VENTING OF BUILT-UP ROOFING SYSTEMS

Wayne Tobiasson
Cold Regions Research and Engineering Laboratory

The purpose of this paper is to discuss the objectives of venting the components of built-up roofing systems and to assess the effectiveness of current venting techniques. I contend that vents are often installed for the wrong purposes (e.g. to prevent membrane blistering and system damage by pressurization) and that venting is often ineffective.

Why vent a roofing system?
Vents are openings installed to allow air or a liquid to escape from somewhere. Roofing systems are vented to permit escape of moist air.

The components of roofing systems, notably insulation, are deteriorated by moisture (Refs. 2, 6, 7 and 12).

It is relatively easy to ventilate a cold attic below a gabled residential roof since a large air space is available. It is far more difficult to ventilate a compact roofing system (i.e. one where little or no air space exists between the components). The primary components of a compact roof are the membrane, the insualtion and the deck. A vapor retarder may also be present, usually on the warm side of the insulation (Figure 1).

For one or more of these components, venting might achieve some of the following objectives:

1. To permit release of moisture **during** construction.
2. To permit subsequent drying of a wet-applied component (Figure 2).
3. To prevent accumulation of moisture.
4. To remove moisture that has accumulated.

Venting can only achieve some of these objectives, and then only under certain circumstances.

What objectives can by met by venting of membranes?
The only valid objective of venting a hot-applied bituminous built-up membrane is to remove excess moisture on or in the felts during construction (i.e. Objective 1 above). Small amounts of moisture trapped within a membrane can result in blisters and other flaws that promote premature membrane deterioration. Many roofing felts are perforated to allow moisture to escape **during** hot mopping of the membrane plies. Newer permeable glass felts also allow for venting during construction.

FIGURE 2
Placing a wet-applied insulation (Photo from the Roofing Industry Educational Institute Collection).

There is no way that a built-up membrane "itself" can be vented to satisfy Objectives 2, 3 or 4 listed above. Consequently, if blisters develop between the felt plies, installing vents is not the solution.

What objectives can be met by venting of decks?
Steel, precast concrete, timber, plywood and most other

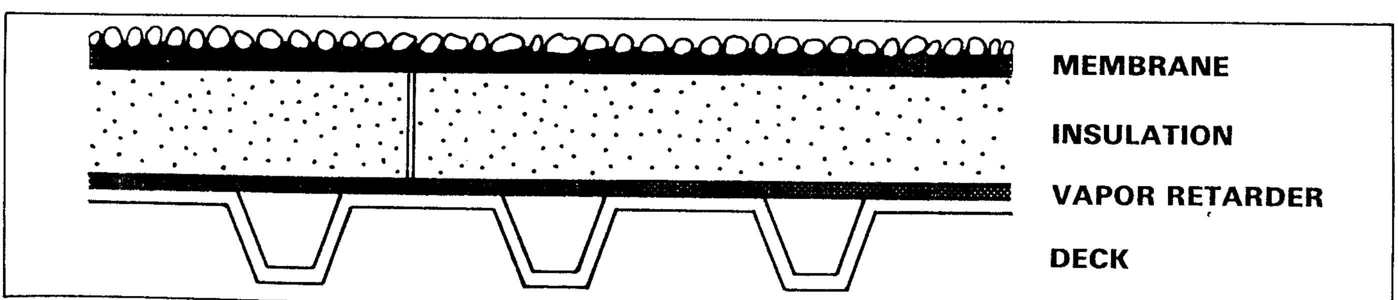

FIGURE 1
Cross-section of a compact roof.

decks are installed essentially dry. As long as these decks are not sealed on their bottoms, they will tend to stay dry by self-drying into the building below. Consequently, nothing can be gained by venting such decks during construction, or over a period of years.

"Green" cast-in-place concrete decks contain moisture that must subsequently be removed. However, most of that moisture escapes during the curing process prior to installation of the roofing system. The amount of moisture present in a cured concrete deck will usually be so low that it is of no great concern. Consequently, cured concrete decks seldom create moisture problems. They should not be sealed at their base since downward drying by evaporation into the air within the building is desirable. Concrete decks dry more slowly when cast or corrugated steel forms which remain in place. If roofing is applied to such a deck while it is still wet, and no vapor retarder is placed above the concrete, deck moisture may move upward into the insulation (perhaps wetting it).

