

How Moisture Infiltrates Into Dwellings

Moisture can cause serious damage to the structure of your home. Moisture causes more than \$1 billion in damage to homes annually, from minor damage like peeling paint, to major damage, such as rotting, crumbling structural floor joists.

You can greatly reduce the cost of moisture damage in your home and eliminate the risk of structural loss if you learn how to control for moisture. It is important to control all sources of moisture that enters homes. Most moisture that is generally known to cause problems in homes is roof leaks, basement leaks, and plumbing leaks. These three types of leaks are the most obvious.

ROOF LEAKS

In the average year, three feet of water hit a house--that is 75 tons or 518,400 raindrops by someone's estimate. The question most asked by resale home buyers (after does the basement leak) are, does the roof leak. Roofs are exposed to tremendous environmental stresses - rain, snow, ice, sun, and extreme temperatures. Eventually, the materials wear out and require replacement to keep your house dry. A typical shingle roof will require replacement after 16 years.

Many roofs are hazardous and dangerous to walk on. Your inspection will only be based on what is visible from the ground level with or without binoculars. Only professional roofers should walk on rooftops. Shingles are soft in hot weather, and brittle in cold weather. Minimize walking on the roof during temperature extremes. Do not chip ice from a roof - you will do more damage than good. I have heard that you can use a low-pressure washer with warm water to remove ice dams. Roofs and ladders can also be very slippery. Your safest call would be to a roofing professional who has the knowledge and safety equipment to assess and correct your roof problems.

The condition of a flat, metal, or built-up roof often cannot be determined unless it is possible to closely inspect its surface. All slate, tile, and concrete roofs will require yearly inspection and possibly yearly repairs. Older slate, tile, and concrete roofs, become more sensitive to weather and tend to crack, chip, or become loose, and require more maintenance than other roof types. Life expectancy of new roofs in yrs.: Asphalt /Fiberglass 16-25, Wood 16-40, Slate 60-100, Roll 7-10, Tile 40-60, Metal 20-60, Asbestos 35-50. It is possible to have more than one type of roofing when you have multiple membranes. When downspouts and gutters are not properly

maintained on garages and dwellings, poor drainage can cause seepage into the dwelling. All gutters and downspouts should be free of debris and properly installed. Many times, past property owners disconnect downspouts at the base and install splash type blocks. These types of repairs might be indicators of past seepage, which the present owner should disclose. Penetrations at vents and chimneys and roof flashing should be inspected periodically for deterioration and possible leaks.

Most common causes of roof leaks:

- Improper flashing, sealing or worn through flashing around projections through the roof such as, plumbing stacks (vent pipes), chimneys, skylights, antennas, dormers, etc.
- Missing, broken or pierced shingles caused by stones, hail, broken branches or walking on a roof.
- Tears or deterioration in valleys, caused by expansion and contraction or someone walking in the valley. In addition, debris can build up in a valley and block its run-off process causing rain and snow to build up and cause excessive damage.
- Exposed nails, nails in the wrong places, or nails not set flush with the underlying shingles.
- Wind driven rain may enter through the chimney, brick, mortar or under shingles. In addition, through the siding and behind the step flashing, where a lower roof joins the vertical side of the main house.
- Ice dams, which prevent water run-off, force standing water behind the ice dam, to backup under your roof shingles.
- Improperly hung gutters or drip edge.
- Improperly installed roofing, or a roofing type, which is incorrect for the slope of the roof involved.
- Cracking and blistering of roof mastic on rolled asphalt or on built up roofing.
- Ponds of water, created when flat or low-sloped roofs begin to sag.
- Clogged roof and gutter drains.

BASEMENT LEAKS

A damp and musty basement is not only unpleasant; it can also adversely affect the health of the occupants. Most basement moisture problems can be easily recognized by doing a thorough and systematic

inspection of the basement, looking for any problems in corners, between basement walls and floor slab, behind furniture, underneath carpet, ceilings, at outside sheathing, and around windows.

