



MAINTAINING  
YOUR HOME

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# Winter Home Moisture Problems

**P**ersistent fog or frost on windows, mold on ceilings and walls, and musty odors are all signs of moisture problems in the home. If allowed to persist, these problems are not only annoying, but can damage your home — and in some cases, can cause health problems.

Frost on your windows?  
Mold on your walls?

To solve winter moisture problems in your home, you must first recognize the nature of the problems and understand their cause. This publication introduces you to the simple physics and basic terms associated with humidity and condensation.

Armed with this basic understanding of moisture problems, you will be better able to solve the problems yourself or evaluate solutions others propose.

## Understanding home moisture

### Moisture terms

The following terms are used throughout this publication.

**Water vapor** — the gaseous form of water — is the invisible source of many home moisture problems.

Most air contains some water vapor, or **humidity**. The amount of water vapor the air holds depends on these combined factors:

- **Air and surface temperatures** (dew point)
- **Moisture available** (relative humidity)

**Air temperature** determines how much water vapor air can hold. The warmer the air, the more water vapor it can hold.

**Relative humidity** is a measure that describes the amount of moisture the air holds relative to the most it could hold at a given temperature.

For example, if the air temperature is 70° Fahrenheit (F), a relative humidity of 40 percent means that air at that temperature contains only 40 percent of the moisture it could hold.

If air temperature then drops from 70° F to 55° F, the relative humidity will climb to nearly 70 percent — even though the amount of moisture in the air remains unchanged. This happens because colder air cannot hold as much moisture as warmer air.

Keep winter indoor humidity at 30 to 40 percent.

If air temperature drops still further, from 55° F to 44° F, the relative humidity will be 100 percent. At this point, some water vapor in the air will begin to condense to liquid water because the air can no longer contain it.

The **dew point** is the temperature to which air with a given humidity level must cool for water vapor to condense to liquid. In this case, 44° F is the dew point.

In figure 1, temperatures in the left column and relative humidity levels in the middle column represent some common combinations. Temperatures in the right column show how much air with that humidity level would have to cool to reach its **dew point** — the point at which condensation occurs.

**Condensation** leaves fog or frost on windows in winter, and water on walls and other household surfaces. This results from moist air coming in contact with surfaces that are colder than its dew point temperature.

Water condenses on basement walls and floors in summer because these surfaces are often cooler than summer dew points.

## Winter relative humidity

In cold climates, the ideal indoor relative humidity level needs to balance between human comfort and risk of condensation.

**When humidity levels are too low**, people complain of dryness and static electricity. Wood floors and furniture develop cracks.

**When humidity levels are too high**, moisture condenses on cold surfaces.

The compromise often recommended is to keep relative humidity levels between 30 and 40 percent in winter.

## Estimating humidity levels

One of the first steps for diagnosing the cause of moisture problems is to check the humidity level in your home.

You can estimate the relative humidity in winter by observation. Use the information in figure 2. Check your windows for fog or frost, and compare indoor with outdoor temperatures for the kind of windows you have (see next page).

For example, if you have **double-glazed windows**, set your thermostat at 70° F, and fog or frost persists on bare windows during the day when outside temperatures are 0° F or above, **relative humidity is more than 40 percent**.

