Fact or Fiction?

"Cool" Roofs Cause Condensation – Fact or Fiction?

by Phil Dregger, PE, RRC, Technical Roof Services, Inc.

(Editor's Note: Phil Dregger is a professional engineer, registered roof consultant, author, and fellow of the Roof Consultants Institute. He has investigated problems and provided testimony regarding virtually all types of roof and waterproofing systems since the early 1980's. He has special expertise in roof wind damage (hurricanes), rooftop solar photovoltaics (PV), and complex moisture accumulation problems. Dregger has authored several articles on roof technology. He may be reached at pdregger@DNG-Group.com.)

It's not so unusual. Right after the first couple sunny spring days you get a call. The owner complains his roof is leaking but it hasn't rained for a week. You investigate. It is not a roof leak. It is condensation. And, "dripping" is just part of the problem. You find a wet roof deck with something that looks a lot like mold growing on it.

Sometimes this scenario plays out shortly after a conventional built-up roof was replaced with a "cool" roof. And when that happens, the question is often asked if the cool roof caused the problem. "After all," the owner says, "condensation was never a problem before."

Back to the question raised by the title of this article. Do "cool" roofs cause condensation? The answer is, drum roll please, it depends. For many, if not most reroofs, installation of a cool roof brings the benefit of reduced summer cooling costs and few drawbacks. For other reroofs, installation of a cool roof can cause condensation problems. In most cases, however, the cool roof is more like the "straw that breaks the camel's back," it inadvertently disrupts a delicate balance.

Usually it turns out the old non-cool roof had been accumulating large amounts of moisture in the wood deck during the winter months for years with no apparent problem. The old roof, usually a cap-sheet surfaced built-up membrane, had helped keep moisture in check by getting fairly hot and facilitating downward "drying" every time the sun came out, winter or summer. Then, after installation of the cool roof, the roof no longer got very hot and this changed the balance between wetting and drying. The wood deck was still accumulating moisture like it did before but now it was not drying nearly as rapidly or as completely as before. This can cause occasional early spring "dripping" or worse. It sometimes causes wood decay and fungal growth where they did not occur previously, at least not to a noticeable extent.

FIGURE 1

Figure 1 shows severely deteriorated plywood discovered a few years after replacing an old cap-sheet built-up roof (BUR) with a white single-ply roof in the San Francisco Bay Area. Workers sent to investigate reports of the roof "dripping" found no obvious openings for "roof leaks" but found many "soft spots." Before the white single-ply roof was installed, the old BUR had been in place for many years without similar reports of dripping or "soft spots." Changing from a non-cool roof to a highly reflective "cool" roof is believed to have at least contributed to these problems.

It is important to mention that the causes of condensation in roof systems are many and varied. Buildings with conventional non-cool roofs can develop condensation problems, and changes other than to roof reflectance (e.g., building use, HVAC operation) can negatively tip previously maintained "balances" between the wetting and drying of roof systems. This article focuses on the potential impact of increasing the reflectance of low-sloped roof systems installed on commercial buildings directly over wood deck with fiberglass insulation below – a common west-coast construction practice.

West Coast Construction It is quite common in the western states to construct commercial buildings with wood decks and to install thermal insulation, usually fiberglass batts with facers, below the deck. For the rest of the country, it is more common to install some sort of rigid board insulation above a steel or concrete roof deck.

Wood roof decks with glass-fiber batts installed below tend to accumulate more moisture, in general, than wood decks with rigid board insulation installed above. This is true for a couple of reasons.

The temperature of the wood deck tends to track that of the roof membrane (and outside air) rather than that of the air inside the building. This means that in cold weather the temperature of wood decks regularly drop below the "dew point" of the interior air.

Wood sheathing decks, by their very nature, can serve as reasonable air-retarders while glass-fiber batts, even with vapor retarder facers, do not. Openings and air spaces associated with glass-fiber batts installed below roof decks allow relatively large amounts of interior air to intrude up into the thermal insulation. The exception of course would be a below deck insulation system which has been carefully sealed

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against air intrusion.

To understand why these considerations make a moisture accumulation difference, we need to talk a little about condensation and the profound impact of air intrusion.

