Moisture Control in Homes

Although a moderate level of indoor humidity is recommended for health and comfort, insulating and weatherizing a home can cause excessive moisture build-up in winter. A proper moisture reduction program should eliminate condensation on windows, walls and ceilings, control the sources and paths of the necessary moist air, and maintain the indoor humidity at the proper level (30-50 percent in winter and 40-60 percent in summer, depending on the part of the country in which you live).

People, plants, pets, cooking, bathing, washing (i.e., laundry & drying) and damp basements all add to the indoor humidity levels (or water vapor pressure). The water vapor pressure is the contribution made by water to the total atmospheric pressure. When cool, moist indoor air is heated, the water vapor pressure increases causing moisture to move towards an area of lower vapor pressure, such as the outdoors. As the moisture meets cool walls or the cold siding of the house, it can condense and damage the building materials.

In warm, humid climates the moisture often moves in the opposite direction. In the summer, high vapor pressure pushes moist outdoor air into an air-conditioned house.

As a homeowner, you should be aware of the symptoms of moisture problems, how to identify the sources of moisture, and how to deal with any problems. Not only will you protect your home from damage, but you also will provide a healthier environment for your family, since excess moisture promotes the growth of molds and bacteria.

Symptoms of Excess Moisture

There are many symptoms of excess moisture in a home, including:

**Condensation** on windows, walls, or other smooth surfaces signal either excess moisture, or the need to insulate or warm the surface in

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Figure 1. Moisture Transfer Methods
question. In late fall and early
winter, expect some condensation
on windows due to rapid changes in
temperature. This should gradually
disappear, however, as the indoor
air is heated and temperatures
stabilize.

**Strong odors** that do not dissipate
may indicate high relative humidity.
Musty odors may indicate mold,
mildew or rot. Also, household
odors that seem to linger may
signal that ventilation in the house
must be increased.

**Mold or mildew** on interior sur-
faces, ranging in color from white to
orange, or from green to black, in-
dicate that indoor air is full of
moisture.

**Rot and wood decay** indicate ad-
vanced moisture damage. Unlike
surface mold and mildew, wood
decay fungi penetrate, soften and
weaken the wood. Look for any type
of rot or fruited bodies (mushroom-
like growths).

**Paint peeling, blistering or
cracking** may indicate that moisture
from outside or inside the home is
damaging the paint on siding. If the
raw wood can be seen between
paint cracks or under blisters, the
cause is most likely excess
moisture.

**Corrosion**, oxidation and rust on
metal are unmistakable signs that
moisture is at work.

**Deformed wooden surfaces** may
result as wet wood swells, and then
warps and cracks as it dries.

**Concrete and masonry
efflorescence** is a white, powdery
substance or line left after moisture
has moved through a masonry foun-
dation or basement wall, and in-
dicates that ground moisture is
entering the basement.

If you suspect that the indoor
humidity is above the recommended
range, buy a few inexpensive
hygrometers and place them in
suspected problem areas, such as
the kitchen, bathroom, room above
or next to kitchen and bathroom,
and basement. Monitor the humidity
for several weeks. While fluctua-
tions will occur due to weather con-
ditions and indoor activities, a con-
stant reading of 50 percent or
higher in winter signals that your
house has excess humidity.

**Identifying and Controlling
the Sources of Moisture**

Moisture arises from both inside
and outside the home. Outdoor
moisture sources usually result from
poor drainage and blocked air cir-
culation near the house, and high
outdoor relative humidity. An impor-
tant transfer of moisture from out-
side to inside the house takes place
when windows are opened at night
to allow fresh air to enter, because
night air often has a high relative
humidity.

**Domestic activities**, such as cook-
ing without lids, using open flame
cooking appliances, bathing, and
hanging wet clothes to dry indoors
may cause excessive moisture.
Unvented bathrooms and kitchens
are a common problem. Clothes
dryers vented indoors may also add
moisture.
Solutions: Use existing or install exhaust fans in kitchens and bathrooms. Make sure that the kitchen and bathroom fans are powerful enough to remove moist air in a short time. Bathroom fans should run for at least 15 minutes after a shower or bath. Vent clothes dryers to the outdoors.

