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Please note

Early builders in Canada discovered by hard experience the destructive power of the Canadian climate on masonry used where serious wetting followed closely by freezing could occur. Some of these lessons are about to be re-learned the hard way by many designers and builders who, without thought for the consequences, are introducing humidification in winter into commercial and industrial buildings of conventional design. This does not mean that buildings cannot or must not be humidified in winter, but unless sound principles are followed in design and construction, operating difficulties as well as degrading effects on the building fabric are likely to be encountered. Unfortunately, many trends in current building practice are increasing the risk of subsequent difficulty.

One of the important determinants of the suitability of the design of exterior walls, including windows, for Canadian use is the relative humidity to be carried in the building during periods of cold weather. Relative humidities in commercial and industrial buildings have commonly been very low - as little as 5 to 10 per cent in the coldest months - for reasons which were set out in **CBD 1**. At these levels the moisture problems encountered with windows, walls and roofs are minor, and the possibility that they may occur can be, and usually is, ignored by designers. There have always been problems in such buildings as textile mills and dairies, and in certain other buildings housing factory operations that lead to high indoor humidities in winter. In many cases the difficulties have been tolerated; in others, notably in textile mills, special design considerations have been introduced. Now, however, intentional humidification is being introduced into hospitals, schools, libraries, laboratories, museums and even into apartment and office buildings. This trend toward increased winter humidification is likely to continue and a growing demand for increased humidification in existing buildings can be expected.

Some supposedly humidified buildings encounter little difficulty, mainly because the intended humidity levels are not maintained during the cold weather period. But there are an increasing number of buildings, such as hospitals, libraries and museums, in which the maintenance of humidity levels is highly desirable and is established as one of the required functions of the building. Already there is a noticeable increase in the incidence of problems attributable to humidity: window condensation, wetting and staining of plaster, dripping from top floor ceilings, excessive efflorescence on the outside of exterior walls, disruption of parapets and wetting, shifting and failure of exterior cladding.

The principles to be followed in order to avoid difficulties arising from increased winter humidities have been known for some time. They are easily stated though not always easily followed in building design. In addition, some reinterpretation has been shown to be necessary by recent experiences in humidified masonry buildings.

The first and usually the most obvious requirement is that all surfaces of the building enclosure exposed directly to humidified inside air must be kept above the dew-point temperature in order to avoid surface condensation. In houses the glass surfaces of windows are usually the coldest interior surfaces and thus limit the relative humidities that may be carried without glass surface condensation in cold weather. These limits are discussed in **CBD 1** and in more detail in **CBD 4**. It may be recalled from **CBD 4** that sealed double glazing units will usually be colder at the edges than will separately glazed double windows; and that metal window frames and, in some cases, metal sash may require special treatment by way of incorporation of thermal breaks in order to avoid further limitation of the relative humidity that may be carried without condensation. Other interior surfaces in houses framed partly or wholly in wood are usually much warmer than windows and seldom become involved in surface condensation.

In commercial and industrial building practice, masonry and metal having much higher thermal conductivities than wood are used, and it becomes much more difficult to achieve the high thermal standard possible in houses. Consequently there are many configurations in masonry and metal constructions that may present interior surfaces as cold or colder than the surfaces of double windows, and sometimes colder than the surfaces of single windows. It may be assumed that the basic wall section will always have an over-all thermal conductivity (U) value less than that of 0.45 for double windows so that it will not be subject to surface condensation. But high conductivity metal and solid masonry paths through the wall are difficult to avoid and may lead to localized cold areas where surface condensation may occur.

Unfortunately, the thermal analysis of many of the situations occurring at window frames and at sections where columns, beams and floor and partition slabs meet or are incorporated in the exterior wall is extremely difficult. The designer must learn to recognize these situations where two- and three-dimensional heat flows occur and cold surfaces are most likely to be encountered. About the only general advice that can be given, short of recommending thermal studies, is to point out the dangers of what may be called "fin-effect." When a metal component such as a metal window frame, which is itself highly conducting, extends through a wall, its over-all resistance to heat flow may be largely made up of the air film resistances at the surfaces. Increasing the surface exposed to outside air will lower the metal temperature, whereas increasing the surface exposed to warm inside air will raise it. Metal mullions placed flush with the inside of a wall and standing well out into the cold outside air produce a strong fin effect that leads to greatly reduced inside surface temperatures, which may well be much colder than window surfaces.

Similar, but modified, fin effects occur where floor slabs, roof slabs or concrete partitions extend through the exterior wall and project past it. In these cases the fin effect is not so marked as it is when metal is involved. The effect of the increased surface area presented by the fin is offset in part by the appreciable resistance to heat flow provided by the masonry. As a result, the effective length of these fins from a cooling point of view is only two or three times their thickness. The extent of the bridging of the wall, and particularly of the exposed area of solid material, should be kept in mind in the interests of improved interior surface temperatures.

It may be noted that adding insulation to the interior of a wall on which a floor slab rests may result in a kind of fin effect at the slab, because the wall is made colder by the addition of insulation. This raises the point that (consistent with other requirements) it will usually be easier to meet rigid surface temperature requirements if the materials in the wall that provide the bulk of the insulating value can be placed close to the exterior surface. When this is done the inner, highly-conducting solid structure of the building is protected from the effects of low outside temperatures. There are other advantages as well as difficulties in achieving such a design, but these cannot now be discussed.

