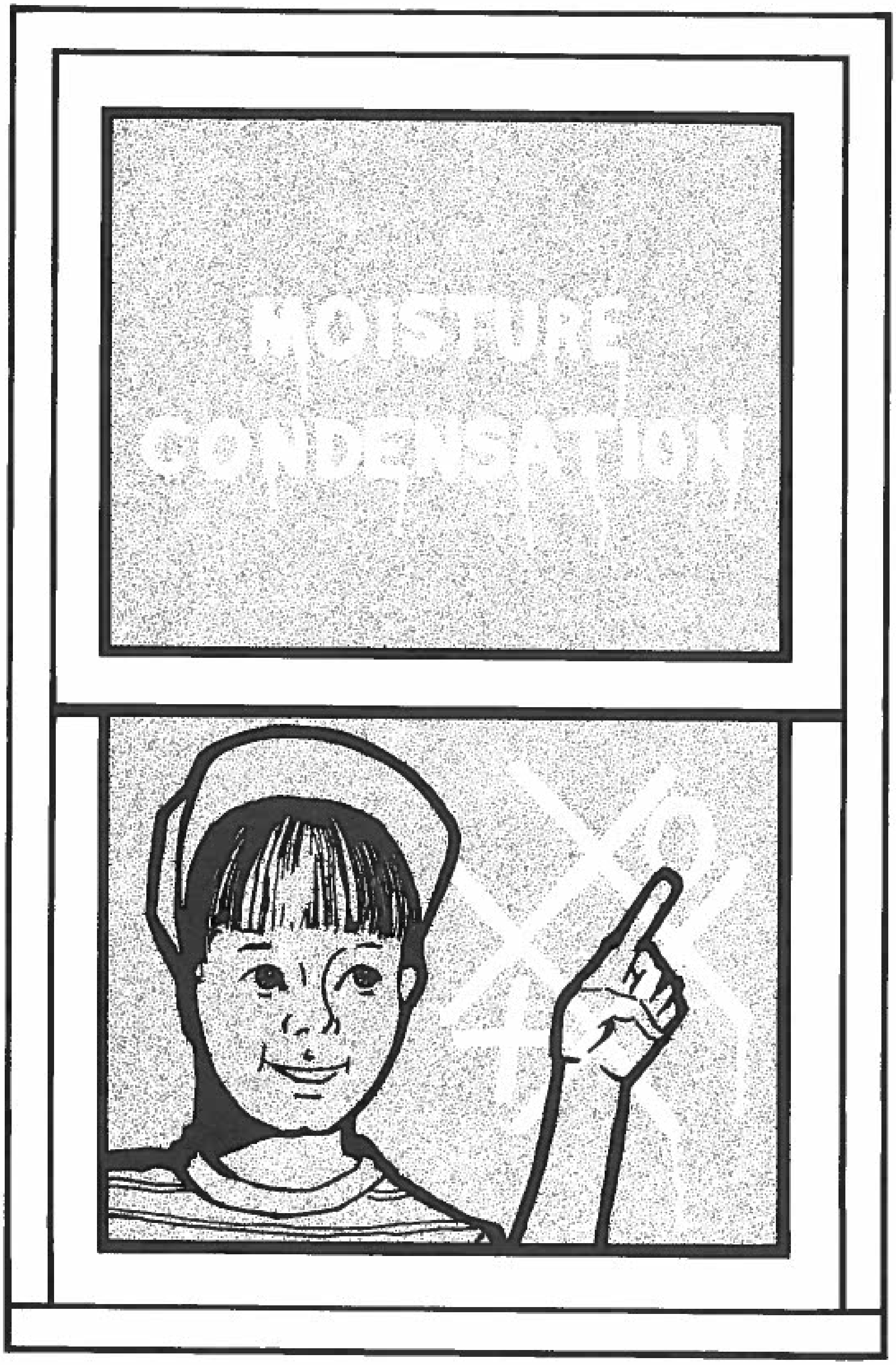
University of Illinois at Urbana-Champaign
Small Homes Council-Building Research Council

COUNCIL NOTES



INTRODUCTION

Where there is insufficient moisture in the air, the occupants of a home may suffer from drying out of the nasal passages, increased susceptibility to respiratory infections and the general discomfort of excessive static electricity in carpets and clothing, and shrinkage of wooden items such as furniture, resulting in broken or weakened glued joints. If the air is too dry, moisture can be added by using humidifiers or vaporizers.

