estimate of the rate at which water vapour diffuses through the building envelope to outside air.

The expression used is:
vapour transmission rate kg/s =
area of material (m^2)
× vapour pressure across material (N/m^2)
÷ vapour resistance (MN s/kg).
(It is sometimes expressed in g/day).

For composite construction with layers of different materials, the sum of the vapour resistances of the layers is used. There are surface resistances to vapour flow like those used in heat flow calculations, but they are unimportant, given all the other approximations made.

The water vapour pressure difference between air at 22°C and 50 per cent r.h. and outside air at 0°C and 50 per cent r.h. is about 1 KN/m^2. Water vapour will penetrate the slightest weakness in any would-be vapour barrier.

Diffusion is too slow a process to offset most of the vapour emitting processes. For example, diffusion alone might account for the loss of roughly 3 g/hr water vapour through a 225 mm external wall of permeable brick of 6 m^2 area. A person sleeping in the room would produce about 40 g/hr of vapour.

3.3 Air movement

Water vapour can be moved much more rapidly by bulk air movement than by diffusion. In the example in 3.2 above, where diffusion could not cope, the r.h. could be maintained at 60 per cent by introducing air from outside (0°C, 100 per cent r.h.) at less than one-third air change per hour.

Unfortunately, if air movement is the main mechanism of water vapour transport, the risk of condensation is much harder to estimate than if diffusion rules. This is because, as already explained, natural ventilation is highly variable. Nevrala & Etheridge* found that at low wind speeds (up to about 4 m/s when ambient temperature is 20°C) stack effect dominates air movement, *2*, but above that 'large changes in ventilation rate due to changes in wind speed and direction are likely to occur often'. However, work on natural extract systems for houses using the stack effect (discussed in detail next week) has shown that it is possible to design a self-regulating system that functions at low wind speed without being draughty when it is windy.

3.4 Intermittent heating

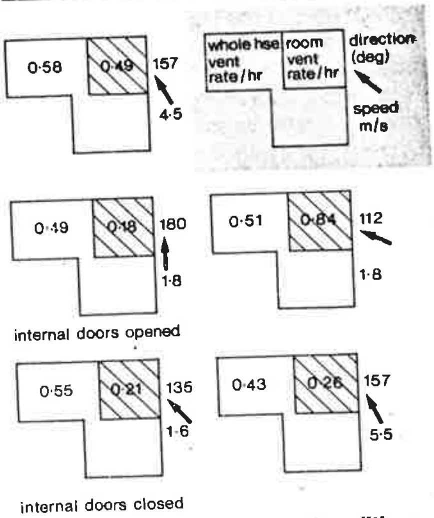
Design based on steady state heating with an unchanging temperature profile through the structure can be misleading, as figure 6 shows.

Ventilation of domestic buildings, No 6 in Energy Efficiency Studies series paper by Nevrala & Etheridge.

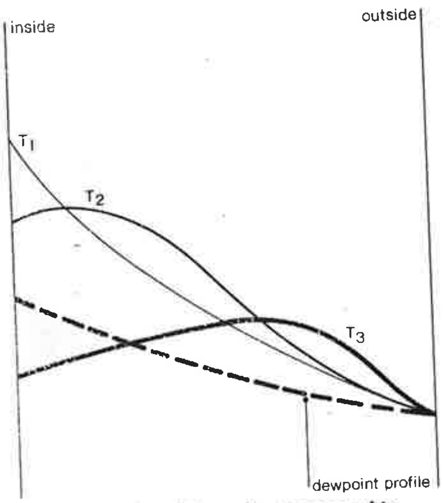
Table III Water vapour resistivity—examples of the range of values*

Material	*Resistivity GN.s/kgm*	*Resistance GN.s/kg*
Aerated concrete	40-54	
Aluminium foil		175-10 000
Asbestos cement	2·08-3·5†	
Brickwork	25-100	
Corkboard	250-333	
Expanded polystyrene	100-600	
Exp. polystyrene bead board (25 mm)		6·7-10·5
Foamed polyurethane, open cell	29-181	
Foamed polyurethane, closed cell	1000	
Foamed ureaformaldehyde	20-33	
Fibreboard	15-60	
Hardboard	500-1000	
Kraft paper		0·22-0·62§
Gloss paint, average		7·5-40
Mineral wool	6	
Plaster	60	
Polythene (0·1 mm)		219-250†
Roofing felt		4·35-100
Plywood	1500-6000	
Woodwool slab (25 mm)	14·3-41·6	0·24-0·32

*From Prangnell R. D., *Materiaux et constructions* no 24, vol 4—Nov-Dec 1971 †Varies according to whether 'dry cup' or 'wet cup' test method is used §Range covers from single ply to five ply paper



5 Ventilation rates vary with wind conditions (British Gas).



6 Consideration of dynamic, as opposed to steady state, heating conditions may show risk of condensation. T_1, T_2, T_3 are structural temperature profiles as the element cools down from design room temperature to cold. Intermittent heating in heavy weight structures can give surface condensation.

4 Conditions for surface condensation

Surface condensation occurs because air that is 'too' heavily loaded with water vapour meets 'too' cold a surface.

4.1 Walls

Table IV lists factors that have a bearing on surface condensation.

4.2 Roofs/ceilings/floors

The general causes of surface condensation are much the same as for walls. Ground floors at the perimeter and projecting upper floors can exhibit cold bridge effects, especially where the latter are in-situ concrete. A similar problem has afflicted ceilings under inadequately insulated external balconies and walkways (AJ 1.8.79 p222). Solid floors with edges that are exposed on the perimeter or concealed only by thin cladding, such as brick slips, also form cold bridges.

Ceilings beneath pitched or flat roofs with voids of significant depth (not solid concrete roofs) are not often prone to surface condensation because they are relatively light and warm up quickly and because they benefit from the insulating effect of the void above (which almost always has some added insulation nowadays).

But serious condensation on surfaces within that void, and especially the underside of the roof, is common. The particular problems of ceiling voids over swimming pools and high humidity industrial processes, and from the night sky cooling of metal roofs, were mentioned in the first part of this article.

BRE Defect Action Sheets 1, 3, 4 and 59 address the condensation problems caused by providing insulation at ceiling level without taking steps to reduce the movement of water vapour into the roof space, and to ensure its removal by adequate ventilation.

