Air and Vapor Barriers

Understanding and preventing moisture movement are the first steps in protecting a house from water damage

Moisture takes its toll. **Sheathing and hemlock timbers in this Falmouth, Maine, house were so decayed in places that the wood could be pulled apart by hand. The apparent causes were high indoor humidity and a polyethylene air/vapor barrier that failed.**

by Scott Gibson

Bob Thurrell's callback from hell began with a phone conversation sometime in the fall of 1987. The call concerned a timber-frame house that Thurrell and his partner had built five years earlier in Falmouth, Maine. The owners wanted an addition, and the builder they hired to do the work was on the phone...with a problem. After stripping some siding from the back of the house, the builder had found sheathing and structural timbers so rotten the wood could be pulled apart by hand (photo above).

Thurrell couldn't believe it. The house had been a labor of love. Despite his subsequent efforts to repair the damage, the dispute with the owners eventually landed in court. The house that Thurrell's young timber-framing company had built to last two centuries would last only another two years. Arguing that the house was rotten to the core, the owners won $50,000 from Thurrell's insurance company and tore it down. He still has an album full of snapshots taken just after the house was finished. Looking at them made me a little uncomfortable. It was like being shown pictures of a friend's dead uncle.

What happened? There probably isn't any single answer. Thurrell had installed a 6-mil polyethylene air/vapor barrier on the warm side of 2x4 stud walls built between the timbers. On the outside, T&G board sheathing was wrapped in 1 in. of extruded polystyrene insulation. But the house wasn't airtight. The green hemlock timber frame shrank as it dried out and opened gaps of up to ⅛ in. between the 2x4 walls and the hemlock frame. Moreover, interior humidity was driven up by an unvented clothes dryer and by firewood drying in the basement. The structural damage in the walls of the house is a testament to how building components (including air/vapor barriers) and indoor moisture can, under the right conditions, conspire to seriously harm a building's structural integrity.

With a few exceptions, such as the Maine house I just described, reports of pervasive moisture damage are rare. That's the good news. The bad news is that moisture problems, even on a small scale, are still problems you must deal with. Mold, mildew and rot are possible consequences of uncontrolled air leaks or incorrectly installed vapor barriers when coupled with high humidity. Unfortunately, there's no single rule for installing air/vapor barriers that works for all houses in all climates. An air/vapor barrier installed correctly in Minnesota, for instance, could be a disaster for a house built on a Mississippi bayou. The truth is that air/vapor barriers are only part of the answer to controlling the moisture that can damage houses. Ventilation, indoor humidity and overall construction quality all are just as important. Some would argue more important.

To understand how and where air/vapor barriers should be installed, I talked to builders, energy experts and researchers in Canada and the United States. None of them claims to understand everything about the subject. But they do know enough to give builders plenty of options for controlling moisture and cutting energy costs. The real trick is understanding where and why moisture problems start and then choosing the best construction method for the climate in which the house is being built.

What air barriers and vapor barriers do— Builders are constructing tight houses for two reasons: (1) to keep heated air or air-conditioned air inside the house and hence reduce utility bills; (2) to keep moisture out of wall cavities. Moisture can move into walls in one of two ways: by vapor diffusion or by air leaks. The movement of moisture through a material is called vapor diffusion. Diffusion occurs because warm air holds more moisture than cold air, and the difference in humidity and temperature pushes warmer, moist air toward cooler areas. In addition to vapor diffusion, air leaks also move moisture through a house. Wind pushes air through a leaky building envelope. Leaky ducts can create pressure imbalances inside a house and induce air leaks. The stack effect can encourage air leaks, too; it is the chimneylike result when warm air rises inside a house and is replaced by cooler air getting in under your kitchen door.

Whether moisture gets into a wall from vapor diffusion or from air leaks, problems begin when

Photo this page: Doug George

the air reaches its dew point on the way through a wall or ceiling, and water vapor begins to condense on cooler surfaces (for more on dew points, see sidebar and drawing on p. 52). This is what you see when a cold glass of ice tea beads up with water on a summer day. The more humid the air, the higher the potential for water accumulation inside walls and ceilings. Household appliances and the activities of occupants add to the problem by producing moisture around the clock. Everything from showers to humidifiers contributes water to the air.

There are two ways of stopping moisture from getting inside wall cavities: Stop warm air from leaking into wall cavities or insulate the wall cavity so that any warm air leaking into it won't condense. Here's where air barriers and vapor barriers come in. These building materials slow the movement of air and moisture through floors, walls and ceilings. Air barriers and vapor barriers work in different ways and can be of different materials, although some materials do both jobs and are called air/vapor barriers. Let's look at vapor barriers first.

