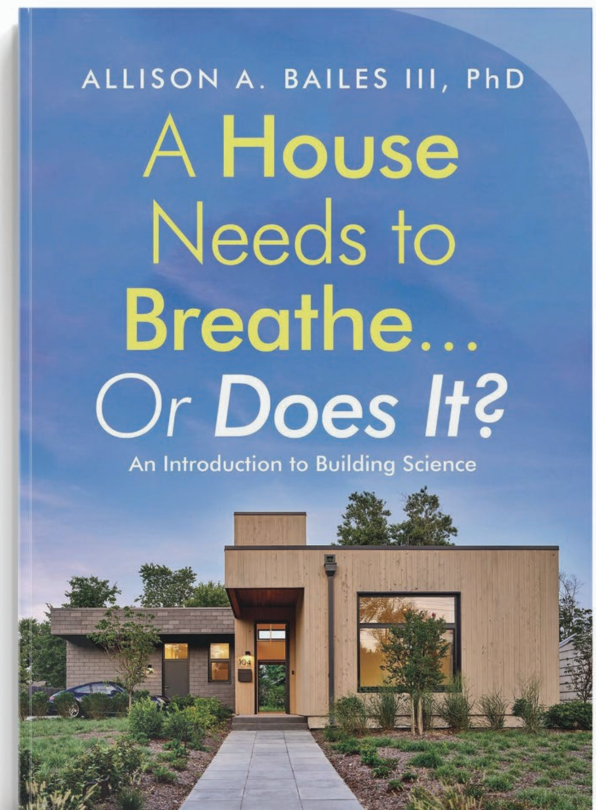
A House Needs to Breathe … Or Does It?: A Conversation With Allison Bailes

This past summer, JLC editor Clay DeKorne had a chance to sit down virtually with Allison Bailes to speak with him about his book, A House Needs to Breathe … Or Does It? An Introduction to Building Science. *The following is a portion of that discussion.*



Clay DeKorne: If there's one book on building science I would recommend to builders and remodelers, it's yours. Here, I want to first give readers an overview of that book before we delve into a few of the topics I have previously found difficult to understand and that your book helps me understand much better for solving real-life building problems.

To begin, the book is organized into three parts, and the first is titled "Start at the End." Can you explain what this means?

Allison Bailes: Well, if you start down a path and don't know where you're going, who knows where you're going to end up. Now that's a valid way to travel sometimes, but if you're building something, you want to know what it is you want to end up with. It's not just: What should it look like? It's also going to be: What's the experience of the people who occupy that building? I'm talking about residential—about homes—and these are places where people raise their families. It's where they spend a lot of time. They sleep, they breathe a lot of air inside that house. They want to be comfortable, and they want to be able to have conversations without having to speak over the noise of the air conditioner. By beginning with "What's the Purpose of a House?" I'm just reminding people why building science is important. As I explain in the book, I'm inspired by the work of Robert Bean, a retired engineer who had a big impact on me and others. And he always says: "Design for people and good buildings will follow." For me, that is how we must begin. It's good to remember building is not all about the joinery and the materials; it's about the people who are going to occupy that house.

CD: Still keeping with the 30,000-foot view of the book, the remaining two parts are "The Building Enclosure" and "Mechanical Systems," in that order.

AB: I put them in that order intentionally. You have to start with the building enclosure. When you're talking about heating and cooling and ventilation, you need to first know how much heating and cooling a house needs and that depends on the building enclosure. Really, you want to minimize the amount of heating and cooling you need. You also want to minimize the pollutants that come from outside and from buffer spaces like the garage. So, you've got to start with the building enclosure because that's where all the action happens.

CD: I love the way you organize the building enclosure around controlling the various elements. In our industry, people often frame building science around the four "control layers"—water, air, vapor, and thermal. But I like how you don't just throw those terms around. You focus on the principles governing the interactions of elements that our buildings need to overcome, before you start talking about the things, the layers, that control these elements.

AB: Yes, language is very important. And defining the different control layers clearly, not just throwing these terms around without explanation, is important.

