UDC 699.82

Revised June 1970

Experimental Building Station — Department of Transport and Construction

EBS Notes on the Science of Building NSB 61

Condensation in Dwellings

Condensation on walls of kitchens, bathrooms, and laundries that are in use during cold weather is a familiar occurrence, and there is a general awareness that wall surfaces and their decorative finishes should be selected for durability. However, condensation of a more sustained and damaging nature can occur in concealed spaces, as is indicated in NSB No. 32. The most serious form of condensation damage is rot hazard to structural timbers of timber-frame construction, but other damage can be caused to ceilings, wall linings, and paintwork.

The purpose of the present Note is to consider in detail the formation of condensation in concealed positions, which is a problem that is often wrongly regarded as unusual in Australia. Paradoxically, this problem is accentuated where certain improved practices in building are adopted without due regard to the new circumstances created.

SOME BASIC FACTS

1.01. Although the technical considerations that cause condensation are elementary, the growth of the problem suggests that many people fail to visualise clearly the circumstances that lead to condensation. For this reason, the subject is examined here right from its basic principles.

1.02. **Water vapour.** Because water vapour is a component of air, it is always present in the air within a house, in quantities that vary on a seasonal basis and with the domestic habits of the occupants. The quantity of water vapour that can be held in the air within a space increases with the temperature of the air. At any particular temperature, air that contains the maximum amount of water vapour it can hold is saturated and has a relative humidity of 100 per cent. Though the relative humidity of air in rooms is generally less than 100 per cent, warm air commonly encountered in winter in well heated rooms of homes does not need to be cooled a great deal before it becomes saturated. Still further cooling of the air leads to the deposition of free moisture as condensation. The temperature at which condensation first occurs is the dewpoint temperature of the air at that time; its numerical value increases with the amount of water vapour that is contained in the air.

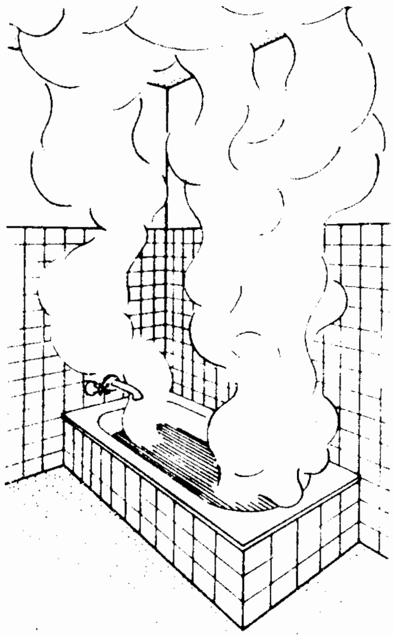
1.03. Water vapour, being in the gaseous state, exerts a pressure that is greater when more of it is present in the air. In cold weather, pressure is greater indoors than outdoors, particularly in heated rooms of a house into which much water vapour is liberated without restriction, by cooking, ablution, and laundry processes, or by the combustion of liquid fuels or town gas in unvented appliances. Vapour will then be under pressure to escape outdoors through the bounding construction where it can cause condensation problems as described in subsequent paragraphs. In principle, such rooms should be vented directly to the atmosphere, preferably with the aid of an exhaust fan in the case of kitchens and in spaces where laundry is dried indoors or where wash boilers are used.

1.04. **Vapour barriers.** Most common building materials permit the passage of water vapour through them at rates that warrant their being classified here as permeable. Exceptions include metallic foils and bituminous membranes which are often reinforced with paper, felt, and plastic film and which have such low permeability that they can be regarded as vapour barriers. Rather less effective vapour barriers are provided by coatings of certain types of paint that have low permeability; these include paints with bitumen and epoxy-resin bases, and some latex-based paints.

1.05. **Temperature gradient.** A temperature difference commonly exists between the air against the indoor surface of an external wall of a house and that against the outdoor surface. This difference is accentuated in the case of heated rooms. It is possible to calculate the approximate temperatures within a wall, by the application of principles given in literature for heat transmission under stable conditions. Broadly, the temperature of an element within a wall is assessed from the temperature difference existing across the wall, the overall thermal resistance of the wall, and that proportion of the overall thermal resistance that exists between the element and one side of the construction.

