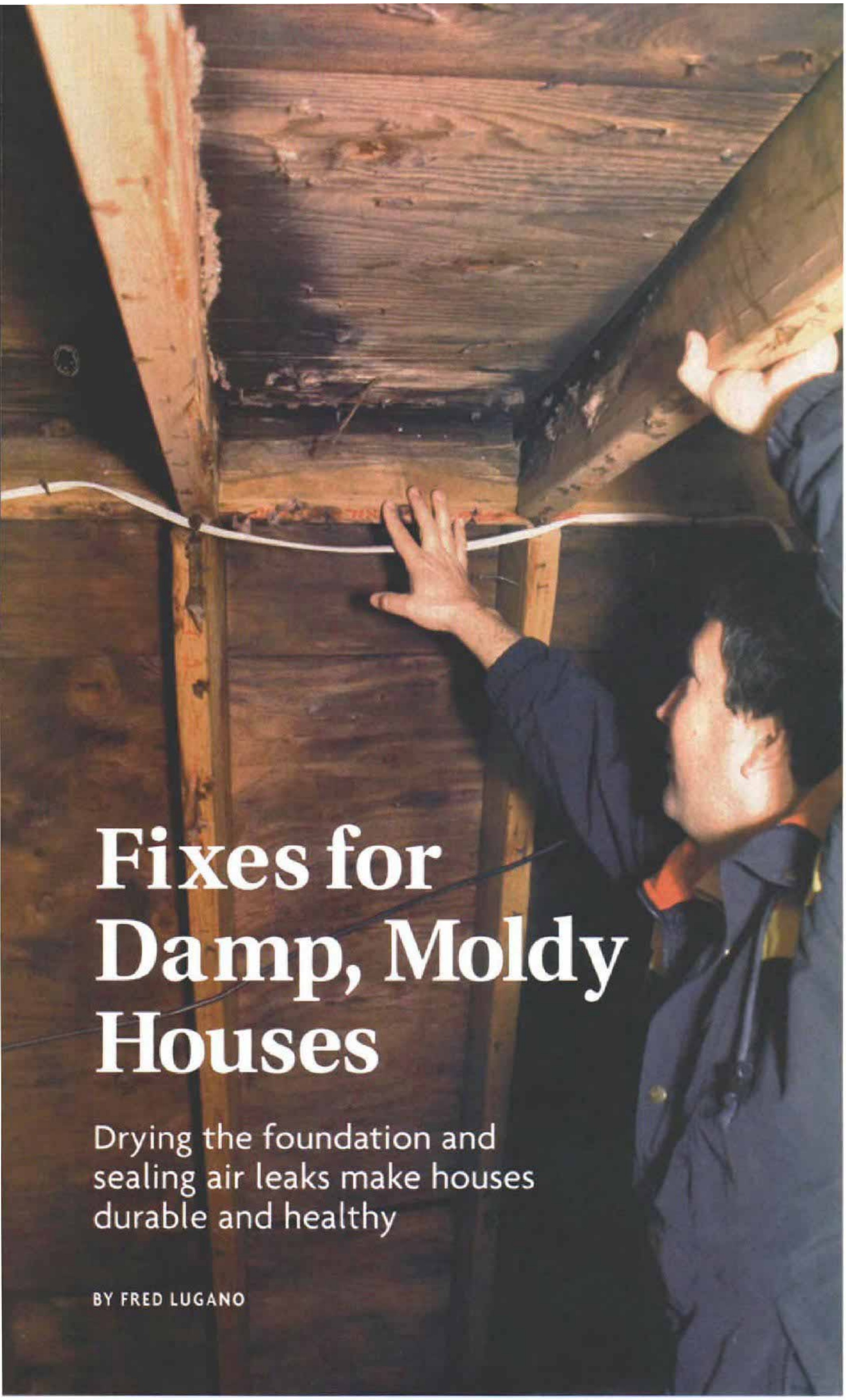


Fixes for Damp, Moldy Houses

Drying the foundation and sealing air leaks make houses durable and healthy

BY FRED LUGANO

Condensation leads to mold growth and rot in the attic. The moisture source is probably the basement, and leaks in the building shell and in ducts carry the moist air upward.

