Fixing the Holes Where the Air Gets In

by Bruce Torrey

To get the best performance from insulation, either the framer has to build an airtight shell or the insulation contractor has to install an airtight product. It's a proven fact that insulation R-values are compromised by uncontrolled air leakage into the building shell. Convective air currents moving through wall and ceiling bays can bypass poorly detailed insulation almost as if it weren't there at all, with consequences that can come back to haunt the builder.

As a GC who also specializes in diagnosing home energy performance, I receive a steady stream of calls from homeowners, property managers, and other builders requesting help with energy-related issues. Surprisingly, most of these problems occur in new or newly-renovated homes. Common problems include drafty interiors, frozen pipes, high heating bills, ice dams, and comfort complaints. And yet these buildings also have code-approved levels of insulation, tight windows and doors, and high-efficiency heating systems. What's going on?

What's happening is a breakdown in the building sequence at the point where the framer stops and the insulation contractor starts. At that point, at least when air sealing is involved, the typical construction plan becomes vague or incomplete. This lack of continuity increases the likelihood that thermal and air bypasses will get built in to the project. Any space, large or small, that comes between the air barrier and the insulation is a possible conduit for leakage.

> Tighten the envelope to improve insulation performance, and don't forget the mechanical ventilation

Figure 1. A blower door is a calibrated, variable-speed fan used to depressurize a house, creating a pressure difference between indoors and out. By measuring air flow through the fan, the total volume of air leakage through the building envelope can be determined.

Same Old Frame, Almost

To eliminate this disconnect, my company handles both framing and insulation in-house. Our framing methods are identical to standard practice in every way: 2x4 or 2x6 studs on 16-inch centers, plywood sheathing, dimensional or engineered lumber joists, and stick or truss roof framing assembled in typical fashion. Our goal is not to make the building absolutely airtight — an elusive goal at best — but to reduce the aggregate amount of leakage and to manage the flow of air entering and exiting the shell. Our typical target is a building with a passive rate of exchange of about 1/10 ACH per hour (.1 ACH). After we insulate a job but before the drywall is hung, I perform a blower-door test to measure how tight the insulated shell is (see Figure 1).

Over time, the test results have shown us where to concentrate our air-sealing efforts during framing. Fortunately, what's required adds little time or effort to the standard workflow. Instead of ordinary sill sealer, we use a rubber (EPDM) gasket between the foundation and mudsill (Figure 2). The $5^1/_2$-inch-wide gasket is designed to provide a positive seal under a heavy structural load; it also serves as a moisture barrier between the concrete and wood. After setting, stringing, and squaring the rim joists, we run a bead of construction adhesive over the joint between rim and mudsill. We've tried EPDM gaskets under the rim, but they tend to get in the way. Adhesive is less expensive and nearly as effective. It's important to take this step before rolling the floor joists into position; otherwise, rim sealing becomes a long, hard slog. Glue-and-nail subfloor installation has become standard industry practice. However, not everyone glues the edge of the rim joist on the assumption that the walls hold the subfloor down at the edges. In fact, this is a common point of air entry, which we handle with a continuous bead of adhesive. We frame and

Figure 2. EPDM rubber building gaskets, such as this sill sealer (right), are designed for heavy structural loads. The author uses several different configurations to seal various framing components. Between the rim joist and the mudsill, a continuous bead of subfloor adhesive provides an effective and inexpensive seal (above).

sheathe the walls on the deck before standing them on a rubber gasket tacked around the perimeter of the deck (Figure 3). I buy my gaskets from Resource Conservation Technology (410/366-1146,www.conservationtechnology.com) and Denarco (269/435-8404). These companies carry a good selection of gaskets designed for sealing a variety of framing configurations.

Because I'm convinced that air doesn't move through plywood, I sidestep the whole housewrap debate. Instead, shortly before installing the siding, we tape all the horizontal seams and any other cuts in the sheathing that aren't backed by framing. We use either DuPont Contractor Tape (DuPont Tyvek, 800/448-9835, www.tyvek.com) or 3M Builder's Sealing Tape (3M, 888/364-3577, www.3m.com) or both (Figure 4).

Gaps and Penetrations

Once the shell is tightened and weathered in, we turn our attention to interior air gaps and passages. Plumbers and electricians create their share of holes between bays and between floors. Expanding foam caulk does a good job of sealing around wire and pipe penetrations. If left open, these holes become interconnected convective air conduits to the roof soffits and attic.