Most common causes of basement leaks:

- Water penetrating through foundation walls
- Water penetrating through foundation floor
- Standing water on floor
- Water stains on concrete blocks
- Damp, humid air
- Condensation or dew points on cold walls, band joists and floor in heating seasons
- Condensation on vapor retarders in cooling seasons
- Odor, mold and mildew
- Buckling of wood and lifting-up of floor tiles and carpeting
- Staining or rot of wood headers, joists, framing and sill plates
- Staining and blistering of wall covering

Special note to prospective new homebuyers

Basement leak from many different types of conditions. Prior to purchasing a home, is important for prospective buyers to perform several steps. Prospective buyers should have a professional inspector or engineer look the foundation walls. When walls are recently painted and patched, foundation conditions are often difficult to determine. The prospective buyers need to ask previous homeowners what the walls looked like prior to the painting and patching. The prospective buyer should also investigate and inquire if their were ever sewer backups, tree root blockage, foundation conditions, flooding, structural conditions, soil movements, or any other notable condition that ever existed or occurred prior to purchasing this home. This can be done by checking city records for permits, asking adjacent neighbors questions about past conditions, searching old real-estate records for past sales, reading past home inspection reports, or any other resource that would provide more knowledge. Basement moisture or seepage is frequently mentioned on property disclosure forms. It is not the duty of the inspector or engineer to interpret these comments. Clients should personally ask sellers if past seepage, moisture, mold, flooding, run-off problems, erosion, sewer back-up, sewer odor, musty odor, underground conditions, structural repairs, settlement, cracks, water-proofing, or any other moisture or structural related conditions ever existed with the foundation or dwelling in the past. All basement

and crawl defects such as cracks, leaks, settlement, mold, mildew, unlevel conditions, and other uncommon conditions, require second opinions. The prospective buyer should also get a warranty on any waterproofing or structural repair that has been done in the past. When basement walls are covered by paneling or drywall, potential moisture, or mold conditions may exist behind walls. Dismantling the finished systems for observation is usually necessary for a proper examination.

PLUMBING LEAKS

Plumbing leaks occur from many different sources. In older homes, they occur from corrosion of galvanized pipes or rusting sanitary lines. In newer homes, plumbing leaks occur from defective plastic pipes or failed plumbing systems. In homes with surrounding trees, plumbing leaks occur from tree root back up. In all homes, plumbing leaks occur from poor maintenance of fixtures, leaking wax seals, loose drains under sinks, dripping faucets, leaking supply lines, cracked stacks and more. The most common major plumbing leaks are frozen pipes and overflows. When claiming insurance, the term overflow should be used. Terms such as back up, blockage and clogged drains may not be covered by insurance carriers. Long-term plumbing leaks will cause microbial fungal reservoirs.

Moisture movement is much more complex than just the three above-mentioned methods. Below we have listed seven methods where moisture can enter a home.

MOISTURE CAN ENTER THE HOME THROUGH THE FOLLOWING METHODS:

1. Rainwater
2. Groundwater
3. Capillary suction below grade
4. Capillary suction above grade
5. Air movements
6. Air pressure
7. Vapor diffusion

RAINWATER

Rainwater is the most common water entry. Rainwater can leak into buildings from roofs, overhangs, building envelopes and foundations.

It is imperative that rainwater be shed or controlled away from the building components. Strategic building placement can minimize wind driven rain leaks. Proper building roof overhangs will shed water away, and architectural detailing of construction materials installation will minimize moisture migration into building systems. These are the obvious and conventional rainwater control methods.

Less obvious means of rainwater entry are air pressure difference, momentum, surface tension, and gravity. If the exterior pressure is higher than that of the pressure in the wall cavity, the rainwater can be drawn into the wall cavity. It is important to have equal pressure on the exterior and interior of the wall. If straight horizontal wall penetrations exist, rainwater can be drawn into the wall cavity through momentum. By installing key-ways or upward angles in wall systems, rainwater momentum can be diminished. If kerfs or drip edges do not exist in wall penetrations, rainwater can enter through surface tension. If flashing is missing, rainwater can be drawn into the wall cavity through gravity. These are all conditions that should be evaluated prior to construction. Two installations that control these types of entry are rain screens and flashings.

A typical rain screen and flashing example is properly installed brick siding. The gap or air space that is 3/8-1/2 inch in size behind the brick serves as a rain screen to allow water to flow downward. The weep holes at the bottom cause pressure equalization within the wall cavity and allow water to exist. The flashing at the base or at weep hole area stops water from migrating into the building envelopes. This brick system also should also have a vapor barrier or damp-proofing membrane on the exterior side of the sheathing or masonry or other construction material that is exposed in this small space or gap. When systems are properly installed, all four moisture intrusion mechanisms, air pressure difference, momentum, surface tension, and gravity are demised.

Vinyl and aluminum siding are rain screens because they both have air gaps on the backside for water to drain, and weep holes for water exist.

