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Controlling Moisture in Houses

Few moisture problems will occur when a home's relative humidity is below 40 percent. Here's how to keep the situation in check.

By Anton TenWolde and Jane Charlton Suleski

High indoor humidity levels can lead to serious moisture problems during the winter in cold regions. These problems range from mildew in wall corners and closets to condensation on windows to decay inside the wall or on the underside of the roof sheathing. On the other hand, moderate levels of indoor humidity are important for human health and comfort. With an understanding of the basic principles of moisture balance, you can design and manage for proper moisture levels.

Determining indoor humidity

Just as indoor temperature is the result of a balance between heat gain, heat loss, and heat storage, so is indoor humidity the result of moisture gain, moisture loss, and moisture storage.

In a home, moisture comes from several sources. People, plants, and pets provide part of the moisture; washing, showering, and cooking supply more. A damp basement or crawl space, or a leaky roof can also add to this. Typically, a family of three produces around 20 pounds of water vapor per day, of which about 80 percent is from human respiration and perspiration. These amounts, of course, vary with lifestyle, the number of plants and pets, and the indoor temperature.

Water vapor escapes from a house in two ways. The first is convection: water vapor escapes the house through open windows, the chimney, and cracks and other air leaks.

The second way is diffusion through walls and ceilings from areas of higher concentration to areas of lower concentration of water vapor. Considerably more moisture is lost through convection than through diffusion—10 to 4000 times as much. Thus, infiltration and ventilation play a major role in the determination of indoor humidity.

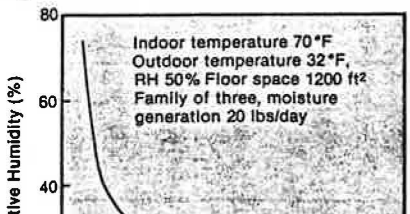
Moisture storage moderates swings in indoor humidity in much the same way that thermal mass prevents excessive swings in temperature. An 8-foot-long 2x4 wood stud at 8-percent moisture content can store as much heat as 150 cubic feet of air. The same stud, however, holds as much water vapor as 1500 cubic feet of air at 70°F and 40 percent RH. Even a house with little thermal mass has a significant amount of "moisture mass" because materials such as wood, brick, and concrete all store moisture. Although moisture storage probably does not play a major role in seasonal indoor humidity changes, it usually does moderate daily or even weekly humidity variations.

So the basic principles of moisture balance tell us that indoor humidity increases with the amount of vapor produced in the house. The smaller the home, the greater the effect. It also increases with diminishing ventilation or air infiltration. How much it goes up depends on how airtight a house is. Energy-efficient homes are more likely to have moisture problems than conventional homes.

Reducing infiltration—how far?

How far can infiltration be reduced before

Figure 1.



As infiltration rates fall below 0.5 air changes per hour (ACH) relative humidity builds up rapidly. Conversely, ventilating much past 0.5 ACH does little to lower humidity.

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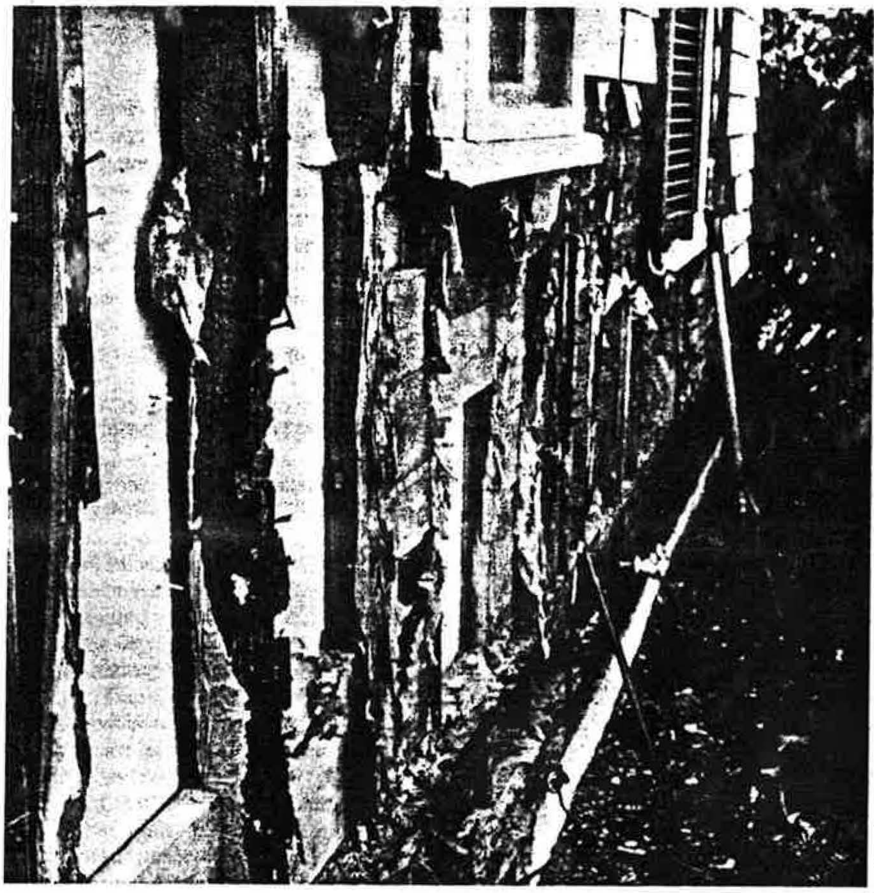


William Lotz

Moisture rising up through the wall from a wet crawl space led to severe rot in studs, sheathing, and clapboards on the north wall of this home in York, Maine. The cure: sump, poly, and ventilation.

moisture problems occur?

