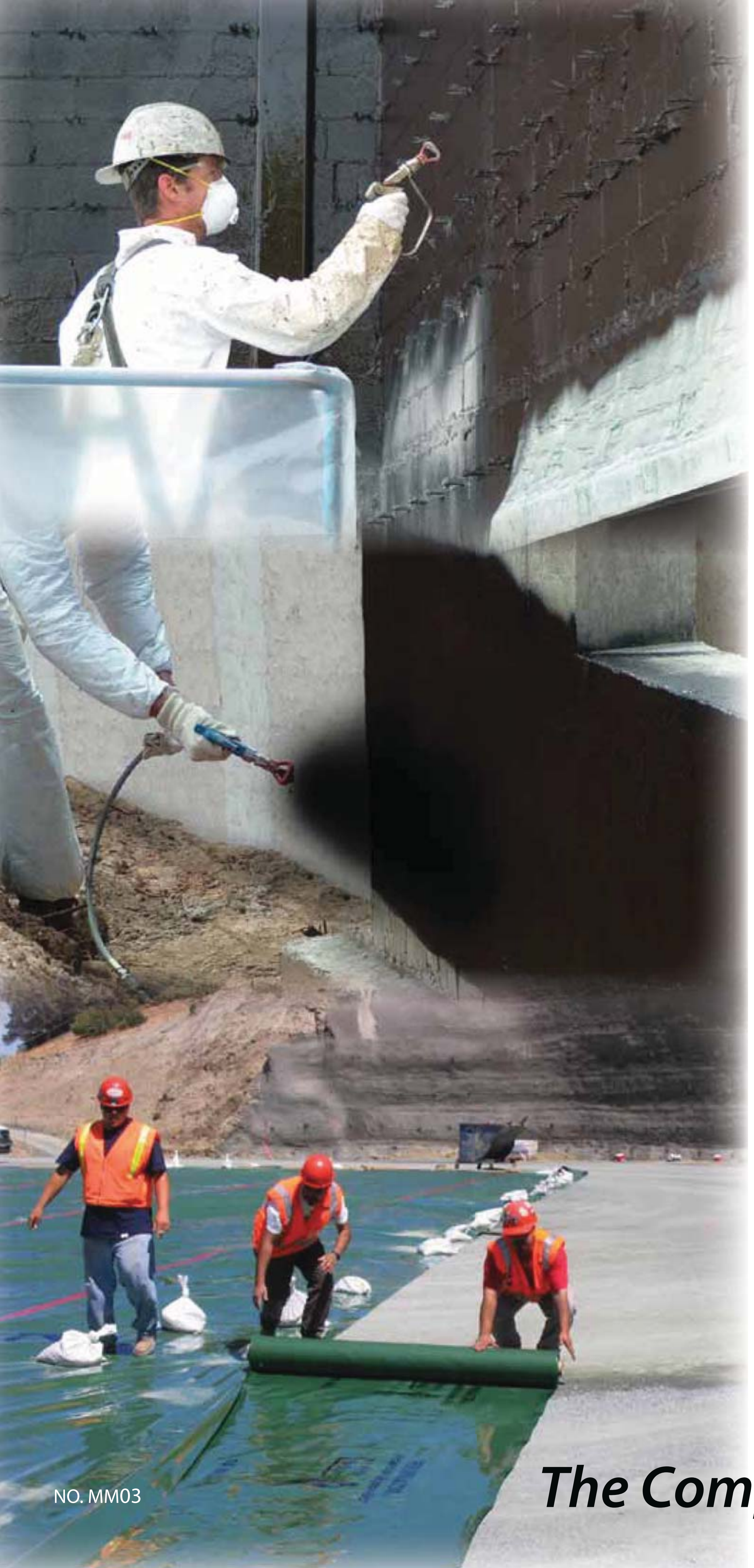

CONTROLLING MOISTURE MOVEMENT IN BUILDINGS:

W. R. MEADOWS
SEALTIGHT

The Complete Approach

Controlling Moisture Movement in Buildings:

The Complete Approach

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Prologue

Methods of controlling moisture in building construction have become extremely important to owners, specifiers and contractors. The objective of controlling moisture movement is to prevent building envelope problems before they occur – and save the building owner unnecessary maintenance and energy costs. This publication discusses the various types of moisture movement through the building envelope, provides examples of the effect of uncontrolled moisture movement has on the structure, and details methods to address the different types of moisture movement.

This current publication expands the original scope of below ground moisture movement to include moisture movement above ground by both air and vapor diffusion. By looking at both the above ground and below ground mechanisms of moisture movement, we can start to look at our structures as a 'system'. In addition, this revision includes detailed references and definitions to support the design community.

The below grade portion of this publication was originally published in 1956 and is currently still available. It has undergone eleven revisions as building science has evolved and new building envelope materials have developed.

The objective of this publication is to:

- Identify the various types of moisture movement through the building envelope
- Provide examples of the effect uncontrolled moisture movement has on the structure
- Detail methods to address the different types of moisture movement

Refer to the references and definitions provided to further your understanding on these important building envelope issues.

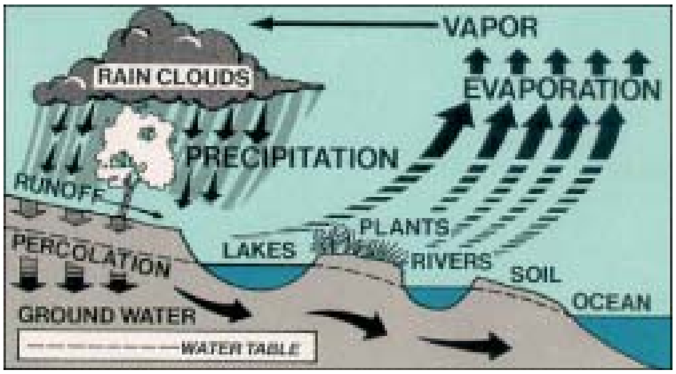
Introduction

The objective of controlling moisture movement is to prevent building envelope problems before they occur – and save the building owner unnecessary maintenance and energy costs. Fortunately, as building science has evolved, manufacturers have developed many effective products which specifically meet the building designer's requirement for addressing and controlling moisture movement.

One of the more complicated issues today in building science is addressing moisture movement through the building envelope – both above and below ground. Not only does building design have to recognize that moisture movement will occur, but it must also factor in climate, workmanship, durability and a range of other important variables.

Moisture Movement – General

Moisture is moving everywhere around us. In fact, thinking back to grade school science, we know that we are all part of the hydrological cycle – the never-ending cycle of evaporation from open water and condensation to produce clouds, precipitation in the form of rain, snow, sleet or hail, and the dissipation of rain by runoff back into the open water or through the soil. Our buildings interrupt this natural cycle, so we must understand how moisture moves – and how to accommodate it.