GROUNDWATER

Groundwater is the second leading cause of moisture in dwellings. The most effective groundwater strategy to minimize moisture infiltration is proper foundation grading. A declining slope of one inch per foot for the first five feet is optimal. This declining slope allows water to run away from the foundation. The soil at this area should be clay or impermeable so water cannot easily be absorbed.

Proper foundation drainage systems are needed to ensure that moisture migration into the building systems does not occur. The foundation backfill should be poured and allow gravity to pull the water down the drain tile system. The foundation walls should be properly damp-proofed so water is not absorbed into the foundation wall system. The drain tiles should be installed to allow water to travel away from the structure to storm systems.

Many older foundation wall systems crack, bow, or fail. They fail from initial under-designed foundation wall systems, from hydrostatic loading of wet soil, footing settlement, soil loading, or other condition. In many older homes, drain-tiles systems fail and the exterior soil becomes heavier and water saturated. This heavier soil exerts more pressure to the wall and causes cracks. Cracks penetrate through the entire foundation wall and leak. Many homes that have finished basement walls with leaking cracks have interstitial mold reservoirs. Everytime it rains, the cracks leak water, and mold behind the walls amplifies. These cracks can also leak from poor grade, sprinkler heads being close to foundation, leaking gutters, or leaking or spilling downspouts.

Vertical cracks generally are shrinkage type cracks. Vertical cracks do have the potential to leak and get larger over time. When this condition occurs, digging the exterior and waterproofing the crack is necessary. Horizontal cracks, step cracks, and combinations are signs of soil movement and soil pressure. These horizontal and step crack conditions can be caused by, and not limited to wet heavy clay, under-designed foundations, poor drainage, poor grading, excessive soil on the exterior foundation wall or other exterior loading conditions. Horizontal and step crack conditions often get worse over time and often require structural maintenance or repairs. Horizontal and step cracks can get larger, leak water, and cause upper structural distress. We recommend that you get a second opinion from a structural engineer to determine soundness and integrity of all horizontal and step crack conditions.

CAPILLARY ACTION BELOW GRADE

Capillary action below grade is the absorption of moisture in porous materials. This is why damp proofing or waterproofing of foundations is necessary. The porous foundation material must be sealed so moisture cannot be absorbed. An example of capillary action can be seen sometimes in garages. The garage foundation block will have efflorescence stains in the interior of the garage foundation masonry block. This condition occurs because builders generally will not

waterproof or damp-proof garage foundations. All brick or foundation material that is to be buried in soil or exposed to soil should be sealed, waterproofed, or damp-proofed. Many slab homes have conditions caused by capillary action below grade. Many older slabs in homes were poured with no vapor barrier and no coarse aggregate substrate. Moisture can be absorbed into the slab material when these types of conditions exist. Many times, you will see moisture stains efflorescence stains in cracks. Other times you will see heaving of slabs. Heaving of slabs is also hydrostatic pressure related. It is important to install stone below the slab and a vapor barrier just under the slab to control capillary action. Sometimes this condition is also referred to as damp-rise.

CAPILLARY ACTION ABOVE GRADE

Capillary action above grade is the absorption of moisture in porous materials. The most common is wood siding. Wood siding is porous and absorbent. This is why we seal and paint wood siding. The sealant or paint membrane seal off the porous wood, making the system less absorbent. When installing cedar shakes or shingles it is advised to also install firing strips being the wood siding. This is to allow the wood to dry out if it becomes wet.

Brick siding is a good example of capillary action above grade. When brick becomes wet during, rainfall it will absorb moisture. If wet brick is exposed to sunlight, then moisture will travel further into the brick through capillary action and vapor diffusion. As mentioned earlier, these brick systems need drain screens to move the unwanted moisture away from the inner building components.

Another example of control of capillary action is wood shingle and shakes roofs. The wood will absorb moisture through capillary action. The wood roof shingles or shakes need furring strips. The furring strips will allow the moisture to dry out on both sides. Also building paper is needed to be installed over the furring strips to serve as a moisture barrier.

AIR MOVEMENT

Air can move into the building from the exterior. Air can move out of the building from the interior. Air is not a moisture problem unless it is also carrying moisture or humidity. Air that carries moisture through building envelope can deposit some of this moisture within the building envelope through dew points or condensation. We cannot control the exterior moisture in the air, due to nature, but we can control the

interior air that contains moisture. Interior moisture levels can be controlled several ways. The three main ways to control moisture are control the source of moisture, mixing the moist air with non-moist air and using a dehumidifier.