Plumbing leaks provide a steady source of moisture, particularly if the moisture stands or soaks into building materials.

Solutions: Fix all leaky plumbing. Check for signs of hidden leaks in walls.

Faulty or improperly combusting flame-fired heating equipment, such as gas and oil furnaces or kerosene heaters, may be releasing water vapor and carbon monoxide into the air.

Solutions: Check for blocked vents or a blocked chimney. If the flame on the heating unit is yellow or flickers, call the heating contractor or utility to check out the system. Provide proper venting for the heating unit.

Newly installed building materials with high moisture content, such as green lumber, wet wood, concrete, wallboard taping, and masonry fireplaces, release moisture for a long time. This is a worse problem in tightly constructed houses.

Solutions: Increase ventilation during construction and the first year. Don’t use green lumber or wet wood.

Certain types of cooling systems and humidifiers can be sources of excess moisture. Evaporative coolers, in particular, increase indoor relative humidity.

Solutions: Don’t use evaporative coolers in high humidity climates. Use humidifiers only when necessary. Keep air conditioners set no lower than 75°F.

An attached sunspace (greenhouse) can cause moisture problems in the wall to which it is connected, particularly if it is being used for growing plants. Plants continually release moisture into the air and poor drainage allows pools of water to collect on the greenhouse floor.

Solutions: Provide adequate air circulation and ventilation in the greenhouse. If greenhouse relative humidity is high, avoid venting into the home. If the greenhouse is used for heating, limit the number of plants. Avoid excess watering of plants.

Frost or ice dams in roof valleys (where two roof lines meet) and along the roof edge frequently result from insufficient ceiling or attic insulation, and poor ventilation in the attic. After a snowfall, moisture from snow or ice may be forced under the shingles and into the attic as it is melted by escaping heat or the sun, and then refrozen as temperatures drop.

Solution: Add ceiling or attic insulation. Ventilate the attic. When replacing a roof, install a heavy-duty moisture barrier along the roof edge and in roof valleys.

Poor drainage of surface water and moisture from rain and snow can be a problem, especially in locations with clay soils.

Solutions: Check for blocked downspouts and gutters. Check for cracks in foundations, and install proper dampproofing. Slope soil away from the foundation and use gravel or soil mixed with gravel as backfill next to the foundation.

A high ground water table may cause problems by forcing moisture up through the ground into the basement or crawl space. This moisture then moves up through the house.

Solutions: Put a vapor retarder over the ground in the crawl space or basement. Ventilate the crawl space or basement. Improve basement drainage with drain tiles, a drain pipe or sump pump. In new construction, put a vapor retarder under the concrete slab floor. Apply a waterproofing material to the outside of the foundation.

To combat the sources of excess moisture, start with the easiest, least expensive solutions that correct the most critical problems. A few highly-effective measures may bring the moisture content to an
acceptable level. If the quick remedies do not solve the problem, consider the more difficult, expensive measures. Since proper installation is crucial to the effectiveness of some of these remedies, obtain the advice of a professional with moisture control experience when applying complicated solutions.

**Other Control Measures**

Lowering indoor humidity is the first step to control moisture. Even at moderate humidity levels, however, the indoor moisture can condense on cold building surfaces and be absorbed into the walls and ceilings. The extent to which this occurs in a house varies according to climate, local temperature and air pressure and your type of heating system. Therefore, investigate the possible paths of moisture circulation in your home and evaluate other measures that can more effectively control moisture migration and condensation.

**Controlling Condensation On Windows**

One of the first places condensation appears is on cold windows. In late fall and early winter in colder climates, condensation almost always occurs as the summer humidity that the building has absorbed slowly evaporates. This moisture usually disappears as the heating season progresses, but if the problem persists several things can be done:

- Add storm windows or install double pane windows. Use triple glazing or its equivalent in the coldest climates;
- When adding a storm window, small weep holes at the bottom of the storm window are recommended to allow moisture to escape;
- Caulk and weatherstrip all leaky windows;
- If a window insulation product is added, make sure all edges are tightly sealed.