The hydrologic cycle

This never-ending source of moisture forces designers to incorporate systems within the building structure to prevent the ingress of uncontrolled moisture.

How we deal with this moisture varies. It depends on whether the moisture is above grade, within the wall and roof assemblies or below grade. Any amount of uncontrolled moisture below grade is considered detrimental.

Moisture can move through a building in many ways:

- Large droplets (i.e., rain/snow/sleet) (outside the scope of this document)
- Water in vapor form (Moisture Movement Above and Below Ground by Vapor Diffusion)
- Small droplets carried in the air (Moisture Movement Above Ground by Air)
- Ground water (Moisture Movement Below Ground)

Resistance to large droplets, such as from wind-driven rain, can be accommodated in the wall design. For example, in cavity wall construction, the outer wall is designed to allow some rain to enter, flow down through the cavity and back outside through a drainage system of flashing and weep holes. Materials used in this type of construction must be resistant to moisture and corrosion and be able to withstand multiple freeze/thaw cycles.

Moisture movement - by air and vapor diffusion - through the building envelope is more complicated.

While still detrimental, the slow diffusion of vapor through an above grade wall assembly is small when compared to the massive amount of moisture transported by air leakage.

Fortunately, building science is constantly advancing methods and techniques to address both these types of moisture movement. Water vapor within the building comes from normal activities: respiration, perspiration, mechanical humidification, plants and interior cleaning. These types of activities typically can also be controlled by mechanical ventilation and dehumidification.

A key challenge for designers is to control moisture movement from the exterior to the interior of the building that is less tangible. For example, one of the more complicated areas of moisture movement occurs below ground through the floor slab. In these cases, large amounts of moisture are available and must be controlled by installing properly designed vapor barriers under the floor. This part of the building design should be one of the first lines of defense against uncontrolled moisture movement, but is often overlooked or improperly designed.

Moisture Movement Below Ground

What happens?

Any time a concrete slab comes in contact with the soil surrounding the structure - whether in slab ongrade construction, basements or crawlspaces - water intrusion is a common problem. After all, these spaces are interrupting the hydrological cycle and are continuously combating water runoff and moisture movement through the soil. By knowing where the water is coming from, effective solutions can be developed to eliminate or retard moisture movement. The surrounding soil around a foundation is a significant source of moisture in both liquid and vapor forms. Moreover, liquid stored deep below the surface means that there is typically an inexhaustible supply of water vapor.

Consequently, these below grade areas are exposed to a completely different environment than those above grade, yet the interior conditions are expected to be the same. This is the challenge - to design the below-ground building envelope to accommodate the different loads and moisture sources.

Moisture can travel from the exterior to the basement interior by three mechanisms:

Liquid water flow: Liquid water in the surrounding soil can enter through openings in the foundation, windows, flashing details, cracks, imperfect waterproofing, etc. Some builders estimate that up to 50% of all basements leak, so proper design and detailing are essential. In addition, liquid water flow can be significant if the surrounding water table is high and gravity works to move large quantities of water through any openings or cracks (hydrostatic forces).

Capillary action: Capillary action refers to moisture movement through small pores in a material from areas of high water concentration to areas of low concentration. Water will wick up through these small pores and will make its way into the interior, much like a sponge soaks up water. Often this is seen at the base of many basement walls where water has wicked through the wall/slab joints. The degree of water saturation that occurs depends on the fineness of the soil and the depth of the water table. For example, fine-grained soils can draw water from considerable distances. Although capillary action may be slow, it acts day after day over the whole area of the basement or floor, so that large amounts of moisture may migrate over time.

Vapor diffusion:

Vapor is always present in the surrounding soil. Given the proper conditions, it will move from the wetter exterior into the drier interior of the building through the relatively porous concrete foundation wall and floor. For the vapor to move, there must be a vapor pressure 'drive' or differential. In vapor diffusion, vapor moves from an area of high vapor pressure to an area of lower vapor pressure, as well as from warm locations to colder locations.

Below ground, it is important to also calculate the vapor pressure 'drive' to fully understand the potential amounts of vapor that could enter the interior space if no vapor barrier was installed. By knowing the temperatures and relative humidity on either side of the basement floor, the vapor pressures can be calculated. The difference between the vapor pressure is the 'drive'; the vapor will flow from a point of higher pressure to a point of lower pressure just like air flow created by fans during forced-air cooling. For example, if the surrounding soil is at 55° F (13° C) and 100% relative humidity (common in most parts of North America) and the interior conditions are 70° F (21° C) and 30% relative humidity, the vapor pressure beneath the slab [0.214 lb./sq. in. (1.48 kPa)] is greater than the interior space [0.108 lb./sq. in. (0.74 kPa)]. This means that without a proper vapor barrier, vapor will move into the interior space and cause problems. Large amounts of moisture are available and must be controlled by installing properly designed vapor barriers under the floor slab. For example, in a one-year study of 60 homes without any method addressing vapor diffusion through the floor, the average evaporation was approximately [1.3 oz/sq. ft./day. (4.1 L/sq. m)] or [10.16 gal./1000 sq. ft./day (38.5 L/92.9 sq. m/day)]. For further information see The Hydrological Cycle and Moisture Migration by W. R. MEADOWS.

What might you see?

Some signs of moisture intrusion are obvious – wet floors and walls caused by leaks – but others are more difficult to see and to identify the source. Look for efflorescence, indicating moisture in the wall is dissolving salts in the mortar or concrete. Other clues are rusty nails, rotted wood at lower levels, rusted metal feet on appliances, mold and mildew, peeling paint and even lifted floor tiles.

Photo courtesy of Peter Craig

If flooring is installed over a concrete slab without a proper vapor barrier, the flooring may delaminate from the excessive moisture. If a carpet with foam backing is installed, the foam padding may become saturated.

Photo courtesy of Mr. Robert Cox, Construction Consultant

As people switch over from solvent-based to water-based adhesives, we are seeing more flooring failures due to uncontrolled moisture re-emulsifying the adhesive. This is just one more reason to install a properly designed vapor barrier.

Damp basement areas provide an ideal environment for mold and mildew growth

Please note:
Concrete floors, especially after just being constructed, contain a significant amount of moisture. The distribution of water in a freshly placed slab is affected by numerous variables such as: placing and finishing techniques, evaporation rates during finishing, rate of bleed water evaporation, curing practices and materials, etc. While all of these factors will have some impact on the moisture content of concrete, it is the changes in moisture movement/distribution found after the slab has hardened that will have the most substantial impact on the performance of subsequent flooring materials.

