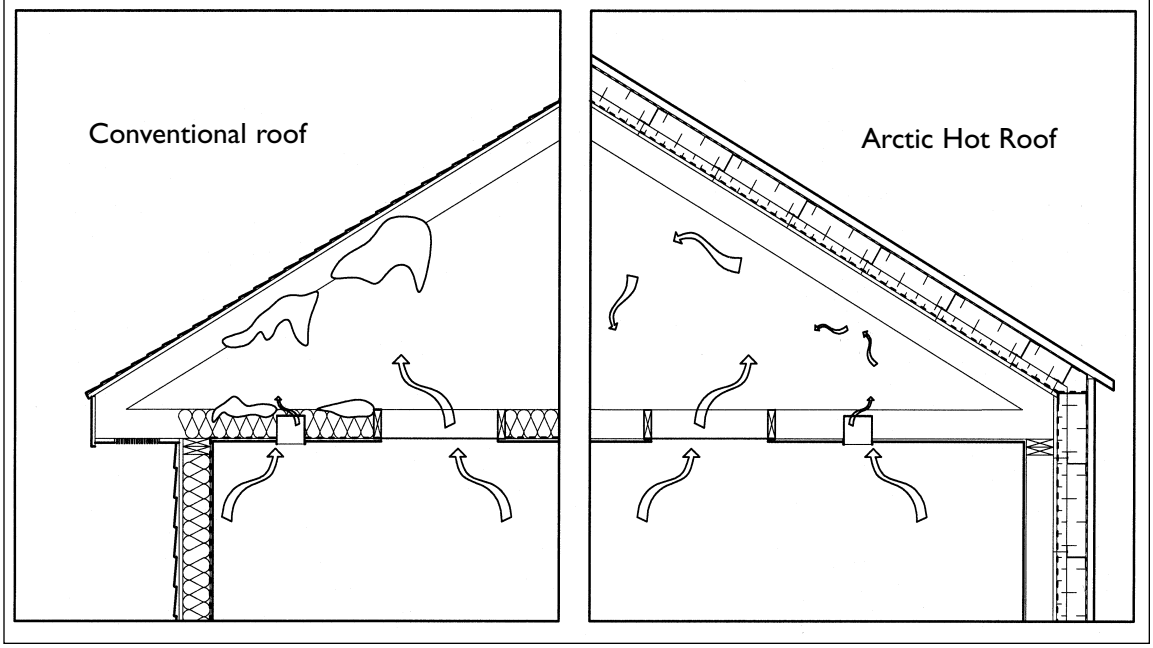
ABOUT YOUR HOUSE

North Series 6

ARCTIC HOT ROOF DESIGN

The roof is the most exposed part of a building. It is a particular challenge to designers, contractors and building managers in the North, where building envelopes are subject to severe environmental conditions. They include wide daily and seasonal temperature swings; large temperature differentials between interiors and exteriors; snow, wind and structural loads; and, of course, moisture.

Figure 1—Conventional roof versus Arctic Hot Roof design



Air pressure differentials drive warm interior air and water vapour outwards and upwards through the envelope. As air travels through the insulation, its temperature, and the amount of vapour it carries, drops. The moisture condenses on the nearest cold surface, where it can threaten the building assembly's integrity. This causes even more pronounced problems in the North's extreme climatic conditions. The Arctic Hot Roof is a roof system specifically designed to meet the North's extreme conditions.

In the North, tight envelope construction is one way to prevent building degradation and significantly reduce maintenance and energy costs. Conventional systems have been installed with a poly-vapour barrier above the ceiling, below the roof structure and insulation. Poor installation, poly degradation and openings for ceiling fixtures, electrical outlets, etc. compromise the air-vapour barrier and allow moisture-laden air to pass through.

In the North, roof systems that rely on venting to purge moisture, such as open attics and ventilated cathedral ceilings, seldom vent moisture before it condenses and turns into frost (see Figure 1).