Vapor barriers—Vapor barriers retard, but don't stop, the diffusion of water vapor through a material. If you want to be very precise, call them "vapor-diffusion retarders." Their effectiveness is measured in units called "perms"— anything rated at 1 perm or less is generally considered a vapor barrier. Unlike air barriers, which I'll cover next, vapor barriers are still effective when ripped or torn. If a vapor barrier covers 95% of a wall surface, for instance, it will still slow 95% of the potential water vapor from passing through by diffusion. Vapor barriers can be made from any impermeable material, including polyethylene, foil, rigid-foam insulation and even vapor-retarding paint (for a list of the permeance of common building materials, see chart, right).

But vapor diffusion is slow. By itself, it accounts for relatively small amounts of moisture getting into wall cavities in all but extreme climates. Some building experts doubt that vapor barriers by themselves are all that important in areas that aren't very humid.

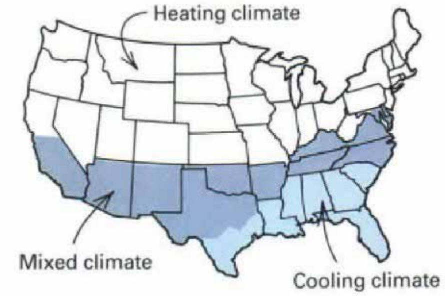
Air barriers—Much more important are air barriers, materials that stop air leaks—what researchers call the bulk movement of air. Although not all building scientists agree, some say that air barriers can go either on the inside or the outside of a building. The theory is that if air can't get out of a wall cavity, air won't go in to begin with. Air barriers can be vapor permeable and still be effective. For instance, Tyvek, the DuPont housewrap, has a perm rating of 77, making it 77 times as leaky as a material barely qualifying as a vapor barrier. When applied on the outside of a house, housewrap prevents the movement of air through a wall. Because Tyvek is vapor permeable, any trapped moisture in the walls can escape (although plywood itself is a pretty effective vapor barrier).

Air movement is more worrisome than vapor diffusion because it can move 100 times more moisture into a wall cavity than diffusion can. The Canadian Home Builders Association estimates that air leakage (not vapor diffusion) through a hole less than 1 sq. in. could allow passage of nearly 8 gal. of water over the course of a single heating season. That helps explain why air barriers should be installed carefully. They must be continuous to be effective—all seams, leaks, tears and penetrations must be sealed if the air barrier is going to perform as intended. Builders use a variety of materials for air barriers—some of them vapor permeable and some of them vapor impermeable. They include drywall that has been sealed or gasketed to the wood frame, housewraps such as Tyvek, rigid-foam insulation, polyethylene sheeting or even dense-pack cellulose insulation.

Air/vapor barriers—Then there is a third, and probably best-known, category: air/vapor barriers. These materials block both air movement and vapor diffusion. The most common, and probably most cost effective, is polyethylene film applied to the warm side of the building. Some builders combine poly air/vapor barriers with other materials to provide a second line of defense against air leaks, especially in parts of a house that are difficult to seal against air leaks (see sidebar p. 50).

Climate and moisture control

Strategies for using air and vapor barriers differ with the climate. Joseph Lstiburek, a builder and energy expert, divides the country into three zones, each with its own moisture profile. Hawaii is in a cooling climate.



Perm ratings of common materials

Anything with a perm rating of 1 or less is considered a vapor barrier.

Material	Perm rating
Gypsum drywall	50
Plaster on metal lath	15
Latex primer	6
1-in. pine	5
15-lb. building felt	4
1-in. expanded polystyrene bead	2-5.8
1-in. extruded polystyrene	1.2
¼-in. interior plywood	2
Kraft-paper insulation facing	1
Brick wall	.8
¼-in. exterior plywood	.7
½-in. exterior plywood	.5
Vapor-retarding paint	.5
8 in. of concrete	.4
4-mil polyethylene	.08
8-mil polyethylene	.04
Aluminum foil (.3-mil)	.05

Source: ASHRAE Handbook of Fundamentals

Decisions on which materials to use, and how to apply them, have a lot to do with geography—whether a house is being built in a heating climate, a cooling climate or somewhere in between (drawing left). I'll discuss each of them. But it's worth saying at the outset that a few basic guidelines seem to hold true no matter where the house is built. One is that air barriers are a good idea anywhere in the country and are essential in extreme climates. Where differences between indoor and outdoor temperature and humidity are not extreme, vapor barriers seem to be less important. The exception is the use of a polyethylene vapor barrier under concrete floors in the basement or over dirt in a crawlspace to control ground moisture. That practice is a good idea anywhere.