Packing fiberglass around the jambs of a window or door isn't particularly effective at stopping drafts, especially when the gap's too narrow to stuff. Expanding foam doesn't move with the frame's expansion and contraction cycles, and runs the risk of distorting the jambs on installation. Instead, we use another EPDM gasket configuration made for the task. The soft rubber slides into narrow cracks without undue force and provides a positive seal that moves with the framing (Figure 5, next page). Cracks too narrow to slide a gasket into get caulked with silicone.

It's a good idea to size rough openings slightly larger than standard to ensure that the gasket has sufficient space to expand and seal.

Sealing the Deck

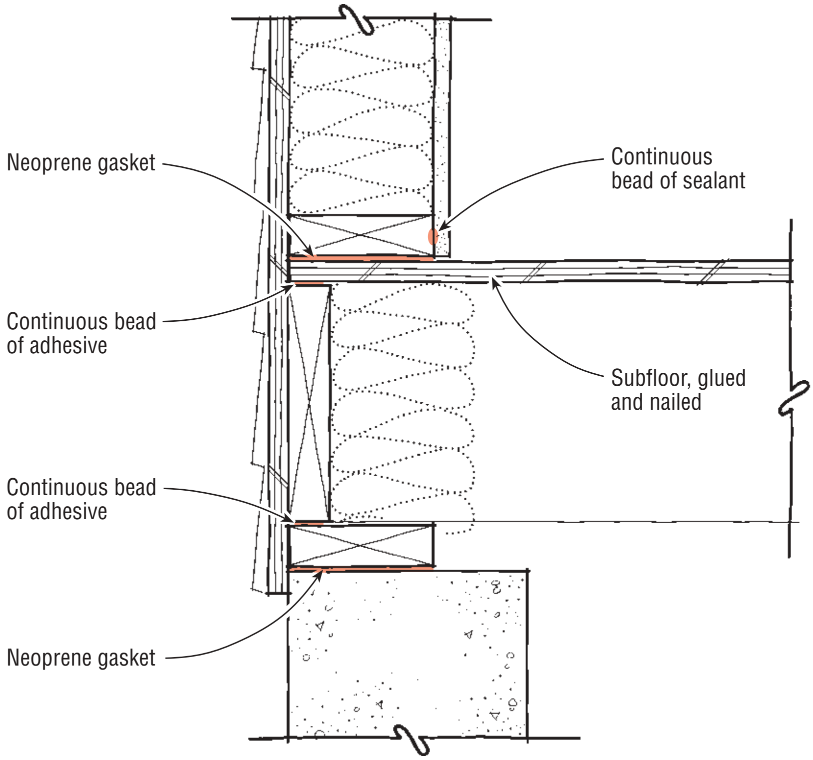

Figure 3. Bottom plate gaskets may be tacked to the deck or the underside of the plate before sheathing and standing exterior walls.

Figure 4. Instead of using housewrap, the author relies on plywood seam tape to block wind penetration. Tape installs easily just prior to siding.

Figure 5. A compressible dual-tube rubber gasket, forced into the shim gap around windows and doors with a drywall knife, provides a highly effective air seal.

Sealing the Ceiling

Balloon-frame configurations and open plumbing and mechanical chases provide prime conduits for cold attic air to enter the heated space. In new construction, these types of through-the-floor gaps are required to be fire-stopped with some form of noncombustible material, typically sheet metal. But fire stopping alone isn't so tight that moisture-laden air can't find its way into the attic. So we seal all the seams between fire stop and flue or chimney with a high-temperature silicone caulk.

Ceiling strapping, a typical framing detail in New England, can create a common air bypass, and a big one at that. The 3/4-inch-wide gap introduced by the strapping between batt-type insulation and a drywall ceiling can allow cold soffit air to travel between the two, effectively short-circuiting the insulating layer (Figure 6). Even in

