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Roof-Snow Behavior and Ice-Dam Prevention in Residential Housing

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CONTENTS

ABSTRACT

THIS PAPER:

EXPLAINS the melting behavior of roof-snow;

EXPOSES widely held misconceptions of roof-snow;

DESCRIBES the extent and severity of snow-water damages to residential housing;

REVEALS the deplorably inadequate state of the art in coping with eave-ice;

SUGGESTS practical design concepts for ice-dammed snow-water prevention for new construction;

and

DISCUSSES the feasibility of eave-ice prevention methods for existing dwellings.

OVERVIEW

The intent of this publication is to awaken public interest in the behavior of roof-snow and the part it plays in ice-dam formation. Each year, ice-dams cause millions of dollars in damage to homes located in the "snow-belt." Yet there is little understanding among homeowners, builders, and suppliers as to the cause of these ice-dams and the remedial measures that can be undertaken to prevent further damages to residential units.

Many areas and facets of roof-snow could not be included in this publication. Further in-depth investigation by better equipped technicians is recommended. The interpretations presented are generally based upon first-hand observations; perhaps higher levels of technical sophistication will be needed to convince reluctant building interests that they are clearly "involved" in the problems of roof-snow behavior. Satisfactory servicing of ice-dammed buildings requires the enthusiastic support of responsible and knowledgeable suppliers of both materials and services.

In general, ice-dams are formed when attic heat moves upward to warm the roof and melt roof-snow at or near ridge areas. Melting of snow occurs at the snow-shingle interface and runs downward (under the snow) as snow-water. At or near the edge of the roof, colder conditions exist that usually result in the freezing of the snow-water, thus forming the ice-dam. Subsequent melting of roof-snow usually accumulates as a pocket of snow-water that eventually backs up under the shingles to cause major damage in the plateline area. This damage can appear in the form of soaked (inefficient) insulation; stained, cracked, and spalled plaster or sheetrock; damp, odorous, and rotting wall cavities; and stained, blistered, and peeling wall paint, both inside and outside the house. Insulation alone will not solve the ice-dam problem nor will contemporary ventilation techniques. Other commonly used techniques such as heating cables and the removal of snow at roof edges are of little value in combating ice-dam problems. Rather, it is the proper use of insulation and ventilation in conjunction with correct house design that offers the best solutions to the problem.

As a final note, the authors do not intend this report to be used as a "book of instructions" or as a maintenance guide. Improvisations by do-it-yourselfers or untrained installers will most likely result in blunders, disappointments, and disillusionment in the bright promises of the observations, comments, and products mentioned in this report.

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THE TROUBLES WITH ICE-DAMS

Introduction

Freshly fallen snow, adding powderpuff layers to the pillowed roofs of snow-country houses, is the building material of artists and poets. So, too, are the ornamental eaves strikingly decorated with ice-formations glistening in the sun as winter slowly progresses.

The cozy quaintness of the fairyland decorations unfortunately often transforms into a destructive nightmare of roofs leaking profusely at subzero temperatures; sidewalls soaked, stained, blistered, and rotting; interior plaster tarnished, cracked, or spalling; and distraught homeowners with no *effective* methods to prevent a reoccurrence. Expensive redecoration and casualty insurance to help sop up the costs are the distressed homeowners' only choices of action.

Methods of coping with ice-dammed snow-water are numerous. Advocates annually offer advice in the early winter editions of newspapers and magazines, and gadgets, services, and tools for roof-snow removal are offered for sale in ads and in merchandising promotions each fall. NONE OF THESE PROVIDE THE SATISFACTORY SOLUTIONS SO BADLY NEEDED BY FRUSTRATED HOMEOWNERS IN THE SNOW-COUNTRY.

The explanations, interpretations, and suggestions of this report are founded on a 10-year study of actual roofs and visible roof-snow behavior in several thousand observations as well as color slide documentations in 36 states and 5 Canadian provinces.

Visible evidence everywhere has indicated the frustrations of building owners and the inability, or unwillingness, of building professionals to adequately cope with extensive damages caused by eave ice-dams and blocked snow-water penetrations.

These observations can be verified by streetside observation during almost every winter in the Twin Cities in late February, three winters out of four in Chicago, and at least occasional winters throughout latitudes as far south as the Ohio River.

Although snowloading of structures has been well recognized and documented in architectural texts and structural design data, few references (13, 3, 6, 7) to roof-snow melting and ice-dam behavior have been found in technical literature. Hopefully, this report will bridge a sadly neglected informational gap and also stimulate homeowner response and action to eliminate this needless, but widespread and devastating, fault of building design and performance.

Recognition of Ice-Dams

Our investigations have revealed that many extensively involved and troubled homeowners are reluctant to admit (and discuss) *their individual* problems with ice-dams. The most common response to our question has been, *"What are ice-dams?"*

Figure 1. Typical snow-country eave in late winter.

Figure 1 shows late winter snow on a roof, a bulge of ice attached to the eave, with numerous icicles that may drip from it on warmer days, and stained siding that may be optimistically written off as *"a bit of rust stain from the overloaded rain gutters."* Similarly, a wetted interior ceiling and wall are hopefully nothing more than a *"bad place in the shingles that we will fix next spring."* Perhaps this is true, but the attacks are more likely to be as indicated in figure 2 revealing the "actions" inside the cornices and attic spaces.

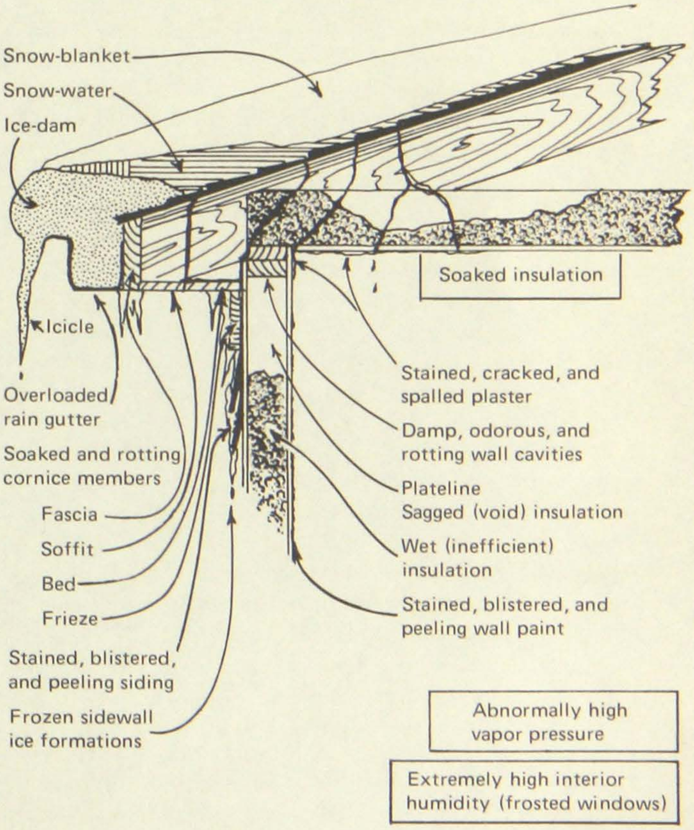


Figure 2. This sketch of the ice-dam problem identifies both the ice-dam and its damages. Of course, all the damages illustrated may (or may not) occur at any one instance. The damages illustrated here are far more common and costly than is generally acknowledged.

The ice-loaded eave, the puffed snow-blanket, and the dangling icicles of figure 1 may be all that is apparent; but inside the cornices, within the attic spaces, and within the wall cavity, the destructive actions – seldom detected by direct observation – are illustrated for easy recognition in figure 2. The existence of these hidden actions is occasionally betrayed on the exterior by wetted walls, by massive wall ice formations, by wall stains, and subsequently – usually later in the spring – by blistered and peeling paint.

Inside the house, the distraught housewife may not identify ice-blocked snow-water as the source of wetted ceiling and walls, of stained and peeling paint or blistered, cracked, and spalling plaster, and perhaps the offensive, yet difficult to locate, odor of mildewed and rotting wood.

Unseen, *and detectable only indirectly,* are the damages in the wall, ceiling, and cornice cavities, such as soaked, sagging inefficient insulation; mildewed and rotting wood structural members; rust-marked, stain-oozing degraded sidewalls; and corrosion of nails, flashings, and fasteners. Hidden cavities are also slow to dry out after the roof-snow season. Such severely soaked insulation and wall cavities contribute substantially to house moisture and to damages associated with excessive vapor pressures in residential interiors.

Occurrence of Roof-Snow and Ice-Dam Problems

Ice-dams develop on buildings whenever and wherever roof-snow accumulates on roofs to depths of an inch or two and when the weather turns or remains generally below freezing for 3 or 4 days.

No precise limits of snow-depth and temperature conditions have been determined, nor would such specific limits be significiant; wide variations in the range of roof-snow depth and temperature depend on the whims of nature, the direction and velocity of winds, and the shape of the roof.

In general, the deeper the snow, either by single incident snowfall or by accumulations, and the lower (and more persistent) the subfreezing temperatures, the more inevitable and sizeable are the ice formations for typical houses.

A 5-year study (1) of winter conditions in 25 locations sought to develop an index of snow-cold severity for comparisons of relative ice-dam susceptibility in such diverse locations as *Sault Ste Marie*, Michigan (Ontario); *Minneapolis*, Minn.; *Madison*, Wis.; *Chicago*, Ill.; *Pittsburgh*, Penn.; and *Lexington*, Ky. Snowfalls and roof-damages, as anticipated, proved generally more severe, frequent, and enduring with increasing north latitude locations. Other climatic factors may supersede latitude.

Wind direction and velocity may free some roofs of snow or selectively clear certain planes and drift deeply on another plane or in a susceptible valley.

Heavy snowstorms characteristically move as low pressure frontal systems across the midwest in approximately southwesterly to northeasterly directions. Such blizzard-type winds blow moisture in from the southeast, shifting to the northeast and to heavy snow as the storm front moves in. Snowfalls diminish as winds shift to the north and northwest as the front passes and cold temperature air follows. Thus, deepest snow and drifts occur normally on northerly and westerly roof planes and valleys. Such selective orientation of deepest snow helps explain why snow depths and snow-water damages are generally greater on northerly and westerly roof planes and valleys. Wind and complex roof-structures may confuse observers of roof-snow actions unless wind factors are carefully recognized and considered.

Farm homes and buildings with wind-exposed roofs are less prone to roof-snow problems. Clearly, roof planes freed of snow will avoid ice-dams and snow-water difficulties.

Affluent suburban homes where trees have been carefully preserved or where trees have been densely re-established have a much higher incidence and severity of eave-ice damming than do rural or windswept (treeless) new developments. High winds, or the lack of winds, that may or may not blow snow from roofs are key factors in the relative depths and damages of roof-snow.

Within metropolitan areas, there may be startling variations in ice-dam susceptibility from dense residential areas to the windswept, thinly built-up, outlying areas.

There are striking local variations, such as Chicago's lakefront in relation to its western suburbs. The moderating effect of large bodies of water distorts the norms of latitude, and the greater incidence of snow in South Bend's Chicago-polluted air indicates need for further study of the snow/cold variables that lead to roof-snow and snow-water damages. Snow density, as it affects both roof loads and snow-water quantity, has received little attention and consideration.

The snow/cold conditions for severe roof-snow difficulties vary little from year to year for the Soo and the Twin Cities, where coping with snow and cold is accepted as part of life. In Madison and Chicago latitudes, severe snow/cold may occur in only 2 years out of 5, and, in more southerly latitudes, damaging roof-snow may occur only once in several years. Curiously, homeowner attitudes appear to be optimistically myopic in locations where chances of ice-dammed snow-water attacks are less than 50 percent; this is sadly shortsighted, because one ice-dammed snow-water attack in a 10-year period can be devastating.