Heating climates—There's no universal agreement on how to define a heating climate. Joseph Lstiburek, a pioneer in the field of building science whose advice is highly regarded by builders all over the country, makes the cutoff at 4,000 heating degree days a year. That's the northern United States and Canada (drawing left). Other experts draw the line at different points, some as low as 2,500 heating degree days annually. Regardless of where the line is drawn, low outdoor temperatures can lead to condensation inside walls or ceilings. The more severe the climate, the more serious the potential for moisture accumulation. If water collects, and walls can't dry out, problems can result.

Should you use air barriers and vapor barriers in a heating climate? Yes, especially way up north. An effective air barrier will keep a house warmer and help prevent water damage. In the northern part of the country, vapor diffusion may be significant, too, so a vapor barrier should be installed on the warm side of the building envelope. The idea is to keep the vapor barrier on the warm side of the dew point and prevent condensation on cold surfaces inside the wall.

The most practical heating-climate option seems to be a continuous polyethylene air/vapor barrier on the warm side of walls and ceilings and in basement or crawlspace floors. Although common 4-mil poly is effective, thicker poly better resists construction wear and tear and may have fewer manufacturing defects. A high-quality poly may well be worth the extra money because it is stronger than standard poly and is made more carefully (see Manufacturers of specialized polyethylene, p. 53).

Detailing makes all the difference. To work, the air/vapor barrier must be continuous. Seams and joints should be kept to a minimum and sealed with acoustical caulk or with a special construction tape made for the job. All penetrations of the air/vapor barrier, including those for plumbing and wiring runs, should be sealed. It's smart to pay particular attention to electrical receptacles on outside walls and make sure the barrier is sealed to electrical boxes. Or consider using special receptacles that come with their own gasketing system like those by R&S Enviro Products Limited (1 Church St., Keswick, Ont., Canada L4P 3E9; 905-476-5336). The ceiling between an unheated attic and the house should be sealed carefully, with the air/vapor barrier lapped over the barrier on the sidewall and taped and caulked. Don't forget the floor. Air leaks can reduce the R-value of insulation between an unheated basement and the house by 20%.

A poly air/vapor barrier isn't the only choice, though it may be the best one in a heating climate. Foil or kraft-paper backing on fiberglass insulation (if stapled to the faces of studs) or foil-backed drywall also make reasonably good vapor barriers. But these materials by themselves are not effective air barriers because of the leaks along joints and between framing members. So if you rely on kraft paper or foil insulation backing as the vapor barrier, you'll have to add a separate air barrier. One way to accomplish that is with housewrap sealed to the building and taped at the seams or with insulated sheathing, which I'll explain in a minute. Another choice is the Airtight Drywall Approach (ADA), pioneered by Lstiburek in the 1980s. ADA uses gaskets or caulk to seal gaps between framing members and between drywall and framing for the air barrier. Vapor-retarding paint provides a vapor barrier (for more on ADA, see *FHB* #37, pp. 62-65).

Keeping the wall cavity warm—Rigid-foam insulation, such as extruded polystyrene, can provide an external air barrier as long as all joints and seams are sealed. Polystyrene insulation has low vapor permeability (extruded polystyrene has a lower perm rating than expanded polystyrene), so the technique, in effect, creates a vapor barrier on the cold side of the house. This seems like a violation of the cardinal rule in heating climates of putting the vapor barrier only on the warm side of the building. But as research by George Tsongas of Portland State University found, this apparent disadvantage is outweighed by the benefits. An adequate thickness of insulation keeps the temperature of the wall cavity high enough to prevent warm house air from condensing if it does get into the wall cavity. Lstiburek recommends 1½ in. to 2 in. of rigid-foam insulation on the outside in heating climates in conjunction with an air/vapor barrier on the inside. The extra precaution of the poly inside is smart in a heating climate, Lstiburek says, but may not be crucial in milder climates.

The other advantage of using rigid-foam insulation is that it provides a capillary break between the siding and the wall cavity. That means any moisture that would normally be wicked from wet siding into wood sheathing or framing lumber won't pass through the rigid insulating sheathing. An exhaustive study in the Northwest convinced Tsongas that, in general, moisture getting into a house from the outside does a lot more damage than any moisture originating inside. So he thinks providing a capillary break

Techniques for an airtight house

Builders in the United States and Canada have been tinkering for years to come up with reliable ways of making houses airtight. New products make the process easier and more reliable, but the technique still depends on careful detailing.

Doug George of Dover, New Hampshire, builds only superinsulated houses in a part of the country where the climate can be harsh. His houses have two air/vapor barriers—one on the inside and one on the outside—to control moisture and heat loss. Inside, George puts a layer of 8-mil Tenoarm polyethylene (see bottom sidebar, p. 53) over the 2x6 stud wall (top left photo, below). To bond seams he uses the Teno sealant that comes with the poly or Sikaflex polyurethane sealant (Sika Corp., Construction Products Div., Lyndhurst, N. J. 07071; 201-933-8800). Outside, George bonds 7/16-in. oriented strand board (OSB) sheathing to the frame with construction adhesive and seals joints between panels with Sikaflex. On top of the OSB is 1½ in. of extruded polystyrene with taped seams. Over the rigid insulation goes 1x3 strapping vertically 2 ft. o. c. to create a vented ram screen and then, finally, the finish siding.

