CRAWL SPACE MOISTURE CONTROL - A Fundamental Misunderstanding

By Peter Carpenter, member ASHRAE, SBCCI

A crawl space needs to be ventilated with outside air. Without ventilation there will be growth of molds, spores, bacteria, higher levels of chemical vapors (termiticides), radon, all of which migrate into the home.

The Standard Building Code specifies a ratio of foundation ventilation area to crawl space area. This ratio was increased to 1 sq ft of opening for each 150 sq ft of crawl space, in recognition that existing codes were not preventing excessive crawl space humidity. Unfortunately, this revised specification does little to improve the situation.

- Most of the moisture in the crawl space is not coming from the ground. Since some moisture does, it is a problem that has to be addressed.

- Unassisted airflow in and out of the crawl space via foundation vents is minimal, and not much of a factor in controlling crawl space moisture.

- Crawl space humidity is controlled by outdoor atmospheric conditions.

- Whether or not foundation vents are open or closed, crawl space humidity moves up and down simultaneously with all changes in water vapor content of outdoor air.

This is important, and it's worth repeating. Crawl space humidity moves up and down simultaneously with changing outdoor water vapor content.

Here's the point! If crawl space humidity moves simultaneously with changing outdoor atmospheric conditions, it cannot be possible that moisture moves down through the ground, under the footer, back up through the ground, then passes through the vapor barrier, more or less, instantly. In reverse, after a heavy rain, the ground is saturated. Yet the crawl space humidity falls immediately when the weather front moves away. This is clearly shown on Chart 1.

Crawl space humidity moves even with subtle changes in weather conditions (Chart 1). Moisture is moving in and out of the crawl space, by vapor diffusion, entering through foundation vents, block walls, and every minute opening around the rim joists.

Explanation:

1. Let's understand water vapor content and [1]vapor pressure. This is the absolute total amount of water (moisture) contained in a body of air. In this paper we are going to use the term "vapor pressure" to express water vapor content, because the term "pressure" more easily explains what is taking place.

2. Within the narrow temperature differentials (Kelvin scale) between outside air and crawl space air, absolute moisture content, water vapor content, and vapor pressure are the same.

3. Vapor pressure moves like air pressure, from higher pressure to lower pressure. Movement of water vapor is unstoppable, unless there is a total seal like the tire on your car.

[1] Technically, "Partial Vapor Pressure".

4. Crawl space humidity moves with all weather changes. Chart 1 shows that when a weather front (wet or dry) moves in, crawl space humidity not only moves with it, but moves exactly at the same time!

5. Aside from poor construction or drainage there are at least three mechanisms that subject *all* crawl spaces to wet air. These mechanisms cause outdoor vapor pressure to be greater than crawl space vapor pressure. It is this higher outdoor vapor pressure that *drives* moisture into the crawl space.

6. Crawl space humidity does not track outdoor humidity nor does it track outdoor temperature.

7. Of course, crawl space vapor pressure does follow outdoor vapor pressure. If you compare the two, then science to a drier crawl space is simple. Turn the fan on at the right time, keep it off otherwise.