Condensation Basics During the winter, the air inside a heated and occupied building typically contains more water vapor than the air outside. The higher water-vapor level inside works to equalize itself with the lower level outside by migrating or diffusing out through the walls and ceilings. It's kind of like air slowly escaping a balloon. As the water vapor migrates it also cools. And, if it cools below its dew point, it will condense on one of the components within the roof or wall assembly. This is true of all roof and wall systems.

Figure 2 shows severe deterioration caused by water vapor migrating up through the ceiling of a laundry room (with insulated rafter spaces) and condensing on the "cold" underside of the roof membrane and plywood roof deck. Eventually, the plywood got wet enough, warm enough, and for long enough to support the growth of wood decay fungi.

FIGURE 2

Mild Climate Example Severe conditions can develop even in mild climates. Figure 3 shows stains on the sides of beams in an office/warehouse building in California. The owner reported that the old built-up roof was quite old but it had been recently overlaid with a highly-reflective, reinforced elastomeric coating system. And, although he remembers previously getting occasional reports of drips in the Spring, he was sure he never got the kinds of reports he was getting now of wide spread water dripping and even of water soaked insulation falling to the floor (Figure 4). He mentioned, however, he still was not getting any reports of leaks during rains.

Although apparently not the case in this example, rainwater leaks from openings in roof covering systems (usually at flashings) remain the most common cause of roof moisture problems. Roofs over wood decks with insulation below are no exception.

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Nevertheless, this project is believed to be an example of where installation of a "cool" roof inadvertently caused problems by changing the balance between "wetting" and "drying," and the "physics" agrees.

WUFI Pro 5.1 Results of simulations run over a three-year period using WUFI Pro 5.1, a sophisticated hydrothermal computer modeling program, indicated that the wood deck below the built-up roof after installation of the reflective overlay, accumulated more water and held it longer than it did before.

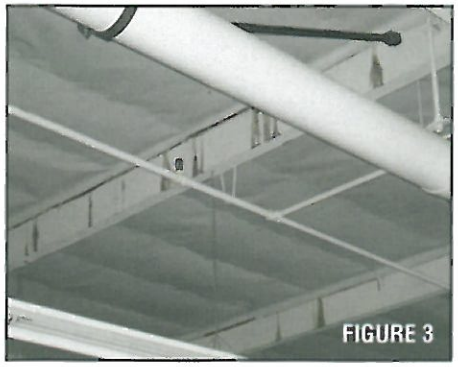

FIGURE 3

FIGURE 4

Figure 5 indicates WUFI predicted fluctuations in temperature and relative humidity (a measure of the water present) near the bottom surface of the plywood roof deck with the original built-up roof. Figure 6 indicates WUFI predicted fluctuations in temperature and relative humidity after installation of the highly-reflective overlay. Superimposed on both figures are yellow lines representing 80% relative humidity (RH) and 41°F.

The WUFI graphs indicate that after installation of the reflective overlay the plywood did not get as hot (e.g., maximums near 115°F rather than 155°F) and accumulated more water (higher RH), and held it longer, than it did previously. Is this predicted difference important? According to a new ANSI/ASHRAE Standard, yes, it could make a significant difference.

ANSI/ASHRAE Standard 160-2009 "Criteria for Moisture-Control Design Analysis in Buildings" recommends specific performance criteria to "minimize the undesirable effects of moisture in a building or building envelope." Among other things, the standard recommends roof and wall systems be designed to limit how high the RH of materials like wood get and for how long. One criterion is that the "30-day running average surface RH <80% when the 30-day running average surface temperature is between 41°F and 104°F." Again, the yellow lines in Figures 5 and 6 represent 80% RH and 41°F temperature.

Even without considering the effects of air intrusion, the impact of changing from a relatively non-reflective roof to a highly reflective roof, can make a significant difference.

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The Problem of Air Intrusion If there is enough humidity inside and it's cold enough outside, condensation can be a problem regardless of roof construction or air intrusion. However, with air intrusion, buildings with relatively modest amounts of humidity inside and located in relatively mild climates, can accumulate large amounts of water and suffer from wood rot and mold growth in localized areas.