Traditional drapery and blinds may aggravate window condensation because the recessed window surface gets cold, heat circulation is impeded, and the window covering doesn’t provide a tight seal. One of the best remedies for this, particularly in colder weather, is to add a storm window inside the main window. Most hardware stores and home centers sell plastic storm window kits. By tightly fitting the storm window over the window opening, a second dead-air space is created between the room and the window, which increases the insulating value of the window. Since the storm window surface is warmer than the window, condensation is less likely to occur. This is also a good way to prevent sweating on the inside of metal window frames.
**Table 1. Generic Permeance of Materials to Water Vapor**

Perm ratings for a given generic product will vary, depending on manufacturing techniques used and other variables. Permeance is measured in two ways—wet cup and dry cup testing. Wet cup testing exposes the material to greater amounts of moisture. A material’s perm rating will be lower in dry cup testing than wet cup, which means wet cup ratings are best when choosing a vapor retarder for an extremely wet location.

The following table gives the dry cup perm ratings for a representative sample of standard building components. The ratings shown in the table will permit comparisons and should be used only for general reference. For specific applications and materials, selection of vapor retarder materials should be based on values obtained from the manufacturer or from recognized laboratory test results.

Perm values in the table are given for the thickness of material shown. When a material is followed by the notation "perm-in," which means perm value per inch, the permeability for greater thicknesses can simply be estimated by dividing the perm-in by the number of inches. (For example, to determine the perm value of concrete 8 inches thick, divide the perm-in value of 3.2 by 8. This gives a perm value of 0.4 for 8 inches of concrete.)

<table>
<thead>
<tr>
<th>Basic Materials Used in Construction</th>
<th>Permeance (Perm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete (1:2:4 mix)</td>
<td>3.2 (Perm-in)</td>
</tr>
<tr>
<td>Brick masonry (4&quot; thick)</td>
<td>0.8</td>
</tr>
<tr>
<td>Concrete block (8&quot; cored, limestone aggregate)</td>
<td>2.4</td>
</tr>
<tr>
<td>Tile masonry, glazed (4&quot; thick)</td>
<td>0.12</td>
</tr>
<tr>
<td>Plaster on metal lath (3/4&quot;)</td>
<td>15.0</td>
</tr>
<tr>
<td>Plaster on wood lath</td>
<td>11.0</td>
</tr>
<tr>
<td>Gypsum wall board (3/8&quot; plain)</td>
<td>50.0</td>
</tr>
<tr>
<td>Hardboard (1/8&quot; standard)</td>
<td>11.0</td>
</tr>
<tr>
<td>Hardboard (1/8&quot; tempered)</td>
<td>5.0</td>
</tr>
<tr>
<td>Plywood (douglas-fir, exterior glue, 1/4&quot; thick)</td>
<td>0.7</td>
</tr>
<tr>
<td>Plywood (douglas-fir, interior glue, 1/4&quot; thick)</td>
<td>1.9</td>
</tr>
</tbody>
</table>

**Thermal Insulations**

| Air (still)1"                              | 120.0          |
| Cellular glass                             | 0.0            |
| Corkboard (1")                             | 2.1-2.6 (Perm-in) |
| Expanded Polystyrene - extruded           | 1.2 (Perm-in)  |
| Expanded Polystyrene - bead                | 2.0-5.8 (Perm-in) |
| Expanded Polyurethane (R-11 blown, board stock) | 0.4-1.6 (Perm-in) |

**Plastic and Metal Foils and Films**

| Aluminum foil (1 mil)                    | 0.0            |
| Aluminum foil (0.35 mil)                 | 0.05           |
| Polyethylene (4 mil)                     | 0.08           |
| Polyethylene (6 mil)                     | 0.06           |
| Polyethylene (8 mil)                     | 0.04           |
| Polyethylene (10 mil)                    | 0.03           |
| *Polyethylene cross laminated high density (4 mil) | 0.02      |

**Building Paper, Felts, Roofing Papers**

| Duplex sheet, asphalt laminated, aluminum foil one side | 0.002         |
| Saturated and coated rolled roofing               | 0.05           |
| Kraft paper and asphalt laminated, reinforced 30-120-30 | 0.3       |
| Blanket thermal insulation back up paper, asphalt coated | 0.4         |
| Asphalt saturated and coated vapor barrier paper  | 0.2-0.3        |
| 15 lb asphalt felt                               | 1.0            |
| 15 lb tar felt                                   | 4.0            |
| Single kraft, double                             | 31.0           |
| *Olefin, spunbond, high-density polyethylene fiber | 94.0         |