Where there is excessive moisture in the air, the problem is far more complex — but it can be solved. Excessive humidity can cause a number of undesirable conditions — some obvious to the observers but others not always evident or visible. Evidence of excessive moisture may present itself as:

- Damp spots on ceilings or warm-side surface of exterior walls.
- Water, frost, or ice on the room surface of double glass windows.
- Moisture on basement walls and floors.
- Paint blistering and peeling.
- Ice and frost on the underside of roof sheathing boards.
- Fungus, mold, and mildew growth.
- Delamination of plywood materials.

It is sometimes difficult to tell the difference between problems caused by leaks and problems caused by moisture condensation. For example, the damp spot on the ceiling may be either. Careful observation of the time of the problem will help find the cause. Moisture condensation problems occur largely in the cold season; leaks occur following periods of rain and blowing snow.

This circular will describe the causes of excessive moisture, how condensation occurs, and some of the methods that can be used to control excessive moisture in the cold climates.

Air and Moisture

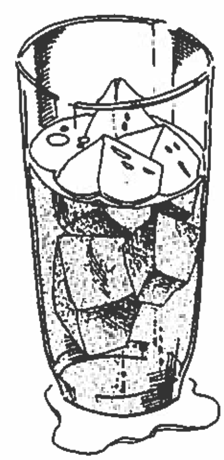
The air we breathe is really a mixture of two invisible gases — dry air and water vapor. Each of these elements may act independently, but they also act together.

For example, the amount of water vapor that can be contained in a given volume of dry air depends upon the temperature of that air; the warmer the air, the more water the air can hold. Consider a room with a volume of a thousand cubic feet (10' x 12.5' x 8'). With the air at a temperature of 75°F, the room can contain as much as 1.4 pints of water (in vapor form), but if the air is at 45°F, it can hold less than a half-pint of water.

The moisture content of air is generally given in terms of *relative humidity*. As an example, 50% relative humidity means that the air is holding half the amount of water vapor that it could hold. Unfortunately, this method of indicating moisture content in the air is misleading, because it does not give a true picture as to the actual amount of water in the air. For example, air at 30°F with a relative humidity of 80% contains about half as much moisture as air at 70°F and 35% relative humidity. This is because, as mentioned above, warm air can hold more moisture than cold air. It also shows how bringing in cold outside air will reduce a moisture problem — the outside air is usually much dryer in terms of actual moisture than indoor air, and mixing it with the moist room air will lower the relative humidity in the room.

At 100% relative humidity the air contains all the moisture that it can hold, and is said to be *saturated*. The dew point temperature of a moist air mixture is the temperature at which saturation is reached and condensation first begins to appear.

Condensation occurs when moist air touches a surface that is colder than the dew point of the air. If the cold surface is below freezing, the condensation will appear as frost. A common example of condensation is the water or frost which appears on windows in cold weather. Winter condensation and moisture problems are most likely to occur in climates where the average January temperature is 35°F or colder. Where average winter temperatures stay above 35° or 40°F, condensation does not seem to be a problem.



A

A common example of moisture condensation is the glass of ice water that "sweats."

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REDUCING MOISTURE AT THE SOURCE

To avoid moisture condensation problems it is necessary to limit the amount of water vapor in the house. One way to do this is to *control the water vapor at its source*. There are many sources of moisture in the house. Mopping the floor in a 150-square-foot kitchen can release 4½ pints of water; a shower bath about ½ pint; washing the dinner dishes about ½ pint; and a family of four gives off about ½ pint of water per hour by just breathing. It takes only 4 to 6 pints of water to raise the relative humidity of a 1000-square-foot house from 15% to 60%.

As moisture is released in a house, it moves to all rooms by natural air movement and by the vapor pressure of the moisture. This is not an instantaneous movement like air rushing out of a balloon, but is a definite movement from the area of high vapor pressure (bath, kitchen, laundry) to other areas where the air is dryer.

One rule of thumb which can be used to tell the allowable relative humidity is this: When water or frost appears on the inside surface of the inside pane of glass of living room or bedroom windows that have storm sash or insulating glass the relative humidity is too high.