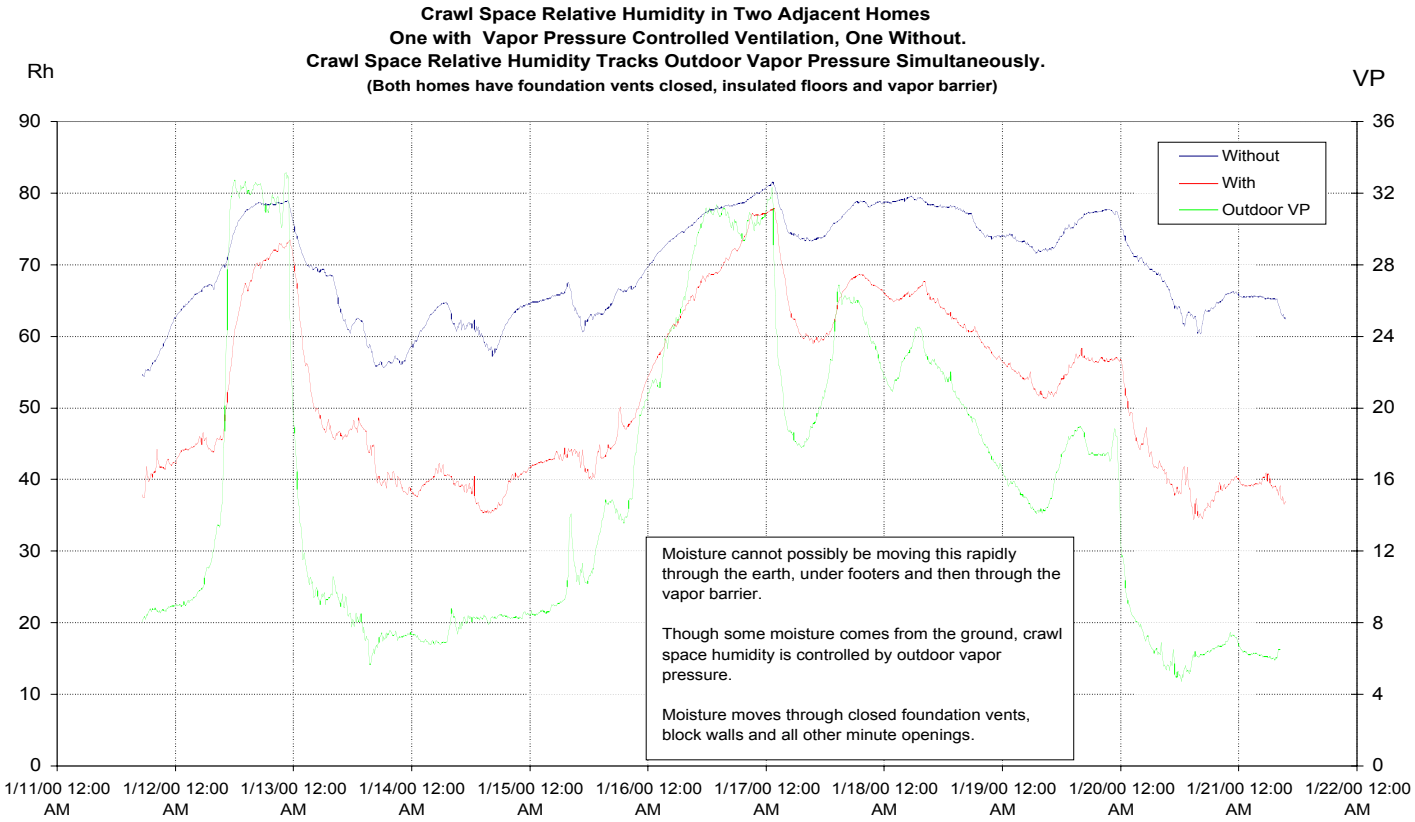


Chart 1

Data recorders were put into crawl spaces of several homes. Two homes are side by side. A third data recorder logs outdoor conditions at these two homes. Both homes have insulated floors and vapor barriers on the crawl space earth. It is winter and foundation vents are closed in both homes. One home has a "vapor pressure" controlled mechanical ventilation device (a fan). The other does not.

Chart Interpretation

Peaks are periods of rain. There are periods of intermittent rain, warm dry air, and cool dry air.

The vapor pressure controlled device turns on its fan when outdoor vapor pressure is lower than crawl space vapor pressure. Thus, a high ventilation rate occurs only when outside air has a drying effect.

1. The most important fact is how quickly crawl space relative humidity rises and falls with outdoor vapor pressures. When a weather front moves in or out, and outdoor vapor pressure rises or falls, humidity in both crawl spaces rises or falls, immediately.

2. If moisture had to move through the ground and vapor barriers, these relative humidity changes could not possibly occur immediately.

3. The average relative humidity in the home without the vapor pressure controlled device is 70%, whereas the home with the device averaged 52%. Using a fan only at the right time becomes highly beneficial.

4. This is winter. In summer, without a ventilator, even with all the foundation vents open, the relative humidity will be 80 to 90%. See Reference : Samuelson "Relative humidity exceeded 90% for 44 weeks".

