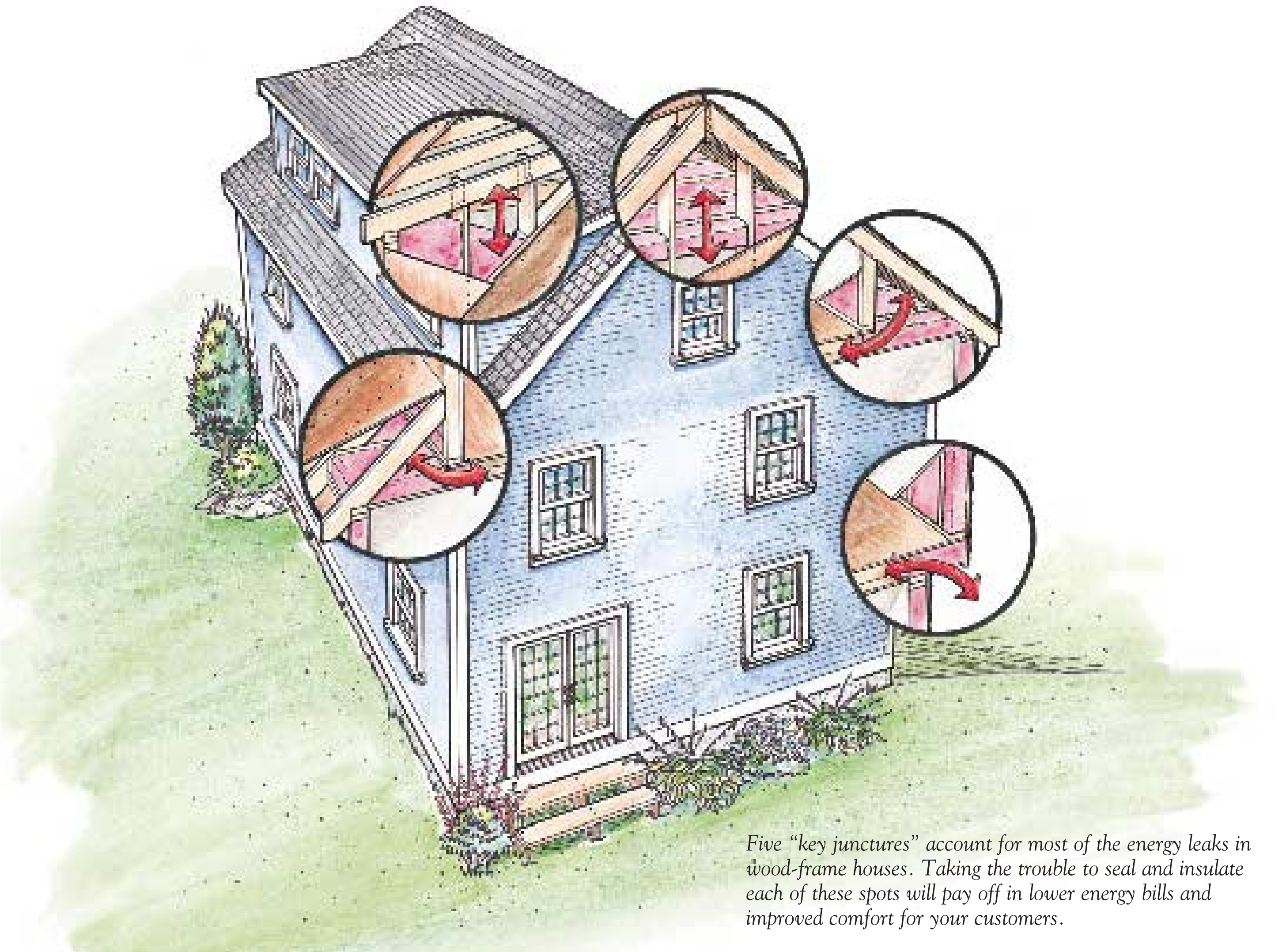
AIR-SEALING THE STORY-AND-A-HALF

BY DAVID LEGG

For increased energy-efficiency in a wood-frame house, plug air leaks at overhangs, knee walls, and gable ends



Five "key junctures" account for most of the energy leaks in wood-frame houses. Taking the trouble to seal and insulate each of these spots will pay off in lower energy bills and improved comfort for your customers.

