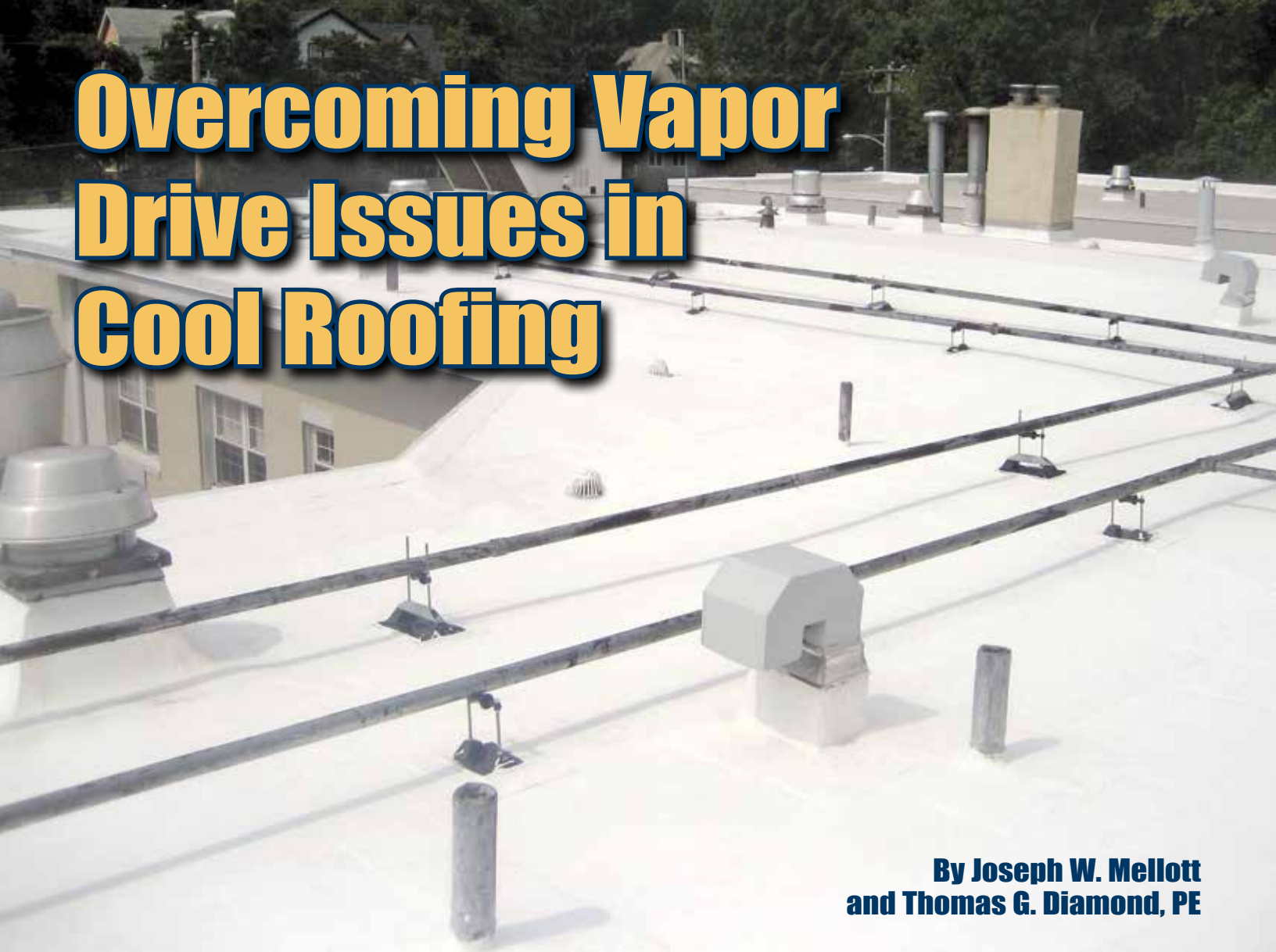


# Overcoming Vapor Drive Issues in Cool Roofing



**By Joseph W. Mellott  
and Thomas G. Diamond, PE**

*Figure 1 – Reflective roof surfaces can provide many benefits, but the roof must be designed and installed properly.*