Controlling the source of the moisture is very important. If moisture is not initially put into the air, than we do not have to remove it. Moisture that enters a home from foundation walls of dirt crawl space floors, are a major source of water entry into building systems today. When building new, you must properly install foundation drainage and you must properly install vapor barriers. Other sources of moisture that are indoors are as follows:

Moisture source by type. Household produced.	Estimated moisture In PINTS.
Bathing tub (excludes towel and spillage) size bath	0.12 standard
Bathing shower (excludes towel and spillage) shower	0.53/5-minute
Clothes washing (automatic, lid closed)	0
Clothes drying (vented outdoors)	0
Clothes drying (vented indoors) /load electric	4.68 to 6.16
Clothes drying (vented indoors) /load gas	4.68+ to 6.16+
Combustion (un-vented kerosene space heater) kerosene	7.6/gallon of
Combustion (un-vented gas space heater) available	(huge) data
Combustion back drafting or spillage	0 to 6,720+/year
Cooking breakfast for family of four gas)	0.35 (plus 0.58 if
Cooking lunch for family of four gas)	0.53 (plus 0.68 if
Cooking dinner for family of four gas)	1.22 (plus 1.58 if
Cooking simmer at 203F 10 min 6 inch pan	0.13
Cooking boil 10 minutes 6 inch pan uncovered)	0.48 (0.57
Desorption of material seasonal /average day	6.33 to 16.91
Desorption of material new construction day	10+/ average

Dishwashing breakfast	0.21
Dishwashing lunch	0.16
Dishwashing dinner	0.68
Firewood storage indoors (cord of green wood)	600/6months
Floor mopping	.03/square foot
Gas range pilot light (each)	0.37/day
House plants 5-7 total	0.86 to 0.96day
Humidifiers	120+ /day or 2.08
ave./hr	
Pet's	fraction
Respiration perspiration family of four	0.44 /hour
Refrigerator defrost	1.03/day
Saunas, steam baths, and whirlpools	0 to 2.7+ / hour

DATA PROVIDED BY W.Angell and W. Olson, Cold Climate Housing Information Center, and University of Minnesota.

It is actually amazing how much moisture a home could produce.

Example

- Family of four on a football Sunday in a winter month
- New 2000 Sq/ft tight home with house wrap.
- New high efficient furnace with humidifier that is on.
- Ventless fireplace that is on all night.
- Seven nice plants in home throughout.
- All home cooked meals.
- Washed 1000 Sq/ft of floors during cleaning
- Treadmill used by two occupants for 30 minute each.

This home could produce up to 15 gallons of water that will contribute to the humidity in the home.

Mixing the moist air with non-moist air, helps in minimizing dew points or condensation. This method will not generally work in the warmer climates due to the mixing air, which generally is the exterior air, which contains higher moisture content or humidity than that of the interior air. In the winter months, using cold exterior low humidity air for mixing may not be thermally efficient.

Dehumidification is the most common moisture control. Many homes with leaking foundations, cannot afford new waterproofing systems so the plug in dehumidifiers. In summer months, nature dehumidification

occurs during the use of air conditioning. Moisture is removed from the drain pan as water drips from the evaporator.

AIR PRESSURE

Pressure in homes is an important element in determining a healthy or un-healthy environment. If your home is sucking air, it is depressurized (negative pressure). If you were to close all the windows, seal all the exterior wall penetrations, and then turn on an attic fan, house fan, clothes dryer, or a bathroom fan, the home would be sucking air and possibly become depressurized. These mechanical units are moving air from the inside of the home to the outside of the home. If you removed house air, new air must replace the space. This air can come from wall cracks, crawl spaces, chimneys or stacks, interstitial walls, leaking doors, leaking windows, stucco cracks, weep holes, wall penetrations, construction holes, and other venting areas.

Dwellings and buildings all leak air. Interior or conditioned air escapes, and outside air is sucked in. This outside air is not conditioned and contains moisture and potential mold spores. These conditions can seriously add to the problem of indoor air quality, sick building syndrome, building related illness, smoke and fire spread, condensation, mold, corrosion, decay, deterioration, humidity, odor, energy consumption, maintenance, and added housekeeping.

The following are the three natural conditions that can change the pressure in your home:

Wind Effect.

When the wind blows against the dwelling, it creates a high-pressure area on the windward side and air is forced into the dwelling. A low-pressure area is created on the leeward side where air is drawn out of the home. This causes depressurization and possible moist air infiltration. Many homes near oceans and lakes have moisture or odor problems. The large water mass



has no obstructions and the wind is a direct hit on the ocean side. A musty crawl space would be sucked out and all the crawl air could end up in the upper dwelling. If the bathroom is facing the waterside, look behind the vinyl wallpaper for mold. A more common example is a high-rise hotel near the water. Many of these buildings are mold-infested and wind effect is definitely a contributor. In the lower examples, wind is only one contributor to the mold contamination.