Identification of Snow-Water Damages

Icicles

Icicles, sparkling in the sun of mid-winter days, are only indicators of the interactions of roof-snow, the efficiency of ceiling insulation, and the effects of warmed attic spaces. Decorative icicles hanging beyond the eaves are solidified snow-water that is out and over the dams and are hazardous only to those who carelessly knock them down.

Roof-ice glacier actions

The visible troublemaker on snow-decked buildings is the massive ice formed from successive flows of roof snow-water freezing as it emerges from the protective insulating blanket of roof snow. The disruptive forces of expanding ice-actions may damage roof shingles and the roof-deck. The glacierlike forces on roofs and in valleys deserve better consideration by building designers.

Rain gutters

Rain gutters (eaves troughs) are often condemned as responsible for ice-dammed eaves. Ice-filled rain gutters may contribute to concentrated overloads at the eaves. Massive ice in (and around) eaves troughs inevitably slows melting and interferes with desirable roof drainage and runoffs; however, rain gutters, like icicles, are simply symptomatic of snow-water actions, rather than causative.

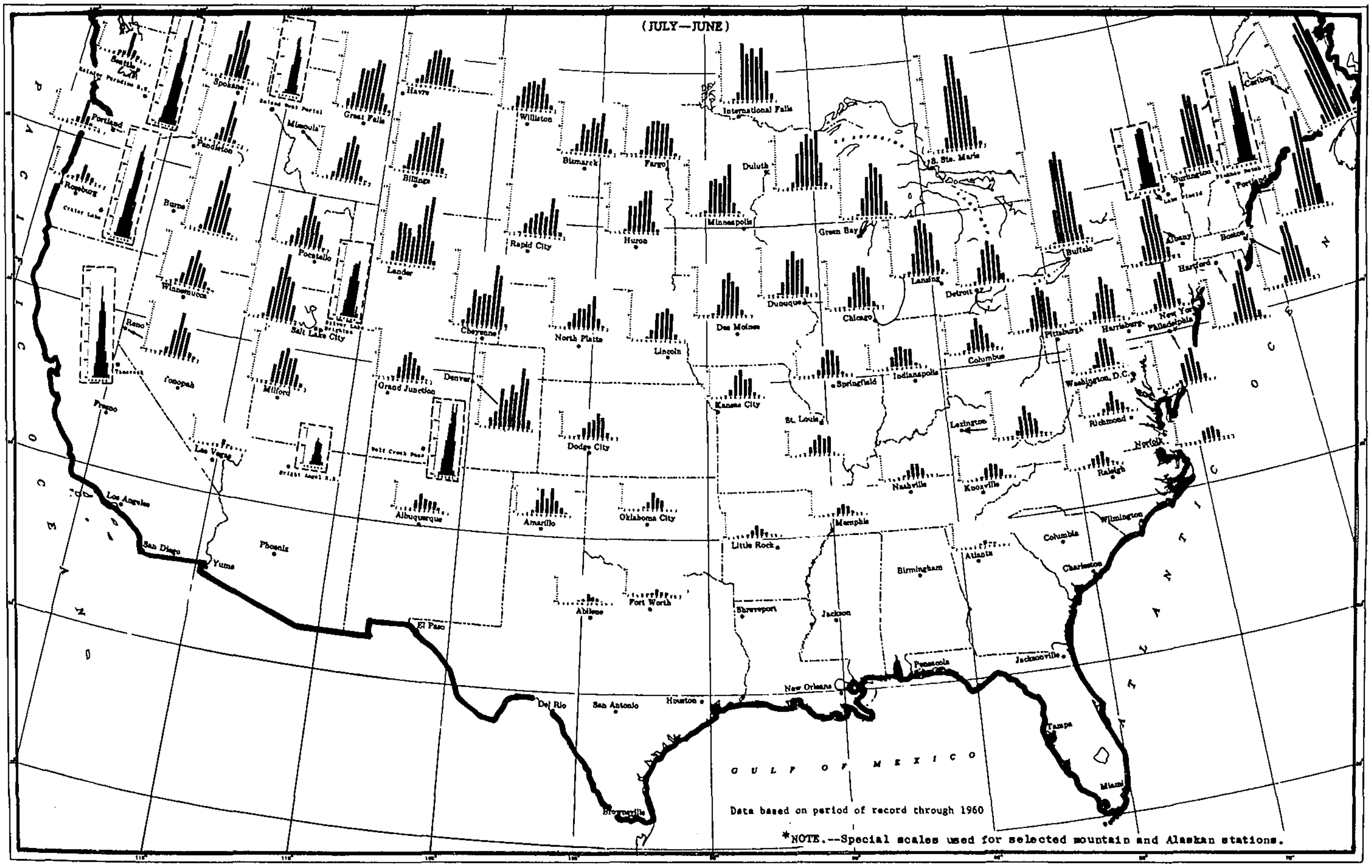
Snow-water penetrations

The deceptive offender on winter roofs is snow-water. Its many actions are disguised in successive transformations. It develops from snow-crystals of varying densities into snow-water, and it may transform on cooling into massive ice-dams that block further runoff at the eave. Roof-snow can sporadically alter its water-ice character with thermal variations in atmosphere and roofdeck thermal relationships. Snow-water deceptions have been inadequately recognized and confronted.

Snow-water blocked by ice-dams may develop to depths sufficient to penetrate cracks and flaws in a deck that was not built to resist water attack from below and beneath it. Alternate freezing and thawing increases both the incidence and the magnitude of roof-deck flaws. Snow-water penetration into the structure may follow paths and channels difficult to analyze as the source of sidewall soaking. Penetrating snow-water often seeps down rafters, along plates, into wall cavities, and saturates sidewall insulation to reduce its efficiency, passes into and through sheathing-siding as either water or vapor, and may stain or blister the thin skins of paint to effect a thoroughly undesirable appearance and a lowered protective performance. The ultimate damage through rotting of structure by successive waves of snow-water attacks may destroy the building, even when cosmetically covered with vapor and water-impervious materials.

The amount of sidewall moisture originating from snow-water is impossible to determine because most of the evidence is hidden initially by the snow-cover and, after penetration, by

Figure 3. Map of the United States indicating snowfall distribution. "Mean Monthly Total Snowfall (Inches) for Selected Locations," Publication of the U.S. Department of Commerce (18). Each bar graph shows snowfall for the location from July to the following June.



the roof and sidewall coverings. Actions within the sidewall cavities can be deduced from the sometimes visible wetting and from the occasional frozen sidewall-icicle, the developing stains, and the subsequent paint blisters. Winter snow-water seepages may be difficult to identify, but the musty odor of wet and rotting wall and cornice members may permeate the house during summer. Massive sidewall soaking may saturate cavity insulations and retain moist and rotting conditions for months.

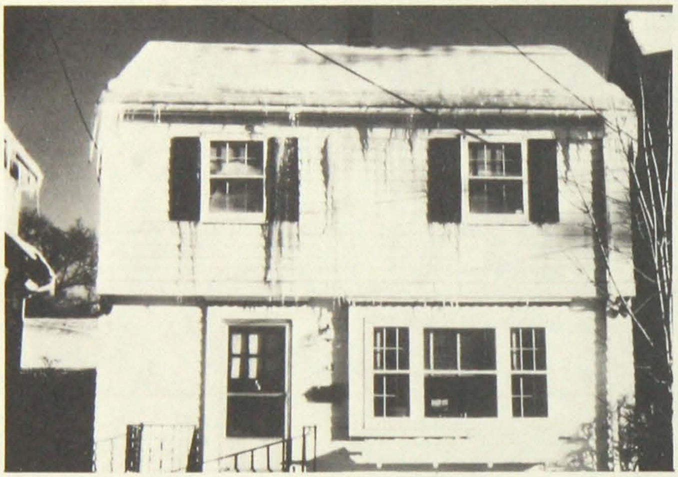


Figure 4. Frozen sidewall leaks emanating from ice-blocked eave.

Frozen sidewall leaks

Visible evidence of the penetration of ice-dammed snow-water into attic-warmed cornices is not rare in the upper midwest in December through March. Intensely cold weather may freeze the cornice leaks in a stop-action sidewall ice-formation, as displayed in figure 4. The visible ice may be apparent for only a few days. With even slight warming, the frozen action may melt to an almost invisible flow. Similarly, ice-blocked snow-water undoubtedly also flows on the interior of the wall cavity where its detection is difficult; evidence of its presence may subsequently develop as stain, blistering, and peeling of the painted siding.

Sidewall degradation

Snow-water penetrations through roofdecks, into cornices, and seeping generally within and without the sidewall cause not only paint failures, but general degradation of the structure. Insulation wetted by water seepages loses most of its efficiency with consequent increases in snow-melting thermals in the attics and cornices.

Plateline thermals

Perhaps the most neglected heat losses of well-insulated modern houses occur at the exterior platelines. Sagging sidewall insulation – due to settling, wetting, or careless installations – adds to the overlooked heat losses in the critical plateline region. Such heat losses further aggravate snow-water penetrations by supporting the liquid ice-dammed pool in a most vulnerable position for penetration damage on the roof immediately above the eave platelines. The conditions promote snow-water seepage during extended periods of cold/snowy winters to soak insulation and wall cavities. Complete drying is extremely sluggish, and the rot-promoting conditions may persist for several months.

Other damages

A re-examination of the damaging effects shown in figure 2 will identify and explain the damages of ice-dammed snow-water far better than words. All damages illustrated have been observed and recorded in a series of private audio-visual reports (2). These audio-visual reports form much of the data substantiating these comments. The authors will be pleased to arrange for private or group examination and discussion of these reports as compiled from field observations. The dank and rotting odor of some of the soaked structures is the one feature that cannot be described nor sensed with the audio-visual data.

Homeowner Confrontations With Roof-Snow Problems

Expert advice and the state of the art

With periodic regularity, matched only by falling leaves and snow, newspaper and magazine articles offer warnings, tips, and counsel for homeowners faced with the annual siege of ice-dammed snow-water on roofs. With good intentions, but with a deplorable revelation of the inadequacies of the art, "expert advisors" are prone to contribute to the problem rather than to its solution.

Roof snow removals

The most common, and apparently reasonable, advice is to shovel or rake the snow from the roof, since with no snow, there will be no snow-water, or ice-dam, and, ostensibly, no problems. However, homeowner reactions to such news article suggestions often develop even more frustrating side effects than the predictable hazards of falling bodies and broken bones following each snowfall.

Partial roof snow removals

Most homeowners are seldom equipped with sufficient incentive and enthusiasm to achieve more than partial snow removal. Equipment, energy, dedication, and the many required roof-snow removals appear to limit the effort to a short reach uproof. Such partial snow removals leave substantial snow-blankets on the upper part of the roof slope.

With only partial removals, uproof snow will melt and run downslope to emerge from the protective snow-blanket, freeze, and build into an ice-dam that blocks snow-water uproof in what may be a more vulnerable leak position than at the eaves. Such secondary ice-dams – oftentimes multiple uproof ice-dams – are visible to observers who take the time and winter-cold discomfort to examine the reaction of homeowners to the "shovel-it-off" advice of newspaper authorities.