1.06. However, it is not instructive to compute temperature gradients through construction in order to assess the possible occurrence of condensation within it, unless the temperature is maintained essentially constant while consistently low outdoor temperatures occur – circumstances that are uncommon in Australia.

1.07. **Variability of dewpoint temperature.** Another factor that precludes precise analysis of the domestic condensation problem is the wide variability in the humidity of indoor air, and hence in the value of the dewpoint temperature. Not only does the dewpoint temperature vary from room to room in a house, and from time to time, according to the domestic activity, but it can also be variable from house to house, because of differing domestic habits in the use of lids on cooking pots, the period of bathroom showers, the degree of ventilation, and so on.



A source of vapour

CRITICAL CLIMATIC CONDITIONS

2.01. Because condensation can occur under a wide range of conditions – even those of a relatively mild winter – a practical basis must be established for examining the problem. It is suggested somewhat arbitrarily (though not necessarily conservatively) that the occurrence of condensation within the external walls of a house is likely to be acute at times in areas where the mean minimum winter temperature is 4°C or lower, or where provision is made for continuous high-efficiency heating because of the coldness of the winter season. The following list, taken from EBS *Technical Study*, No. 36, gives some areas that experience a mean minimum winter temperature of 4°C or lower:

Armidale, N.S.W.	Hamilton, Vic.
Ballarat, Vic.	Katoomba, N.S.W.
Bathurst, N.S.W.	Lameroo, S.A.
Benalla, Vic.	Launceston, Tas.
Bendigo, Vic.	Oatlands, Tas.
Bridgetown, W.A.	Omeo, Vic.
Bushy Park, Tas.	Sale, Vic.
Canberra, A.C.T.	Scone, N.S.W.
Condobolin, N.S.W.	Stanthorpe, Qld.
Cooma, N.S.W.	Tamworth, N.S.W
Dubbo, N.S.W.	Wagga, N.S.W.
Griffith, N.S.W.	Zeehan, Tas.

Other relevant data are published by the Bureau of Meteorology.

CONDENSATION DAMAGE

3.01. **To timber.** The damage to structural timbers in dwellings by sustained wetting resulting from condensation can occur in timber-frame walling, flooring systems, and roof framing, under conditions discussed in subsequent paragraphs. In all such circumstances, the condensation problem can be reduced by the appropriate use of a vapour barrier.

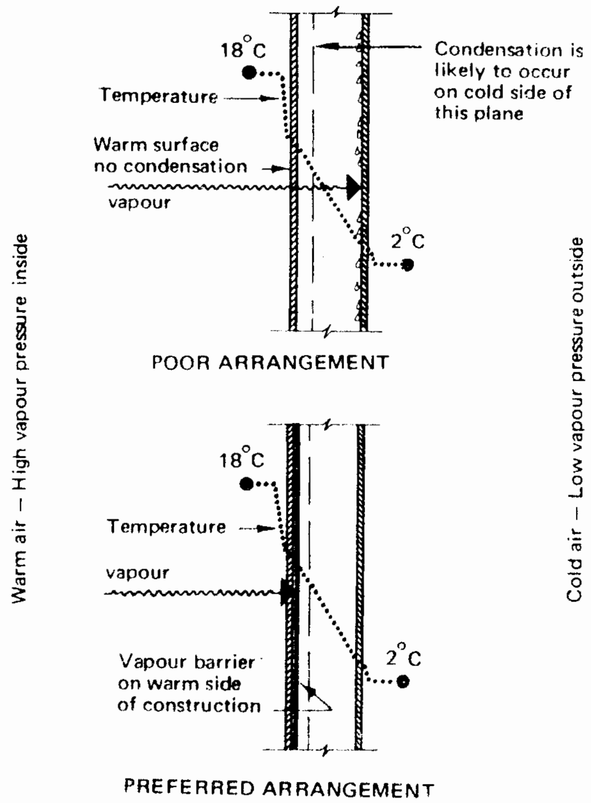
3.02. **To surfaces and ceilings.** Condensation damage to wall linings, paintwork and ceilings is also discussed in later paragraphs.

