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COLD CLIMATE HOUSING INFORMATION CENTER

UNIVERSITY OF MINNESOTA

Humidity and Condensation Control in Cold Climate Housing

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This publication discusses cold climate construction techniques and humidity control measures that can be used to minimize condensation within or on walls, ceilings, and windows. Using properly installed vapor retarders, air barriers, insulation and controlled ventilation, homes may be designed and built to avoid potentially destructive condensation problems.

Humidity is water vapor that is absorbed in air. *Condensation* is the product formed when the vapor is cooled enough to convert it back into liquid water, such as the fog, water, or ice often seen on a cold window, or the dampness that sometimes occurs on cold wall surfaces. The more humid the air is, the more likely it is to condense when it is slightly cooled. Condensation can lead to problems such as dripping on windows, wet sills, damp walls, mold, wet insulation, wood rot, and corrosion of metal.

Prevention

Preventing condensation problems requires a four-part strategy as summarized below:

1. Maintain comfortable humidity, which would be between 30-50 percent (and no higher) on a scale of relative humidity. Humidity should be reduced to the lower end of the range during very cold weather (condensation on windows will indicate when this is necessary). Ventilation fans can be used to regulate the upper limit of humidity. Some form of a controlled ventilation system is required in houses that are tightly constructed. Many researchers suggest .30 to .50 air changes per hour of continuous ventilation with intermittent higher rates when necessary.[1]
2. Install an interior-side vapor retarder (warm side) and a continuous air-barrier system to prevent vapor-laden air from penetrating into cool areas of the building structure, either by diffusion or air leakage.
3. Install adequate corner insulation and thermally insulated windows and doors for warm interior surfaces. Extra wall insulation may be required in bathrooms because they are subject to high humidity.
4. Control excessive moisture sources, such as wet basements, unvented clothes dryers or kerosene heaters, indoor firewood storage, overly frequent showers, or misuse of humidifiers.

A 30-50 percent humidity level is enough to control the problems of dry skin, dry throats, coughing, and static electricity sparks. Higher humidity is not necessary[2] and may actually be unhealthy because of the increased potential for mold and mildew.

Even with reasonable indoor humidity, however, condensation can occur if water vapor is allowed to penetrate into cool parts of the structure. As a result, wet insulation and associated loss of insulating ability can occur. Indoor vapor pressure pushes water vapor toward cool areas. Since warm air rises, the flow of warmer, humidified air through openings (called *exfiltration*) can also carry water vapor to cooler areas, such as attics. With prolonged dampness in cool areas, wood rot may occur in studs, wall sheathing, or roof decking.

Natural Humidity Balance

In many homes, typical natural household moisture sources (showering, breathing, cooking, etc.) add approximately the right amount of moisture to humidify the dry outside air that ventilates the house during cold weather. Adsorption of moisture by interior surfaces and furnishings and its later release help to stabilize the hour-to-hour humidity level inside a house. Exhaust fans in bathrooms or the kitchen may have to be operated a few hours a day to remove short-term excess humidity. Humidistatically controlled bathroom and kitchen ventilation fans or whole house ventilation systems help keep the natural balance at the proper level by removing

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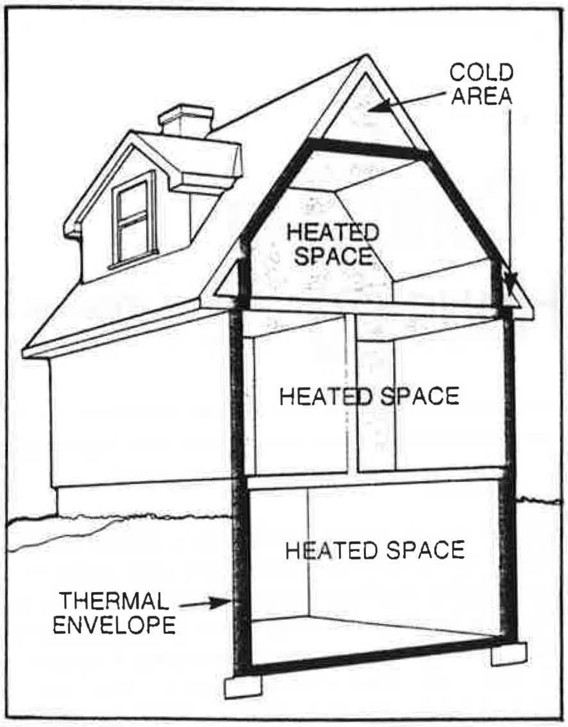

Figure 1 The thermal envelope consists of all the insulated walls and ceilings that enclose the heated and humidified living spaces.

excess humidity for short periods. Unusually high rates of moisture release (such as from long, hot showers or internally vented clothes dryers) must be avoided if possible because such releases waste energy by requiring ventilation fans to be run almost continuously. In this case, it is more efficient to reduce the moisture sources that make ventilation necessary.