Floor covering and adhesive manufacturers often require that specific conditions be met, before they will warrantee the performance of their product(s). The following list provides some examples of the types of items these requirements may cover:

- Vapor retarder/barrier
- Concrete properties, materials, etc.
- Curing
- Finishing Techniques/Surface finish
- Floor Flatness
- Maximum allowable MVER (Moisture Vapor
- Emission Rate)
- pH requirements

In addition to the manufacturers requirements/recommendations, ACI 302.2R-06: *Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials,* is an extremely valuable reference source which contains materials, design and construction recommendations for the successful application of flooring materials. ACI 302.2R, Chapter 3, outlines various test methods that can be used for determining the MVER of concrete slabs. These include:

- ASTM E 1907 — *Standard Guide to Methods of Evaluating Moisture Conditions of Concrete Floors to Receive Resilient Floor Coverings*
- ASTM D 4263 — *Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method*
- ASTM F 1869 — *Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride*
- ASTM F 2170 — *Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes*
- ASTM F 2420 — *Standard Test Method for Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurements and Insulated Hood*

In the past few years, ASTM F 2170, % RH (Relative Humidity) testing appears to be becoming the preferred test method, often replacing ASTM F 1869, the Calcium Chloride Test, which had been the test method of choice for many years. Ultimately, it will be the flooring material(s) manufacturer's requirements that will dictate which test method is used.

After addressing MVER test methods, ACI 302.2R-06, Chapter 3 continues with recommendations for the positioning of the vapor barrier – in relation to the concrete slab. Section 3.4.9, states:

Acceptance limits for surface moisture tests, such as the calcium chloride test, are established based on the assumption that a vapor barrier/retarder is present. Moisture in the capillary pores will redistribute after flooring is installed, but the supply of water will not be replenished from an external source.

For slabs not placed on a vapor retarder/barrier, the validity of any moisture test taken at the surface or with probes in the concrete should be questioned. The test result cannot be used to estimate the amount of water that can move to the floor covering once it is installed because the amount of water entering the bottom of the slab is impossible to determine.

ACI 302.2R-06 recommends that a concrete slab to receive a moisture-sensitive floor covering be placed directly on a vapor retarder/barrier. Previous versions of this document recommended placing a granular layer between the vapor retarder/barrier and the slab, however, rainwater or water used to aid compaction can later pass through the slab in a liquid or vapor form and accumulated at the interface of the concrete and the floor covering.

WARNING – A moisture test should not be used to predict future concrete drying behavior, to provide evidence that moisture criteria are satisfied, or to establish expected floor covering performance if the concrete slab has not been placed directly on a vapor retarder/barrier.

In addition to MVER testing, manufacturers typically require pH testing be performed prior to the application of the flooring materials. Highly alkaline (high pH) solutions can degrade and ultimately destroy many types of flooring adhesives. ACI 302.2R-06, Chapter 4 outlines test methods and recommendations for pH testing of a concrete slab. ASTM documents relating to pH and concrete slabs include:

- ASTM D 4262 *Standard Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces*
- ASTM F 710 *Standard Practice for Preparing Floors to Receive Resilient Flooring*

For MVER, pH and any other related testing and/or requirements, it is extremely important to follow the material(s) manufacturer's instructions PRIOR to installing flooring materials over a concrete slab.
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What can you do?

The solution depends on the cause of the moisture movement.

In most cases, the source of the moisture is a combination of all methods: liquid water, capillary action and vapor diffusion. As a result, in certain cases, consider using a combination vapor barrier/waterproofing membrane to ensure that moisture migration is controlled.

Liquid water flow: The type of soil, flashing details, landscaping, drainage system and waterproofing can all affect this type of moisture movement. Where there is concern about excessive water in the surrounding soil (i.e., high water table), detail and install a robust waterproofing system that will withstand hydrostatic forces, aggressive installation methods and harsh soil conditions while maintaining long-term waterproofing performance.

Capillary action: To minimize capillary action, consider the use of crushed stone as a capillary break. Then, install a proper vapor barrier on top of the crushed stone.

Vapor diffusion: To minimize vapor diffusion through the foundation walls and slabs, install an effective vapor barrier on the exterior of the foundation walls and under floor slabs. In general, the vapor barrier is installed on the exterior of the foundation wall and under the floor slab to retard the inward flow of water vapor from the surrounding soil. Look for a product with a low water vapor permeance.

Controlling vapor diffusion through the floor slab is critical. Therefore, it is recommended that a high-quality bituminous vapor barrier be used. A vapor barrier is a product that has been designed and tested to ensure that negligible amounts of water vapor can permeate through it. It also has to be durable enough to withstand construction traffic.

Don't confuse waterproofing and vaporproofing.

"All materials that are vaporproof are inherently waterproof; not all materials that are waterproof are necessarily vaporproof."

Vaporproofing products:

- Are designed to effectively stop the movement of water vapor, as well as liquid water, from entering a structure
- A "true" vapor barrier will also act as an excellent waterproofing material, if designed to withstand hydrostatic forces and an aggressive environment

A Vapor Barrier Product Is:

- **Able to perform a dual role as a waterproofing membrane**
- **Designed with a low water vapor permeance**

Under concrete floor slabs, specify a vapor barrier with the lowest possible perm rating and one that meets ASTM E 1993-98: Standard Specification for Bituminous Water Vapor Retarders used in Contact with Soil or Granular Fill under Concrete Slabs or ASTM E 1745: Standard Specification for Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs.

- **Compatible with surrounding soil and other adjoining construction products (i.e., sealants)**

Take into consideration the various soil types surrounding the installation and other construction products in the assembly.

- **Robust and durable over the life of the building**

The vapor barrier must outlast the life of the building. Use materials with demonstrated performance that will withstand climatic variations, such as moisture and temperature. The vapor barrier must be durable and tough enough to withstand normal handling, foot traffic, aggregate impact and backfill abrasion during the construction phase.

Application of ASTM E-96 vapor barrier (PREMOULDED MEMBRANE® VAPOR SEAL with PLASMATIC® CORE)

Please note:
- Install thermal insulation on either the interior or exterior of the foundation walls to reduce the potential for warm, humid air to condense on the interior of the wall.
- Remember to let the wall cure sufficiently to allow water vapor to escape from the freshly poured concrete before installing a vapor retarder on the interior wall.
- Because water vapor will be escaping from freshly curing concrete, do not install flooring, carpets or tile until it has cured sufficiently.

Detailing joints of ASTM E-96 vapor barrier (PREMOULDED MEMBRANE VAPOR SEAL with PLASMATIC CORE)

Waterproofing products:

- May have a higher water vapor permeance than vapor barriers
- May not be an effective vapor barrier, since water molecules are larger than vapor molecules

A Waterproofing Product Is:

- **Durable both during and after construction**

The installation stage is sometimes the most potentially damaging for waterproofing layer(s), depending on the product being installed. This layer must withstand potential mechanical damage during construction, such as abrasive action during backfilling. Consider installing a protective layer, such as a hardcore asphalt protection board.