4.3 Mould growth

Mould on walls, floors or ceilings is evidence of dampness of that surface and condensation that persists for any length of time will give rise to it. Once established, many kinds of mould can withstand drying out. A relative humidity of about 70 per cent is the minimum level in the atmosphere that will sustain growth. Some surfaces, wall paper beside a window sill for example, can be saturated with condensate running off adjoining construction even though the atmospheric r.h. is below 60 per cent.

Moulds can grow without light. They flourish in or on paint films and on wall paper and wallpaper paste. Vinyl papers, though relatively impermeable, can suffer stains from mould growing underneath them.

There is some evidence that high concentration of mould spores can be a contributing factor in sick building syndrome. Some people are allergic to certain spores. Spore concentrations in rooms with heavy growths will be much higher than normal.

Table IV Causes of surface condensation on walls

Surface too cold: room inadequately heated	Heating can raise the surface temperature of structure and reduce risk, but condensation may become interstitial. If ventilation is not adequate, heating may also promote processes that cause more condensation to occur
Room intermittently heated	Heavy construction slow to heat up, stays or becomes below dewpoint as air temperature rises, especially if ventilation inadequate. If the heated air takes up more vapour there is more chance of condensation on the still-cold structure when the heating goes off because the dewpoint temperature has been raised. Same total amount of heat at lower level, but constant, might avoid condensation
Lack of insulation	Surface resistance to heat transfer means surface temperature always below internal air temperature, if U-value is poor, for example, single pane glass, condensation can occur, though r.h. in room is only 40 per cent. Planned condensation on glass can dehumidify the air somewhat
Cold bridge	Local reduction in insulation or increase in external surface area such as solid lintel, metal window frame or external fin
Local internal insulation	Furniture, curtains and so on reduce heat transfer from rest of room and allow local cooling of surface and air
Radiative losses	Areas such as window reveals can lose heat by radiation through glass to cold night sky, the geometry of corners increases the surface to volume ratio and therefore radiation losses
Relative humidity too high: water vapour emission rate too high	Some activities, see Table III, have particularly high vapour emission rate
Ventilation rate too low	Condensation is bound to be a problem unless average water vapour removal rate is removed as fast as it is being added to the air

Box 2: Identifying condensation

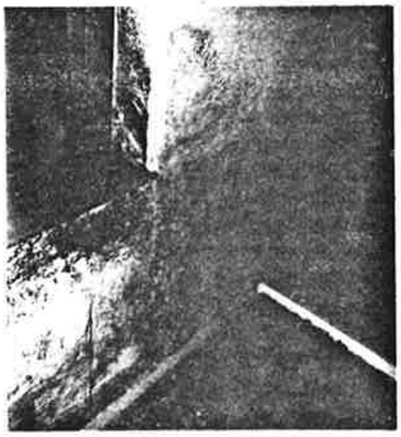
When damp occurs in a building, condensation is not the only possible cause. It could be the result of rain penetration, rising damp or leaking pipes or tanks. How do you tell?

Condensation problems are related to the weather to some extent. They tend to be a winter phenomenon, especially when there is little wind, the r.h. is high, or the nights are clear. If the symptoms coincide with periods of rain, then the chances are that it is a penetration problem rather than condensation. But there are exceptions to this, such as the condensation caused by the flow of cold rainwater in pipes or gutters.

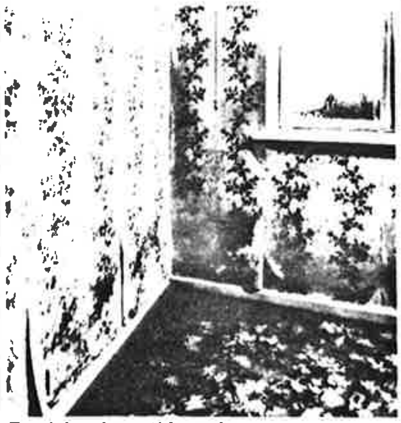
Condensation damp patches tend to be diffuse, *A*, without sharp edges, whereas rising damp often produces a tidemark effect, *B*. Condensation often shows around openings where there are cold bridges (for example, solid lintels) and the possibility of radiation to the outside, or where the external surface area of the wall increases locally so that heat loss is greater.

The upper corners of rooms, especially at eaves level, are very common condensation sites for this reason, and because there is probably less air movement there.

Another sign that a damp problem may be a condensation one is that the markings often have a pattern to them that can be traced to some construction feature, cold bridges due to fixings, for example.



A—typical condensation mould growth in a corner.



B—rising damp tidemark.

5 Conditions for interstitial condensation

As mentioned in section 3, the accuracy of calculations to check the risk of interstitial condensation is severely limited. However, the simple steady state model gives useful information for constructions that respond quickly to thermal and moisture changes, and is a worthwhile indication of the extent and location of possible condensation in other heavier constructions. The point is not to apply these results without reservations.

5.1 Walls

The cases of interstitial condensation in walls that the experts we spoke to have seen were almost all due to breaches in the construction, rather than failure to anticipate the location of the intersection point in the structural temperature and dewpoint temperature profiles. Unsealed openings for services or failure to continue insulation or vapour checks are typical causes.

Many insulation materials have relatively high water vapour permeability and adding insulation to the inner face of walls without a vapour check tends to increase the risk of interstitial condensation. The insulation lowers the structural temperature while making little or no difference to the dewpoint profile, 7. If a less permeable insulant is used, more care is needed in detailing and construction to avoid gaps which would probably cause heavy local condensation.

Metal sheet cladding can be cooled below ambient air temperature by radiation to a clear winter's night sky. The space behind the cladding is often ventilated to the exterior and condensation is possible if the r.h. is high, regardless of conditions inside the building and whether there is a vapour barrier in the wall or not. Theoretically cladding finished in dark colours should be at greater risk, but in practice the differences are minor.

5.2 Roofs

The outer surface of a roof with radiation losses to a cold night sky (with an effective temperature that can be as low as $-50°F$), it can be the coldest part of the building. In built-up felt and polymeric membrane roofing the outer layers are also of high vapour resistance. There is, therefore, a big risk that water vapour will accumulate below this sort of covering and condense. Added to this is the difficulty of ventilating the spaces between joists of a typical domestic-scale cold deck flat roof.