Humidity and Condensation Control

Vapor Retarders and Insulation

As shown in Figure 1, the thermal envelope of a house consists of all the insulated walls and ceilings that enclose the heated and humidified living space. A vapor retarder is needed on the interior (heated) side of the thermal envelope to restrict interior water vapor from penetrating into the insulation layer or into unheated areas such as the attic. A vapor retarder can be polyethylene film, special paint or sealer, or other vapor-resistant material, provided it is installed on the interior side of insulated walls and ceilings (or close enough to the interior so that condensation will not occur on the retarder itself)[3].

Because water vapor has a tendency to find openings and penetrate through them, reasonable efforts need to be made to seal the vapor retarder and install an air barrier[4] to prevent air leakage (see Figure 2). Such openings include holes for wires, wiring boxes, and pipes. Special construction tape, rubber gaskets, or sealants are now available for sealing vapor retarders and air barriers at an economical cost. For further information, see *Ceiling Airtightness and the Role of Air Barriers and Vapor Retarders* (CD-FO-3568).

The effectiveness of a vapor retarder is measured by its perm (permeance) rating. A low perm rating means there is low passage of water vapor, provided all holes are sealed. In some regions of the country, films, foils, sealers, or paints with a perm rating of *less than 1.0* are generally considered adequate interior-side vapor retarders. Polyethylene is a commonly used vapor retarder.

Surface Condensation and Insulation

Surface condensation can occur wherever water vapor in the indoor air comes in contact with a cool surface (see Figure 3). In many houses, condensation on window glass

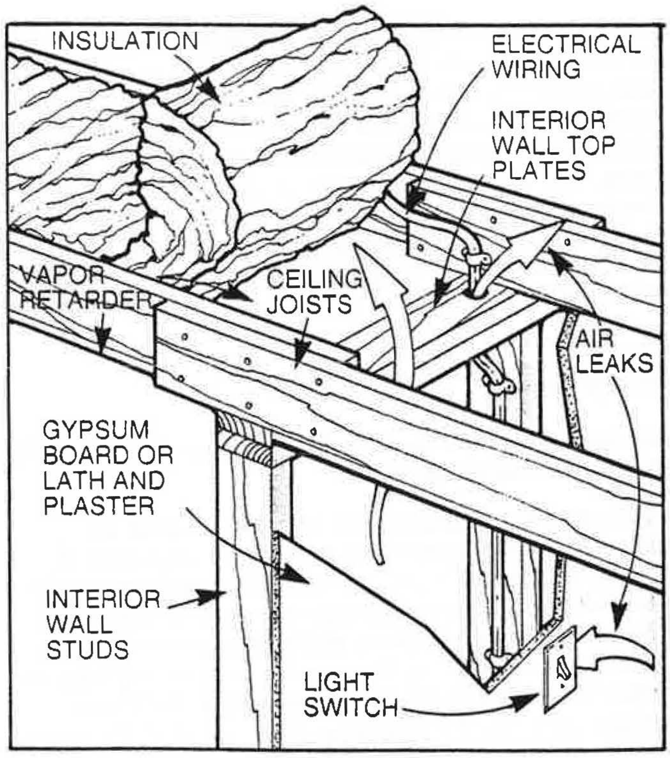

Figure 2 Vapor retarders control vapor diffusion while air barriers retarders control air leakage. Construction practices which allow a large amount of air leakage to occur in cold climate housing need to be addressed in order to prevent large amounts of moisture-laden air from condensing in wall, ceiling, and attic areas.

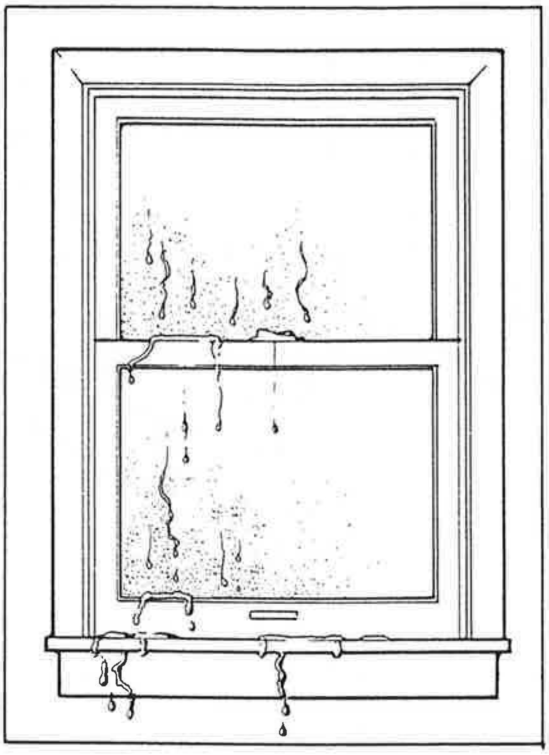

Figure 3 Condensation on window glass and frames is common during cold weather, and occurs wherever humid indoor air comes in contact with cool surfaces.

and frames is common during cold weather, often resulting in dripping that can cause interior damage such as peeling paint, swelled or splitting wood, window frame and sill rot, staining, and mold. Triple-pane insulating windows (or their equivalent, which are double-pane plus storm window, or high-performance double-pane insulating glass) are important for preventing condensation. This type of window will help reduce heating costs and improve comfort.