For years, I was a technical supervisor at Mass Save, a Massachusetts-based energy services company. I trained crews and provided technical supervision of energy retrofit work done on thousands of New England homes. I've seen lots of houses built in the '80s and '90s, framed and insulated according to the codes, whose occupants could barely pay the heating bills. Over time, we learned that one of the toughest styles of houses to insulate and seal is, surprisingly, one that is visually very simple — the cape. The architectural details that make cape homes popular and attractive — the cozy upstairs rooms with knee walls, the affordable "expansion" shed dormers — can also make them big energy losers. Another style that creates problems is the Colonial with an overhanging upper story.

Using blower doors, infrared imaging cameras, and pressure gauges, weatherizers have identified the main structural areas in wood-frame homes that cause heat to bleed away. We call these critical framing points the "key junctures" in a house. Over the years, we've learned to cut energy losses in existing homes by attacking these key junctures in order of importance. The bulk of energy savings is often achieved by plugging a few big leaks.

Knee Walls

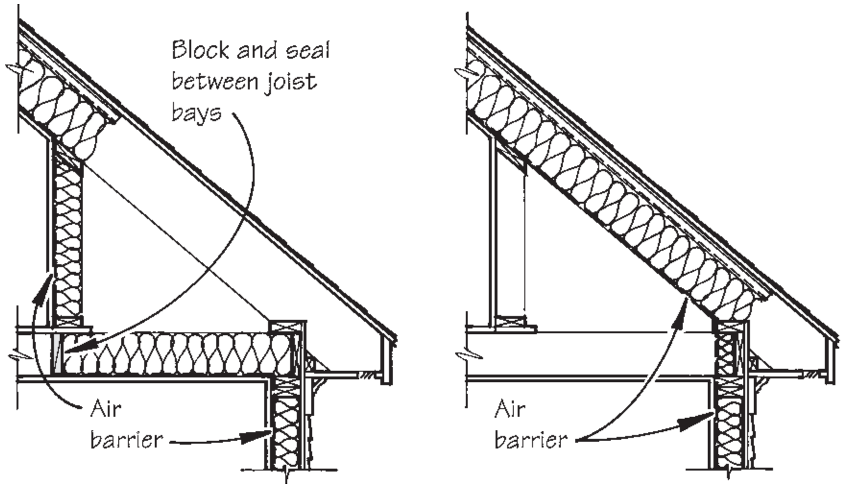


Figure 1. *When building knee walls, make sure that you place an effective air barrier on the warm side of the insulation. When the thermal boundary follows the knee wall — a tricky detail to get right — it's especially important to install an air block between the joists directly below the knee wall (left). The author prefers to insulate between the rafters all the way to the outside walls, then install a continuous air barrier on the inside face of the rafters (right).*

Unfortunately, however, the big leaks aren't always accessible. That's why it's most cost-effective to seal up a frame house while you're building it, rather than coming back later to crawl around under the eaves plugging leaks.

The Five Key Junctures

Five main framing details cause most of the energy problems in wood-frame houses (see previous page):

- floor-knee wall transitions
- eyebrow roofs
- cantilevered floors
- balloon-framed gable ends
- balloon-framed shed dormers

Unless these five areas are carefully sealed and insulated, the building will have one of two problems, and probably both. In the simplest cases, heated air will escape from the house completely, with cold makeup air finding its way in somewhere else. But often, even when house air can't actually leave the building, convection currents will move air around or through insulation, so that either cold air contacts a warm surface or warm air contacts a cold surface. The result is often not only heat loss, but condensation on roof or wall sheathing, which can lead to mildew and rot.

1. Floor-Knee Wall Transitions

Knee walls can cause big energy losses, even in a tight house. Usually, the problem is that the insulation (thermal boundary) and the air barrier (sometimes called the "pressure boundary") are not located in the same place. The key to insulating this area successfully is to make sure that there is a continuous thermal boundary *and* a continuous air barrier, and that both are in the same place.

There are two common ways to insulate the knee wall area. Some builders install fiberglass batts in the crawlspace floor, in the knee wall, and in the ceiling rafter bays. This creates a thermal boundary in the floor and the wall. Others simply install batts between the rafters all the way down to the exterior wall top plates. In the latter case, the thermal boundary follows the roof.