Complete removal of roof-snow, of course, prevents ice formations and snow-water damages. In many cities that are annually plagued with roof-snow the yellow pages of the phone directory list firms pleased to be paid to remove each successive snowfall. The recurrent expense discourages many

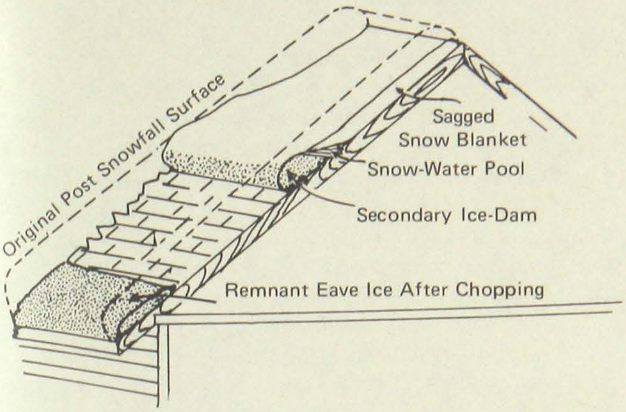


Figure 5. Partial roof-snow removals develop secondary ice dams.

homeowners. Many budget-strapped and ill-advised homeowners attack the roof-snow and eave-ice in a desperate do-it-yourself assault of shoveling, chipping, hosing, picking, chiseling, and (believe-it-or-not) blow-torching to rid their eaves of ice-dammed snow-water.

Neither professionals, who are seldom reported falling from the treacherous roof planes, nor the amateurs, who frequently drop into the news as killed or injured, should risk cavorting around on slippery roofs. Nor should prudent caretakers permit such stomping around on winter-embrittled roofs that were not designed to resist such rip-roaring gyrations. Roofing companies are pleased to shovel off roof-snow as off-season employment; they may score a "double-shot" in returning later to repair or replace the shattered shingles and leaking roof.

Eave heat tapes (electric cables)

Building owners, under the duress of ice-dam inundations, often install electric cables along the eaves and in the valleys. Unfortunately, the melting effectiveness of such heat tapes is limited to only a few inches from the cable; the typical zigzag pattern of installation betrays this localization of melting effectiveness.

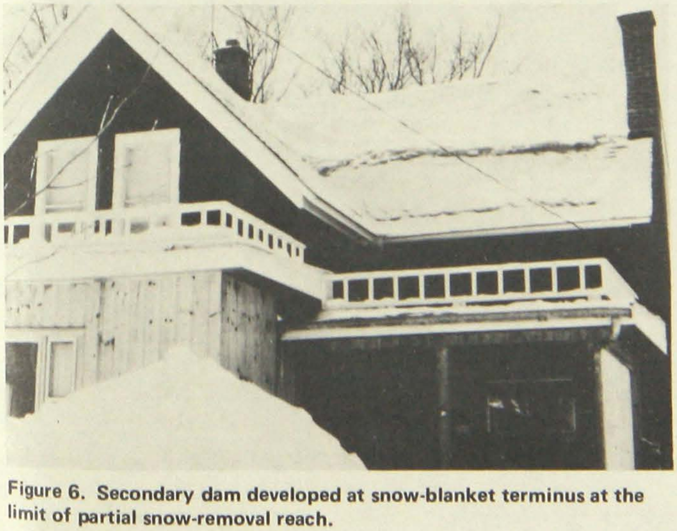


Figure 6. Secondary dam developed at snow-blanket terminus at the limit of partial snow-removal reach.

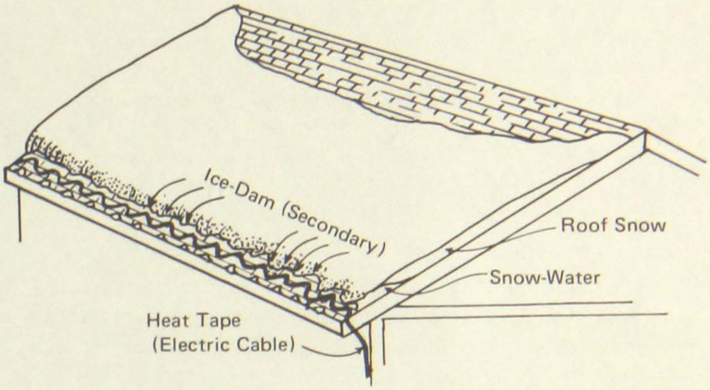


Figure 7. Characteristic zigzag pattern of limited melting zone of eave heat tape.

Figure 8. Secondary ice-dam developing uproof above heat zone of electric cable.

Heat tape secondary ice-dams

The characteristic sawtooth melting of snow within a few inches of the heat tape develops a limited and selective removal of snow and ice; partial removals, whether by raking, shoveling, or localized heat cables, often develop uproof secondary ice-dams. Heat-tape secondary dams are observable along the terminal lines of the protective snow-blanket in a zigzag pattern prescribed by the limited melting zone of the heat tape.

Figure 7 shows the characteristic pattern of limited zone melting of an electric heat-taped eave. Figure 8 verifies the formation of the heat-taped secondary dam immediately above the highly localized melt zone of the heat tape.

Valley heat tapes

Electric cables have been frequently observed in their zigzag pattern in valleys. Limited melt zones near the cable are often flanked with secondary ice-dams that obstruct normal drainage into the valleys. It is difficult to justify the expenses of electric cables, their installation, their recurrent power demands, and their adverse side effects in light of their limited effectiveness. Employing heat to melt ice into water on a troubled roof where heat has already produced the potentially penetrating snow-water suggests such approaches are not only wrong solutions, but are clearly complications of the eave-ice problem. Surprisingly extensive use of eave and valley heat tapes may be attributed to the futility and desperation of frustrated homeowners seeking "push-button gadgets" to alleviate their problems. Heat tapes are more numerous on roofs in latitudes where winters are not severe than where eave-ice is an annual assault and the futility and wasted expenses of localized melting is better recognized.

Counteracting roof thermals

Confronting roof-snow with controlled thermal gradients to melt the snow (as with electric heat cables) has been studied and developed for structures in the specific climate of the California High Sierras at Lake Tahoe (13). The energy costs and the adaptation to a specific climate of freeze-at-night and thaw-by-day limit the usefulness of houses designed to establish thermal gradient patterns from eave to ridge to melt troublesome roof-snow. Such counter-gradient installations in the upper midwest would effect a return to the old *heat waster* (figure 13, page 11) performances of roof-snow melting.

Hosing with tap water

Another method of thermal attack on roof-snow has been employed in emergency situations to remove roof-snow and ice. Simply hosing down the roof (on mild days) from ridge to eave with tap water will remove roof-snow with reasonable efficiency; the method might be acceptable *if* the owner has no concern for the ice-formations that coat and overload the shrubbery around the house. Melting snow with flows of water is a method that has most of the hazards to life, limbs, and shingles of the ill-conceived shoveling techniques.

Eave flashings

In the snow-country near the Canadian border from Maine to British Columbia, many houses can be observed with eave flashings of metal. The 2 to 3-foot widths of eave flashing seldom improve the appearance of the house, but distressed people living in deep snow-country seem willing to forego the esthetics of appearance for some measure of protection from snow-water penetrations.

Figure 9. Eave flashings of aluminum.

Flashings of smooth metal (or roll roofing) serve as leak protection devices along the leak-vulnerable eaves. The smooth (usually aluminum) edge-band eases the slough-off of eave snow and ice along the eave projections where attic heat is insufficient to sustain further down-roof flows of snow-water. With the lowest edge of the snow-blanket a few feet above the eave, *secondary ice-dams will form and build above the metallic flashed eave.*

Heat tapes fastened to eave flashings have been observed in several states and provinces. Such improvisations suggest a high degree of owner frustration and compounded desperation in such "systems" of ice-dam prevention. The practical usefulness of such metallic eave flashings appears to be in the leak protection of a continuous (monolithic) sheet of material.

Metal roofs

Sealed-seam metallic roof coverings are common on homes of deep-snow ski areas from Stowe, Vt. to Aspen, Colo. These interlocked (monolithic) coverings indicate an awareness of the damage threats of roof-snow and ice. Such "total roof flashings" are directed toward leak protection and appear to defy or ignore ice-dams. Metal roofs apparently serve well (especially on steeply pitched roofs) by simply sloughing off the troublesome roof-snow.

Double roofs

Double surface roofs constructed with cool-air venting spaces between them are reportedly used in European snow-countries to prevent ice formations (13). The report also suggests this device has found little acceptance in this country because of the excessive costs of an insulated inner roof with a second weather-roof spaced atop by the furring supports. In several thousand observations, only one building (at Lake Louise, Alberta) was detected as newly constructed with an inner roof to retain the attic heat and an offset top surface (of corrugated steel) to protect against snow and rain. Furring strips running from eave to ridge supported the "weather roof" and provided space between the two roofs for a gravitational flow of air from eave to vented ridge. Presumably, the inner roof was well insulated to retain and conserve attic and room heat. What little heat that does escape the inner roof should air-wash upward and out the ridge without *melting the weather-roof snow-blanket from its underside.*

When such vent-spaced double roofs are functioning properly, roof-snow is not melted by room and attic heat, and snow-water does not flow down the roof-slope beneath the snow-cover to freeze into ice formations at the eaves. The double roof is, in effect, a "cold roof" and is a natural method of avoiding destructive ice-dams.

Explanations of roof-snow melting behavior considerations should precede further considerations of cold-roof performances. An understanding of roof-snow behavior (and misbehavior) on familiar roof designs and shapes leads to logical explanations of the errors and follies of our present approaches to ice-dam problems and results in an appreciation of the natural efficiency of a simple adaptation of the "cold-roof concept" of eave-ice prevention.

A following section of this publication shows how the concept of a "cold-roof" can be achieved by practical methods without the excessive expense of the furred-out double roof.

Why the Neglect of Ice-Dams?

Anyone recognizing the extent, frequency, and severity of roof-snow damages may be puzzled by homeowners' strangely apathetic and passive tolerance toward houses plagued with such a visible deficiency.

Respected technical professionals have generally neglected, ignored, or denied the impacts and importance of roof-snow behavior. It may appear incredulous – as it was for us early in this research – that technically competent and responsible professionals in building design and supply have so strangely failed to attend and resolve the destructive impacts of eave ice-dams and roof-snow.

Some possible explanations of this neglect are offered here, not to fuel an argument, but to encourage evaluation of these observations that may initially appear to affront established custom and conflict with the (limited) writings of respected technical professionals.

With ice-dammed snow-water visibly soaking the ceilings and sidewalls of their homes, distraught owners have had no obvious target for their wrath. Homeowners cannot identify any specific material or product manufacturer to blame. Materials suppliers and installers neither recognize nor acknowledge any involvement with (or responsibility for) the ice-dammed destruction. Technically responsible authorities have generally ignored the extent, severity, and increasing intensity of roof-snow damages; such experts must recognize the inadequate state of the art and endorse research and development programs if this correctable fault of building performance in the snow-country is to be eliminated.

The lack (or avoidance) of involvement in snow-water actions by building industry leaders is vividly indicated in an upper midwest newspaper quote (7) of a building association chief executive in recommending heat tapes and shoveling the snow from the roof: "It's the homeowner's responsibility, just as much as shutting the windows when it rains or removing the snow from the sidewalk." The director of a highly respected government research laboratory confirmed those recommendations as the state of the art in coping with ice-dams.

Such building industry attitudes are in puzzling conflict with private communications with federal housing officials and another metropolitan builders' association executive who said such ice-dammed snow-water "is the greatest single complaint we receive from homeowners."