The issue is how much water vapor actually finds its way to where the below-dew-point temperatures are. If the water vapor has to diffuse through several layers of materials before it starts condensing, the volume of water that ends up condensing or being absorbed is rather modest – low enough that wood doesn't rot, mold doesn't grow, and water doesn't drip in the early spring.

If instead of diffusing, water vapor is carried along on a current of air through modest openings in the ceiling construction, very large volumes of water can end up accumulating and fueling wood rot, mold growth, and spring dripping. Air-intrusion related condensation is usually localized and exhibits some pattern consistent with the openings that allowed it to occur.

Figures 7 and 8 show roof construction along truss purlins where modest gaps in the foil-faced batt insulation allowed interior air to enter, condense, and accumulate on the wood deck during cold weather. In the spring, with higher temperatures and plenty of water to work with, very high vapor pressures were created at wood deck level, forcing water vapor downward where it condensed on nearby metal surfaces and dripped out.

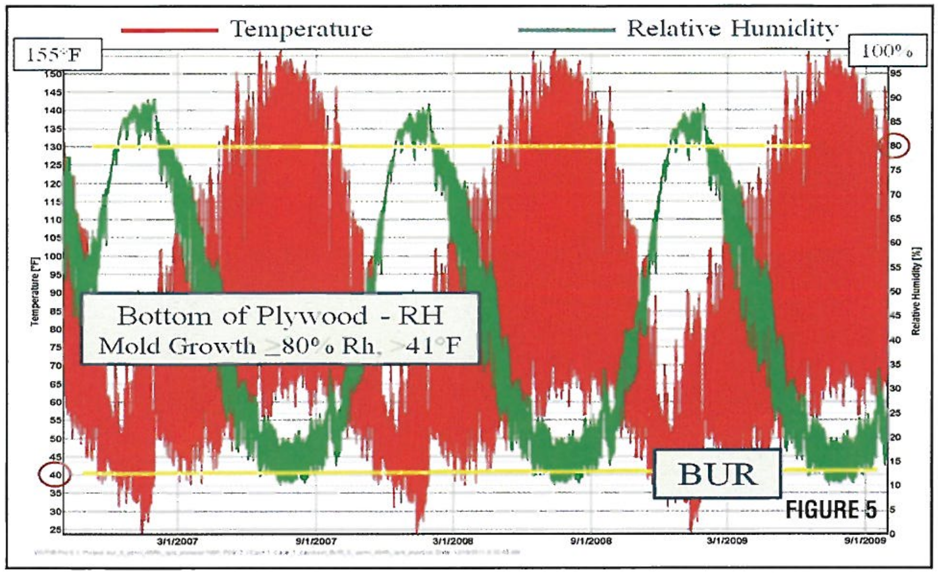

FIGURE 5

Cautions about air intrusion are not new. The 1985 version of ASTM C755 states, "the quantity of water vapor that can be transported by air [intrusion]... can easily be several times greater than that which occurs by vapor diffusion alone." The ASHRAE Fundamentals book published in 1989 states, "the relative amounts of water deposited in a wall or roof... as a result of air leakage as by vapor diffusion... [can] be 100:1 or higher."

Ventilation Would venting of the space between the wood roof deck and the insulation have helped? Yes, it probably would have helped. First, let's be clear. The space between the wood roof deck and the below-deck insulation is not vented on the vast majority of commercial buildings with low-sloped roofs in the western states. And, it can be argued that providing such venting is not something practically done as part of a reroof project. However, when "condensation" problems develop as part of a reroof project, the question of whether or not venting of this space was, strictly speaking, required to comply with the current building code is something that often ends up being asked.

Building Codes All roof systems, including reroof systems, need to be designed, installed, and maintained in accordance with local codes. This includes provisions for "attic" ventilation. This article will reference provisions in the 2009 International Code Council family of codes since they serve as the model code for the codes adopted by most states and municipalities.