## **ABSTRACT**

With an increase in the use of reflective coatings in North America, we are experiencing more and more installations of reflective roofing surfaces in cooler climates as well as warm climates. As a result, observations indicate that there are concerns with subsurface condensation where reflective surfaces are employed. This paper will explore the net effect of vapor drive on reflective roofs and will offer proper system design and product selection remedies, including insulation and the need for an installed vapor control layer.

## **DISCUSSION**

The benefits of cool roofing are abundant and extend well beyond the thermal impact they can provide to a facility. It is proven that through the use of reflective

coatings and membranes, the resulting surface temperature of the roof is dramatically decreased. Reduction of surface temperature and thermal shock are recognized to extend the overall useful life of a roof. Further, the additional layer of protection reduces the UV exposure to the waterproofing system and can eliminate exposure to harmful chemicals, if present.

It is also recognized that lower surface temperature reduces cooling costs in the summer. In unconditioned spaces, the comfort of the inhabitants/occupants of the building is increased. How does one put a price on comfort?

Finally, studies have indicated that through the use of reflective surfaces, cities can lower the urban heat island effect. This also reduces the net effect of additional cooling needed to lower conditioned tem-

peratures because of retained heat in large urban structures.

Simply put, coatings provide benefits in both warm and cool climates (although in cooler climates, the energy savings related to cooling the building may be limited). They extend the life of roof systems and reduce the energy required to cool a facility (*Figure 1*). However, understanding the net effect that using a reflective product may have in different climates is critical to the long-term success of any given facility.

Specifically, problems can arise from cool (reflective) roofing, especially when installed on roof systems that previously had darker surfaces. These problems are observed as drips and unexplained leaks that occur when no evidence of a roof system failure can be found, especially in the spring. It is well understood that dew point

temperature location changes within the roof assembly throughout the year. Vapor drive and dew point temperature locations are directly related to external and internal environmental conditions. Vapor drive can become more severe in the winter with the cooler exterior roof assembly. As a result, higher amounts of moisture can condense within the roof assembly. This is a result of air leakage from the interior of the building into the roof system structure.

In cases where a darker roof is installed, the dark roof will have a warmer surface than a comparable light-colored or cool roof. The dark roof will heat up the entire roof assembly and cause downward drying to occur. The cooler roof surface does not allow the roof assembly to become as warm, reducing the drying effect; and, as a result, the subsurface condensation remains and accumulates.

### CONSTRUCTION TYPES

Acceptable and typical construction types vary across the United States. Assemblies in the Midwest and East usually consist of some type of rigid board insulation above a structural deck such as steel or concrete. The South and the Gulf Coast

are similar, with the exception that a light-weight concrete pour over a form deck is as common as a steel or concrete deck. West Coast construction typically consists of a wood deck, below which fiberglass insulation with vapor retarder facers are installed. Each system has its own advantages and challenges and is selected for performance, life cycle, and economic reasons. Each type presents different thermal conditions and must be understood and handled correctly to maintain long-term performance.

### THE PHYSICS

Several facts are omnipresent when considering thermal and moisture conditions:

- Moisture is always present, in either vapor or liquid form. It is unavoidable.
- Water vapor will occur on both the exterior and the interior of a roof assembly.
- Warm air rises.
- Water vapor, in general, is driven from warm spaces to cold spaces.
- Pressure wants to be equalized. High pressure moves to low-pressure areas.