Insulated Exterior Doors and Door Sills

Energy-efficient doors have insulating core material and thermal spacers at the edges that also help to prevent condensation or frost (see Figure 4). Metal door thresholds should have thermal spacers as well. High-quality weatherstripping (see Figure 5) keeps cold air from entering and also helps to prevent condensation or frost from forming on the frame of the door. Besides controlling condensation, insulated and airtight doors also increase comfort. Metal thresholds should especially be avoided, unless they have a complete thermal break from inside to outside.

Insulated Corners

Corners of rooms tend to be cool and are therefore at risk for condensation. Lack of proper insulation is common with standard corner construction methods. Exposure to cold on two sides on the exterior draws heat away rapidly. On the inside, warm air cannot circulate into corners very well. On the outside, wind washing across the corners and into the wall can dramatically reduce surface temperatures. Thus, it is common for

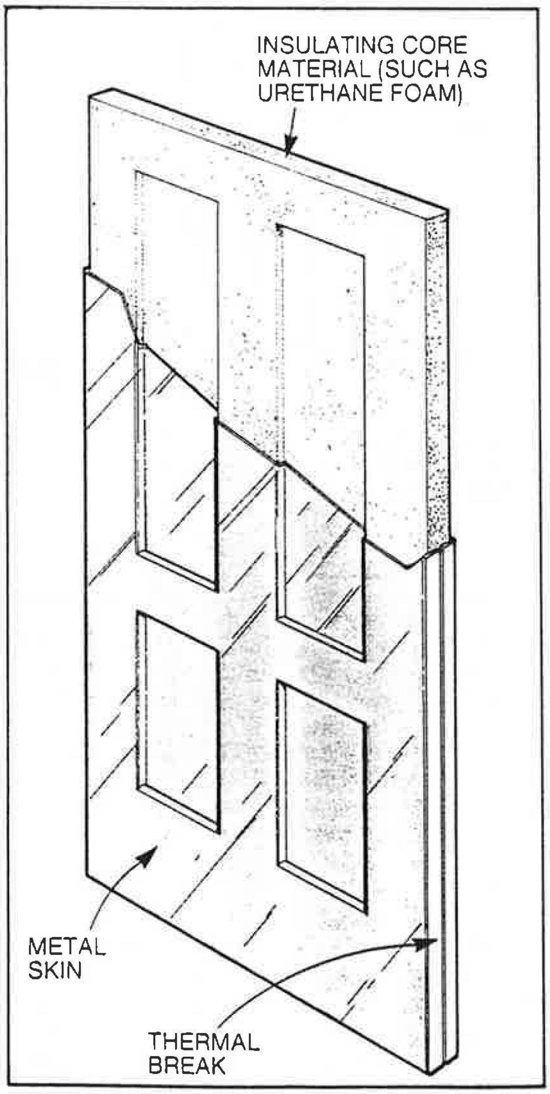

Figure 4 Energy-efficient doors combine core materials of high insulation value and thermal breaks when a heat-conducting skin, such as metal, is used.

