FOCUS ON ENERGY

Roof Venting: How Much Is Enough?

by Ted Cushman

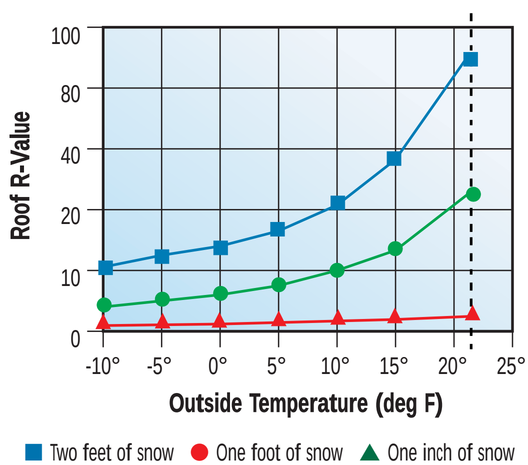
Most builders in the snowy North take pains to ventilate their roof systems, even when it's not easy (see "Venting Details for Cathedral Ceilings," page 36). One important reason is to prevent the formation of damaging and dangerous ice at the eaves. Deep snow insulates a roof and traps heat inside the attic, but a well-vented attic will allow the heat out before it can melt the snow.

So how can a person determine how much venting it takes to keep a given roof icefree? Code requirements like the 1:300 rule (one square foot of free vent area per 300 square feet of attic floor area) and the 1:150 rule are a good start, but in some cases they may provide either less or more ventilation than is strictly necessary. However, recent research by the U.S. Army Corps of Engineers has produced a more precise design tool: a set of attic and outdoor temperature limits that building designers can plug into a simple formula to calculate the required vent area. If passive vent openings won't provide the necessary roof cooling, you can use the same calculation method to size powered ventilation fans. The formula will also help you figure out if upgrading an attic's insulation will help solve an ice dam problem.

Researchers Wayne Tobiasson, James Buska, and Alan Greatorex, of the Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL), in Hanover, N.H., developed their attic venting guidelines based on studies of army buildings at Fort Drum, an installation in upstate New York. For several winters, the team recorded outdoor temperatures and attic air temperatures in five buildings: one building with no ice dam problems and four with problems ranging from slight to severe. The findings allowed the engineers to define the temperature conditions in which icing would occur and to prescribe methods to keep attics within a safe temperature range. By installing passive vents in some attics and a combination of passive vents and thermostatically controlled exhaust fans in others, the team was able to eliminate severe ice dam and icicle problems.

The icing envelope. Ice-ups are a combination of two events: First, snow on the roof melts; and second, the melt water refreezes at the eaves. Heat escaping from the building into the attic (along with heat contributed by ductwork or heating equipment located in the attic space) is the main cause of the melting, and the reason for the refreezing is low outdoor temperatures. As it warms up outside, snow over a warm attic is more prone to melting; but when the outdoor temperatures rise above a certain point, the melt water will

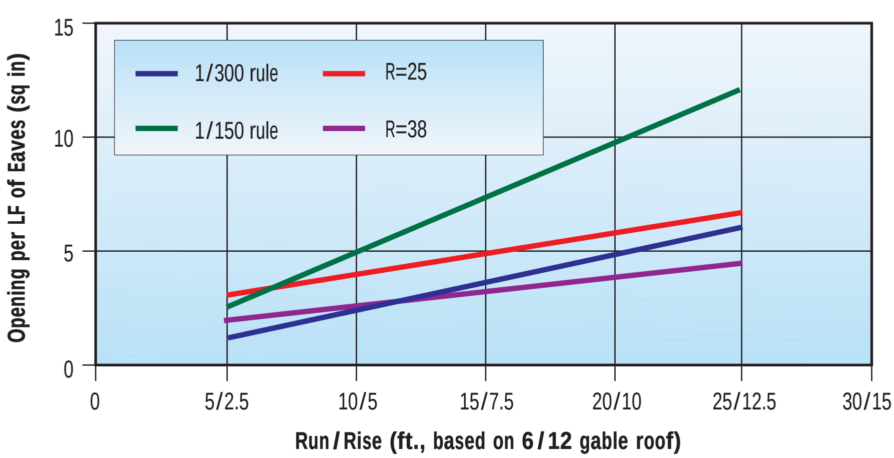
A. Deeper Snow Requires More Insulation



CRREL staffers generated this graph based on a thermal analysis of heat loss from a hypothetical insulated attic through an ***unvented*** *roof without any venting and covered with varying depths of snow. The graph shows the levels of attic insulation required to keep the snow from melting as the outdoor temperature rises to 22° F. (Above 22° F, snow melt runs off before it can refreeze into an ice dam at the eaves.) Attic cooling slows as the outdoor temperature rises, and more slowly still with deeper snow levels. More insulation is needed to counteract the increasing amount of heat that would be trapped in the attic.*

For example, the chart shows that a roof with a 1-foot blanket of snow would need nearly R-50 insulation in the attic to prevent an ice dam when the outdoor temperature is 22° F. If the snow were 2 feet deep, the amount of insulation required would be almost R-90.