I recently responded to a frantic call from the owners of an opulently remodeled older home. The weather was subzero, and water dripping from the ceilings pinged in dozens of pots and pans throughout the house. The owners thought that ice dams were causing their roof to leak. They were wrong, though. Condensation was the problem.

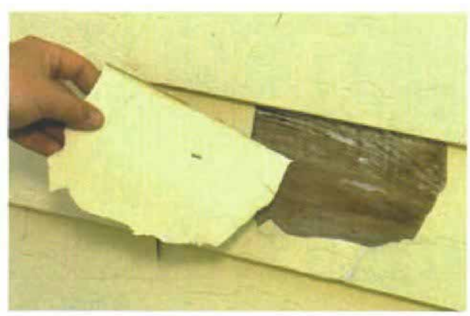
The underside of the roof deck was solid mold. Dozens of recessed ceiling lights and a board ceiling in the living room channeled warm, moist air into the attic. Water from foundation leaks stood shoe-top deep in the basement. Moisture evaporated here, traveled though ceiling leaks to the attic and condensed on the cold roof. Sealing air leaks, drying the basement and installing a moisture barrier on its floor fixed the trouble.

As a weatherization contractor, I frequently repair damp, moldy houses. People call me to fix soaking, rotting roof decks (photo left), or a rotting exterior wall revealed during a remodeling project, or a cellar causing a stink through a house. Sometimes paint peels from walls (photo below), and brown mildew streaks indicate the location of wall studs. With no leaks in plumbing, roofing or siding, the problem is condensation that leads to the growth of fungus—mold and mildew.

Fungi are brutally territorial about their food supplies, and they produce powerful toxins to protect their turf. Their poison is aimed primarily at other microorganisms, but it also makes many people deathly sick inside their homes. Fungi inoculate every part of our world. They make life possible by breaking down dead-plant matter into soil. Unfortunately, our dwellings are built mostly from dead-plant matter, namely wood,

Fungi need lots of water to grow

Water constantly moves through walls, roofs and ceilings, mainly borne on air currents. It most often blows in as vapor, condenses, ad-



Peeling paint is a symptom of moisture trouble. Interior moisture, driven outward by air pressure, condenses in cold walls. Diffusing through the siding, the water makes paint peel.

Photo right this page: Fred Lugano

heres to the wood fiber for a while, then diffuses out again. Every house gets wet and dries out in daily and seasonal cycles, and usually without harm.

The problems begin when the framing gets wet faster than it can dry. When wood reaches a moisture content of 30%, fungi start to grow wildly. Once begun, fungal destruction (or feasting, depending on your point of view) doesn't stop until the wood's moisture content falls back below 20%.

Five elements are required to generate harmful levels of condensation. There must be a source of water to load warm air with vapor and a cold surface where vapor can condense. Air passages must connect these two places. A source of pressure must be present to drive moist air down the air passages. Finally, a diffusion barrier must keep condensation from drying faster than it is deposited (drawing p. 76).

Eliminating anyone of the above elements will stop wetting. Doing all the easy work on two or three of the five elements can also stop wetting and is generally the simplest approach to fixing a damp, moldy house. As a practical matter, two of the five elements—condensing surfaces and diffusion barriers—can't be helped.

Condensing surfaces can't be eliminated

As long as there is a temperature difference between inside and out of, say, 30°F, a condensing surface exists. Its location varies depending on the amount of insulation and the temperature differential. Typically, in northern winters, the inside of the wall sheathing or the bottom of the roof deck is the condensing surface. In air-conditioned houses, it's the back of the drywall.