**Figure 1:** Dew points for common air temperature-relative humidity combinations.

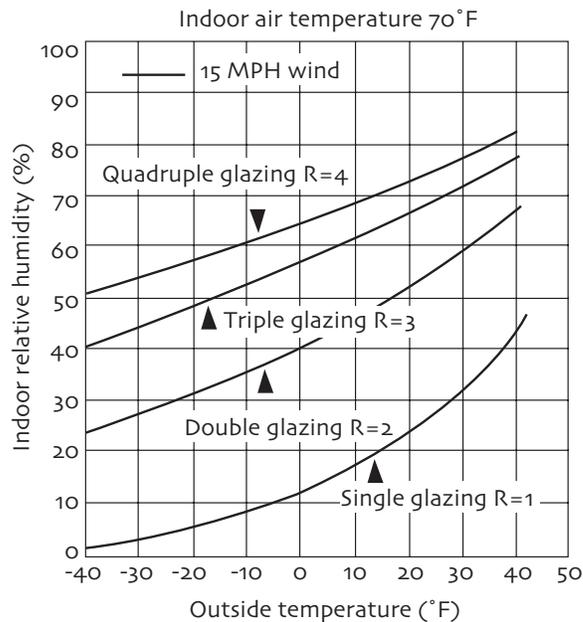
| Temperature (Fahrenheit) | Relative humidity(%) | Dew point (F) 100% RH |
|--------------------------|----------------------|-----------------------|
| 80°                      | 60%                  | 65°                   |
|                          | 40%                  | 53°                   |
|                          | 20%                  | 35°                   |
| 70°                      | 60%                  | 56°                   |
|                          | 40%                  | 44°                   |
|                          | 20%                  | 27°                   |
| 60°                      | 60%                  | 46°                   |
|                          | 40%                  | 37°                   |
|                          | 20%                  | 20°                   |
| 55°                      | 60%                  | 41°                   |
|                          | 40%                  | 31°                   |
|                          | 20%                  | 15°                   |

If the temperature in your home or in specific rooms is cooler than 70° F, the relative humidity level that yields persistent condensation on double-glazed windows will be somewhat lower.

You may not need a more accurate measure of humidity than this estimate.

Figure 2 shows condensation on windows as affected by outside temperature, indoor relative humidity, and window insulation (R value) when wind speed is 15 miles per hour (MPH). Use this information to estimate relative humidity in your home in winter.

Figure 2: Condensation on windows



Source: Hellevang, Kenneth J., *Keep Your Home Healthy AE-1204*. North Dakota State University Extension Service, June 2003: <http://www.homemoisture.org/kyhh/ae1204-1.htm>

## How moisture moves

Water vapor moves primarily by two means:

1. **Diffusion** — Water vapor tends to move from areas of high concentration to areas of low concentration.

Water vapor diffuses very quickly in air, so the amount of moisture in various rooms quickly equalizes. However, if the temperature varies from room to room, relative humidity may also vary in each room.

2. **Air movement** — As air moves through and about your home, it carries water vapor with it. Air moves due to two natural forces:

- a. **The stack effect** — Warm air rises, as it is lighter than cool air. A familiar example of the stack effect is heat rising up a chimney.

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To replace warm air rising up and out of your home, cool air is drawn in at the base through ground floor cracks under doors and around windows.

- b. **Wind pressure** — As the wind blows against your house, it forces air in through cracks on the windward side. This pressure causes air to escape from the opposite side of the house.

During the heating season, air movement brings cool outside air into your home. Even though this outside air may have a high relative humidity, it contains only small amounts of moisture because it is so cold.

After the cold air enters your home, its temperature increases and its relative humidity decreases. Once the air is warmed, it picks up water vapor generated by household activity. The warm moist air then rises and exits through the chimney, cracks around windows, and other openings in the walls and ceilings of your home.

Water vapor from warm air escaping around upper story windows condenses on cold windows. This is why you often see frost on the inside of second story windows, while the first story windows remain clear.

Older construction techniques allow the stack effect and wind pressure to exhaust warm, moist air and to introduce large amounts of cold outside air into homes. This is why indoor humidity levels in older homes are so low in winter and humidifiers are often needed.

## Side effects of weatherizing

The same air movement that removes moisture also removes heat. Energy conservation practices such as caulking and weatherstripping are aimed at trapping heated air indoors and reducing the infiltration of cold outside air.

