Energy & Moisture Matters

We ask a panel of building scientists and builders — all keen, experienced observers of wood-frame performance issues — to answer some of the questions that never seem to go away

Q Do vapor retarders do any good?

A ***Joe Lstiburek, PE, a principal of Building Science Consulting in Westford, Mass., responds:*** The answers are "sometimes" and "it depends." The primary purpose of a vapor retarder is to reduce the amount of moisture that gets into an assembly. Unfortunately, the same vapor retarder can also reduce the amount of moisture that can get out of an assembly. So what we really want is a way to prevent moisture from getting into an assembly *and* a way to allow any moisture that does get in to get out. So far, this is pretty logical and easy to understand.

But it gets more complicated. Moisture flows from "more to less" (flow follows a concentration gradient) and from "warm to cold" (it also follows a thermal gradient). Homes in cold climates that are heated in the winter have a higher concentration of moisture inside than out, and — obviously — a higher temperature inside than out. Thus moisture flow is from the inside to the outside during winter.

But the same home may be air conditioned in the summer, and then the flow is reversed. So where do you locate a vapor retarder? If you put one on the inside, it may cause problems during air conditioning. If you put one on the outside, it may cause problems during heating.

So here is the final word on the subject (until I change my mind again): In cold climates in non-air-conditioned buildings, install vapor retarders on the inside. In hot, humid climates in air-conditioned buildings, install vapor retarders on the outside. Everywhere else, you're better off without them.

The 2009 IBC will provide detailed guidance on this subject, including climate maps and assemblies — the whole nine yards.

Q Is installing painted wood siding and trim over an air space — so-called rain-screen siding — really worth the effort?

A ***Paul Eldrenkamp, owner of Byggmeister, a custom remodeling firm in Newton, Mass., responds:*** The first project we did with rain-screen siding was in 1989. It entailed stripping existing shingles, applying rigid foam insulation over the old sheathing, screwing horizontal 1x3 battens through the foam into the sheathing, and then installing cedar shingles that had been prestained on all edges over the strapping.

We have been back to the house several times since, including a couple of months ago, and the whole installation has held up superbly: The shingles lie flat, the stain is holding up well (the house has been restained once in the intervening years), and the strapping has consistently been bone dry when we've tested it. This is on a house with minimal overhangs along the eaves, no overhangs on the gable ends, and a lot of shading from large trees, so water exposure is significant and drying opportunities are limited.

We also used the rain-screen approach at my own house in 1997. I have clapboards above first-floor window-sill height, but up to the sill height we installed tongue-and-groove fir beadboard for a wainscot effect. All the wood was preprimed and prepainted on all sides prior to installation and installed over strapping, which in turn was installed over rigid foam. I have small overhangs — 6 inches on the gable ends, 12 inches at the eaves.

The 10-year-old paint job shows no sign of failure whatsoever. There are a few mildew spots, which wash off easily with a mild detergent solution when I bother to do it. On several occasions after an extended rainy period I've tested the wood siding for moisture content, and I've found elevated readings (18 percent or so is not unusual), but never any sign of paint failure, which to me indicates a resilient system.

Additionally, we once had occasion to do work on a stucco house built in the 1940s. Felt had been applied to the sheathing, then vertical wood strapping, then metal lath, then three-coat stucco. The lath was a little corroded in places, but overall the stucco was in good condition, and the strapping and felt appeared to have another half-century of life left in them.

These are not the only jobs we've done (or seen done) this way; there have been dozens over the years. They all perform extremely well.

So rain-screen siding clearly works. For me, the question has been, "Is it overkill?" In other words, is the extra benefit really worth the extra work? Actually, I'm so confident it's worth the effort, we don't install siding any other way. But I'm also keenly aware of what I perceive to be still-unanswered questions, such as "If I'm using wood siding, do I need to both prefinish on all sides *and* create the air space, or can I do one or the other?" And "How big does the air space need to be?"

With wood siding (especially clapboards), back-priming seems to be more important than the air space. We have done some jobs with no air space but with wood siding prefinished on all sides, and the paint's held up very well (10 years without failure, in at least one case). These jobs do seem to have more mildew and cedar bleed, but I don't know if there's a connection (or even if that observation would really hold up if I tried to quantify it).