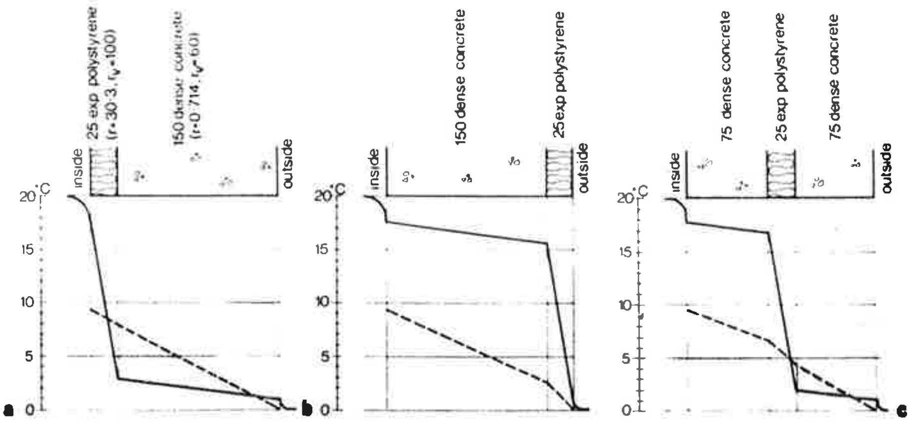
The other widespread cause of roof condensation has been the extra insulation we now install at ceiling level. Experience of insulation above, or at, rafter level suggests that this may be a more certain way of avoiding condensation. The roof space is warm and does not require cross-ventilation, so does not depend on wind to prevent condensation. However, it is more expensive.

Some experts we spoke to would not consider using a flat roof with insulation below the waterproofing layer, because they consider the chances of failure are too high.

In the AJ of 12.6.85 (pp73-74) the increasingly common failure of sheeted industrial roofs was discussed. It is interesting to find that the then Building Research Station investigated the problem in the mid-1950s (National Building Studies: Research Paper No 23 *Condensation in sheeted roofs*, HMSO, November 1957).

There are at least three main features to the industrial roof problem: the impossibility of stopping water vapour penetration into the roof from below, the large and rapid swings in temperature under the metal top sheet, and the large areas of construction involved.

In most cases penetrations of the inner lining boards for fixings and services and the gaps between boards allow vapour free entry to the roof, helped by stack effect and wind pressures. Condensation occurs in or above the insulation, and ice is often formed. This melts quickly in the morning sunshine and in effect concentrates the product of an otherwise slow condensation process. In any large roof it is likely that there will be flaws in the construction to let the water into the building. Fixings also loosen enough with time to let water through.



7 The effect of putting insulation in different parts of the construction; a, on inner face, b; in the middle; c, outer face (after Addleson).

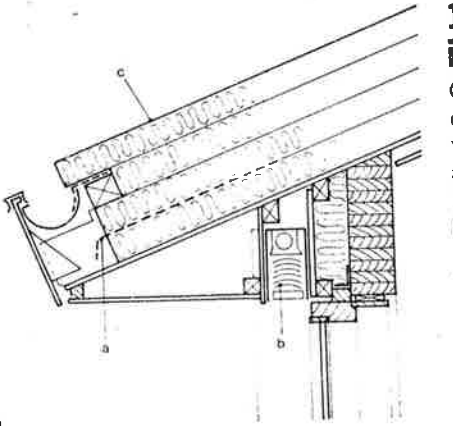
CONSTRUCTION RISKS AND REMEDIES

CONDENSATION

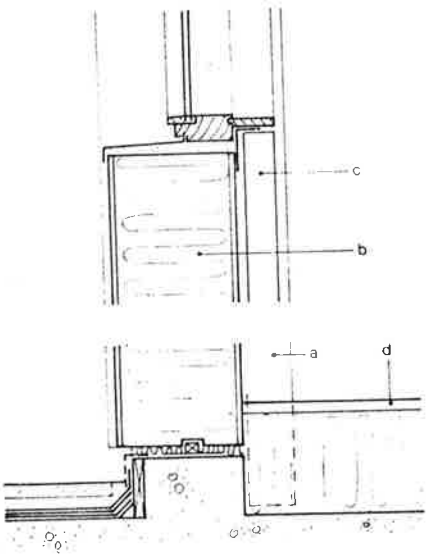
A253

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

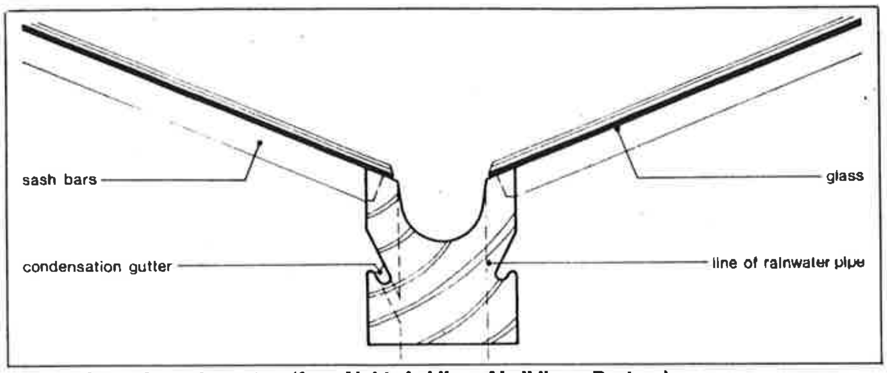
2.1 Dehumidification, controlled condensation

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.