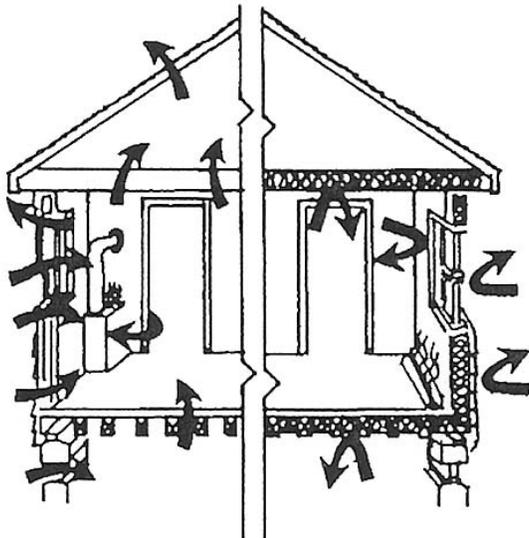
As a side effect of weatherizing, sometimes moisture is also trapped indoors. And too little outside air is introduced to reduce humidity levels (see figure 3).

However, the solution to excess humidity is not to go back to loose construction that allows air to move freely in and out of the home. Those homes are at the mercy of outside weather conditions.

The forces that move air through the house are most active when temperatures outside are coldest and winds are strongest. So loosely constructed homes are likely to be over-ventilated on the coldest days, resulting in drafty, dry homes.

Figure 3: Weatherizing may increase humidity.

- |   |  |
|---|--|
| <p><b>Before ventilation—</b></p> <ul style="list-style-type: none"> <li>■ high infiltration</li> <li>■ low humidity</li> </ul> | <p><b>After ventilation—</b></p> <ul style="list-style-type: none"> <li>■ low infiltration</li> <li>■ high humidity</li> </ul> |
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Figure 3 shows how the solution to one problem — sealing and insulating to keep out cold air and prevent wasteful heat loss — can sometimes cause another — excess indoor humidity.

# Solving winter moisture problems

## Solve water problems first

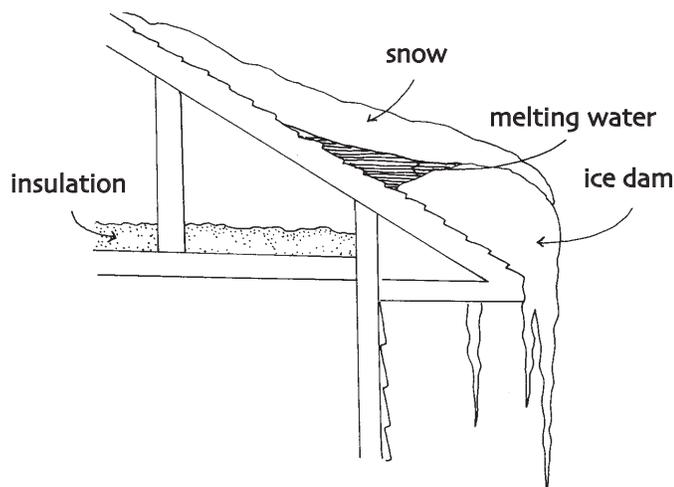
The first step is to find and fix leaks and water damage. Check under sinks and around tubs and showers for drips, damp areas or dark stains. Check the walls and ceilings in adjacent rooms as well. The problem may show up as water stains on the wall or ceiling that backs up to the leak.

**Check the roof for leaks.** Icicles hanging from the eaves may indicate ice dams. **Ice dams** form when snow piles high on the roof and the weather stays cold. Snow touching the roof melts, runs down the roof under the snow to the eaves, and refreezes. Water may back up behind the dam and leak into the attic or sidewalls of the home, causing damage (see “First aid for ice dams”).



As figure 4 shows, icicles on the eaves may signal ice dams on the roof. Prevent ice dams to keep melting snow from leaking into the attic.

Figure 4: Ice dam



**Check basement walls and floors.** Stains on basement walls mean water has soaked through and evaporated. Tape a piece of clear plastic tightly to the wall or floor. If water collects behind the plastic after 24 hours, moisture is seeping through. If the moisture is on the room side of the plastic, condensation is a problem.

