



CONDENSATION CAUSES AND CONTROL

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Whenever moist air comes into contact with a cooler surface, condensation is likely to occur. The cool surface may be the underside of roof sheathing or the inside of wall sheathing in winter, or the underside of a subfloor in summer when the building is air conditioned.

The only requirements for condensation are moist air and a cool surface. In the winter, the moisture content of the indoor air (usually measured as relative humidity or vapor pressure) is important, as is the temperature of the surface on which this moisture could condense. The amount of moisture in the air outdoors is also sometimes a factor.

Condensation can be controlled three ways: (1) reduce the amount of moisture initially in the air; (2) prevent the moisture from reaching a cold surface by introducing a vapor retarder and sealing penetrations; or (3) carry the moist air away by ventilation.

CONDENSATION EXPLAINED

Water stays in the air as vapor as long as the temperature of the air and the amount of water are such that the air can hold it. The amount of water in the air, relative to the amount which the air can hold, is called "relative humidity." Warm air can hold more water vapor than cold air.

Thus, as air with a given amount of water vapor in it is cooled, the relative humidity will rise until a temperature known as the "dew point" is reached. At this point relative humidity becomes 100%, and some of the moisture will condense as "dew." If moist air contacts a surface at or below its dew-point temperature, condensation will occur on that surface.

Water vapor in the air produces "vapor pressure," which is a measure of moisture concentration. Air with high vapor pressure tries to escape to or seek equilibrium with air of lower vapor pressure. The vapor can escape either with a flow of air through cracks or openings in the building shell, or without it by direct penetration of building materials.

"Vapor permeance" is a measure of the ease with which vapor can penetrate solid building materials. Materials with low permeance (typically 1 perm or less) are rated as "vapor barriers" or, more properly, "vapor retarders."

Changes in construction due to energy-saving features have tended to increase moisture levels within today's homes. Washers, dryers, cooking, showers, indoor steam rooms and swimming pools are sources of water vapor within houses. In older houses, air infiltration around doors and windows, and often directly through cracks in the walls, more or less automatically eliminated condensation. With the tighter, energy-efficient houses being built today, control of condensation must be planned.

CONDENSATION CONTROL

The first step in the control of condensation involves reducing excess moisture inside the home. Vent clothes dryers to the outside and **not** to the attic or crawl space.

Install range hoods over cooking stoves, and operate them when any appreciable amount of steam is being generated. Install exhaust fans in bathrooms and vent them to the outside and **not** to the attic (consider wiring the fan so that it goes on automatically with the bathroom light).

Methods of moisture control vary with location in the house. For attics and enclosed cathedral ceilings, the simplest form of control involves ventilation. A ceiling vapor retarder is recommended in conjunction with ventilation for cathedral ceilings. With today's ever-increasing amounts of insulation and "tighter" construction, a ceiling vapor retarder may not be as necessary for attics when adequate ventilation is provided. Its omission would allow vapor to more easily travel through the ceiling and out through the attic vents. It is important, however, to seal or avoid penetrations for electrical ceiling fixtures, which can allow mass movement of moist air into the roof cavity or attic.

For walls, ventilation is impractical, and condensation controls will generally take the form of vapor retarders and adequate sealing or avoidance of penetrations. Vapor retarders in walls, and at other locations, should always be on or nearest the winter warm side in order to block vapor before it reaches a portion of the construction with a temperature below the dew point. (In hot, humid climates, a wall vapor retarder is sometimes omitted. Check local practice in these areas.) If vapor is allowed to penetrate a wall, and temperature reaches the dew point within the wall, the vapor may condense and cause trouble.

Wood floors are seldom so cool as to cause surface condensation of vapor from within the house. Structural panel floors bonded with exterior adhesives have sufficiently low vapor permeance (1 perm or less) to prevent excessive indoor moisture from escaping into the crawl space, when penetrations or openings are adequately sealed. This is particularly important when insulation is applied to the underfloor area.