Homeowners, with little competent technical support to guide them, turn to various makeshift methods, gadgets, attitudes, and escapes from the attacks of snow-water and eave-ice. A few methods are partially helpful, some are monstrously hazardous, some are illusionary, and some are little more than deceptions. Distraught homeowners are reluctant to discuss degradations of their property. They have developed, perhaps with the support of compensatory insurance settlements, an amazingly apathetic, stoical, or calloused acceptance of this "unmentionable" of north country homes.

A fundamental reason for the apparent indifference of technical professionals to the damages of ice-dammed snow-water may be found in the assignment of vapor condensate as the almost sole source of sidewall moisture problems. Sidewall inundations from eave-blocked snow-water penetrations have been ignored or assigned an insignificant role by most technologists in residential housing.

Our observations and recorded color slide data indicate a substantial, if not a major, role of snow-water in sidewall moisture accumulations and damages.

It will be productive to assign competent technical attention and consideration to long-neglected ice-dammed snow-water as a significant source of sidewall moisture and damage. As promised in this report, *eave-ice can be prevented, and with the prevention of eave-ice, homeowners can be assured there will be no sidewall moisture originating from blocked eaves.*

It is not productive to argue the relative importance (or destructions) of vapor condensate versus ice-dammed snow-water as sources of unwanted sidewall moisture. It is important to note that, even with the best recommendations for blocking vapor movement into sidewalls, moisture damages continue to occur with embarrassing frequency in spite of scrupulously specified (and installed) vapor barrier installations.

Vapor condensate theory

A classic study and report (5) of the causes of sidewall moisture in the '30s – when houses were initially tightened with insulation and asphalt shingles – identified and emphasized sidewall moisture sources as vapor movement from the tightened interior. Unfortunately, eave-blocked snow-water was apparently neither considered nor researched.

Acceptance of vapor movements as the major (if not the only) troublesome source of sidewall soaking has permeated all segments of the responsible building industry. This is evident in pamphlets from paint, vapor barrier, insulation, design, louvering, and associated manufacturers and associations (see References 4, 5, 6, 8, 10, 11, 12, 14, 16, 17, 22, 23, 24, 25). Four decades of neglect of ice-dammed snow-water as a second (and possibly major) cause of sidewall soaking may be explained, but to continue to ignore snow-water attacks is unconscionable.

Definition of sidewall damage region

The classic definition of geographic limits of sidewall moisture troubles as the "January Mean Temperatures of 35°F." is illustrated in figure 10. The origin of this geographic definition of sidewall troubles can best be understood from the following quote from page 15 of FPL Report #1710 (11), originally issued in September 1947:

"The Forest Products Laboratory has been receiving reports of condensation in houses from various parts of the country for many years. In normal or mild winters most of these are from areas north of the Ohio River, but after a severe winter, such as occurs every 4 or 5 years, the reports are more numerous and include many from areas farther south. On a basis of these reports, it has been established that condensation problems may be expected in houses in those parts of the country where the average January temperature, according to Weather Bureau reports, is 35°F. or lower."

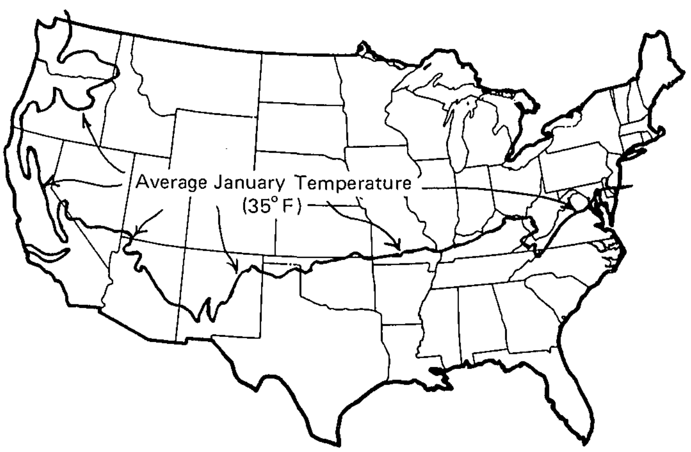


Figure 10. Map of the United States associating sidewall moisture damage susceptibility with temperature (6).

It is interesting, if not amazingly revealing, to find that January 35°F mean temperature geographical limit of sidewall moisture problems coincides almost precisely with the U.S. Dept. of Commerce Weather Bureau's map of the 6-8-inch Mean Annual Total Snowfall. [See figure 11 reproduced from U.S. Department of Commerce Weather Bureau Map and Data (18).] Had those geographical limits of trouble been identified by *snowfall criteria* instead of *temperature criteria,* ice-dams (as well as vapor) might have received some, if not a major, consideration in sidewall moisture problems.

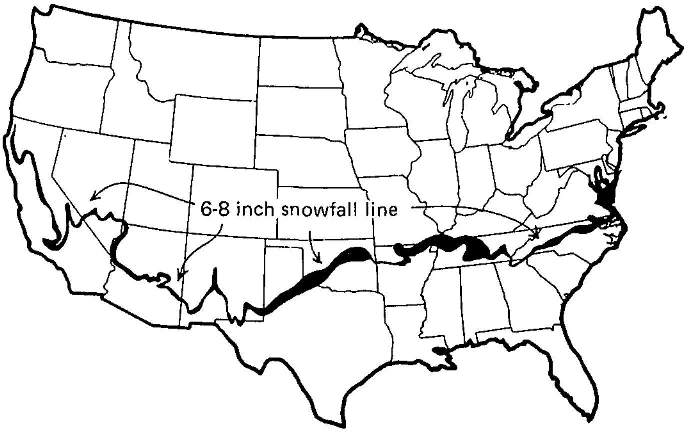


Figure 11. U.S. Weather Bureau Map and Data (18) of Mean Annual Total Snowfall With 6-8-inch line delineated.

Ice-dams overlooked

Ice-dams and damages have been almost ignored in reports of sidewall moisture problems throughout several revisions and building industry derivations of the classic vapor study (5); a recent (1972) revision (6) of the original research has added sketches and brief explanations of ice-dams caused by insufficient insulation and ventilation.

In discussing what appears to have been an honest, but possibly embarrassing, oversight of the important factor of roof-snow effects on sidewall degradation, we do not want to be argumentative. We believe it is in the public interest to reexamine all sources of sidewall moisture.

MELTING BEHAVIOR OF ROOF-SNOW

Typical Roof-Snow Melting Actions

Contrary to popular implications, the radiant energy of the sun does not provide the major source of heat that melts roof-snow on snow country buildings. During cold winter days, attic air warms the roofdeck, which then melts roof-snow from its underside.

Light and fluffy snow crystals serve as unusually efficient insulation that slows atmospheric melting, supports roof-contact melting, and maintains fluid flows of roofdeck snow-water during subfreezing weather.

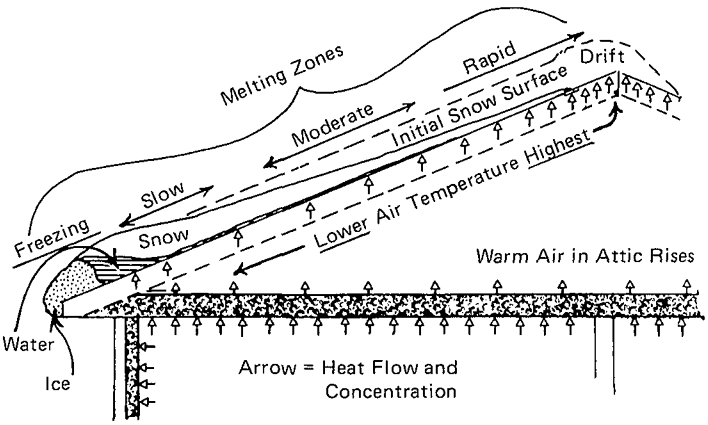


Figure 12. Schematic representation of roof-snow melting.

In figure 12, "heat" arrows are used to indicate thermal movement, direction, and concentration. Room heat is shown passing sluggishly (slowed by insulation) into the attic where it warms the attic air. As attic air rises in temperature, it expands, becomes lighter, and rises to accumulate and increase air temperatures in the higher attic spaces at or near the ridge. Attic air warms the roofdeck, making it warmest near the ridge and less warm toward and along the eaves. These thermal gradients of the roofdeck cause the roof-snow cover to melt initially and more intensely at the warmer ridge zone.

Roof-snow, melted from its underside by the heat of the attic-warmed roofdeck, flows downroof as snow-water under the insulative snow-blanket. When typical snowstorms are followed by subfreezing cold, melted snow under the snow-blanket flows slowly downroof to emerge from the snow-cover and freeze into accumulating ice at the edge of the snow-blanket. Normally, ice-dams form and develop along the eavelines where the snow-blanket ceases to protect the fluid flow and where the roof-extension beyond the plates has less (or no) attic heat to keep it liquid.

As the snow-water emerges to freeze into ice masses along the edges of the snow-blanket, subsequent water beneath the protective blanket may be blocked from runoff by the "ice-dams"; it may freeze or be held as pools under the insulating blanket of snow. Blocked by massive ice-formations, snow-water pools develop and may rise on roofs to heights sufficient to penetrate between and under the shingles and roofdeck. Snow-water penetrations through spaces, cracks, and flaws of the roofdeck lead to soaking and extensive damages to the roof, cornices, and sidewalls. Such typical roof-snow behavior is illustrated in figure 12, and damages are shown in figure 2.

The major destructive agent on snow-covered roofs is the ice-blocked snow-water, which is kept liquid by attic heat and protected from atmospheric freezing cold by the insulative snow-blanket. The roof-snow covers and hides the deceptive liquid – ice – liquid (and vapor) transformations energized by attic-heated roofdecks.

Roof-melted snow-water accumulates and develops ice formations at any roof location where there ceases to be sufficient attic heat to counteract freezing or where the insulating snow-blanket is terminated. If the snow-blanket is undisturbed, the ice-dam will form at the eave; if snow is removed part way uproof from the eave, the ice-dam will form at that newly established snow/freezing-air interface.

Intermittent and sporadic melting and freezing of roof-snow and snow-water is difficult to follow because most of the actions are invisible beneath the covering of roof-snow.

Simple corroboration of these actions of roof-snow can be observed from streetside. Thin coatings of frost or light snow showers reveal many highly localized sources of attic heat, such as: chimney; bathroom; dryer; vent-stacks; voids of carelessly applied ceiling insulation; platelines, because of their higher thermal contribution; and the pattern or ridge area heat concentrations.

Such visible indicators of roof-snow behavior develop more slowly with heavy snow blankets and during severely cold weather. Attic-heat actions are visibly evident in terms of the diminishing depths of roof-snow near the ridge where the warm air of the attic rises to produce thermal concentration. Roof-snow patterns provide proof that roof-snow melting proceeds primarily from roofdecks warmed by the internally developed attic or building heat.

With very short (or no) cornice projections, massive ice and blocked snow-water pools develop at the platelines where attic heat and sidewall heat leakage are greatest; observations suggest that such short cornice houses have the greater incidence of *visible* sidewall soaking because pools are more likely to develop directly over the wall lines. Cornice projections, increased insulation, steeply pitched roofs, "cathedral" ceiling structures, knee-walled half stories, split-levels, lean-tos, and improved louvering practices have varying influences on the formation of snow-water and eave-ice.

Roof-Snow Performances on Pre-30's Houses

A review of the progress in house construction since the 1930's reveals some of the reasons for increasingly troublesome roof-snow problems. These considerations also disclose inadequacies of present construction methods, materials, codes, and standards in coping with roof-snow.