Part 2 on the building enclosure begins with Chapter 5, "Building Science 101," in which we have that initial definition of control

CHAPTER 7

Controlling Liquid Water

"*You can't trust water: Even a straight stick turns crooked in it.*"
–W.C. Fields

Now that we understand the properties of water, we can discuss controlling it. Because liquid water is the most important one to control, we'll begin there. The exterior of a house is covered with some kind of cladding, like brick, siding, or stucco on the walls and shingles, metal, or tile on the roof. Although the cladding stops a lot of the rain from getting through to the materials behind, it doesn't stop all of it. Wind, for example, can drive rain through gaps and into the space behind the cladding. That's why we need a liquid water control layer back there.

Before we get into the details, though, let's discuss vocabulary. Here are some important terms used for this part of the building enclosure:

Water control layer: Combination of the drainage plane, flashing, and other liquid water management details on the outside of a house. Sometimes it's called the liquid water control layer or the rain control layer.

Drainage plane: Water-repellent materials used in the field of roofs or walls to drain the liquid water, integrated with flashing and other liquid water management details to form the continuous water control layer. They may also act as the water vapor control layer, or they may allow water vapor to pass through. Common types include house wrap, building paper, and peel-and-stick membranes. (More on this below.)

Water-resistive barrier (WRB): Another term for the material used as a drainage plane; it's also called water-resistant barrier, weather-resistant barrier, or weather resistive barrier.

Flashing: Components that divert water away from parts of the building. It must be integrated with the drainage plane and is used around windows, doors, and transitions, such as where a roof meets a wall.

Drain the Rain

Draining a house properly is the aikido of building science. Just as an aikido master uses an opponent's momentum against him, an effective liquid water control layer incorporates slopes and diverters to keep water moving down and out from a house. Here's Joseph Lstiburek, PhD, PE, explaining the objective:

"The fundamental principle of water management is to shed water by layering materials in such a way that water is directed downwards and outwards out of the building or away from the building." [10]

The water wants to go down, and you design and install a series of layers that will ensure it also goes out. Down and out is the rule for draining the rain (Figure 7.1).

Think of it in personal terms. When you wear rubber boots, rain pants, and a raincoat, you have to put them on correctly to stay dry in the rain. You don't tuck the rain pants into your boots or your raincoat into your pants. You layer them the other way to keep the rain moving down and out.

Figure 7.1. *Layer your liquid water control materials to keep the water moving down and out from the house. [Courtesy of Joseph Lstiburek]*

10. RR-0103: Water Management. https://www.buildingscience.com/documents/reports/rr-0103-water-management/view, (9/15/01)

A sample page from Allison Bailes' best-selling book on building science.

layers. Then I devote a whole chapter (Chapter 6) to the properties of water before addressing why we need to control liquid water, air, water vapor, and heat in chapters 7, 8, 9, and 10. Chapter 11 is about applying those to an actual enclosure.

CD: Chapter 9 is on controlling water vapor. What I like about reading this chapter is that you force me to constantly go back and make sure that I've read and understood Chapter 6 on the properties of water. Water vapor seems an elusive substance in a building. It reminds me of how way back in the early '90s, *JLC* published an article called "The Last Word (We Hope) on Vapor Barriers" (Aug/1993). Of course, it wasn't the last word by a long shot. Why are condensation, water vapor, and diffusion so hard to understand?

AB: As you were talking there, something popped in my head that could be an article for one of my newsletter columns or a LinkedIn post—that is, which one of these things is not like the others: liquid water, heat, air, and water vapor? Well, for liquid water, air, and heat, we absolutely need control layers in every single house. Every assembly must have control layers for those; for water vapor, though, we may or we may not need a layer.

In general, we do need things to be able to dry out more than we need to be able to stop water vapor from moving through the materials. In really extreme climates—for example, in a very hot, humid climate—vapor retarders can be important on the outside of the structure. And in very cold climates, vapor retarders on the inside are often required. But even in these extreme climates, the vapor retarders may not always be Class 1 [such as poly]. These can end up causing more trouble than they prevent because they trap water.

When you go with Class 2, in the 0.1 to 1 perm range, the vapor retarder lets some water vapor through, but it stops enough to prevent problems; to prevent condensation on the cold exterior sheathing in a wall, for example.

CD: I like "one of these is not like the other." I see the point that there's no absolute rule, no one way to control water vapor. Sometimes the answer is to add nothing so the wall can dry. Don't add poly to the wall assembly; just make sure your interior paint is permeable. But we're going to paint the interior wall anyway and more likely than not with latex. With liquid water, on the other hand, we have to be much more purposeful.