Use a vapor-retarder ground cover to prevent introduction of moisture from the ground beneath the house to the crawl space or interior. This is easy in crawl-space houses, where a layer of 6-mil polyethylene over the ground in the crawl space is usually all that is required. It is more difficult in basement houses, where vapor retarders should be installed under basement floors and outside foundation walls. The ground should be sloped away from the foundations of all houses.

Condensation in the crawl space is unlikely in winter when a ground cover is used and adequate drainage is provided around the foundation to prevent moisture accumulation. Thus, foundation vents may be closed during the winter for energy savings. Closure of vents in winter for energy saving is particularly effective when foundation walls, rather than the underside of floors, are insulated. This technique is also more effective than floor insulation for preventing summer condensation, particularly when the building is air-conditioned.

In modern basement houses, ventilation is usually inherent with forced-air heating systems. Ventilation and air movement should be given separate consideration when heating systems are used that do not provide air circulation, such as baseboard heaters.

VENTILATION REQUIREMENTS

Minimum ventilation requirements are usually covered in building codes. The requirements in Table 1 are based on the ICC International Residential Code and International Building Code, and may be used as a guide for residential construction.

The required net free area of vents can be found by multiplying the value in the third column of the table by the appropriate floor or attic area of the building. Note that these are minimum code requirements, which have been found to be adequate under most normal residential circumstances. However, ventilation in excess of these minimums may be necessary when unplanned moisture is introduced by venting an appliance, such as a clothes dryer, into the space (which is not recommended), or by misdirected surface or rainwater. Care should also be taken to provide adequate extra attic vent area when moisture-laden air is introduced to the attic by “whole-house” fans. In such cases, attic vent area should be increased in accordance with the manufacturer’s recommendations. Attic ventilation strategy should also consider location of vents to minimize dead air spaces.

Ventilation in excess of minimums may be necessary in high occupancy structures or in structures that contain moisture-producing activities, such as commercial kitchens or laundry facilities. It is traditionally the responsibility of the building design professional to determine the amount and location of ventilation to assure satisfactory performance.

TABLE 1

**MINIMUM VENTILATION REQUIREMENTS –
BASED ON ICC INTERNATIONAL RESIDENTIAL CODE AND INTERNATIONAL BUILDING CODE**

Location	Construction	Natural ventilation ^(a) net free area opening as proportion of floor or attic area
Attic and structural spaces ^(b)	No vapor retarder	1/150
	Vapor retarder in ceiling	1/300
	At least 50% and not more than 80% of required vent area in upper portion of space to be ventilated at least 3 feet above eave or cornice vents ^(c)	1/300
Crawl space ^(d)	No vapor retarder and one vent opening within three feet of each corner	1/150
	Vapor-retarder ground cover and one vent opening within three feet of each corner	1/1500

- (a) Note that where power attic vents are used, they should provide at least 0.7 cfm per square foot of attic area (15% more for dark roofs), and air intake of one square foot of free opening should be provided for each 300 cfm of fan capacity. Although intended to exhaust warm summer air, power vents should also operate during cold months to help prevent condensation.
- (b) There are some instances where unvented conditioned attic assemblies are permitted by the code. The requirements for such an assembly are highly dependent upon the regional climatic zone. See the ICC International Residential Code for additional information.
- (c) Certainly the code provision should not be interpreted to violate a reasonable balance between low and high vents. (For natural ventilation systems, some experts recommend that 60% of net free area should be provided at eaves and 40% at the ridge or high gables. To meet the code provision for minimum 50% high vents, this would require that the free opening of high vents total 1/600 and low vents total 1/400 of attic area, for an overall ratio of 1/240.)
- (d) Ventilation openings are not required for crawl spaces when a vapor retarder is used in conjunction with insulated perimeter walls. In addition, one of the following shall be provided for the crawl space:
 - A continuously operated mechanical exhaust ventilation system at a rate equal to 1 cfm for each 50 ft² of crawl space floor area, including an air pathway to the common area.
 - A conditioned air supply sized to deliver at a rate equal to 1 cfm for each 50 ft² of crawl space area, including an air pathway to the common area.
 - Plenum complying with the appropriate requirements of the code if the under-floor space is used as a plenum.

