# Whair DID ALL THIS WATER COME FROM?

By Danielle M. Czyzewski, PE and Gregory G. Schober, PE

See moisture distress on ceiling tiles or at the interior finishes of an exterior wall? That must mean the building envelope is leaking, right? Most building consultants have come across something similar at one time or another; and yes, building envelopes do leak. But what are they leaking? Water? Air? Typically, people are far more cognizant of waterl eaks than air leaks, though with the adoption of the 2012 International Energy Conservation Code, this is beginning to change.

It is also worth mentioning that a building envelope that leaks liquid water is also capable of leaking air. A little less obvious is the fact that air leaks can transport moisture, and this can cause distress similar to that caused by a water leak. Much less obvious is the fact that moisture distress can also occur in exterior walls through capillary suction and vapor diffusion—even in the absence of an air or water leak. And while moisture distress due to liquid water intrusion into the building envelope remains a common problem in today's construction, this article will focus on moisture-related distress due to these less well-known sources: air leaks, capillary suction, and vapor diffusion.

## BUILDING ENVELOPES AND MOISTURE MIGRATION

A building envelope is the assembly of materials that separate the exterior environment from the interior of a structure. The envelope serves as the outer shell or "skin" that protects the building from the elements and facilitates climate control within the same. Moisture movement across the building envelope occurs through four transport mechanisms: liquid flow, air movement, capillary suction, and vapor diffusion. Liquid flow normally involves water breaching the building envelope through openings and penetrations. Air movement can transport moisture-laden air through unsealed openings and penetrations. Capillary suction (e.g., wicking) is the result of adhesion or surface tension of water in porous materials such as brick and mortar. Vapor diffusion allows moisture in the vapor state to travel through the permeable materials in the building envelope when subjected to a vapor pressure differential.

Often, moisture distress to interior finishes occurs from a combination of some or all of the above-mentioned transport mechanisms. Of these four transport mechanisms, air movement is the primary contributor to high indoor relative humidity and surface condensation, while capillary suction and vapor diffusion typically manifest as moisture distress in the exterior wall assemblies. The extent of distress is influenced by seasonal climatic changes.

## AIR MOVEMENT (CONVECTION AND INFILTRATION)

So, what would cause a building to leak air, and is the air leaking out of the building or into it? Air leakage typically occurs at openings and discontinuities in the building envelope air barrier system due to pressure differentials across the building envelope. Pressure differentials can be induced by wind; stack effect; and/or the building's heating, ventilating, and air-conditioning (HVAC) system. This article will focus on pressure differentials caused by the HVAC system.

An air barrier system includes the windows, doors, waterproofing, finishes, roof membranes, air barrier membranes, and so on. Discontinuities of the air barrier system most frequently occur at material transitions, such as between the roof membrane and the air barrier membrane of the wall. Each component of the air barrier system must be fully integrated with the adjacent air barrier materials for the air barrier to function as intended. While a completely airtight building envelope is not realistic