AB: Yes, for liquid water, it's down and out and watch out for capillary action.

CD: So, can I throw a case study at you relating to vapor control?

AB: Sure.

CD: Imagine a crawlspace below an addition off the back of the main house. The house has a full basement, and there's no access to the crawlspace through the foundation wall between the addition and the main house. And there's very little space in the crawlspace. Above the dirt floor, the crawlspace varies between about 8 and 16 inches below the joists.

AB: In what climate zone?

CD: Climate zone 6. And because it's cold, they want to insulate the floor when they renovate what will become the kitchen.

AB: Are there vents to the outside of the crawlspace?

CD: No vents. It's an old house, built in the 1850s. When they opened the floor, it was super dry. But with dry dirt, there still might be moisture coming up through it, so the first thing they did was put a 6-mil poly vapor retarder over the dirt. And to insulate the floor, they used a combination of 2-inch rigid foam cut and fit between the joists at the bottom, sealed at the edges with can foam, and then the cavity above the foam was filled with Rockwool. So, they have a nice air barrier with the foam, along with insulation as a thermal barrier.

AB: Is a rubble foundation holding up the walls?

CD: Yes, there's a rubble stone foundation under the addition. When they ripped up the existing floor, they used spray foam to seal and insulate the perimeter. So, they've created this sealed space with poly on the bottom, spray foam on the sides and rigid foam on the top. If moisture gets in this space, can it dry out? With no access, how would you tell if you were creating a moisture problem? To me, it creates a risky space that can't dry. How would you deal with this, maybe place monitors in there?

AB: Yes, real data beats hypothesis and theories every time. You can't go wrong putting a data logger in there to "see" if it ever gets bad enough to cause any issues. If I wanted to understand what's going on in there, I would put a temperature and relative humidity monitor down there to see if the relative humidity ever goes really high. And if it does, how long does it stay there? Here's another case study: my in-laws' house two blocks from where I am right now. They have a 1962 Midcentury-Modern house with a basement in the center, a crawlspace on one side, and a crawlspace on the other side. So, two separate crawlspaces with the basement in between.

Both have ductwork running through them, so I encapsulated both of them and put a thermo-hygrometer with a remote sensor in each of the crawlspaces. One of them stayed below 60% relative humidity all the time; the other one was 70% and higher sometimes. So, one of them needed a dehumidifier, the other didn't.

With existing homes, it's difficult to predict if you're going to get it dry enough. You can seal the heck out of it and do your best, as I did on both crawlspaces. I thought I sealed them equally.

CD: Yeah, old houses get funky fast, right? There are just so many pathways that you can't predict because you can't see them.

One reason I wanted to zero in on vapor control is I feel like this is one of the areas where the energy code needs some work. The code seems well aligned with building science around air-sealing and insulation requirements but maybe falls down a bit on vapor control. The insulation requirements in the code [Table R402.1.2] could lead to a risky wall [prone to condensation] if you use a Class 3 vapor retarder [such as latex paint] in climate zones 6 and 7. (For more on this, see "Avoiding Wet Walls," *JLC* May/2017.)

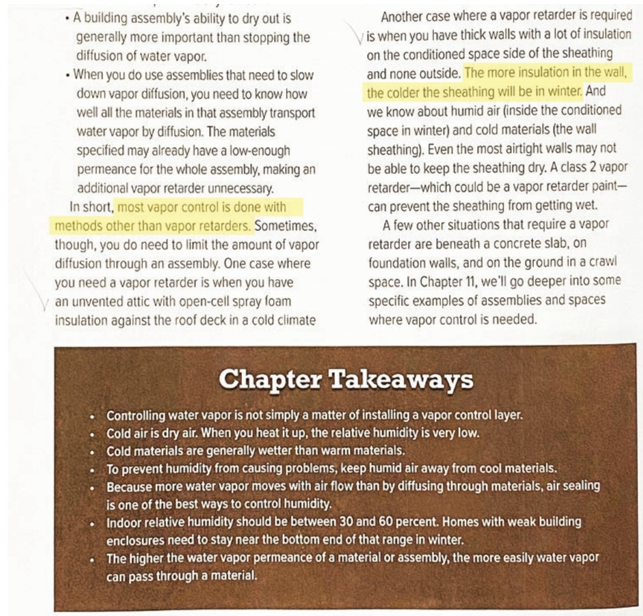
I also think that the code needs work on mechanical ventilation. This seems to be a part of the building code that code officials often don't understand well, especially whole-house airflow rates. I feel like this is a danger zone for our industry because we have solid air-sealing requirements now making tight buildings, without having a similar solid understanding of ventilation beyond installing bath fans. And in this post-COVID world that we inhabit, people are much more attuned to indoor air quality and to the impact of indoor pollutants and their impacts on our health.