- **Effective against moisture intrusion**

The main requirement of a waterproofing product is that it has a high resistance to water flow under hydrostatic forces.

- **Robust and durable over the life of the building**

The waterproofing product must outlast the life of the building. Use materials with demonstrated performance that will withstand climatic variations.

Sheet-applied waterproofing membrane and drainage layer (MEL-ROL® Waterproofing Membrane and MEL-DRAIN™ Drainage Board)

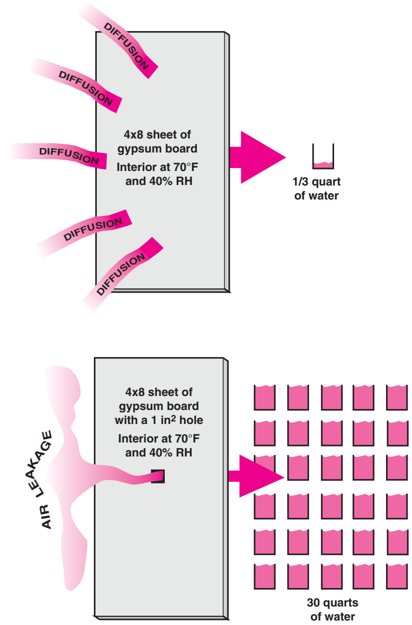
Spray-applied waterproofing membrane (MEL-ROL LM)

Rolled, self-adhering waterproofing membrane (MEL-ROL)

Moisture Movement Above Ground

The movement of moisture into a building through the wall assembly above grade can take two main forms. The first is the slow transmission of water vapor through vapor diffusion, driven by pressure and temperature differentials. The second is the more severe movement of moisture-laden air through porous building materials, holes, and/or penetrations in the building envelope.

Addressing moisture movement above grade by air is the most significant vehicle in eliminating moisture in the wall. Moisture movement by air accounts for 70-90% of uncontrolled moisture, while the remaining 10-30% is moved by vapor diffusion.



Diffusion vs. Air Leakage
Source: Building Science Corporation 'Builder's Guide'

Moisture Movement Above Ground by Air

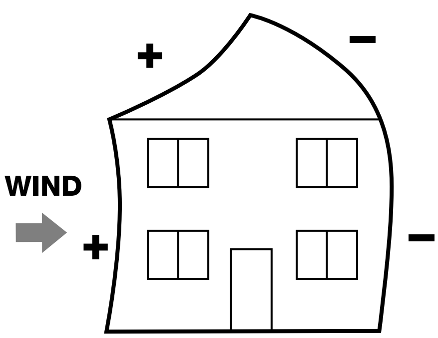
What happens?

Air will move through the building if there is a pressure difference across the building envelope. As a result, any hole or penetration in the building envelope can allow moisture-laden air to move through the wall.

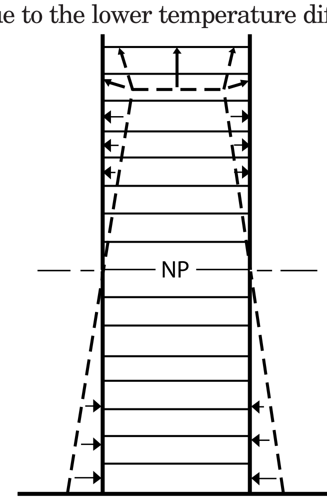
Air is moved by:

- Building location and wind
- Stack (or chimney) effect
- Mechanical means (HVAC systems)

Building location and wind:
Wind hitting the building will put one side of the building under positive pressure and force unconditioned air in, while the other side (leeward) will be placed under negative pressure and conditioned air will be sucked out.



Stack (or chimney) effect: During the heating season, warm air, being less dense, rises. Consequently, warm air inside the building will rise up and out through any hole in the upper part of the building envelope. The escaping warm air is replaced by cooler air in the lower part of the building. During the cooling season, stack effect is reversed, but is weaker due to the lower temperature differences.



Mechanical means (HVAC systems): HVAC systems typically put the conditioned space under positive pressure, compared to the outside, to minimize drafts and outdoor pollutants. Realistically, holes or penetrations in the air barrier will occur from poor workmanship, incorrect details, renovation changes, etc. Accepting this, the key then is to design a system that addresses the air barrier limitations, monitors temperature and humidity control within the conditioned space, and accounts for air pressure differentials across the building envelope.

What might you see?

Uncontrolled air leakage through the building envelope will affect the performance of the building materials within the wall assembly.

Rising energy costs are an international concern. These costs can rise when the conditioned space is either diluted by cold, incoming air (cold climates) or when the cooler temperature of the room air is leaked outside (hot climates). Air leakage may require additional costs for humidity control through humidification or dehumidification. According to the Air Barrier Association of America, the United States Department of Energy has found that up to 40% of HVAC cost in a building is due to air leakage. In addition, moisture accumulation in certain insulations can reduce the overall R-value of the insulation, resulting in higher energy costs.

Moisture in exterior claddings, coupled with repeated freeze/thaw cycles, can lead to spalling of bricks, delamination of facers, etc. This can be particularly damaging in the more northern climates where the building envelope is exposed to multiple freeze/thaw cycles annually. In these cases, rust can form on concealed reinforcing (rebar), forcing large cracks in the exterior facade.

Photo of brick delamination/spalling. Photos supplied courtesy of Retro-Specs Consultants, Ltd. (Kevin Knight)

Given the following circumstances - sufficient moisture, heat, and presence of mold spores - mold growth may occur within the wall assembly. Generally, this type of mold is benign; however, certain types of mold and mildew can cause respiratory problems. Most molds grow at temperatures above 40° F and when the relative humidity is greater than 80%. The presence of mold may indicate that there is moisture movement across the wall assembly and in sufficient quantities to be an issue.

Photo of mold in wall. Photo supplied courtesy of Canadian Home Builders' Association (CHBA) and Canadian Mortgage and Housing Corp. (CMHC)

Look for "shadows" on the interior walls over joists. This might indicate that moisture is condensing on the wood joists and dust is adhering to those areas.

Sometimes salt deposits, or efflorescence, occur on the exterior masonry. This indicates that moisture has dissolved the salts in the mortar and brick and left behind the salt stain when it evaporated.

Photo of efflorescence. Photo supplied courtesy of Retro-Specs Consultants, Ltd. (Kevin Knight)

What can you do?

To prevent air movement through an exterior wall, a continuous air barrier system (or airflow retarder) must be installed. An air barrier system can be defined as a system of building assemblies within the building enclosure – designed, installed, and integrated in such a manner as to stop the uncontrolled flow of air into and out of the building enclosure.