The following are some of the most critical moisture sources, along with ways of controlling them:

Poor Site Conditions

- Grade the lot correctly for good drainage.
- Use wide overhangs and/or gutters and downspouts to divert rain water away from the foundation.

Uncovered Ground in Crawl Space

- Lay a vapor-resistant ground cover, such as 4- or 6-mil polyethylene film, on the ground in the crawl space to stop the rise of water vapor from the ground. Provide foundation vents to let the moisture escape from the crawl space.

Concrete Floor Slabs (at or below grade)

- Install a 4-inch base course of washed gravel or crushed rock under the slab.
- Place a vapor barrier such as 6-mil polyethylene film between the base course and the slab.
- Seal under-slab ductwork to keep water and water vapor out.
- Provide drainage under concrete floors where ground water is likely to be a problem. Local architects and builders should know if there are problems. *(See Circular F2.0,* Basements.*)*

Clothes Dryers

- Vent clothes dryers to the outside.

Kitchens, Laundries, and Baths

- Provide exhaust fan with manual switch, time delay switch, or switch controlled by a humidistat. (Bathroom fans are sometimes connected to the light switch.)

Humidifiers

- Turn off the humidifier if there is any sign of a moisture problem.

REDUCING MOISTURE BY VENTILATION

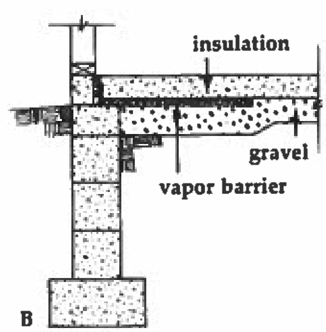
A second major way to reduce the moisture content of the air is to dilute the moist room air with drier air. In the winter, outside air, which normally holds less actual moisture than room air, can be brought into the house. Exhaust fans cause some infiltration of outside air, but it is better to have a controlled source of ventilation air than to depend upon air coming through cracks around doors and windows or from opened windows. Preferably, the amount of air brought in should be controlled, and the air should be heated and properly distributed.

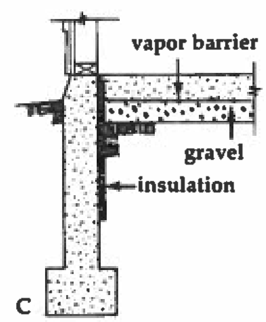
Many people object to the noise produced by exhaust fans. This problem can be reduced by using larger fans operated at the lowest speed or, better yet, by installing remote outside fans with ducts to the spaces to be ventilated.

VISIBLE SURFACE CONDENSATION

Condensation occurring on surfaces is easy to see. Besides water or frost on windows, other examples that are often seen in the winter are: condensation on metal that extends outdoors (such as uninsulated metal doors and window frames), and condensation on cool walls and floors. In summer, condensation occurs on cold water pipes, on cooling ducts, and on basement walls and floors.

Assuming the room moisture content has been controlled, surface condensation can be avoided by raising the temperature of the surface.





Raising Surface Temperatures: by Heating

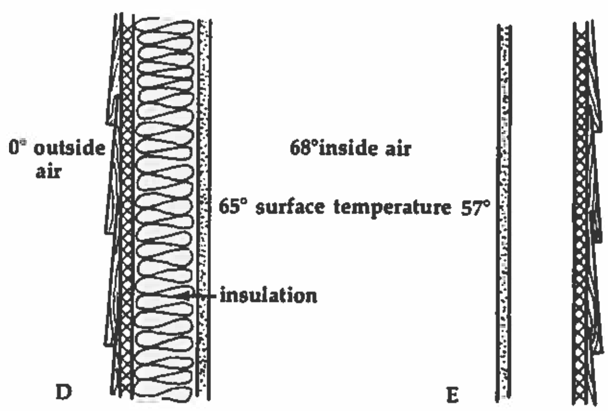
Surface temperatures can be raised by installing properly designed heating systems. For example, heat delivered to the room under windows and at the bottom of outside walls warms these surfaces and reduces condensation. Baseboard and floor registers of modern warm air systems and baseboard radiation used with hot water or electric systems not only improve comfort but also help reduce moisture condensation problems.

By Insulating

The temperature of the various surfaces in the house can be raised by the proper use of insulation.