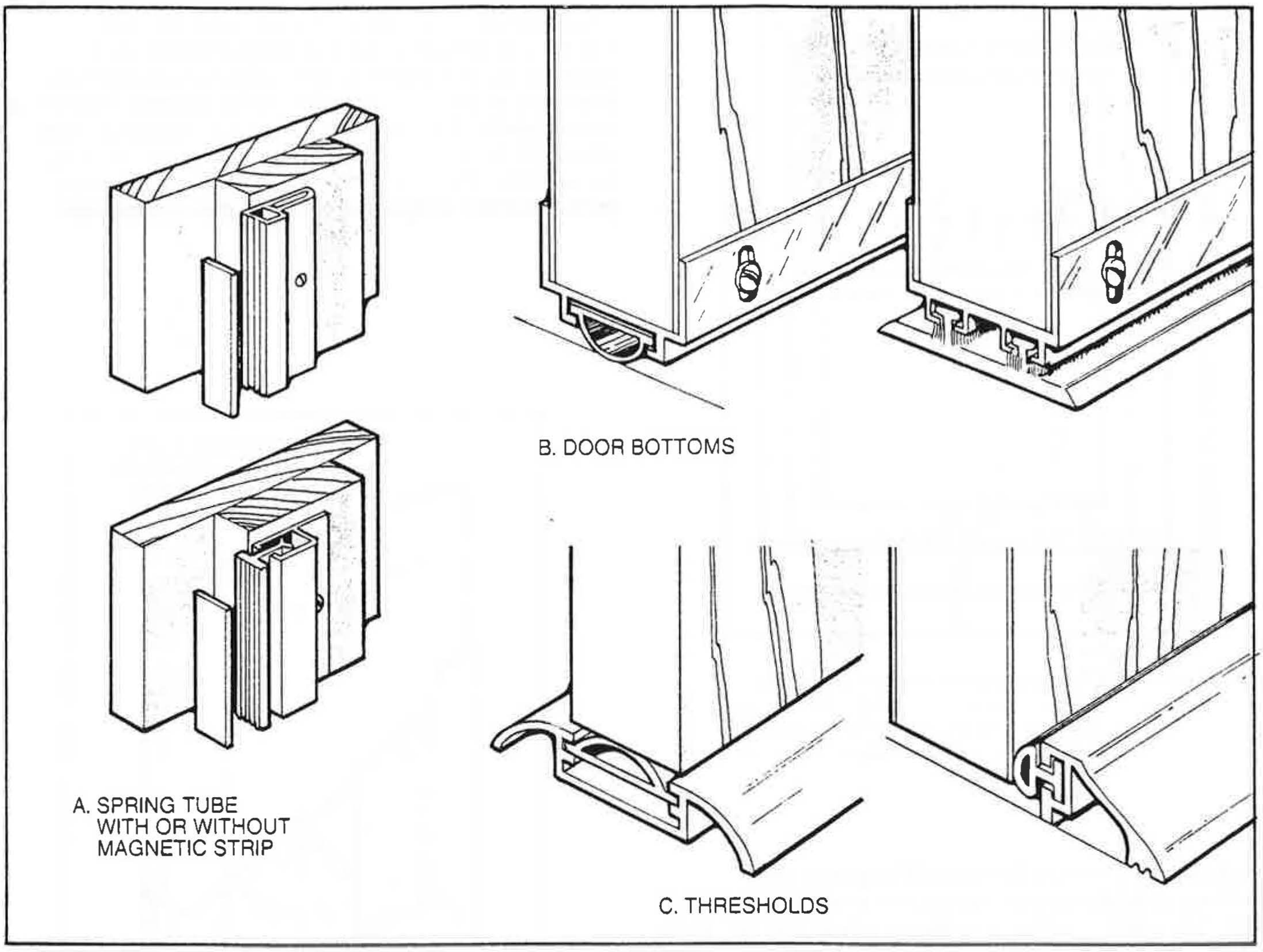

Figure 5 A variety of (A) high quality weatherstripping, (B) door-bottom sealers, and (C) thresholds are available that allow effective elimination of air leaks around exterior doors. Vinyl weatherstripping is not generally recommended because of its short life span. Consideration should be given to urethane and silicone bulbs or other high performance weatherstripping materials. Metal thresholds should be avoided unless they have a complete thermal break from inside to outside.

condensation to occur in corners, particularly where 2x4 wall construction with standard sheathing is used. Dampness in corners can result in stains, mold and mildew, and paint or wallpaper peeling. Using thick wall framing and insulation (e.g., 2x6 framing) or adding insulating foam sheathing to the interior or exterior is recommended to improve the insulation of corners. In existing houses, insulating sheathing can be added to the exterior during residing, or can be added to the inside of the wall during interior remodeling. Foam sheathing installed on the exterior (cold side) must have a permeance (susceptibility to vapor transmission) at least five times higher than the rating of the interior (warm side) vapor retarder.

Well-Insulated Bathrooms

The worst condensation problems typically occur in and near the bathroom where there is usually the highest level of humidity in the house. It is particularly important to have triple-insulated glass (or its equivalent) in bathroom windows and to have well-insulated walls and ceilings to keep surface temperatures as warm as possible, thus controlling surface condensation. In new houses, extra insulation can be easily installed in bathroom walls with furred-in framing if the floor plan design allows for extra space in tub enclosure areas. Extra insulation in the ceiling of a bathroom is also useful.

These measures not only reduce condensation but also make the bathroom warmer and more comfortable. Extra careful workmanship with vapor retarders is needed in bathrooms to control hidden condensation and keep insulation dry.

Attic or Ceiling Construction

Holes where wires, pipes, ducts, or light fixtures go through the ceiling must be sealed so humid air cannot leak through the ceiling into the insulation or attic space (see Figure 6). In addition, attic insulation must be adequate to provide warm interior surfaces and prevent condensation on ceilings. High-heel roof trusses are designed to allow sufficient space to install ceiling insulation full depth to the edge of the attic plus a roof venting space allowance (see Figure 7). Baffles to deflect the wind from entering the edge of the insulation in attics are also important (see Figure 8). For additional information, see *Ceiling Airtightness and the Role of Air Barriers and Vapor Retarders* (CD-FO-3568).