This material is the primary barrier within the building envelope that separates the indoor conditioned air from the outdoor unconditioned air. Proper integration of an air barrier system within the building enclosure can positively affect the energy efficiency of a structure, providing greater comfort for the occupants of the building, but can also drastically decrease the amount of moisture moving through the building envelope.

It is important to note that an air barrier can be located anywhere within the building assembly. However, the type of air barrier needs to be carefully selected and installed to optimize the performance. If it is placed on the warm side, it should have a low permeability rating, more commonly called an air/vapor barrier. If it is placed on the cool side of the wall, it should be a vapor permeable material.

In addition, an air barrier should also be designed and constructed to drain water. The complete system should be interconnected with flashings, window and door openings, and other penetrations of the building enclosure to provide drainage of water to the exterior of the building.

An Effective Air Barrier Is:

- **Impermeable to air flow**

The main requirement of an air barrier is that it has a high resistance to air flow. Check the local building requirements for the maximum air leakage rate allowable and design an air barrier system to meet these requirements.

- **Continuous at corners, partition wall, floors, etc.**

Because an air barrier must be continuous, the air barrier becomes a system with different materials at the joints, corners, intersections, etc. All these supporting materials must be compatible with each other and be easy to install and inspect. In addition, any dimensional changes (from temperature or shrinkage) must not adversely affect performance.

- **Designed to withstand mechanical force/ trauma during and after construction**

The installation stage is sometimes the most potentially damaging for the air barrier – the air barrier must stand up to rain, heat, ultraviolet light, cold, and mechanical damage during construction. After construction, it must be able to perform under wind and stack-effect forces.

- **Robust and durable over the lifetime of the building**

The air barrier system must outlast the life of the building. Use materials with demonstrated performance that will withstand climatic variations such as moisture, temperature, and ultraviolet light, if applicable.

- **Other important properties to consider include thermal stability, fire and flammability performance, and ease of installation.**

Please note: In addition to installing a proper air barrier system, consider the use of a masonry water repellent or proper interior sealer to reduce unsightly efflorescence and spalling in porous substrates.

For opaque wall systems, there are two main types of air barriers:

- Rigid air barriers
- Membrane air barriers

Rigid air barriers

Rigid air barriers, as the name implies, are made of inflexible materials, such as drywall, plywood, or other air impermeable products. Joints must be gasketed or sealed to reduce airflow. Depending on the vapor permeability of the rigid air barrier, it may have vapor retarder properties.

The most common rigid air barrier used is drywall. It is important that all junctions between the drywall and subfloors, framing members, and other components are well sealed together. To obtain this seal, some changes in building construction may be necessary. For example, all wiring and plumbing penetrations must be sealed, and drywall on exterior walls must be gasketed and caulked.

Although a rigid air barrier system is not easily damaged during construction, often changes made after construction damage the integrity of the air barrier system. If the rigid air barrier used is vapor permeable, a vapor retarder must be incorporated into the wall assembly, often as a separate material.

Photo of rigid air barrier

Please note:

In some light commercial or residential construction, there may be a need for a rigid air barrier system. This can include certain rigid insulation materials or a membrane house wrap (spunbonded polyolefin/polypropylene sheeting). In cold climates where a separate vapor retarder is installed on the winter warm side (i.e., interior) of the building, it is crucial that the exterior air barrier is NOT a vapor retarder. This will allow adequate vapor transmission while stopping air movement. For additional information, see Dew Point (page 17).

Membrane air barriers

Membrane air barriers are predominately found in industrial, commercial, and institutional construction. These air barriers are flexible spray, trowel-applied, or sheet products that typically also have vapor retarder capabilities built in. Used as a combination air/vapor barrier, they negate the need to install a separate vapor barrier on the interior of the building. When utilizing a product that acts both as an air and vapor barrier, care must be taken to place it in the correct position within the wall assembly. (See page 15: "Installed in the proper location.") For a membrane air barrier, detail all seams and joints that occur over a solid backing and are overlapped. Detailing at penetrations (electrical boxes, ducting, etc.) requires special attention to ensure continuity. All sealants, tapes, and caulking must be compatible with the other materials used in the membrane air barrier system.

Flexible sheet-type membrane air barrier being applied to exterior wall. (AIR-SHIELD)

There are two types of membrane air barriers:

- Air/vapor barriers
- Vapor permeable air barriers

Selection of these materials is dependent on certain important factors that include:

- Climate
- Wall design – placement of the air barrier and insulation layer within the wall system
- Use of the building – current and predicted

Air/vapor barriers

This material is designed to control airflow through the building enclosure system, and also to control the diffusion of water vapor through the system. As stated earlier, vapor diffusion is independent of air pressure and its movement is determined by a difference in vapor pressure. It separates an environment that is at a higher vapor pressure than that of a lower vapor pressure. This vapor pressure is dependent on differences in temperature and relative humidity on either side of the enclosure. For best results, it is important that the vapor barrier is continuous, but it does not have to be perfectly continuous. Unsealed laps or minor cuts do not affect the overall resistance to diffusion significantly. As stated earlier, a vapor barrier must also be located on the warm side of the insulation or at least in a location in the wall near enough to the warm side to remain above the dew point temperature of the indoor air during cold weather.

Vapor Permeable Air Barriers

This material is designed to control airflow through the building enclosure system, and also allows the diffusion of water vapor through due to the high permeance of these types of materials. Typically, but not always, they are used in conjunction with a separate vapor barrier. Currently, there is no specific requirement or agreement that defines vapor permeability, but materials that typically have a perm rating of 5-15 perms can be defined as vapor permeable.

Because of its location within the building construction, the membrane air barrier cannot be easily accessed after construction. Ease of installation, inspection, and a measure of durability during the construction phase is key to ensuring an effective, long-lasting air barrier system.

Liquid-applied vapor permeable air barrier (AIR-SHIELD LMP).

Moisture Movement Above Ground by Vapor Diffusion

What happens?

In vapor diffusion, vapor moves from an area of high vapor pressure to an area of lower vapor pressure. Another driver of vapor is thermally induced; vapor moves from a warm side to a cold side of the building envelope. Vapor pressure is the concentration of moisture at a specific location – or the density of water vapor in air. The result is vapor will diffuse through materials going from a higher concentration to a lower vapor concentration.

What might you see?

Although moisture carried by vapor diffusion is significantly lower than the amount carried by air movement, it still contributes to the adverse effects illustrated in the previous section.

What can you do?

To reduce problems with vapor movements through an above-grade wall, install a vapor retarder. By installing a vapor retarder, the diffusion of water vapor is slowed down.