**Liquid Applied Coating Materials**

<table>
<thead>
<tr>
<th>Commercial Latex Paints:</th>
<th>Permeance (Perm-in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor retarder paint</td>
<td>0.45</td>
</tr>
<tr>
<td>Primer - sealer paint</td>
<td>6.28</td>
</tr>
<tr>
<td>Vinyl-acetate/acrylic primer</td>
<td>7.42</td>
</tr>
<tr>
<td>Vinyl-acrylic primer</td>
<td>8.62</td>
</tr>
<tr>
<td>Semi-gloss vinyl-acrylic enamel</td>
<td>8.61</td>
</tr>
<tr>
<td>Exterior acrylic house &amp; trim</td>
<td>5.47</td>
</tr>
</tbody>
</table>

**Adding Insulation**

Condensation may occur on colder building surfaces even at moderate humidity levels. To reduce temperature differences on exterior surfaces, such as walls, windows, ceilings, basements, and crawl spaces, insulation should be added wherever possible. If the walls already contain loose fill insulation, check to see if it has settled or deteriorated, and add more if necessary.

If adding insulation is not possible, increase ventilation or the warm air circulation rate near the colder areas. Use electric heaters or space heaters that are vented to the outside to warm the area.

Rigid insulation can be added to interior or exterior wall surfaces, but make sure that moisture will not be trapped in the wall by the improper combination of low perm materials (see Table 1). All inside openings in the wall should be carefully sealed, particularly for interior retrofits. Studies by the U.S. Forest Products Laboratory indicate that exterior rigid board insulation effectively increases the exterior wall temperature, and therefore lowers the potential for unwanted condensation inside the wall cavity.

**Increasing Ventilation**

As houses are made tighter with insulation, caulking, and special building techniques, adequate ventilation has become more crucial, not only for moisture control, but also for healthful air quality. Relying on natural ventilation to remove moisture and indoor air pollution from well insulated houses is no longer considered adequate for providing the minimum recommended ventilation rate of 0.5 (one-half) air change per hour. Besides using kitchen and bathroom fans, many experts now recommend a central ventilation system to provide continuous control. In cold climates, however, the direct use of outside air in winter months will increase the heating load requirements of the house. By connecting the ventilation system to a moisture-
sensitive control (humidistat) the fan can be set to run only when the moisture level is too high. One way to increase ventilation without raising your heating bills is to install an air-to-air heat exchanger. See Figure 6.

An air-to-air heat exchanger is a device that exhausts stale, warm air from the house and transfers the heat in that air to fresh, cold air being supplied to the house. This process of heat exchange between the outgoing and incoming air reduces the energy required for heating. In air conditioned houses, heat is transferred from the incoming warm air to the outgoing cooler air, reducing the energy required for cooling. Air-to-air heat exchangers are frequently used in superinsulated houses, but experts debate their applicability for conventional houses. They are also expensive and difficult to install so you may want to investigate other ventilation techniques before considering an air-to-air heat exchanger.

Some heat exchangers, called "enthalpy" models, allow moisture to pass into the fresh air stream. These exchangers should be avoided if excess moisture is a problem. In non-enthalpy models the moisture in the outgoing air is condensed and drained off to the sewer.

Dehumidifiers

Dehumidifiers perform the same function as air conditioners. They cool air and remove moisture from it, thereby lowering indoor humidity. For homes without air-conditioning, dehumidifiers can be used to lower indoor humidity to about 50 percent, a level acceptable to most people.

Protecting Walls, Ceilings and Insulation

A primary concern in well-insulated houses is preventing indoor moisture from reaching the insulation and condensing on the cold outside wall surface. Although experts debate about whether the moisture actually damages the walls and ceilings, current building standards require that insulated walls in new homes be protected against moisture penetration. One way is to install a vapor retarder on the inside surface of all exterior walls. The familiar term "vapor barrier" has been recently replaced with the term "vapor retarder" to avoid the misconception that vapor barriers stop all moisture transfer, when actually they only reduce the rate of moisture transfer.