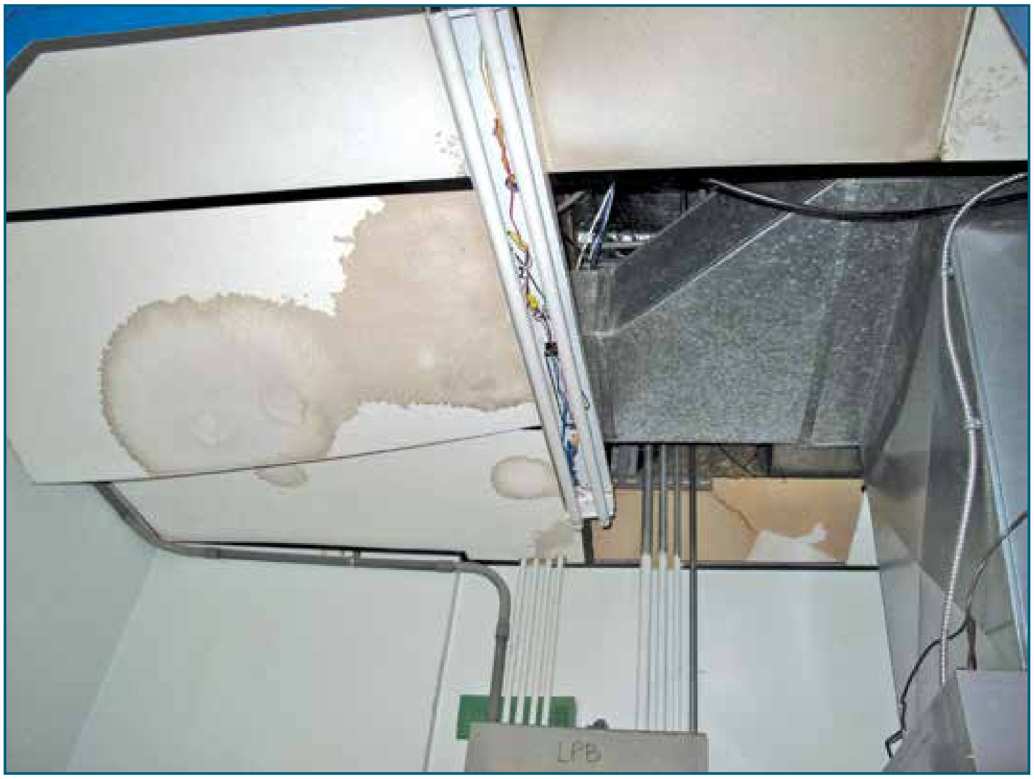


*Figure 1 – Stained ceiling tiles caused by condensation dripping off of mechanical equipment above.*

under real-world conditions, discontinuities must be minimized in order to restrict air movement.

## BUILDING PRESSURIZATION

If a building is negatively pressurized (the building's air intake is less than the amount of air exhausted), unconditioned outdoor air will be "sucked" into the structure through the openings and discontinuities in the air barrier system. Movement of moisture-laden air due to negative pressure can result in visible moisture distress to building materials and contents.

Negative building pressure causes unconditioned outside air to infiltrate the building directly into the conditioned space. This moisture-laden outside air bypasses the cooling coil and mixes directly with the room air, effectively short-circuiting the HVAC system's dehumidification process. As a result, moisture levels in the conditioned space are increased, and condensation may form. Surface condensation forms when the water vapor in moist air comes in contact with a nonporous surface that has been cooled to a temperature lower than that of the dew point of the air. The visible distress caused by condensation can appear similar to distress due to a water leak and is most frequently observed at windows and mechanical equipment (*Figure 1*).

Negative building pressure also causes unconditioned outside air to infiltrate the attic space above the ceiling (the attic space is also sometimes referred to as the plenum or interstitial space). When the return air and exhaust air systems are ducted (as opposed to a plenum return system), the attic space above each floor is unconditioned. In a negative building pressure environment, the attic space in a ducted return system is more susceptible to condensation problems than in a plenum return system, because the attic spaces are not diluted with the drier conditioned air from the occupied space below. The moisture level in the unconditioned and negatively pressurized attic space is higher