The wall has two impermeable layers—the poly on the inside and the foam and the OSB sheathing on the outside—so it won't dry readily if it becomes wet. George counts on moisture not getting in the wall to begin with, so sealing seams in the poly air/vapor barrier is critical. He uses as few sheets as possible to minimize seams and puts up all of his ceiling poly before erecting interior partitions. The poly is sealed with Sikaflex to electrical boxes (top right photo, below), and gaps between windows and framing material are filled with polyurethane foam.

Rim joists and framing members—Rim joists are a real headache because

Details make all the difference. New Hampshire builder Doug George uses an 8-mil polyethylene air/vapor barrier on the warm side of the wall. The poly is caulked to framing members and electrical outlet boxes to prevent leaks.

Sealing electrical boxes. An alternative method for sealing electrical boxes on outside walls is the "poly hat," which forms an air seal around receptacles. This technique is used by builder Peter Amerongen of Edmonton, Canada.

Sealing the rim joist. Builder Peter Amerongen devised an air-barrier technique that uses polyethylene on inside walls and strips of Tyvek housewrap to seal the rim joists. Acoustical caulk seals the top edge of the housewrap to the frame.

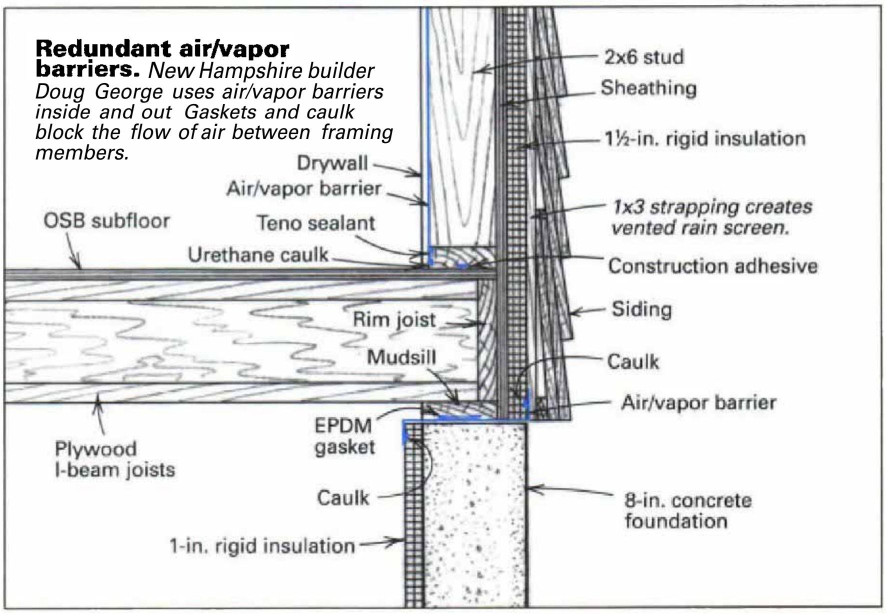
Second-floor rim-joist seal. To provide an air barrier at second-floor rim joists, Tyvek strips are sealed with acoustical caulk to top and bottom wall plates. Here, David Schuman puts a bead of acoustical caulk along the wall before it's raised into place.

they're difficult to seal properly and can be a ready source of air leaks. George cuts small pillows of fiberglass insulation to fit between joists right next to the rim joist, then covers the fiberglass with tightly fitted rigid-foam insulation that is sealed in place with foam. The **1½** in. of extruded polystyrene on the outside of the building is another hedge against moisture problems because it keeps the run joist above the dew point. The run joist is set back from the outside face of the wall by 2 in. to accommodate the sheathing and the foam insulation.

