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Sources of Moisture and Its Migration through the Building Enclosure

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ABSTRACT

This paper describes the various sources of moisture in houses and quantify their relative contribution to the moisture levels in the living spaces. It also defines the mechanisms of moisture transfer across the building envelope and it briefly describes how to control them.

RÉSUMÉ

Ce document décrit les diverses sources d'humidité dans les maisons et indique leur importance vis-à-vis des taux d'humidité dans les espaces habités. Les mécanismes de transfert de l'humidité à travers l'enveloppe du bâtiment et la façon de contrôler ces mécanismes sont également examinés.

Sources of Moisture and Its Migration through the Building Enclosure

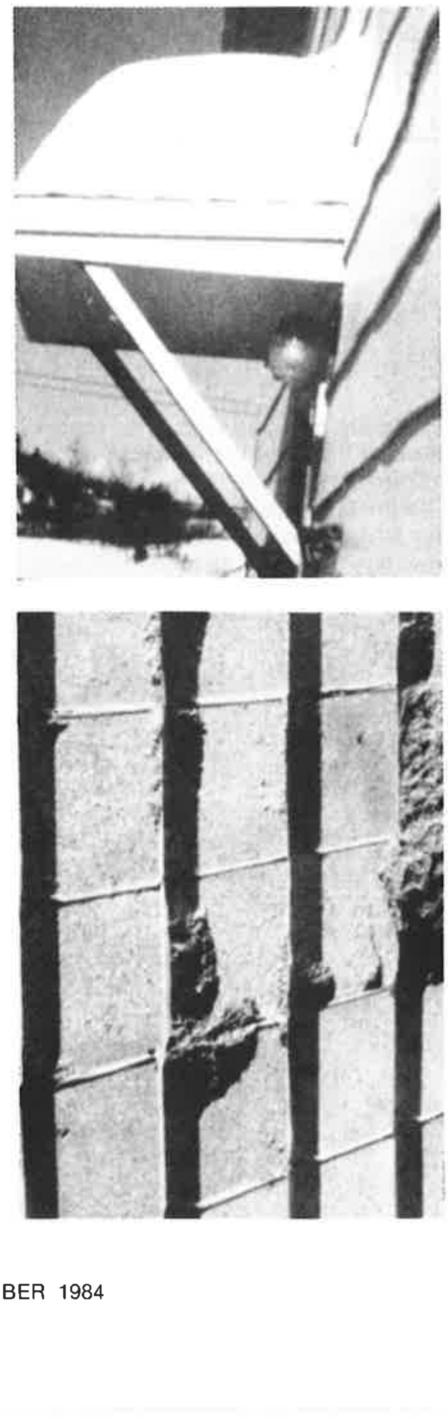
Madeleine Z. Rousseau

Cause of Moisture Damage

The deterioration of exterior cladding such as the buckling and warping of fiberboard siding, the peeling of paint, the efflorescence on brick veneer and the spalling of brick and concrete block cladding is damage due to an accumulation of moisture in walls. Does the moisture come from inside the building as vapor until it reaches the dew point temperature location on its way out, or does it come from outside as rain or snow? It could be either or both, and in many cases it is difficult to determine. In any event, whether the moisture comes from inside or outside, the major mechanism of moisture transport to the cavities is common, that is, air leakage (infiltration or exfiltration). The design and construction of proper control measures are, therefore, of prime importance for the durability of buildings.

Moisture Balance

Every building operates under a moisture balance regime. The rate of moisture removal from the living spaces must equal the rate at which it is generated. As more moisture is generated, more moisture must be removed in order to maintain a constant humidity level. An interesting paradox is that field investigations sometimes indicate that buildings experiencing moisture problems operate at quite low humidity levels. This can be explained by the moisture balance of the building. A constant low humidity level may be maintained whether the input rate of moisture is high or low. The rate of moisture removal has to be proportional to it. Figure 1 illustrates this; the containers A and B represent the buildings, and their liquid and their humidity level. Building A has no moisture input and no moisture removal, while building B experiences high moisture input and removal. The humidity levels of both buildings remain constant. This analogy demonstrates that the humidity level can be controlled by either reducing the sources of moisture or increasing the rate of moisture removal by means of dehumidification and ventilation. Unless the building is made airtight, exfiltration of moist air leading to condensation in the building envelope will become the undesirable way of removing moisture.