Vapor Retarders

In cold climates, vapor retarders (materials that have a low permeance to moisture transfer) traditionally have been used to prevent condensation by stopping water vapor from diffusing outward under pressure through building materials.

New information shows that much more moisture is transferred by air...
Warm Interior

Interior Wall Covering

Sealed Electrical Outlet Box

"Low-Perm Vapor Retarder Location"

Cold Exterior

*Breathable Horizontal Wood Siding

*Breathable materials on the cold side of the wall should be 5 times more permeable than the vapor retarder on the warm side of the wall.

Figure 8. The location of vapor retarding and high permeability materials in cold climate regions is an important consideration.

leakage into the walls than through diffusion. Thus, to truly block most moisture transfer, the vapor retarder must be carefully installed to stop air leakage as well as diffusion. This means sealing any cracks between the vapor retarder and windows, doors, floor boards, outlets and wall fixtures. Seams must be overlapped and sealed with acoustical sealant or other long-lasting sealant. All openings and breaks in the retarder must be sealed or patched.

A new process, known as the "Air-tight Drywall Approach" (ADA), is also being tried in new construction to prevent air and moisture leakage. This process involves gaskets rather than caulking to seal the drywall at the top and bottom. The drywall is also placed behind interior partitions. Drywall products that incorporate a vapor retarder layer are also available.

The goal in installing a vapor retarder, whether in a new building or a retrofit, is to provide an unbroken impediment to moisture transfer and air infiltration. Careful attention to locating and sealing the retarder is the key to quality installation. See Figure 7.

In cold climates vapor retarders should always be located on the warm side of the building surface. The cold side of the wall must be allowed to breathe to allow any moisture that does pass through to escape. See Figure 8.

Vapor retarder effectiveness is measured in "perms," which stands for permeance of the material. The lower the perm rating, the better the material is at slowing moisture transfer. The outer skin of the wall should be at least five times more permeable than the vapor retarder. This 1:5 ratio should be applied when choosing a vapor retarder and also when choosing sheathing materials for the outer skin of the house.

The current state of the art is to use vapor retarders of 0.1 perm or less. Polyethylene films, which have perm ratings in the .02 to .08 range, are the most popular. Several new products that are more resistant to tearing than polyethylene are also available. See Table 1 for a list of perm ratings for common building materials.

Retrofit Applications

For extensive renovations where wall cavities are opened and filled with blanket, batt, or rigid board insulation, it is simple to add a vapor retarder before the wall is re-finished. Walls that have been retrofitted with blown-in or loose fill insulation typically do not have vapor retarders. While research indicates that some condensation does occur in these walls, wood rot and decay problems seem to be more dependent on local climatic conditions and are not prevalent. In cases where indoor moisture levels are not extreme, researchers have found that moisture that enters the wall will eventually evaporate and not damage the building materials.

In rooms with high humidity (e.g., kitchens, bathrooms) and no vapor retarder, it is important to seal all air leakage points from the inside of the house. This means sealing penetrations around windows, doors, where the wall meets the ceiling and floor, and any cracks or holes in wall surfaces. Vapor retarder paint can then be applied to make the wall surface resistant to water vapor diffusion.

Special Considerations with Vapor Retarders

- Vapor retarders often are not recommended in areas where little winter heating and con-
siderable summer cooling are called for because the vapor retarder may be on the wrong side most of the time. See Figure 10 for guidelines on controlling moisture in warm, humid climates.

- Avoid using low-perm products on the outer skin of a wall in areas with high indoor humidity. This includes vinyl or metal sidings without vents, metal siding used on uninsulated homes in cold climates, insulated shearings with foil coverings, and low-perm plastics that are substituted for breathable building papers.

- Avoid double vapor retarders, or vapor retarders on both sides of a wall. Using a low-perm product on both sides of a wall can result in moisture build-up as air leaks into the wall cavity. Moisture so introduced is difficult to remove because of the temperature or pressure required to drive it out of the wall.

