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The Art of Moisture Management

The study of Building Science tells us that there is a functional relationship between the environment and a home's various components. The building envelope, the home's mechanical systems and its occupants all interrelate, so that even a small change in one component can have a dynamic effect on the entire house.

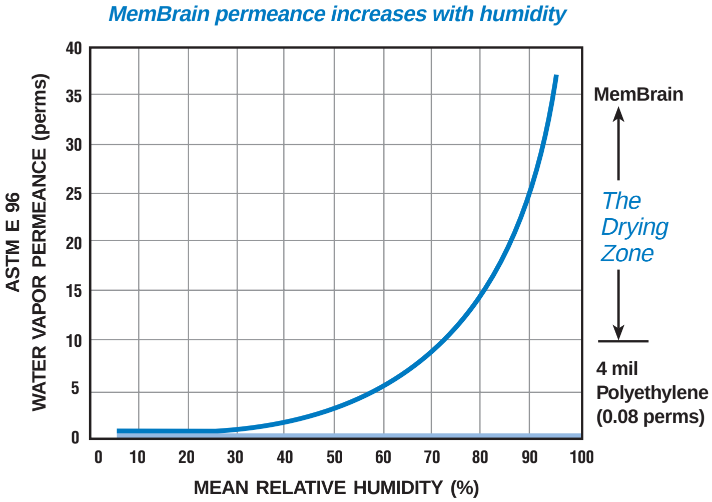
These building dynamics are driven by physical, chemical and biological reactions. The study of moisture flow is one crucial building dynamic affecting home comfort issues – the kind of issues that home buyers complain about and home builders seek to avoid. Understanding moisture flow within a home, as well as the underlying relationship between the transfer of heat and moisture, can help builders better evaluate existing and new solutions for achieving better moisture control, and thus for homebuyer satisfaction.

Moisture Flow in the Home

Moisture is one of the most important factors affecting both the ability of a home's materials to resist deterioration as well as the overall durability of the home. Controlling moisture helps to control many problems, including mold – one of the most important issues home builders face.

Many normal, daily family household activities – cooking, bathing, washing dishes, and drying clothes – produce airborne water vapor. Moisture from groundwater, rain and dew also enters homes from basements, crawlspaces and leaks.

In general, moisture will follow the path of least resistance, moving from warm to cold. In cold climates, moisture from interior conditioned spaces attempts to get to the exterior by passing through the building envelope. In hot climates, moisture from the exterior attempts to get into the cool/conditioned interior by passing through the building envelope.



There are two methods for moisture movement:

- **Diffusion** refers to the movement of moisture through a substance. In areas where vapor pressure is different from one side of an object (e.g., a wall) to another, moisture is diffused through the object (wall) to equalize the pressure. "High permeability" materials, such as brick, gypsum board and fibrous insulation, allow moisture to move freely. "Low permeability" materials, called vapor barriers or vapor retarders, resist the flow of moisture.
- **Air leakage** also creates moisture movement due to the water vapor that's part of air. Moisture carried into (infiltration) or out of (exfiltration) a home due to air leakage can be 10 to 100 times greater than moisture transferred by diffusion, which is a slower process. The same pressure differential factors influencing the flow of air also influence moisture flow. Therefore, in an "energy-efficient" air-sealed home, less moisture is released to the outside – allowing for a potentially damaging amount of moisture to build up inside the home.

Warm air holds more moisture than cold air. The temperature at which the moisture starts to condense is called the dew point (the point at which the air is completely saturated with moisture and can't hold any more).

Relative humidity (RH) is a measurement of the amount of moisture in the air, relative to the amount of moisture it can hold at that temperature. The dew point equals 100 percent relative humidity. If air at 100 percent relative humidity is heated, the relative humidity decreases. That's because at higher temperatures, air can hold more moisture. For example, air at 70ºF/50%RH has the same moisture content as air at 85ºF/30%RH.

Climate Zones

A firm knowledge of climate zones is key to understanding how moisture flow works inside homes in various regions of the country.

Historically, building codes in the United States have divided the country into northern and southern climates for the purposes of vapor retarder use and placement. This northern/southern climate designation typically called for vapor retarders to be located at the interior in heating-dominated (i.e., cool) climates and at the exterior for cooling-dominated (i.e., warm) climates.