Basements often leak because poor surface drainage allows heavy rain or rapidly melting snow to pool next to the foundation.

As much as 12.5 gallons (100 pints) per day can migrate through porous basement floors and walls from wet soil outside.

**Correct improper surface drainage.** Check the grading around your home. The ground surface should slope noticeably away from the foundation at all points. If you have gutters and downspouts, make sure they function properly and direct water well away from the foundation.

**Seal basement walls and floors.** If your grading and gutters keep water away and moisture seepage seems slight, commercial damp-proofing compounds may solve the problem. These are applied like paint to inside walls.

If water problems are severe, contact a reputable contractor.

## First aid for ice dams

Clear snow from the roof a few feet back from the eaves with a long-handled roof rake. This rake is designed so you can safely remove snow from the ground. If you cannot reach the roof from the ground with this rake, consider hiring a roofing contractor.

**Prevent ice dams — Keep the attic cool** Seal gaps where warm air leaks into the attic. Non-expanding foam in a can will plug most leaks. If air leaks around something hot like a stovepipe, form a gasket with sheet metal or use fiberglass insulation that will not burn or melt.

**Add insulation.** In cold climates, the attic should have an **insulating value of R=38 or more — at least 1 foot of insulation on the attic floor.**

**Ventilate the attic.** In older homes, attics should have 1 square foot vent opening for every 150 square feet of floor, divided equally between the top and bottom of the roof. Cold air flows in through vents in the eaves, pushing warm air up and out vents near the ridge.

**Reduce moisture from crawl spaces.** If your home is built over a crawl space, reduce moisture from this source by covering the crawl space with a moisture-resistant material such as 6 mil polyethelene plastic.

Roll the material several inches up the edge of the foundation. If you need more than one sheet, be sure to overlap them. Use stones, bricks or dirt to keep this moisture barrier in place.



Figure 5: If you have a crawl space with an earth floor, line the floor with thick plastic to prevent evaporation.

Figure 5: Cover crawl spaces.

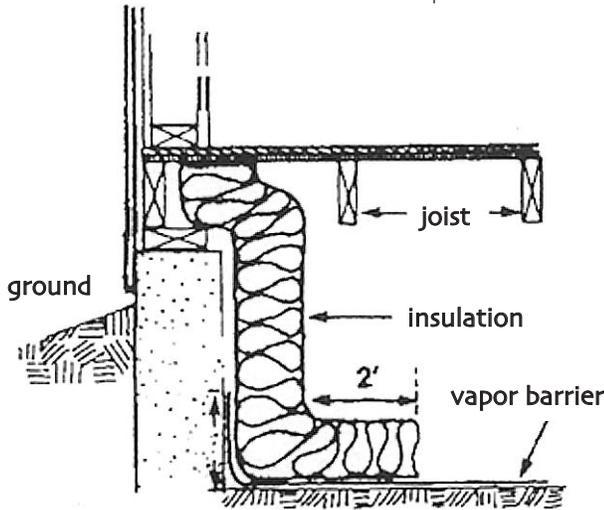
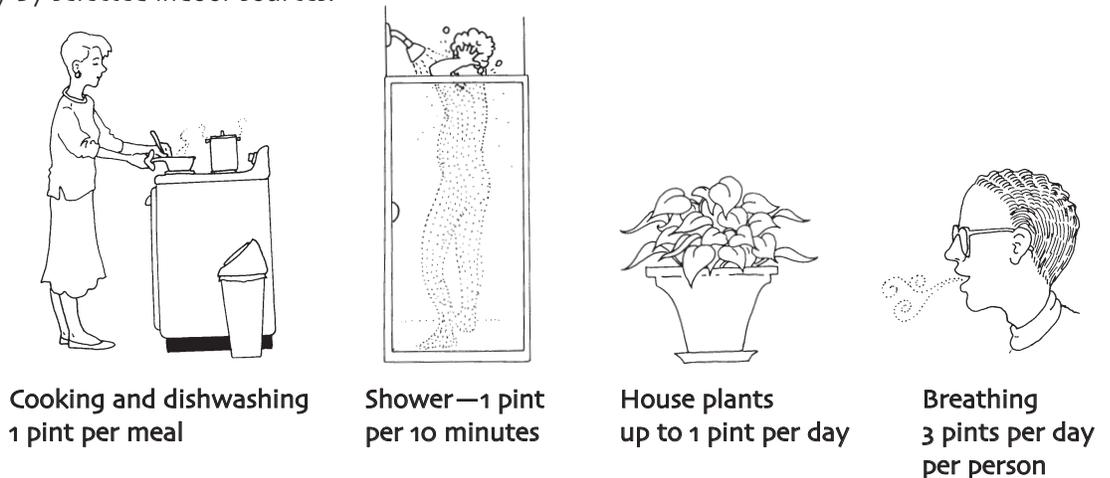