An Effective Vapor Retarder Is:

- **Designed with a low perm rating**

A low perm rating is an indication of the permeability of a material. Impermeable materials have low perm ratings. Many building codes define a low perm rating to be a material with a permeability of one perm or less. Vapor retarders are classified according to their permeability and measured in perms. The lower the perm number, the better its vapor retarder properties. A perm is a unit of measurement, which looks at the transfer of water across a certain area under a pressure difference. Essentially, this measures the amount of vapor that passes through a material when subjected to a driving force (vapor pressure differential). The more vapor passing through the material, the higher the perm rating. Remember, too, that a rigid or flexible material may have a high perm rating, but if an additional coating vapor retarder (i.e. paint coating) is applied, the perm rating may decrease significantly. In some special cases, a vapor retarder may have such high resistance to vapor diffusion that it is called a vapor barrier.

- **Installed in the proper location**

Install the vapor retarder to minimize condensation. Condensation will occur on any surface below the dew point temperature. Install enough insulation on the cold side to keep the vapor retarder relatively warm and prevent condensation. (See Dew Point, page 17). Because of the nature of vapor movement, continuity of the vapor retarder is not as critical, as with an air barrier.

Depending on the building location, climate, and placement of other components, the position of the vapor retarder within the building envelope may vary. The key is to position the vapor retarder in a location above the dew point (see Dew Point, page 17). For example, in high humidity locations, the vapor retarder typically is installed on the exterior side of the building assembly to minimize moisture movement from the exterior to the interior. Due to the fact that some moisture will get into the wall assembly, design the wall so that the interior finish has a higher perm rating than the exterior vapor retarder does.

In cooler climates, the vapor retarder is typically installed on the winter warm side of the insulation to minimize the possibility of moisture moving into the wall assembly from within the building. Since some moisture will get into the wall assembly, design the wall to accommodate this and ensure that the exterior materials have a higher perm rating than the interior vapor retarder. For example, some building codes require the perm rating of the exterior materials be ten times more permeable than the interior vapor retarder.

- **Robust and durable over the life of the building**

The vapor retarder must outlast the life of the building. Use materials with demonstrated performance that will withstand climatic variations, such as moisture, temperature, and ultraviolet light, if applicable.

- **Compatible with other materials in the system**

Check compatibility with heat-producing surfaces, such as chimneys, sealants, and other compounds.

- **Easy to install**

If using a specialty paint as the vapor retarder, check that it is applied evenly to the required thickness to be effective.

The three main types of vapor retarders are:

- Rigid
- Flexible
- Coating

Rigid vapor retarders include:

- Aluminum
- Stainless steel
- Reinforced plastics

Rigid vapor retarders, as the name implies, are usually mechanically fastened in place.

Flexible vapor retarders include:

- Metal and laminated foils
- Coated felts and papers
- Plastic films and sheets
- Self-adhesive sheet products

Typically, these types of retarders come in rolls or laminated sheets of insulation.

Coating vapor retarders include:

- Semi-fluids or mastics
- Specialty paints
- Hot melt (thermofusible) sheet materials

Application of coating vapor retarders, depending on the product, may include spray on, roller, trowel, brush or sheet. In many cases, these types of retarders can also be air barriers.

Summary of Air and Vapor Movement

Vapor diffusion should not be confused with air movement of moisture – they are very different mechanisms.

Moisture movement by vapor diffusion	Moisture movement by air
Does not require an air pressure difference – only requires a vapor pressure or temperature difference	Moves through building envelope because of an air pressure differential
May be in the opposite direction than air movement. For example, in an air-conditioned house in the summer, air moves from the inside to the outside. However, because of the high humidity and hot outside temperatures, vapor diffusion will occur from the outside to the inside.	May be in the opposite direction than vapor diffusion. Moves through building envelope in direction of air pressure differential
Reduced by properties of vapor retarder – not as dependent on tight seals and joints	Reduced by sealing the building envelope in a continuous blanket – very dependent on tight seals and joints
Affected by permeability of the material	Affected by wind, stack and mechanical systems and the air barrier properties of the system
More 'forgiving' during renovations/changes	Easy to lose continuity during renovations/changes, thereby reducing the effectiveness of the air barrier properties
Moves small volumes of moisture (10-30% of total quality)	Moves large volumes of moisture (70-90% of total quality)

Please note:
Remember that an air barrier is not necessarily a vapor retarder. Both address different modes of moisture movement. If you are using a combination air/vapor barrier, it must be continuous. If you are using a separate air barrier and vapor retarder, the air barrier must be continuous; however, the vapor retarder need not be.

Dew Point

Dew point affects us in many ways. For example, on a hot summer day, the beads of "sweat" on a cold beverage glass are an example of dew point: the moisture in the warm air is condensing on the exterior surface of the glass. This happens because the surrounding warm air cannot hold the moisture as vapor anymore. As it cools, it appears as water droplets on the cold surface.

The dew point temperature (or saturation temperature) occurs where air at a given temperature cannot hold any more water as vapor. Warm air can hold more water vapor (think high humidity days); colder air holds less water vapor (think dry skin in winter).

Psychrometric charts provide the dew point temperature for any given air temperature at a given relative humidity. For example, if the outside temperature is 70° F and the relative humidity is 50° F, the dew point temperature is 50° F. This means that if a sample of air is cooled to 50° F, water will condense on the next rigid surface. In a wall, this could mean that the cooled air will condense on the inside of a vapor retarder and then puddle in the wall assembly.