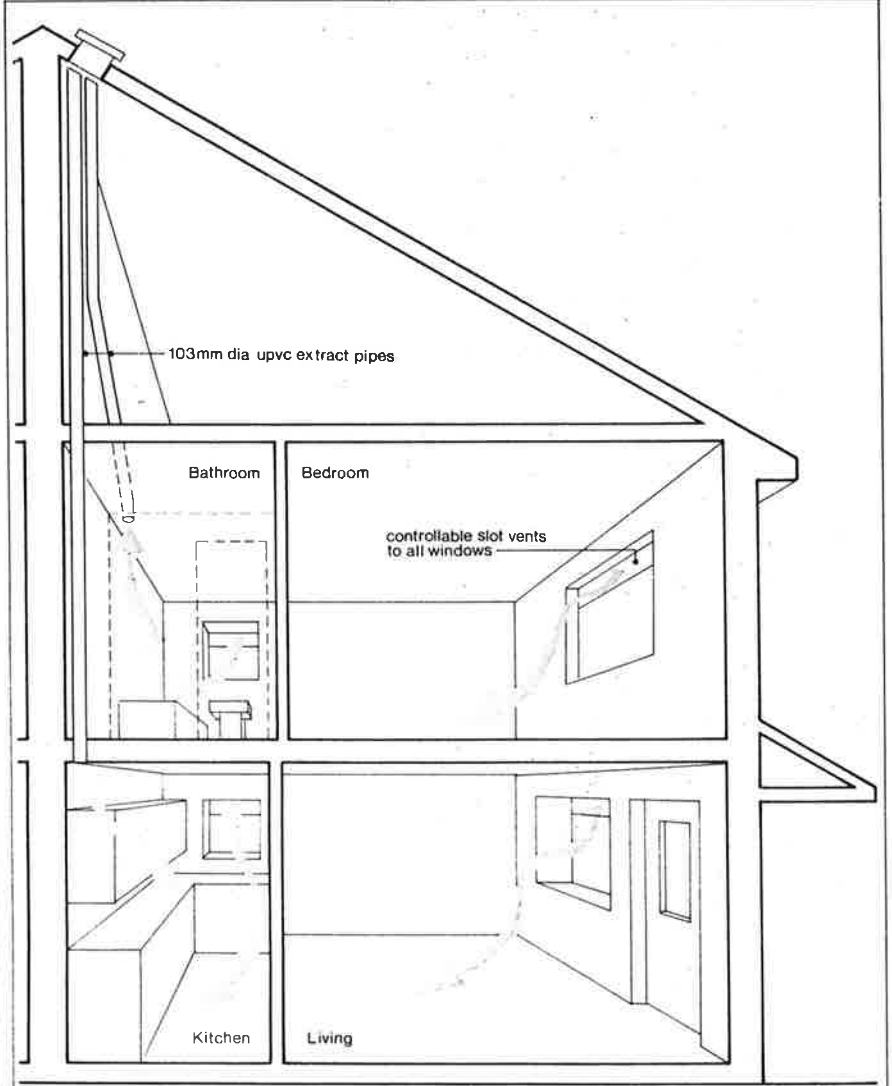
The BRE and others have experimented with dehumidifiers in houses and mobile and built-in electric machines have been on the market for several years. The conclusion so far has been that they will do some good in well heated spaces that have condensation problems, but in cold rooms they have no more 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.

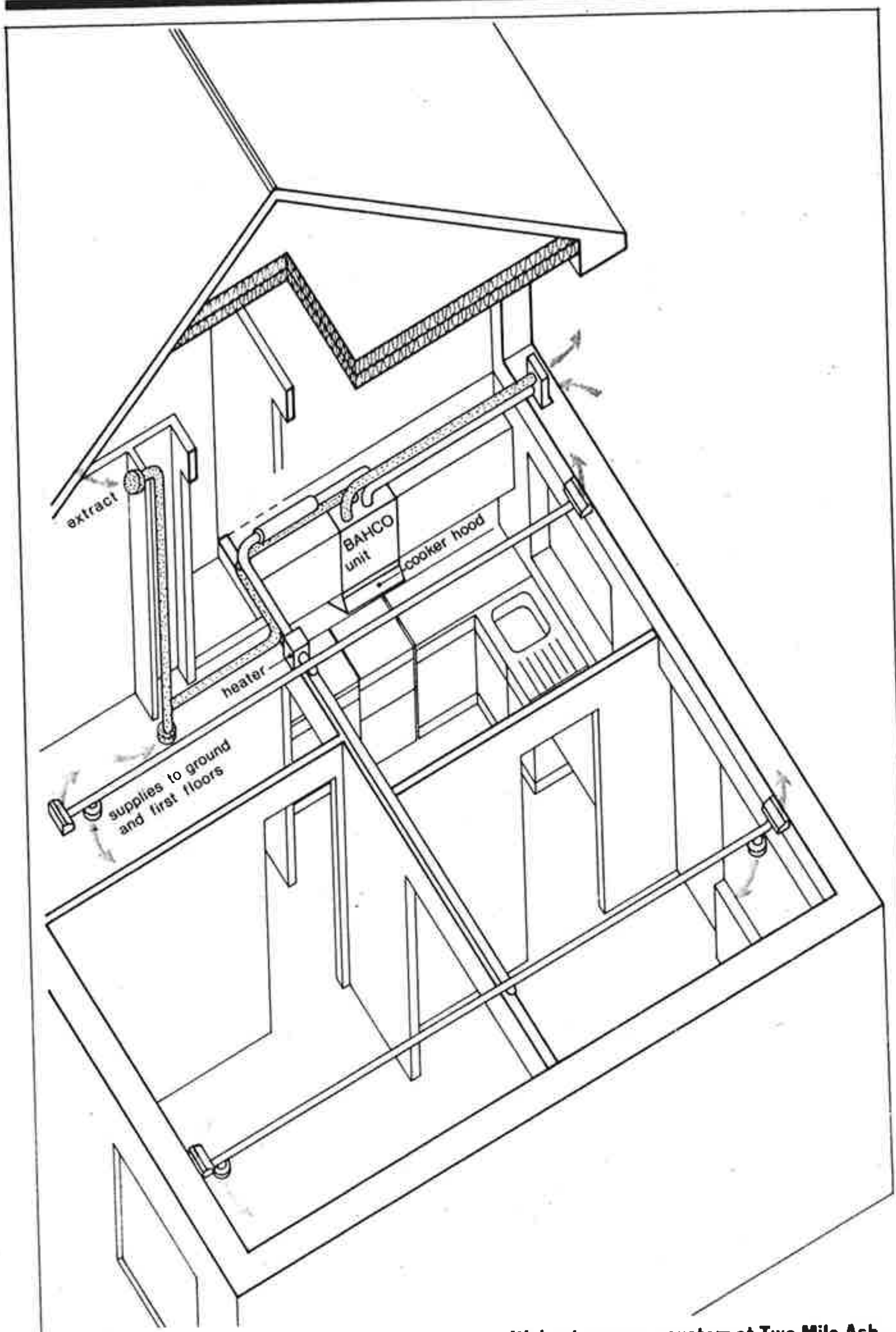
Extractors should either be ducted or positioned near cooker and sink, above door head level if possible. There must be sufficient leakage for make-up air without short circulation or negative pressure on gas appliances. Most tumble driers must be vented to the outside.