Unblocked Ceiling Joists

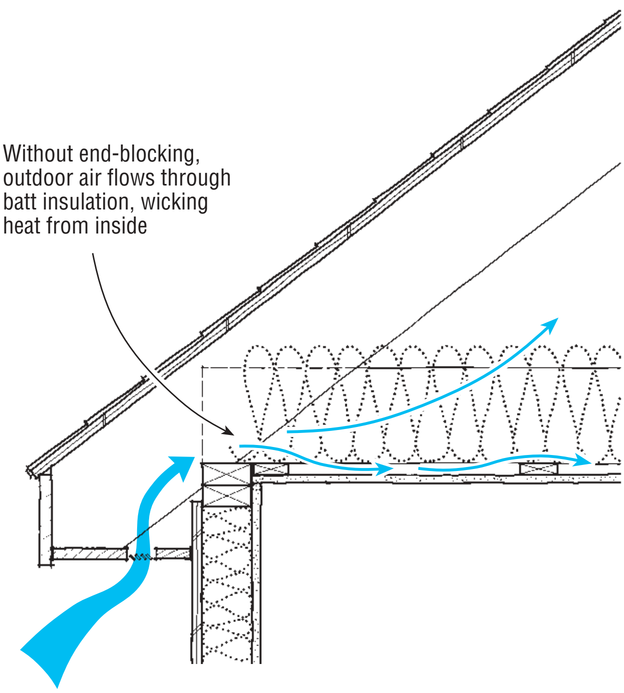

Figure 6. If ceiling bays aren't end-blocked, soffit air can travel below the ceiling insulation and neutralize its function. Piling on more insulation does nothing to correct a cold ceiling complaint (left). Rigid foam blockers, cut to fit around standard insulation baffles, direct ventilation above the ceiling insulation and prevent cold air infiltration (above).

ceiling configurations that aren't strapped, batt insulation is unlikely to lie in absolute contact with the ceiling board and can permit the same kind of infiltration. The result is a cold ceiling and a customer comfort callback. In this situation, adding another layer of insulation to the attic does little but waste money. To reduce soffit air infiltration, we direct incoming air above the insulating layer into the attic, using custom-cut soffit blockers of 1-inch rigid foam board that fit snugly between the ceiling joists or rafters. The top edge of the baffles is contoured to fit a typical foam insulation baffle, and the seams are sealed with expanding foam.

Frozen pipes. Infrared photography can reveal some surprises. The leakiest areas of a building may not be the exterior walls but interior partitions that conceal hidden air pathways to the attic. Ceiling drywall, an otherwise effective air barrier, typically stops short at either side of an interior partition, leaving the top plate exposed to the attic space. Loose-fitting and air-permeable attic insulation can allow cold attic air to flow past the plate into the wall cavity through continuous narrow gaps between the drywall and the framing (Figure 7). A convective air loop results, with cold incoming attic air replacing warm indoor air drawn through electrical outlets and other drywall gaps. More than once, I've responded to seemingly freakish complaints of frozen pipes within an interior partition in a brand-new "well-insulated" home. In new construction, we make sure that all interior and exterior partitions are sealed at the top and bottom plates, using either drywall adhesive or a continuous rubber gasket along both sides. To correct an existing problem wall, we expose the top of the partition in the attic and seal the plate with a layer of expanding foam.

Rafter chutes. In a sloped ceiling design, soffit-to-ridge ventilation is critically important to ensure continuous removal of moisture-laden air that finds its way through the ceiling insulation.