Glass. In the average home, moisture condensation appears first on glass in windows and doors, because these are usually the coolest surfaces in the building. Except in unusual circumstances, the use of two layers of glass separated by an air space, such as storm windows, storm panels, or insulating glass, will solve the moisture condensation problem.

Walls. The effect of insulation on the surface temperature of a frame wall is shown below. Masonry walls also require insulation to avoid surface condensation.



Ceilings also must be insulated to avoid condensation problems as well as to reduce heat loss from the house.

Concrete floor slabs which are exposed to the outdoors at the edge are especially susceptible to moisture condensation. In colder climates, all such slabs should have edge insulation.

Pipes and ducts. Moisture frequently condenses on cold water pipes, cold air ducts, and refrigerant lines, particularly in late spring and summer. To avoid condensation drip, pipes and ducts should be covered with insulation that has a vapor barrier on the outside, and the joints between sections of insulation must be sealed with barrier tape.

CONDENSATION WITHIN THE STRUCTURE

It is hard to tell if there is moisture condensation inside **walls.** One of the most frequent signs is peeling of the exterior paint (See box on page 7). Sometimes the condensed moisture will soak siding materials and cause a stain. The wall can be opened for inspection. If damp wood or insulation, ice, or mold are found, moisture condensation is the most likely cause, although water leakage could also be responsible.

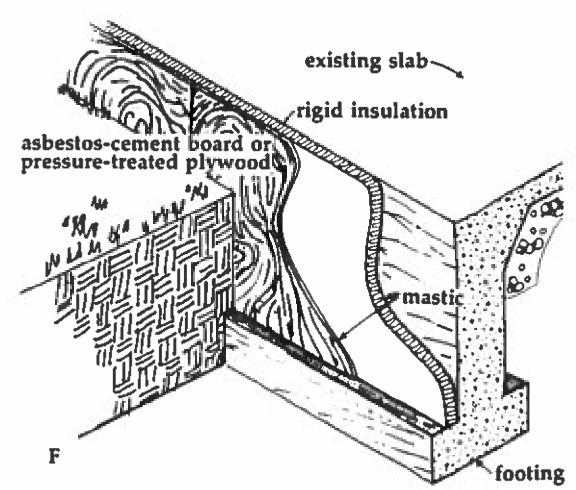
Condensation problems in **roofs and ceilings** are also difficult to find without inspecting the attic and roof spaces. Signs that can be seen include paint peeling on the gable ends and soffits of overhangs, curled asphalt shingles, and damp spots on ceilings. Inspection of the attic and roof structure may reveal damp insulation, mold or mildew on roof sheathing, and other indications of deteriorating materials.

How Moisture Condenses within the Structure

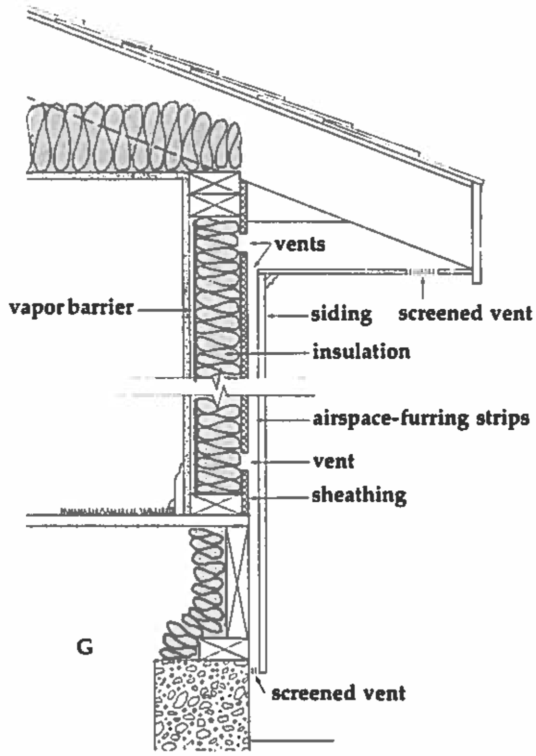
The basic cause of moisture condensation within the structure is the same as for surface condensation — warm moist air strikes a cool surface and condensation occurs on that surface. The difference is that because the cool surface is located inside the structural parts of the house the condensation is hidden.