The 2009 Int'l Building Code, Chapter 12, Interior Environment, 1203.2 Attic Spaces states, "Enclosed attics and enclosed rafter spaces formed where ceilings are applied directly to the underside of roof framing members shall have cross ventilation for each separate space..." Unfortunately, what exactly qualifies, as "an enclosed rafter space" is not defined. Do the rafters have to be sloped? Securing gypsum boards to

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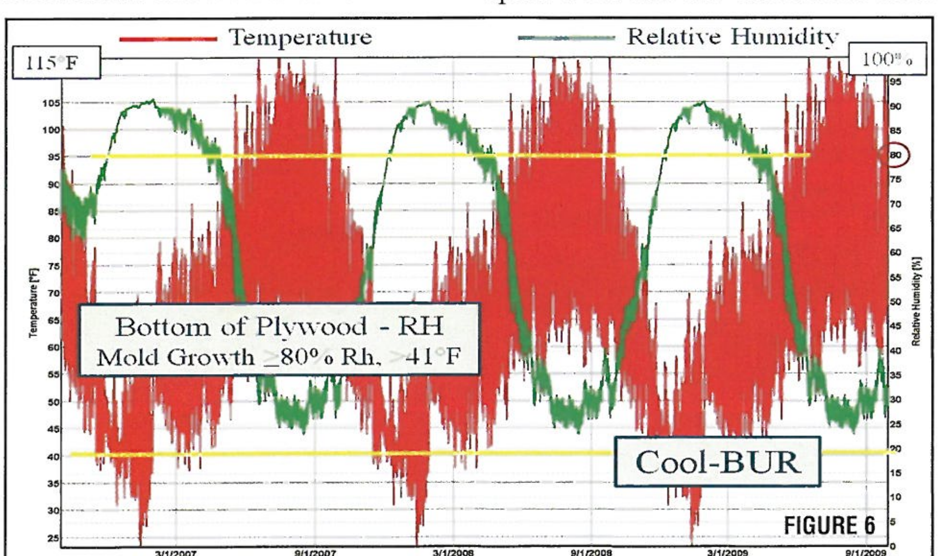

FIGURE 6

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the bottom of the rafters probably qualifies as enclosing the spaces but what about sheets of vinyl or foil or kraft paper? And, if the project already has unvented yet "enclosed" rafter spaces, is the contractor installing a new roof responsible for making it "code compliant?"

The phrasing of this familiar "attics and enclosed rafter spaces" venting provision has changed over the years. Older codes (e.g., 1997 Uniform Building Code) prefaced it


FIGURE 7

with the caveat, "Where determined necessary by the building official due to atmospheric or climatic conditions." The current wording seems to imply that the basic applicability of this provision is no longer subject to local weather or climate.

Living in the litigious society we do, the suggestion of this author is, "When in doubt, obtain an interpretation from the authority having jurisdiction (AHJ), usually the local Building Official. Afterwards, provide a courtesy email back to the building official thanking him/her for the information and, by the way, keep the email in your files.

There are other Building and Energy Code provisions that when complied with serve to limit the amount of water vapor that enters and accumulates in a roof system (e.g., installation of vapor retarders, sealing of "openings, joints, and penetrations" in the exterior building envelope, ventilation of interior spaces) but discussion of these is beyond the scope of this article.

Combating "Cool Roof" Effects

When the combination of a "cool" roof and air intrusion results in condensation problems, there are several

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different ways to help remedy the situation. Examples, which can be used alone or in combination, follow.

Add insulation above the roof deck.

Reduce relative humidity inside.

Install a vapor-permeable air retarder system below the insulation.

Provide "cross ventilation" for each separate enclosed space (typically not practical).

In the opinion of this author, the most effective of these procedures is to insulate above the roof deck.

As long as the common roof industry guidelines suggest condensation (due to water vapor diffusion alone) should not be a problem, adding insulation above the deck should do the trick. The key here is to "warm" the surfaces most likely to be exposed to the intruding air. Adding insulation above the roof deck does just that. It "warms" the roof deck to temperatures closer to that of the interior spaces than that of the exterior environment. Thereafter, even if large amounts of moisture laden air come in contact with the wood deck, it does not condense because the wood is at or above the dew-point of the air.

How much insulation needs to be added and deciding if the below-deck insulation needs to be removed, are important questions but must be evaluated on a project to project basis. The good news is that for most projects a relatively modest amount of R-value on top can make a big difference below.