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.

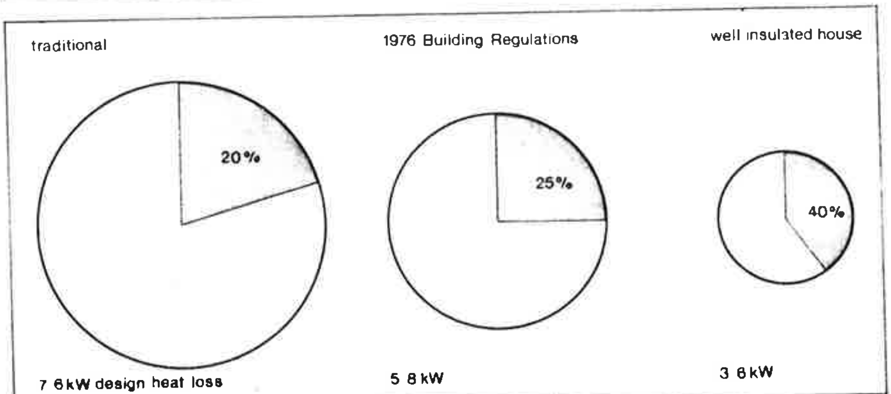


Mechanical extraction of vapour at source comes with heat recovery system at Two Mile Ash.

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.

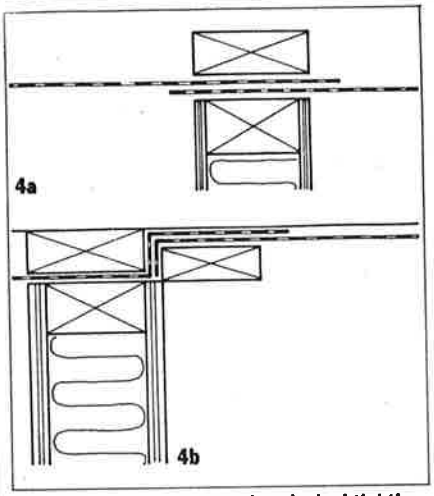
On still nights these cold roof spaces will contain condensation. The 1971 DOE publication *Condensation in dwellings Part 2* advised against eaves ventilation with roofs pitched at less than 20° 'in very humid climates', and it specifies Scotland. It suggests a vapour barrier instead.

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.

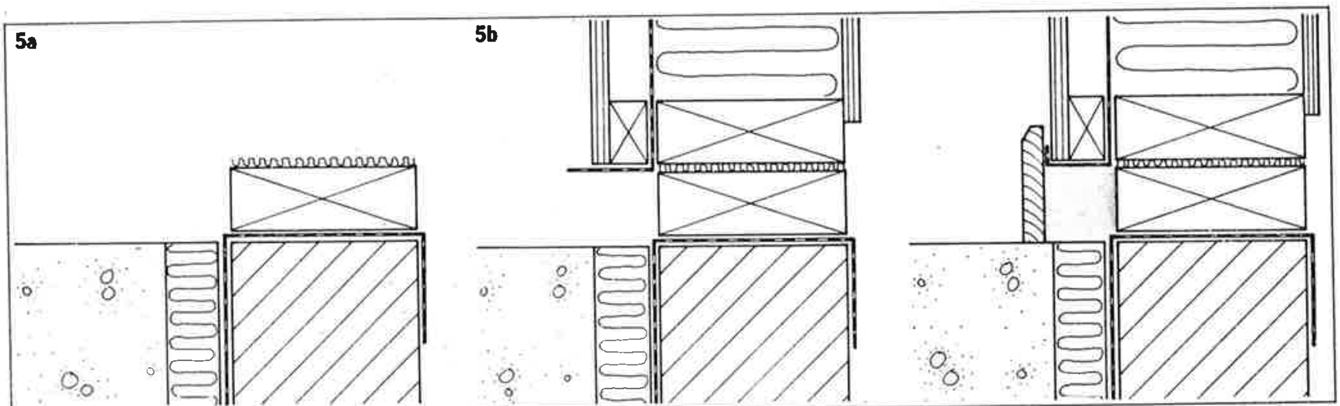
Opinion now favours the warm roof for these situations with the insulation above the rafters, but a steeper pitch with extra vents in the ridge might be a cheaper solution.

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

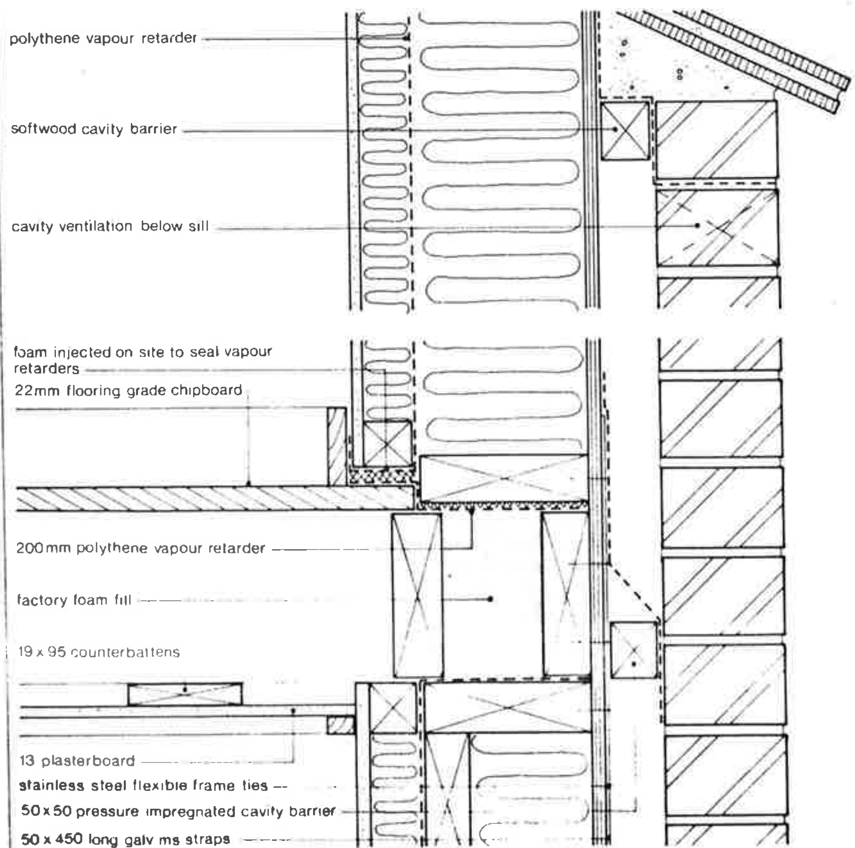
Early advice on vapour barriers underestimated the difficulty of making them work and so the term vapour check appeared. Instead of claiming to stop all vapour penetration the vapour check restricts the 'flow' of vapour so the ventilation that is available in cavities outside the check can disperse moisture 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.