In Vermont, we get a minimum of four months of winter conditions that create a 30°F temperature differential. Hot siding and attics in air-conditioned southern homes create a temperature differential of at least 30°F during summer months. The only way to eliminate the temperature differential, and hence the condensing surface, is not to heat or cool our homes.

Diffusion barriers are the second element that can't be helped. Most water vapor that enters building cavities is airborne. Most drying, however, takes place by diffusion. Anything that stops diffusion is counterproductive from a moisture-control standpoint. Plywood, oriented strand board and foam sheathing, as well as interior polyethylene sheeting, are diffusion barriers.

I've found that combining diffusion-barrier sheathing with an interior polyethylene layer is asking for trouble. This notion may sound heretical because placing polyethylene inside our walls and ceilings has been common practice in many areas since the energy crisis of the 1970s. Common sense says it keeps interior water from entering framing, a worthy goal. Trouble is, poly doesn't work.

Heating and cooling indoor air creates pressure zones within the house. This air pressure drives conditioned interior air outside; the interior air will pass through any pinhole in the poly to get out. Of course, any moisture in that heated air condenses on the first cold surface in the wall. With diffusion barriers on both sides of a wall, water can't get out once it condenses.

Removing the existing poly behind drywall means removing the drywall itself. Typically, I do this only on renovations where the interior finishes are coming down anyway. Don't panic if drywall has poly behind it. Take the measures presented later in the article to dry the house and balance air pressure from ducts, and you should have no trouble.

Drywall with no poly behind blocks harmful, moist airflow, yet it allows some beneficial diffusion drying to take place on the interior. I don't rely on poly in new construction, but on sealing the drywall to the framing and on using high-density blown-cellulose insulation to keep out air.

First, eliminate the water source

Containing the source of the water is generally the cheapest, most effective method of stopping condensation. Although bathing, cooking and washing may produce obvious condensate on cold windows, they are small sources that usually generate a few pints of water per day. I've had clients who feared that taking long showers was causing their house to rot. I installed bath fans and told them they could shower until their skin was prunelike. Even in tightly built homes, exhaust fans in baths, kitchens and clothes dryers remove the moisture they're supposed to remove. An average three-bedroom house needs to be loaded with hundreds of gallons of water to develop trouble.

The most important source of water is usually the foundation (photos right). It can infuse the building with tens of gallons of water every day. The first step in fixing or preventing a moisture problem in the house is stopping groundwater and outside humidity from penetrating the foundation.

Water enters the foundation by capillary action through dirt floors or porous masonry, or it diffuses through dense foundation materials, such as concrete. In a friend's house, water pouring into the basement through the sleeve around the incoming well line was an annual harbinger of spring. Poorly sealed slabs, crawlspaces and basements are all vulnerable.