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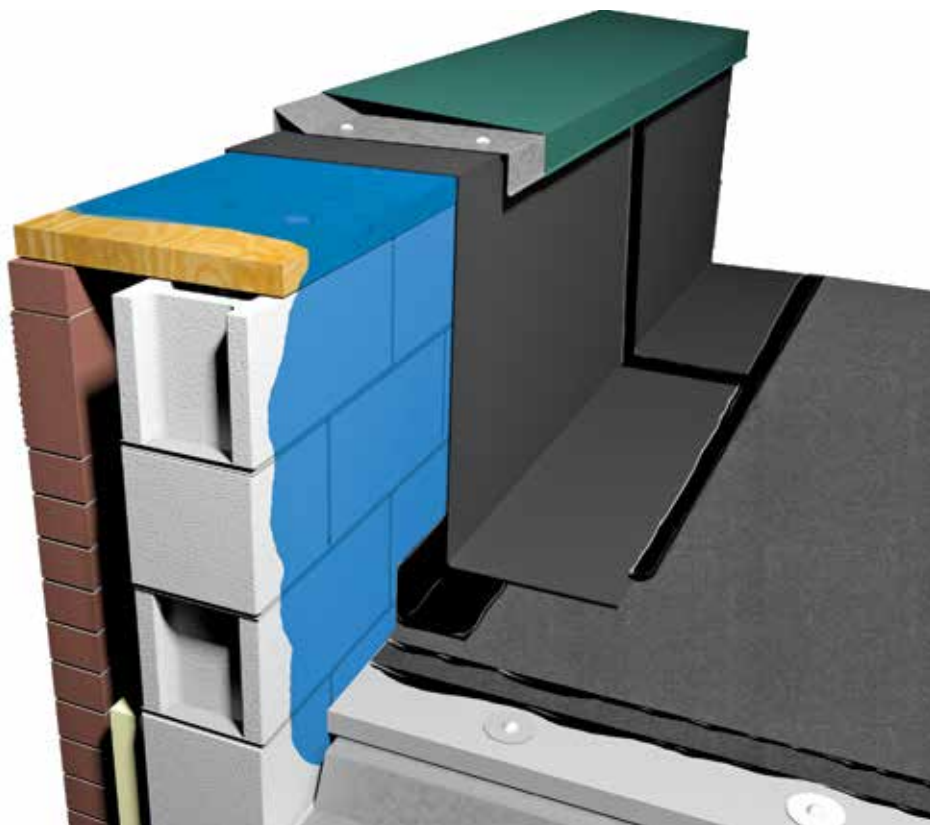


Figure 2 – Careful consideration must be given to transitions such as this. Notice the air barrier tying into the wall.

The dew point temperature is the temperature at which water vapor condenses into liquid. Within a roof assembly, water vapor condenses into liquid when it contacts a surface that is at or below this dew point temperature. Understanding these basic principles and terms of physics (and the unavoidable presence of water) is necessary to control reflectance-related condensation. There are several issues that can arise when improper construction meets physics.

## ISSUES

Insulation installed above the roof deck often provides the best opportunity to design a high-performance roof system. Many times, the insulation is attached directly to the deck. While the deck itself can act as a reasonable air barrier, it does not always stop the migration of air and water vapor through the deck (from the interior of the building). This can occur through penetrations in the deck and where the deck meets transitions in the building, such as walls, elevation changes, and differing deck types (Figure 2). Vapor can also migrate through the vapor-retarding facer on the fiberglass batt insulation where it is not perfectly sealed against all penetrations and walls. Inconsistencies in the design with respect to the “air barrier” will allow rising air into the roof assembly, which can transport very large amounts of water vapor. Air movement itself can “transport” over ten times more water vapor than diffusion alone will.

Moisture migration (vapor drive) from

the interior to the exterior of the building usually occurs in winter months when the interior relative humidity is higher than the drier exterior environment. The interior air is typically warmer than the outside air, compounding the issue. Vapor drive can also be caused by the overall differential in pressure between the interior and the exterior of the building. Wind is an additional factor in the mix. When wind whips across the roof surface, it creates a pressure differential (negative and positive, depending on location). The resultant airflow through the structure can result in the deposition of moisture within the roof assembly.