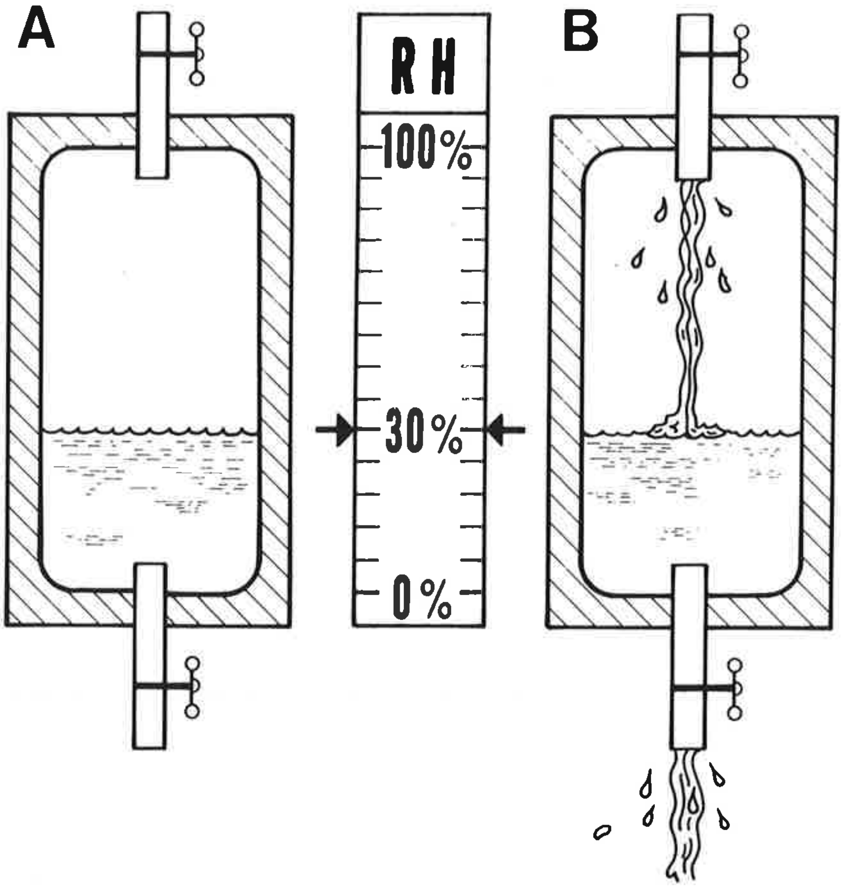
The buckling and warping of fiberboard siding (*top*) and the spalling of brick and concrete block cladding (*bottom*) are just two examples of damage due to an accumulation of moisture in walls.

Moisture Sources

The most common sources of moisture in houses are people and their activities, plants, unvented combustion appliances, humidifiers, wet building materials, and the surrounding soil. The significance of some varies as a function of the occupants' lifestyle. Figure 2 gives approximate values for the amount of water vapor released per activity.

Other sources, like building materials, release moisture in proportion to their wetness and surface exposed to the inside. For an average Canadian house, it can be estimated that the lumber used at 19 percent moisture content can release a total of about 200 litres of moisture as it dries to average conditions. Concrete foundations can release 2,400 litres of water during the curing process. Soil surrounding the building can be an important contribut-

FIGURE 1—Rate of Moisture Removal



ing source, particularly in the case of a crawl space, where as much as 40 to 50 litres of moisture per day can be released by exposed soil.

Given that most houses are vented during the summer, the high moisture content of the outside air is partly absorbed by building materials and furnishings. This moisture is released later when the ambient humidity level starts to drop. Three to eight litres per day may be released in the early fall.

Rain penetration also may be considered as a source of moisture although it is difficult to estimate its impact.