Figure 6: Moisture sources in the home—approximate amounts of water vapor produced per day by selected indoor sources.



## Reduce moisture produced indoors

Another way to reduce relative humidity is to decrease the amount of water vapor generated in the home. As figure 6 shows, considerable water vapor is produced in the course of daily living. For example, a family of four will generate a gallon and a half (12 pints) of water vapor a day — just by breathing.

Here are some ways to reduce the amount of water vapor produced in the home:

- **Be sure the clothes dryer vents outdoors.** A clothes dryer vented indoors produces more than half a gallon (5 pints) of moisture per load.
- **Keep showers and baths short.**
- **Cover pots and pans when cooking.** This reduces both evaporation and cooking time.
- **Avoid storing firewood indoors.**

## Increase ventilation

Problems with excess moisture during winter have become more severe in cold climates since houses have been tightened up to reduce heat loss. Reducing the amount of moisture generated in the home helps, but often ventilation must be increased as well.

Unlike the traditional home in which natural forces determine ventilation rates, the new approach allows occupants to determine ventilation rates.

When you first start using ventilation to reduce cold weather condensation problems, you may not get immediate results. This is because moisture is stored in your home's wood and trim during summer when warm air holds more water vapor, then released as temperatures cool. A house will produce 6 to 16 pints of moisture per day — up to 2 gallons — as indoor materials dry during fall.

So condensation can be a particular problem at the beginning of the heating season. The relative humidity of indoor air will drop only after moisture levels in the structure have dropped.

In winter, ventilation is the most effective and least expensive way to reduce relative humidity. In summer, remove moisture with a dehumidifier or air conditioner.

**Note:** Avoid using dehumidifiers in winter. Dehumidifiers work best at higher temperatures and at humidity levels above 50 percent.

## Exhaust fan ventilation

The easiest option for increasing ventilation is to use existing exhaust fans. A true **exhaust fan** is installed in a wall or ducted through the roof or an exterior wall, and draws air out of the house.

Be aware that ductless kitchen and bath fans do not exhaust air, but simply filter and recirculate air. Bathroom fans with infrared heat lamps only help circulate air.

To remove moisture effectively, run exhaust fans for 20 minutes after showers, and 30 minutes after cooking and dishwashing.

If this is inconvenient or inadequate, consider installing a **dehumidistat control** to operate your exhaust fan. You can set the fan to switch on whenever moisture exceeds a certain level.

Open a window slightly on the opposite side of the house to replace vented air with cold, dry outside air. Improved ventilation will more than offset the heat you lose by opening the window when the fan is running.

**If you need to install an exhaust fan,** look for one with:

- A tight-fitting exterior damper.
- Eight air changes per hour for a bathroom fan.
- Twelve to 15 air changes per hour for a kitchen fan.
- Very low noise level so family members will use it.

Run exhaust fans after showers and meals to remove moist air.



## Whole house ventilation

For new well-constructed homes, whole house ventilation systems may be the answer. The type best suited for cold climates exhausts air from kitchens and bathrooms, and supplies fresh air to bedrooms.