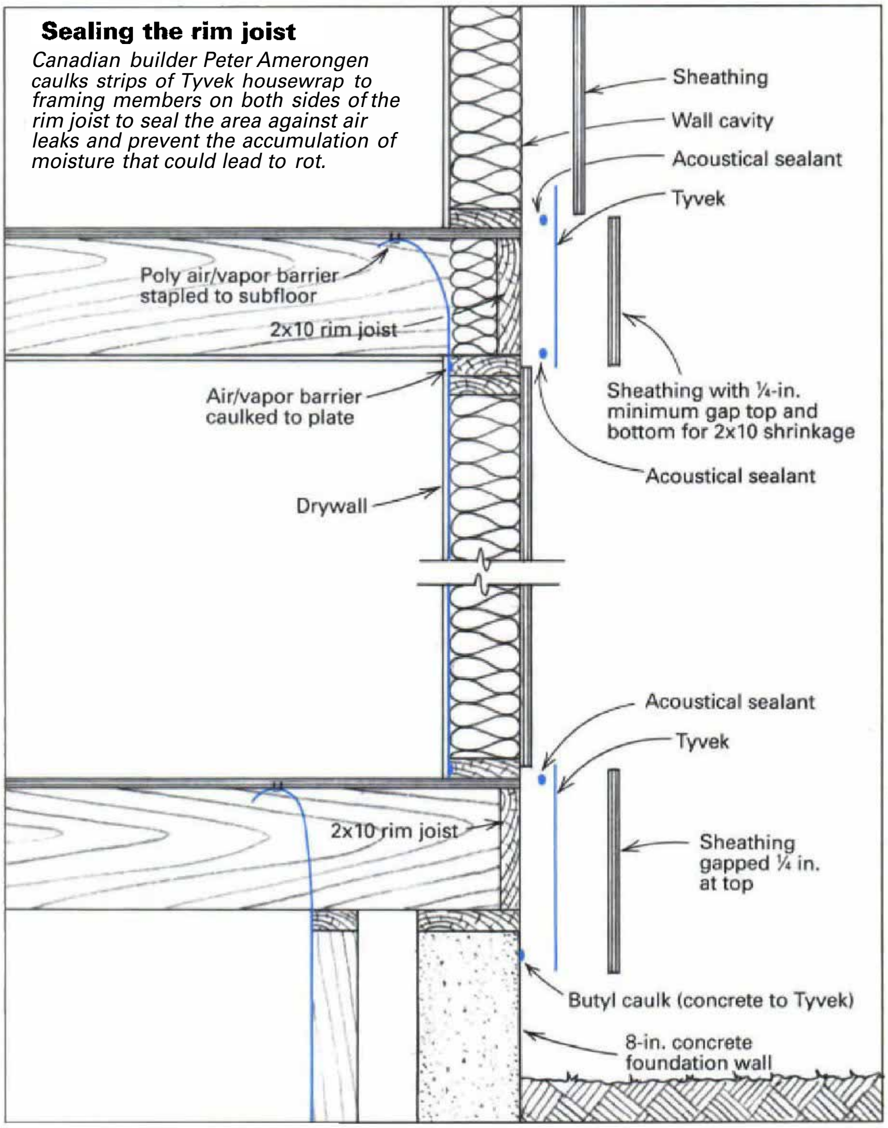
A far simpler approach is used by Peter Amerongen, an innovative builder of energy-efficient houses in Edmonton, Canada. He prevents air leaks at the run joist by sealing strips of Tyvek to the outside of the house at the rim joist with acoustical sealant (bottom left photo, below). He leaves out a strip of sheathing at the rim joist, installs the Tyvek and then covers it with sheathing to protect it (bottom drawing, right). On inside walls, Amerongen uses a 6-mil poly air/vapor barrier sealed to top and bottom plates with acoustical sealant. Because both the strip of Tyvek and the ulterior air/vapor barrier are sealed to top and bottom plates (bottom right photo, facing page), air leaks are eliminated. Amerongen doesn't use housewrap on the rest of the building's exterior because he has already provided an air/vapor barrier with the poly inside.

Joints between subflooring and bottom plates are another source of air leaks. Gaskets of foam or EPDM, or the use of a flexible caulk, will reduce or eliminate them.

Basement walls and floors—A polyethylene vapor barrier under a concrete basement floor, or over a dirt crawlspace, can stop moisture from wicking upward. George's approach goes even further. He builds concrete footings over 8 in. of compacted ¾-in. stone and buries his 4-in. foundation drain in the stone (not level with the outside of the footing) so that water won't pool at the base of the footing. Poured concrete walls are coated with a sprayed-on waterproof membrane. On the inside, the crushed stone is covered with filter fabric, then 8 in. of compacted **fill**, then a polyethylene vapor barrier, 1 in. of rigid foam and finally the poured concrete floor. To inside foundation walls, George attaches 1 in. of extruded polystyrene insulation and tapes all the seams. The vapor barrier in the floor is sealed to the face of the insulation. At the top of the wall, another piece of poly is sealed to the foam, fed over the top of the foundation wall (under the mudsill) and sealed to the insulation on the outside of the house. This isolates the concrete from any wooden framing members and prevents condensation on inside foundation walls that could damage framing or insulation in a finished basement. *—S. G.*



Redundant air/vapor barriers. *New Hampshire builder Doug George uses air/vapor barriers inside and out Gaskets and caulk block the flow of air between framing members.*



Sealing the rim joist

Canadian builder Peter Amerongen caulks strips of Tyvek housewrap to framing members on both sides of the rim joist to seal the area against air leaks and prevent the accumulation of moisture that could lead to rot.