The combination of these factors creates a very strong moisture drive in the winter. If the roof system is not designed with an airtight air barrier, or if a vapor retarder installation is not done properly, large amounts of moisture can become trapped within the roof assembly. The moisture, in vapor form, will loop up until it meets a condensing surface. If the surface is below dew point temperature, such as the bottom of a roof membrane in a cold winter environment, the moisture in the air will condense on it. When the air and moisture loops back down into the roof assembly, it will be in the form of condensed liquid.

Another factor to consider is the facility’s use of air conditioning. There are many cases where a reflective roof brought the internal temperature of the building down considerably in the summer. This created a scenario where the air conditioning within

the building did not run nearly as often as before. As a result, the interior relative humidity of the building rose considerably, causing condensation within the facility that had not occurred previously. Once this moisture-laden air enters the roof assembly, it will continue to migrate upwards until it reaches the dew point temperature within the insulation at the membrane surface. This can even occur on the bottom of the roof deck in West Coast construction assemblies. By definition, once water vapor hits the dew point temperature, it condenses into liquid.

In typical, nonreflective roof assemblies in summer months, some of the moisture within the assembly will be able to “dry out.” The rooftop surface temperature can rise to between 160° and 170° Fahrenheit. At that temperature, it will “reverse the moisture drive” back into the building. The high heat will then drive any moisture trapped in the roof assembly into vapor and equalize into the building. However, when the roof surface temperature is lower (around 110° Fahrenheit), the drying action is significantly reduced. Much of the trapped moisture will start to condense.

The condensed moisture can result in many undesirable effects. In many cases, the “leaks” are misdiagnosed as roof leaks. In any case, the trapped moisture can cause degradation of the roofing components and eventually lead to structural damage to the deck. Further, moisture present in the insulation will lower thermal protection, since

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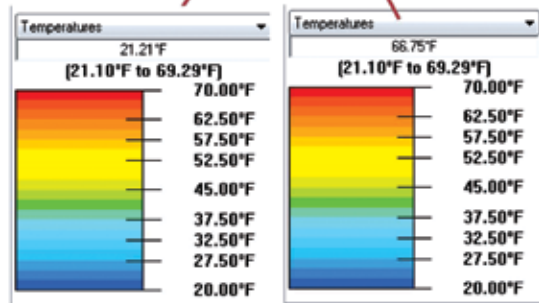
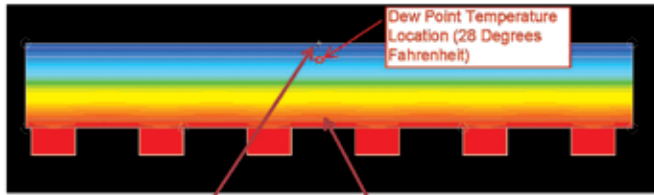


**A** NORTHERN ROOF SOLAR EFFECTS – MINNEAPOLIS, MN

WINTER DESIGN CONDITIONS

Dark Roof Surface – No Snow Cover

Day Time Roof Surface Temperature with No Snow Cover = 21.2°F



BUR MEMBRANE  
 1/4" FIBERBOARD (R2.5)  
 3 1/4" POLYISOCYANURATE (LTTR20) INSULATION  
 AIR BARRIER/VAPOR RETARDER  
 1/4" FIBERBOARD (R2.5)  
 22 GA "B" STEEL DECK