Some researchers have suggested that a clear preservative on the back of the claps would be preferable to primer or paint, creating the best balance of antiabsorption and drying properties. I think that this is over-thinking the problem, and that it fails to acknowledge the realities of the job site. Ordering the claps prefinished on all sides is much easier and faster — and, in my experience, yields an entirely effective end result. Plus, should any problems arise, just imagine your conversation with the paint-manufacturer representative when you tell him you have a different finish on each face of the clapboard.

So if there is absolutely no way to create an air space — a job, for example, where there's no latitude to thicken the wall even by a fraction — at the very least order your clapboards prefinished on all sides. Our contracts often include a drop-dead date by which the homeowner has to select an exterior paint color so we have time to have the prefinishing done.

How big an air space to use is a harder question. Some researchers seem to think that only drainage is important — that the depth of the space needs to be just enough to allow water to flow down behind the siding, something on the order of 1⁄8 inch or even less.

Others seem to think that ventilation is important, too — that there should be clear continuous channels not only for top-to-bottom drainage but also for bottom-to-top airflow. This is the thinking behind Benjamin Obdyke's Home Slicker and the old-fashioned 1x3 (or plywood strip) battens that we use. A few researchers seem to think that the air space itself is what's important — to allow for even drying of the cladding material when it does get wet.

My observation of our projects in our Boston-area climate is that you will have a durable, trouble-free exterior regardless of what products you use and of whether you actually achieve continuous top-to-bottom drainage, as long as the following conditions are met:

- The flashings and building paper guide the water away from the sheathing and to the outside with 100 percent reliability.
- You have an air space of at least 1⁄2 inch behind the siding material.
- All wood siding and trim is finished on all sides before installation.

Every new exterior job we do gives us an opportunity to test the durability of rain-screen siding. To complete the experiment, we need to observe its outcome over an extended period. There is no substitute for going back to past projects in a systematic way and seeing first-hand how they've held up.

Q: Ever since we began building tighter walls and ceilings, it seems we've been getting more moisture and mold problems in houses. Isn't it better to leave our houses a little bit leaky than to make them too tight?

A: ***Martin Holladay, editor of* Energy Design Update, *responds:*** A hundred years ago, most houses had uninsulated walls and numerous air leaks. Now that tighter building practices are standard, any incidental water that gets into a wall dries very slowly, and problems with wall rot and mold have increased. But building a new home to be "a little bit leaky" is more apt to increase than decrease the likelihood of moisture problems.

Filling framing bays with insulation — rather than leaving them empty — makes walls and ceilings less forgiving of moisture intrusion, for three reasons: Insulation can act like a sponge, absorbing water that might otherwise have drained out; it reduces airflow, slowing the rate of drying; and it makes the exterior sheathing colder, introducing a potential condensing surface.

Since building uninsulated houses is no longer an option, builders must learn how to assemble walls and roofs in ways that minimize water intrusion. To keep out exterior water — wind-driven rain — a house needs careful flashing at windows and other penetrations, and the flashing must be properly integrated with a water-resistant barrier. Ideally, a wall should include a free-draining air gap (rain screen) between the siding and the sheathing.

Interior moisture is usually less of a problem for walls and ceilings than exterior moisture. Since recent research has shown that interior polyethylene can do more harm than good in many U.S. climates, knowledgeable builders in all but the coldest areas often omit interior poly. The most common way that interior moisture enters walls and ceilings is by hitching a ride with exfiltrating air; that's why it's important for most homes to have a very good air barrier.

What's wrong with leaving a house "a little bit leaky"? In theory, a certain amount of air exchange is a good thing: Introducing fresh air is good for a home's occupants, and air movement through walls and ceilings can, in some circumstances, help dry out moisture that would otherwise be trapped.

In practice, however, this approach doesn't accomplish either task very well. If interior air enters a wall through one of the "little leaks," moisture in the air can condense on the back of the wall sheathing. In other words, even though air movement through a wall assembly can help dry out moisture in some circumstances, it can deposit moisture in others.

Moreover, infiltration levels vary with the weather. In cold weather, the stack effect increases airflow through a house; in mild weather, infiltration and exfiltration are lower. Similarly, wind increases the rate of air exchange in most homes. But people need a relatively constant supply of fresh air, whether the weather is hot or cold, windy or still.

