



# “LEAKY” EXHAUST VENTS - The 500-lb. Gorilla of Condensation Problems

By Philip D. Dregger, FRCI, RRC, PE

**M**any factors contribute to excessive condensation in low-slope membrane roof systems installed over wood decks with insulation below: high interior relative humidity (RH), high roof reflectance,<sup>1</sup> and especially air intrusion.<sup>2</sup> One contributor—the impact of warm humid air leaking out the ends of improperly terminated exhaust vents—is like the proverbial 500-lb. gorilla. We are keenly aware he is in the “reroof” room with us, but we’ve done a pretty good job of ignoring him. When this big guy creates a problem, however, roof professionals are often asked to explain why they did not “correct” the improper exhaust vent termination conditions before installing new flashing assemblies over them.

This article will explain why complete discharge of exhaust air—especially gas combustion products—is so important, will review code requirements for

termination of exhaust vents, identify tell-tale signs of existing condensation problems, and will offer ways to avoid exhaust vent-related condensation problems.

Although broken or disconnected exhaust vents can pose an even more serious problem, this article will focus on how improper termination of exhaust vents can contribute to excessive condensation in low-slope membrane roofs. All photos in this article are courtesy of DNG Group Companies – Technical Roof Services and Pacific Building Consultants – and show

projects located in California in ASHRAE Climate Zone 3.

#### SOFT SPOTS

Serious condensation problems often start with someone noticing a soft spot like that shown in *Figure 1*. Typically, the soft spot is positioned near a “high” point on the roof, the roof construction contains air spaces with cold surfaces, and the reroof membrane is considerably more reflective than the old roof membrane. More often than not, the roof is installed over a residential occupancy.



*Figure 1 – Serious condensation problems usually start with someone noticing a soft spot.*

Before we go further, let's review some condensation-related concepts: RH, dew point, radiative cooling, and convective air currents.

### DEW POINT AND RH

Let's say it is 52°F (11°C) outside and foggy. The air can't hold any more water vapor; it is at its dew point temperature. It is at 100% RH. Water vapor starts condensing on exposed surfaces. Since warm air can hold more water vapor than cold air, if we let this air inside and heat it up to 72°F (22°C), its RH drops to 50%, but the dew point temperature doesn't change. So, if we cool the air back down to 52°F (the dew point temperature), condensation of water on surfaces will begin again. Pretty straightforward. Condensation is primarily related to the temperature of the air and the surfaces it encounters.

What we need to keep in mind is that on most winter nights, the temperature of our wood roof decks (when we insulate below the deck) gets well below the dew point temperature of the air inside our buildings—even here in sunny California. This means that if the air inside our buildings were to come into contact with our wood decks at night, it would condense. It does and it does. I'll explain why.

### SMOKE AND DEW

Two things we learned as kids: Smoke rises, and dew forms on grass overnight. Later, someone explained to us that this was because warm air is less dense than cool air (thermal buoyancy), and surfaces exposed to a clear sky at night lose lots of heat (radiative cooling). This means that the air inside our buildings naturally wants to rise up into our roof assemblies. And, if it's cold outside—and especially if the sky was clear overnight—the intruding air will cool down to its dew point temperature and condense inside our roofs.

This happens all the time, and usually our roofs have enough water storage capacity that it doesn't create a problem. But sometimes too much water ends up condensing, and things we don't like to talk about start to grow and wood starts to decay. At the moment, I'm referring to condensation of water vapor that hitched a ride up into the roof on a convective air current. It can get a whole lot worse if the air we're talking about condensing is being propelled under pressure out the end of an improperly terminated bathroom fan duct or gas flue vent.

There are two basic kinds of exhaust vents: environmental air ducts and gas vents. Living units (single-family homes or multi-unit apart-



Figure 2 – A high concentration of exhaust vents on the roof of a three-story apartment building.



Figure 3A – A “soft spot” (red arrow) found next to an improperly terminated gas vent.