Other wet-applied decks, such as concrete decks made with insulating light-weight aggregates, contain large quantities of water that may persist for a relatively long time. Roofing components are commonly placed on such decks while they still contain a lot of water. Slotted steel forms or moisture-permeable form boards allow downward drying on such decks.

If a bituminous membrane is to be placed directly above a wet-applied deck that still contains moisture, it should not be hot mopped to the deck. As the deck dries from below, shrinkage cracks are likely to occur. If the membrane is adhered to the deck, cracks may progress upward through the membrane. Consequently membranes should be spot adhered or, preferably, mechanically fastened to wet-applied decks that contain moisture.

Since it is likely that the membrane's bottom surface will sometimes be wet from deck moisture, a coated base sheet or other product not adversely affected by moisture is required there. In an attempt to dry wet-applied decks from their top surface, special venting base sheets have been developed. Grooves or granules on their bottom surface create air passages through which moisture can move laterally to the edge of the roof or to a breather vent where the bottom side of the base sheet is vented to the exterior. The bottom side of two venting base sheets is shown in Figure 3. Such sheets are mechaically fastened to the deck.

Because there is not much of a driving force for moving moisture laterally in a roof, I doubt that venting base sheets promote much drying. I have discussed this matter with several individuals and their collective field experience suggests that some lateral drying may occur. Nevertheless, I do not think it is appropriate to consider that vented base sheets will dry a wet material below. For most buildings in the contiguous United States, the magnitude of downward drying during warmer portions of the year greatly exceeds the upward wetting potential during colder portions. Consequently the annual tendency is to promote downward drying of a wet-applied material. Because of the importance of downward drying, vapor retarders or other seals should not be located **below** wet-applied decks.

Some individuals argue that a venting layer is essential above a wet material to avoid the creation of blisters in the membrane above. If the membrane is solid-mopped to the substrate but contains skips and other unbonded "holidays", blisters may develop. However membranes should not be solid-mopped to wet-applied decks as stated above. I see no possibility of blister formation **between** a mechanically fastened membrane and a wet deck.

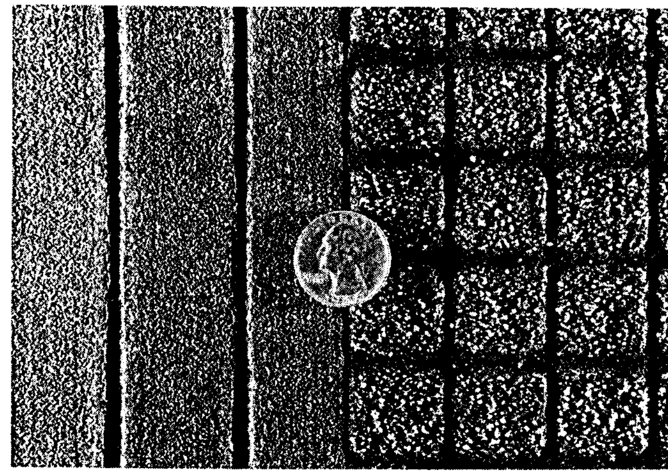

FIGURE 3
Bottom side of two venting base sheets.

If insulation boards are to be placed above wet-applied decks, a vapor retarder should be installed first to prevent moisture in the deck from migrating into the insulation. Vapor retarders (like membranes) should not be solid-mopped to wet decks containing moisture and their lower ply must be of moisture-resistant material.

What objectives can be met by venting of wet-applied insulations?

Wet-applied insulation begins to dry during installation (Figure 2). Since such insulation must be relatively dry to be thermally effective, it is imperative that additional drying occurs after a membrane is placed on it. As with wet decks, the most effective way to dry a wet-applied insulation is downward into the building. However, with a mechanically fastened venting base sheet as the bottom ply of a built-up membrane above, some drying from the top may occur. Again, it seems wrong to assume that a venting base sheet will allow a wet insulation to dry significantly. Consequently, it is wrong to seal the bottom of wet-applied insulation since most drying should occur downward from that surface. If, for some reason, the bottom is sealed, I doubt that a venting base sheet above will significantly dry a wet material over many years.

Is there a need to vent dry insulation boards during installation?