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

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.

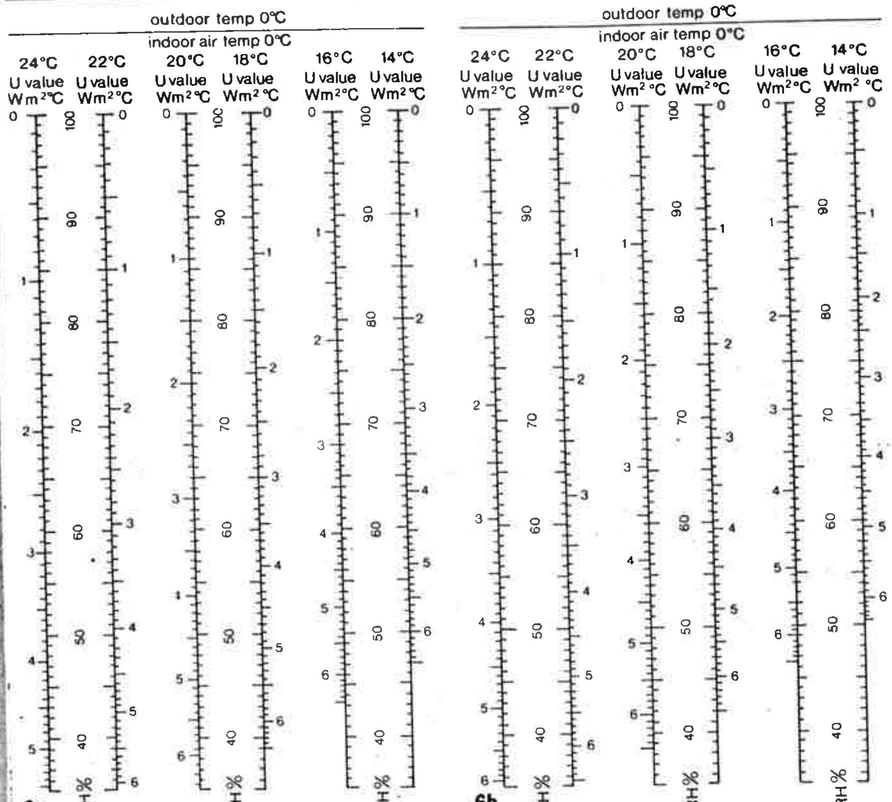
The first floor panel supports the upper wall panels. Cold bridge and loss of v.r. continuity is avoided by factory filling the space between the two trimmers to the floor panel with foam. A 200 mm strip of polythene is fixed to the top of the edge of the floor panel, and over the chipboard floor. A 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.



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.