Crawl spaces are regularly bathed with wet air, and a crawl space can't be made drier with wet air. So let's look at three mechanisms that cause wet air (high vapor pressure). The mechanisms are:

1. Rain. Periods of rain are easily understood. The relative humidity will be high, perhaps 90 to 100%.

2. Warm air holding more moisture than cooler air. A body of warm outside air may have a much lower relative humidity than the air in a cool crawl space. Yet the warm air may hold more moisture than the crawl space air. In summer at 95°f and 40% relative humidity outdoor air contains twice the maximum desired water content in a crawl space. When this air enters the crawl space and cools to crawl space temperature, crawl space relative humidity becomes 90%.

3. Nighttime. Many mornings arrive with dew on the ground. This comes about as the atmosphere cools early in the evening. The cooler part of the atmosphere (higher) can no longer hold as much moisture as it did when it was warmer, so moisture moves to lower (warmer) levels. At ground level moisture levels are usually very high in the evening in the summer. Outdoor vapor pressure has risen. After a few hours with rising moisture, and no solar heating, dew point (100% Rh) is easily reached.

These mechanisms, cause the outdoor vapor pressure to be greater than crawl space vapor pressure. And again, higher outdoor vapor pressure ***drives*** moisture into the crawl space.

After dawn, solar heating begins. The process reverses. Vapor pressure in the atmosphere is now lower than at ground level, some moisture has been absorbed by plant life, and some moisture escapes upward. However, in the crawl space some of the moisture at ground level

was ab(ad)sorbed, and is not released as easily. A crawl space does not have the advantage of solar heating or drying winds, so it stabilizes at an elevated vapor pressure. Relative humidity is 70% to 90%. This is a normal condition, and it is damaging.

Chart 1 shows there is no set time of day or night that is a favorable or unfavorable ventilation period. Vapor pressures can change at any time. Over the course of a single, sunny day variations greater than 100% were observed. Subtle weather changes occur that raise or lower the outside vapor pressure on a time as small as a few minutes. Because of the affinity of a crawl space to retain excessive moisture, successful ventilation requires detection of favorable and unfavorable periods.

To summarize:

- Recognize the sum of these three mechanisms means there is less time available for outdoor air to reduce crawl space moisture than time outdoor air will increase crawl space moisture.

- The problem becomes when to ventilate? Ventilation should occur only when outdoor vapor pressure (moisture) is lower than crawl space vapor pressure.

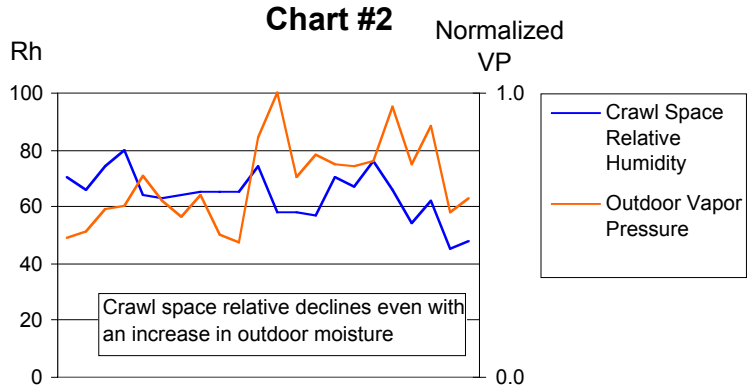
- Favorable ventilation periods, are shorter and fewer than unfavorable periods. Therefore, air must be exchanged air at a high rate during favorable periods, and a low rate when it is not favorable to ventilate.

- Only mechanical ventilation can fulfill this requirement.

- Ventilation schemes must be sufficiently intelligent to discern favorable periods from unfavorable periods.

An intelligent vapor pressure controlled device can exploit weather variations that are imperceptible to a human, detecting subtle, short duration weather changes that raise or lower outdoor vapor pressure, and use these variations to advantage. When a favorable period is detected, the fan is energized to exhaust air from the crawl space, and continues to exhaust until it is no longer favorable to ventilate.