The imperfect membrane permits heat and moisture to escape into the

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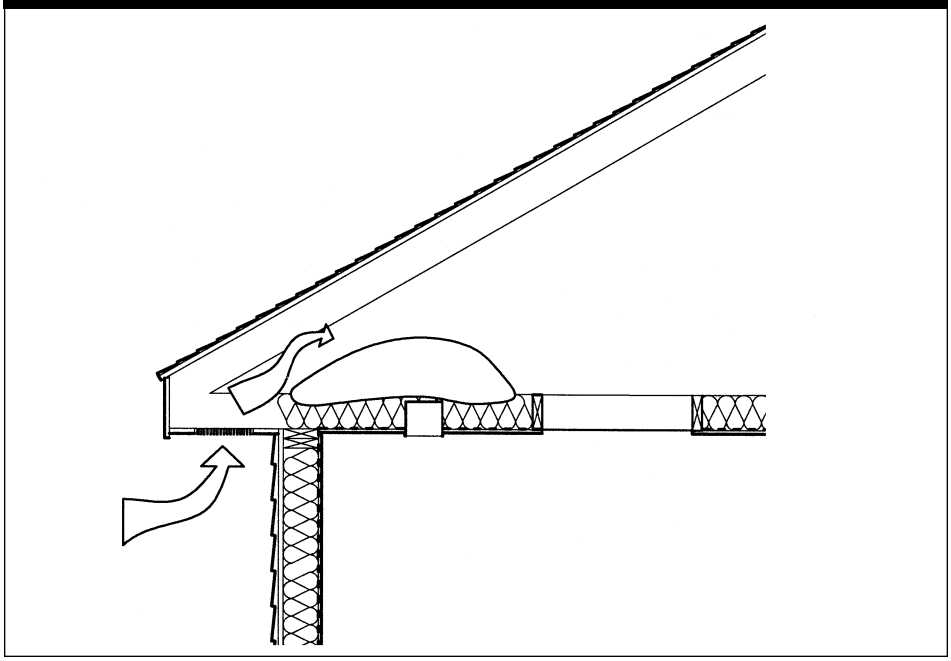
Figure 2—Snow infiltration in conventional roof systems



assembly and damage insulation. This increases heat loss. The ongoing cycle damages interior wall and roof finishes and degrades insulation and the structure. In addition, if high winds and fine snow infiltrate the vents, snow piles up in roof cavities. In the spring thaw the snow melts and drains through the leaky membrane (see Figure 2).

The Arctic Hot Roof's design minimizes the amount of moisture that can enter the assembly and provides adequate, controlled, non-damaging venting. Any moisture entering the assembly can escape without reducing the insulation's efficiency or penetrating the building membrane.

Essential to this system is a continuous-membrane air and vapour barrier on the warm side of non-organic insulation, but still on the outside of the structure and decking. This stops moisture-laden interior air travelling through the insulation to the dew point, where condensation occurs. The colder the climate, the more important the quality of installation of the barrier.

The Arctic Hot Roof membrane and insulation are on the exterior side of the structural members. This placement achieves the following:

- Potential for damage to the structure from condensation is virtually eliminated.
- Interior finishes can be applied directly to structural framing, with no need for additional strapping or protection for the membrane.
- Penetration of the membrane by mechanical and electrical systems is reduced to those elements that must exit the building, while a secure utility chase is created between structural members.
- With fewer penetrations and the application of the membrane directly above a rigid deck surface, good quality installation is easier.
- Thermal bridging between the structural members and the roof cover is eliminated.

The hot roof system has been used successfully in the North in apartments, houses and larger buildings for about 15 years. There are four basic components in a successful hot roof design (see Figure 3):

1. **Roof deck**, for continuous, rigid support for the membrane, eliminating the problem of the barrier "drumming" as air moves back and forth through the roof assembly.

2. **Continuous membrane**, as both the air and the vapour barrier, on the warm side of the insulation. Modified bitumen membrane (MBM), a single-ply, torched-on membrane, is a strong sheet material that remains flexible at temperatures as low as -40°C. It has proven to be very suitable in this application. When properly installed and sealed, MBM maintains its integrity and is not susceptible to moisture degradation.