Recent problems associated with membrane blistering over urethane insulation (Ref. 11) indicate the need for venting above this material during membrane installation. The National Roofing Contractors Association suggests use of either a layer of fiberboard, perlite board or fibrous glass insulation or installation of "the base ply so as to allow for venting" (Ref. 9). Except for urethane, insulation boards do not require venting during installation of the roofing system.

Is there a need to vent insulation boards since they may inadvertently contain excess moisture when installed?

No insulation board is installed "bone dry," but the amount of moisture picked up from the atmosphere during shipment and storage should not adversely affect the performance of the insulation—providing, of course, that proper shipping and storage techniques have been used. If the insulation has been exposed to rain or stored above damp ground under an impermeable polyethylene wrap, it may contain excess moisture when installed.

During the summer, any moisture in insulation in most roofs tends to be driven down into the space below. Just as it is usually much easier to dry a wet-applied insulation from below, it is usually much easier to dry wet insulation boards downward into the building. Consequently vents are not needed for this purpose, provided that downward drying is possible.

A vapor retarder located below the insulation essentially eliminates downward drying. This is one reason why vapor retarders should not be used unless dew point-vapor flow calculations clearly indicate that they are necessary (Ref. 3). The National Roofing Contractors Association recommends considering vapor retarders in areas where the outside, mean January temperature is below 40°F **and** the interior relative humidity during the winter is 45% or more (Ref. 10).

Proponents of vents urge their installation in a roofing system containing a vapor retarder for the following reasons:

1. To rid the insulation of any excess moisture (not only installed moisture but any subsequently enters).
2. To prevent preassurization of the insulated space, which is sealed on the bottom and sides by the vapor retarder and on the top by the membrane.

Before the advent of coated base sheets and fibrous glass felts, the No. 15 felts used as the bottom ply of a bituminous built-up membrane could deteriorate from relatively small quantities of moisture that condensed on the bottom surface of the membrane and were absorbed by the felts. Membrane riding at insulation joints was often caused by moisture from below. Coated felts and glass felts are resistant to moisture, and their increased use in recent years has greatly reduced this type of problem. If moisture-susceptible felts are used as the membrane's bottom ply, it is important to prevent moisture condensation there. This is very difficult to assure. Rather than using felts that are moisture-susceptible, it makes far better sense to install membrane systems that can survive even if wet at their base. When a membrane can resist moisture attack from below, far more moisture can accumulate in the insulation at the membrane underside without creating serious roofing problems.

In some situations enough moisture accumulates in the insulation to create other problems: e.g., loss of thermal resistance, loss of strength, delamination, and susceptibility to freeze-thaw deterioration.

Condren (Ref. 3) discusses various moisture limit states and relates the need for a vapor retarder to the temperature and relative humidity within the building and the climate where it is located. He estimates the amount of moisture that will pass a vapor retarder during the winter and the amount of summer-drying potential to show that roofs (without external leaks) in areas as far north as Boston have ample ability to completely dry out during the summer. Quantitative guidelines as to just how much "winter moisture" various roofing systems can tolerate is lacking at this time. Research is certainly needed in this area.

Unfortunately, there is little evidence that wet insulation can be dried effectively by edge venting or by breather vents. Baker and Hedlin (Ref. 1) measured slow drying trends for various insulations in the presence of breather vents. Tests of various commercially available breather vents, so-called "breathable membranes" and edge vents have been underway in the backyard of CRREL since August 1979. Although it is still too soon for final conclusions from this work, no significant drying trends appear to be occurring for any of the specimens.

Infrared surveys I have conducted on roofs across the country over the past five years uncovered wet areas around essentially all breather vents encountered on roofs. Although not conclusive evidence, this experience does suggest that breather vents are not drying out wet areas as intended. Repeated infrared surveys some months apart and core samples for verification purposes have shown that in most instances, the size and moisture content of wet areas do not shrink. Slight drying trends occasionally have been noticed for fibrous glass insulation. This insulation is quite permeable and should be better able to rid itself of moisture than other insulations, since air can flow through it. However, it is not drying any better than perlite insulation in the controlled venting tests at CRREL. (Note, however, that few of those tests allow cross ventilation.)