If you want a house with few mold and moisture problems, you have two choices. The first — to build a house without any insulation at all — is illegal in most locations. The second and more logical choice is to build a tight building envelope — designed to handle incidental moisture — and equip the house with some type of mechanical ventilation.

Q Is spray-foam insulation worth the extra expense?

A ***Paul Eldrenkamp, owner of Byggmeister, a custom remodeling firm in Newton, Mass., responds:*** Often, but not always. For an effective insulation job, you need both good R-value and good air-sealing. Spray foam is an expensive way to get R-value but a relatively cheap way to get good air-sealing — especially in retrofits.

Spray foam is probably *not* worth the extra expense in the following types of projects:

- Closed-cavity retrofits, like the walls of an older home with no insulation. Here, use cellulose, and try to get it installed to a high density — 3.5 pounds of material per cubic foot of volume. You may have a hard time finding a cellulose insulation contractor who knows how to do this (or has even heard of it), but it's worth trying.
- New construction or large-scale additions where you can cost-effectively wrap the structure (both walls and roof) with a layer of rigid foam before applying the exterior finish. This minimizes thermal bridging and provides good air-sealing (as long as you tape or gasket the joints in the foam boards). And it means that almost anything you use for framing cavity insulation — including fiberglass batts — will be effective.
- New construction or large-scale additions where you can get a quote for cellulose (blown-in/mesh system or damp-spray system) that beats the quote you get for spray-foam. A good cellulose installation is often less costly and just as effective as a spray-foam installation.
- Attics with a simple geometry in which you choose to insulate the floor rather than the rafters. You do need to make sure to seal all of the penetrations in the ceiling plane before you blow in the cellulose, and you should avoid putting mechanical equipment in the attic above the insulation.

- Cast-concrete basements or crawlspaces where the walls and floors are even enough that you can install sheets of rigid foam easily and tightly.

Spray-foam *is* usually worth the extra expense in these types of projects:

- Relatively small jobs, like small additions or partial guts, where there's a logistical and scheduling advantage to having just one subcontractor and one material to deal with.
- Houses where the attic is wholly or partly finished. Once the attic starts becoming living space, it's almost always most effective to insulate and air-seal the outermost plane of the roof structure (rafters rather than knee walls, for instance). This is where spray foam shines. Install it from the top plate of the wall up to the ridge all around the attic, like putting a cap on the house. Don't worry about venting the roof. Most researchers I've spoken with (Joe Lstiburek, William Rose, Terry Brennan) advocate applying one or two coats of latex paint to open-cell foam insulation to minimize vapor diffusion. There's uncertainty as to whether this is a necessary precaution, but it's cheap and easy enough to do. Closed-cell foams have a low enough perm rating that they do not need the vapor diffusion retarder.
- Any house where it's difficult to define a simple, continuous boundary between tempered and untempered space. Houses with lots of angles, plane changes, split levels, dormers, bays, and so on are often going to be easier to insulate and air-seal with foam than with other methods.
- Old, uneven basement walls and floors. We use a closed-cell foam on old basement walls and then spray it with shotcrete to get the flame-spread rating required by code. We've even sprayed the higher-density closed-cell foam on basement floors, then poured lightweight concrete over the foam to create a level, insulated floor slab.

Ultimately you need to figure out for yourself when one material or technique is more appropriate than another. A lot depends on the relative skills of your crew, on which insulation subcontractors in your area are most reliable and knowledgeable, and on what types of houses you work on. One unavoidable fact, though, is that you will never know for sure which materials and techniques are working best unless you regularly test your jobs with a blower door and infrared camera; otherwise, you'll just be guessing.

Q My insulation contractor installed dense-pack cellulose in the walls of a 100-year-old house. Two years later, the exterior paint began to peel, even though the paint job was only four years old. Did the insulation cause the paint to fail?

A *Martin Holladay, editor of* **Energy Design Update,** ***responds:*** Indeed, adding insulation to the walls of an older home can shorten the life of the exterior paint. The phenomenon has been observed for decades; when conducting research on vapor retarders, William Rose, a building researcher at the University of Illinois at Urbana-Champaign, unearthed evidence of failing-paint disputes between insulation contractors and exterior painters dating back to the 1940s.