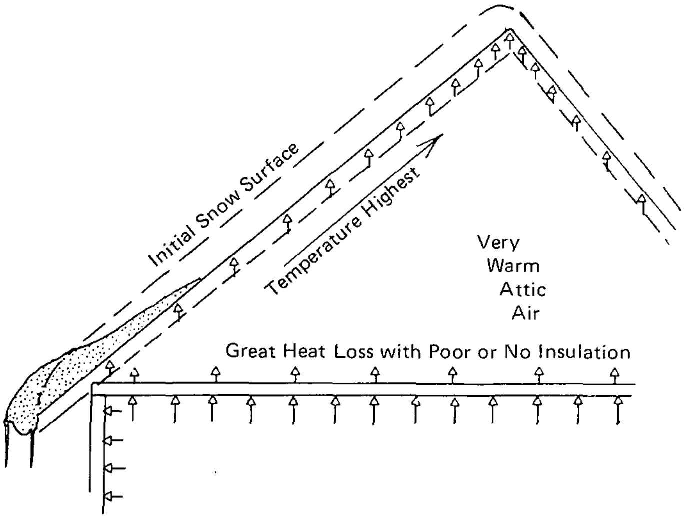


Figure 13. Schematic representation of thermal influences on roof-snow melting of pre-1930's houses "The Old Heat Wasters".

Typical American houses built before 1930 were constructed with relatively steeply pitched roofs, with "open" (spaced) sheathing, and mostly with wood shingles; these (cedar) shingles had spaces between them that closed when wetted. Such gaps between shingles served to ventilate attics and to cool the roofdecks.

Most "pre-30's" houses had no insulation in either ceilings or walls; indeed, there was little demand for heat conservation when rooms were selectively *warmed* by stoves rather than heated by a central furnace. Some homes had central heating, of course, but only a few had insulation in ceilings and sidewalls. Wood and coal were plentiful; there were no outraged public demands for energy conservation. Nor were paint staining, blistering, and peeling of the traditional wood siding embarrassing and expensive problems. *The houses built in those days were not plagued with paint problems until they were modernized;* "updating" with asphalt shingles, insulation, and other installations designed to "tighten the old heat waster" and conserve heat led to sidewall moisture and paint failures of alarming severity.

Numerous pre-1930 houses in our country have been "modernized" with tight roofing, variable (but almost always inadequate) insulation, ventilation, and vapor barriers. Because of the highly heated air of the attic, the warmed roof melts roof-snow rapidly; in only a few days, roof-snow is transformed to snow-water and/or ice.

Figure 13 is a schematic representation of the roof-snow melting of such houses. Heat concentrations and heat escape movements are indicated in the quantity and directions of the arrows.

Notice the hot air concentration (as heat arrows) in the high spaces of the attic where the warmest air rises and is trapped. Such ridge buildup of attic heat initiates and supports the most intense melt actions on the warmer roofdeck nearest the ridge. Roof-snow converted to snow-water flows downroof under the protection of the snow cover. On the old heat-wasters, the excessive attic heat supports rapid flows of snow-water downroof to the cooler eave projection and beyond. When air temperatures are less than extremely cold and attic heat is in plentiful supply, rapid melting of roof-snow quickly clears the roof of snow – with only a gutterful or eave-line of ice and icicles.

Such roofs flow fast and furiously; roof-snow disappears initially at the ridge, next from the mid-run, and last from the eave. "Old heat wasters" flow comparatively rapidly and copiously with snow-water; their roofs clear of snow more rapidly than do neighboring moderns; snow-water penetrations are of comparatively short duration; and massive eave-ice may be all that remains of the roof-snow until the next snowfall.

Roof-Snow Performances on Modern Houses

Roof-snow blanketing on modern houses, in contrast with "old heat wasters," melts slowly; beneath the cover, water pools may threaten penetration into the house for periods of weeks or months in the snow/cold of the upper midwest.

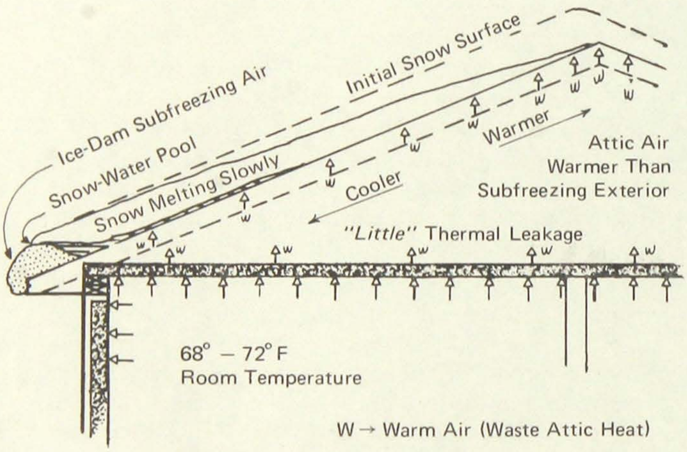


Figure 14. Schematic representation of thermal influences on roof-snow melting of modern (contemporary) houses.

Modern houses, as a type apart from the old heat wasters, are generally considered adequately insulated and ventilated since they meet contemporary standards, codes, and recommendations.

With codes usually stated as minimums in thickness (or R-factor), builders tend to insulate (and ventilate) close to the minimums to keep building costs competitive. Few houses, other than those specified for electric heat, have more than the minimums. Generally, there is an unquestioning public acceptance of the minimum standards as "adequate."

Residential areas are dominated by "old heat wasters" in older communities and by many "adequately" insulated and ventilated moderns in the newer developments. Roof-snow melting may be observed as fast and furious for "old heat wasters"; in contrast, modern houses melt roof-snow with comparative slowness, greater deception, and often more insidious damages. Simply increasing insulation will not stop the flow of waste heat into attics; insulation will only slow the movement of thermal energy to economic and ecologic levels of acceptance. Warm, if not hot, attics are an undesirable characteristic of millions of "modern" American homes.

Thermal movements and concentrations for moderns are represented schematically by the arrows in figure 14. Compared with the "old heat wasters," there are fewer arrows of heat passing through the ceiling into the attic. Because insulation only slows heat escape, some waste heat passes into the attic air in contact with the roofdeck. With less heat entering the attic, there will be less intense heating of the roof; indeed, if heat escape is very slight because of generously insulated ceilings, only slight warming of the roofdeck may be expected. However, with present attic venting standards, the roof is often warmer than the freezing atmospheric air; imperceptibly slow and intermittent melting of the underside of the snow blanket will (and does) develop roof snow-water that persists and threatens roof penetrations for periods of several weeks or months.

Roof-snow melting of modern houses will usually initiate near the ridge where the thermal concentrations of the attic create the warmest gradients. Streetside observations reveal these thermal gradients in the sagging patterns of roof snow-blankets. Ridge-snow, melted by the warm roofdeck, will flow downroof under the insulative snow-blanket to freeze into ice – either at the edge of the roof-snow blanket with the subfreezing air or where the roof thermals will not maintain the liquid flow. Roof snow-water may sporadically freeze and thaw as it progresses downroof to eventually emerge from the snow-cover where it meets the sub-freezing cold air, solidifies, and grows into massive ice-dams with blocked snow-water pools immediately uproof. With long periods of formation, snow-water pools, and potential penetrations, modern houses are more prone to severe damages from snow-water than are the icicle-trimmed old-timers.

The sagging roof-snow pattern of figure 15 demonstrates the effects and locations of thermal gradients on this 1962 house. Differences in melting actions as delicate as the shingle pattern are evident. The deeper snow along the rake and eave cornices is a result of cool roof projections beyond the attic heat supply. The eave ice-dam, with its probable snow-water pool immediately uproof, is topped and protected with an insulative snow-cover along the 24-inch eave projection.

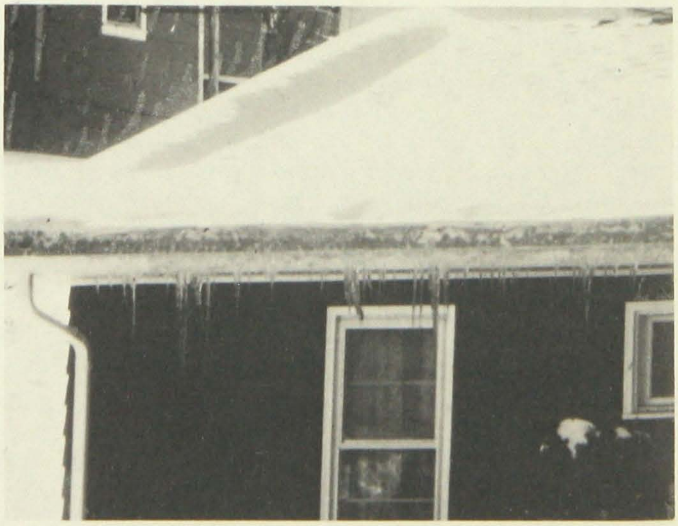


Figure 15. Telescopic lens photo of shrinking and sagging roof-snow on a modern (1962) roof.

Thermal patterns on this roof are somewhat more pronounced than are many contemporaries, but the roof-heat pattern is characteristic for houses built under minimum standards.

Observations attest to this slow, deceptive, and insidiously penetrating attack by roof-snow on "adequately" insulated, and even on electrically heated, houses. The problems of roof-snow melting and its damages can be seen on almost all buildings: the older poorly or non-insulated houses and on moderns complying with the latest insulation and ventilation building codes and standards. Contemporary specifications may provide only illusions of adequate protection.

Ice-dams and snow-water damages occur on almost all homes, ranging from "old heat wasters" through modernized old timers and contemporary moderns to the thermally efficient electric heated homes: *all develop ice-dams,* either fast and furiously flowing with snow-water or slow insidious seepage for as much as 3 months duration. The roof performances can be visibly verified almost every year during February and March in the Twin Cities and in those recurring "hard" winters in Chicago's western suburbs.

The present emphasis (and sales promotions) of "thicker" insulation to offset the inflating costs of residential heating should be considered in relation to ice-dam formation. If energy conservation is limited to only greater insulation depths (and R-factor improvements) without recognizing and considering roof-snow behavior, *sidewall soaking and related damages can be expected to intensify* to epidemic proportions, possibly more confusing and devastating than the scourge of baffling sidewall degradations of the 1930's and 1940's.

These explanations of roof-snow behavior ranging from old heat wasters to the "adequate" moderns are intended to stimulate thought and consideration of roof-snow actions; they are also essential for a fair appreciation of the extent of this wintertime scourge of the snow-country where *almost no contemporary dwellings are immune to roof – snow – water damages.*

Observations and recognition of roof-snow actions on contemporary housing point to an appalling inadequacy in present standards and lack of building industry response to this neglected misperformance of snow-country buildings.

THE COLD-ROOF CONCEPT OF EAVE-ICE PREVENTION

Roof-Snow Behavior on a Cold-Roof

Elimination (or control) of undesirable attic heat suggests a fundamental approach to eave-ice prevention; in essence, the object is to develop inexpensive cold-roof houses.

The effectiveness of cold-surface snow behavior to avoid massive ice formations is exhibited everywhere in winterized snow country. There are no massive ice formations on felled timber, rock outcrops, woodpiles, picnic tables, sheds, patios, marquees, and *unheated buildings!*

Cold-surface reaction to covers of snow is the way nature confronts and directs orderly melting and dissipation of snow. Ice may accumulate as glaciers from snow-packs or snow-water accumulations; however, generally, *nature is not troubled with ice-dams.* Man, with his heated constructions, has created the monster, and as we errant humans are so often reminded, "It is not nice to fool Mother Nature!"

Examination and interpretation of an idealized cold-roof performance should prove helpful, encouraging thought and action for practical application and adaptation of the cold-roof principle of eave ice-prevention. Such an ideally functioning house is illustrated in figure 16.