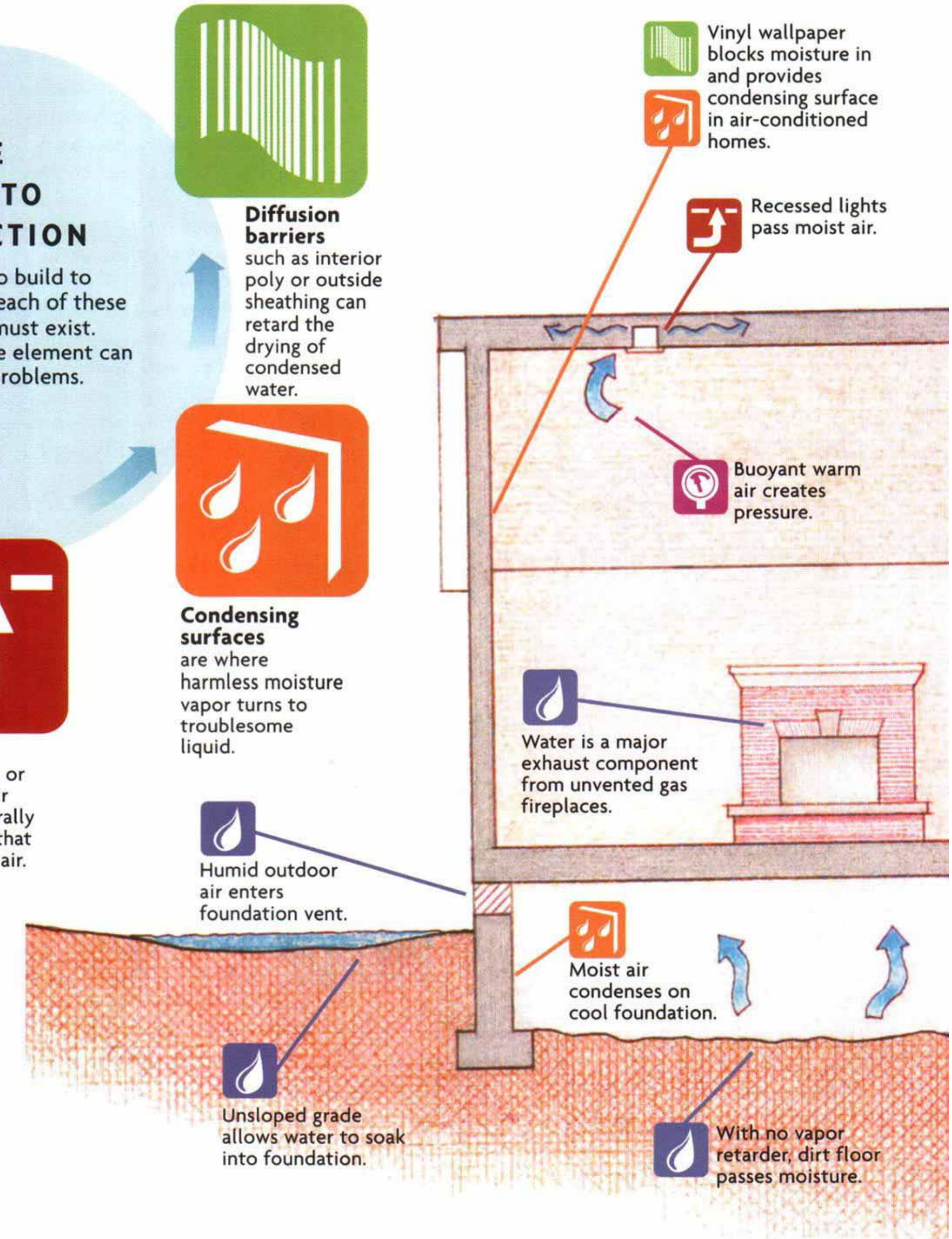
During the heating season, many foundations seem to dry out. While cold air and frozen ground can decrease the flow of water into these spaces, the real cause of drying is on the other side of the equation. Cold winter air is dry. Bring in that outside air and heat it, and it becomes parched. This thirsty air sucks water out of soil and masonry. When this now moisture-laden air contacts a cold surface, the water condenses.

I test dry-looking foundation walls and floors for moisture flow by sealing a square yard of poly onto the surface overnight (top photo). If moisture is passing through, beads of water will show under the plastic. To stop this moisture flow permanently, I cover all exposed soil with a rugged moisture barrier such as Tu-Tuf (Sto Product Corp.; 888-786-2683). I seal the moisture barrier to stone foundation walls with polyurethane foam (*FHB* #121, p. 122), and to concrete or block walls with acrylic roofing cement. If I'm sealing a floor, I add a walking surface

TIPS TO HELP FIND MOISTURE SOURCES

The poly test determines if dry-looking masonry is passing water. Left overnight, a plastic sheet will cause misleadingly dry-looking concrete to dampen visibly.

A mirror reveals open block cores, a great moisture source. The fix is easy, though. Cap the cores with expanding foam or simply stuff them with wads of plastic sheet.



such as washed stone or, better, a thin concrete slab over the moisture barrier.