Sealing Interior Partitions

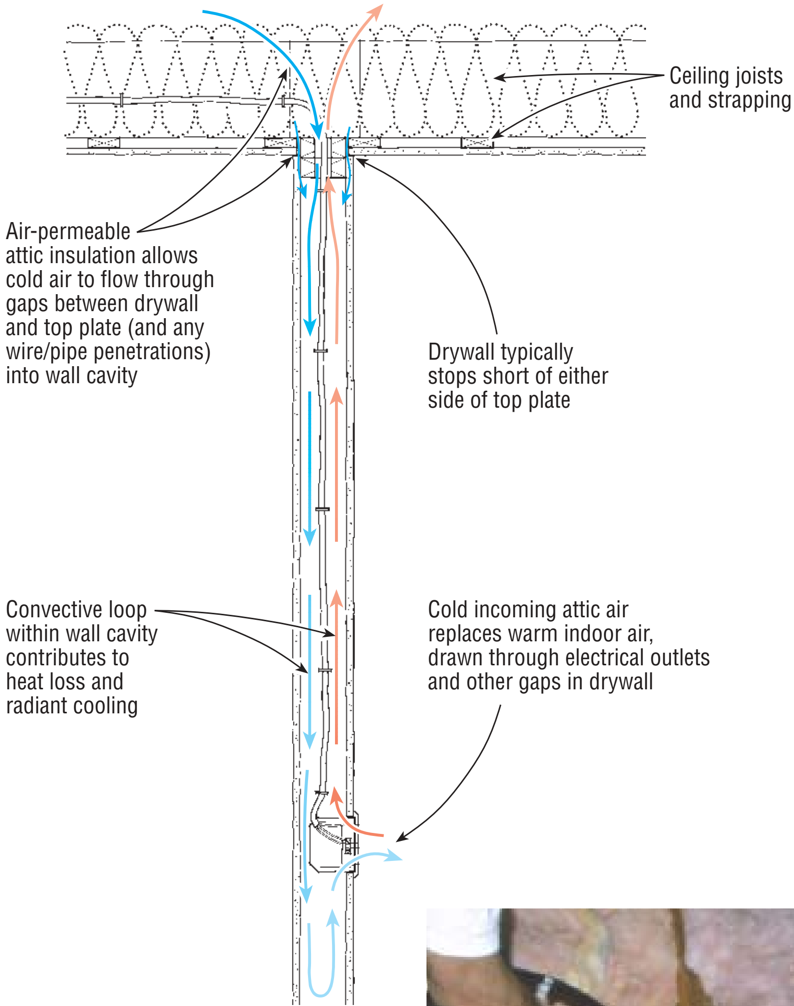

Figure 7. Interior partitions can be leakier than exterior walls, as cold attic air bypasses the top plate through cracks behind drywall and wire or pipe penetrations (drawing, top; photo, left). In remedial work, the author seals the plate with two-part expanding foam to prevent convective looping inside the wall (photo, above).

Figure 8. The author uses full-width vapor-permeable cardboard chutes in cathedral ceilings rather than rigid foam baffles. A bend in the bottom piece allows it to act as a wind stop at the top plate.

We use cardboard "chutes," purchased from insulation wholesalers, rather than the ubiquitous polystyrene insulation baffles, which don't fully cover the underside of a rafter bay or prevent soffit air from moving under and through ceiling insulation (Figure 8). The chute has a smooth, flat face and prekerfed stapling flanges that automatically space the panel an inch away from the sheathing as it's installed. The cardboard is vapor-permeable but durable enough to be permanent. Installation begins at the top plate as a soffit blocker, then transitions to follow the slope of the roof to the ridge vent. I've recently acquired a rapid-firing pneumatic stapler (Kihlberg, www.kihlberg.se) that makes chute installation a breeze.

Dry-Blown Cellulose

Fiberglass batts are widely regarded as the most cost-effective insulation. But it's difficult to properly detail batts around obstacles like wires, plumbing, and electrical boxes and in irregular framing configurations. Chemical smoke testing also shows that fiberglass provides little resistance to air movement. Expanding polyurethane or icynene foams provide good solutions to these problems, but are way more expensive. For us, the answer is cellulose; we've had good results dry-blowing cellulose in both new and retrofit work. Blown-in cellulose effectively fills very small voids and hard-to-access areas at a competitive cost per square foot. Its R-value is 3.5 per inch, and when installed at the proper density of 3.5 pounds per cubic foot, it is highly effective at reducing air infiltration. The fact that cellulose is a recycled product (newspaper) makes it even more appealing to my clients.

Settling not a problem. Complaints that cellulose is prone to settle after installation are based on a common misconception. Voids found in an existing cellulose job are invariably due to faulty installation. If the wall bay isn't filled at the minimum density, or is incompletely filled, voids will occur, regardless of the insulating material. Blown at a minimum density of 3.5 pcf, cellulose is installed at a density greater than its own natural settled density, which eliminates future voids.

Walls First

The best way to blow cellulose in a new home or addition is to treat walls and ceiling separately, at different stages. Flat ceilings are best blown after the drywall has been hung. Drywall provides containment, a built-in air barrier, and unyielding support for a 16-inch-deep layer of cellulose.

For walls, we use a reinforced plastic membrane for containment. In an ordinary wall installation, I use par/PAC (par/PAC, 877/937-3257, www.parpac.com) reinforced poly membrane. The membrane is tacked up, then stretched taut over the edges of each stud and stapled to its inner face. Stapling the membrane like this prevents the cellulose from "migrating" across the stud face when blown, trapping lumps that interfere with drywall installation.

Proper density. The difference between good and poor cellulose installation is about 15 seconds per stud bay and some basic technique. To ensure complete, void-free filling, I use a rigid PVC wand tubing at the end of the

Figure 9. Blowing the wall from the center down, then up, ensures complete filling. A rigid extension wand enables the author to blow to the extremes and gradually withdraw as the cavity fills.

feeder hose. By inserting the wand through a slit in the middle of each stud bay, I first fill from the bottom, withdrawing the wand as the cellulose fills to slit level. I then reverse direction and fill from the top of the bay down (Figure 9, previous page). To blow the cellulose into narrow and hard-to-reach areas, I switch to a smaller-diameter, flexible adapter, made from a length of vinyl tubing. The membrane is designed literally to take a beating. As the bay fills, I vigorously slap the membrane to help condense the cellulose and flatten the face, which otherwise bulges from the fill. With experience, you develop an accurate feel for the proper fill density.