A Two-Edged Sword Installing vapor retarders can be a very effective way to limit the amount of water vapor that enters a roof system and thereby control condensation. They can also have a downside. They can "trap" moisture. This is not necessarily intuitive. One could ask, "Don't vapor retarders "keep out" as much as they "trap?" Yes, but only if the vapor retarder is also effective at preventing air intrusion - which is not easily accomplished on glass-fiber batt insulation systems installed below decks with pipes and ducts in the way.

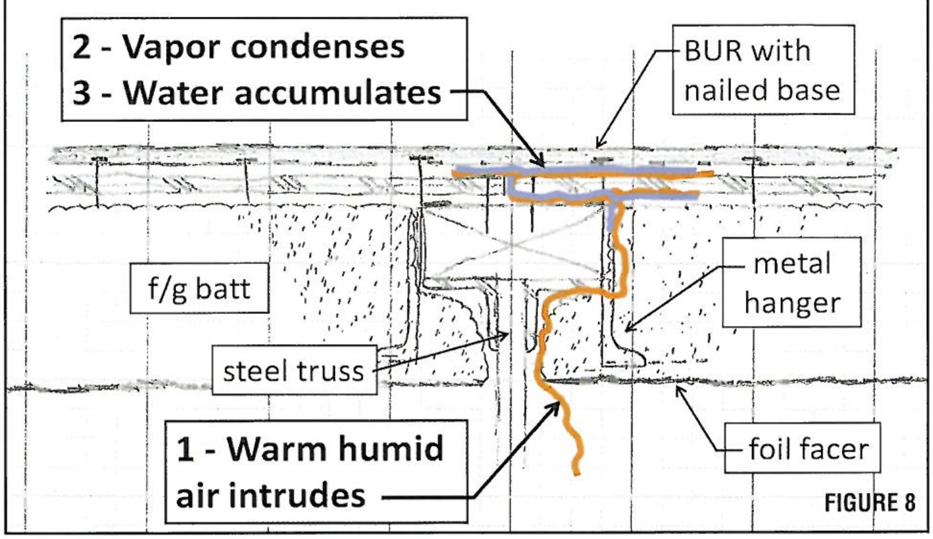

FIGURE 8

If modest openings in a vapor retarder inadvertently allow air to move in volume up into a roof system, the presence of a vapor retarder can have a net "negative" impact on water accumulation, at least in localized areas. This is because the forces working to drive moist interior air up into roofs in the winter are routinely greater than the forces working to drive it back down again. Without going into detail, the following are some reasons why more water vapor is driven up into roofs in the winter than down.

Warm air rises.

Humid air rises. I know this is not intuitive but it's true.

Still air tends to move toward moving air. During winds, the air above the roof is at a lower pressure than the air inside. Differences in air pressure, like differences in vapor pressure, try to "equalize," working to move interior air up into the roof system.

In the experience of this author, installing a vapor retarder below existing below deck insulation systems often has less than desirable results. On the other hand, installing a vapor-permeable air retarder type system is almost never a bad idea. Keep in mind that not just any material is suitable. Materials exposed to occupied spaces need to stay below certain maximum levels of flame spread and smoke development.

Suggestions When roof professionals are asked to design and/or install a cool roof on an existing wood deck with insulation below the deck, this author recommends the following:

Ask about reports of spring roof "leaks" and/or recent "energy efficiency" projects that may have inadvertently increased interior RH.

Check for "enclosed" unvented rafter spaces and for signs of past below-deck moisture accumulation (e.g., stains running down beams at purlin hangers).

Comply with codes, including local amendments, and recognized roof design aids. Seek interpretations if needed from the local building official.

Recommend adding insulation above the roof deck as part of the reroof, even when not required by the energy code (e.g., roof overlays).

Advise the owner or the owner's design professional of potential changes in "moisture accumulation and drying" associated with installation of "cool" roofs.

Acknowledgment and Further Reading The author wishes to thank Wayne Tobiasson for useful comments and suggestions during preparation of this article. For additional information readers are directed to the following links for other articles by this author on the topic of condensation in roofs. http://www.trsroof.com/Pubs/Dregger/2006-12-dregger.pdf and http://www.trsroof.com/Pubs/Dregger/2002-06-dregger.pdf.