The failing paint has often been blamed on the fact that the walls of most old houses lack interior polyethylene. With little to slow vapor diffusion, interior moisture is said to travel through the walls until it reaches the sheathing, the siding, or the back of the paint film, causing the exterior paint to fail.

As it turns out, this explanation is incomplete and misleading. Although vapor diffusion can occur through exterior walls, the effect of vapor diffusion on exterior paint performance has been greatly exaggerated. Moreover, since most old houses have several layers of interior paint, the walls in question usually do include a vapor retarder; even two coats of paint have a relatively low permeance (1.5 to 5 perms), and each additional layer of paint will improve the paint's performance as a vapor retarder.

In fact, adding insulation to a wall does make the siding more humid, but not because of the lack of a vapor retarder. Adding a thermal barrier between the siding and the warm interior makes the siding colder; under the same conditions of vapor pressure, colder materials are wetter than warmer materials. In other words, before the insulation was installed, the relatively warm stud bays helped keep the siding dry.

Of course, damp siding doesn't hold paint as well as dry siding. The source of the moisture absorbed by cold siding under these circumstances — called "regained moisture" by building scientists — is the exterior environment, not the interior.

On a new home, several measures can lengthen the life of a paint job, among them specifying siding that has been factory primed on all sides and installing the siding over rain-screen strapping. On an existing house, such measures are not usually possible; in many cases, homeowners who choose to insulate the exterior walls of an older home may have to get used to more frequent exterior-paint jobs.

Despite evidence that it's harder to keep paint on an insulated wall than an uninsulated wall, a good painting contractor should not hesitate to stand behind an exterior paint job on an old, recently insulated house. Exterior paint will last longer when the siding is carefully prepped; ideally, this work should include the complete removal of all the old paint, down to bare wood. If quality paint is specified and the paint is applied in good weather, the paint job should last for many years.

Q **Mold has been around forever; many of us grew up in houses that had the occasional mildew spots in the corner of the ceiling, or mold-stained lumber in the basement or attic. But in recent years it seems like mold has become a really big deal. Is this much ado about not very much, or a justifiable concern? Put another way, is mold a worse health problem today or are there just more lawyers?**

A ***Terry Brennan, a principal of Camroden Associates in Westmoreland, N.Y., who served as a moisture consultant on the Institute of Medicine's Committee on Damp Indoor Spaces, responds:*** Good question! Mold has indeed been here much longer than we have and will no doubt still be here in the distant future. And yes, there are certainly more lawyers now than there were when I was a country boy in upstate New York. Ben Wattenberg, in the PBS production *The First Measured Century*, reports that the number of lawyers per thousand people has increased from 1.3 to 3.5 in the last 40 years.

While I don't have those kinds of statistics for mold, I do believe the amount of mold in buildings has increased as changes in construction have occurred. Some construction changes made walls stay wet longer — filling the cavities with porous insulation, replacing diagonal board sheathing with sheets of plywood and OSB, and adding poly vapor retarders (or unintentional vapor barriers like vinyl wallpaper) to the inside of walls.

We also gradually replaced relatively mold-resistant materials — such as brick, plaster, and old-growth heartwood — with materials containing sugars and starches that many molds can use as food, like paper-faced gypsum board, wood-based composites, and wood species with little resistance to mold growth.

During the same period, we also began air conditioning more buildings, which cools indoor walls, ceilings, and floors below the outdoor air temperature. When the outdoor dewpoint is higher than the indoor air temperature, the ventilating air no longer dries out the house, but wets it. Any surfaces in the air-conditioned house that are colder than the room temperature — for example, the supply ducts, the supply diffusers, or anything the supply air blows on — will be the first to collect moisture and grow mold.

So in general, there's more humidity in the house, better food, and, yes, more mold. But is it harmful?

The Institute of Medicine of the National Academy of Sciences convened the Committee on Damp Indoor Spaces to examine the medical literature for evidence of health effects linked to occupying damp buildings. In 2004, the committee published its findings in a book, *Damp Indoor Spaces and Health,* which reported evidence of an association between living in damp spaces and upper-respiratory (nose and throat) symptoms, wheezing, asthma symptoms in sensitized asthmatics, coughing, and hypersensitivity in susceptible persons, as well as limited evidence of an association between living in damp spaces and lower-respiratory illness in otherwise healthy children.