The second main principle in avoiding moisture difficulties arising from increased indoor relative humidities in winter relates to the prevention of concealed condensation or condensation within the construction. Water vapour can travel into a construction on its way to the outside, encountering colder and colder parts until, finally, condensation within the wall occurs. This process has commonly been regarded as the result of diffusion of water vapour. The remedy has been to make it difficult for the water vapour to enter the wall and easy for it to escape. To achieve this in house construction it has long been recommended that vapour barriers should be incorporated near the warm side of a wall but avoided toward the cold side, and that, if necessary, cavities in the wall be ventilated to the outside to facilitate the escape of water vapour before it can accumulate to condensation levels. While this concept is still considered sound, it is now becoming apparent that it requires some modification in masonry constructions.

The use of vapour barriers, particularly in some insulated metal buildings and in buildings in the North operating under extreme conditions, has not always been effective in preventing condensation. It is now realized that water vapour can be carried into a construction by air leakage as well as by diffusion, and that vapour barriers as installed are not always effective against both mechanisms.

Vapour diffusion occurs under the influence of a vapour pressure difference, which causes water vapour molecules to find their way through many materials, including still air. The rate of flow of water vapour in this way is dependent upon the vapour pressure difference and the permeability of the materials. A few small holes or cracks do not add greatly to the vapour transfer by diffusion, because the area involved is small even though the local permeability may be relatively large. Consequently, it has usually not been considered necessary to seal all joints in vapour barriers. This practice has been satisfactory as long as some other element in the construction, such as the interior finish, provided adequate resistance to air flow. It has been realized for some time that openings around lighting fixtures in exterior walls and ceilings of frame construction allowed serious condensation to take place, but this has not always been properly attributed to air leakage.

Air leakage, unlike vapour diffusion occurs because of air pressure differences. Further, air under even small pressures can flow quite freely through small holes and cracks as long as a continuous path is provided to the outside. The volume of air involved is not usually significant in terms of building heating and ventilating, but the amount of moisture that can be carried out along with it from inside a humidified building can be large enough to cause serious trouble.

Air leakage may occur as a result of wind pressure differences, which exist only when the wind is blowing. But there is usually also a chimney effect caused by differences between indoor and outdoor temperatures that tends to produce air infiltration at the lower levels of a building and an outward air flow at upper levels. The pressure differences in buildings and the resulting leakage of air are discussed more fully in **CBD 23**, "Air Leakage in Buildings."

It is the air leaking outward, usually at the upper levels of a building, that can produce difficulty. When the air is dry no difficulty will be experienced, but when a building is humidified water vapour is readily drawn along with the air, encountering cooler and cooler surfaces along the outward path of the air flow until condensation occurs. Air leaking through the construction and carrying water vapour with it may produce more serious condensation conditions than vapour diffusion. This does not mean that vapour barriers can be disregarded or that the concept of vapour diffusion is incorrect. Both air leakage and diffusion mechanisms must be kept in mind. Vapour barriers may be made to serve a dual function if they are continuous and are adequately sealed against air leakage at all joints.

Modern buildings are almost always of full-frame construction. Cracks often develop between masonry wall panels and the surrounding frame because of movement and shrinkage. Spandrel zones above suspended ceilings are seldom back-plastered, which would help to seal the passages through which air leakage occurs. Brick or concrete unit masonry alone can be relatively permeable to air leakage. The addition of plaster, however, can reduce air leakage through it by a factor of as much as 100. Unplastered emergency stairwells and other roughfinished or unplastered portions of buildings can provide generous paths for outward air leakage.

It is now believed that some parapet failures are the result of the deposition of water from moist air leaking outward and upward through the wall below into the parapet. Locations around and under windows where back-plastering of convector recesses may be omitted and other faults occur are often wetted by condensation arising from air leakage, When furred spaces are used in exterior walls they are often continuous through several floors, and at the same time may be connected by cracks or construction faults with both the inside and the outside. Service spaces may provide many unintentional breaks at each floor where piping and ductwork connections are made. Air pressure differences from chimney action in the building promote air leakage into these spaces and out of them to the outside.

The deposition of water within a masonry wall by outward air leakage at below-freezing temperatures can lead to serious degrading effects. Not only is the freezing of wet masonry destructive to it, but it now seems possible that disruption of a wall can be produced by growth of ice lenses within weak porous mortar or at weak joints if, as a result of the heat and moisture provided by the escaping airstream, water is fed in appreciable amounts from the warm side to a freezing plane within the wall.

Effective precautions are not too difficult. Design to promote air-tightness of the interior wythes of the wall. Plaster or back-plaster over unit masonry. Where cracks at joints can be anticipated, allow for them by providing chases and caulking near the warm side with flexible materials. Avoid furred spaces in exterior walls, which cannot be sealed on the warm side against air leakage. Keep air leakage in mind when detailing window frame connections, convector recesses and other vital sections.

When insulation is placed on the inside or warm side of walls, the need for protection against vapour diffusion through the use of vapour barriers should still be considered. This must depend on the relative permeabilities to water vapour of the inner and outer constructions. Keep in mind, however, that water vapour can by-pass a vapour barrier through air leakage if there is a higher air pressure inside than out and a clear leakage path to the outside.

Finally, it has become common practice to pressurize buildings, that is, to make the fresh air supply rate intentionally larger than the exhaust by as much as 10 to 20 per cent. Though the extent of such pressurization is seldom sufficient to oppose infiltration due to wind pressures, it does mean that at ail times a certain portion of the warmed and humidified ventilation air is forced to leave by leakage paths through the construction. This topic was also discussed in **CBD 23**. There is insufficient knowledge as yet to predict the leakage rates and vertical air pressure gradients in tall buildings, but it would appear to be sound to avoid undue pressurization of buildings unless the benefits can be shown to outweigh the possible difficulties from increased outward air leakage.