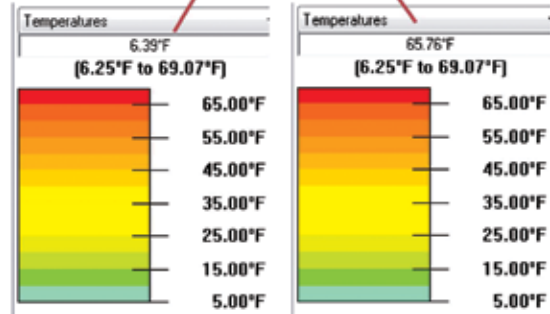
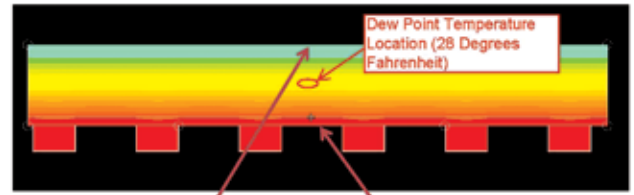
ASHRAE Outside Winter Design Temperature  
 (@ 0.4% Probability Frequency) = -13.4°F  
 Inside Temperature = 70°F  
 Inside Relative Humidity = 20%  
 Interior Dewpoint = 38°F  
 Top of Fiberboard on Roof Deck = 66.75°F

**B** NORTHERN ROOF SOLAR EFFECTS – MINNEAPOLIS, MN

WINTER DESIGN CONDITIONS

Light Roof Surface – No Snow Cover

Day Time Roof Surface Temperature with No Snow Cover = 5.6°F



BUR MEMBRANE  
 1/4" FIBERBOARD (R2.5)  
 3 1/4" POLYISOCYANURATE (LTTR20) INSULATION  
 AIR BARRIER/VAPOR RETARDER  
 1/4" FIBERBOARD (R2.5)  
 22 GA "B" STEEL DECK

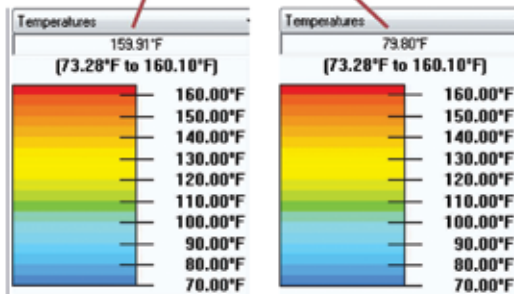
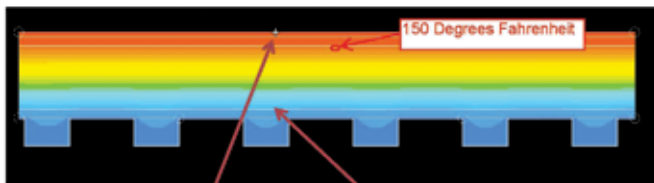
ASHRAE Outside Winter Design Temperature  
 (@ 0.4% Probability Frequency) = -13.4°F  
 Inside Temperature = 70°F  
 Inside Relative Humidity = 20%  
 Interior Dewpoint = 38°F  
 Top of Fiberboard on Roof Deck = 65.76°F

**C** NORTHERN ROOF SOLAR EFFECTS – MINNEAPOLIS, MN

SUMMER DESIGN CONDITIONS

Dark Roof Surface

Day Time Roof Surface Temperature with Solar Effects = 161°F



BUR MEMBRANE  
 1/4" FIBERBOARD (R2.5)  
 3 1/4" POLYISOCYANURATE (LTTR20) INSULATION  
 AIR BARRIER/VAPOR RETARDER  
 1/4" FIBERBOARD (R2.5)  
 22 GA "B" STEEL DECK

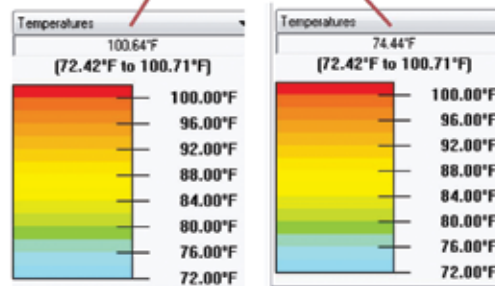
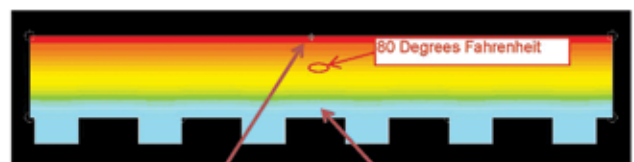
ASHRAE Outside Summer Design Temperature  
 (@ 0.4% Probability Frequency) = 91°F  
 Inside Temperature = 72°F  
 Inside Relative Humidity = 35%  
 Interior Dewpoint = 42°F  
 Top of Fiberboard on Roof Deck = 79.80°F