Continuous removal of attic air to maintain the roofdeck at atmospheric air temperatures requires minimizing the amount of heat entering the attic, together with a scavenging free movement of air from eave inlets to uproof (ridge) outlets. The small thin arrows in figure 16 illustrate escaping room heat passing sluggishly through the insulated ceiling. Arrows are few because heat loss of this very efficiently insulated house is minimal compared to the conventional modern house of figure 14.

In this idealized sketch, none of the heat arrows contact and warm the roof. When comparatively insignificant amounts of heat are lost through the well-insulated ceiling, the expansion of the warmed attic air causes it to rise slowly and be swept out the ridge vents by the natural flow of air from eave to ridge. Incoming atmospheric air flowing under the roofdeck keeps the roof cool.

For an ideally functioning cold-roof house, the snow-blanketed roofdeck will be maintained near the atmospheric temperature; the roofside of the snow-blanket will remain frozen during cold weather; on warm (or sunny) days, roof-snow melting will progress from the exposed atmospheric side of the roof-snow blanket.

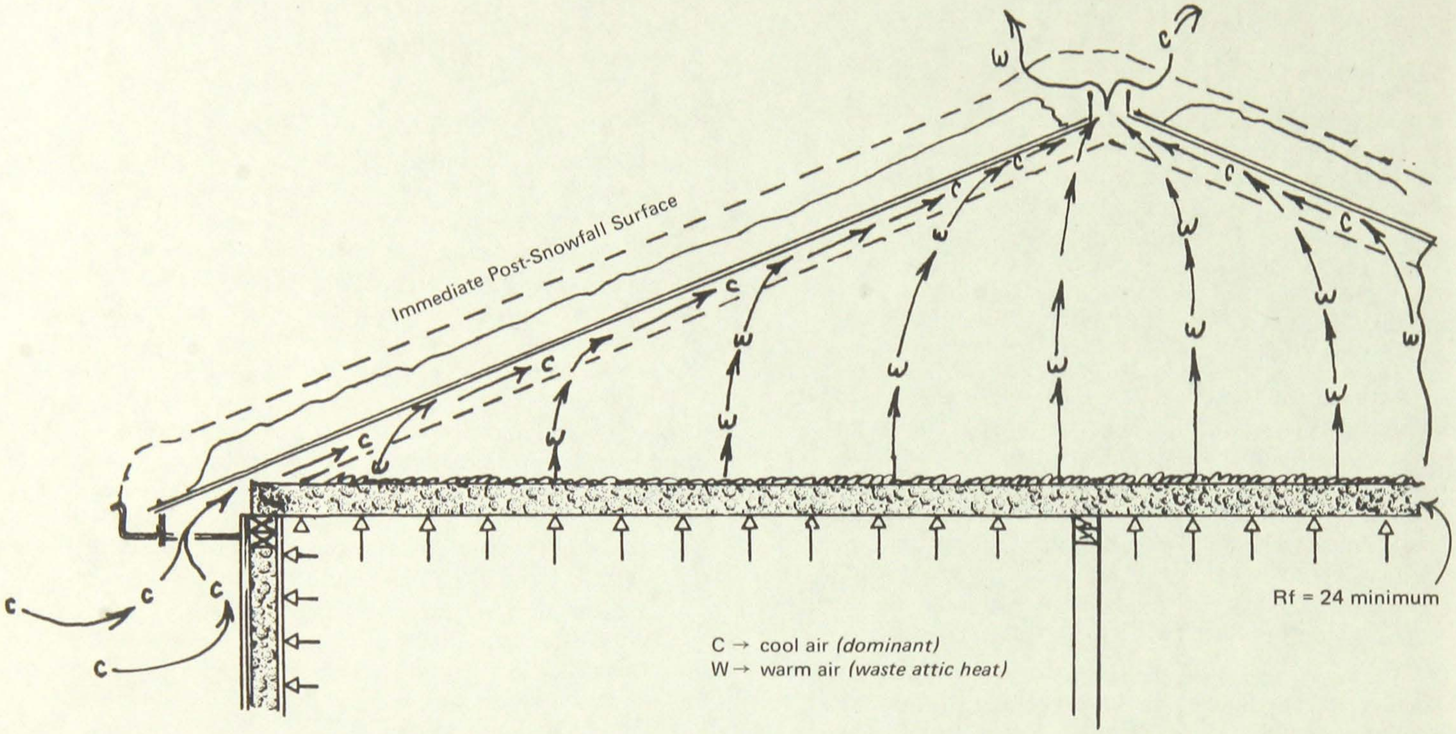


Figure 16. Schematic representation of roof-snow melting behavior on a cold-roof house.

Cold-Roof Performance in Warm Climates

The performance and desirability of cold-roof designs for warmer climates and for *better summer characteristics* should be recognized; cold-roof technology should be made available for all homeowners.

Because of this paper's concern for and emphasis on roof-snow, the full performances and benefits of cold-roof house construction may appear beneficial and limited to only deep snow-country buildings.

Attic heat buildups are possibly more undesirable and uneconomical in summer than they are in winter. The cold-roof design, with its attic air-sweep of air, merits its adaptation to all climates.

Attic air temperatures build to the 140-150°F. range under the hot summer sun. With a room cooled to 75°F. and the attic at 150°F., the heat flow impact is equivalent to the typical winter conditions of the room at 72°F. and the attic at -3°F. The need for generous insulation to slow the heat flow is easily recognized. For both summer comfort and air-conditioning (cooling) energy conservation, sales promoters urge homeowners to purchase attic exhaust fans.

Electrically operated exhaust fans consume energy in their operation to conserve energy. Designed cold (atmospheric) roofs flush out the rising (expanded and lightened) air in the free air-flow movements from the lower eave inlets to higher ridge outlets.

No energy-consuming exhaust fans are needed in the cold-roof attics in the summer, either in the north country or in the hot deep-south.

Unique Characteristics of Cold-Roof Snow Patterns

Roof-snow disappearance patterns display sharply contrasting differences between cold-roofs and others; these contrasts provide visible evidence of a cold-roof performance; on cold roofs, the edges are the first to melt, and the center of the blanket is the last to disappear. Roof-snow disappearance patterns provide a convenient means to evaluate thermal gradients on subject buildings and for monitoring the effectiveness of cold-roof conversions.

Figure 17. Residual snow pattern on a cold-roof house specifically designed for ice-dam immunity.

The snow on the roof of the cold-roof house of figure 17 is in a midroof pattern that is in sharp contrast with most (occupied) residential buildings. Notice the rake areas have cleared, and the eave edge is also free of both snow and ice; snow-water drainage has been as free-flowing and orderly as the run-off of rains. This performance can be better appreciated in its contrast with the roof-snow pattern of figure 15 where attic-warmed ridge and midslope areas melt first, the cooler rake edges follow, and the eave-ice persists in its drainage-blocking action until it, at last, melts.

Detection of cold-roof efficiencies in roof-snow patterns

The distinctive patterns that develop as roof-snow dissipates provide a convenient way to recognize and evaluate a subject roof's characteristics in eave-ice resistance.

The sketches illustrating three types of melt patterns developed from the snowfall of figure 18 are shown in figures 19, 20 and 21. These three house types relate to an "old heat waster," a modern, and a cold-roof. These roof-snow patterns may be correlated to the melting performances earlier described for these three characteristic types of residential housing.

A properly functioning cold-roof can often be visibly identified in the unique ruffling and eroding of the roof-snow edges into the peculiarly concave shapes indicated in figure 21. Cold-roof snow edges at ridge, rakes, and eaves contrast revealingly with the convex eave and rake edges of roof-snow on almost all contemporary buildings.

When there is no attic (or under-roof) heat to melt the snow-cover from its underside, the snow-blanket on the cold-roof will dissipate initially and progressively from the exposed edges at ridge, rakes, and eaves.

ROOF-SNOW PATTERNS

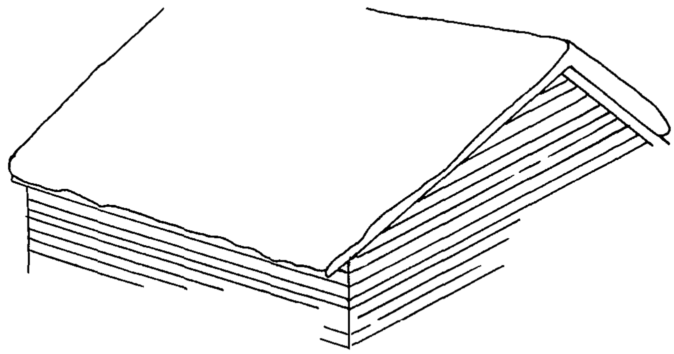


Figure 18. Typical post-snowfall pattern.

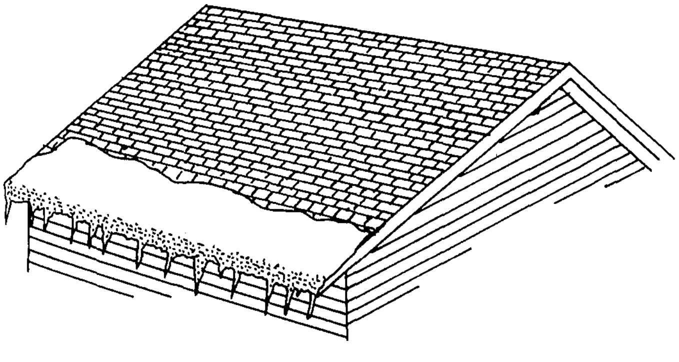


Figure 19. "Old heat waster" after a few days.

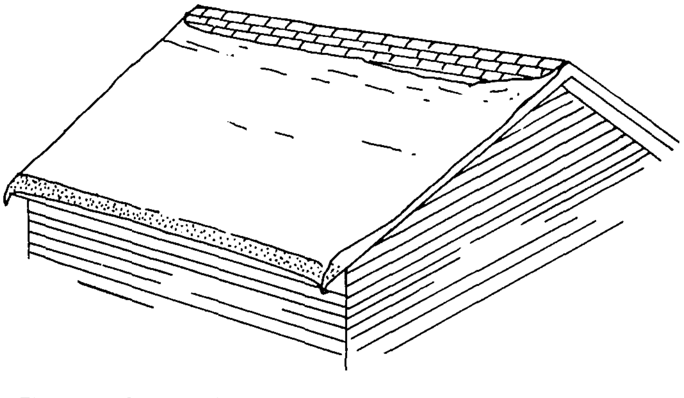


Figure 20. Modern after several days or weeks.

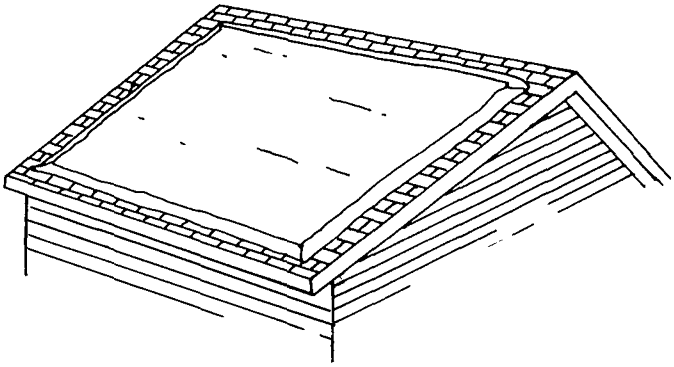


Figure 21. Cold-roof house.

On a cold-roof, snow melting and compacting is accompanied by wind actions that activate blow-offs, sublimation, evaporation, melting, and a generally orderly free-flowing dissipation and drainage at the greater surface exposure of the edges.