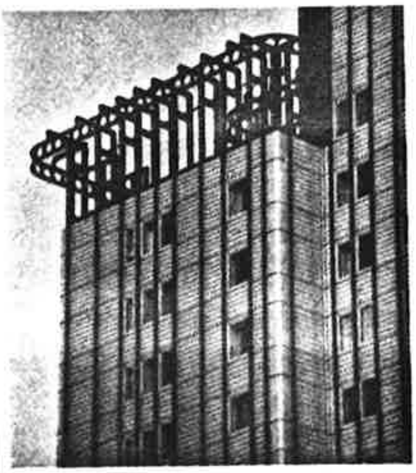
The charts of U-value against ▶ 77

Rainscreen cladding

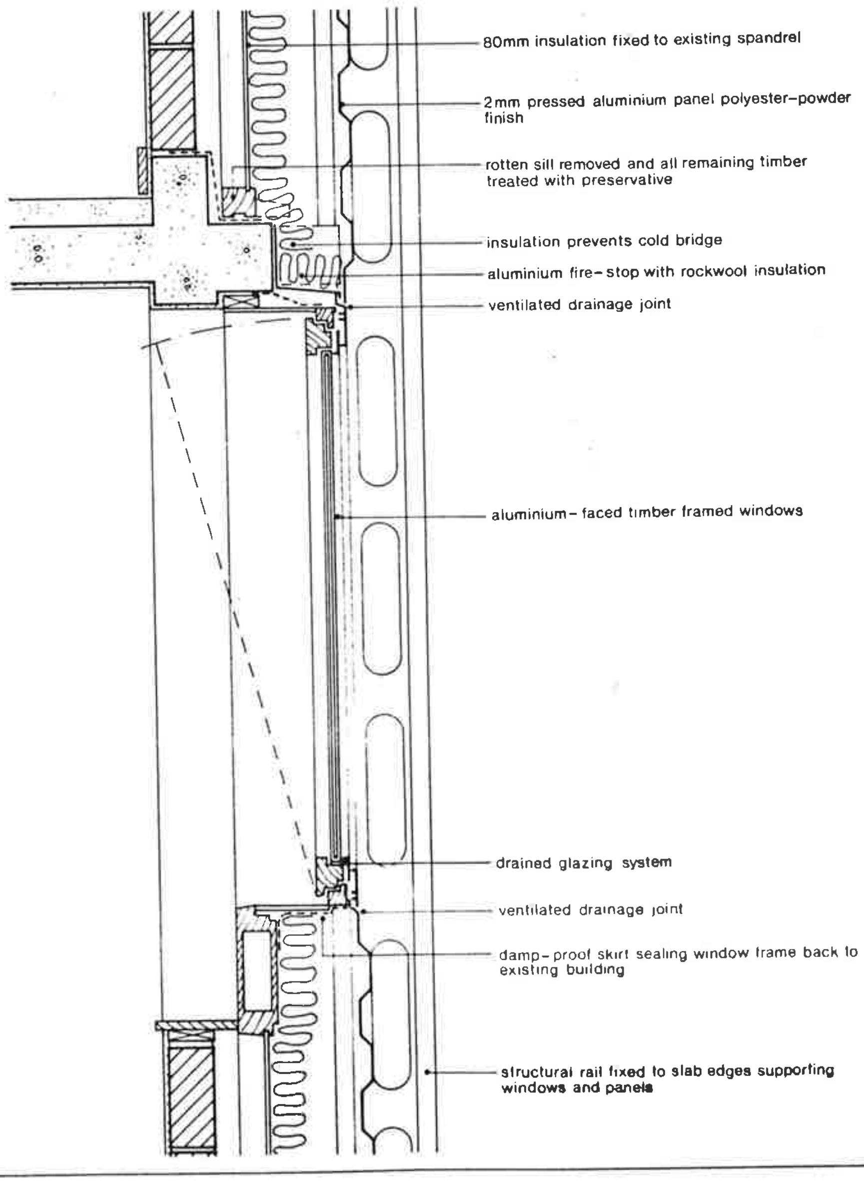
Parson's House is a 20-storey block of flats on the Edgware Road in the City of Westminster. The section shows the construction. The old infill panels were poorly insulated and accumulated condensation was blamed for the rot in their timber sills.

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.

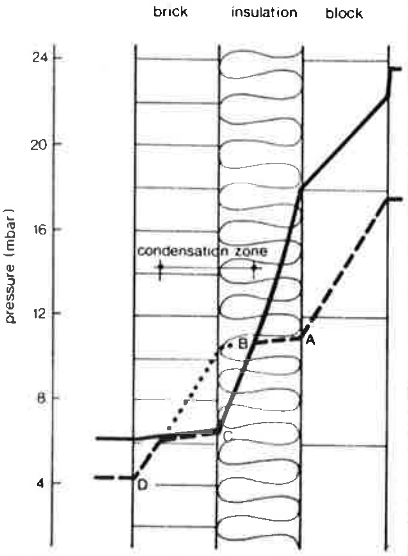
Where the structural temperature drops below the dewpoint temperature (dotted line) there is held to be a risk of condensation.

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 $0 \cdot 12$ $m^2 °C/W$. It is easy to see why condensation frequently occurs on single glazing (U-value $5 \cdot 6$ $W/m^2 °C$). 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.

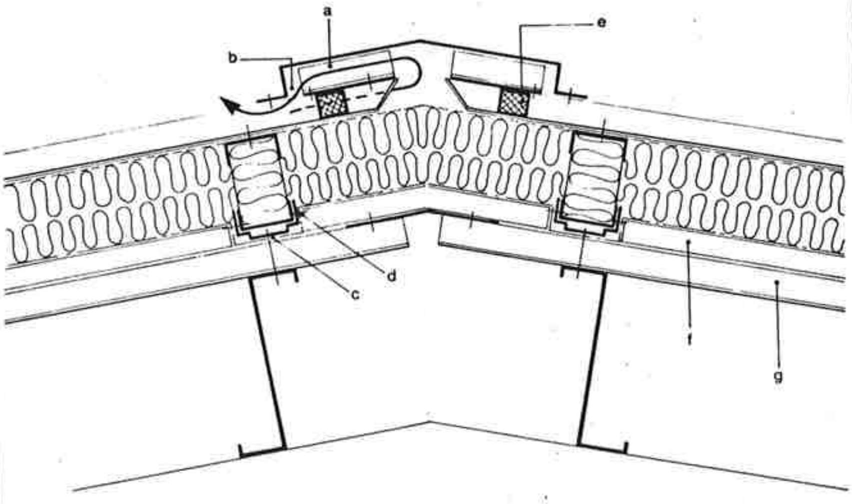
The Ecclesiastical Architects' and Surveyors' Associations work in conjunction with the Lead Development Association found two primary factors and several secondary ones:

- 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.

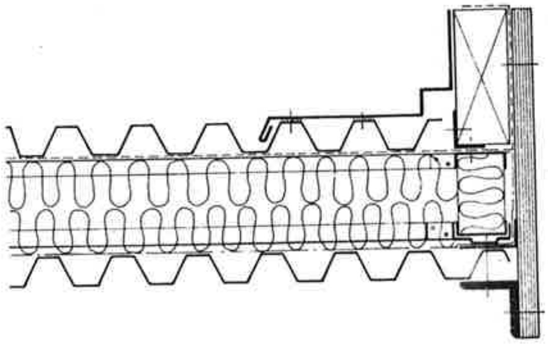
The best defence measures are therefore:

- 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.

18a



18b



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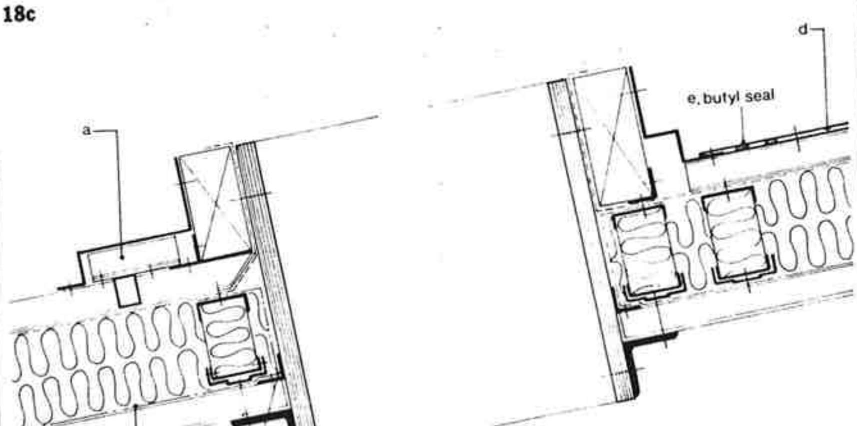