CONDENSATION IN WALLING

4.01. **Cavity walls.** Condensation in brick cavity walls of houses is not a major problem under Australian climatic conditions. It is a practical problem only where brickwork or applied render, affected by condensation, is decorated with a paint susceptible to damage when on a wet base, or where the disruptive action of frost must be expected.

4.02. **Sarking.** The practice of sarking weatherboard cladding applied to timber framing is to be commended, as is the selection of a sarking material judged to have a long life. Unfortunately, the sarking materials that are likely to have the longest service life are frequently vapour barriers also. Thus a vapour barrier often is unwittingly fixed immediately behind the external cladding where, in a cold-winter region, it can accelerate the deposition of moisture on studs, plates, and noggings, and can retard the subsequent drying.

4.03. Where the critical temperature conditions already noted are likely to be encountered, it is good



Temperature gradients and flow of water vapour in wall

practice to provide a vapour barrier at the wall lining, over the insides of the studs. Joints between successive strips of vapour-barrier materials should be lapped and folded, and securely fixed against a solid backing. Under no conditions of fixing should there be reason to believe that the inner vapour barrier might be more permeable than the sarking. Where similar materials are used for both purposes, it is desirable that joints in the material at the sarking position be merely lapped to ensure weathertightness. Alternatively, nominal ventilation to the outside can be provided for the spaces between adjacent studs, though this provision will reduce the thermal resistance of the wall, and will introduce the problem of ensuring weathertightness of the construction.

4.04. **Wall surfaces.** Although this Note is concerned primarily with condensation in concealed spaces, reference is made to two less familiar aspects of condensation on wall surfaces.

4.05. One of these is the likely occurrence in winter of condensation on the indoor surface of external walling of heavyweight single-thickness construction. The frequent lack of inherent thermal resistance in this type of construction tends to reduce the temperature of internal surfaces of the wall construction below the dewpoint temperature of the indoor air.

4.06. The second matter has a paradoxical component, in that the incorporation of thermal insulation in timber-frame external walling can, at times, induce condensation on (or in) external cladding -- to the detriment of applied finishes -- in climatic circumstances where condensation would not form in corresponding uninsulated construction. The explanation is that thermal insulation can so impede the outward flow of heat from a house that the external cladding becomes colder than otherwise would be the case. Clearly, the foregoing represents a borderline condition, but it does accentuate the need to assess carefully the possible implications of varying the thermal characteristics of traditional construction.

CONDENSATION IN ROOFS

5.01. **Metal roofs.** The dripping of condensation from the underside of roof sheeting, with consequent damage to ceilings, is a matter of common experience. Proprietary absorbent paints and other applied finishes are available commercially, but their use in existing construction can prove difficult in practice. Where the winter climate is essentially sunny, it is feasible to intercept this 'frost drip' by laying over ceiling joists a metal-foil, plastic, or other impervious membrane, to serve as a drip tray, pending the evaporation of the water intercepted.

5.02. Increased ventilation in a roof space cannot be relied upon to alleviate frost drip; it can even aggravate the problem. This is because metal roof sheeting, in particular, when exposed to a clear night sky, can become colder than the outdoor air and can thereby condense additional moisture from the increased quantity of air passing through the roof space. This problem is examined more fully in NSB No. 78, paragraphs 4.05 to 4.07.