A common type is a **heat recovery ventilator**. These balance exhausted air with incoming air, and transfer heat from the outgoing air stream to the incoming air stream. These systems are powered by quiet, low-volume fans that do not produce drafts.

## Warm up cold surfaces

Warm up cold surfaces to a temperature above the dew point for indoor temperature-humidity conditions.

In many cases, high relative humidity levels are not the cause of moisture problems. In homes where the relative humidity is in the acceptable 30 to 40 percent range

for winter, moisture problems can occur because surface temperatures drop below the dew point for air with that amount of water vapor.

Single pane windows offer a convenient example. A single layer of glass has very little insulating value. So the inside surface temperature of the glass will be close to the outdoor temperature.

A review of figure 2 reveals that room air at 70° F with a moderate 30 percent relative humidity could still produce condensation on the surface of single-glazed windows when the outside temperature drops below 20° F. This is because the inside surface temperature of the glass would be 33° F, or roughly 4° F below the dew point.

By adding another layer of glazing, you would raise the surface temperature above the dew point of 37° F and prevent condensation.

When your relative humidity levels are higher or outside temperatures are lower, the second layer of glazing might not be enough. For example, if the outside temperature drops to 0° F, condensation can be expected on double-glazed windows if the relative humidity remains at 30 percent.

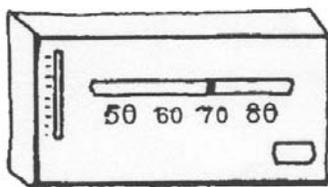
A third layer of glazing will stop condensation in most situations. Double-glazed windows with a **low e (low emittance) coating** may also be effective.

You could also add a tight-fitting interior storm window or layer of plastic. Kits containing clear plastic and double-stick tape are available for this purpose.

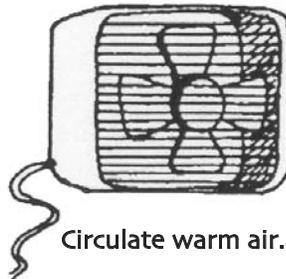
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Figure 7: Warm up cold surfaces and exhaust moist air from your home to prevent condensation in winter.

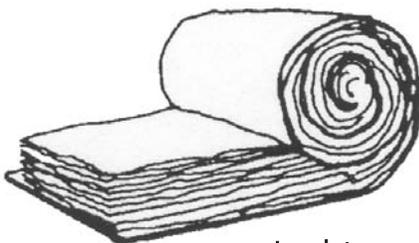
Figure 7: Prevent condensation in winter.



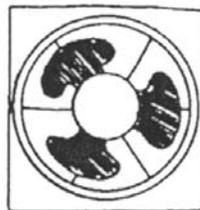
Raise the temperature.



Circulate warm air.



Insulate.



Ventilate.

## Trouble spots

Covering windows with loose-fitting drapes can make condensation problems worse. This blocks air circulation and lowers the window pane temperature. Yet moisture still diffuses to the area behind the drapes and condenses on cold windows.

This is similar to problems that sometimes occur behind furniture placed against outside walls, or in closets against exterior walls.

Moisture may condense on these walls because heated room air does not circulate there to warm them, yet they are open enough to let moist air through. When moisture condenses on these walls, mold can grow there.

## Circulate warm air

The simplest short-term solution is to improve air circulation to cold surfaces.

Make sure warm air reaches problem areas:

- Open drapes to warm up windows.
- Leave closet doors open, and make sure warm air circulates to the back.
- Move furniture away from outside walls.
- Raise the temperature in problem rooms.

## Improve insulation

The ideal long-term solution is to improve insulation for the surfaces where moisture condenses in winter.

Another trouble spot in some homes is the corner between outside walls and ceilings. Attic insulation often is thin at this point because either there is not enough space between the ceiling and the roof deck to accommodate the full amount of insulation, or structural materials displace insulation.