B. How Much Vent Area Is Enough?



This graph shows required vent area as calculated by the 1/300 and 1/150 rules compared with CRREL calculations based on building size, roof slope, and insulation levels. In most cases, the 1/150 rule provides more than adequate venting area, even at lower insulation levels; the 1/300 rule also works well for well-insulated attics. However, for small buildings, such as those depicted at the extreme left end of the chart, these rules of thumb may fall short.

drain off without refreezing.

The CRREL team's observations showed that snow on the roof would begin to melt at the base anytime the attic temperatures went much above 30°F, but would only refreeze on the eaves when the outdoor temperature was below about 22°F. The researchers called this set of conditions the "icing envelope" and concluded that ice dams could be avoided if attic ventilation could maintain the attic at 30°F when the outdoor temperature was 22°F or below.

By plugging those values into ASHRAE formulas for airflow and heat removal (see box, below), the team was able to design vents of the right capacity for the situation. The same method is broadly applicable to many buildings.

But what about insulation? In theory, of course, if the quantity of heat escaping into the attic could be reduced enough by heavily insulating the ceiling below, the vent area required to remove the heat would approach zero. But Tobiasson has concluded that in roof systems with no cooling ventilation at all, very high levels of insulation would be needed to prevent icing.

Tobiasson and Greatorex did a thermal analysis to show a superinsulating company how much insulation would eliminate melting on an *unvented*, snow-covered roof under different weather conditions and snow depths (see Graph A). "As it warms up outside, more insulation is needed to prevent melting," wrote Tobiasson. "The critical condition is when it is just a bit colder than 22°F outside. It takes a massive amount of insulation to prevent icings then. For example, if 2 feet of snow is present on the roof, the R-value of the roof (to prevent icings) would have to be around R-90.

"This is not an exact answer," Tobiasson continued, "but it is a good indication that insulation alone, even big piles of it, is seldom the way to stop icings at eaves. The best strategy is to insulate the roof sufficiently for energy conservation reasons, then ventilate the space above the insulation and below the snow with outdoor air to create a cold-ventilated roof."

Calculation vs. rule-of-thumb. At JLC's request, Tobiasson and Buska compared the results of their calculation method with results given by the standard 1:150 and 1:300 ratios, in a simple house design with a 6:12 roof pitch and attic-floor R-values ranging from R-25 to R-38 (see Graph B).

The rule-of-thumb approach based on attic area means bigger vents for larger attics, regardless of insulation R-values. But when the required openings are calculated using CRREL's design criteria, buildings with wider spans (or steeper roofs) turn out to need proportionally smaller vent openings, because higher peaks generate a greater stack-effect airflow. And the better the attic insulation, the smaller the necessary vents.

There's good news here for home builders: Simple houses built with today's standard methods usually have more venting than they need for ice dam protection. In most houses, standard ridge and soffit vents actually provide more vent area than even the generous 1:150 rule calls for. And for tricky designs where code-required venting is hard to achieve, calculations may show smaller openings to be sufficient. ■

Sizing Attic Ventilation to Prevent Ice Dams

by Wayne Tobiasson, James Buska, and Alan Greatorex

The first step in sizing a vent system to prevent ice dams is to find out how much heat the vents will need to remove. If we know the thermal resistance of the ceiling and the indoor and attic temperatures, we can determine the conductive heat losses from a heated building into its attic. To this, we add any heat introduced to the attic by hvac equipment or ducting located there (an important source of heat that should not be ignored).

For design purposes, we assume that all heat escaping into the attic from the building below will have to be removed by the vents, since very little heat will pass through the snow-covered roof.

Knowing the conditions we want to achieve — namely, to keep temperatures inside the attic 30°F when outdoor temperatures are at 22°F — we combine two well-known formulas to arrive at a single formula for finding the vent size required.

The first formula tells how much airflow is needed to remove a given amount of heat when the attic air is 30°F and outside air is 22°F:

$$Q = 6.94H$$

where Q = airflow rate required to remove heat (cfm) and H = heat to be removed (Btu/min.).

A second formula tells us how much vent area is needed to provide this airflow. If the airflow is to be provided by natural stack effect, with 22°F air entering the 30°F attic all along its eaves and exhausting all along the ridge, the flow rate created when the attic has nearly equal intake and exhaust openings is as follows:

$$Q = 28.4A \times \sqrt{\Delta h}$$

where Q = stack induced flow (cfm), A = free area of inlet openings (square feet), and Δh = height difference between inlet and exhaust openings (feet). If the inlet and outlet areas are not about equal, a correction must be applied.

To determine the free area of inlets needed to cool an attic enough by natural, stack-induced ventilation, we combine equations 1 and 2. Then,

$$A = 0.244H \div \sqrt{\Delta h}$$

If the required inlet and outlet areas can be provided, natural ventilation will be enough to keep the attic cool enough to prevent ice from forming. If the required inlet and outlet areas cannot be provided, mechanical ventilation will also be needed.

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