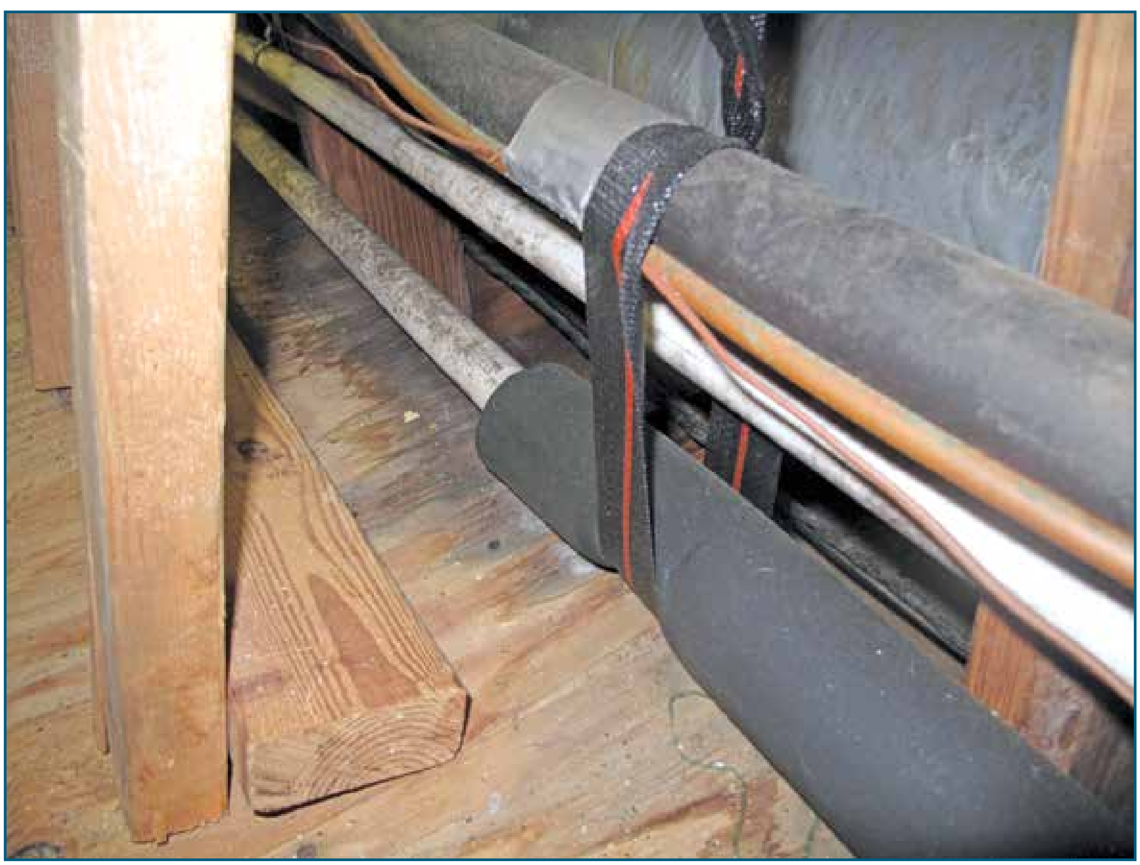

*Figure 2 – Moisture staining below uninsulated section of plumbing within an unconditioned attic.*

than the occupied space and can approach 100% relative humidity during periods of very humid or rainy weather. This high-humidity condition results in the formation of condensation on building materials and mechanical equipment in the attic whose surface temperatures are below the dew point of the attic air.

For example, when the insulation layer on a mechanical component that contains a chilled fluid is damaged, discontinuous, or displaced, water vapor from the hot and humid attic air (as in the condition described above) will condense on the exposed, chilled surface. This condensation will often drip onto the finishes below, causing moisture stains. Common examples of this condition include air-conditioning supply air ducts, refrigeration suction lines, condensate drain lines, and domestic cold-water pipes (*Figure 2*).

Buildings with ducted return and exhaust air systems are more sensitive to negative building pressure than buildings with plenum return systems. Buildings with ducted return and exhaust air systems must maintain positive pressure at all times during the cooling season to avoid moisture condensation in the attic spaces.

### CAPILLARY SUCTION

Capillary suction occurs when liquid water is transmitted through a porous material. Therefore, exterior walls that utilize porous cladding materials must contain a capillary break. This capillary break is achieved by the installation of an air cavity in masonry veneer walls or the use of a drainage plane in stucco walls.