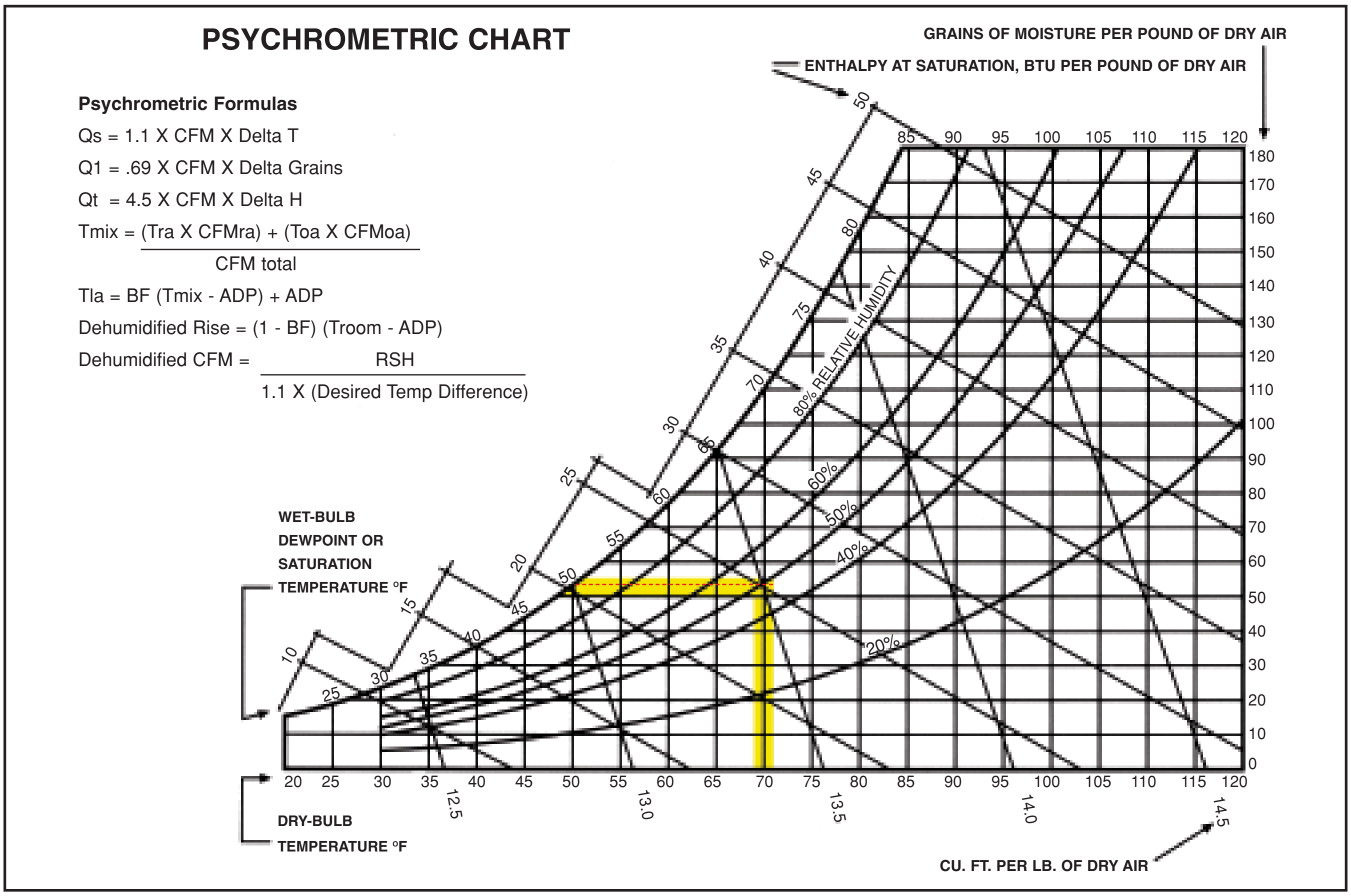


Chart supplied courtesy of Carrier Corporation: A United Technologies Company

Air Temp °F	% Relative Humidity																	
	100	**95**	**90**	**85**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	**45**	**40**	**35**	**30**	**25**	**20**	**15**	**10**
110	110	108	106	104	102	100	98	95	93	90	87	84	80	76	72	65	60	51	41
105	105	103	101	99	97	95	93	91	88	85	83	80	76	72	67	62	55	47	37
100	100	99	97	95	93	91	89	86	84	81	78	75	71	67	63	58	52	44	32
95	95	93	92	90	88	86	84	81	79	76	73	70	67	63	59	54	48	40	32
90	90	88	87	85	83	81	79	76	74	71	68	65	62	59	54	49	43	36	32
85	85	83	81	80	78	76	74	72	69	67	64	61	58	54	50	45	38	32	
80	80	78	77	75	73	71	69	67	65	62	59	56	53	50	45	40	35	32	
75	75	73	72	70	68	66	64	62	60	58	55	52	49	45	41	36	32		
70	70	68	67	65	63	61	59	57	55	53	50	47	44	40	37	32			
65	65	63	62	60	59	57	55	53	50	48	45	42	40	36	32				
60	60	58	57	55	53	53	50	48	45	43	41	38	35	32					
55	55	53	52	50	49	47	45	43	40	38	36	33	32						
50	50	48	46	45	44	42	40	38	36	34	32								
45	45	43	42	40	39	37	35	33	32										
40	40	39	37	35	34	32													
35	35	34	32																
32	32																		

Knowing the dew point is important when designing the building envelope. To accommodate any condensation occurring within the wall, steps can be taken to assure the performance of the wall assembly. For example, in some climates, the dew point may be reached within the wall during the winter months of the year.

By installing sufficient levels of insulation, air barriers, and a vapor retarder, the dew point can be moved out of the wall and most of the condensation can be prevented. By calculating the location of the dew point, you can ensure that it is not within certain insulations: some insulation loses R-value when wet.

Calculating the dew point temperature can be done by many commercially available software applications, or by following the procedure detailed in Chapter 22 of the 1997 ASHRAE Fundamentals Handbook. In these calculations, temperature drops across each individual component of the building envelope are calculated based on interior and exterior temperatures, thickness, R-value, and the permeability of the component. By calculating the temperature across the wall, plus the resulting saturation vapor pressure and actual vapor pressure, the location of the dew point temperature can be identified (if applicable).

Case Study

Knowing the theory and science behind moisture movement through the building envelope is one thing – but actually applying it in practice is another. In this section, we will look at the design of the building envelope and identify products that meet the requirements for the intended use.

The Building Design:

- Commercial construction in northern North America
- Brick façade with concrete block interior wall using rain screen wall construction
- Closed cell extruded polystyrene insulation in the cavity
- Vapor retarder
- Air barrier

The Issue:

- Require an air barrier system that is economical, easy to install, provides long-term performance, and is durable during the construction phase.
- Require vapor retarders and vapor barriers throughout the building envelope.

The Solution:

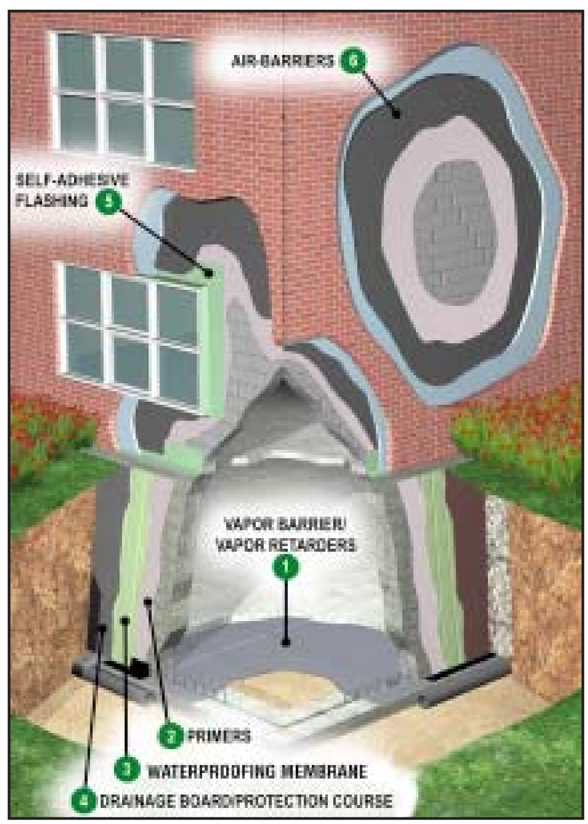
Above grade: Install a combined air/vapor barrier system within the wall cavity. Consider AIR-SHIELD self-adhering air/vapor and liquid moisture barrier or AIR-SHIELD LM liquid membrane air/vapor and liquid moisture barrier.