Figure 1 shows how indoor humidity varies with the average infiltration rate for a family of three in a 1200-square-foot house when the indoor temperature is maintained at 70°F and the average outdoor conditions are 32°F and 50 percent RH. Although different conditions and assumptions would change Figure 1, the general shape would stay the same. As you can see from the graph, indoor humidity drastically increases when infiltration is reduced below a critical point, usually around 0.5 air changes per hour (ACH).

Recognizing the critical point

How will you know when ventilation is below the critical point? This depends a great deal on climate, but continuous condensation on double-glazed windows is a good indication that problems are beginning to occur in wall or ceiling cavities. In our example house, window condensation is likely to start at indoor humidities over 50 percent, on double glazing. Single-glazed windows would fog over well before that.

In many homes in the northern United States, window condensation occurs during the late fall and early winter. This is not necessarily a sign of poor ventilation. It is caused by the sudden change in outdoor temperature and should gradually disappear. Because of the large amount of moisture stored in the house, the indoor humidity doesn't decrease fast enough to stop the windows from fogging up. After several weeks, a house with typical infiltration rates will dry out and condensation should stop. Occasionally airing the house during this time will also help.

If vapor continues to condense on a window, the window may be to blame. If the window is single-glazed, adding a storm window may solve the condensation problem. If there is already a storm window, check to see that it fits tightly. If condensation occurs on the storm window, the main window is apparently leaking. If both window and storm are tight and the condensation persists, indoor humidity should be lowered. Changing to triple glazing may stop surface condensation, but this should be accompanied with effective measures to control humidity.

Lowering indoor humidity

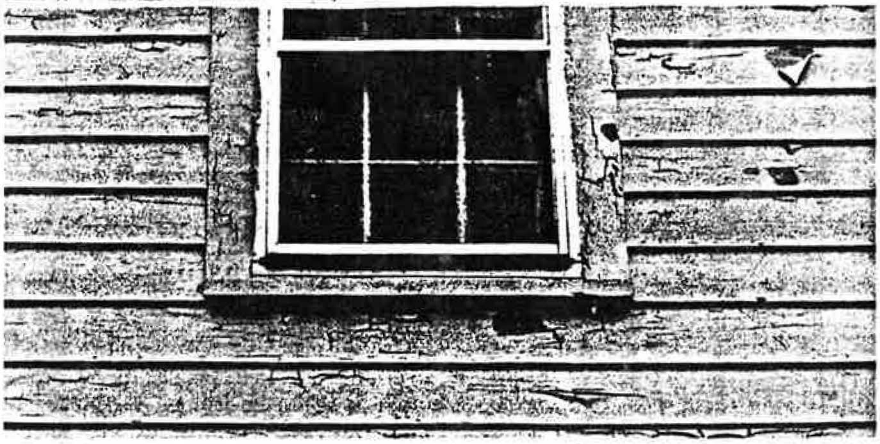
What can you do to lower the indoor humidity if moisture problems persist? If the high humidity can be traced to a single moisture source, eliminate it. For instance, install a 6-mil polyethylene ground cover in a crawl space and provide adequate crawl-space ventilation. Make sure rainwater is conducted away from the foundation. Another moisture source is the clothes dryer if vented into the home. Vent it outside. In some cases, high humidity problems have been traced to mounds of cord wood drying in the basement. Many moisture sources, however, are difficult or even impossible to control.

Increasing ventilation is another effective way to lower indoor humidity. If ventilation is increased in our example house from 0.2 ACH to 0.4 ACH, the indoor relative humidity decreases 19 percent. Additional ventilation, however, does not lower the humidity much further. The optimal amount of ventilation, then, is just enough to keep the indoor humidity below the level where condensation becomes a serious problem.

Recommendations to design a house to naturally ventilate at 0.5 ACH, though, are meaningless. It is highly unlikely that natural infiltration will provide the optimum ventilation rate—it will either provide too much or too little depending on wind and temperature conditions. Also, no design guidelines currently exist to provide exactly this amount (0.5 ACH) of natural infiltration.

A workable alternative is mechanical ventilation with exhaust fans. A fan can be

Air leakage plays a much greater role in removing moisture than diffusion does, even in this example where the air leakage rate is extremely low and the diffusion rate relatively high.



Excessive moisture condensation in a wall can cause exterior paint to fail. The blistering and peeling will be irregular and will expose bare wood.

controlled either manually, with a timer, or with a humidistat. A timer can minimize heat loss by limiting ventilation to warmer periods in the day.