This photo was taken on the east side of a hotel located facing the Atlantic Ocean. The vinyl wallpaper was removed and mold was exposed. The remodeling company was not wearing PPE and no mold abatement strategies were implemented.



The second photograph, was the fifth story outside wall, facing Lake Erie. On this particular wall, you could actually see the mold reservoirs through the wallpaper. Many times, you will see pink or gray blemishes. These were gray. We are not solely blaming wind effect in either of these two examples because other factors were also contributors.

Stack Effect.

In a conditioned or heated building, less dense warm air rises, expands creating a higher-pressure area near the upper elevation. This air escapes through holes or penetrations in the ceiling. This air also escapes through leaking windows, doors, and other mechanical penetrations. The force of the rising air creates lower pressure near the bottom on the building. This is also known as negative pressure or depressurization. This condition causes outside or soil air,¹ to rush in through cracks and opening



¹ Air trapped in soil voids or cracks.

in the lower levels of the structure. Stack effect may have some correlation with odor concentrations. As stack pressure increases, so do odor levels. The two main variables that affect the stack effect, are temperature and building elevation. The colder the exterior temperature, the greater the stack effect. The higher the building elevation, the greater the stack effect.



Combustion and Ventilation Effects.

Appliances that burn fossil fuels or manufactured fuels need air to support combustion and provide the draft in the chimney. This negative pressure air is replaced by outside air through unintentional openings in the building envelope.

This is why people often notice that a room becomes drafty when there is a fire in the fireplace.² The room is now depressurized. That means this room may be sucking air from other undesirable areas, primarily unconditioned exterior air.

In newer homes, many furnaces or hot water heaters have power vented exhaust systems. These white PVC pipes stick out of siding on residential dwellings. These pipes are taking air out of the home. For every action, there is an equal and opposite reaction; air must come from somewhere to replace this exhausted air. This can depressurize a basement and cause moisture to be sucked through cracks in basement walls. This moisture can cause upper levels of humidity and dew points. Dew points usually equal mold.



We will get calls on certain winter days in northeastern Ohio. The call comes in and the prospective client says, "water is dripping behind all my basement insulation". When we arrive, we will see sections of

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insulation fastened to the basement walls. The insulation is foil-faced with the foil side exposed. The basement is tight and insulated and the door to the area is closed. The newer high efficient furnace has a power driven exhaust, installed with no make up air wall penetrations. The basement lacks a dehumidifier. The furnace is sucking out the basement moisture. This basement is depressurized and moisture is being sucked out of the soil through foundation walls and shrinkage cracks. This moisture dissipates and creates high humidity that is trapped behind the insulation. The ground is cold and the humidity reaches dew point behind the insulation. This is why the insulation is dripping moisture to the floor. The process is as follows: depressurization causes moisture infiltration, then high humidity, resulting in dew point, which ultimately causes mold reservoirs. All you need to do is remove one of the variables, and this phenomenon is ceased.

Some other ventilation effects that created dwelling depressurization were clothes dryers, kitchen exhaust fans, bathroom exhaust fans, make up air ducts, HRV's,³ ERV's,⁴ central vacuum cleaners, and powered attic fans.

Example 1:

A West Virginia home was being depressurized by continual dryer usage. The house never had problems until the home went under renovation. New exterior insulation and siding was installed. The contractor also covered all the gable vents with insulation. This home was now tight. The dryer was located in the basement next to a very large crawl space. The crawl space had an exposed soil floor with many cracks in the foundation. The home was also built into a hillside with the crawl being buried. The dryer sucked the moisture out of this crawl and caused upper levels of humidity. The result was mold in closets, on attic sheathing, and on