In a trial a year ago with a vapor pressure controlled device (see chart 2), before the trial started, water (condensation) was on top the ground cover. For the trial all foundation vents were closed. When the fan is running, the crawl space is slightly depressurized, permitting a more even draw around the entire structure… leakage inward from *all* the foundation vents, the perimeter plate, rim joists, and every small opening into the home. Compare this air exchange with the usual setup where an outside air current pressurizes only a couple foundation vents, likely pushing crawl space air into the home.



1999 Trial of Vapor Pressure Controlled Ventilator

Start-up took place in winter, when a crawl space is expected to be dry. Measurements continued through spring to early summer with outdoor vapor pressures rising. Even though outdoor vapor pressure (moisture) levels rose significantly, crawl space relative humidity declined. The water on the polyethylene was gone.

This trial showed reducing crawl space moisture is a lengthy period. Extracting moisture from a wood structure is a slow process outside of a kiln.

After the test shown in chart 2 was completed, the vapor pressure controlled device was removed, and all foundation vents were opened to see how the crawl space would respond.

Crawl space relative humidity rose quickly, with readings as high as 89%.

Finally, questions about the role of vapor barrier ground covers need answering. Does a ground cover lower crawl space humidity? The answer is yes, and the reason is simple. The earth under a home contains clay, and like a desiccant, it readily absorbs moisture, but gives it up more slowly.

How does the vapor barrier function? Remember, crawl spaces are regularly bathed with wet outside air. So, in part, the vapor barrier prevents the earth from picking up moisture from the water vapor that has been driven into the crawl space above the vapor barrier. Thus, the vapor barrier helps lower crawl space humidity. In reality, the vapor barrier does double duty.

Unfortunately, the vapor barrier creates another problem. Beneath the barrier the relative humidity is 100%. Molds, spores, and bacteria thrive in this environment, and migration into the home occurs.

It is important to ventilate a crawl space. But by ventilating intelligently, you can stop the drenching of the under-home structure. Termites thrive when the relative humidity is above 60%. Equally important, intelligent ventilation will mitigate molds, bacteria, wood rot, undesirable odors, chemical vapors, and gases such as Radon.

Depressurizing the crawl space slightly will improve Indoor Air Quality (IAQ) in the home.

In addition to comparison of water vapor content, smart controls offer many options. For

instance, this ventilator does not ventilate until a 43°f minimum outdoor temperature is reached. Crawl space winter temperatures were in the mid 50°s, minimizing home energy losses, and protecting pipes from freezing.

Homes built over crawl spaces have a lot of advantages. Smarter technology is used in building materials, home appliances, and HVAC equipment to improve the environment. Applying technology for controlling crawl space moisture is just another logical step.

It was stated earlier that vapor pressure moves, just as air pressure, from higher to lower pressure areas. The inside of a home is certainly sealed better than a crawl space, yet, for health and comfort, air conditioning of the home is required to remove moisture. This process, of course, lowers the indoor vapor pressure, forcing water vapor migration inward continuously.

In developing the current building code, earlier studies focused on evaporation rates of soil, and assumed unrealistically high rates of air changes through open foundation vents. It is clear that unassisted air flow into a crawl space is minimal, negligible in relation to vapor pressure forces.

A paper is being prepared for submission to SBCCI and BOCA proposing a change in building code acknowledging vapor pressure controlled mechanical ventilation will facilitate a healthier environment for the crawl space, and ultimately, the home. That such a device should include a minimum ventilation temperature, and where hardwood floors are built over a crawl space, parameters to help stabilize minimum and maximum moisture in the crawl space.

Other studies indicating moisture is driven into crawl spaces by higher water vapor content of outdoor air:

Samuelson 1994 stated:

Vapor concentration in the crawl space has been linked to…vapor concentration of the outdoor air and an additional moisture input". "with a moisture input of 2g/m^3 it (crawl space) exceeds 90% RH for 44 weeks."

"A relative humidity of 85-90% can be expected in a normal, well-insulated, and well ventilated crawl space foundation structure during the summer."

"Introducing outside air into a cool crawl space during summer raises crawl space relative humidity, at a time when temperatures are most conducive to formation of mold and decay."

Stiles & Custer 1994.

"A strong correlation was found between moisture content and effective leakage area between the crawl space and outside."
Proposed that crawl spaces should be sealed, with no operable vents, while some conditioning should be included to ensure crawl space is dry.