Deep roof-snow has long been recognized (and proclaimed in insulation promotions) as an indicator of well-insulated houses. Unfortunately, the depth of snow accumulations does not indicate the combined, or balanced, efficiencies of insulation and ventilation.

How roof-snow "shapes-up" after a period of exposure to winds, sun, and interior heating energy will provide a simple means to evaluate the insulation-ventilation characteristics of any subject house or building.

As you look for the characteristic edge dissipation patterns of cold roofs, you will find almost none on contemporary housing, UNLESS you chance upon a residence where the occupant has vacated and the house-heat is cut back or off.

Simple visible verification of most of the observations and comments of this paper may be monitored in roof-snow patterns, especially in *late* winter.

With reasonable recognition of the erratics and complexities of wind-drifted snows, interpretations of roof-snow behavior should prove stimulating and productive.

EAVE-ICE PREVENTION TECHNOLOGY

Basic Guidelines

The fundamental concept of a cold-roof is quite simple: adaptation of the basic guidelines to new construction, and to existing buildings, may be accomplished with *apparently* little more than these two modifications of conventional residential construction:

1. *Insulate* room ceilings far more than customary to minimize heat losses and attic temperatures.
2. *Ventilate* profusely at all eaves and ridge for a natural flow of air to sweep out the warmed attic air.

Limitations, Exceptions, Difficulties, and Solutions

Earlier in this publication, better eave and ridge venting was suggested, as well as improved insulation for homes. Such broad suggestions, like our basic guidelines, may be technically profound, but of dubious practical value without further explanations of the details and problems of their applications.

The *apparently* simple application of the basic guidelines for eave-ice prevention may often be difficult, sometimes less than fully satisfactory, and downright impractical for a few building types.

The cold-roof concept is simple; its applications are complex.

The following discussions on the complexities of eave-ice prevention technology are not intended to discourage corrections. The difficulties are described and the limitations are interpreted to *prevent misapplications* and possible disillusions with the effectiveness and widespread adaptability of *competently installed eave-ice constructions and corrections.* Cautious homeowners should be aware of these difficulties and limitations so they may judge applicator capability as well as the quality of the completed application.

The trouble with insulation

"If a little is good, more is better." Certainly this phrase has its limits of judicious application, but in present standards (and existing installations) of ceiling insulation, much, much, *MUCH MORE* will be better for 99+ percent of residential housing; this is especially important if attics are to be properly vented and eave-ice is to be prevented.

Apologetic marketing of ceiling insulation still persists since the early introductory sales of the 1930s when the additional expense of an unfamiliar item met "dubious-buyer" resistance. Justification and redemption of insulation costs through amortization of "additional outlays" has, until the recent energy conservational promotions, limited installations of ceiling insulation to little, or no more than, the Federal Housing Authority (FHA) minimum standard specifications.

No stipulations of the amount of insulation (or louvering) can be recommended *as sufficient,* partly because of the innumerable variables in residential designs and requirements, but mostly because there should be no interpretation of such a stipulated "sufficiency" that might inhibit an owner's urge to "really insulate (and ventilate) the house!"

A homeowner might be satisfied that he has accomplished all that is feasible in ceiling insulation when room to attic heat losses are reduced to the level required for efficient electric heating. Such quality of room heat retention is in harmony with the needs and promises of contemporary promotions for energy conservation.

Budget-strapped homeowners may be somewhat reluctant to purchase these "extra" insulation improvements, but the savings in energy outlays alone should not be difficult to appreciate in this era of runaway fuel costs. The savings available through prevention of snow-water damages may be more indirect and difficult to foresee; however, coupled with the fuel savings, *"maximum" insulation can be doubly rewarding!* This may mean that as much as 10 to 12 inches of insulation should be applied in attic areas; *AND it must be intelligently and carefully installed.*

Building code specifications usually specify the insulation requirements in terms of "*Minimum* Standards". Cost-conscious builders, under the pressure of price competition, tend to supply the bare minimum. Of course, additional insulation may be purchased, and there are many high-grade installations by quality builders; proof of these "quality jobs" can be observed in deep and winter-enduring roof-snow that melts and converts very, very slowly into ice-blocked eaves. Unwittingly the quality conscious builder or owner *rarely matches the adequate insulation with a comparable maximum of ventilation.*

Much contemporary residential construction barely meets minimum building codes; in many cases, houses are deficient not only in "thickness" or R-factor (that is, resistance to heat loss), but in addition, ceilings are prone to numerous voids and discontinuities in the protective insulation.

Builders often pay too little attention to the care with which insulation is installed. Continuity of the protective ceiling blanket is frequently interrupted by bridging, wires, recessed ceiling fixtures, scuttles, stair-entrances, and a variety of occupant actions such as careless attic storage, TV, Hi-Fi, and associated attic uses and mis-uses.

Extremely conscientious ceiling insulation application and care must not be considered trivial; cold-roofs for eave-ice prevention cannot tolerate the flaws, voids, thin spots, and discontinuities that are frequently associated with present construction practices.

Seldom considered and rarely examined attic spaces are too easily disregarded, ignored, forgotten, and neglected! *At least biennial inspections of ceiling insulation should be a maintenance routine;* sagged, compressed, wetted, blown-out, disturbed, or other diminished insulation should be located and corrected. Energy conservation programs may suggest your concern for insulation efficiencies; cold-roof ice-prevention *demands* it!

Disruptions in the ceiling insulation are costly not only in wasted room heat, but also because such flaws lead to roof hot spots that develop intensified localized roof-snow melting. Such hot spots are sometimes identified by spot shrinkages in the snow and related ice-dams downroof at the eave. An attic door or scuttle inadvertently left open may be revealed in the sagging snow-pattern on the roof.

Uninsulated chimneys (furnace flues), gas vents, bathroom, kitchen, clothes dryers, and any other warm exhaust equipment may contribute to a troublesome supply of attic heat; some pipes may have to be re-routed, and all of such attic heat contributors should be carefully wrapped with effective insulation. Eave-ice prevention technology requires MINIMIZATION OF ALL ATTIC HEAT SOURCES!

"Reading" roof-snow patterns to reveal insulation defenses of houses is as easy for the trained ice-prevention technologist as "reading a pass defense" is for an all-pro quarterback. The insulation picture blurs for ice-prevention analysts only when extremes of attic ventilation are encountered. Because almost all contemporary houses are vent-specified for *no more than minimums for vapor removal,* streetside observers will find properly vented houses extremely rare.

Ventilation problems

Some building owners may find it necessary to dispel the notion that attic heat is an asset to be retained. Perhaps such misconceived reverence for attic heat was reasonable in early dwellings before insulation was available to slow escaping room heat to insignificant heat losses.

Anyone who has endured the discomforts of an uninsulated summer resort or motel cabin where sleep was delayed until early morning (when the overly abundant attic heat had dissipated) can appreciate the importance of ventilation in preventing attic heat buildup in summer; prevention of eave-ice with cold-roofs and cold attics demands a similar ventilation removal of attic heat in winter.

Builders and homeowners reluctant to accept ventilator-to-ceiling-area ratios of 1/900 to "as much as" 1/250 may be shocked with cold-roof designs demanding infinitely greater louvering – both in size, number, and distribution.

Standards in venting specifications, such as those quoted for attic vapor control, are both inadequate and meaningless in eave-ice prevention. Roof shapes, cornice styles, and appearance esthetics restrict many installations; available positions for louver distribution may limit ideal venting. Some cold-roof installations may have to settle for less than maximum ventilation; ice-prevention performances may, therefore, be proportionately less than fully effective.

Louver products of various types and shapes are presently available for venting both eaves and ridges.

Triangular gable louvers may be satisfactory for vapor dissipation if they are large enough and if they are strategically placed to utilize wind or air currents; seldom are gable louvers suitable for development of the eave-inlet ridge-outlet patterns of air-wash required for a properly functioning cold-roof.

Pitched bonnet-type roof vents, either powered or gravity exhausting, are seldom used in sufficient quantity and distribution to achieve the blanketing air-wash needed for complete cooling of the roof-surface.

Rectangular soffit louvers, circle-spot louvers, and alternated perforated soffit panels usually limit the eave inlets to less than desired inlet free-air venting and distribution. Generously perforated soffit materials may promote embarrassing wind-blasting of insulation. On house designs of little or no cornice projection, there is little or no room for soffit louvers; a proprietary dual-walled fascia (19) has been developed and effectively tested for such soffitless house designs, but the product is not commercially available.

Strip louvers on ridge and eaves are the simplest products for securing a good distribution of eave inlets and ridge outlets. Most ridge strip louvers are apparently designed to be unobtrusively small to avoid affronts to residential esthetics in styling. Such size limitations may leave much to be desired in deep-snow country where such ridge venting may become submerged and plugged by deep snow.

Because the naturally rising action of warming air generates eave-to-ridge movements for cooling roofs, the stack effect of cupolas and chimneys may find greater adaptations in future ice-prevention designs; a simple corbelling of the brick chimney as it passes through the attic can supply additional attic-venting flues and also contribute to the balanced appearance of a massive chimney emerging from the roof-ridge. Such stack actions, integrated with free distribution of eave inlets in soffit or fascias, effectively assure cool attics for summer comfort and cold-roofs for winter ice-prevention.

There appears to be a challenge for creative designers in the development of innovative devices for venting roofs for ice-prevention in harmony with the esthetics of acceptable appearance. Perhaps the multiple roof attractions of Chinese and Japanese structures may find a justifiable place in American home designs.

The watchwords for venting attics, as with ceiling insulation, is simply: *"you can only install too little, never too much!"*

And yet under certain *careless insulation practices,* it may, at first, appear that there is too much ventilation!

Too much venting?

Where insulation is not carefully fastened or protected near the eaves, strong wind-blasts through freely vented eaves may blow insulation away to expose room ceiling areas to the attic's winterized temperatures. When the bared ceiling areas drop below the dew point or freezing point, those ceiling surfaces will develop wetted, stained, and frosted ceiling spots where room moisture has condensed on the cold ceiling areas.

When insulation has been blown backward from the plateline area, you commonly encounter a very infuriated housewife, a bewildered builder, and a workman that has been ordered by the builder to "stuff the stuff along the platelines" to block recurrent wind-blasting of the plateline insulation. The builder blames the unhappy situation on the designer who "uses too much ventilation" and attempts to assure the hostile housewife that "nothing like this will happen again!" No, it won't happen again when the venting is all but completely choked off, but it won't be long before the "ice-dam cometh" on the eave again, *again,* and *again!*

Is the blunder of insulation blow-outs due to "excessive" venting, or is it due to careless insulation application? If eave-ice prevention is an objective, there is no doubt that insulation must be more carefully positioned, and perhaps fastened, than has been customarily practiced by the building trades.

Restricted plateline gaps

The plateline region has been misunderstood, unrecognized, or ignored by many builders as a critically vulnerable region for heat-loss as well as a restricted passage that almost always limits and often inhibits air-flow from eave inlets to uproof outlets.

Exterior wall-to-ceiling corner joints are characterized by unavoidable cracks of: doubled plates; exterior sheathing edges; lath or wallboard joints at the interior corners; and usually *ceiling insulation that has been terminated at the platelines.* Wall insulation tends to sag beneath the plates and loses both its effectiveness as an insulator (and possibly its positioning) when moisture from condensate OR BLOCKED SNOWWATER wets and soaks the sidewall insulation. Thermographic analyses disclose exterior platelines as major heat loss areas. The state of the art of residential design, construction, and research indicates gross neglect of this critical heat-loss region. Excessive heat losses at the exterior platelines also contribute to snow-water penetrations by supporting the liquid pool immediately over the plates. Quality construction calls for consideration, reduction, and preferably elimination of the plateline heat concentrations.