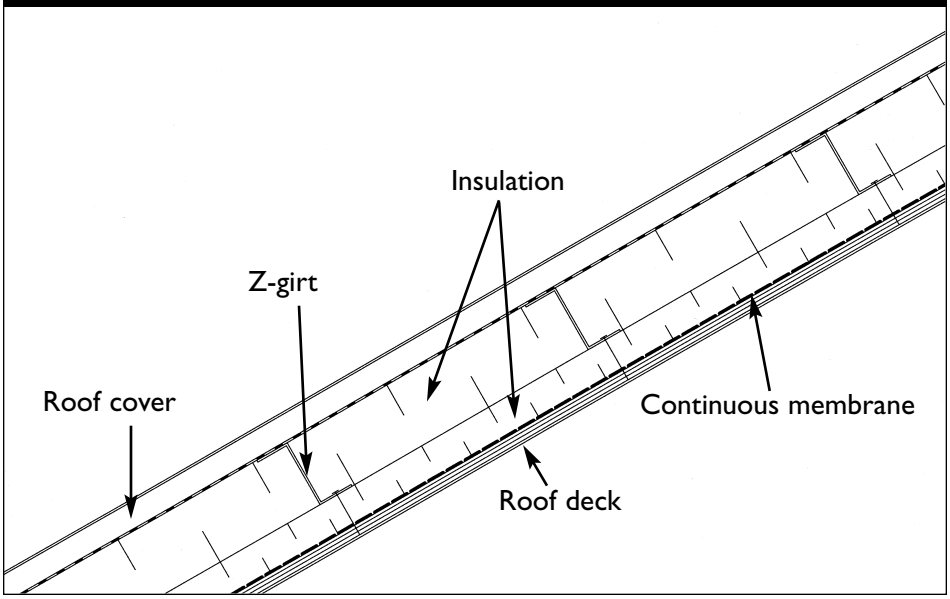
3. **Two layers of rigid insulation** that are impervious to moisture-caused degradation. Installing insulation panels at right angles to each other and attaching one layer with "z-girts" and the other with screws minimizes thermal breaks. This also reduces penetration of the membrane.

4. **Roof cover** that serves as UV protection and sheds moisture.

The sod roof, which has been used effectively in northern countries for centuries, is the historical model for the Arctic Hot Roof.

A sod roof is placed above a timber-framed roof structure. Birch bark, which provides a shingled drainage surface, or some other moisture barrier, goes on the timber frame. An earth-sod cover is insulation over the "shingles."

Figure 3—Arctic Hot Roof assembly



The inverted roof is the contemporary interpretation of the sod roof. It has been an alternative since the 1960s to the continuing problems of roof membrane failure in conventional systems. The Arctic Hot Roof is an interpretation of the inverted roof—with one fundamental difference.

The inverted roof allows moisture to seep to the level of the membrane, which is the only barrier in the system. The Arctic Hot Roof keeps this single-ply membrane and adds a water-shedding weather barrier above the insulation, which can be created in several ways. This system is a response to the North's high winds and blowing snow, and is especially applicable to residential buildings.

Deciding if an Arctic Hot Roof design is right for you

The amounts of snowfall and wind conditions are primary factors to consider when deciding whether to build an Arctic Hot Roof. Snow infiltrating roof vents is of particular concern in areas where snow tends to be very fine and winds sweep freely across the landscape—which can cause conventional, vented roofs to function poorly. High winds also increase the air pressure differential across a building, increasing the force of air and vapour movement through the envelope.

Builders should be aware that snow's insulating value is approximately RSI 7 per metre (or R1 per inch). Where snowfall accumulation can exceed 20 cm (8 in.), the roof's surface temperature might cause the snow to melt, create ice and then dam. Water can then leak under asphalt shingles, over flashing or through any seam in the roofing membrane.

The Arctic Hot Roof design strategy relies on the wind to clear the roof of accumulated snow. To be effective, the average annual wind speed must be at least 16 km/h (10 mph)*. Other ways of removing snow must be found if there is a heavy snowfall, or if the wind and the slope of the roof cannot clear the roof of heavy snow loads.

Assembly

The single-ply membrane prevents both air and vapour from flowing through a building's wall and roof assemblies. The barrier must be continuous to be effective. That means that it must not leak through individual panels, joints between the panels or at service penetrations. Connections between wall and roof membranes must be properly detailed to prevent water vapour from inside the building and moisture from outside the building from leaking into cavities or into the interior of the building. The protected location of the membrane in the Arctic Hot Roof system saves it from many of the hazards of a conventional roof system, including:

- Degradation from ultraviolet light.
- Damage from hailstones, roof traffic and general mechanical damage.
- Temperature swings. A conventional membrane may experience a temperature range of as much as 38°C over a day, and as much as 93°C over a year. A properly designed Arctic Hot Roof experiences swings of less than 6°C a day and 17°C over a year at the membrane†.
- Thermal stress. Virtual elimination of thermal stress in the membrane, which remains above freezing even in the coldest weather.