Drawings: Vince Babak

is vital. Housewrap or building felt is a better capillary break than no moisture barrier at all, Tsongas says, but not as good as exterior insulating sheathing.

Some builders take every possible precaution to prevent air leaks and vapor diffusion that might lead to moisture damage in walls. Doug George of Dover, New Hampshire, seals sheathing to the frame of the house and then caulks all joints between sheathing panels (see sidebar on p. 50). He follows that with rigid-foam insulation and tapes all the joints between panels. This technique, when backed up with an air/vapor barrier on the inside of the house, is very effective at stopping air and vapor movement through the wall. But the wall won't dry readily if any moisture gets inside, so care must be taken to use dry framing lumber (with a moisture content of 19% or less); and if you use wet-blown cellulose insulation, make sure it has dried before walls are closed up. Tsongas says sealing the exterior plywood to the frame would be a bad idea without the addition of the rigid-foam insulation.

Cooling climates—The warm, humid conditions of the Gulf Coast present an entirely different set of headaches. Just about everything that works in a heating climate works here—but in reverse—because the warm, humid conditions are outside, not inside. The lower the air-conditioned temperature inside the house, the higher the vapor pressure and the greater potential for moisture damage. According to Lstiburek, vapor pressure acting on a wall in the deep South in summer can be higher than the pressure exerted on a house during a Minnesota winter. Air leaks are damaging in the South, too.

The danger in this part of the country is that warm, moisture-laden air from the outside cools as it penetrates a wall or ceiling. Water vapor can condense on the back of interior walls or ceilings, especially if the wall is covered with an impermeable material like vinyl wallpaper. If the inside of a house doesn't reach the dew point, though, water vapor traveling through the wall won't condense. It will just pass into the house without causing a problem. So the inside design temperature of a house has a lot to do with picking the right moisture-control strategy.

In addition to vapor pressure and air movement, another important factor in the deep South is intense sunlight. After a rainstorm, the sun can drive large amounts of water in the siding toward the inside of a wall. If the moisture isn't stopped by a capillary break (like housewrap, building felt or a vented airspace behind the siding, called a rain screen), wall cavities will get wet, even without air conditioning inside.

Just as they are in the North, air barriers are more important than vapor barriers in the South because they stop the bulk movement of air. Builders in this part of the country have a number of options. The most comprehensive explanation of them is in a book that Lstiburek coauthored, published last year (see Suggested reading on the facing page). Options include a polyethylene air/vapor barrier on the outside of the building envelope; rigid-foam insulation (with seams taped) on the outside; or plywood or OSB sheathing sealed to wooden framing members. All penetrations of the shell of the building should be sealed. In masonry construction, an impermeable parge coat (similar to stucco) can be applied to either the outside or the inside of masonry block walls. An air/vapor barrier like polyethylene also can be applied behind a brick, block or stucco wall.

But the deep South is one of those areas where researchers are still trying to devise the best moisture-control strategies. Research at the Oak Ridge National Laboratory, for instance, suggests that vapor-permeable walls, without any vapor barriers, work best. That's probably because these walls have a high drying potential. In any case, no vapor barrier should be used on interior walls. This means that interior wall coverings should be vapor permeable so that drying can take place toward the inside, and moisture isn't trapped against cool interior walls. So skip the vinyl wallpaper and foil-backed drywall. If you're using faced fiberglass batts, remember to install them with the foil or kraft paper on the outside, not the inside. Better yet, use unfaced batts.

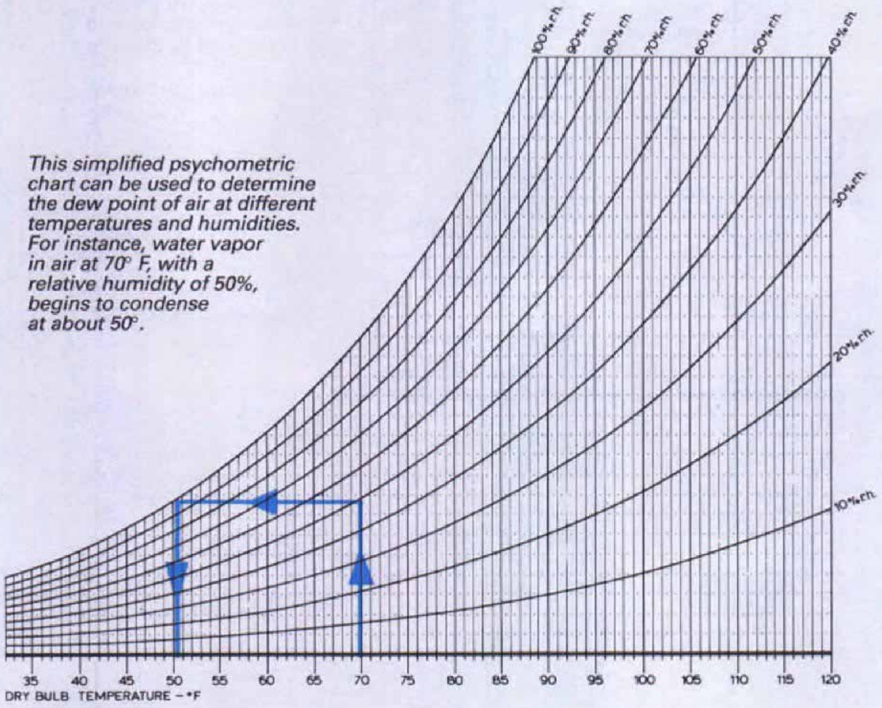
The installation of poly in a ceiling right below the attic (on the warm side of the ceiling) is a