Eliminating Condensation within the Structure

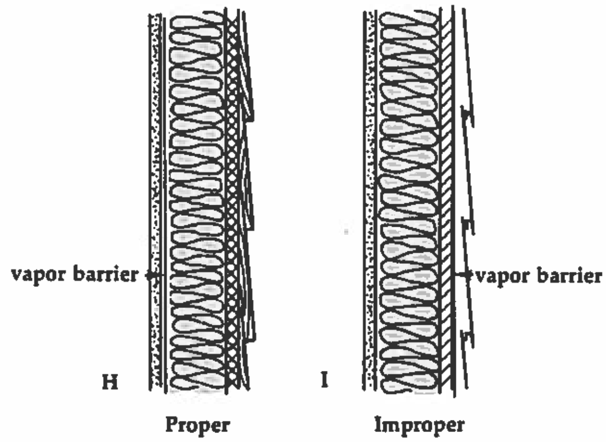
The first step in eliminating moisture condensation is to keep water vapor from entering the structure of the building. If moisture vapor could be completely excluded from the structural spaces, condensation could not occur.



If a concrete slab is not properly insulated during construction, as shown in illustrations B and C, insulation can be added to the slab edge outside the foundation.



Ideal cold side venting



In modern construction, **vapor barriers*** are installed near the warm surface of the wall, ceiling, or floor to reduce the movement of the moisture. However, since it is impossible to keep all water vapor out, a second line of defense must be established.

Once vapor has entered a space within the wall or roof, it is important to allow a means for it to escape. This is done by providing **cold-side venting** or ventilation for the space.

To avoid moisture condensation, the ideal structure (using a wall as an example) is illustrated above.

In general, poorer vapor barriers require more positive provisions for cold-side venting. One rule that is often applied is that the exterior skin should be 4 to 5 times as vapor porous as the interior skin.

VAPOR BARRIERS

Vapor barriers should be used wherever the average January temperature is 35°F or colder (north of the Ohio River). If there are exceptionally high indoor humidities, however, vapor barriers should be used wherever any cold weather occurs.

Membranes. The several types of vapor-resistant membranes are:

- Polyethylene film
- Aluminum or other metal foil (usually paper-backed)
- "Duplex" (or laminated) papers, consisting of a continuous sheet of asphalt between two sheets of paper
- Surface-coated and glazed asphalt-saturated building paper. (Ordinary asphalt-saturated roofing felt and building papers are not good vapor barriers.)

Membranes may be attached to the back of the plaster base or drywall (as in the case of aluminum foil on the back of wall board); aluminum foil or duplex paper barriers are often attached to the face of blanket or batt insulation; and polyethylene film is often used to cover the entire insulated wall, and is attached to the face of the studs. In remodeling work, a membrane is sometimes applied to the existing wall surface and then a new interior wall finish installed over it.

To be effective, a membrane must be continuous and unbroken to prevent passage of moisture around the barrier. All joints must be lapped and securely fastened on studs, joists, or bracing.

In applving vapor barriers, don't overlook the space under the attic stairs, openings around ceiling light fixtures, openings in either exterior or interior walls which connect the attic space with the basement, or openings from stud spaces of interior partitions to the attic.

Vapor Barriers in Floors

If insulation is installed in a floor over an open crawl space, a vapor barrier should be installed above the insulation or between the subfloor and finish floor. If the crawl space is insulated and heated, the barrier should cover the entire ground surface.

* The term *vapor barrier* is commonly used to indicate materials that have a permeance of less than one perm. Most of these materials do permit the passage of small amounts of moisture; therefore, the term "barrier" is not totally accurate.

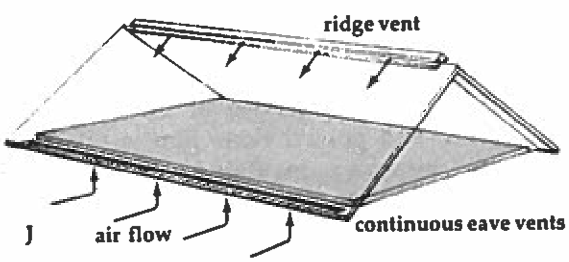
REDUCING MOISTURE CONDENSATION BY COLD-SIDE VENTING

Since vapor barriers cannot be installed so that moisture penetration is completely stopped, it is advisable to take added precautions by venting the cavities in structural elements. Basically, the idea of cold-side venting is to relieve the vapor pressure in the cavity by providing a vent to the outside air, which usually has a lower vapor pressure. All vents to the outside air must be screened to prevent insects from entering structural spaces.