The exterior platelines require more and carefully positioned insulation; they must also retain spaces for a free flow of air past the usually restricted gaps above the plates. Such a dual requirement appears to produce an impasse for the majority of homes where the roof-pitch, rafter-heel-cut, and sheathing allow less than 6 inches of clearance – often as little as 3½ inches.

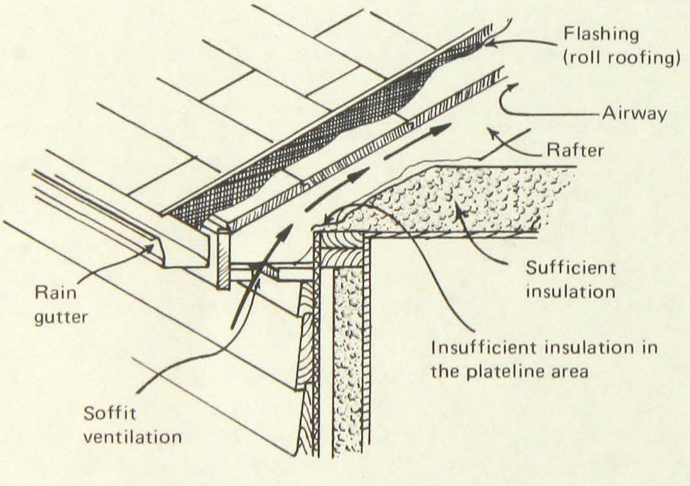


Figure 22. The plate-gap (as FPL Report (6) shows it).

The plateline gap difficulty is sketched in figure 22 as it appeared in a recent publication (of the Forest Products Laboratory, Madison, Wisconsin). Notice that free air-flows are indicated, but at an unfortunate sacrifice of insulation that was probably not intended. That sketch not only helps illustrate the restrictive nature of such exterior platelines, but it also demonstrates that the state of the art recognizes the NEED for adequate air flow into attics, but *has failed to explain HOW such essential airflow and insulation can be accomplished!*

The sketch of figure 23 illustrates a solution for compromising the restricted passages between *air-flow demands* and *insulation optimums.* The proprietary product (20) called "Air Passage Protector," is not commercially available.

Bridging the plateline gaps

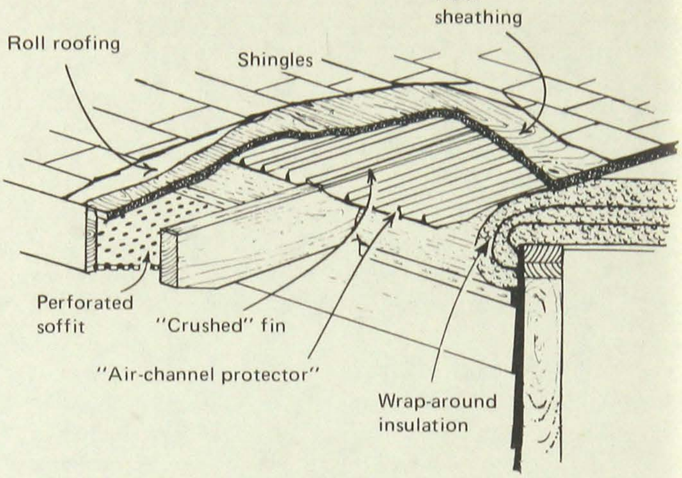


Figure 23. Sketch of plate-gap with "air passage protector" in position between sheathing and wall plates.

Figure 24. Workman applying air passage protector along eaves.

New construction applications of this air passage protector add little to labor costs. Placement requires only positioning. The subsequently fastened sheathing holds the roll on to the rafters with the fins upward; the resilient insulation inserted beneath it support and force it upward against the sheathing, but is limited by the fins to assure air channels of fin depth between the insulation and the roof sheathing. Any fin on a rafter is simply crushed as the sheathing is nailed.

Positioned tightly between the sheathing and insulation, the spaced-fin roll not only creates and assures air channels at the restricted plateline gaps, but also serves as an interior flashing to help protect this leak-prone eave-zone from inadvertent roof-leaks above it.

With little additional labor cost, the roll-out-on-rafters procedures may be used on existing houses about to be reshingled. Often, especially where there has been a history of ice-dammed snow-water on the eaves, the weak and rotted roof sheathing should be replaced; the roll-out-on-rafters installation of the plateline air-passage protector (and flashing) material can be accomplished as simply as in new construction.

Where reshingling is not needed on an existing dwelling, the insulation baffles may be prepared as finned *panels* sized for simple insertion *between* the rafters to bridge the plateline insulation. Such insertions may be made from the attic where that approach is feasible, or from ladder or scaffold along the exterior with the fascia removed for direct access to the plateline gaps.

PROVEN COLD-ROOF PERFORMERS

Existing houses which have been corrected for ice-dams offer convincing proof of the effectiveness and practicality of the materials and methods developed to convert roofs decked with thermal gradients into cold-roof performers. Proof of performances of these developments can be observed on a few houses in southwestern Wisconsin that were planned and constructed to perform as cold roofs. Most of the owners are unaware of the unique eave-ice protection built into their homes.

Figure 25. Well-insulated house built in 1933 with its almost annual eave-ice-dam.

Figure 25 is a photo of a Colonial-type house constructed in 1933; it was generously insulated (even by today's standards). It has no vapor barriers; it had a thirty-nine year history of blistered and peeling paint; it has also been decorated with eave ice-dams almost every winter until 1972.

In the summer of 1971, the house in figure 25 was converted (with the materials and methods described in this publication) into a cold-roof house. Since the correction was made, the house has had no eave ice-dams.

Figure 26. The house of figure 25 after its modifications into a cold deck performer.

Converting the house of figure 25 into a cold-roof performer not only eliminated the eave ice-dams, but altered the roof-snow melting pattern, as may be seen in figure 26. Notice the roof-snow edges at both rake and eave exhibit a ruffled concavity where wind actions have initiated roof-snow dissipation and removal. This house now sheds both rain *and snow-water* in an orderly drainage.

One of the most interesting "conversions" has been performed on a contemporary house distressingly troubled with ice-dammed snow-water. After corrections were made in late December, the snow-water penetrations stopped, *ice-dam growth ceased,* and by late February, the ruffled concave eave pattern (characteristic of a cold roof) was evident and reassuring of the effectiveness of this rare, and not normally recommended, midwinter correction.

Detailed observations and comments of these and other "case history" performances in these developments have been logged in several audio-visual reports. The audio-visual presentations have been prepared for training installation personnel in the whys, wheres, whens, hows, and how-nots of the practical application of ice-prevention technology.

Figure 27. A house planned and constructed for cold-roof performance, but without the expense of the double roof structure.

BIBLIOGRAPHY

1. "An Introduction To The IDP Rating." A survey and analysis of "Tough Winters" at twenty-five stations over five years – 1967-1971. By Howard L. Grange, R.P.E. An unpublished report of *I*ce-*D*am-*P*otential.
2. "Audio-Visual Reports For Tape-Color Slide Review and Presentation" by Howard L. Grange, R.P.E. Personal papers and audio visuals prepared for consultation and teaching the methods and materials of Ice-Prevention Technology.
3. "Comparative Study Of The Effectiveness Of Fixed Ventilating Louvers" by H.S. Henrichs. A report for HC Products Co., Princeville, Ill. 61559.
4. "Condensation In Farm Buildings" by L.V. Teesdale, Engineer, Forest Product Laboratory. Information Reviewed and Reaffirmed January 1956 FPL No. 1186.
5. "Condensation Problems In Modern Buildings" by L.V. Teesdale, Engineer, Forest Products Laboratory Report for presentation before Conference on Air Conditioning, University of Illinois, March 8-9, 1939.
6. "Condensation Problems: Their Prevention And Solution" by L.O. Anderson, Engineer, Forest Products Laboratory, Forest Service, U.S. Department of Agriculture. Research Paper FPL 132, 1972.
7. "Home Builder Says Ice In Eaves May Cause Roof To Leak" by John Newhouse in Wisconsin State Journal, newspaper article of January 3, 1970.
8. "Insulation: Where And How Much" by Laurence Shuman. Technical Reprint Series No. 4 from HHFA Technical Bulletin No. 3 (March 1948) Housing and Home Finance Agency. From Supt. of Documents.
9. "Local Climatological Data." United States Department of Commerce, National Oceanic And Atmospheric Administration, Environmental Data Service, National Climatic Center, Federal Building, Asheville, N.C. 28801.
10. "Moisture Condensation" by Frank B. Rowley, Director, University of Minnesota Engineering Experiment Station; University of Illinois Bulletin, Vol. 44 No. 34, Jan. 27, 1947. Issued by The Small Homes Council Circular Series Index Number F6.2.
11. "Remedial Measures For Building Condensation Difficulties." Original reported dated September 1947, written by L.V. Teesdale, Engineer, Information reviewed and reaffirmed August 1962, Forest Products Laboratory Report N. 1710.
12. "Save Your Home From the MENACE OF MOISTURE." A pamphlet issued by the National Paint, Varnish, and Lacquer Association, Inc.
13. "Snow Country Design" by Ian Mckinlay, A.I.A. and W.F. Willis. R.P.E. procured from Mackinlay/Winnacker AIA & Associates, 5238 Claremont Ave., Oakland, Ca. 94618 for nominal fee.
14. "Some Construction Defects Which Permit Water To Menace Homes." Circular 763, issued October 1953 by the Scientific Section, National Paint, Varnish, and Lacquer Association, Inc.
15. "The Wald-Way System of Component House Construction" by Howard L. Grange, R.P.E. The book is a licensed private communication.
16. "Thermal Insulation Made Of Wood-Base Materials, Its Application And Use In Houses" by L.V. Teesdale, Engineer, Forest Product Laboratory, Revised October 1958, FPL No. 1740.
17. "Understanding The Mechanisms Of Deterioration Of House Paint" by F.L. Browne, Forest Products Laboratory. Reprint from November 1959, Forest Products Journal (Vol IX, No. 11).
18. United States Department of Commerce Weather Bureau Map and Data "Mean Monthly, and Annual Total Snowfall (inches." U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Federal Building, Asheville, NC 28801 *"Taken from the Climatic Atlas of the U.S."*
19. "U.S. Patent #2,797,180 'Ventilated Roof Construction'" Howard L. Grange, Inventor. Canadian Patent #949718.
20. "U.S. Patent #3,683,785 'Roof Construction Providing Air Flow From Eave to Ridge'" Howard L. Grange, Inventor. Canadian #995,869.
21. "Weather And The Hand Of Man." Environmental Science Services Administration Pamphlet of the Department of Commerce.
22. "What To Do About Condensation" by E.R. Queer and E.R. McLaughlin, Engineering Professors of Penn State College, a technical reprint from HHFA Technical Bulletin No. 4 (May 1948) of Housing And Home Finance Agency, Division Of Housing Research. From Supt. of Documents.
23. "Wood Decay In Houses and How To Control It." Home and Garden Bulletin No. 73, U.S. Department of Agriculture. From Supt. of Documents.
24. "Wood Handbook." Handbook No. 72. Forest Products Laboratory, Forest Service, United States Department of Agriculture. From Supt. of Documents.
25. "Wood-Frame Construction" by L.O. Anderson and O.C. Heyer, Engineers, Forest Products Laboratory, Forest Service, U.S. Department of Agriculture. Handbook No. 73; from Supt. of Documents.

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