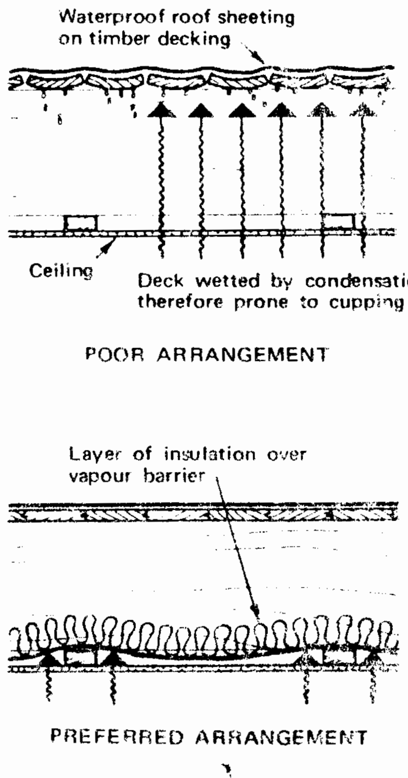
5.03. **Vented ceilings.** The frost-drip problem will be accentuated if rooms or appliances that liberate water vapour, are vented directly into the spaces beneath metal roofs. It is even desirable that light fittings recessed into ceilings should be sealed to the ceiling sheeting to avoid gaps through which water vapour could pass freely into the roof space. Likewise, the tops of wall cavities that communicate with sub-floor spaces should be covered.

5.04. **Tiled roofs.** The venting of humid spaces into a roof space is conducive to the formation of condensation on sarking under tiled roofs also. The problem is intensified where the sarking behaves as an effective vapour barrier because of the presence of, say, a metal-foil or plastic film beneath the roof. In this case, ventilation of the roof space is helpful. Effective natural ventilation is, however, often difficult to ensure in a hipped roof, and it is a thermal disability in cold weather, and possibly a bushfire hazard in summer.

5.05. The above problems are intensified with skillion (single-pitched) roofs where the ceiling is fixed parallel to the roof cladding.

5.06. **Flat roofs.** In flat roofs, as in sarked walling, the waterproof membrane is usually so fixed as to behave as an effective vapour barrier on the cold (upper) side, instead of on the warm (lower) side, of the construction. Thus where the 4°C critical temperature conditions occur, serious wetting of the deck by condensation is to be expected. Decks are commonly of timber or other cellulosic material, which can warp, and even rot, in the circumstances. Ventilation of spaces between joists is seldom practicable, and can be undesirable thermally, as noted above, unless air movement takes place above thermal insulation over ceilings. The proper safeguard is to put a vapour barrier immediately above the ceiling sheeting.

5.07. Self-supporting metal roofing, being a vapour barrier, is similarly prone to condensation. A fibrous thermal-insulation material is commonly placed in contact with the underside of such roofing material to serve the multiple purposes of providing thermal insulation, reducing rain noise, and reducing the likelihood of condensation dropping.



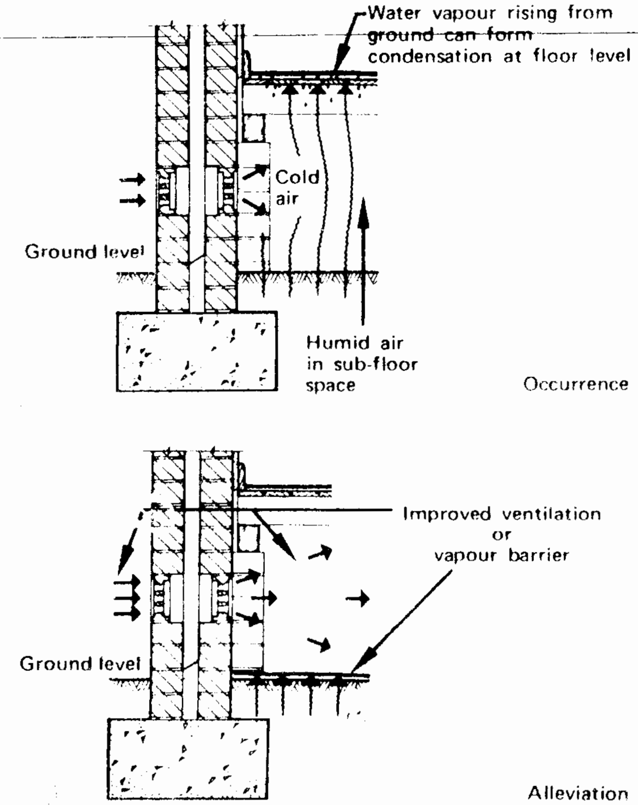
Temperature gradients and flow of water vapour in flat roof

CONDENSATION UNDER FLOORS

6.01. **Ventilation.** Although building regulations require the provision of permanent ventilation openings to enclosed underfloor spaces, and do so reasonably, this provision is quite nominal, and is often ineffectual for various reasons. However, vent openings required by regulation are usually adequate to safeguard against excessive humidity where the site is reasonably dry. Even so, account should be taken of the effect upon sub-floor conditions where sustained watering of gardens or lawns is practised close to a house.