**D** NORTHERN ROOF SOLAR EFFECTS – MINNEAPOLIS, MN

SUMMER DESIGN CONDITIONS

Light Roof Surface

Day Time Roof Surface Temperature with Solar Effects = 101°F



BUR MEMBRANE  
 1/4" FIBERBOARD (R2.5)  
 3 1/4" POLYISOCYANURATE (LTTR20) INSULATION  
 AIR BARRIER/VAPOR RETARDER  
 1/4" FIBERBOARD (R2.5)  
 22 GA "B" STEEL DECK

ASHRAE Outside Summer Design Temperature  
 (@ 0.4% Probability Frequency) = 91°F  
 Inside Temperature = 72°F  
 Inside Relative Humidity = 35%  
 Interior Dewpoint = 42°F  
 Top of Fiberboard on Roof Deck = 74.44°F

Figures 3A-D – The results of solar effects on thermal models in Minneapolis, Minnesota, at different times of the year and with both light and dark roof surfaces.

mulation within it, a more in-depth model should be performed. Doing so will allow one to determine not only if moisture accumulates within the roof assembly, but also if it will have the ability to dry back out.

### PROPER DESIGN AND PLANNING

How can we overcome these potential issues so we can still enjoy the benefits of cool roofing? Of course the solution for new construction is much easier than in reroofing. Existing conditions may be much more expensive to fix due to reconstruction and redesign costs, which is why doing it right the first time is critical.

With new construction, the following steps must be considered.

#### Include Air Barriers

Always ensure that an effective air barrier is installed above the deck. Redundancies in air barriers are very advantageous. High-performance building enclosures cannot afford even moderate amounts of air leakage. While staggered insulation boards can act as an air barrier, a membrane installed below the insulation performs bet-

ter. Continuity is key! Air barriers must be sealed around penetrations and must tie into the wall's air barriers. Even minor gaps in the air barrier can lead to large quantities of moisture migration, as well as heat transfer into and out of the roof assembly.

#### Include Vapor Retarders/Barriers

Vapor barriers are not to be confused with air barriers. Air barriers can be:

- Vapor-open
- Vapor retarders
- Vapor barriers

The type of vapor profile needed is highly dependent on the functionality of the building, as well as the climate. Each building should be handled uniquely. Generally, warmer climates can afford (and typically prefer) a vapor retarder or a vapor-open profile. An open vapor profile will allow any moisture that finds its way into the roof assembly to eventually dry out through diffusion. If a moderate amount of moisture finds its way into the assembly via diffusion through the air barrier, it will, in theory, be able to diffuse back out in the summer

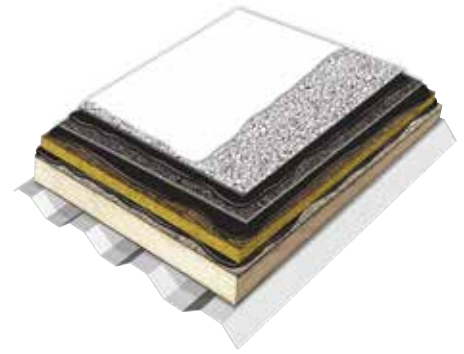


Figure 4 – Common commercial or industrial roof system in a warm climate with low relative humidity.

months. This small amount of moisture is usually not enough to create condensation issues. (See Figure 4.)

In more severe climates and in buildings where even moderate amounts of moisture are prohibited (such as museums and data centers), and in buildings where the interior relative humidity levels are extremely high (such as swimming pools or paper mills), a vapor-closed profile is needed.

For metal decks, fasten a gypsum board

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to the deck and then install an air/vapor control membrane.