Figure 3B – A gas vent improperly terminated inside the roof flashing assembly very near deck level.





Figures 4A (left) and 4B (below) – A “wet” coverboard is shown next to 7-in. air ducts that terminate below 5-in. T-top flashings.



ment buildings) typically have two or three exhaust vents per unit—something like one or two every 1000 sq. ft. of roof area. Roofs over most nonresidential occupancies have far fewer exhaust vents. *Figure 2* shows a high concentration of exhaust vents on the roof of a three-story apartment building.

#### ENVIRONMENTAL AIR DUCTS

Environmental air ducts are typically single-walled, do not have any required clearances from combustibles, and are connected to exhaust fans serving bathrooms, stove hoods, and/or clothes dry-

ers. The exhaust air is “pushed” along by a fan.

#### GAS VENTS

Gas vents are typically dual-walled, require minimum clearances from combustibles (because they can get hot), and are connected to appliances like gas water heaters and gas furnaces. By the way, when gas is burned, it produces heat, CO<sub>2</sub>, and lots of water vapor. This is why you sometimes see water dripping out of a car’s exhaust pipe. Water heaters typically rely on convective currents to carry the combustion products up and out of the gas vent.

up and out of the gas vent.

If the gas combustion products are completely vented to the outside, great. If not, you can get serious condensation and wood decay. *Figure 3A* shows a “soft spot” (red arrow) found next to an improperly terminated gas vent. *Figure 3B* shows the gas vent improperly terminated inside the roof flashing assembly very near deck level.

You might ask, “How, then, are exhaust vents supposed to be terminated?” Good question. It depends on the type of exhaust vent you’re asking about. Code requirements for environmental air ducts and gas vents are different.



Figures 5A (above) and 5B (right) – Two air ducts are positioned in an oversized deck opening and terminated inside one large roof flashing.



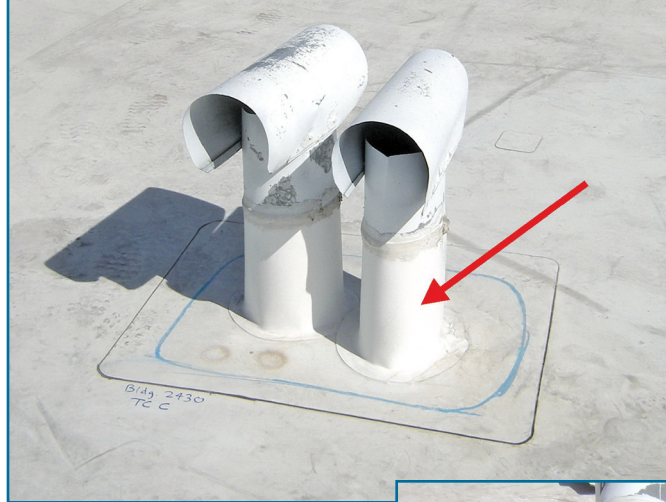
## CODE REQUIREMENTS

The 2013 California Mechanical Code (CMC), based on the 2012 Uniform Mechanical Code, Chapters 5 and 6, requires environmental air ducts, including joints, to be substantially airtight and terminate outside the building at least three feet from openings into the building. (Note: The 2013 California Residential Code refers back to the CMC for requirements.)