Finding the dew point

This simplified psychometric chart can help you find the dew point for air at different temperatures and humidity levels. The dew point is where water vapor begins to condense, which could be inside walls and ceilings where it can cause damage. Knowing how to find the dew point can help you understand, and avoid, moisture problems in a house.

The chart is easy to use. Let's say the indoor air temperature is 70° F, and the relative humidity is 50%. Start on the bottom line at 70, make a line vertically until it intersects the curved relative-humidity scale at 50, then draw a horizontal line to the left. When the horizontal line intersects the 100% relative-humidity curve, drop down to the temperature line where you started and get the result. The dew point in this case is about 50°, meaning water will start to condense when the air comes into contact with any surface at 50°.

What about the dew point inside a wall? Knowing where the dew point occurs in a wall is tricky because many variables affect it—insulation, building materials, construction. Doug Burch, a researcher with the National Institute of Standards and Technology, says a computer program he codeveloped with Dr. William Thomas, called "Moist," can help you predict how various construction methods will perform. For a free copy of "Moist," write to Kim Whitter at the National Institute of Standards and Technology, Building 226, Room B320, Gaithersburg, Md. 20899; (301) 975-5648. —S. G.



This simplified psychometric chart can be used to determine the dew point of air at different temperatures and humidities. For instance, water vapor in air at 70° F, with a relative humidity of 50%, begins to condense at about 50°.

good idea up North but not here. It would be better to skip the poly barrier here, use a vapor-permeable paint like latex and allow the ceiling to dry toward the inside. Adequate venting of the roof also will help clean out moisture that accumulates below the roof deck (which is also true in other climates). Another approach in the ceiling is to use rigid-foam insulation immediately behind the ceiling drywall. This acts as a vapor retarder, but it also raises the temperature of the roof cavity so that moisture is less likely to condense there. A vapor barrier should be used in the basement or crawlspace—beneath a poured concrete floor or over a dirt crawlspace—to block moisture from the ground. But keep those crawlspace vents closed—there's no need to let in warm outside air where it might condense on cool surfaces.

Mixed climates—Somewhere between Minneapolis and New Orleans is the Twilight Zone of air and vapor barriers. In this part of the country, builders may be faced with significant heating *and* cooling seasons. How can houses be designed to deal with both conditions? You won't drive yourself crazy if you remember that no solution is perfect.

According to Lstiburek, the overall approach in a mixed climate is to combine good building practices with air and vapor barriers to control moisture. Walls, Lstiburek says, should be built so that they can dry to either the inside or the outside if they get wet. A well-designed wall would include an air barrier, such as sealed drywall, plywood or OSB sheathing or rigid-foam insulation that has been sealed to the framing. In addition, a continuous sheet of polyethylene can be applied on the inside, right behind the finish wall, as a continuous air/vapor retarder (drying of walls with an interior poly air/vapor barrier will be better if the exterior is kept vapor permeable). Because cooling loads are less here than they are in the deep South, the risk of condensation against the back of the drywall is lower when a poly air/vapor barrier is used.

These strategies aren't perfect because there may be long spells of both heating and cooling in this part of the country. But here, too, it is more important to stop the bulk movement of air through a wall or ceiling than it is to provide a perfect vapor barrier. Rigid-foam insulation applied to the outside of a building has the same advantages in a mixed climate as it does elsewhere: The foam is an air barrier with low vapor permeability; it provides a capillary break between the siding and the wall cavity, and it raises the temperature of the wall cavity during the heating season to reduce condensation.

Because climates tend to be milder in this part of the country, vapor diffusion by itself may be less of a problem than it would be in the far North or along the Gulf Coast. The exception is ground moisture in basements and crawlspaces, which should always be controlled with polyethylene sheeting.