Mechanisms of Moisture Movement

When the moisture has been generated in the living spaces, it may migrate to the outside through the building enclosure. In a cold climate, this induces a potential for concealed condensation and its effects. Three conditions are required for the condensation to occur: some moisture in the air, a mechanism to move it through the enclosure, and a surface below the dew point temperature of the air. In winter, it is more or less inevitable that the air in the building will contain more moisture than the saturation moisture content of the outside air and the outer parts of the building envelope will be below the dew point temperature of the room air. Thus, it is left to the designer to control the mechanisms that move the moisture into the building envelope, namely, air leakage and diffusion.

Air Leakage

Air can leak through the envelope when an air pressure difference acts on holes and openings that create an open path from the inside to the outside. The air pressure difference acting on an assembly of materials is the result of a combination of the wind action, the mechanical ventilation and operation of combustion equipment, and the difference in temperature between inside and outside, the stack effect. The combinations of these loads provide quite complex distribution patterns of the air pressure difference over the enclosure.

The various paths for air leakage are usually the junctions between materials, components, and planes. This includes windows, doors, parapets, soffits, cantilevers, floor and wall junctions, and electrical outlets and fixtures, to list a few.

Since concealed condensation is primarily due to air exfiltration, one method to control condensation could be to reverse the direction of the air flow to create air infiltration. Unfortunately, this solution has its own problems. Air infiltration may cause condensation problems on inside surfaces, the cooling of inside air, the lowering of the humidity level, an increase in heating costs, and some problems of combustion equipment backdrafting.