- Vapor retarders must be installed properly. All areas of the house must be included when installing a vapor retarder, otherwise missed areas may deteriorate over time. Vapor retarders are not effective if they are not tightly installed.

Attics and Ceilings

Until recently, attic ventilation was the main strategy used to prevent moisture problems in attics, except in the coldest climates. Tightly installed ceiling vapor retarders, however, are becoming more the common strategy in areas where condensation occurs, particularly for new construction. The ASHRAE and RCS guidelines (see Reading List) recommend using ceiling vapor retarders in regions where the temperature dips below 0°F in the winter. A carefully installed vapor retarder is the only way to avoid moisture damage if attic ventilation is inadequate, especially with flat roofs or cathedral ceilings.

When adding batt or loose fill insulation to attic floors, polyethylene can be cut into strips and tightly fitted between joists. Do not block existing vents and eaves. See Figure 11. If a vapor retarder is not used in the attic or ceiling, attic ventilation must be greater than if a retarder is used. A basic rule of thumb for determining the size of attic vents is to multiply the square footage of the attic by .0067 if no vapor retarder is used, or by .0034 if a vapor retarder has been installed. If anything obstructs the vents, such as screening or louvers, the total venting area will need to be doubled to compensate. Areas of the attic that have little air circulation, such as knee walls or partially finished areas, and possible air leakage sites, such as recessed lights, should be monitored for moisture build-up.

Summary

This factsheet has touched on the basic sources and causes of, and solutions to moisture control. There are many variables that influence how moisture is produced and transferred within a house. While some of the basic solutions, such as using fans in bathrooms and kitchens, can be implemented immediately, a thorough analysis should be done before installing or implementing the more expensive measures. A particularly helpful

Since the moisture path in houses in warm, humid climates is from the outside to the cooled inside area, different measures must be used to manage moisture problems.

1. The vapor retarder (low-perm material) should be on the outside, not the inside. Some experts recommend eliminating the vapor retarder altogether because of the difficulty in providing a complete seal.

2. More attention should be given to sealing air leakage points on the outside than on the inside.

3. Materials with a higher R-value (thermal resistance), such as rigid board insulation, should be used on exterior surfaces to raise the dewpoint temperature of the outside walls.

4. Air conditioners should be properly sized to avoid overcooling. Reheaters and dehumidifiers should be used to remove moisture from the incoming air.

5. Air circulation should be maintained at all times.

6. Exterior surfaces that don't receive sun or wind, such as corners, should not be blocked or shaded continuously.

7. Cold water pipes should be insulated and the insulation should be checked periodically for moisture damage.

Figure 10. Guidelines for warm, humid climates (Florida and Gulf Coast, Hawaii, and Puerto Rico).

Figure 11. Insulation work should not block attic ventilation at the eaves.
CAREIRS also has information on related energy conservation topics including insulation, air-to-air heat exchangers and ventilation. For information on these topics and other energy conservation and renewable energy topics, write or call:

CAREIRS
P.O. Box 8900
Silver Spring, MD 20907
800-523-2929

Reading List

The following publications provide further information on moisture control. This list does not cover all the available books, reports and articles on moisture control nor is the mention of any publication to be considered a recommendation or endorsement. To obtain the publication in this bibliography, contact your local library, bookstore or the publisher. Check the prices through your bookstore or the publisher before placing an order.

Book and Reports


Articles

Air Leakage and Moisture Damage - Four Case Studies . . . Energy Design Update 4(5):4-10, May 1985. (Energy Design Update frequently carries articles on moisture control research and techniques.)


Sources of Illustrations


Figure 2. "Solar Age," Vol. 9, No. 1, p. 36, January 1984.

Figure 3. "Moisture and Home Energy Conservation," p. 10.

Figure 4. Ibid, p. 23.

Figure 5. "Window Insulation: How to Sort Through the Options," by National Center for Appropriate Technology, Butte, Montana, March 1984, p. 14.

Figure 6. "Moisture and Home Energy Conservation," p. 12.

Figure 7. Ibid, p. 19.

Figure 8. Ibid, p. 15.

Figure 9. Ibid, p. 17.

Figure 11. Ibid, p. 18.