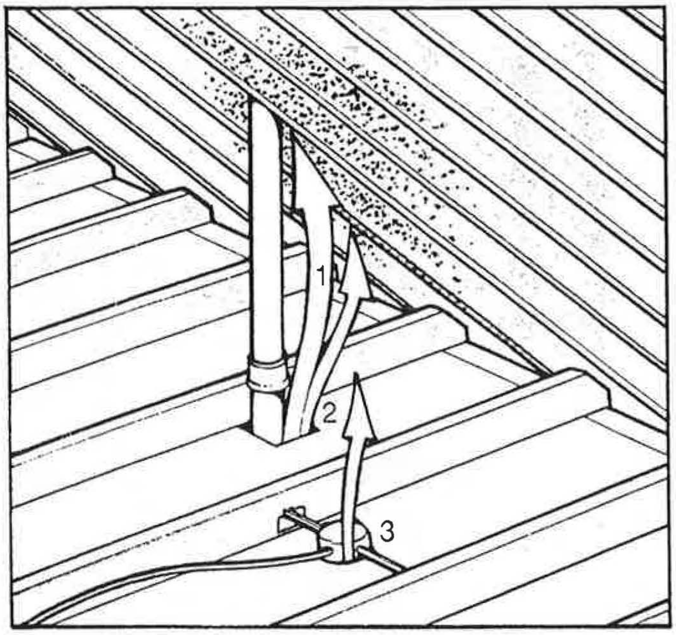

Figure 6 Holes where wires, pipes, ducts, or light fixtures go through the ceiling must be sealed so humid air cannot leak through the ceiling into the insulation or attic space.

Humidistatically Controlled Humidifiers and Fan Ventilation

In houses with tight construction, mechanical humidifiers usually are unnecessary. If humidifiers are used, however, they should be equipped with a humidistat to avoid overhumidifying.

A humidistat is a mechanical device that provides convenient, automatic management of indoor humidity. A humidistat reacts to falling indoor humidity; if the indoor air becomes too dry, it will turn on the humidifier and then shut it off when the optimal humidity level has been reached.

Ventilation systems should include a humidistat for controlling fan operation to remove excess humidity that might occasionally occur from household activity. A ventilation humidistat reacts to rising humidity; it turns on (or turns up) the ventilation system if indoor humidity becomes too high, thus removing excessively humid air and providing fresh air. Some ventilators run continuously at low speed and rely on humidistats to turn them up to high speed. If the ventilation humidistat is set at 50 percent relative humidity (RH), the humidifier humidistat must be set at 40 percent RH or lower (otherwise the humidifier-produced humidity might cause the ventilation fans to operate constantly).

To be most effective in removing humidity, ventilation exhaust fans (or exhaust registers for a central ventilation system) should be installed in the rooms that consistently contribute the highest levels of everyday household moisture, such as bathrooms, the kitchen, and the laundry room. Vents in these rooms should be carefully positioned in order to draw moisture from the entire space (see Figure 9).

Proper Venting of Fuel-Burning Equipment

The burning of fuel produces water vapor (steam). Proper venting of furnaces, water heaters, wood-burning stoves, and fireplaces is important not only for proper humidity control, but also for the maintenance of safety and health. Proper venting of fuel-burning equipment requires that the appliance area be kept at neutral air pressure with a constant supply of outside air. All exhaust fans, exhaust hoods, and exhaust appliances (such as clothes dryers or downdraft cooking ranges, furnaces, water heaters, wood stoves, and fireplaces) must be balanced with an adequate supply of outside air into the house or directly to the equipment (if it is designed for direct outside air). This is especially a problem with downdraft cooking ranges which have high airflows, but typically have not been provided any air supply. Balanced ventilation fan systems, in which supply flow equals exhaust flow, help to reduce pressure in the entire house and move it toward a more neutral plane.