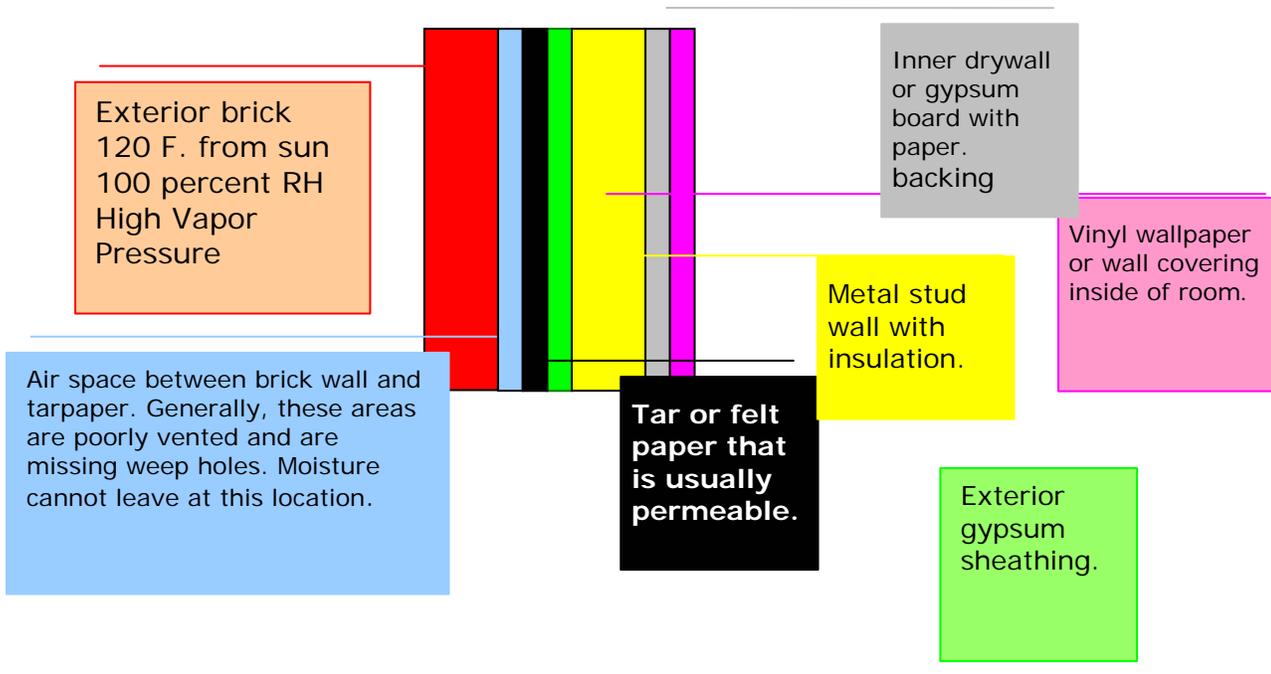


basement joists. We cannot blame the entire contamination on the dryer, due to other variables that were contributors. The client went into her attic and cut a gable vent to help equalize the home pressure and provide more attic ventilation.

VAPOR DIFFUSION

Vapor diffusion is the movement of moisture that is mixed in air through building materials. Vapor diffusion can move into the building from the exterior. Vapor diffusion can move out of the building from the interior. Vapor diffusion only occurs, when there is a pressure difference in walls or on either side of the building materials. No pressure differences in walls; no vapor diffusion. When buildings are heated in cooled climates, the vapor pressure is higher inside the building than the outside. This means that the vapor pressure will travel from the interior to the exterior. The problem occurs when this vapor diffusion condition causes the moisture to condensate within the interstitial wall cavities. Similarly, when buildings are cooled in warm climates, the vapor pressure is higher on the outside the building than that of the inside. This means that the vapor pressure will travel from the exterior to the interior. The problem once again occurs when this vapor diffusion condition causes the moisture to condensate within the interstitial wall cavities. The following are several examples when vapor diffusion occurs:

EXAMPLE 2: Brick wall that gets wet after rain.



This is an example of how mold gets behind the vinyl wallpaper. This condition is very common and found in many hotels, high-rise office buildings, and dwellings. For example, let us assume that it rained in the morning and the sun came out in the afternoon. The testing was done in the afternoon after the sun had been out for some time.

- Outside temperature is 80° F. It just rained and the RH is 75 percent. Using the psychrometric chart, the vapor pressure is roughly .68 inches of mercury.
- Inside the room, the temperature is 75° F. the RH is 60 percent. Using the psychrometric chart, the vapor pressure is roughly .54 inches of mercury.
- NOTE: Notice the vapor pressure is slightly higher on the exterior than the interior. This means that the force direction of the vapor will travel from the exterior to the interior. In the drawing above, this would be left to right.