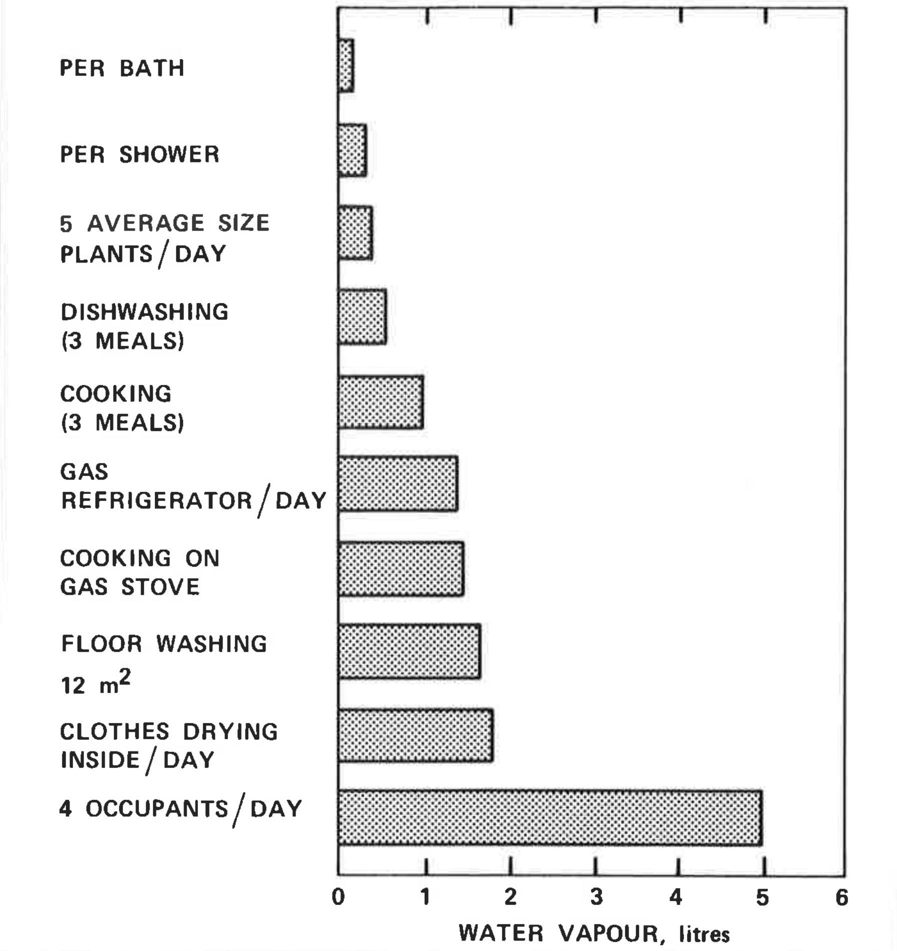
Airtightness

The most viable approach is to control the flow of air itself rather than its direction so that there will be neither infiltration nor exfiltration. What are the requirements for the assembly of materials that will stop air flow? Until recently, the emphasis was placed on the requirement of the continuity of some selected elements over the whole enclosure and the air permeability of these elements. The building community often interpreted this as meaning only the sealing and stuffing of the flexible plastic membrane joints used originally as vapor barriers.

Recently, more thought was put into the quantitative performance criteria for what Canadians call an air barrier system. In other words, what range of air pressure difference should the air barrier withstand without losing its continuity, which is the major aspect of its durability.

In order to stop air, the air barrier system must sustain the loads induced by the wind, the mechanical ventilation, and the stack effect. Especially in high-rise buildings, the combination of these loads can induce some quite high outward pressure differences on walls and roofs. Therefore, the air barrier system must have structural strength and be directly supported by the structure of the building. This applies equally to the elements of air barrier, the joints between materials, and the junctions between assemblies of materials. This is the most difficult part to achieve because it requires that designers and builders have a good knowledge of material properties, a good design of construction details, and a good quality construction. The connections between elements are usually the most neglected and the weakest link in the chain.

FIGURE 2—Sources of Household Moisture



A relatively new requirement called for is rigidity. This has two purposes. The first is a matter of durability. A flexible material that is constantly flexing back and forth in a cavity may become brittle and crack. The second reason has nothing to do with stopping air leakage but with the control of rain penetration. The rain screen principle requires a pressure equalization in the compartmented cavity bounded by the back of the exterior cladding, the air barrier, and the horizontal and vertical boundaries to the width of the cavity. Since the pressure will vary as the volume of the cavity changes, it implies that the volume of the equalization cavity should be constant in order to keep the pressure variation to a minimum.

Just how still a material must be in order to be adequate has not been determined, but clearly, an unsupported, flexible membrane is not stiff enough.

In principle, the location of the air barrier does not have to be on the warm side of the wall because the air will be prevented from entering the cavity if it cannot leave it. The moisture is carried by the air and if the air does not move, neither will the moisture. The practicality of all possible air barrier locations is still under investigation.

Diffusion

There will be a movement of moisture towards the outside by diffusion in a cold climate. Diffusion is the movement of moisture through a material from a location of high moisture content to a location of lower moisture content. This is a slow process and occurs without any flow of air. Since the diffusion rate is a function of the permeability, its control can be achieved by the reduction of the material permeability. The selection of materials like plastic films, aluminum foil, or several types of paints and their installation on the warm side of the enclosure practically eliminates the possibility of condensation due to diffusion.

Summary

All of the moisture problems are related to three conditions: the indoor temperature and humidity, the outside climate, and the design and construction of the building envelope. In order to get an adequate moisture balance in the building, three factors can be adjusted. Moisture sources can be reduced or eliminated in some cases, ventilation can be increased, and the building can be designed and built to control built-in moisture flow through the envelope.

In order to control the concealed condensation problems, there must be vapor and air barriers in the enclosure. Their characteristics are completely different but too often confused in the building industry.

The vapor barrier deals with the water vapor, a gas that migrates because of a difference in concentration between inside and outside. A material with a low permeability to water vapor installed on the warm side of the enclosure will control this movement. The air barrier deals with moist air that moves in or out because of the wind, the ventilation, and the stack effect. To control air leakage, the air pressure difference must be resisted, and to this end, a continuous juxtaposition of building materials capable of withstanding the air pressure difference is required. This means that the materials used to prevent air leakage, the air barrier system, must be structurally adequate, of low air porosity, rigid, and assembled in such a way that continuity is maintained over the whole building enclosure. ■

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