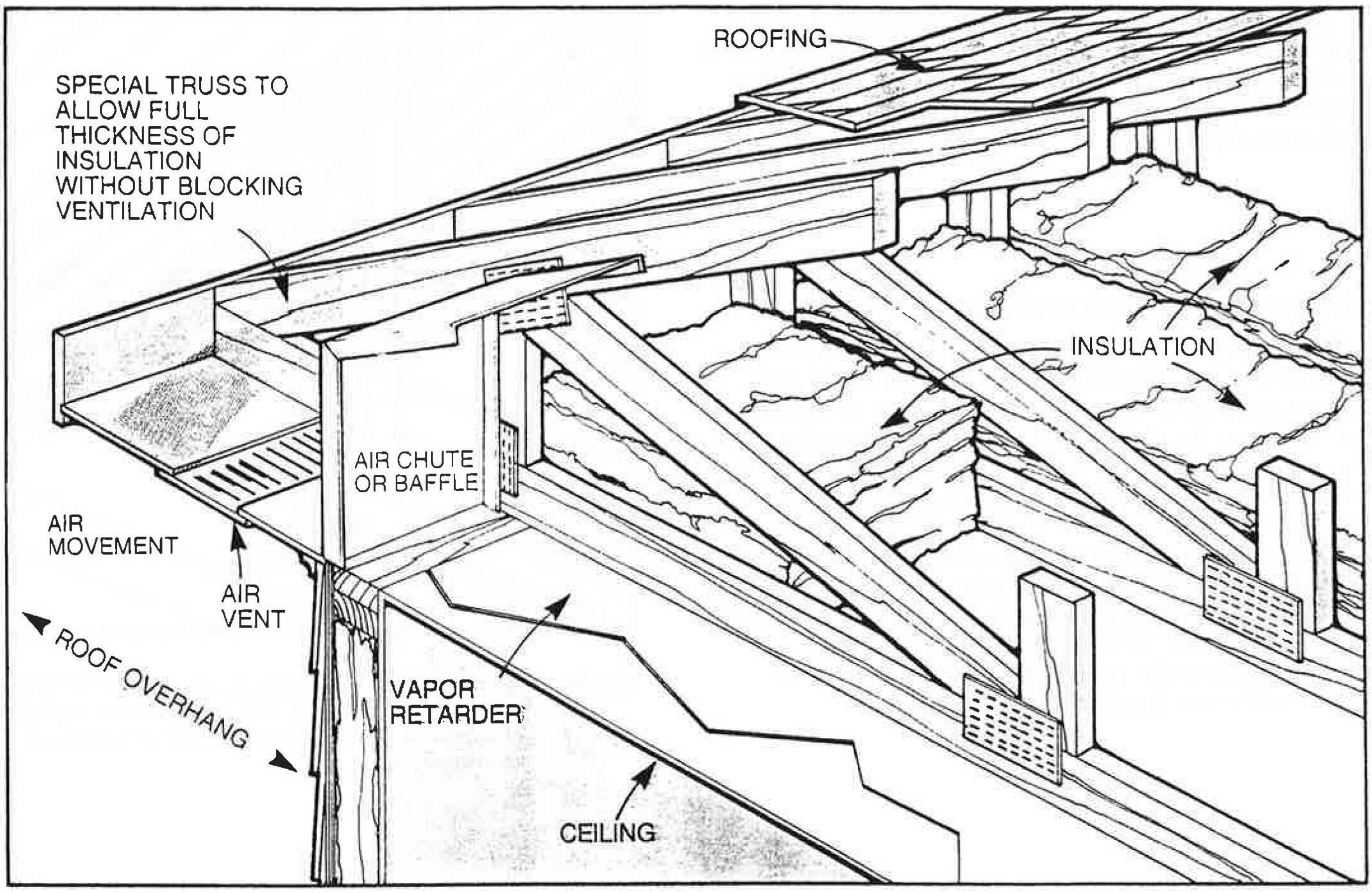

Figure 7 High-heel roof trusses combined with roof overhang allow sufficient space to install ceiling insulation full-depth to the edge of the attic and to provide adequate roof-venting space.

Consult with your local building official before installing exhaust fans and appliances or fuel-burning equipment. Improper installation can result in dangerous carbon monoxide buildup or fire. *In tightly constructed homes, controlled ventilation systems should be incorporated into the design of the structure.*

Common Questions About Vapor Retarders and Humidity

Q. Should a house be built with a few random holes to allow "breathing"?

A. No. The reason being that humidity-laden air can readily leak through such holes or areas without an air barrier/retarder, leading to the potential for wet insulation, wood rot, or other problems. It is better to protect the insulation and structure by installing a good vapor retarder to control vapor diffusion (interior side), installing an air barrier to control air leakage (with all openings sealed), and installing humidistatically-controlled ventilation fans to regulate indoor moisture. Remember, a tightly constructed house will likely need some form of controlled ventilation. Then, no harm is done when occasional excess natural moisture is generated, because it is quickly removed by the exhaust-supply ventilation system and because proper vapor retarders and air barriers protect the structure.

Q. Does a vapor retarder or an airtight air barrier result in excessive indoor humidity?

A. A house with a full coverage, airtight air barrier will retain a comfortable high indoor humidity, provided there are no gaps in the air barrier. *Such a house must have a ventilation fan system* that is set to remove humidity when it becomes too high (usually for short periods each day around mealtime and showering). Controlling air leakage is extremely important in neutralizing the effects of excessive indoor humidity in tightly constructed houses. The moisture flow (by convection) through a one cm^2