The difference between the exterior and interior conditions is rather small. However, the brick (first membrane) will absorb heat and become heated to 120° F. Due to the rain, the brick is wet and RH is 100 percent. This value is so high that it is off the psychrometric chart. You need to go to the steam charts that engineers use. The higher the vapor pressure the higher the driving vapor force pushing it. Significant and adverse conditions will occur. In most buildings, the air space behind the brick is not generally ventilated. The vapor pressure pushes the moisture through this space. By not being ventilated, the moisture and vapor pressure cannot escape. The next membrane (second) is usually felt paper. Most felt products are permeable and will allow vapor pressure to travel through. Many times, large sections of felt are missing or torn or damaged during construction, and vapor will travel quickly through these holes. The next membrane (third) is usually the exterior gypsum sheathing. This is permeable and vapor will travel through. The next membrane (fourth) is the metal stud with fiberglass insulation. This is permeable and vapor will travel through. The next membrane (fifth) is the interior drywall or gypsum board. This is permeable and vapor will travel through. The final membrane (sixth) is vinyl wallpaper. This is not permeable and the vapor stops and condenses. The wall vinyl backing, adhesives, and paper-covered gypsum or drywall interface are nutrients and mold will grow. Mold will digest the adhesives and amplify over time. In some occasions, you will see pink spots on the wallpaper. The pink spots occur when the mold releases digestive enzymes that react with nutrients or cellulose in the wallpaper or the paste.

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The problem with this example is the construction design is faulty. The vapor barrier is in the wrong location. The vinyl wallpaper served as the vapor barrier. The vapor barrier should have been placed behind the brick siding or brick veneer.

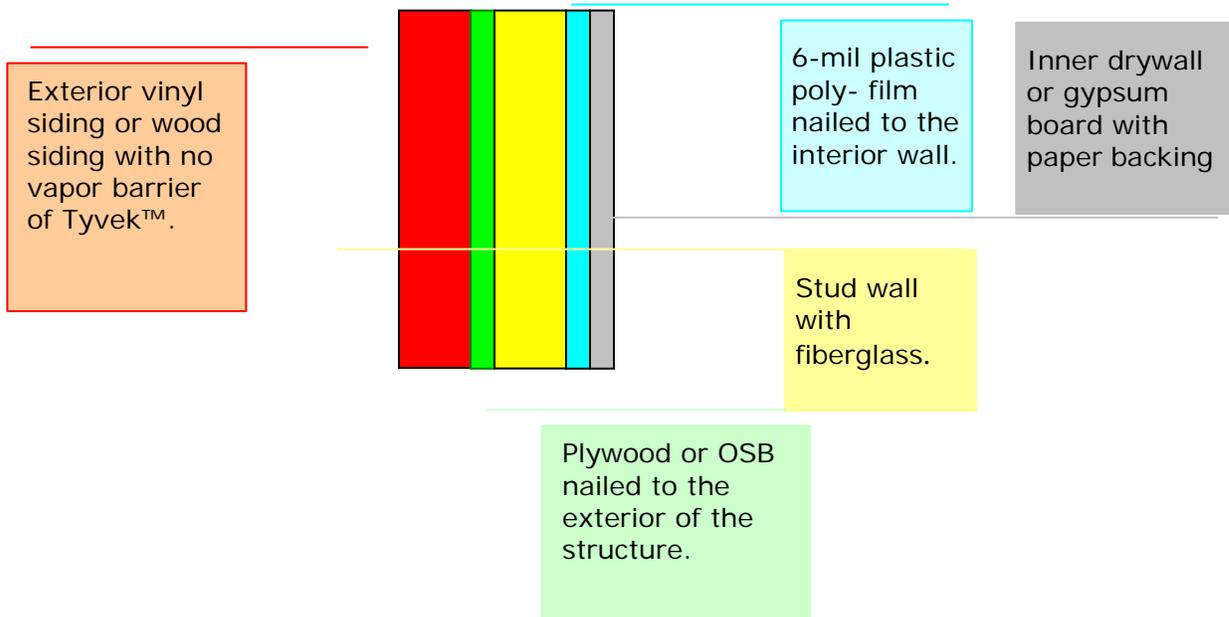
This is a picture of an interior wall in a condominium complex. The unit had vinyl wallpaper on the southeastern side. This unit was on the ninth floor. The odor in the unit was stagnant and slightly musty. A slight pinkish color can be seen in the far-left corner.

This is the same picture of this interior wall with the paper peeled back. Mold reservoirs are amplifying behind the vinyl wallpaper.

SYMPTOMS OF THE ROOM: Pink stains on vinyl wallpaper, loose corners of vinyl wallpaper, stagnant air, musty air, complaints about illness. This example can occur at different temperatures, moisture contents, and vapor pressures.