Realistically, however, the United States (and North America as a whole) is a mixture of cold, mixed and hot climates with varying relative humidity levels. This new way of looking at climates is being supported by the Department of Energy's Building America program, ASHRAE, ASTM, ICAA and EEBA (see Figure 1 – DOE Building America Program Hygrothermal Regions Map).

Hygrothermal:
Heat and moisture transfer.

According to this new climate zone schematic, developed by Dr. Joe Lstriburek of Building Science Corporation, the country's hygrothermal regions include:

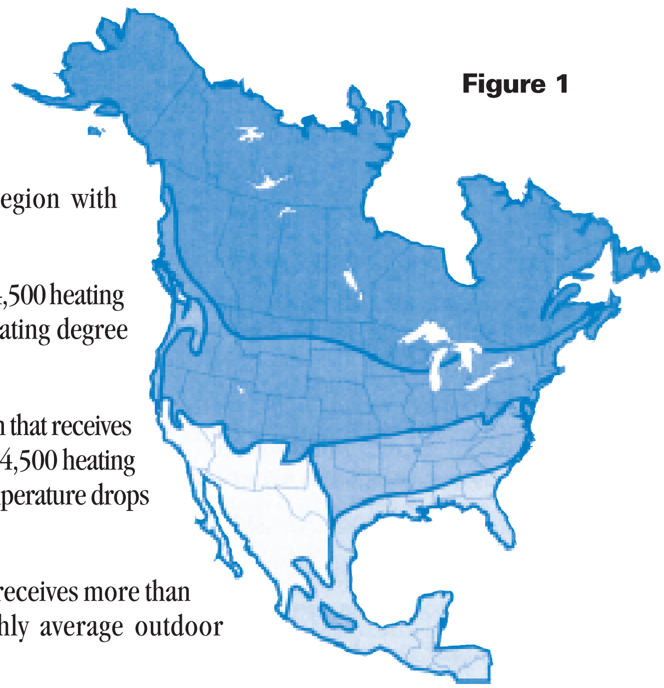


Figure 1

- Severe-Cold—A severe-cold climate is defined as a region with approximately 8,000 heating degree days or greater.
- Cold—A cold climate is defined as a region with approximately 4,500 heating degree days or greater and less than approximately 8,000 heating degree days.
- Mixed-Humid—A mixed-humid climate is defined as a region that receives more than 20 inches of annual precipitation, has approximately 4,500 heating degree days or less and where the monthly average outdoor temperature drops below 45°F during the winter months.
- Hot-Humid—A hot-humid climate is defined as a region that receives more than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45°F throughout the year.
- Hot-Dry/Mixed-Dry—A hot-dry climate is defined as a region that receives less than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45°F throughout the year.

  A mixed-dry climate is defined as a region that receives less than 20 inches of annual precipitation, has approximately 4,500 heating degree days or less and where the monthly average outdoor temperature drops below 45°F during the winter months.

What is a Degree Day?

A degree day is the difference in temperature between the outdoor mean temperature over a 24-hour period and a given base temperature. For example, Charlotte (a city in the Mixed-Humid climate zone) has 3,162 heating degree days.

In mixed-humid climates (which cover vast portions of the central U.S.), the moisture-drive direction is balanced between winter and summer seasons. This can make it difficult to correctly choose and place vapor retarders, air barriers and other materials to minimize the potential for water vapor condensation while allowing for some drying. Another White Paper in this series discusses a new vapor retarder technology that is ideal for use in such climates.

Building Materials and Wetting/Drying

All building materials/systems have the potential to become wet. It's therefore important to understand the balance between wetting and drying and how the type of building materials used in construction can influence that balance.

Moisture accumulates in the building envelope when the rate of moisture entering the building system exceeds the rate of moisture removed from the system. When moisture accumulation exceeds the ability of the building's materials to store that moisture, problems such as rot, decay, mold and corrosion can result.

This moisture-storage capacity is a key determinant of system performance. For example, wood has a relatively large capacity to store water. Wood used in sheathings and wood frame walls can typically store moisture until the moisture content by weight exceeds 16 percent. Masonry systems have an even larger capacity to store water. Building materials such as steel studs and gypsum sheathing, on the other hand, have little to no moisture storage capacity. In these types of systems, even the smallest leak or moisture diffusion can lead to problems.