The membrane may be adhered to the deck either fully or partially. Uncertainty about effects of cracks and joints is one argument for spot-adhering the membrane to the deck rather than fully adhering it. However, the advantage of spot-adhesion is probably more than offset by the difficulty of locating a water leak in the membrane. When the membrane is only spot adhered, water can move

* Richard Seifert, *Attices and Roofs for Northern Residential Construction*
† C. W. Griffin, *Manual of Built-Up Roof Systems,* p. 227

long distances along the top of the deck before it enters the building. With full adhesion, lateral movement of water at the interface between deck and membrane is inhibited. A fully adhered membrane should not be specified on a deck that may be subject to expansion and contraction. The torched-on membrane is a fully adhered system.

Extruded polystyrene has proven to be the most successful in this type of application. Two layers of insulation with staggered joints eliminate thermal bridges created by joints in single-layer insulation. Both layers may be attached by z-girts, or the first may be connected by screws, and the second laid at right angles to the first and connected using z-girts. The insulation protects the roofing membrane from UV radiation, thermal stress and physical wear and tear. Therefore, the insulation itself must be protected from UV radiation (see Figure 3).

The final covering of the roof is the protective layer for the insulation and a moisture-shedding layer for the assembly. This can be dealt with in a number of ways, depending on the slope of the roof and its desired appearance. Metal roofing or shingles in conjunction with a weather barrier can be used above the insulation if the proper strapping or decking is provided. Corrugations in metal roofing or the air space created by adding strapping to accommodate shingling provides sufficient space to vent the roof assembly.

To ensure that the roof will function properly throughout its anticipated lifespan, there should be regular maintenance inspections and a knowledgeable contractor should repair damage as soon as possible.

Detailing the roof with attention to building as a system

For the roof system to work properly, the roof membrane must be continuous. Any junction or break in the continuity of the membrane must be carefully designed and constructed.

The barrier must carry over the top plates of partition walls. All chimney and flue penetrations must be properly sealed with a flexible air barrier material. Tight seals must be provided because of their thermal expansion and contraction, as well as shrinkage of the membrane and settlement of the house frame. Additional details that require close attention in both design and construction include flashing, roof-wall junctions, roof projections and expansion joints.

While the roof assembly must be sound unto itself, remember that it is only one part of an envelope system that is affected by a number of building components. Detailing must be planned and executed so that moisture draining off a carefully designed roof does not infiltrate the wall cavity or leak into the interior of the building. The barrier should lap and form a seal with the barrier in the wall, with flashing detailing directing moisture away from the envelope assemblies, allowing vapour trapped in the roof to escape.

Cautions

The Arctic Hot Roof relies heavily on good design and equally good workmanship. This is vital for all roofing applications, but is even more so for a single-ply membrane. For example, a multi-ply built-up membrane has some safety margin against one poorly applied layer. A single-ply membrane has none. Failure at a seam in a single-ply membrane means an almost certain leak. Special care must be taken on parts of the roof where the assembly is interrupted—at the edges of the roof where it connects with walls below or above and at all penetrations.

Hot roof systems tend to fail at exposed edges first. The membrane must be properly protected by insulation to the edges to be shielded from UV radiation and temperature fluctuations.

Because it is placed above the membrane rather than below it, insulation in hot roofs is at risk from solvent spills, including fuels and adhesive solvents. Failure of the insulation can be caused by emissions from some roofing membranes or from solvents used with them. Manufacturers usually spell out how to use their product and warn against incompatible material. For best thermal performance, specify at least two insulation layers, with staggered joints.

Controlled venting must be carefully provided to ensure that if moisture gets into the roof assembly it can get out. A positive slope towards eaves at a minimum of 1:25 is recommended. It should be detailed to ensure that minor frost that builds up in the roof system or rain that bypasses the roof cover will simply run down the weather barrier above the insulation and out of the roof. For flat roofs, an air space between the insulation and roof cover, complete with vent stacks, serves a similar function, capped to ensure that additional moisture does not infiltrate the roof assembly.

Advantages and disadvantages of the system

Advantages

- Protects the membrane against mechanical damage—objects must penetrate the top cover and insulation before they reach the membrane. The location of the

membrane above the structural members means that it is no longer penetrated by electrical boxes located on the ceiling, lighting fixtures and the like, thus expanding the range of lighting possibilities.