EXAMPLE 3: Mixed Climate home with the vapor barrier installed on the warm side.



This is an example of how mold gets behind the six-mil polyethylene plastic inner-wall vapor barrier. This construction condition is very common in the south. It works better in the south, due to the warmer climate. In the north or in mixed climate areas, this design may have problems.

In an air-conditioned home in the summer, the air in the home is cooler than the outdoor air. The interstitial wall cavity will also be cool. If the home is pressurized, the cool air travels to the exterior. The air becomes warmer and warmer, as it moves to the exterior side. This air will eventually infiltrate through random holes. As the infiltrated air gets warmer during its travel, its relative humidity also goes down. Warm air can hold more moisture than cold air, and condensation will not be a factor. In conclusion, cool air that is escaping due to interior house pressurization will not cause interstitial mold or moisture problems with these conditions. However, if the reverse occurs, a





serious condition may occur. We have an attic exhaust fan that is always on in the summer. We also have two eight-inch ducts that travel to a furnace utility room for make-up air purposes. The fan is sucking air out of the home and out of the utility room. This home is now de-pressurized. Now we are drawing warm, moist, outdoor summer air into the home. This warm moist air is infiltrating into this air-conditioned house. This warm air now is getting cooler as it travels through the interstitial space toward the interior. Remember the drywall is cool, and we have a six-mil vapor barrier. Now the humid air gets cooler during its travel inward and the relative humidity goes up. It stops at the six-mil plastic vapor barrier and condensates. When the condensation becomes excessive, it runs down to the sill plate. The water and moisture eventually cause deterioration.



Do the math: The temperature indoors is 75° F. The temperature outdoors is 95° F. The outdoor humidity is 70 percent RH. The temperature behind the drywall is 76° F. By using a psychrometric chart, you find the incoming air dew point is 84 °F. This is what the six-mil plastic interstitial vapor barrier looks like after you remove the drywall. The inside of the surface of the plastic is where the condensation will occur.

Looking down into the wall cavity you can see the deterioration beginning. Then interstitial inside face of the OSB oriented strand board exterior sheathing wall is also starting to develop mold reservoirs.

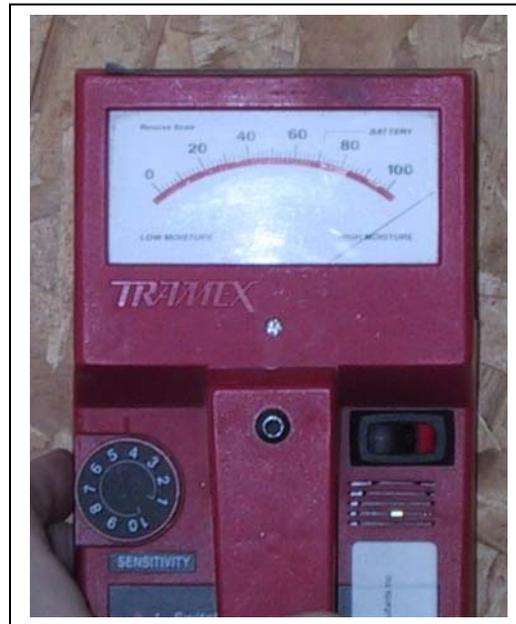
Let us now look at a couple different scenarios:

Scenario one;

A mixed climate home, summer day with high humidity, air conditioning on, home is depressurized, no six-mil plastic vapor barrier. Now this wall is more forgiving⁵ and moist air can pass through to the interior. Sometimes, forgiving walls are better in mixed climate areas.

Scenario two;

A mixed climate home, summer day with high humidity, air conditioning on, home is depressurized, no six-mil plastic vapor barrier and interior vinyl wallpaper is installed. Now condensation occurs on the backside of the vinyl wallpaper. The vinyl serves as the new vapor barrier and moist air cannot pass through to the interior. This wall is not forgiving. Forgiving walls are better in mixed climate areas.



Scenario three;

A mixed climate home, winter day, heat on, home is pressurized, no six-mil plastic vapor barrier. Now this wall is more forgiving and moist interior air can pass through to the exterior. When this interior moist air travels to the exterior, it becomes cooler. Now the condensation will occur on the interstitial inner-side of the exterior sheathing. Do the math: interior temperature is 69° F., outdoor temperature is 0° F., wall temperature on the drywall is 67° F. The exterior sheathing behind the siding is 9° F. A dew point will form on the inside wall of the exterior sheathing.

⁵ This means moist air can easily travel through a wall system without being stopped by a vapor barrier.