But either way you do it, you must make sure that the air barrier will follow the insulation (Figure 1). If you install the insulation in the floor and the knee wall, you must also install a continuous poly air barrier on the inside face of the knee wall, and on the ceiling below the insulation. In addition, you have to block air movement through the joist bays by installing solid wood blocking, waxed cardboard, or rigid foam, then caulking or foaming the joints.

If you choose to install your insulation in the rafter bays, you need to put the air barrier on the bottom side of the rafters, facing the heated space. A continuous poly barrier is fine, but it should be sealed to the framing at the bottom with tape. In retrofits, we usually attach 4x8-foot sheets of rigid foil-faced foam insulation to the rafters, sealing the edges and joints with expanding foam (Figure 2).

Often, builders staple Kraft-faced fiberglass batts up to the rafters inside the knee wall crawlspace. If you then cover the insulation with drywall and seal the edges, that can make an effective air barrier. But Kraft-faced insulation by itself, with nothing covering it, is ineffective as an air barrier. I recall one particularly bad case of a cape house with Kraft-faced insulation between the rafters. The occupants were extremely uncomfortable because the air was always very dry in the winter, despite a humidifier that ran constantly. The humidified air easily bypassed the insulation batts in the knee wall area, and the moisture condensed on the underside of the roof sheathing. That house was very expensive to heat, very uncomfortable, and the roof sheathing was a fungal jungle. But curiously, it had a pretty low blower-door reading because it was a reasonably tight house. The problem was that the effective air barrier formed by the roof sheathing was on the cold side of the insulation. To prevent condensation and heat loss, the air barrier has to be continuous and be on the warm face of the insulation.

The most common mistake builders make is not providing an air barrier between the joists below a knee wall. Fiberglass batts between the joists, by themselves, will not stop air movement. Without an air barrier, warm air in the joist bays between the first and second stories will flow through the fiberglass into the cold crawlspace, contacting the roof sheathing or even making its way into the attic and outside. If the first-floor ceilings are strapped for drywall, which they often are, the strapping provides a further channel for airflow, and effectively connects just about every framing void in the building to the attic.

Figure 3 shows an effective air barrier and insulation combination for the knee wall-floor area in a new cape. The poly air barrier on the outside walls continues up onto the ceiling of the first floor. The plastic is taped to rigid foil-faced foam insulation installed between the floor joists. The joist cavities are insulated with R-30 fiberglass batts. When insulation and a poly air barrier are installed in the knee wall

Figure 2. *In existing structures, foil-faced foam provides an effective air barrier behind knee walls. Here, spray foam seals the gaps left where the foam board has been installed over unfaced batts between the rafters.*

Figure 3. *In new construction, rigid foam can easily provide an air block below an upper-story knee wall. Gaps are sealed with spray foam and the ceiling air/vapor barrier taped to the foil face of the foam board.*

directly above, there will be a continuous pressure and thermal boundary between the heated space and the cold space, ensuring a snug house.

2. Eyebrow Roofs

Depending on how they are framed, these small decorative roofs, usually attached to shed dormers, can cause significant problems. In retrofits, we've often found that sealing up the floor-knee wall transition on one side of the house has no effect until major leaks in the eyebrow roof area are plugged.

I often see eyebrow roofs that have no insulation at all — I suppose because the builders don't think they're important. But if air from the house can get into the small eaves area, it is often able to move along to the end of the building and flow up the gable-end rafter cavities into the attic. That kind of large leak is quite costly.

In retrofits, we try to find a way to pack the whole eyebrow roof space with dense-blown cellulose. (To provide an air barrier, cellulose has to be installed at a density of 3.5 pounds per cubic foot. This requires a powerful blower in good working order.) How we gain access to the space depends upon the framing details. Usually we have to drill a hole for the blower hose through either the soffit or the roof sheathing, then patch and seal the hole.

In new construction, it's important to concentrate on stopping the airflow. It helps to sheathe the wall before you frame the eyebrow roof, attaching the small rafters to a ledger board nailed over the sheathing (Figure 4). If you frame the eyebrow roof by nailing small rafter-tail pieces onto the sides of second-floor wall studs, it will be hard to seal and insulate the area — you'll create a lot of small, irregular voids.