Although some very slow drying of some wet insulations may be possible, I doubt that venting is an effective means of drying wet insulation. Since it is extremely difficult to dry wet insulation trapped between a membrane and a vapor retarder, it is critically important to install the insulation dry and prevent it from geting wet during its service life. That is easy to say, but hard to accomplish in our fallible "Murphy's-law" world. It thus seems prudent to assume that some wet insulation exists or will exist in most roofs sometime during the building's service life. Since air expands when heated, creating significant pressures on a confined space, particularly a moist, confined space (Ref. 4), the second reason for venting listed above (i.e. to prevent pressurization) is promoted by many individuals.

Pressurization of the air and water vapor within membrane flaws causes interply blisters, but venting the space below the membrane can have no effect on such pressures.

Frankly I am not too worried about pressurizing the space between the membrane and vapor retarder, because in our fallible world it is virtually impossible to build a perfectly sealed membrane-vapor retarder system. Current roofing practices provide many opportunities for pressure release, particularly at flashings and penetrations. Although the pressurization mechanism is there, it seldom has a chance to cause problems, since safety valves are inadvertently built into essentially all roofing systems. Evolution of new roofing systems and practices that eliminate these inadvertent safety valves could create pressurization problems, and some means of venting might be necessary to overcome them.

Since no membrane is perfectly bonded to insulation over its entire surface, some individuals are concerned that pressures, and therefore blisters, may develop where skips exist at the membrane-insulation interface. Only a few individuals say they have ever encountered a blister at this interface. I never have. Obviously a breather vent some distance from the unbonded spot would not prevent pressurization at the spot. A venting base sheet could, but current practice does not require one since there is little evidence of blistering at the membrane-insulation interface even though many roofs contain wet insulation.

If it is assumed that my "safety-valve" explanation is inadequate and pressure release is necessary between a membrane and a vapor retarder, some additional factors should be considered. Pressures cannot be sustained locally in fibrous glass insulation because of its high vapor permeability. Since all the edges of each fibrous glass insulation board are not sealed, it is unlikely that localized pressures could accumulate in individual boards. Therefore **if** it is necessary to vent fibrous glass insulation to avoid pressure buildup, only one vent should be needed for each sealed area rather than the recommended practice of one vent for every 10 squares of roofing.

Most other board insulations cannot release pressures created rather rapidly by the sun. For such materials the path of least resistance for pressure release probably involves the gaps between boards. Therefore it seems appropriate to install any breather vent so that it interconnects with insulation board joints rather than simply cutting it into the middle of a board of closed cell material. (I haven't figured out how excess pressure can get from a problem area to the network of seams, and this is one reason why an effective way of providing pressure release within most insulations still escapes me.)

Is there a need to vent insulation applied between a built-up membrane and a vapor retarder to avoid creation of a vapor trap?

No vapor retarder is an absolute barrier to vapor flow. (That is why the roofing industry favors the word "retarder" to "barrier.") Inevitably, some moisture will pass the retarder and enter the insulation. Since the vapor permeability of a built-up membrane is near zero, and therefore somewhat lower than that of the vapor retarder, a moisture trap may be created. By venting the insulation the potential vapor trap can be avoided.

Venting makes good sense for residential walls and ceilings where it is difficult to achieve vapor retarder continuity because of plumbing and electrical penetrations, etc. In such construction, air leakage paths are created, along which large quantities of moisture enter insulation that is often quite permeable. Ventilating these places is an admission of the adverse affect of air leakage (Ref. 8), and the difficulty of achieving vapor retarder continuity.

Things are different for compact roofs. Far better vapor retarders can usually be created and far fewer penetrations are encountered. Even when vapor retarder continuity is breached, the relatively low air permeability of roof insulation boards (fibrous glass boards excepted) inhibits lateral flow of moisture. Consequently, flaws in a vapor retarder are often not as harmful in compact roofs as for other building systems.

For most buildings in the U.S. that require vapor retarders, the moisture that enters a roof during the cold season has ample opportunity during the warm season to turn around and go back out the way it entered.

Vents tend to create air leakage paths that may cause more moisture to accumulate in the insulation than would accumulate if the insulation were tightly sealed on top (Ref. 1).