Keeping water out of foundation walls

One little-known but disastrous moisture source is the open cores at the top of block foundations (bottom photo, p. 75). The cores have three times more surface area to evaporate wicked-up groundwater than do the faces of the blocks. I think of these cores as hundreds of chimneys drafting moisture from the soil directly to the framing.

This situation happened in the lakefront retirement cottage of an elderly client. Plagued by mold allergies, she'd spent over $10,000 on special air filters and foundation sealing before calling me. The mold was unabated. A quick check with a mirror revealed open block cores in her basement walls. I sealed the cores by filling plastic bags with fiberglass insulation for loft and stuffing them into the tops of the cores. Within a few weeks, the house had dried, and my client was breathing easily.

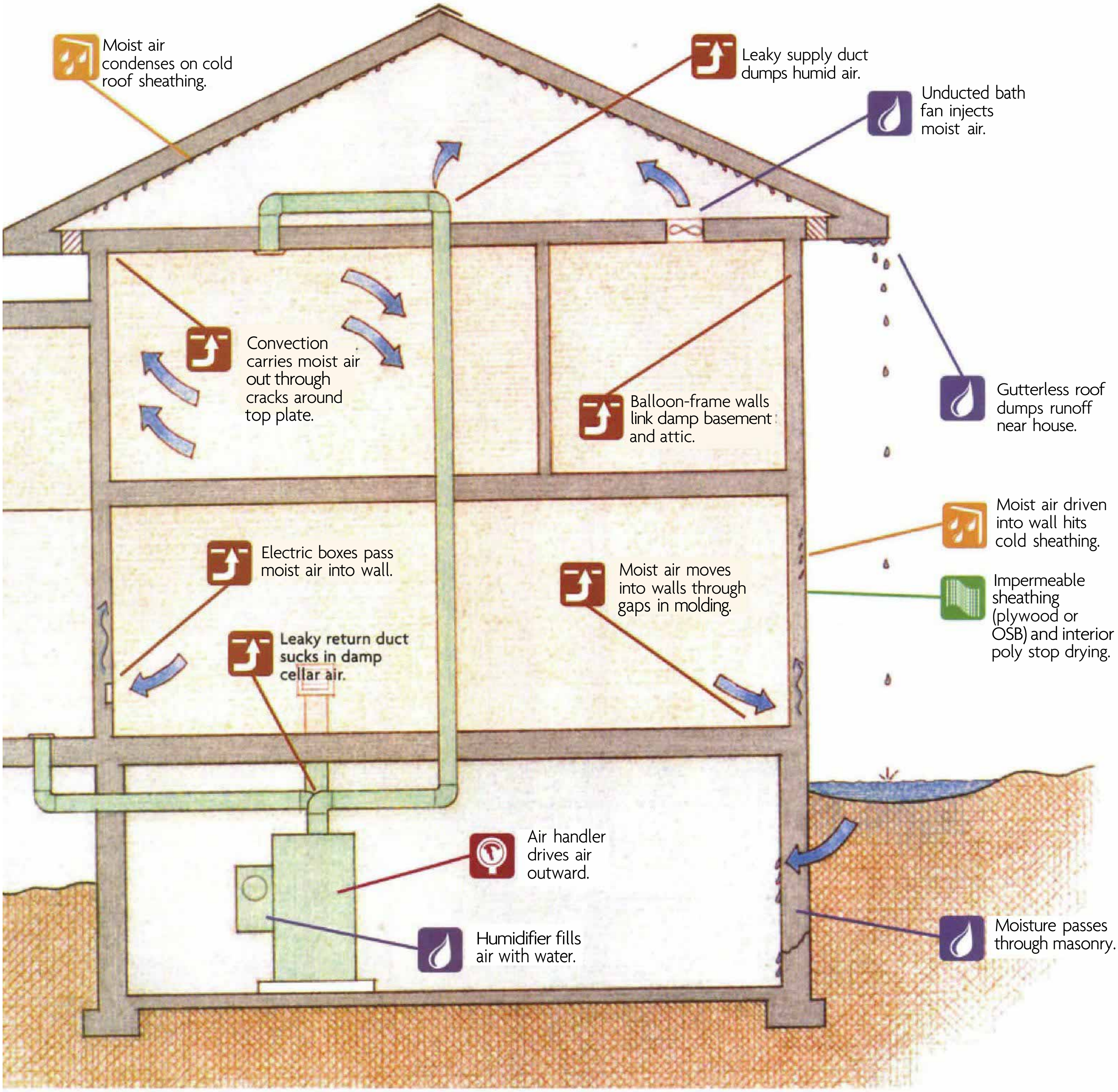
New foundations generally are best treated from the exterior. There isn't space here to detail all that can be done to waterproof the outside of foundations (*FHB* #95, pp. 48-53). To keep water away from foundations, I employ William Rose's recommendations (*FHB* #111, pp. 98-103). The keys are damp-proofing, footing drains, gutters and downspouts that guide water away from the house, and backfill graded to slope at least 1 ft. in 10 ft. away from the house.