Cold-side Venting of Attics

Attic ventilation is essential. The specifications of the Federal Housing Administration recommend that, if a vapor barrier has been installed in the ceiling, the free area* of the attic ventilators be equivalent to 1 square foot for each 300 square feet of attic area.

Best results are obtained when the ventilation area is uniformly distributed along the roof and is equally divided between high and low. The combination of continuous slots in the overhangs and a ridge vent gives the best overall distribution of air flow. The high-low location of the vents takes maximum advantage of thermal convection to move the air through the attic.



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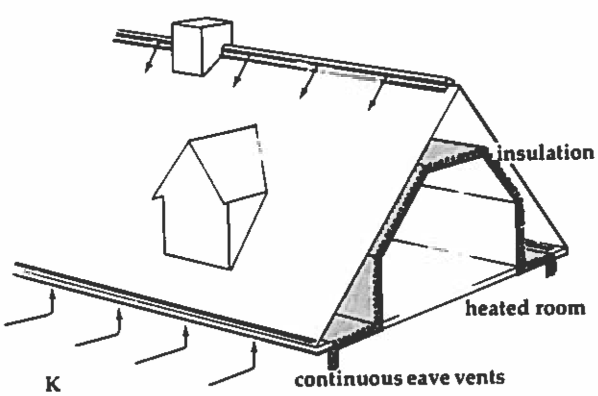
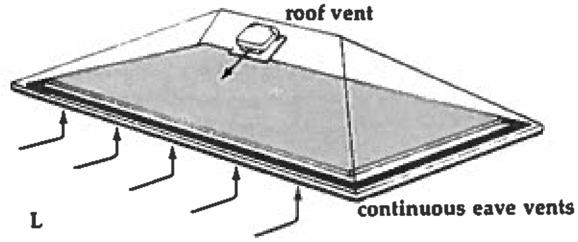


K

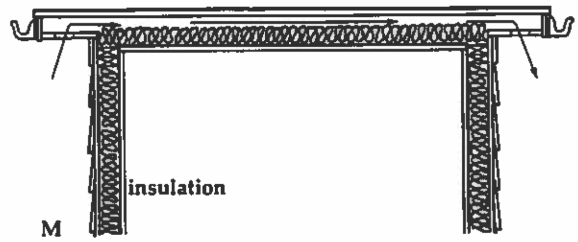
Continuous ridge and eave vents

* To obtain the required free area when the ventilation area is covered with 16-mesh screen, the area must be doubled; when covered by both louvers and 16-mesh screen, the area must be tripled.



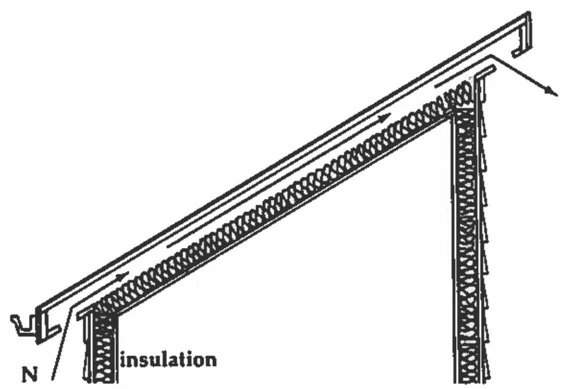
L

Roof ventilator(s) in hip roof — should be at high point



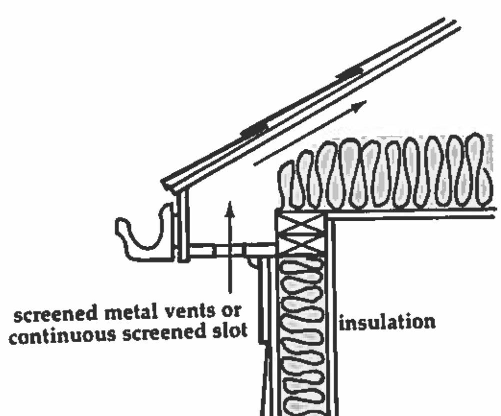
M

Eave vents should be used on flat roofs, although a center vent or mechanical ventilation may be necessary