Ventilation and humidity—It doesn't make sense to talk about air barriers and vapor barriers without mentioning two related issues—mechanical ventilation and humidity. The owners of the house Thurrell built in Maine had an unvented clothes dryer inside, stored green firewood in the basement, apparently neglected to use bathroom or kitchen fans and often ran two humidifiers inside during the winter. Humidity levels weren't measured, but these practices almost certainly contributed to the problems.

In heating climates, an inexpensive hygrometer can help you keep an eye on interior humidity levels during the winter. Or watch your windows—condensation on the inside of the glass is a good indication that humidity is high. And the higher the relative humidity of inside air, the higher the dew point. George, the New Hampshire builder, is so confident of his building system that he doesn't see a problem with interior relative humidity levels of 50% during the winter. Lstiburek and many others think the relative humidity should be more like 35% at 70°. Is the difference significant? Maybe. There is a 14° difference in the dew point of 70° air with a relative humidity of 50% and 70° air with a relative humidity of 35%, and vapor pressure will be higher in the house with greater relative humidity. With imperfect air barriers and vapor barriers, the risk of moisture collecting inside walls and ceilings is greater.

Suggested reading

Moisture Control Handbook: Principles and Practices for Residential and Small Commercial Buildings by Joseph Lstiburek and John Carmody, Van Nostrand Reinhold, 115 5th Ave., New York, N. Y. 10003 (800-842-3636), 1993. $49.95 hardcover; 214 pp.

Canadian Home Builders Association Builders Manual, Canadian Home Builders Association, 150 Laurier Ave. West, Suite 200, Ottawa, Ont., Canada K1P 5J4 (613-230-3060), 1989. $55 U. S., $58.85 Canada softcover; 284 pp.

Moisture Control for Homes: A Primer for Designers and Builders by J. D. Ned Nisson, Cutter Information Corp., 37 Broadway, Arlington, Mass. 02174 (800-964-5118), 1989. $35 softcover; 54 pp.

Manufacturers of specialized polyethylene

Dura-Tuff, a 3-mil, 3.5-mil or 4-mil high-density polyethylene, by Yunker Plastics, Inc. (P. O. Box 190, Lake Geneva, Wis. 53147; 800-236-3328).

Rufco Super Sampson, a cross-laminated poly made by Raven Industries (P. O. Box 5107, Sioux Falls, S. D. 57117; 800-635-3456).

Tenoarm, a stabilized, 8-mil Swedish product distributed in the United States by Resource Conservation Technology (2633 North Calvert St., Baltimore, Md. 21218; 410-366-1146).

Tu-Tuf, a cross-laminated polyethylene made by Sto-Cote Products, Inc. (P. O. Box 310, Richmond, Ill. 60071; 800-435-2621). Tu-Tuf comes in 3-mil and 4-mil thicknesses.

Extremely tight houses need mechanical ventilation because without it there may not be enough fresh air to make people feel comfortable. There's another advantage to mechanical ventilation systems: They can work with air barriers and vapor barriers to control moisture. In a heating climate, mechanical ventilation can slightly depressurize the interior of a house in winter. Any air leaks through walls will be toward the inside, bringing dry air with it and preventing any outward flow of warm, moist air into wall cavities. Also, bringing outdoor air in helps keep humidity levels lower. In a mixed climate, mechanical ventilation can keep a house slightly pressurized during cooling seasons (blocking the inward migration of moisture-laden air) and slightly depressurized during heating seasons. Tsongas suggests combining spot ventilation in bathrooms and kitchens, dehumidification and whole-house ventilation. But a word of caution: An article in *Energy Design Update* (Cutter Information Corp., October 1993) says leaky ductwork can lead to pressure imbalances that increase air infiltration. Make sure duct joints are well-sealed.

Use common sense—Air barriers and vapor barriers aren't magic. Installed on a badly built house, they may be a waste of money. At the top of Tsongas' bad building practices list is bringing wooden siding to within inches of the ground, or not sealing the bottom edge of siding that will soak up water (he suggests leaving at least 1 ft. between the siding and grade). Good building practice is the most important ally in building a trouble-free house. That means the use of foundation drains and gutters, sloping the grade away from the house, ventilating moisture-producing areas like bathrooms and kitchens, and keeping siding away from the ground.

But as plenty of researchers and builders told me, air barriers and vapor barriers are relatively cheap insurance. Builders don't always know who will live in the houses they make or whether the owners will know about moisture control. Maybe the owners don't understand or care why humidity is an issue or why a bathroom fan should be used when they're showering. One family may have no problems in a house whose air and vapor barriers are only marginal while the next owners could have problems because they're not careful. So if there is a "last word" on air barriers and vapor barriers, maybe it's this: Do your homework and build for the worst-case owners in the climate where you live. □

Scott Gibson is associate editor of Fine Homebuilding. *Photos by author except where noted.*