Upgraded wall system. My preference, where the budget allows, is to sheathe the interior wall, using 3/4- or 1-inch-thick foil-faced foam board, after filling the cavity with cellulose. The foam board provides a thermal break over the studs, reducing convective heat loss through the framing. This application virtually guarantees that there are no "cold spots" on the wall where moisture might condense and support mold growth. The foil facing, with all seams and fastener penetrations taped and sealed, creates an effective air barrier that also retards the convective movement of moisture into the wall cavity (Figure 10). To retain the cellulose, I use a less costly, vapor-permeable membrane such as 100% polypropylene InsulWeb (Hanes Industries, 828/464-4673, www.hanesindustries.com) or MemBrain (CertainTeed, 800/233-8990, www.certainteed.com), a polyamide film whose permeability changes with ambient humidity conditions. Both products claim to avoid the potential moisture-trapping problems of conventional vapor retarders.

Ceiling Insulation

On sloped ceilings, we nail up 1-inch-thick foil-faced foam board but leave a narrow "window" near the middle of each slope for blowing access (Figure 11). Before installing the board, we cover the window area with a strip of containment membrane; elsewhere, the board holds the cellulose in place. After we blow the rafter cavities, the window is closed with foam board. All the seams and fastener penetrations are then sealed with housewrap tape.

Intricate or hard-to-reach framing transitions like tray ceiling perimeters, floors behind cathedral knee walls, and cantilevered rim joists are difficult to properly seal and insulate. We've had good success using a two-component polyurethane foam marketed as Zerodraft (Canam, 877/272-2626, www.zerodraft.com), especially in remedial applications where initial air sealing was never properly done. The two-component pressurized system is a rapid-high-expansion foam, packaged with a 30-foot hose and applicator, with a 600-board-foot coverage capacity. The foam cures in 45 seconds and makes it simple to seal otherwise challenging configurations in short order (Figure 12, next page). At around $400 per pack, it's too expensive to use as the primary insulation, but it's unbeatable for tricky areas and sealing leaks. I typically get about four average houses out of a pack.

Mechanical Ventilation

Tight houses require ventilation to avoid problems with indoor air quality, condensation, and mold. Quantifying how much fresh air is neededis a nearly impossible as well as somewhat subjective task. The ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standard recommends .35 ACH, or a complete

Figure 10. Foam board applied to the interior face of the exterior walls breaks thermal bridging through the studs and provides and effective air and vapor retarder.

Figure 11. A narrow access strip in the middle of a cathedral ceiling insulated with rigid foam allows the author to view the bays as he fills them.

Figure 12. Two-component expanding foam seals and insulates in one step, making it an ideal solution for awkward configurations like this overhanging second-floor rim joist.

Figure 13. The author often installs a remote-mounted inline fan (above) to provide ventilation for one or more bathrooms, as well as for the whole house. A programmable control is set to provide the correct flow based on the number of occupants and the house's infiltration rate. The author verifies the fan's rated capacity with a flow meter (right).

replacement of indoor air every three hours. Another standard states that for each occupant, you need 15 cubic feet of air change per hour. This provides a decent working rule of thumb for determining exhaust ventilation rates. But because natural ventilation rates vary widely with wind pressure and differences between outdoor and indoor temperatures, mechanically assisted ventilation is essential to ensure a continuous rate of ventilation under all conditions. And, because the number of occupants and their activities also vary, the ventilation system itself should be variable. But that doesn't mean it has to be complicated.

I always install quiet high-efficiency fans in the bathrooms or a remote-mount inline fan to provide whole-house exhaust ventilation (Figure 13). There are many such fans available from a number of manufacturers, including Aldes, Fantech, and Panasonic. I typically install an Airetrak microprocessor control system (Tamarack Technologies, 800/222-5932, www.tamtech.com) to operate the fan. The programmable control operates the fan at a constant low speed, moving the air at, say, 75 cfm for a family of five (5 x 15 cfm = 75 cfm). But if one of the occupants takes a shower or wants a momentary higher rate of ventilation, pressing a "boost" button runs the fan at higher velocity for a preset interval of 20 minutes or a longer programmable period. As an option for clients who want a more hands-off system, I'll install Tamarack's Humitrak control in the bathroom. This automatically boosts the fan speed as the humidity level rises. The manual boost option is still available. Finally, to make sure the fan is performing at its intended capacity, I verify its operation with a flow meter.

When I have a client who places a high priority on ventilation control and energy efficiency, we'll install a heat recovery ventilation (HRV) system.

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