N

Sloped ceiling requires ventilation space above insulation



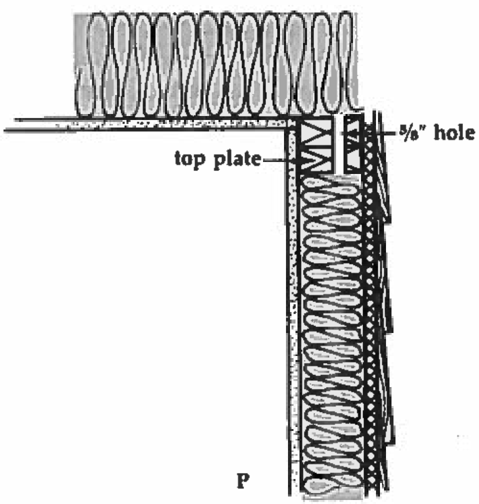
O

Typical eave vent

Cold-side Venting of Walls

There are a number of methods to vent frame walls. As a guide, each stud space should have vents totalling one square inch of free area.

Vents in top plate. In one-story construction, holes may be drilled in the top plate to vent the wall cavities to the attic. Use three 5/8" diameter holes per stud space. Experience has shown that this precaution is likely to eliminate any vapor problem which might result from any "leak" in the vapor barrier, but the addition of a vent at the bottom of each stud space would improve the ventilation. (See illustration P.)

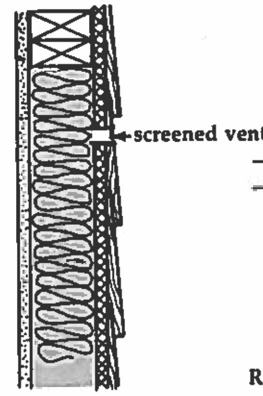


P

Vents in siding and sheathing. Vents may be installed by drilling holes through the siding and sheathing into each wall cavity. (See illustration Q.) Small louvers are used to keep out rain and insects. It is best to provide a vent at both top and bottom of the cavity so that the vapor movement is aided by natural convection.

If the cavity of the wall is filled with insulation, the vapor release is reduced somewhat, but it is usually adequate to solve the problem.

If the siding has been saturated due to moisture condensation, it may be necessary to wedge it away from the sheathing in a number of places to permit enough air flow to dry the siding.



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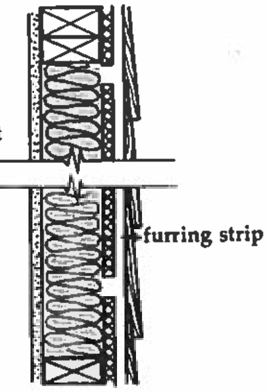


R

Venting by furred siding. In cases where the vapor problem is expected to be severe due to very tight siding materials, it is desirable to build the wall so as to have a vented space immediately inside the exterior cladding material. (This system has the added advantage of reducing the sun load on the walls.) Drill holes in the sheathing to vent the wall cavity. (See illustration R.)

Crawl-Space Ventilation

Crawl spaces should be vented to permit water vapor to escape. If a ground cover is used, one 8" x 16" vent for each 350 square feet is needed, with a minimum of four vents. See *Circular F4.4, Crawl Space Houses.* Foundation wall ventilators are not required for a basementless space one side of which, exclusive of structural supports, is completely open to a basement, except that basementless spaces having a greater area than the basement shall be separately ventilated.

In most instances, ground covers such as polyethylene have proven so effective that the vents may be closed during the winter.

PAINT PEELING

Paint peeling and/or blistering may result from condensation of moisture within the house. Characteristically, the blisters will contain water and the paint peels down to bare wood. (Poor paint, faulty application of paint, and exterior moisture also cause paint troubles, but they are not within the scope of this circular.)

Typically, the moisture in the room penetrates the walls until it reaches the underside of the exterior paint. The building materials through which the water vapor has passed are porous; the paint is not. As a result, the moisture gathers underneath the paint, forms blisters, and eventually the paint peels away from the wood. A membrane vapor barrier eliminates such difficulties by preventing the moisture from entering the walls.