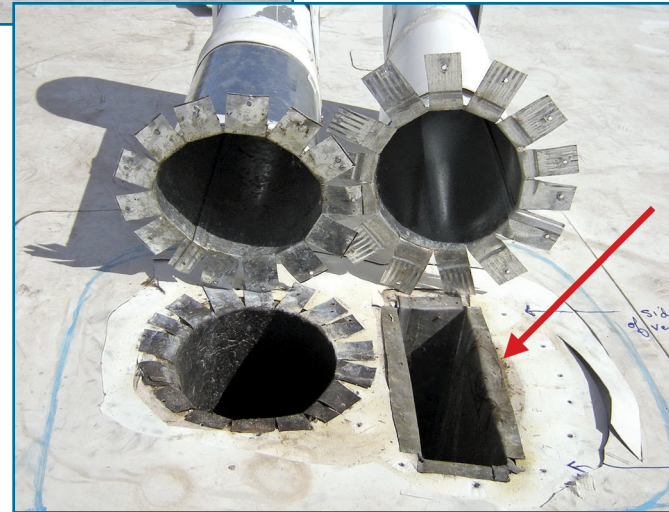
The conditions shown in Figures 4, 5, and 6 were all discovered while investigating “soft spots” on reroof projects. Figures 4A and 4B show a “wet” cover board next to 7-in. air ducts that terminate below 5-in. T-top flashings. Figures 5A and 5B show two air ducts positioned in one oversized deck opening and terminated inside one large roof flashing. Figures 6A and 6B (red arrows) show a rectangular air duct stopping at deck level and then “extended” upward using a round roof flashing.

It is not clear if the metal flashings installed over these air ducts would be considered extensions of the duct or not, or if the openings in the decks around the ducts would be considered “openings into the building.” Nevertheless, these duct terminations and flashing conditions were all strongly suspected to allow some portion of the exhaust air to flow back into the insulated rafter spaces and make a major contribution to the excessive condensation conditions present.

Gas vents have different termination requirements. The 2013 CMC, Chapter 8, requires gas vents to extend completely through roof flashings, extend to a height at least 12 inches above the roof deck, and have “listed caps.” Figure 7 shows two properly extended and terminated gas vents.



Figures 6A (left) and 6B (below) – Red arrows show a rectangular air duct stopping at deck level and then “extended” upward using a round roof flashing.



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Figure 7 – Two properly extended and terminated gas vents.

### KNOW YOUR CODES

Codes address other aspects of roof construction that potentially impact how much water accumulates in a roof assembly. I'll mention just two applicable California codes:

- The 2013 California Energy Code (CEC), Section 110.7, requires sealing of joints, openings, and other potential sources of air leakage into or out of the building envelope.
- The 2013 California Building Code (CBC), based on the 2012 International Building Code, Section 1203, requires cross ventilation of “enclosed rafter spaces.”

Code provisions are amended and/or interpreted on the local level—sometimes quite differently. Accordingly, I suggest roof professionals review local code amendments and/or seek clarification with the local code official regarding how various code provisions apply (or don't apply) to specific reroofing projects.

### COMPACT ROOFS AND FRAMED ROOFS

Borrowing terms coined by Wayne Tobiasson of the Cold Regions Research and Engineering Lab (CRREL), I refer to roofs with rigid board insulation above the deck as “compact” roofs and those with batt insulation below the deck as “framed”

roofs.<sup>3</sup> Some roofs have or end up having insulation above and below the deck. I call these roofs “a good idea.”

West Coast wood-framed roofs with only batt insulation below the deck are inherently prone to condensation. They are prone to condensation because they contain air spaces with cold surfaces. And, usually, the air inside the building has a pretty easy time working its way up into these air spaces and condensing. Compact roofs, on the other hand, have limited air spaces with cold surfaces (e.g., joints of insulation

boards), and by their very construction, naturally resist air intrusion. We've talked about this before.<sup>4</sup>