For textile mills, swimming pools, and other high humidity buildings located in very cold regions, the downward drying ability during warm periods may not be greater than the ability to wet roof insulation during colder periods. To avoid moisture problems in such buildings, they must be provided with very tight vapor retarders, so the amount of moisture that accumulates in the roof insulation during its service life is below acceptable limits. As an insurance measure it may also be wise to attempt to vent the insulation of such buildings. This might require a "breathable" membrane, a venting base sheet or fibrous glass insulation directly below the membrane. As stated previously, it is unlikely that such venting provisions will remove much moisture, but over the life of such a facility, venting provisions should help to keep the insulation dry if the vapor retarder is a good one. To achieve continuity for such a vapor retarder, it must be sealed to the membrane at all edges and penetrations. To use conventional vapor retarder techniques and an increased number of vents to prevent such problems seems wrong.

Compact roofs are more problematic in cold regions than in temperate areas. Years ago, after studying the textbooks, calculating vapor drives and such, I was convinced that inadequate vapor retarders were the main culprits. After surveying many roofs in cold regions with infrared cameras, I have been surprised to find that almost all wet insulation is caused by water that enters from the exterior through membrane flaws at flashings and penetrations. Vapor retarders are generally doing a good job of holding back internal moisture. Current vapor-retarder techniques and practices seem to suffice in most situations.

Many roofs built with such vapor retarders are not vented either at their perimeter or by breather vents of one sort or another. I have found no evidence of extra problems for such roofs. Consequently I find it hard to accept the NRCA recommendation that roofs with vapor retarders should have one, one-way breather vent for every 10 squares of roof (Ref. 22). This recommendation places vents about 32 feet on center all over the roof (Figure 4) and adds just that many more chances for flaws where **external** moisture (the biggest problem) can enter a roofing system.

Can vents dry out wet insulation?

As stated previously, there is little evidence to indicate that edge vents or breather vents can dry out wet insulation.

We have had some success using a shop vacuum cleaner

FIGURE 4
A roof containing numerous breather vents as recommended by current industry standards. (Photo from the RIEI collection.)

to remove liquid water from fibrous glass insulation. About sixty gallons of water were removed from a 180-sq. ft. wet area which dropped the average moisture content of the fibrous glass from 208% to 21% (dry weight basis). This increased the insulation's thermal resistance from 24% to 83% of its dry value, according to relationships presented by Tobiasson and Ricard (Ref. 12). We also drew heated air through the insulation by creating intake and exhaust holes within the wet area but this did not promote much additional drying.

Although there appear to be options for draining fibrous glass insulation, I understand that the glue that adheres the glass fibers is weakened by prolonged wetting. Consequently, while thermal properties appear to be recoverable, other important properties may not be. Double-drained roofs (Ref. 5) thus seem appropriate when fibrous glass insulation is used.

I have heard many glowing stories about how breather vents dry wet insulation. Further investigation, however, usually reveals that cessation of leaks is usually the only evidence that the breather vent did the job. Almost no before-and-after water content evidence is available. The few breather vent applications I have sampled were still wet, but patching of membrane flaws done in conjunction with the installation of the vents appeared to have prevented entry of additional water and thus stopped the leak. I expect that credit for solving such problems should go to the patch, not to the breather vent.

SUMMARY

Table 1 summarizes the information presented in this paper. The following rules of thumb are offered:

1. Bituminous built-up membranes should be vented during construction to allow excess moisture to dissipate.
2. Do not rely on venting above wet-applied decks or wet-applied insulations to dry them.
3. Allow wet-applied decks and wet-applied insulations to dry into the space below.
4. To make roofing systems less vulnerable to moisture problems avoid using moisture-sensitive materials for the bottom ply of a membrane.
5. There is no reason to vent the insulation of a roof lacking a vapor retarder. In fact, venting such roofs may do more thermal and moisture harm than good.
6. When a vapor retarder is required, focus money and efforts that might be spent on vents to improving the quality of the vapor retarder.
7. Do not expect to be able to encapsulate insulation in a vapor tight, pressurizable envelope. Consequently, do not worry too much about creating excess pressures within the roofing system (except within the membrane itself).
8. Do not expect to be able to dry out wet insulation in compact roofs by venting.
9. Some drying of wet fibrous glass insulation is possible by draining away water.