Q: What's the best way to insulate a basement foundation?

A: ***Paul Fisette, director of Building Materials and Wood Technology at the University of Massachusetts Amherst and a* JLC *contributing editor, responds:*** The answer depends on the budget, the R-value you're trying to achieve, how the space will be used, and whether you're simply housing mechanicals or creating a living space in the basement.

Assuming you don't need a tempered basement space, the best and most economical approach is to insulate the floor that separates the living space from the basement. This will minimize the volume of the home's thermal envelope and the amount of energy required to condition the living space. Also, it's easier to install insulation with higher R-values in the basement ceiling. This is the design that will have the greatest payback in reduced energy costs.

The cheapest way to insulate the basement ceiling is to install unfaced fiberglass insulation. A better method is to cover the ceiling with drywall, then blow in cellulose — a comparatively inexpensive upgrade, considering the benefits. Not only does this method provide superior R-value, but — if detailed well — it stops air leakage at one of the most critical places in the house. (Most of the inward air leakage caused by the wintertime stack effect happens at the bottom of a house.)

If the goal is to provide basement living space, then of course you'll have to insulate the basement walls. Wrapping the outside of the foundation with rigid polystyrene is a common approach; the materials aren't expensive, and the foam board needs protection only above grade.

However, the space between the concrete foundation and the back of the foam board can become a termite highway — a hidden path connecting the soil directly to the framing — unless you add the cost of a carefully installed termite shield. Also, consider that a 1-inch layer of polystyrene provides a meager R-5 of thermal protection; if you increase the thickness to 2 inches or more, the project gets even pricier — plus it's tricky to integrate the foam with the frame wall above.

A simpler, better approach is to insulate the inside of foundation. First, though, make sure the basement doesn't leak and is protected by a good drainage system. In a retrofit situation, applying a layer of damp-proofing on the interior surface of the foundation wall is cheap insurance. I've had good luck using Sto Watertight Coat, a two-component cementitious compound with a low perm rating.

On top of the waterproofing, I attach rigid foam insulation directly to the inside surface of the foundation walls with construction adhesive, then caulk or tape the seams so that warm interior air can't reach the cold foundation. Finally, I build an uninsulated wood frame, spaced away from the foundation to make room for plumbing and wiring. The foam insulation keeps the surface of the wall above dew-point temperature, reducing the likelihood that condensation will form in the wall.

Q **Even though I installed R-38 fiberglass batts on the attic floor, a house I recently built has suffered from roof leaks caused by ice dams. What's the solution?**

A ***Martin Holladay, editor of* Energy Design Update, *responds:*** If the attic floor has adequate insulation, the most likely cause of an ice-dam problem is that warm interior air is leaking into the attic through cracks in the ceiling.

Ice dams begin when warm attic temperatures melt the lowest layer of snow on a roof. The water flows downhill and refreezes when it reaches the colder roofing at the eaves, gradually thickening until an ice dam is formed. Such dams can become thick enough to trap upslope meltwater; in some cases, the water can be forced under the roof shingles and can dampen the ceilings below.

In sunny, cold weather, icicles can appear on any roof. As long as the ice doesn't lead to a wet ceiling, it isn't really a problem. Heavy ice at a building's eaves, however — with or without wet ceilings — is usually a sign that too much heat is escaping through the ceiling.

To some extent, ice-dam problems can be reduced by the installation of a rubberized roof membrane like Grace Ice & Water Shield. While a 6-foot-wide band of rubberized membrane at the eaves is always a good idea, rubberizing the entire roof is a crude defense against roof ice. If the roof sheathing is warm enough to melt snow, the solution is not to install wider and wider bands of rubber, but to prevent the heat from escaping the house.

Many builders try to solve ice-dam problems by increasing the size of soffit and ridge vents, but this strategy rarely works. In fact, since air leakage is a more common cause of ice-dam problems than insufficient insulation, increasing attic ventilation can actually make things worse. A larger ridge vent tends to increase the flow of air into the attic; the source of that air might be the soffit vents, but if the ceiling is peppered with holes and cracks, it might also be the home's interior. In other words, a better ridge vent can actually increase the flow of heated air into the attic.

