Unintended Consequences:

Keeping Alert to Protect Single-Ply Roofs

By Helene Hardy Pierce, FRCI

The current generation of TPO (thermoplastic polyolefin) and PVC (polyvinyl chloride) single-ply systems has achieved an outstanding performance record in the low-slope market. These single-ply membranes have been available and successfully performing in applications for quite some time – in some cases, well over 20 years.

However, like any other system, single plies are vulnerable to the unintended consequences of poorly thought-out design decisions and other incidental issues that have little or nothing to do with the TPO or PVC membranes themselves.

The fact is that the industry has wrestled with some of these concerns since the first single-ply membrane was installed back in the late 1960s. Also, problems such as moisture migration and condensation beneath the membrane can be an issue regardless of membrane type and are not singularly an issue for single plies.

Let's start out with an example of an unintended problem that many roof consultants have seen first-hand. Please raise your hand (we're not looking, really) if you have seen a long run of cast iron pipe sitting on wood blocking over a single-ply or bituminous membrane. Due to the expansion and contraction of dissimilar materials, these wooden supports will move over time and take the cast iron pipe with them.

The same thing can happen when long runs of ballasted solar racking are installed together on a membrane. Despite the overburden, these heavy rack systems may move over time and take the membrane along with them.

Roof consultants, manufacturers, and contractors are not designing these racks and may have no say in how long the runs will be. This simple phenomenon is from "Mechanics of Materials 101," but it can be a serious issue for the membrane under the solar-racking systems. And currently, we don't have a solution for it. The effect of roof-mounted solar arrays on the fire resistance of systems is another challenging

The current generation of TPO membranes has achieved an outstanding performance record in the low-slope roofing market. Shown here is Cardinals Stadium in Phoenix, AZ.

issue that SPRI and the industry at large are currently sorting out and need to address for code compliance.

MOISTURE – PUBLIC ENEMY #1

Roofing professionals have nothing against water – without it we would all be looking for new jobs – but moisture does become a problem when it enters the roofing system and condenses on the insulation or under the membrane.

We can all benefit from reading another detailed treatise on moisture control as a refresher course, but it is beyond the scope of this article. In reality, it is the responsibility of the architect or specifier to determine the need for a vapor retarder and, when required, to make sure it is properly placed within the system. This decision will depend heavily on climate and building use.

However, there has been a lot of discussion lately about moisture condensing on the underside of light-colored single-ply membranes in cold climates. Of course, roof consultants may also find moisture problems in dry climates such as Phoenix, AZ, where unusually high moisture levels inside the conditioned building move up and into the system and condense.

Condensation under white or light-colored roof membranes can be a problem with almost any mechanically attached single-ply membrane where there is a single layer of insulation. Moisture can travel up through the joints in the insulation and hit the cold side of the membrane – or the membrane adhesive – and condense. This may result in "picture framing," depending on the insulation. The condensed moisture (water) may also move laterally through the system, creating even greater problems for the roof consultant and building owner.

This phenomenon is nothing new for roofing professionals. Discussions about moisture condensing under single-ply membranes have been ongoing since the early 1980s. Vapor moisture will condense on any cold surface, and lighter-colored membranes do not dissipate this condensed moisture as quickly as dark-colored membranes.

Again, it is the responsibility of the designer to properly design the system to minimize moisture condensation, either through the use of a vapor retarder or through the use of two layers of insulation and staggering the joints to make it more difficult for moisture to reach the underside of the membrane.

The National Roofing Contractors Association (NRCA) addresses this issue in a variety of areas on its Web site. Here is one link to get you started: www.nrca.net/rp/technical/search/librarydetails.aspx?IDNumber=24829

SPRI also addresses this concern in the results of a field study called "The Effects of Roof Membrane Color on Moisture Accumulation in Low-Slope Commercial Roofing Systems" (see *Figure 1*). For more information, download the paper directly from SPRI's home page (www.spri.org).