3. Cantilevered Floors

Many Colonial-style houses have a section of second floor cantilevered over the first-story wall. Without proper attention, this area can lose a lot of heat.

Typically, insulators jam a fiberglass batt into the space between the joists where it extends past the wall (that is, if they insulate it at all). Often it's an

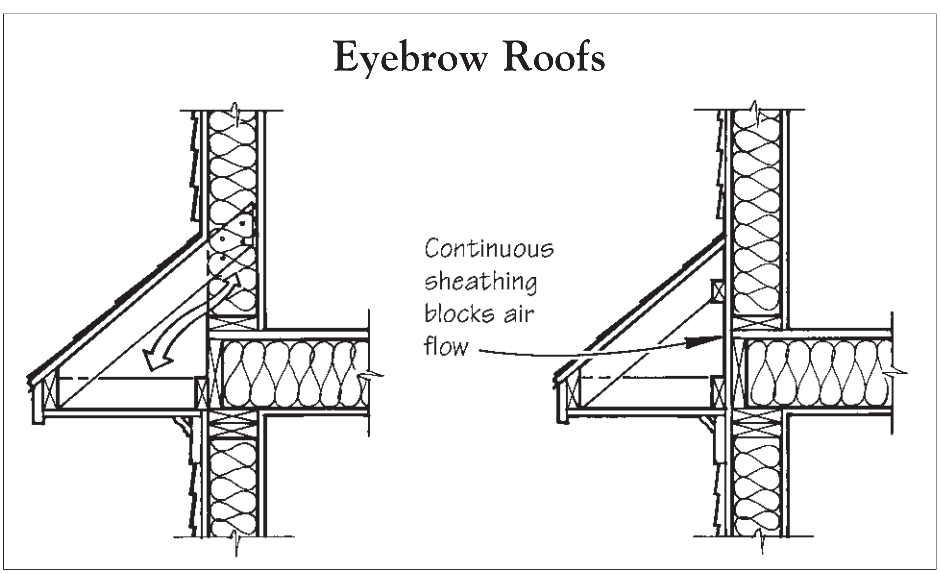


Figure 4. *Eyebrow roofs, if built wrong (left), can allow cold air to penetrate exterior walls and leak out the ends of the building. When building an eyebrow roof on a shed dormer, sheathe the exterior wall first, then attach the rafter tails to a ledger (right).*

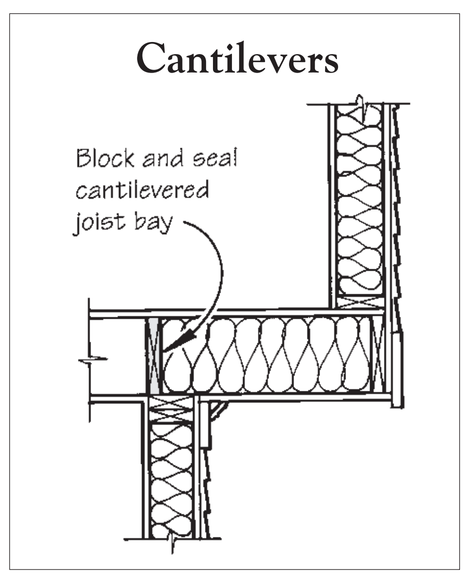


Figure 5. *Cantilevers can cause convective heat loss unless an air block is added in the joist bay above the first-story top plate.*