These flexible air/vapor barriers are strong and durable. Due to their low vapor permeability, these products also provide the vapor retarder properties required for a combined air/vapor barrier. If possible, place the air/vapor barrier on the warm side (i.e., near the interior) of the insulation using the "one third, two thirds rule." Locate the air/vapor barrier so that one-third of the cavity insulation is to its warm side, two-thirds to the cold side. This will minimize condensation and dew point concerns, as well as protect the air/vapor barrier from physical damage during construction or remodeling activities.

For applications requiring a vapor permeable membrane, use AIR-SHIELD LMP from W. R. MEADOWS.

Below grade: Under the flooring slab, install a vapor barrier with the lowest possible water vapor transmission properties. Consider PREMOULDED MEMBRANE VAPOR SEAL WITH PLASMATIC CORE (PMPC), a permanently bonded, multi-ply, semi-flexible core board. Properly applied, it effectively stops moisture migration in footings, concrete floors, and structural slabs. PMPC is both waterproof and vaporproof and, with its built-in protection course, resists jobsite puncturing.

For foundation walls, install a W. R. MEADOWS waterproofing products that provides both waterproofing qualities and durability required during the construction phase. Consider MEL-ROL roll-applied, self-adhesive sheet membrane or MEL-ROL LM single-component, liquid-applied, water-based waterproofing membrane. Where drainage is an issue, specify a drainage layer, such as MEL-DRAIN, in combination with a W. R. MEADOWS waterproofing membrane.



Definitions

Air barrier/air retarder: an element within a building envelope that provides resistance to airflow across the assembly

Air leakage: movement of air through an assembly because of air-pressure difference across the assembly

ASHRAE: American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc.

Building envelope: protective exterior shell of a building

Capillary action: a wick-like action where a liquid will move through a material

Condensation: change of state from a vapor to a liquid

Dampproofing: a bituminous or other coating that provides resistance to moisture movement from capillary action and vapor diffusion, where no hydrostatic head is anticipated

Dew point: temperature at which water vapor in air becomes saturated and condenses to liquid

Humidity: water vapor within a given volume of air

Membrane: continuous film over a surface that is either sheet, rolled, or spray-applied

Psychrometric chart: graph showing the relationship between temperature, humidity and air volume; provides information including specific humidity, dew point, vapor pressure, and wet bulb temperature

Vapor diffusion: the movement of moisture in the vapor state through a material, from an area of high pressure to low pressure

Vapor permeability: rate at which water vapor will diffuse through a material of a given area in a certain time with a unit vapor pressure difference

Vapor permeance: rate at which water vapor will diffuse through a material of a given thickness

Vapor barrier: vaporproofing material that effectively prevents movement of vapor through the building envelope

Vapor retarder: material that reduces movement of vapor through the building envelope

Vapor: substance in gaseous state

Waterproofing: material used to prevent leakage of water through the building envelope under hydrostatic pressure

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DESCRIPTION OF MATERIAL	Weight of roll per 500 sq. ft.	Low	High
Sheathing and roofing products	**Pounds**	**Perms[1]**	**Perms[1]**
15-pound sheathing paper	70	2.555	3.847
15-pound tar felt	70	1.560	4.055
30-pound tar felt	139	33.304	—
15-pound asphalt felt	70	.560	2.007
30-pound asphalt felt	139	.498	3.022
Asphalt coated paper (coated both sides)	50	.146	.287
55-pound roll roofing	255	.030	.081
Duplex or laminated products, asphalt laminate			
30-30-30 untreated	16	.447	1.081
30-60-30 untreated	21	.527	—
30-100-30 untreated	27	.280	—
30-30-30 untreated, creped	14	.583	1.812
30-30-30 untreated, reinforced	15	.305	—
30-85-30 untreated, reinforced	24	.296	.654
30-120-30 untreated, reinforced	30	.346	.389
60-30-60 1 covering sheet saturated with asphalt	30	.935	1.037
Duplex paper coated both sides with reflector's material	35	.226	—
Duplex paper coated both sides with reflector's material reinforced	47	.304	.347
Insulation back-up paper			
Paraffin coating, 1 side; asphalt side ribbed	18	.133	.237
Single infused	12	.433	.583
Single infused, ribbed	18	.162	.232
Asphalt saturated, one side glossy	21	.327	.377
Single sheet kraft, double infused			
Asphalt saturated kraft	11	7.447	—
Asphalt saturated kraft	15	2.469	—
Asphalt saturated kraft	18	3.612	—
Asphalt saturated kraft	23	7.987	11.656
Asphalt saturated kraft, 30 percent asphalt	16	30.764	—
Miscellaneous materials			
3/4-inch fiberboard sheathing with light asphalt coating	—	6.320	8.460
1/2-inch gypsum sheathing	—	18.200	21.950
3/8-inch gypsum lath with aluminum foil backing	—	.061	.277
Polyethylene films, 0.002 inch thick	—	.33	.33
Polyethylene films, 0.004 inch thick	—	.17	.17
Polyethylene films, 0.006 inch thick	—	.11	.11
Products available from W. R. MEADOWS			
PREMOULDED MEMBRANE Vapor Seal with PLASMATIC CORE	—	0.0011	
PERMINATOR 10 mil	—	0.0043	
PERMINATOR 15 mil	—	0.0031	
MEL-ROL	—	0.019	
MEL-ROL LM (ALL SEASON)	—	0.03	
AIR-SHIELD THRU-WALL FLASHING	—	0.035	
AIR-SHIELD LM (ALL SEASON)	—	0.03	
AIR-SHIELD LMP	—	12.00	

Perms[1] per inch of mercury difference in vapor pressure at standard test conditions.
*As measured in accordance with ASTM E-96, Method B
Reference: HUD Research Paper No. 28, Moisture Migration from the Ground.

If you need more information about how our products can help you prevent costly moisture migration, here are four quick and easy access options:

- ***Visit our comprehensive website: www.wrmeadows.com***
- ***Contact W. R. MEADOWS, INC. via e-mail: info@wrmeadows.com***
- ***Call toll-free: 1-800-342-5976***
- ***Fax: 1-847-683-4544***
- ***Follow W. R. Meadows on Twitter: www.twitter.com/wrmeadows***

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