With existing foundations, I often must limit work to interior measures. I fill large holes in foundation walls from the inside with hydraulic cement such as Waterplug or Thorite (Harris Specialty Chemicals; 904-996-6000). Paint or DryLoc (UGL; 800-845-5227) on the walls will slow capillary action. Installing a sump pump can relieve pressure from groundwater.

Keep out humid air

In warm weather, outdoor humidity becomes an important source of condensation. During the summer, foundations are always colder than the outside. When 60°F air at 50% relative humidity enters a 60°F crawlspace, it becomes a rain cloud. Water con-

Drawings: Vince Babak



denses on every cool surface, and mold flourishes. Although this procedure may be a code violation, experience has shown me that permanently blocking all vents in foundation walls is a sure way to save sills and floors from condensation-induced rot. If restricting air to combustion appliances such as a furnace or water heater isn't a problem, I insulate the walls with extruded foam and seal perimeter air leaks with polyurethane foam.

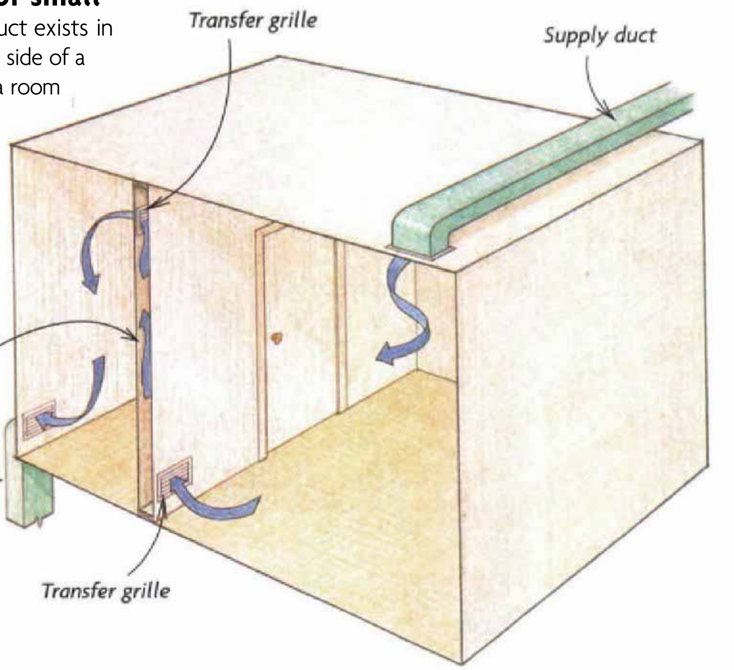
Although most of my work is in the north, condensation doesn't stop at the Mason-Dixon line. Southern homes need complete external air barriers to keep outdoor humidity from condensing on cold, air-conditioned interior surfaces. Most houses have a built-in external air barrier: the sheathing. However, roof and foundation vents puncture those barriers and let water vapor enter. Closing vents keeps out humid air. Air conditioners dehumidify interior air. When the air conditioner is running, typically during the most humid conditions, the framing can dry to the interior by diffusion through the drywall.