VENTILATION CHECK LIST

It is sometimes necessary to inspect an existing building for adequate ventilation where there are signs of unusual moisture. When checking for ventilation, be sure to note the following information:

1. Area of floor and attic to be ventilated.
2. Presence of ground cover and ceiling vapor retarder.
3. Signs of moisture accumulation, including decay, water stains, blistered paint, water standing in crawl space, rusty fasteners or mold growth.
4. Quantity, size, type, location, and condition of roof and foundation vents. Measure vents to be certain of size and check vent manufacturer's data for their net free area.

The free ventilation area published by vent manufacturers varies slightly, so any calculations regarding vent area provided will be approximate. In some cases, the net free area may be marked on the vent. When manufacturer's data is not available, Table 2 may be used to estimate net free vent area.

A vent may actually have zero free area and thus may be ineffective, either permanently or intermittently. Examples include closed foundation vents, covered roof ventilators, inoperative power vents, and eave vents which are clogged or blocked by insulation or paint.

5. Compare actual ventilation with minimum requirements, as shown in the following example.

TABLE 2
NET FREE AREA GUIDELINES FOR VENTS AND SCREENS(a)

Ventilator Type	Area (in. ²)	Net Free Area (in. ²)
Roof (screened "jacks," "button caps")	Vent pipe area ($\pi d^2/4$, where d = pipe diameter in inches)	Area x 0.6
Ridge		18 x lin. ft
Gable or foundation (louvered and screened)		
Rectangular	Height x width	Area x 0.44
Triangular	1/2 x height x width	Area x 0.44
Soffit	Length x width	Area x 0.3
Screens(b)		
1/16" mesh	Height x width	Area x 0.5
1/8" mesh	Height x width	Area x 0.8
1/16" mesh and louvers	Height x width	Area x 0.33
1/8" mesh and louvers	Height x width	Area x 0.44

(a) Estimates only. Check vent manufacturer for actual net free area.
 (b) The model building codes specify corrosion-resistant wire mesh with the least dimension being 1/8 inch (maximum 1/4 inch).

EXAMPLE

A 30' x 45' house has a vapor-retarder ground cover in the crawl space. There are four louver-type foundation vents (46 sq. in. free area per vent). Triangular gable vents (155 sq. in. free area per vent) are at the top of the gables at each end of the house for natural attic ventilation. Does this meet the code minimum ventilation criteria?

1. Determine minimum required ventilation area:

Ratio for attic with at least 50% of vent area in upper half of space to be vented is 1/300. Note, however, that in this case 100% of vent area is in the upper half of the attic, reducing effectiveness of the ventilation and requiring that a ratio of 1/150 be used.

Attic vent area required = Vertical projection of roof area x Ratio = (30' x 45') x 1/150 = 9.0 sq. ft. = 1296 sq. in.

Ratio for crawl space with vapor-retarder ground cover is 1/1500.

Crawl space vent area required = Floor area x Ratio = (30' x 45') x 1/1500 = 0.9 sq. ft. = 130 sq. in.

2. Determine total net free area of vents:

Attic vent area = 155 sq. in./vent x 2 vents = 310 sq. in. (Free area of attic vents is less than that required.)

Crawl space vent area = 46 sq. in./vent x 4 vents = 184 sq. in. (Free area of crawl space vents is more than that required.)

3. Conclusion:

Crawl space vents meet minimum ventilation requirements, but attic vents are less than 1/4 of the required area. Additional attic venting is required, and could be accomplished by using larger gable vents or adding vents along eaves. Eave vents are recommended.

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