- Maintains the roofing membrane at a constant temperature throughout the year, thus avoiding the stresses of temperature extremes, and controls or prevents condensation by maintaining the temperature of the membrane on the warm side of the dew point. The temperature range experienced by the membrane in this system will be minimal through both daily and annual temperature cycles, and will remain consistently above freezing. Temperature ranges will be increased if insulation is added beneath the membrane or the roof covers an unheated overhang. Avoid these situations because ice can form beneath the insulation and displace it.

- Protects the membrane from UV radiation, slowing the aging process.

- Provides a stable base for the membrane since it rests directly on the deck.

- Reduces the risk of trapping condensation in the insulation because it is not sealed between the weather barrier and the roof membrane. Any moisture that does reach the insulation will drain out of the roof assembly along the membrane.

- The insulation's easily accessible location makes it readily removable and replaceable with no disruption in the building's function.

- The system can be dismantled easily, and—if the roof deck and structural members can carry the added dead load—is an easy and convenient way to increase insulating capacity as energy costs rise.

Disadvantages

- Insulation can be exposed to water from rain and melting snow. This severely limits the number of insulations that can be used.

- Heat can be lost at the level of the membrane because of precipitation drainage.

- Installation must be completed in good weather to allow the membrane to seal around screw penetrations, which restricts installation to late spring, summer and early fall.

Installation notes

- Before it is covered by roofing, the deck should be carefully inspected for cracks, unevenness and protrusions. These should be patched or smoothed to provide a smooth base for the roof membrane. Because the single-ply membrane is typically very thin, it is critical to remove all debris from the deck before applying the membrane. Nails, stones and other debris can easily penetrate the membrane. If they do, a leaky roof is only a matter of time.

- The torched-on membrane must be very carefully applied. Potential problem spots are lap joints that may contain air pockets, degradation of the membrane due to overheating by torching during application and delamination of membrane because of insufficient heat causing blistering. Although poor bonding of the membrane has resulted in numerous roof failures in the North, this problem can be avoided if it is identified and understood. There are few suppliers of this product in the North and they will not sell the material to any company or individual who is not certified in the installation of this type of membrane, thus increasing the likelihood of proper installation.

- To ensure the integrity of the completed membrane, a flood test is recommended before installing insulation and surfacing. If it is impractical to flood-test before insulation goes down, flood-test afterwards. This may seem excessive, but it is much easier to detect and repair problems at this stage than after construction.

- Insulation must be kept dry at the construction site so that it will not be damp when applied to the roof. Keep it off the ground and cover it.

- After the membrane is applied, apply the insulation within three weeks. Apply the top covering of the roof within three weeks after applying the insulation. This tight scheduling is recommended to protect both the membrane and the insulation from the detrimental affects of UV radiation, thermal expansion and shrinkage and mechanical damage.

Life cycle costing

The initial cost of installing an Arctic Hot Roof is estimated to be about $7,000 more than a conventional roof for an average house of 140 m^2 (1,400 sq. ft.). There are savings of both time and money—about $2,000—if plumbing, heating, sheet metal and electrical components are

installed in the warm space between the roof's structural members. This reduces installation time and materials. The actual additional cost is then $5,000. The longer anticipated service life of the Arctic Hot Roof makes it a highly profitable long-term investment.

Further benefits, with possible cost savings, include less wind-uplift stress on the structure and greater protection of the membrane and structural components. Only one membrane is required, which doubles as a membrane and vapour retarder.

Conclusion

Design and construction of roof assemblies in the North should maximize the functional life of the roof and all its components; mimimize the amount of outside moisture that reaches the roof assembly; and, ensure that moisture from the inside cannot condense in any cavities or assemblies.

Arctic Hot Roof designs prevent moisture that infiltrates from being sandwiched in, through controlled venting to ensure that it can escape. It is possible that a very small amount of leakage can occur if rain or melt water hits a hole in the membrane where a screw penetrates it. However, the resulting leakage should be minor, lasting only a few days in the spring. This problem is not unique to the Arctic Hot Roof, but is an ongoing concern with roofing in general.

The cost of roofing will always be high, particularly in remote Northern communities The effective life of a roof is a primary concern. The Arctic Hot Roof is an optimal response to environmental conditions in the North, where there is little annual precipitation and prevalent blowing snow conditions in long winters. The system's design promotes superior insulating qualities, ease of installation, effective control of potential indoor moisture damage, provision of a secure utility chase and a built-in escape for moisture that does infiltrate the roof assembly, ensuring that it does not become waterlogged.

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