The condensation machine

After drying the foundation as much as practical, I look at forced-air heating systems. Central humidifiers are the ultimate plumbing leak. Combined with leaking ductwork, a common problem, they turn forced-air heating systems into condensation machines. The moisture source, the path and the pressure are all in one package. Because the furnace runs only when the house is cool, condensing surfaces are always at hand to capture humidity.

People install humidifiers when a house's air is very dry. Houses suffer from winter dryness because they are flooded with cold, dry outdoor air. Bad ductwork frequently causes this excessive ventilation. Supply

Transfer grilles provide return ducting for small rooms. If no return duct exists in a room, a grille on each side of a wall that's shared with a room served by a return duct can balance the air pressure.



Holes and gaps in the framing pass lots of moisture. Sealing the holes is simple, though. A shot of urethane foam stops the flow of moisture-laden air.

Duct-sealing is critical. Unsealed ducts blow hot, moist air into the house's framing cavities, or suck damp air from foundations. By the way, use mastic; duct tape doesn't air-seal.

ducts that leak in the attic blow warm air directly outside the building envelope. This action depressurizes the house and draws in cold, dry outside air elsewhere. Leaks in basement return ducts depressurize the basement, sucking in outside air through framing gaps. Panned return ducts—a sheet-metal bottom nailed over two joists—are guaranteed to be sucking outside air in from around the sill and rim joist. I open panned ducts and air-seal the sill and rim joist, or replace them with sealed metal ducts. Sealing ducts and the attic ends the need for a humidifier.

I shut down the humidifier if the house has one and seal all ducts with a mastic such as RCD #6 (RCD Corp.; 800-854-7494). I smear mastic on every field joint and on every hole made in the ducts for plumbers and electricians to run their pipes or wires. Don't use duct tape. Duct tape has a thousand uses, but it's no good for sealing ducts.

Air pressure can drive moisture into walls

Leaky basement return ducts caused one of the worst condensation problems I ever saw. Moisture was causing sheets of paint to peel from this house's siding (photo right, p. 74). The basement was finished with paneling nailed to furring strips over the foundation walls. A suspended ceiling hid the ducts. All the air sucked in by the leaky return ducts channeled between the paneling and the block foundation walls. This process kept the basement walls extraordinarily dry and loaded the rest of the house with moisture. Pressure from forced-air heat drove this moisture out through the walls, causing hundreds of water-filled paint blisters.

Even with airtight ductwork, bad distribution can force accidental ventilation with the outside. Although not the only culprit, bathrooms are notorious for being fitted with a hot-air supply but no cold-air return. With the door closed, the bathroom inflates. This pressure drives the air through every microscopic puncture in the air barrier. Moving into the wall, any airborne moisture condenses on the first cold surface it encounters.

To equalize the pressure, I trim an inch off the door bottom or cut a hole through an interior wall to a room that does have a return duct. I cover this passage with a grille on each side (drawing above). A vent fan, ducted outside, is helpful. In extreme cases, I control the fan with a dehumidistat. (A dehumidistat switches on with high humidity.)

Seal leaks into the attic

Frequently, large holes connect attics to living areas. Recessed lights, balloon-frame

Bottom photo this page: Courtesy of Lake Construction.

Attic ventilation doesn't always work. Stopping moisture from entering this attic in the first place would have prevented ice from forming.