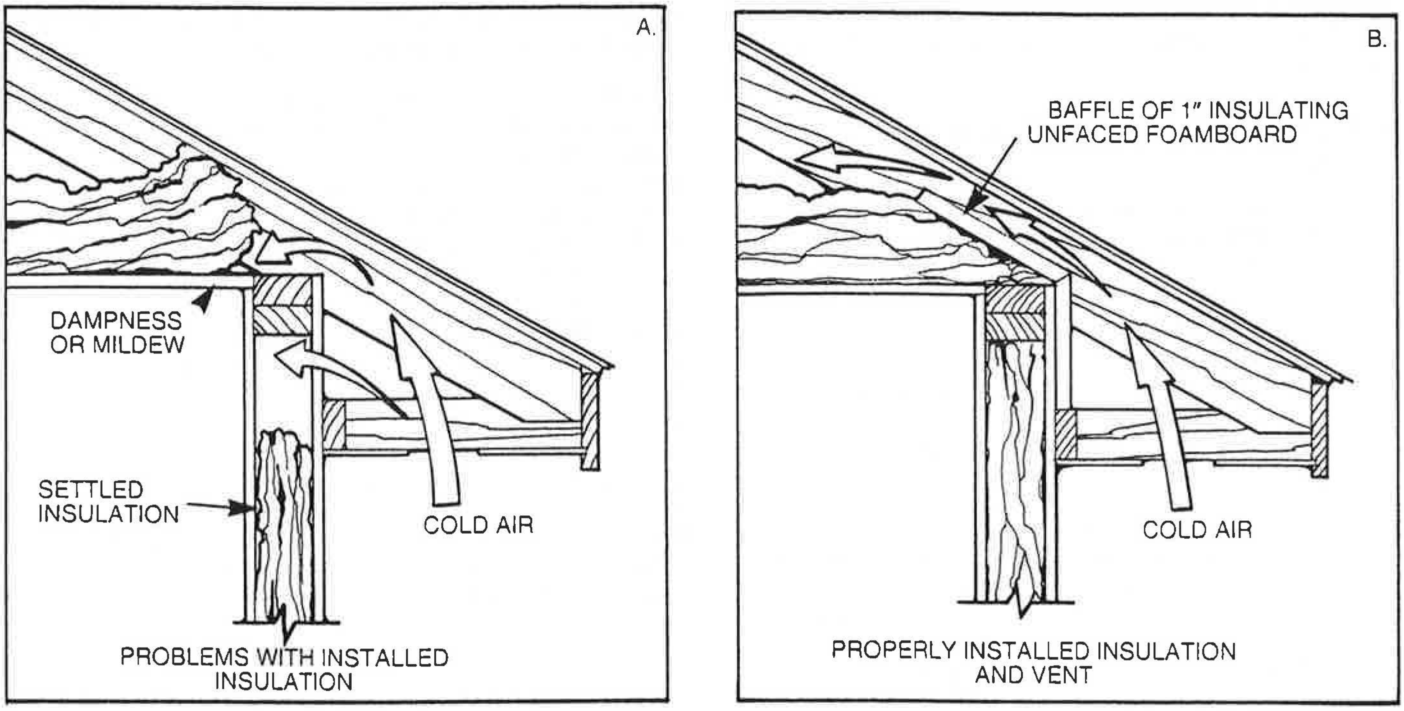

Figure 8 Wind entering the edges of ceiling insulation, combined with settling of wall insulation, can lead to dampness or mildew on interior corners (A).

The use of baffles and proper placement of insulation help to avoid such problems (B).

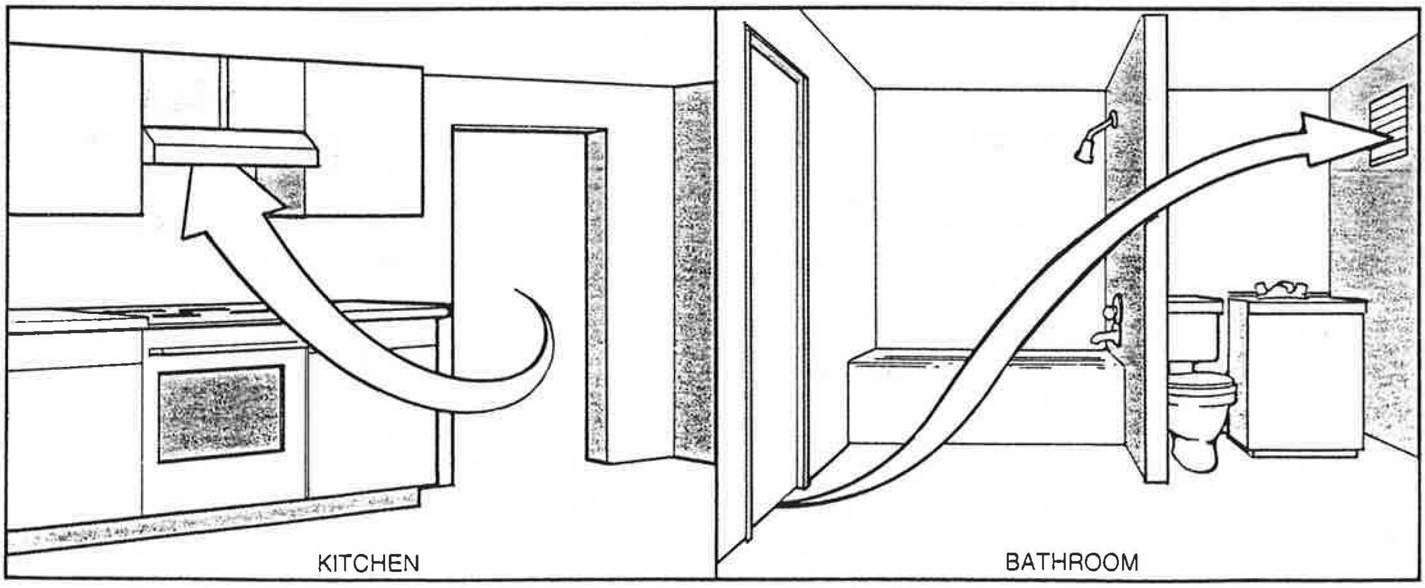

Figure 9 Ventilation exhaust fans should be installed to remove humidity from rooms that are frequent sources of household moisture.

opening is 100 times greater than the moisture movement (by diffusion) through one cm^2 of sheetrock without a vapor retarder.

