SECUROCK® EXOAIR® 430 WHITE PAPER

Air & Water Vapor Permeance: Demystified

Building envelopes have evolved into multi-layered assemblies, where each layer of the assembly serves one or more distinct functions. Well-designed envelopes have layers that serve four primary barrier control functions: air, water, vapor and thermal. Controlling air flows, as well as moisture, in both liquid water and vapor forms, are primary functions for any building envelope assembly. But what does air and moisture flow control entail? This paper seeks to demystify some of the key concepts surrounding air and moisture transport through building envelopes, specifically as it relates to the topic of building material air permeance and water vapor permeance.

Excess levels of moisture can cause serious problems within the building envelope and in the building interior. If excess moisture accumulates within the assembly, it can create a damp environment that allows mold to grow as well as cause corrosion and degrade the assembly components. The presence of mold can, in turn, impact the indoor environmental quality of the building. For this reason, it is important to understand the mechanisms that can result in excess moisture and how to address them.

Moisture Flow Through Building Envelopes

Moisture moves into and through building envelopes by means of four primary mechanisms:

(1) Water leaks
(2) Vapor flow by air leaks
(3) Vapor flow by diffusion
(4) Capillary suction

Each of these can cause severe moisture problems if conditions promote moisture accumulation. In general, mechanisms associated with the bulk movement of liquid water – wind and gravity driven leakage as well as capillary suction – move the greatest amounts of moisture in the shortest periods of time, and can result in the most problems.

(1) Water leaks

Leakage of wind and gravity-driven water must be prevented by means of a water resistive barrier on the weather side of the building envelope. This barrier must be designed to drain all water down and away from the exterior of the building envelope. The water resistive barrier must cover and protect the entire surface of the envelope with all fenestration and penetration openings detailed and sealed to prevent water from draining into the interior of the structure at any point.

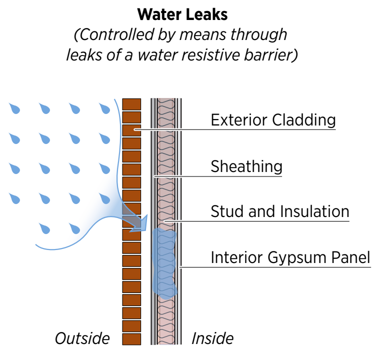
(2) Vapor flow by air leaks

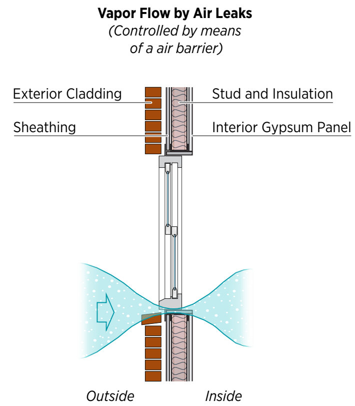
We are all familiar with water vapor suspended in air, which is what we are sensing when we comment on the humidity. Pressure differences between the outside and inside of the building envelope due to wind, HVAC operation or buoyancy effects will drive air flow through any openings or porous areas in the assembly. This air movement can transport large amounts of water vapor if the air has high humidity. If that humid air comes into contact with a cool surface, the moisture in the air can begin to condense on that surface. Likewise, if the air has very low humidity, then just the opposite effect can take place as the air picks up moisture from the surrounding materials and helps dry the assembly.

(3) Vapor flow by diffusion

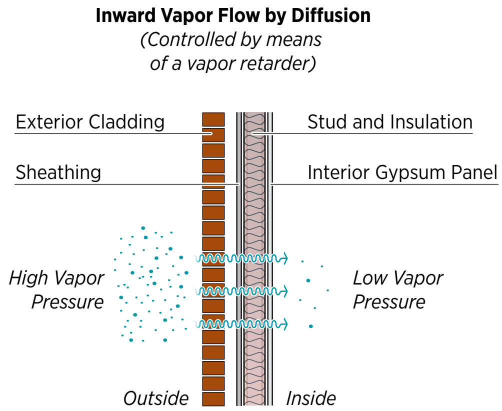
The movement of air must be controlled by means of an air barrier in the building envelope. Air barriers can take a number of forms, but for any approach, the key is to maintain or, have continuity in the system, especially at the junctions, penetrations, etc., to ensure that the air barrier seals the entirety of the building envelope.