Concrete decks require an air/vapor control membrane to be installed directly over the deck.

For wood and other nailable decks, mechanically fasten a base sheet to the deck, and then install an air/vapor control membrane directly over the base sheet. Next, install the rigid insulation board above the air/vapor control membrane. The required amount of R-value is dictated by the International Energy Conservation Code, ASHRAE, or local code requirements.

### Hygrothermal Models

Have a design professional perform a hygrothermal model of the building to see how much moisture will be present within the roof assembly and how quickly it will be able to dry out. Material type, thickness, and location can all be varied within the model to determine the optimum roof assembly.

### Ventilation

Ventilation is critical. Ensure that the proper amount of ventilation is provided for the building. Moving moisture-laden air out of the facility or treating it with air conditioning will help reduce the risk of its finding its way into the roof assembly.

### Application


The most critical component is proper application. No matter how well designed the roof system may be, it is dependent on proper installation. Continuity is critical with respect to the integration of the air/vapor control membrane, as well as with the insulation, roof membrane, and coating. If an air barrier is not sealed perfectly against

any and all penetrations, it presents a point where air can seep into the roof assembly. Ensure that highly skilled contractors are installing the roof and its components. Also consider having a Registered Roof Observer present during the installation to ensure that the roof system is being installed as is intended.

Reroofing existing buildings can be more challenging. Adding ventilation to a building is typically not very cost-effective. Also, if insulation is already present below the roof deck, installing an air barrier/vapor retarder below it can be nearly impossible to do properly, depending on the ceiling finish. In these scenarios, adding additional insulation above the roof deck is almost always beneficial. Even a moderate amount of R-value added above the roof deck will bring the deck's surface temperature above the dew point temperature, moving the dew point above the first condensing surface.

In any case, it is recommended to perform a hygrothermal model on the building to see how the roof assembly will perform with different materials and insulation thicknesses.

### CONCLUSION

Simply put, reflective roofing can be very beneficial. Reducing cooling-based energy demand and protecting the waterproofing substrate are valuable performance characteristics of coatings and membranes. Understanding how thermal changes to rooftop conditions can affect moisture drive is critical in building roofs to perform to and beyond their life cycle expectation. When in doubt, perform the necessary calculations with the assistance of trained professionals to protect assets and to eliminate failure. 



Joe Mellott

*Joe Mellott is VP of Innovative Metal Company, Inc. (IMETCO). He holds multiple patents for roof-related innovations and received the 2006 Industry Statesman Award from the Roof Coatings Manufacturers*

*Association (RCMA) for his work in advancing roof coatings technology. He has also served on the board of the Cool Roofs Rating Council (CRRC) and is a past president and technical chair of RCMA. Mellott has been a member of RCI, NRCA, and ARMA. A graduate of Case Western Reserve University, Joe holds a BS in polymer engineering.*



Tom Diamond, PE

*Tom Diamond, PE, is a product engineer for The Garland Company, Inc., a manufacturer and distributor of building enclosure solutions for commercial and industrial applications. Tom's primary focus involves designing optimum*

*performance roof and wall systems while assuring compliance with building code. He frequently delivers seminars and AIA-approved classes on installation techniques, building enclosure design, and roofing and wall system technology.*

## Roofer Fined for Skylight Death

Pinnacle Roofing Contractors, Inc., Jacksonville, Florida, has been fined \$154,000 stemming from a 24-foot fall that killed John W. Miles III. Miles—working without fall protection—fell through an unprotected skylight in a warehouse roof in November 2014, according to the citation by the Occupational Safety and Health Administration (OSHA). Pinnacle Roofing, founded in 1994, had been cited for a serious safety hazard relating to fall protection in July 2012. In the current case, Pinnacle allegedly allowed employees to work at heights greater than 6 ft. without guardrails or fall protection and had not installed protective systems on the skylights. Citations were also issued for failing to ensure the edge of the roof was marked.