If the capillary break is nonexistent or compromised, moisture is able to wick through the entire wall assembly. Consider a cavity wall composed of the following (from exterior to interior): brick masonry; nonfunctioning, mortar-filled drainage cavity; building felt; plywood sheathing; wood framing infilled with cellulose insulation; and gypsum board. Through capillary suction, water absorbed by the brick veneer migrates across the mortar droppings within the drainage cavity and continues through the wood, insulation, and finishes, particularly if the building felt was damaged during construction or improperly installed. In this example, an air cavity was intended to function as the capillary break, but mortar droppings within the cavity created a capillary bridge from the exterior to the interior. The resulting distress from this condition is commonly wet and stained exterior walls (*Figures 3* and *4*).

### VAPOR DIFFUSION

Moisture movement by vapor diffusion (also known as vapor drive) is another transport mechanism that manifests as moisture distress and is often confused with a building envelope leaking due to liquid water flow. Water vapor is a gas, and gases are happiest when they are in equilibrium. Vapor diffusion occurs when a vapor pressure differential exists, and can occur in the absence of an air pressure differential. In an attempt to reach equilibrium, the water vapor in moist air will migrate from a region of high vapor pressure to a region of low vapor pressure. The vapor pressure of the water vapor in moist air is directly related to its temperature and relative humidity; warm, humid air has a higher vapor pressure than cold, dry air. Therefore, the direction of vapor diffusion across a building envelope will always be from warm and


*Figures 3 and 4 – Fractures in stucco allowed capillary suction across wall assembly, resulting in deterioration of the wall sheathing and framing.*

humid to cool and dry. Vapor retarders can be used to minimize this mechanism of vapor transport.

Imagine a conditioned house in a hot, humid climate that has an air barrier (such as building paper) but not a vapor retarder. During the summer months, the outdoor air is hot and humid, with a high water vapor pressure, while the conditioned air inside the house is cool and dry, with a low water vapor pressure. To reach equilibrium, the water vapor in the warm outdoor air is drawn across the building envelope components (driven by the vapor pressure differential) through to the interior, or until it comes into contact with a nonpermeable surface such as vinyl wall covering. In the event that a nonpermeable surface is encountered that has been chilled to below the dew point of the water vapor, the water vapor will condense on the back surface of the material, eventually resulting in staining and fungal growth. See *Figure 5*.

## VAPOR RETARDERS: TO USE OR NOT TO USE?

The terms "vapor barrier" and "vapor retarder" are often used interchangeably. So what is the difference, and when is it appropriate to use each term? This topic alone could be the subject of its own article. We could write extensively just about where to place a vapor retarder within the wall, if one is installed at all—in short, it depends on the climate. The main point is that a wall must be designed so that when the vapor retarder gets wet (which it will, eventually), there is a path for the moisture to escape, and the wall is able to dry out.

The International Code Council (ICC) classifies vapor retarders into three categories based on the permeability/breathability of the material. Permeability is calculated per ASTM E96, *Standard Test Methods for Water Vapor Transmission of Materials*. Class I vapor retarders have a perm rating of 0.1 or less; Class II vapor retarders have a perm rating of 1.0 perm or less and greater than 0.1 perm; Class III vapor retarders have a perm rating of 10 perms or less and greater than 1 perm. Vapor barriers are Class-I vapor retarders.