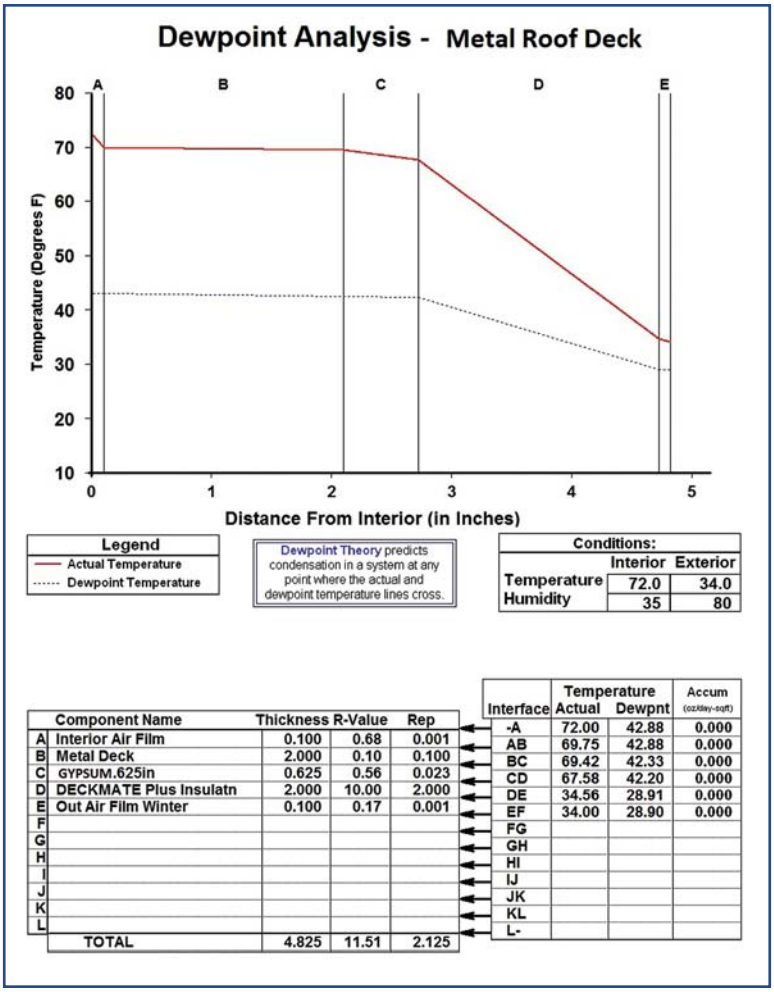

Figure 1 – Dew point analysis of a metal deck used by SPRI as part of its field study, "The Effects of Roof Membrane Color on Moisture Accumulation in Low-Slope Commercial Roofing Systems." (Figure courtesy of SPRI.)

STRUCTURAL CONCRETE DECKS

Moisture emanating from newly poured structural concrete decks has been a problem that is finally getting the attention it deserves. There is a perception in the industry that all concrete decks are the same. The fact is that they are not.

When concrete is poured over a nonremovable, nonventing substrate, the wet concrete will often not dry out. And the use of a surface dryness test is often insufficient to measure the large amounts of moisture trapped inside these poured concrete decks. In fact, one may very well get a "false positive" indicating that the deck is ready for roofing.

Because these decks are not vented from above or below, once the building is conditioned and cooler weather occurs, vapor drive upward into the roof system can cause large amounts of water to enter into the roofing system, often with catastrophic effects.

This problem has become a greater concern as more general contractors realize how much less expensive it is to leave a metal pan in place below the poured structural concrete deck. In the past, these metal forms were typically removed before roofing installation.

This problem has been slow to be addressed because structural concrete decks are used less frequently than the steel decks the industry is so accustomed to seeing in new construction applications.

In warm, humid climates, most knowledgeable general contractors will ensure that the HVAC system is working even before the drywall is put up. This way, when the building is conditioned, the HVAC system handles the moisture generated during construction and dries the building out. But this will only work if the structural concrete

Kiowa County Commons in Greensburg, Kansas, includes high-performance lighting and controls, an enhanced mechanical system, a stormwater runoff collection system, a pair of wind turbines, and water-efficient landscaping, in addition to solar and vegetative roofs. Some of these technologies may also have unintended consequences that must be addressed by the building designer.

deck can vent from the bottom side (i.e., the metal pans are removed).

One individual attempted to solve this problem by drilling holes into the metal pans every six inches. Unfortunately, this still did not allow adequate venting of the structural concrete deck, and it began to "rain" inside the building due to water coming through the holes drilled into the metal pans.

Fortunately, this problem has come to the attention of the Midwest Roofing Contractors Association (MRCA). The group's *Technical & Research (T&R) Bulletin 1/2011,* "Structural Lightweight Concrete Roof Decks," covers this issue in detail and includes a "course of action" for roofing professionals who encounter these decks. The document is available for direct download from MRCA's home page at www.mrca.org.

One month after releasing this document, MRCA came out with another *T&R* advisory bulletin on the "Noteworthy Limitations of Water-Based Bonding Adhesives." This document is also available on MRCA's Web site and should help roof consultants and other roofing professionals avoid blisters in fully adhered TPO and PVC single-ply systems.