Avoiding sheet roof problems

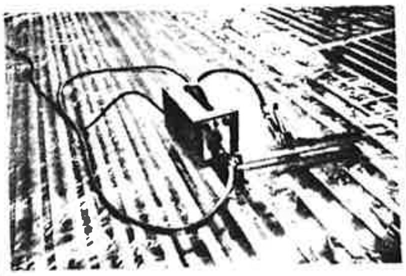
The degree of care needed to avoid the kind of condensation problems with profiled cladding described in section 5.3 last week is illustrated by these details. They were supplied by Design & Construction, a wholly owned subsidiary of Korrugal UK.

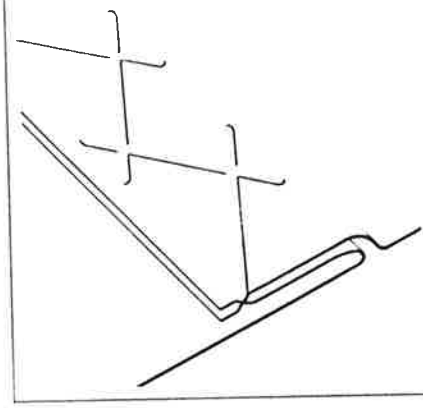
Bottom right, herringbone pattern used for welding polythene v.r. is more reliable than an end-to-end weld.

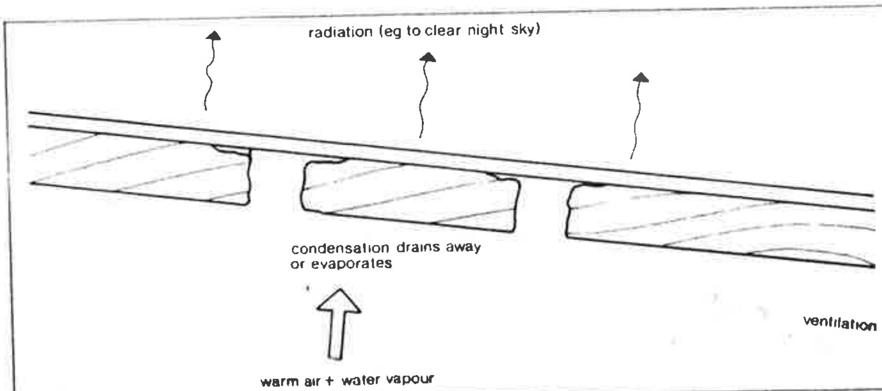
Below, welding machine for heat sealing the sheets of polythene.

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.

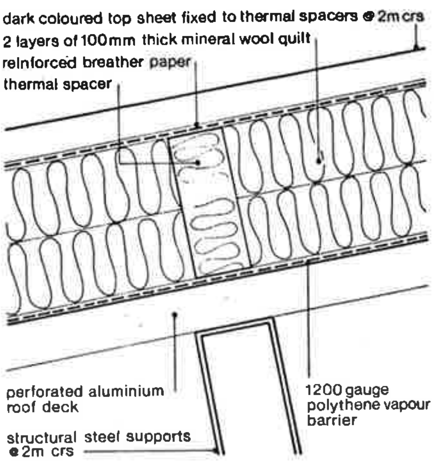






Lead roofs

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:

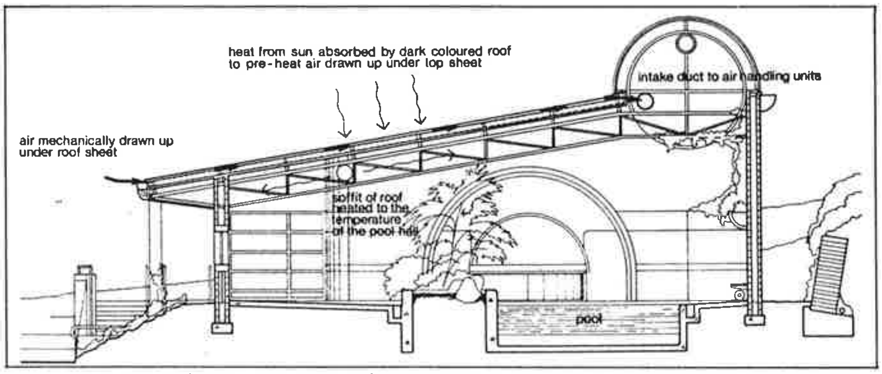
- in two-storey houses or maisonettes with bedrooms over heated living areas, insulation without extra heating may be enough
- in flats and bungalows extra insulation has little effect in unheated bedrooms, and background heating of the room works better
- heating improvements alone can control condensation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

The AJ would like to thank the experts who advised us in the preparation of these articles: Lyall Addleson RIBA, consultant architect, Dr William Bordass, consultant building scientist, Professor Peter Burberry UMIST, Keith Darby RIBA, Feilden and Mawson, Peter Falconer RIBA, Falconer Partnership, Kenneth Jones, Pilkington Bros, Roger Jowett, Bickerdike Allan Partners, Paul Ruyssvelt, Polytechnic of Central London and for their help in providing examples of remedies: Peter Bell and Partners and Sims of Design and Construction (UK).

We are also very grateful to the Ecclesiastical Architects and Surveyors Association for permission to reproduce the findings of its investigation into lead roof corrosion.

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- CP16/70 *Local authority covered swimming pools—case studies of some design aspects*
- CP31/71 *The effects of ventilation and building design factors on the risk of condensation and mould growth in dwellings*

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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*
- 140 *Double glazing and double windows*
- 180 *Condensation in roofs*
- 206 *Ventilation requirements*
- 210 *Principles of natural ventilation*
- 218 *Cavity barriers and ventilation in low pitched roofs*
- 270 *Condensation in insulated domestic roofs*
- 295 *Stability under wind load of loose-laid external roof insulation boards*
- 297 *Surface condensation and mould growth in traditionally built dwellings*

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