Sometimes this situation can be cured by cold-side venting. Venting each stud space, preferably at the top and the bottom, permits the moisture to escape before it condenses.

This problem sometimes first occurs after an older house has been newly insulated. A combination of factors contributes to the problem — the addition of insulation reduces the amount of leakage through the walls, and usually there is no vapor barrier in older houses.

Whenever possible, a vapor barrier should be installed when an older house is insulated. Absence of a vapor barrier, however, does not always result in a condensation problem; sometimes the moisture levels in the house are so low that no problem arises.

PROBLEMS:

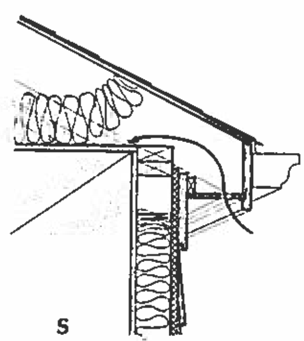
IN THE ATTIC

Evidence: Water, frost or mold on underside of roof; water or frost on nails, soil pipes, etc.
Cause: Too much moisture in the attic which is condensing on the cold surfaces.
Cures: Install vapor barrier in ceiling; increase attic ventilation and improve its distribution. Check all moisture sources.

FIRST FLOOR

Evidence: Moisture or dampness on ceilings at edges near outside walls.
Cause: Ceiling insulation not properly installed at outside wall (it should extend over the wall plate and be fastened down to it). Wind blows under insulation and chills outer part of ceiling. See sketch.
Cure: Reposition insulation.

Evidence: Dampness or moisture at top of exterior walls.
Cause: Insulation in wall may have settled, leaving the upper portion uninsulated.
Cure: Correct insulation.



S

Evidence: Moisture around or dripping from light fixtures, heating-cooling outlets.
Cause: Outlets are usually metal and they may become cold. Condensation is formed when the moist room air strikes the cold surface.
Cure: Make sure insulation covers ducts, etc; avoid recessed lighting fixtures, close cooling ducts during winter.

Evidence: Dampness or moisture in exterior wall corners.
Cause: Insulation is frequently omitted in the corner construction.
Cure: Add insulation when possible, but this is not usually feasible. Check moisture sources.

Evidence: Paint is blistering and peeling; blisters contain water.
Cause: Lack of a vapor barrier has permitted moisture vapor to push its way into wall where it has condensed on one of the outer layers of the construction. Eventually this excessive moisture pushes its way to the exterior surface and damages the paint surface.
Cure: Check sources. Install vapor barrier and/or screened vents through the siding at both top and bottom of each stud space. Use a porous exterior finish, such as a heavily pigmented stain.

WINDOWS

Evidence: Moisture, frost, or ice on window glass, or on metal frames and sash; paint peeling and decay on wood members.
Cause: Single glazing is usually inadequate in moderate climates, glass becomes too cold in winter, condensation runs into sash or frame.
Cure: Use double glazing, that is install storm windows or insulating glass. A heating outlet under the window will often help.
Comment: Double glazing alone is not likely to be effective in bathrooms, kitchens, and laundry areas because of the excessive moisture generated in these spaces. Ventilation is mandatory.

Evidence: Moisture condensation on the inside surface of a storm window.
Cause: Interior window is less tight than the storm window. As a result moisture leaks by the main window and comes in contact with cold glass of the storm window.
Cure: Loosen the storm sash slightly or provide vapor vents by two 3/8" diameter holes top and bottom; or seal interior window more tightly.

FLOOR

Evidence: Moisture or frost on the edge of a concrete floor slab.
Cause: Slab edge and foundation are not properly insulated, slab loses heat to outside and becomes cold.
Cure: Slab may be insulated by placing insulation on the outside (See illustration F). Sometimes condensation may be eliminated by installing heating elements near the outside wall, but this does not solve the basic problem.

BASEMENT

Evidence: Dampness and moisture on walls, floors, pipes, etc. during spring and summer.
Cause: Walls and slabs are cold after winter; warm moist air of spring and early summer strikes the cold surfaces and condenses.
Cure: Do *not* bring in outside air. Outside air is usually very moist at this time of the year and the problem will be increased if such air is brought into the house. Insulate the walls and pipes, increase air circulation within the house and use a dehumidfier.