After discussing the venting question over the past two years with many individuals involved with roofing, I disagree with the widely held view that vents are needed when a vapor retarder is installed to keep a dry system dry and avoid pressurization. I do agree that it is very difficult to dry insulation above a vapor retarder once it gets wet, and, like many others, I recommend removing wet insulation in such roofs.

The NRCA venting recommendation (i.e., one, one-way vent per 10 squares) was developed from the collective experience of many roofing consultants and contractors with many years of experience in the roofing industry. I remind you that my willingness to eliminate specific ventilation features above roofs with vapor retarders conflicts with current industry recommendations.

				INSULATIONS				
		DECKS			NO VAPOR RETARDER		W/VAPOR RETARDER	
Objective	**Membrane**	**Wet-Applied**	**Other**	**Wet-Applied**	**Fibrous Glass**	**Other**	**Fibrous Glass**	**Other**
Release during installation	Yes	No	No	No	No	No**	No	No**
Subsequent drying of wet-applied components	No	Perhaps a little*	No	Perhaps a little*	Perhaps a little*	Probably no	Perhaps a little	Probably not
Prevent accumulation a) of internal moisture	No	No	No	Probably not	Probably not	Probably not	Probably not	Probably not
b) of external moisture	No	No	No	No	No	No	No	No
Remove moisture that has accumulated	No	Perhaps a little*	No	Perhaps a little*	Perhaps a little*	Probably not	Perhaps a little	Probably not

*But downward drying can accomplish this far more effectively.
**Except "Yes" for urethane insulation to prevent membrane blistering.

TABLE 1
Will venting work?

REFERENCES

1. Baker, M. C. and C. P. Hedlin (1976) ***"Venting of Flat Roofs."*** National Research Council of Canada, Division of Building Research, Canadian Building Digest 176, Ottawa.

2. Bushing, H. W., R. G. Mathey, W. J. Rossiter, Jr. and W. Cullen (1978) ***"Effects of Moisture in Built-Up Roofing—A State-of-the-Art Literature Survey."*** National Bureau of Standards Technical Note 965, Washington, D.C.

3. Condren, S. J. (1980) ***"Vapor Retarders in Roofing Systems: When Are They Necessary?"*** Paper presented at the ASTM Symposium on Moisture Migration in Buildings, October, Philadelphia, Pa.

4. Griffin (1970) ***Manual of Built-Up Roof Systems,*** pp. 47-50, McGraw-Hill Book Company, New York.

5. Handegord, G. O. and M. C. Baker (1968) ***"Application of Roof Design Principles."*** National Research Council of Canada, Division of Building Research, Canadian Building Digest 99, Ottawa.

6. Hedlin, C. P. (1977) ***"Moisture Gains by Foam Plastic Roof Insulations Under Controlled Temperature Gradients."*** In Journal of Cellular Plastics, September/October, pp. 313-329. Available as Reprint No. NRCC 16317 from the Division of Building Research, National Research Council of Canada, Ottawa.

7. Knab, L. I., D. R. Jenkins and R. G. Mathey (1980) ***"The Effect of Moisture on the Thermal Conductance of Roofing Systems."*** National Bureau of Standards, Building Science Series 123, Washington, D.C.

8. Latta, J. K. (1976) ***"'Vapor Barriers' What are They? Are They Effective?"*** National Research Council of Canada, Division of Building Research, Canadian Building Digest 175, Ottawa.

9. NRCA (1979) ***"Bulletin #7."*** National Roofing Contractors Association, Oak Park, Illinois.

10. NRCA (1980) ***"Handbook of Accepted Roofing Knowledge,"*** p. 22, National Roofing Contractors Association, Oak Park, Illinois.

11. NRCA (1980) ***"Blisters over Urethane."*** Staff article taken from a session at NRCA's Convention in New Orleans, February, in ***The Roofing Spec,*** May, 1980 issue, pp. 18-26, National Roofing Contractors Association, Oak Park, Illinois.

12. Tobiasson, W. and J. Ricard (1979) ***"Moisture Gain and Its Thermal Consequence for Common Roof Insulations."*** In Proceedings of 5th Conference on Roofing Technology, April, 1977, p. 4-16, Gaithersburg, Md. Proceedings available from National Roofing Contractors Association, Oak Park, Illinois. This paper available individually as CRREL MP 004, Hanover, N.H.