Q. How can indoor moisture generation cause energy waste?

A. If indoor moisture generation is excessive (such as from a damp basement), ventilation fans will tend to run almost continuously, unnecessarily wasting energy. To be efficient, a house must be tight, and excessive interior moisture generation must be controlled.

Q. What practices lead to excessive humidity in a house?

A. High humidity is usually due to temporary sources of heavy moisture such as having too many people in the house, hanging wet laundry indoors, boiling and cooking with open pans, taking long steamy showers, and storing freshcut damp firewood indoors, etc. Excess humidity that is due to people-related activities can often be solved with changes in household habits. Damp basements can cause continuous moisture problems that can only be solved through permanent improvements in drainage and damp-proofing.

Q. What do I do if my basement is a source of moisture problems?

A. Basement moisture is often a major factor in high humidity problems and is best prevented through proper original construction. Subfloor drainage, surface drainage, and damp-proofing applied on basement walls and under the basement floor are recommended.[5] Inexpensive drainage improvements that can be added to existing houses include adding roof gutters and extending roof downspouts, and sloping the grade away from the foundation.

Q. Why do new houses have higher humidity?

A. New houses often have higher indoor humidity during the first 1-2 years after construction because of the built-in moisture of new lumber, plaster, paint, and concrete. Opening windows or extra use of ventilation fans on warm days will help to remove built-in moisture. Houses that are finished and closed up late in the fall or early winter have the worst problems with built-in moisture because there is little chance for moisture to disperse before cold weather arrives. A good ventilation system is useful in controlling moisture in a new house.

Q. Why do windows steam up at the beginning of winter?

A. High indoor humidity routinely occurs in the late fall or early winter, when houses have a great deal of stored moisture from the damp fall weather. Condensation on windows commonly occurs when the weather suddenly turns cold. This is a temporary problem that usually can be corrected by operating ventilation fans several hours every day or opening windows slightly on warm days.

Q. Why do moisture problems sometimes occur when a night-setback thermostat is used?

A. A night-setback (clock) thermostat is set to turn down the heat about the time the family goes to sleep. The furnace may not operate at all until the thermostat clock turns the heat up again in the morning. Because many houses depend on furnace operation to circulate air within the house and pull fresh air in, there may be poor circulation and inadequate fresh air intake when the furnace is off. The house air also begins to cool during the off-period, which reduces its capacity to hold moisture and increases the risk of condensation, particularly in sleeping rooms, where breathing releases moisture into noncirculating air. Adding a timer to operate the furnace fan several times every hour, or leaving the heat on during the night should solve the problem. If window condensation quickly clears in the morning after the house warms up, and if no damage is occurring to the windows, this condensation may be a trade-off that is reasonable in exchange for the energy savings of a night-setback thermostat.

Summary

Indoor humidity is beneficial at the proper level. Housing design, materials, and workmanship must meet the requirements needed to protect a house from moisture damage, as well as provide a comfortable humidity level for the occupants. Household members can help avoid moisture damage by learning to set humidistats, fan times, and clock thermostats properly and by reducing or eliminating sources of excessive indoor moisture.

Endnotes

1. For more information on controlled ventilation systems, please refer to *A Builder's Guide to Iowa's Ideal Homes.* (Iowa Department of Natural Resources 1987).
2. Special health needs might necessitate occasional higher humidity. Extra protection must be provided if a house will be subject to higher humidity. If your physician prescribes higher humidity, the cost of certain features for moisture protection may be tax-deductible.
3. At least two-thirds of the insulating value in an exterior wall must be on the outside of the vapor retarder to keep the retarder warm enough to prevent condensation on the retarder itself.
4. Vapor retarders, depending on construction techniques and materials used, may not be sufficient to contain air leakage from within the building envelope. For this reason, builders should *strongly* consider installing an air-barrier system in conjunction with a controlled-ventilation system when constructing new homes. See *A Systems Approach to Cold Climate Housing*

(CD-FO-3566) for further information on air-barrier systems. When an air-barrier/air-retarder system is used, the importance of having a tightly sealed vapor retarder is diminished. As pointed out in *A Systems Approach to Cold Climate Housing*, it is unlikely that the vapor retarder, even when carefully installed, can serve the purpose of an air barrier.

5. Tight sealing and waterproofing of basements and certain types of subfloor drainage systems are also beneficial in reducing the entry of soil gas, which may contain radon.

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