A SPRI task force headed by Tom Cleverdon is also preparing a paper on water-based adhesives. It should be available by the time this article is published. Water-based adhesives are environmentally friendly and versatile when used with single-ply membranes; but, as with any adhesive, there are limitations to their use.

HEAT AGING OF SINGLE-PLY MEMBRANES

Another important discussion within the industry is the incidental high-heat loading on white single-ply membranes. This is a particular problem at roof/wall junctures, especially beneath high, west-facing walls in warm, sunny climates.

If a white membrane is installed vertically up a wall or high curb, it may reflect down onto the horizontal portion of the roof membrane and create conditions that will accelerate the heat aging of the sheet.

Typically, the in-surface temperature of a white TPO or PVC membrane is around 125°F to 130°F. However, the temperature of the membrane below a highly reflective wall surface can reach 170°F or higher. Obviously, this is an unintended consequence of the designer's not thinking about the ramifications of a high wall, curb, or other highly reflective vertical surface.

The same principle holds true of membranes beneath reflective glass surfaces, curtain walls, painted white walls, metal, or any other type of highly reflective surface. Of course, premature heat aging of TPO and PVC membranes is a function of time, temperature, and UV exposure, all intertwined. So a white wall in Chicago, IL, will be much less of a problem than a similar configuration in Phoenix, AZ.

One solution to this potential issue is to specify a high-performance TPO roof membrane around perimeters or other areas exposed to high heat-aging conditions.

These new TPO membranes are formulated with proprietary stabilizers and UV absorbers specifically for solar roof installations, but they have other uses, as well. Laboratory results show that they have achieved weathering performance far beyond current standards.

It is also important for roof consultants and contractors to understand that colored TPO and PVC membranes may exhibit welding characteristics different from those of white membranes. Also, dark-colored membranes sometimes used for rooftop logos or other applications may be formulated for increased heat aging, while the light-colored membranes they are coupled with may not be. That's why it's important to understand the differences in thermoplastic membrane characteristics when using different-colored sheets on the same roof.

Roof consultants should also think twice before allowing the use of dark-colored materials (walkways, etc.) directly over white TPO and PVC membranes. A more logical choice may be a light gray walkway roll.

Also, areas of poor drainage can create dark stains that can absorb heat and speed up the heat-aging process of a membrane. Dark-colored, thin-film photovoltaic (PV) systems may also contribute to accelerated heat aging of TPO and PVC. In this situation, the roof consultant's safest choice may be a high-performance membrane designed for solar applications.

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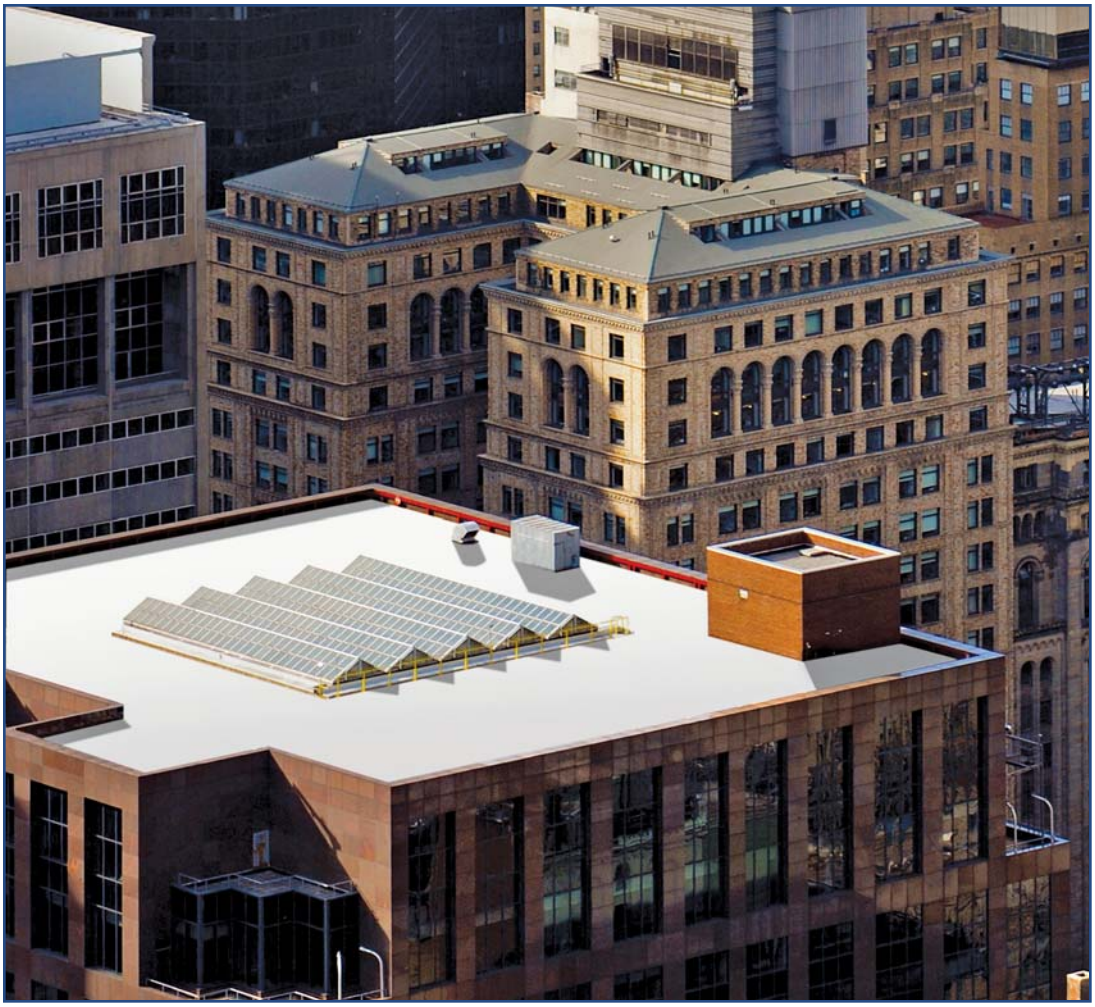
HIGH-SPEED WELDERS