Filling sloped-ceiling bays with blown cellulose. The pipe extension on the blower's hose reaches the bottom of the bay, ensuring a dense, air-sealing pack.

walls, fans, disappearing stairs, plate penetrations for mechanicals—even top plates of walls that have shrunk away from the attached drywall—create paths for warm, moist air to escape (top photos, facing page). Interior air can enter these paths directly or by circuitous routes, such as through electrical boxes or around base moldings. Even if there is no forced-air heat present to pressurize the envelope, buoyant hot air naturally pressurizes the top of the building in cold weather. Most of the water vapor that is generated in a house exits through the attic on its way outdoors.

The only reliable way to keep an attic dry is to cut off the flow of moist indoor air. The easiest place to do this is where the ceilings and walls below intersect the attic floor. I plug all plumbing, wiring and masonry chases, and seal the top plate of every partition to the adjacent ceiling with polyurethane foam.

Open framing bays in sloped ceilings, balloon-framing, stairwells and the joints between existing and new construction are big air-sealing targets. I use sheets of wood, foam, drywall or aluminum flashing to block the tops of these cavities.

Venting the roof may not help

Venting the roof is the conventional and code-recognized means to dry an attic. Sometimes I find it makes the attic wetter. Venting roofs only allows the attic to suck more air out of the living areas by providing a larger exit and cleaner path for escaping air. Mixing cold outdoor air with wet attic air simply causes condensation. In problem attics, frost and icicles often cover the vents themselves (photo left). In my experience, the size and type of vent has no predictable effect on the degree of attic condensation.

Once I've blocked interior air passages to the attic, I block gable vents to keep out rain and snow. Blowing in a thick layer of cellulose insulation will eclipse any small summer heat gain closing the attic vents may create.

Roofs above sloped ceilings often build damaging ice formations. The common practice of installing batt insulation between the rafters, enclosed by a plastic sheet below and a foam vent chute above, is extraordinarily failure-prone. All the roof vents at gables, soffits and ridges serve as exits for indoor air. The indoor air enters through recessed lights, drywall cracks and unsealed holes in the framing.

When there is a large water-vapor source, moisture enters sloped ceilings with this indoor air. I've seen cases where it condenses, freezes and turns the insulation batts into red and yellow Popsicles. When the weather warms, they melt into the ceiling.

In its 1997 Fundamentals Handbook, ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) goes so far as to say "... the benefits of vents in cathedral ceilings do not clearly outweigh their potential drawbacks and should not be required...." ASHRAE is one of the bodies that national code organizations look to when drafting building codes.

Blown-cellulose insulation forms an effective air barrier

Air-sealing a sloped ceiling takes different tactics than I use when I'm air-sealing a flat ceiling. Unlike flat ceilings that have attic space above, sloped ceilings are generally inaccessible. The best solution I've found for sloped-ceiling troubles is to close the roof vents by filling the rafter bays solid with high-density cellulose insulation. Blowing cellulose fiber at high speed completes both the air barrier and the insulation layer in one easy step.

After blocking the soffit vents to keep any loose insulation from drifting out and making sure that any recessed lighting is rated for direct insulation contact (IC is the common designation), I head onto the roof. Tearing off the cap shingles and removing the ridge vent exposes the rafter bays. I stay on top of the existing insulation and extend the end of the cellulose blower's hose all the way to the wall plate (photo right). Then I blow the cellulose at a rate of 3.5 lb. per cu. ft., about twice the standard density for the insulation. This insulation seals off any air passages and fixes the problem.

Filling the rafter bays solid with blown-cellulose insulation violates many building codes and shingle manufacturers' venting requirements. But this technique is in keeping with contemporary building research that hasn't made the codebooks yet, and most important, it works. I know from experience that many conventional approaches to air-sealing and moisture-sealing frequently just don't work. □

Fred Lugano owns Lake Construction in Charlotte, Vermont. For more information on weatherization, log onto his Web site at www.weatherization.com. Photos by Steve Culpepper, except where noted.

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