Vapor flow by diffusion through a building envelope is caused by vapor pressure differences between the outside and the inside of the assembly. This vapor pressure differential is generated by variations in the relative humidity and temperature on either side of the assembly,



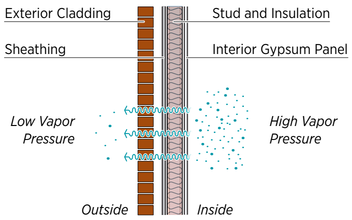


Under similar conditions, air leaks can transport 50 to 200 times more moisture than diffusion. However, problems from vapor diffusion can build up and manifest over long periods of time.



and is dependent upon the exterior and interior conditions that the building envelope is subjected to (the outside conditions are climate-dependent, while the interior conditions would be dependent upon HVAC operations). For example, when the weather is cold and dry outside, and interior conditions are warm and humid, the vapor diffusion drive is from the inside to the outside. In the contrast, if the weather is hot and humid outside and the interior is cool and dry, water vapor diffusion is inward. From an assembly point of view, since the process is driven by both temperature and relative humidity, materials that impact these will change the vapor flow process such as insulating materials change the temperature gradient in the assembly. In some cases, this can result in the air reaching dewpoint temperatures on surfaces, creating condensation.

Outward Vapor Flow by Diffusion
(Controlled by means of a vapor retarder)



What is dewpoint temperature?

Dewpoint temperature is the temperature at which water vapor starts to condense out of air that is cooling - for example when warm moisture-laden air contacts a cool surface. Building envelope assemblies should be designed to avoid having critical materials experience dewpoint temperatures for prolonged periods of time, which raises the risk of condensation.

Moisture in vapor form can move via diffusion through any porous material, and the water vapor permeance characteristics of the material (further explained on page 3) control this movement- some materials allow for rapid diffusion of water vapor through them, while others slow or retard the diffusion process.

Where should the vapor retarder layer be located?

The location of the vapor retarder is critical as it needs to ensure that the vapor does not meet a condensing surface. Therefore it needs to be placed on the warmer side of the insulation in any building envelope assembly. In a cold northern climate, the warm side will be predominantly on the inside, since the building interior will be heated for most of the year. In a hot humid climate with an air conditioned building, this warm side is predominantly on the exterior of the envelope assembly, since the building interior will be cooled for most of the year. For mixed climates with significant summers and winters, the predominantly warm side of the insulation should be determined on a case by case basis.

(4) Capillary suction

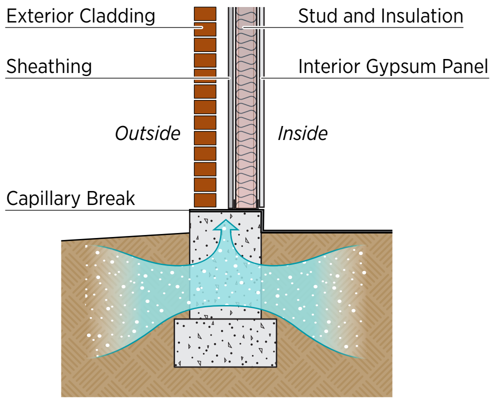
Capillary suction is primarily associated with rising damp, i.e. the phenomenon of water being drawn up into porous construction materials from the foundation soil. It is handled by placing capillary breaks at the foundation to isolate the porous, moisture-sensitive elements of the structure from soil moisture.

All these moisture flow pathways can cause wetting or drying of the building envelope. Since the conditions that generate moisture flows are dynamic and continuously changing over time, it is important that (a) building envelopes are designed with appropriate air and water barriers and (b) vapor permeability of materials utilized in the envelope allows the assembly to maintain appropriate drying capabilities within the conditions it is exposed to such that moisture accumulation within specific materials does not exceed critical levels, and the potential for condensation on or within these materials is minimized.

With vapor diffusion, the assembly must be properly constructed to mitigate air flow and liquid water intrusion, however the improper choice of water vapor permeability (e.g. layers that can trap vapor) or improper placement of layers within the assembly (e.g. vapor barrier installed on wrong side of envelope assembly) can potentially create moisture problems which manifest months or even years later. It must be noted that vapor flow transports less moisture in a given period of time compared to the other moisture transport mechanisms, so it only becomes important for conditions that are maintained over long periods of time, such as seasonal extremes.

So how does one assess when moisture begins to create problems with a building envelope assembly? Proper design requires appropriate measures to limit bulk water intrusion into the building envelope assembly. Evaluating problems from water vapor, either via air leaks or diffusion is complicated and depends upon the specific situation.. ASHRAE Standard 160 provides the best guidance on moisture analysis for building envelope design.