### BLINDSIDED

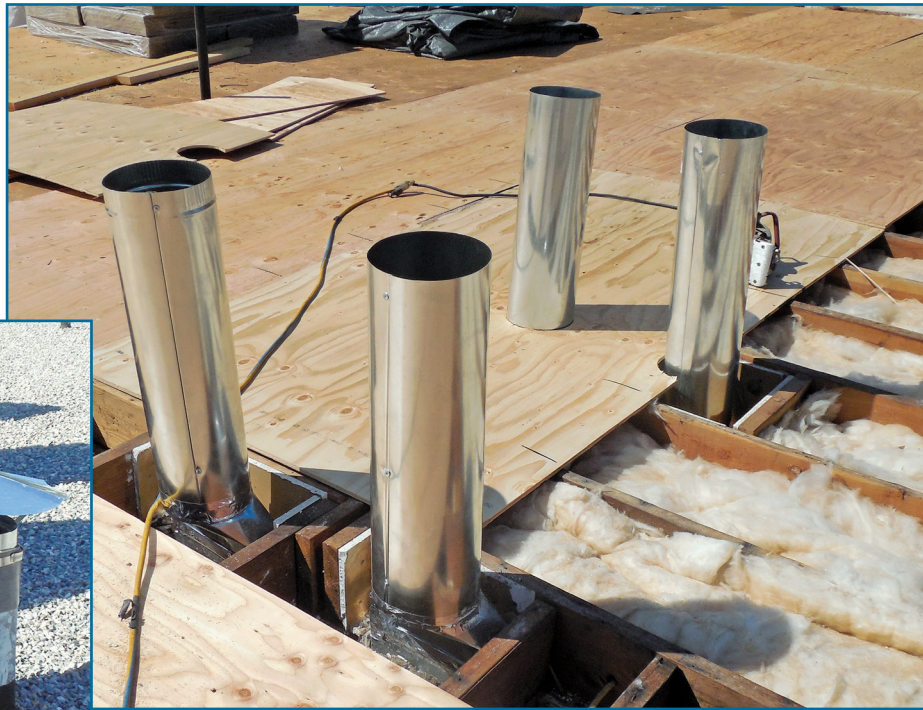
The most common cause of a serious condensation problem (e.g., soft spots) is, well, an existing condensation problem. This is true whether the existing problem is due to intrusion of high-RH air or leaky exhaust vents. In such cases, if highly solar absorptive roofs are replaced with highly reflective roofs, existing condensation problems can inadvertently be kicked into high gear and roof professionals may end up wondering what hit them. Note: The same physics apply when a “cool” coating is applied over a “non-cool” roof membrane.

Many older low-slope membrane roofs installed over wood decks with insulation below have condensation problems; they accumulate more water than they should. Usually, however, they also have roofs that absorb lots of solar radiation. The highly absorptive (non-highly reflective) roofs get hot whenever the sun comes out and work to rapidly dry accumulated water downward. This can keep even fairly serious condensation problems at bay for years. When these roofs get replaced after 13 to 18 years, they often require replacement of an unusually large amount of deck—enough to make a roof professional wonder why the owner didn't complain more about roof leaks.



Figure 8 – An area of concentrated decay.

Figures 9A (right) and 9B (below) – Example of how existing low air ducts can be extended and flashed.



Keep this in mind: A large amount of deteriorated wood decking without a correspondingly high number of reported leaks is a telltale sign of an existing condensation problem.

Unfortunately, when an existing condensation problem is unleashed by installation of a “cool” roof, wood decks can start showing nasty bite marks (e.g., soft spots) after just a few years. This was sort of an

epiphany to me, and maybe to you, too. As mentioned above, the silver lining to this ominous cloud is that existing condensation problems usually exhibit telltale signs—if you know how to read them.

#### WARNING SIGNS

The best time to find out a roof has an existing condensation problem is before the roof is specified and bid. However, the best time to see warning signs is during roof removal.

Before tear-off, warning signs include reports of roof leaks when it is not raining, soft spots not near penetrations or flashings, ceiling stains near high points, and multiple stains below metal hangers.

During tear-off, warning signs include more decay than the number of reported leaks suggest, decay at locations not readily explained by roof leaks, and exhaust vents that terminate very near the roof deck.