Balloon-Framed Gables

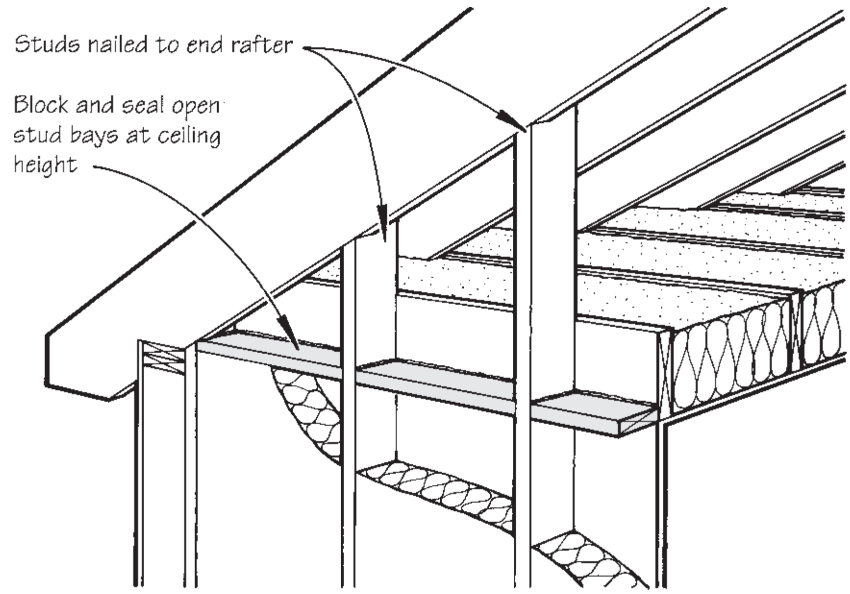


Figure 6. *Balloon-framed exterior walls should always be blocked to prevent convective air movement into the attic.*

R-19 batt that doesn't completely fill the space, so that air movement is not impeded at all. Even if it's a bigger batt and it's carefully installed, fiberglass is still not a good air barrier, and convection currents will bring warm air from between the floors in contact with the building's skin.

To compound the problem, baseboard heating units in second-floor rooms are often directly above this cold between-floor space. We can observe the continuous energy loss from a setup like that from either inside or outside the house with an infrared scanner.

During construction, you can treat cantilevered floors like the floor-knee wall transition, but the vapor barrier goes on the subfloor of the second floor rather than on the ceiling of the first (Figure 5, previous page). Where the poly air barrier on the wall meets the floor, tape the plastic to the plywood. Then seal all the seams in the plywood subfloor with tape or caulk — that way, the plywood will function as an effective air barrier on the warm side of the insulation. Between the cantilevered floor joists, fill the voids completely with fiberglass or cellulose insulation, then install rigid foil-faced foam insulation in the bays where the joists bear on the first-floor wall and seal the edges where the foam meets the framing with caulk or foam. Tape the joint where the poly on the first-floor wall face meets the foam between the joists.

Figure 7. *It's much easier to seal balloon-framed stud bays during framing than to have to do it later. Here, a weatherization worker foams a cardboard baffle into place where a gable-end stud bay passes into the attic.*

4. Balloon-Framed Gable Ends

Often, builders frame gable ends by nailing end-wall studs directly to the end rafter, or to a plate attached to that rafter (Figure 6). The end ceiling joist is then nailed to the gable-wall studs. This means that there is no top plate at ceiling height, and air can move freely between the stud cavity and the attic space.

Sometimes heated air enters the wall through a penetration, like an electrical outlet or even a crack around the baseboard and drywall at the bottom of the wall. The warm air rises in the stud cavity like smoke in a chimney, escaping into the cold attic and exiting through the roof vents. But even where there is no penetration in the wall, cold air from the attic will drop into the stud cavity, where it is warmed by the wall and rises back into the attic. This kind of convection loop carries heat out of the house.

Fiberglass insulation works well as long as the stud cavities are sealed. In retrofits, we crawl into the attic and seal the top of stud bays with waxed cardboard, stapled in place and sealed with a bead of expanding foam (Figure 7).

In new construction, you should block off the top of open stud bays at ceiling height with cardboard, rigid foam, 2-by blocking, or spray foam. Seal the blocking with caulk or expanding foam. Another option is to insulate the wall with dense-blown cellulose.

5. Balloon-Framed Shed Dormers

Shed dormers on many capes are framed like the gable ends, with the sidewall studs attached directly to the rafters, so that open stud bays run past the ceiling, and air can pass freely into the attic. These walls lose heat the same way the gable walls do: Either hot air enters wall penetrations and escapes into the attic, or convection currents carry heat away. The solution is the same as in the gable ends: Close off the tops of the stud cavities, or use an insulating material that is also an air barrier, such as dense-blown cellulose. The simplest option, of course, is to frame dormer sidewalls with top plates in the first place. ■

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