ASHRAE 62.2 [the standard for whole-house ventilation airflow rates referenced in the energy code] seems fraught with challenges: There's been the Max Sherman versus Joe Lstiburek battle for a long time; it's kind of like health versus energy, where Lstiburek is saying we shouldn't over-ventilate and compromise energy performance of buildings by exhausting all the conditioned air away, and Sherman is reaching for a health-based ventilation standard. Lstiburek has a strong point when he says the problem is we don't have any sound epidemiological studies of indoor air that would give us a solid grounding of what's needed for airflow to control health. So, I wanted to throw that out and get your take on whole-house ventilation airflow rates within buildings and what you think is enough.

AB: As you may know, I was a big Joe follower on this 10 years ago, but my thinking has evolved away from what you're asking about. You're talking about indoor air quality, but you just zoomed right in on ventilation. Indoor air quality is about airtightness. It's about source control, filtration, moisture control, pressure balancing, and then ventilation. We've been persuaded for decades by that one saying, "build tight, ventilate right," and people believe that's all you have to do: Build a tight house and ventilate, and you get good indoor air quality. That's not the answer.

With the pandemic and learning about COVID-19, we found you can solve that with filtration. Infectious particles are things you can filter out of the air with a media filter. That's why, of course, the Corsi-Rosenthal Box became so popular, because once we realized COVID is airborne, we got these little particles that become aerosolized and float around for hours, maybe days. Filtration can reduce the number of those particles and the chance of getting sick.

So, when you combine ventilation with those other things—airtightness, filtration, source control, and pressure balancing—then we don't need a super high ventilation rate. Airtightness



- A building assembly's ability to dry out is generally more important than stopping the diffusion of water vapor.
- When you do use assemblies that need to slow down vapor diffusion, you need to know how well all the materials in that assembly transport water vapor by diffusion. The materials specified may already have a low-enough permeance for the whole assembly, making an additional vapor retarder unnecessary.

In short, most vapor control is done with methods other than vapor retarders. Sometimes, though, you do need to limit the amount of vapor diffusion through an assembly. One case where you need a vapor retarder is when you have an unvented attic with open-cell spray foam insulation against the roof deck in a cold climate

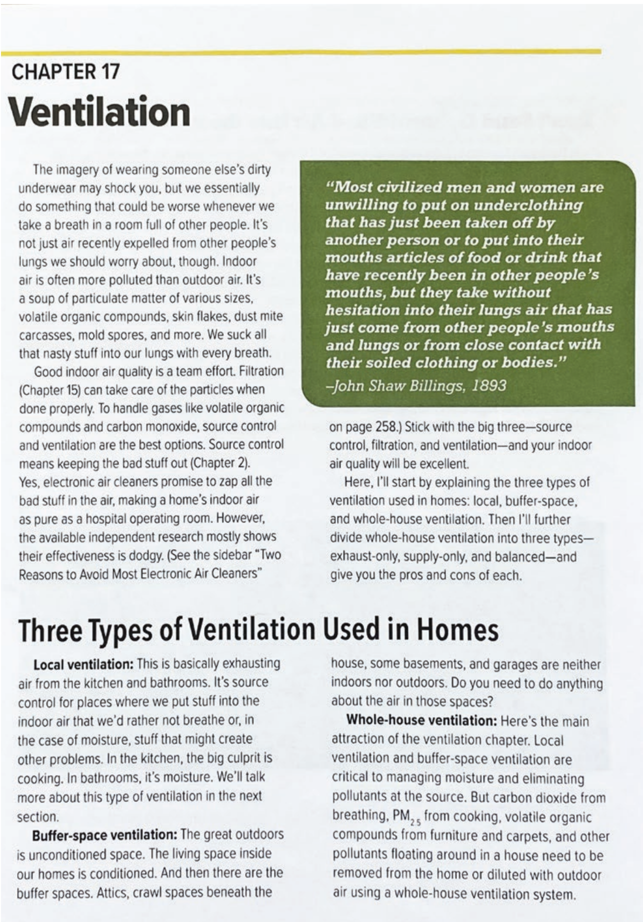
Another case where a vapor retarder is required is when you have thick walls with a lot of insulation on the conditioned space side of the sheathing and none outside. The more insulation in the wall, the colder the sheathing will be in winter. And we know about humid air (inside the conditioned space in winter) and cold materials (the wall sheathing). Even the most airtight walls may not be able to keep the sheathing dry. A class 2 vapor retarder—which could be a vapor retarder paint—can prevent the sheathing from getting wet.