Capillary Suction
(Controlled by means of a capillary break)



Under similar conditions, air leaks can transport 50 to 200 times more moisture than diffusion. However, problems from vapor diffusion can build up and manifest over long periods of time.

ASHRAE standard 160 (criteria for moisture-control design analysis in buildings)

ASHRAE Standard 160 specifies performance-based criteria for predicting, mitigating or reducing moisture damage to the building envelope depending upon climate, construction type, and HVAC operation.

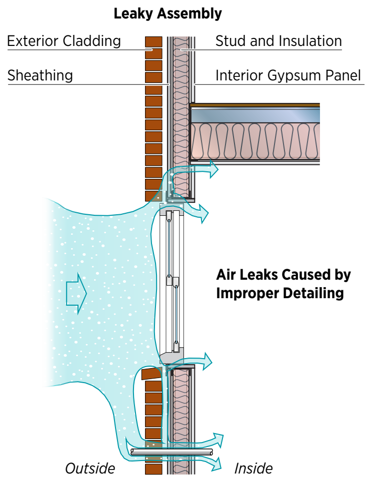
The standard proposes "mold sensitivity classes" for different materials, and based on there classes, helps to calculate a "Mold Index" that can be applied to all materials and surfaces (except for the exterior surface of the building envelope). To minimize problems associated with mold growth, the Mold Index as calculated should not exceed a value of 3.

Beyond mold, the other risk is whether excess moisture accumulates within a layer which could result in deleterious effects. To ascertain the safe moisture limit for a specific material, the designer will need to check with the manufacturer, as different materials have different levels of tolerance towards moisture limits.

Air permeance vs. water vapor permeance

Air permeance of a material indicates how much air can move through a particular material, while air permeance of an assembly indicates how much air can move through a finished assembly which includes that material, including insulation, an interior gypsum panel, etc. On the other hand, water vapor permeance indicates how much moisture can move through a material via diffusion .

All envelope assemblies need to be built to be completely air tight, and prevent any movement of air through them. Creating air-tight building envelopes is one of the most cost effective approaches for reducing energy consumption and demand on the HVAC system, improving indoor air quality, as well as ensuring durability of the entire building envelope assembly. Materials with a low air permeance are critical towards having an assembly that acts as an effective air barrier. Also critical to effective air barrier performance is detailing, specifically at challenging locations like rough openings, transitions, joints, penetrations, etc. It is extremely important that detailing be done properly in order to ensure proper and continuous application of the air barrier system.



Vapor barriers and vapor retarders

The term vapor retarder and vapor barrier is sometimes used interchangeably; however, they are not always synonymous. A vapor retarder is a material that is installed in an assembly to retard the movement of water vapor diffusion. There are different classes of vapor retarders defined by IBC, as shown below. A vapor barrier is usually defined as a material with a permeance rating of 0.1 perm or less.

The International Building Code (IBC) categorizes the different permeance values of building materials into three different classes of vapor retarders which indicates the measure of a material or assembly's ability to limit the amount of moisture that passes through that material or assembly. The three classes defined by the dry cup methods are as follows:

Class I: 0.1 perm or less

Class II: > 0.1 perm and ≤ 1 perm

Class III: > 1 perm and ≤ 10 perm

IBC also states that a material with a permeance of 5 perms or greater when tested in accordance with the desiccant method in ASTM E96 can be called as a "Vapor Permeable" membrane, which permits the passage of moisture vapor through it. Thus Class III vapor retarders slow down but do not stop the water vapor diffusion process, which can be desirable in climate zones where there can be significant vapor drives in both directions as the seasons change.

Should a particular building envelope component be vapor permeable or impermeable? While the IBC offers some guidance on the class of vapor retarders, and where they can and cannot be used, the choice of material water vapor permeance levels should be driven by the design of the particular assembly, and the climatic conditions that the building is located in. Since different materials behave differently, and outdoor and indoor conditions are dynamic and changing, the envelope should be evaluated as a whole for its capacity to provide balanced wetting and drying.

It is important to understand that water vapor permeance and liquid water resistivity can be distinct properties- a material can be highly vapor permeable, but can effectively keep out liquid water (e.g. house wrap materials).