6.02. Where soil beneath a house retains the form of a ball once having been squeezed in the hand, that soil is unduly damp in the present context, and is likely to induce rotting of the floor construction. Improved sub-floor ventilation will improve matters, except that in winter it can lead to the formation of condensation on the floor construction adjacent to points of entry of cold outdoor air.

6.03. **Vapour barriers.** Here again, the use of a vapour barrier is the preferred treatment and, in this case, the barrier is laid over the damp ground. Usually it is sufficient merely to lap adjacent strips of the vapour barrier, and to weight the lapped edges with earth, or brickbats commonly to be found beneath a house. Where such treatment is undertaken, it should cover all ground within perimeter walls. Some water vapour will still rise from the ground, but the reduced quantity can be satisfactorily diluted by normal sub-floor ventilation, thus inhibiting the formation of condensation.



Sub-floor condensation

6.04. The enclosure of sub-floor spaces by foundation walls, or sheeting, or the like, serves to maintain higher air temperatures within the space in winter. The tendency for water vapour from the space above to condense under flooring is thereby reduced.

6.05. Condensation under floors is a more difficult problem in snow country. The precautionary treatment is to prevent water vapour from passing downwards into the floor. However, practical considerations require that the vapour barrier be placed under the floor boards, with consequent loss of thermal insulation between the warm indoor space and the vapour barrier. This factor, together with those of severity of the winter climate, and of constructional details, often makes it necessary to provide thermal insulation under the vapour barrier, so that the temperature of the vapour barrier will remain above dewpoint temperatures. If this condition is not achieved, condensation can occur in the floor-boards or at their underside. One approach to the problem is to provide a double-boarded floor, with the vapour barrier between the two thicknesses of boarding; another approach, applicable to carpeted floors, is to lay the vapour barrier over the customary single-boarded floor, prior to laying the carpet.

6.06. It is to be noted that enclosure of sub-floor spaces will aggravate the condensation problem associated with damp ground, and render it more imperative to cover the ground, as discussed in paragraph 6.03.

SUMMARY

7.01. The preceding discussion can be highlighted as follows:

- Condensation on the internal surfaces of walls of kitchens, bathrooms, and laundries is largely inevitable when those rooms are in service during cold weather.
- Likewise, frost drip from metal roofs is to be expected where cold conditions occur.
- Conditions conducive to rot in timber are likely within enclosed sub-floor spaces over damp ground.
- Condensation within external walling, and in floor and flat-roof construction, should be viewed as a hazard where the mean minimum winter temperature is around 4°C or lower.
- Where climatic conditions as in the item above occur, the use of vapour barriers, in accordance with the preceding discussion, should be regarded as normal good practice.

REFERENCES

1. 'Some Condensation Problems'. *Notes on the Science of Building*, No. 78. Commonwealth Experimental Building Station, Sydney, 1964.
2. KEOUGH, J.J. 'Selected Australian Climatic Data'. *Technical Study* No. 36. Commonwealth Experimental Building Station, Sydney, 1951.
3. *Climatic Averages Australia.* Bureau of Meteorology, Melbourne, 1956.

NOTES ON THE SCIENCE OF BUILDING

Compiled by the Experimental Building Station (Department of Transport and Construction) and published by the Australian Government Publishing Service.

Copies may be obtained from:

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P.O. Box 30, Chatswood, N.S.W. 2067

or by application to:

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RS81/20021 (18) Cat. No. 82 20292 — Printed by J.S. McMillan Printing Group, Rydalmere, N.S.W. — (02) 684 1700