A few other situations that require a vapor retarder are beneath a concrete slab, on foundation walls, and on the ground in a crawl space. In Chapter 11, we'll go deeper into some specific examples of assemblies and spaces where vapor control is needed.

Chapter Takeaways

- Controlling water vapor is not simply a matter of installing a vapor control layer.
- Cold air is dry air. When you heat it up, the relative humidity is very low.
- Cold materials are generally wetter than warm materials.
- To prevent humidity from causing problems, keep humid air away from cool materials.
- Because more water vapor moves with air flow than by diffusing through materials, air sealing is one of the best ways to control humidity.
- Indoor relative humidity should be between 30 and 60 percent. Homes with weak building enclosures need to stay near the bottom end of that range in winter.
- The higher the water vapor permeance of a material or assembly, the more easily water vapor can pass through a material.

At the end of each chapter, Bailes has included a short list of "takeaways." When DeKorne commented on how helpful these are, Bailes cautioned that they might not include every key point. "As an author, you have to make decisions and maybe somebody else wouldn't pick those same things," he said.



CHAPTER 17

Ventilation

The imagery of wearing someone else's dirty underwear may shock you, but we essentially do something that could be worse whenever we take a breath in a room full of other people. It's not just air recently expelled from other people's lungs we should worry about, though. Indoor air is often more polluted than outdoor air. It's a soup of particulate matter of various sizes, volatile organic compounds, skin flakes, dust mite carcasses, mold spores, and more. We suck all that nasty stuff into our lungs with every breath.

Good indoor air quality is a team effort. Filtration (Chapter 15) can take care of the particles when done properly. To handle gases like volatile organic compounds and carbon monoxide, source control and ventilation are the best options. Source control means keeping the bad stuff out (Chapter 2). Yes, electronic air cleaners promise to zap all the bad stuff in the air, making a home's indoor air as pure as a hospital operating room. However, the available independent research mostly shows their effectiveness is dodgy. (See the sidebar "Two Reasons to Avoid Most Electronic Air Cleaners" on page 258.) Stick with the big three—source control, filtration, and ventilation—and your indoor air quality will be excellent.

Here, I'll start by explaining the three types of ventilation used in homes: local, buffer-space, and whole-house ventilation. Then I'll further divide whole-house ventilation into three types—exhaust-only, supply-only, and balanced—and give you the pros and cons of each.

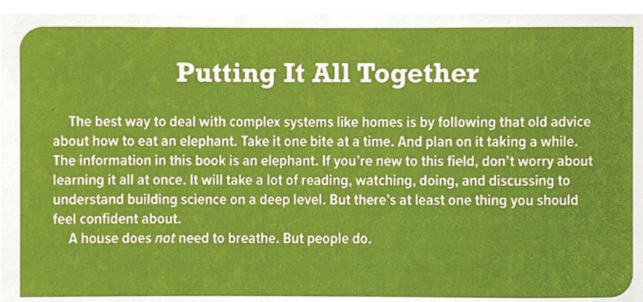
> ***"Most civilized men and women are unwilling to put on underclothing that has just been taken off by another person or to put into their mouths articles of food or drink that have recently been in other people's mouths, but they take without hesitation into their lungs air that has just come from other people's mouths and lungs or from close contact with their soiled clothing or bodies."***
> *–John Shaw Billings, 1893*

Three Types of Ventilation Used in Homes

Local ventilation: This is basically exhausting air from the kitchen and bathrooms. It's source control for places where we put stuff into the indoor air that we'd rather not breathe or, in the case of moisture, stuff that might create other problems. In the kitchen, the big culprit is cooking. In bathrooms, it's moisture. We'll talk more about this type of ventilation in the next section.