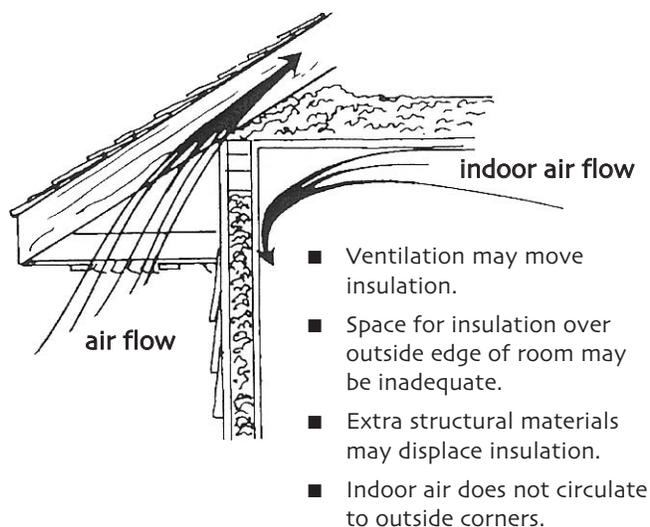
Wind through attic vents may blow insulation away from this area. Wall insulation may settle; and air circulation to this area of the room is limited (see figure 8).

In most cases, reducing indoor humidity levels will cure these problems. Where this solution is not effective, you will need to warm up cold surfaces.

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Figure 8 shows why you may need to insulate corners between outside walls and ceilings to prevent moisture problems that often develop there.

Figure 8: Insulate corners.



## Remove mold and mildew

Drying up indoor air and fixing leaks are the best long-term treatments of mold problems. But if you find small areas of mold on surfaces, you can use the following procedure to remove it.

Scrub the area with a dilute bleach solution: 1 cup of 5 percent household bleach (sodium hypochlorite) in 1 gallon of water.

Wash surfaces with this bleach solution and let dry. Rinse carefully to remove dead mold material. Even dead mold spores can cause allergic reactions.

Bleach is a strong chemical. Follow the directions on the container carefully. Wear rubber gloves and avoid skin contact. Open windows and run fans to ensure adequate ventilation.

**Caution:** If you have extensive mold problems, removing them can pose health risks. Contact your local health department for help locating a mold removal contractor, or your university extension office for mold removal guidelines.



## Checklist for preventing problems

**Are water leaks causing the problem?**

- Check that gutters are clear of leaves and other material.
- Make sure downspouts carry water away from the foundation.
- Check to be sure the ground slopes away from the foundation.
- If icicles form on the eaves, clear snow from the roof. Check the attic for proper insulation and ventilation.
- Check roofing and flashing to be sure it is in sound condition.
- Check that basement walls and floors are dry.

**Does fog or frost persist on double-glazed windows when outside temperatures are above 0° F?**

- Open drapes and shades to allow heated air to reach windows.
- Keep showers short.
- Use exhaust fans after bathing and cooking.
- Make sure the clothes dryer is vented outdoors.
- Minimize indoor storage of firewood.
- Consider reducing the number of house plants.

**Is moisture condensing on walls, but not on windows?**

- Increase air circulation to problem areas.
- Improve insulation of exterior walls and corners near problem areas.

## Conclusion

Moisture problems can be difficult to solve. The solution may often involve several steps, or you may need to choose among several solutions.

This publication provides you with basic information on moisture problems to help you make effective choices and develop your own solutions.

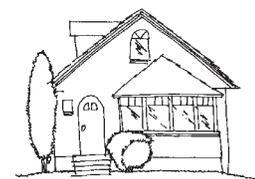
We hope you will use this information to think of winter moisture problems in terms of their causes, and that this approach will save you time, trouble and money.

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**Your county or area university extension office** offers programs and publications on maintaining your home. Look online or in the phone book under county government.

**Web sites** — If you do not have a computer, try your local library. Most libraries have a free computer connected with the Internet.



**Note:** This publication replaces *Moisture Problems in the Home* (NCR312).

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