One key to avoiding moisture problems is to keep the drying time as short as possible. Another key to avoiding moisture problems is to control moisture entry. However, most methods of keeping moisture from getting into a building system also keep moisture from getting out of the system. Conversely, moisture removal methods may also allow moisture to enter the system.

For example, many typical residential building envelope systems use low or semi-permeable construction materials such as rigid insulating sheathings, plywood and oriented strand board at the exterior surface.

Moisture Control By Climate

In all climates, building systems can get wet from the exterior via liquid flow. Therefore, methods to control the flow of liquid are similar in all climates. However, methods for controlling moisture that enters systems via air flow and diffusion are different for each climate.

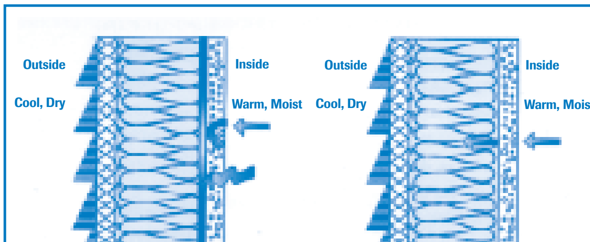
In cold climates, for example, building systems should be protected from getting wet from the interior and must be allowed to dry toward the outdoors. Air and vapor retarders are therefore typically installed toward the interior warm surfaces, and permeable materials should be used as exterior sheathings to allow moisture to escape. In addition, relatively low moisture levels should be maintained in conditioned spaces.

In hot and humid climates, building systems need to be protected from getting wet from the exterior, and they must be allowed to dry toward the interior. Therefore, air barriers and vapor retarders are typically installed on the exterior of building systems, and permeable interior wall finishes and cavity insulations without vapor retarders should be used to allow systems to dry toward the interior. In addition, conditioned spaces should be maintained at a slight positive air pressure with dehumidified air.

In mixed-humid climates, where both heating and cooling occur for extended periods of time, it may be difficult for builders to determine the correct method for moisture control. To that end, ASHRAE recommends that the vapor retarder be placed to protect against the more serious

Did You Know?

For years, building materials have been categorized as being either permeable or impermeable based on the rate at which water vapor transfers through the product. Materials having a permeance of 1 perm or less are considered vapor retarders, as specified by most building codes. Under this scheme, asphalt-backed kraft paper, polyethylene film and aluminum foil are all in the same category of vapor retarders. However, in reality, asphalt-backed kraft paper is 10 to 50 times more permeable to water vapor than polyethylene film or aluminum foil, respectively.



With a Vapor Retarder
Moisture Can't Reach Cold Surface
To Condense.

Without a Vapor Retarder
Moisture Can Penetrate Wall
and Condense On Cold Surface.

surface condensation potential connected to a season (winter or summer). EEBA recommends that wall systems be allowed to dry toward the interior and exterior environment in mixed-humid climates. The box below outlines current vapor retarder placement recommendations for above-grade building envelope applications.

Today, however, home builders can avail themselves of a new concept in vapor retarders—technology that can react to varying conditions and increase the building materials' tolerance to moisture load.

Extreme cold—place vapor retarder at the interior.

Cold—place the vapor retarder at the interior. Potential summertime moisture loads due to geographic location and building material types determine the type of vapor retarder.

Mixed-humid—First, determine whether the system is located in a heating or cooling dominated climate. Position the vapor retarder to the side with the predominant moisture drive direction. Use smart vapor retarders, like MemBrain™, or semi-permeable vapor retarders, like asphalt-backed kraft paper or vapor retarding paint at the interior if the building code requires a vapor retarder at the warm-in-winter side.

Mixed-dry—place vapor retarder at the interior, if required.

Hot-humid—place vapor retarder at the exterior — outside of cavity insulation.

Hot-dry—vapor retarder is not recommended.

Conclusion

Understanding the science of moisture management and the movement of moisture into and out of a home is key to helping builders and their contractors create homes that are more comfortable and that provide better value than homes built just a few short years ago. Another White Paper in this series describes a new vapor retarder technology developed specifically to control moisture in the mixed and cold climates that make up a great percentage of the United States.

References

The authors would like to thank the following for providing source materials for this White Paper: ASHRAE, EEBA, ICAA, ASTM, IRC, and Building Science Corporation. Specific references include:

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