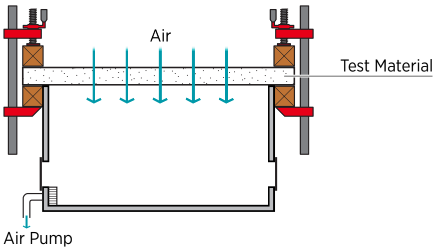
Permeance vs. permeability

The terms permeance and permeability should not be used interchangeably, as they indicate two different values - water vapor permeability is a measure of water vapor permeance for a unit thickness of material. So, permeability divided by thickness provides the permeance values. It has to be noted that this applies only to homogeneous materials, and not composites.

How are air and water vapor permeance of materials measured? What do the measured values mean?

ASTM International has established standards for evaluating water vapor and air permeance of building materials. Standard E96 evaluates the water vapor permeance of a building material and Standard E2178 evaluates the air permeance values for building materials. Standard E2357 evaluates air leakage for air barrier assemblies. It has to be noted that these are only a few of the suite of tests utilized to evaluate overall performance of an air & water barrier.

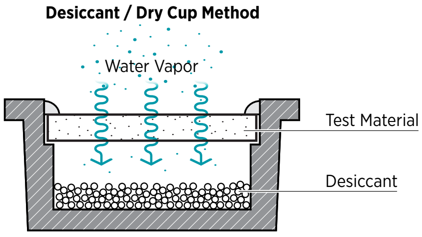
ASTM E2178 Test Apparatus



In the case of air permeance, the values are measured and specified in cubic feet per square foot per minute (cfm/ft2) or liters per second per square meter (L/(s·m^2)) The accepted level for these values as defined in many codes and standards around the country is that they should be less than or equal to 0.004 cfm/ft^2 (0.02 L/(s·m^2)) when measured following the E2178 procedure. This test is conducted at an air pressure differential of 75 Pascals (1.57 pounds per square foot). Sounds complicated? What this boils down to is that these thresholds define the maximum allowable air permeance for a material that can be used to classify an air barrier system. It is also used by the Air Barrier Association of America (ABAA) in their qualification for air barrier materials.

In the case of water vapor permeance, the values are measured and specified in units called perms. Historically, a perm has been defined as one nanogram of water vapor per second per square meter per pascal (ng/(s·m2·Pa)) or one grain of water vapor per hour, per square foot, per inch of mercury (gr/h·ft2·in.Hg) A material with a low perm value will offer more resistance to water vapor flow; in contrast a material with a high perm value will offer less resistance to water vapor flow. The ASTM Standard E96 describes the two most common methods for evaluating water vapor permeance: a desiccant or dry

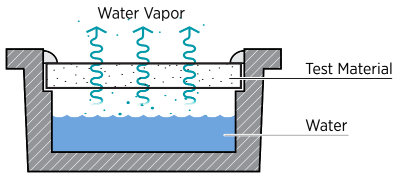
ASTM E96 Test
Desiccant / Dry Cup Method



Test Chamber

cup method and the standard water or wet cup method. The or dry cup is designed to simulate a heated dry building during a high humidity conditions, simulating moisture drive into the building. The water, or wet, cup simulates vapor drive in the opposite direction, i.e. out of the building. Due to the differing vapor pressure differential, these test methods provide different permeance values for the same material.

ASTM E96 Test
Water / Wet Cup Method



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In summary…

Water resistive barriers and air barriers are critical elements for any building envelope. Water Resistive Barriers and Air Barriers are essential for any building envelope for both water and energy management. The water resistive barrier serves as the primary means of moisture management. The air barrier is essential to both moisture and energy management. It also impacts thermal comfort by eliminating unwanted air leaks into and out of the building.

Controlling vapor flow by diffusion is important for air tight building envelopes. With buildings becoming increasingly air tight and well insulated, diffusion-based vapor flow often needs to be managed carefully. The diffusion is impacted by the exterior and interior conditions that the assembly is exposed to, as well as the choice and location of the various control layers within the assembly, including the thermal control layers. Overall, the assembly should have the ability provide sufficient drying to balance out any wetting that it may experience.

Hygrothermal analysis should be utilized to assess moisture performance. As building envelope assemblies are increasingly becoming more complicated with new materials and designs, hygrothermal analysis should be utilized. Hygrothermal analysis involves dynamic simulations of coupled heat and moisture transfer and can provide accurate assessment of moisture performance in building envelope assemblies and under realistic climate conditions. Moisture solutions provided in the codes should be considered as prescriptive, and should only serve as a starting point for the design of an assembly. The tools for hygrothermal analysis require specific expertise for proper usage and interpretation of results, therefore a professional building science expert should be consulted for this analysis.

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