Exhaust fans are primarily located in kitchens and bathrooms, but occupants rarely use them correctly, if at all. Bathroom fans should run for at least 15 minutes after a shower or bath. This is because moisture may have condensed on walls, windows, and mirrors and it should be given a chance to evaporate and be vented to the outside. This can be easily accomplished with a timer. Kitchen fans should run while cooking to avoid excessive moisture buildup. They should be cleaned regularly to be effective. If moisture continues to be a problem, you may need a larger fan capacity, or you may want to run either the bathroom or kitchen fan for longer periods to ventilate the entire house. Keep in mind that the actual flowrate is often far less than the rated fan capacity, given the duct runs and pressure differences in an actual installation.

In our example house, assuming a natural infiltration rate of 0.2 ACH, a fan exhausting 30 cubic feet per minute (cfm) continuously would lower RH from 50 percent to below 40 percent. A larger fan controlled by a humidistat or timer could achieve the same results.

After extensive efforts to weatherize a home, a homeowner may be reluctant to run an exhaust fan all day. It may seem like a waste of energy. How much energy is actually lost and how much does it cost? In our example house, a fan exhausting 30 cfm continuously causes 11,000 Btu of additional heat loss per day, approximately 5 percent of the total estimated heat loss for a house that is well insulated. It takes 3 kWh per day of electricity to run the fan, bringing the total energy cost to between $7 and $10 per month depending on fuel and electricity prices.

Another option is an air-to-air heat exchanger, which reduces heat losses but maintains sufficient ventilation. The heat exchanger transfers part of the heat that would otherwise be lost in the exhaust air to the fresh intake air. The energy savings depend on the heat exchanger and the tightness of the house. In our example house, running the exchanger would save between $5 and $13 per month over the exhaust fan depending on fuel costs. As outdoor temperatures fall, these savings increase.

For these calculations we assumed that the heat exchanger recovers 50 percent of the heat in all the exhaust air. Some heat exchangers are rated at a considerably higher efficiency, but these ratings are based on the performance of the equipment in isolation. Actual overall savings depend on the airtightness of the house and the type of heat exchanger. If the home is not airtight, less heat is recovered because part of the air is entering or leaving the house through other openings, bypassing the heat exchanger. Some heat exchangers, due to poor dampers or faulty installation, may also cause greater air infiltration when not in use. The tighter the home, the closer the overall performance comes to the rated efficiency, resulting in bigger savings.

Dehumidifiers can efficiently lower indoor humidity in areas with a milder and more humid winter, but they are generally not able to lower indoor humidity much below 50 percent, which is rarely enough for colder climates.

Sunspaces

A special humidity problem sometimes occurs in attached, unheated sunspaces, where large amount of condensation collect overnight on the windows. This is not necessarily a sign of excessive humidity but may be a result of daily temperature swings in the sunspace. At night the surface temperature of the glazing often dips below the dewpoint of the air and the window starts collecting condensate. This dries out the sunspace, but enough moisture is stored in materials in the sunspace to supply the window with plenty of moisture.

During the day the sunspace is "recharged" with moisture re-evaporating from the windows and water vapor from the rest of the house. At night the cycle repeats itself. Ventilation is of little help in this case. The best strategy is to keep the moisture off the window with a vapor-tight window cover, such as commercially available insulating shades with sealed edges. It is, therefore, important that windows in sunspaces be designed for movable vapor-tight covers.

Lowering the home's thermostat setting at night can cause condensation problems similar to those in sunspaces. Triple glazing or movable insulating vapor-tight window covers can alleviate this problem.

Vapor retarders

Continuous air and vapor retarders play an important role in preventing condensation in walls and ceilings. Usually they have little effect, however, on indoor humidity levels because vapor transmission through walls and ceilings usually provides a small part of the total moisture exchange in the house.

It is uncertain exactly when vapor retarders are necessary. For example, tests at the Forest Products Laboratory, in Madison, Wis., showed minor condensation but no damage to building materials when foil-faced foam sheathing was installed on the exterior o test wall, even when the interior vapor retarder was damaged. Still, experts agree that a good, continuous retarder is vital when indoor humidities are high. Under these conditions, obvious problems with window condensation and mildew are likely to occur. If indoor humidity is kept below 40 percent in the winter, the potential for damage from condensation in walls and ceilings is limited. In new homes, in cold climates, continuous vapor retarders are recommended as a safeguard against damage within walls. In addition they reduce air infiltration.

Summary

- Most moisture problems in homes in the Canada and the northern United States during the winter are related to too-high indoor humidity.
- Excessive moisture sources such as damp crawl spaces, and lack of ventilation cause this humidity problem.
- Exhaust fans or air-to-air heat exchangers can easily and economically provide sufficient ventilation.
- Vapor retarders generally do not affect indoor humidity.
- Continuous vapor retarders are recommended in cold winter climates to prevent damage from condensation in the walls or ceiling, and to limit air leakage through them.