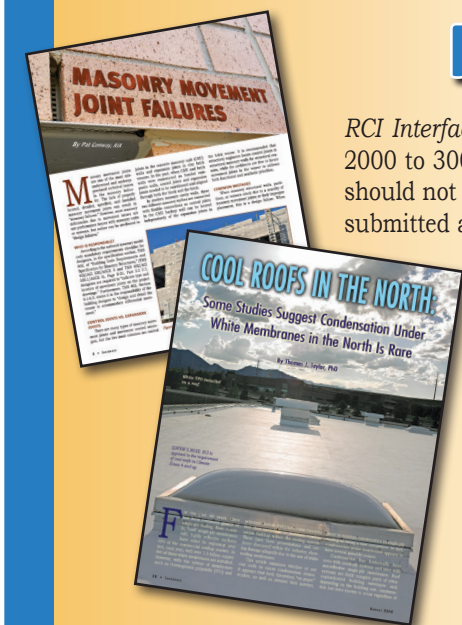
Figure 8 shows an area of concentrated decay. The area is not near a low spot or next to a penetration, but penetrations are nearby. No rain leaks were reported, and the top of the gypsum ceiling boards had

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only limited stains. The decay is not reasonably explained by a roof leak; it is a telltale sign of an existing condensation problem.

#### LOW-EXHAUST VENTS

When “low-exhaust” vents are uncovered, extend them in accordance with code requirements. Obtain the assistance of a mechanical engineer or a design/build mechanical contractor as needed. *Figures 9A and 9B* show one example of how existing low air ducts can be extended and flashed.

#### SUMMARY

The best way to deal with a 500-lb. gorilla is to swing open its cage and face it head on. Keep in mind that improperly terminated exhaust vents can discharge large amounts of water vapor into enclosed rafter spaces, and that some roofs rely on solar heating to keep excessive condensation in check. Extend and flash low-exhaust vents, as needed, in compliance with local code requirements. Watch for telltale signs of existing condensation problems, especially if your project involves replacing a highly solar-absorptive roof with a highly solar-reflective one.

If unusually large amounts of decking need to be replaced, and the large amounts can't be reasonably explained by roof leaks, investigate the cause; it is likely due to the intrusion of high-RH interior air and/or leaky exhaust vents. Depending on the results of the investigations, air sealing around penetrations, adding rigid board insulation above the roof deck,<sup>5,6</sup> repairing exhaust vents, and/or upgrading mechanical ventilation systems inside may be warranted. 

Note: The 2013 CEC, Section 150, based on ASHRAE Standard 62.2-2010, now requires mechanical ventilation for all low-rise residential buildings for indoor air quality, which also helps considerably to control interior RH levels.

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## VERTICAL FOREST PLANNED IN NANJING

Nanjing Green Towers, promoted by Nanjing Yang Zi state-owned National Investment Group Co. Ltd., will be the first vertical forest built in Asia. Located in Nanjing Pukou District, the two towers will be characterized by the interchange of green tanks and balconies, following the prototype of Milan's award-winning Vertical Forest (Bosco Verticale). The project, scheduled to be finished in 2018, is the third prototype (after Milan and Lausanne) of a project about “urban forestation and demineralization” that Stefano Boeri Architects plans to develop worldwide, especially in other Chinese cities, in the hopes of absorbing tons of CO<sub>2</sub> and producing oxygen to the smog-plagued cities.



Along the façades of the Nanjing Green Towers will be balconies with 600 tall trees, 500 medium-sized trees, and 2,500 cascading plants and shrubs. The vertical forest will provide 25 tons of CO<sub>2</sub> absorption each year and produce 60 kg of oxygen per day.

The taller, 200-meter- (656-ft.-) high tower will be crowned on top by a “green lantern.” The building will host offices from the 8th to the 35th floors and will include a museum, a green architecture school, and a private club on the rooftop. The second tower (108 m or 354 ft.) will house a 247-room Hyatt hotel and a rooftop swimming pool. The 20-m (66-ft.) podium will host commercial, recreational, and educational functions, including shops, a food market, restaurants, conference hall, and exhibit spaces.

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