Another installation-related concern centers on the use of the industry's newer high-speed, hot-air automatic welding machines. These stand-up welders are capable of welding TPO and PVC seams at up to 35 ft. per minute under ideal conditions. But as consultants are well aware, in the real world, roof conditions are rarely ideal.

Just imagine an operator walking backward and attempting to weld a seam at 35 ft. per minute while keeping the welder online. If the machine is off by just ¼ in. at the start of the weld, it will be off center by up



The in-service temperature of a white TPO or PVC membrane is around 125°F to 130°F. However, high-performance TPO roof membranes are now available with proprietary stabilizers and UV absorbers specifically for solar roof installations, but they have other uses, as well. GAF's EverGuard Extreme™ TPO is shown here. (Photos courtesy of GAF, Wayne, NJ.)

to 6 in. after 100 ft. of welding is complete.

This situation will be even worse if the operator is welding TPO or PVC membrane over fanfold insulation or gypsum board on a re-cover job. The installer will have to cope with an uneven surface that may be "rocking and rolling" his welder. In the case of uneven roof surfaces, there's a good chance the compression wheel on the high-speed welder will unload, and voids will be created in the newly created seam.

"It's a simple matter of looking at what a high-tech tool can deliver under perfect conditions, versus a real-world roof," says a technician with almost 30 years of experience in TPO and PVC installations. "The expectations of this high-speed, labor-saving, hot-air welding device are not going to be achieved under some jobsite conditions. But a good roofing contractor will make the required adjustments."

Also, if a roof consultant has to probe the seams to verify a proper weld on a TPO or PVC seam, the job may already be in deep trouble.

"Hand-probing does not tell you whether you have a 1-in. weld or a 3-in. weld, and probing will only get you nine or ten pounds per lineal inch (pli) at the seam," says this expert. "You start to get a good weld at about 22 pli, and the seam shouldn't come apart until around 30 pli or greater. You cannot determine that by hand-probing a seam."

If the roof consultant suspects voids or weak welds in a seam, he or she should perform a test cut to verify the quality of the weld.

"And forget about using a hand welder to fix a nonspec seam from the outside," according to this specialist. "We require that you strip-in a new membrane."

Specifically, if the roof consultant finds a welding problem that is systemic throughout the installation, the questionable welds should be stripped-in on both sides. Some manufacturers allow seam tape, but some require a 45-mil flashing strip with a weld on both sides of the membrane – even if that weld is 100 ft. or longer.

Some – but not all – of the roofing situations described above may have unintended consequences that ultimately affect the long-term performance of the system. They can usually be avoided if common sense and good roofing practices are used.

On the other hand, there are issues – particularly with some solar roof installations – where the industry does not yet have all the answers. The good news is that organizations like RCI, NRCA, MRCA, SPRI, Oak Ridge National Laboratory, and others are hard at work to provide the roof consultant community with the definitive answers they seek.

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