The first step in any ice-dam investigation should be to crawl up in the attic and look for ceiling air leaks. (If the house has a cathedral ceiling, air leaks should be sealed from the interior.) Common leak areas include attic access hatches, recessed can lights, plumbing and electrical penetrations, chimneys, bathroom exhaust fans, poorly sealed bathroom and kitchen soffits, and cracks between drywall and partition top plates.

Once the ceiling is relatively airtight, the next step is to verify that the attic insulation is thick enough, especially near the eaves, and that its R-value is not being degraded by wind-washing.

The use of fiberglass batts can increase the likelihood of ice-dam problems. Since fiberglass insulation does little to slow airflow, it can't stop warm air from escaping through a ceiling leak. Moreover, its effectiveness can be degraded by the flow of cold air entering the soffit vents. Fiberglass batts also have a lower R-value per inch than rigid foam and sprayed urethane foam.

In some houses, the space between the perimeter wall plates and the roof sheathing is too cramped for adequate levels of fiberglass insulation, especially if a vent channel is required. If the roof is framed with raised-heel trusses, fiberglass batts may work well, as long as the ceiling is relatively airtight and as long as the builder includes a wind-washing dam above the top plate. In many attics, however, the problematic area under the eaves is best insulated with sprayed polyurethane foam or several layers of rigid foam.

Once the air barrier is in place, the next line of defense is an uninterrupted layer of thick insulation.

Compared with a ceiling air barrier and thick insulation, attic ventilation is a relatively minor concern.

Q What exactly is the difference between an air barrier and a vapor retarder?

A ***Joe Lstiburek, PE, a principal of Building Science Consulting in Westford, Mass., responds:*** Air barriers control airflow, and vapor retarders control vapor flow. Vapor retarders are not typically intended to retard the migration of air; that's the function of air barriers.

Confusion between the two arises because air often holds a great deal of moisture in the vapor form. When this air moves from location to location due to an air-pressure difference, the vapor moves with it. In the strictest sense, air barriers are also vapor barriers when they control the transport of moisture-laden air.

Part of the problem is that we struggle with names and terms: vapor retarders, vapor barriers, vapor permeable, vapor impermeable. In an attempt to clear up some of the confusion, here are the definitions that I use.

Vapor Retarder: An element designed and installed in an assembly to retard the movement of water by vapor diffusion. The unit of measurement typically used in characterizing the water-vapor permeance of materials is "perm." There are several classes of vapor retarders:

Class I vapor retarder: 0.1 perm or less
Class II vapor retarder: 1.0 perm or less, and greater than 0.1 perm
Class III vapor retarder: 10 perms or less, and greater than 1.0 perm
Vapor barrier: a Class I vapor retarder

Materials can also be separated into four general classes based on their permeance:

Vapor impermeable: 0.1 perm or less
Vapor semi-impermeable: 1.0 perm or less, and greater than 0.1 perm
Vapor semi-permeable: 10 perms or less, and greater than 1.0 perm
Vapor permeable: greater than 10 perms

Air barrier: A system of materials designed and constructed to control airflow between a conditioned space and an unconditioned space. The air-barrier system is the primary air-enclosure boundary that separates indoor (conditioned) air from outdoor (unconditioned) air.

Air barriers also typically define the building's pressure boundary. In multiunit construction, the air-barrier system also acts as the fire barrier and smoke barrier between units. In such assemblies, the air barrier has to meet the specific fire-resistance rating requirement for the given separation.

Air-barrier systems consist of individual *materials* incorporated into *assemblies* that are interconnected to create *enclosures*. Each of these three elements has measurable resistance to airflow (in liters per second per square meter at 75 Pascal pressure). The minimum resistance, or air permeance, for each is:

Material: 0.02 l/(s-m2)@ 75 Pa
Assembly: 0.20 l/(s-m2)@ 75 Pa
Enclosure: 2.00 l/(s-m2)@ 75 Pa

For more information on air barriers and vapor retarders, visit www.buildingscience.com/documents/digests.