Buffer-space ventilation: The great outdoors is unconditioned space. The living space inside our homes is conditioned. And then there are the buffer spaces. Attics, crawl spaces beneath the house, some basements, and garages are neither indoors nor outdoors. Do you need to do anything about the air in those spaces?

Whole-house ventilation: Here's the main attraction of the ventilation chapter. Local ventilation and buffer-space ventilation are critical to managing moisture and eliminating pollutants at the source. But carbon dioxide from breathing, $PM_{2.5}$ from cooking, volatile organic compounds from furniture and carpets, and other pollutants floating around in a house need to be removed from the home or diluted with outdoor air using a whole-house ventilation system.



Putting It All Together

The best way to deal with complex systems like homes is by following that old advice about how to eat an elephant. Take it one bite at a time. And plan on it taking a while. The information in this book is an elephant. If you're new to this field, don't worry about learning it all at once. It will take a lot of reading, watching, doing, and discussing to understand building science on a deep level. But there's at least one thing you should feel confident about.

A house does *not* need to breathe. But people do.

The chapter on ventilation (top) comes in Part 3 after chapters on heating and cooling systems, on filtering indoor air, and on dehumidification. This organization underscores the point Bailes makes in this interview that ventilation comes after other strategies for improving the quality of indoor air. The closing of the book (above) brings readers full circle back to the purpose of building better homes: improving life for the people who live in them.

keeps the bad stuff from the outdoor air from getting in. We want a good air barrier between the house and the garage and the moldy basement and a dirty attic or outdoor air with lots of pollen and PM 2.5 [particles that measure 2.5 microns]. You want source control so you don't bring the bad things into the house or do bad things that create pollutants inside the house. You want moisture control so you don't grow mold in the house or inside the walls. Pressure balancing can create infiltration in some areas, exfiltration in others, and that can bring bad stuff into the house. And when you do all this, that's where good indoor air quality comes from. It's not just one or two things you have to do. You really have to do all of them. And when you do all of them, you don't need as much ventilation.

The other thing about ventilation is a lot of people think, "Oh well, you only need ventilation for houses that are at a certain level of airtightness, like below 5 ACH50. Well, I live in a house built in 1961 that probably was like 16 or 17 ACH50 about 12 years ago and now it's down to 8½ ACH50, and with my basement remodel I'm working on now, I'm going to get it down, I hope, to about 5 ACH50.

Yet, even with ACH50 above that, it doesn't mean we always have infiltration happening. And if you do have infiltration, you know the best possible air is not coming from the garage, or from the crawlspace or the attic. And even if it's all coming from outdoors, the amount of infiltration that you have, I'm sure you know, depends on how much stack effect is going on and on how much wind is blowing and on what's happening with your mechanical systems. Often, if you don't have mechanical systems running and it's not windy and it's a spring day, you have pretty much no infiltration. You can sit inside a closed house on that day and build up some serious levels of indoor pollution. So even in old leaky houses, mechanical ventilation can be a good thing.

CD: I know that from my leaky old house when I started using an Airthings Plus monitor up in the kids' bedroom at night and seeing the carbon dioxide levels spike.

You're right that I am influenced by the "build tight, ventilate right" mantra that focuses attention on mechanical ventilation in front of everything else. I formed the notion that it doesn't make sense to put a mechanical ventilation system in an old house until I've gotten it down, you know, to a real blower-door tightness level. I guess that's fallacy #1. And then you're right, I'm pulling away from all these other variables besides the ventilation rate. Thanks for clarifying that for me, as you do so often in your work, the Energy Vanguard blog, and this book included.

I know we've barely scratched the surface of everything you cover in your book. It's such a readable book, and I'm enjoying rereading it. I'll probably need to go through it many times before I consume the whole elephant [see "Putting It All Together," at left, for this reference]. I hope *JLC* readers will be intrigued enough by this discussion to search it out on Amazon and EnergyVanguard.com, right?

AB: Thank you ... Yes, it's available on EnergyVanguardStore.com and is $10 cheaper there than on Amazon.