The climate in which a building is

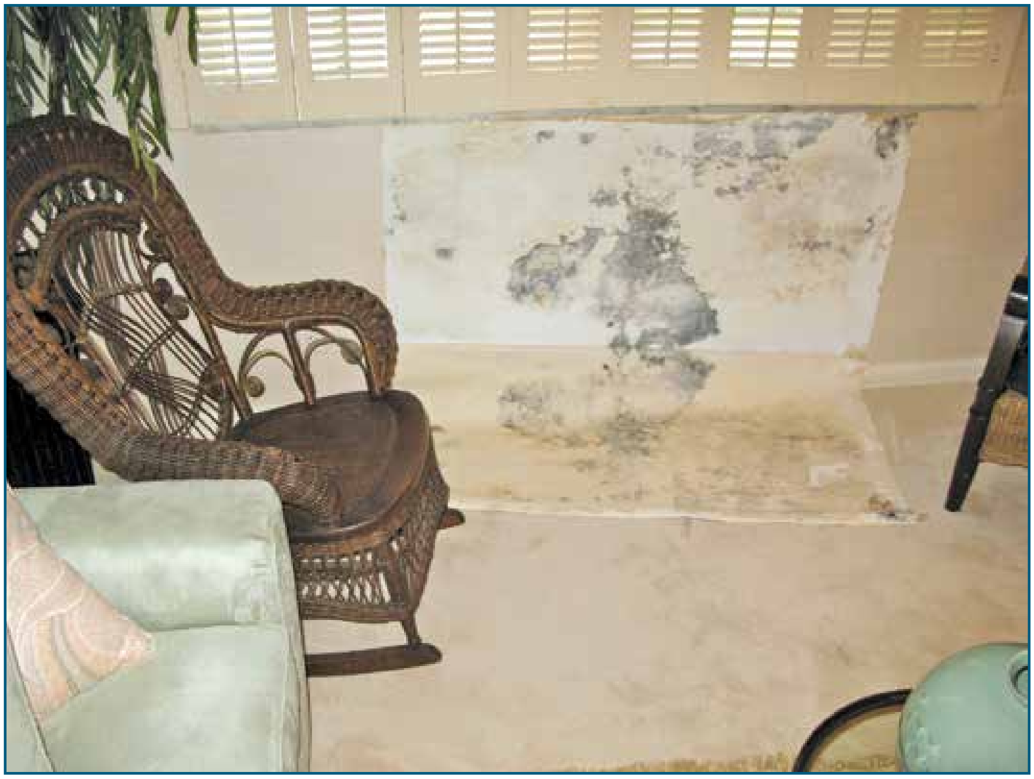

*Figure 5 – Fungal growth behind vinyl wall covering, functioning as an unintentional vapor retarder.*

constructed greatly affects the placement of the vapor retarder within the wall assembly. In cold climates, the vapor retarder is typically placed toward the interior of the wall. During heating periods in cold climates, moisture is inclined to move from the interior towards the exterior; therefore, the vapor retarder is placed toward the interior. However, if any moisture does bypass the vapor retarder, the exterior cladding should be permeable so that the wall can dry out towards the exterior.

In hot climates, the vapor retarder is typically placed toward the exterior of the wall to prevent moisture from moving from the warm, humid exterior to the cool, dry interior. To allow any moisture that does bypass the vapor retarder to dry out, the interior finishes should be breathable.

Deciding where or if to place a vapor barrier in a mixed climate gets a bit trickier and will largely depend on what materials are chosen, the climate in which the building is constructed, and the building's intended use. It is worth repeating here that if the wall does get wet, it must be able to dry. One approach for mixed climates is to omit the vapor barrier and use permeable materials throughout the wall assembly. Another option is to place the vapor barrier near the "thermal middle" of the wall. In each case, the control of both the interior air pressure and the interior moisture must be maintained by the building's mechanical system.[1]

## PRACTICAL APPLICATIONS

So, how can moisture distress in exterior wall assemblies be avoided? Here are just a few questions that should be considered when designing a building system or evaluating a building system for sources of moisture-related distress:

- **Where is the building located?** The climate in which the building is located determines where the air barrier and vapor retarder (if any) should be placed within the wall system.
- **Can it dry out? What is the type of exterior wall construction?** Materials such as vinyl wall coverings or paper- or foil-faced batt insulation can act as unintentional vapor retarders. This can prevent moisture that entered the wall assembly from leaving the wall system, leading to fungal growth and deterioration of building materials.
- **Is the HVAC system capable of maintaining the intended pressurization of the building as well as removing moisture from the air as needed?** The operation of the mechanical systems should be confirmed with the design intent once the systems are up and running and should be properly maintained throughout the life cycle of the building.

## REFERENCE


1. Joseph Lstiburek, "Moisture Control for Buildings," *ASHRAE Journal*, February 2012: 36-41.


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