INSULATION
AIR SEALING

Sealing potential leaks in the building envelope is an essential step in building a durable, energy-efficient structure. It's easy to focus on insulation, but without careful air-sealing, insulation is all but useless.

OVERVIEW

Air barriers must work together to provide a continuous and complete enclosure of the building envelope—floors, walls and roof. Every subcontractor and installer on the job should understand the importance of maintaining the air barrier. A few holes carelessly drilled in the wrong places can undo the work of many other people.

Passive House air-sealing standards. There are now two Passive House standards – one that originated in Germany, and the other a U.S. offshoot set by the Passive House Institute U.S. (PHIUS) Both have rigorous air-sealing requirements, but the climate-specific PHIUS standard is probably a little more forgiving.

Pretty good air sealing. If you're not going that distance, consider shooting for a blower-door result of between 1 and 2 air changes per hour at 50 pascals of pressure (ach50). Under the 2012 International Energy Conservation Code, blower-door testing is mandatory:

- in Climate Zones 3 to 8, houses must test at 3 ach50 or lower
- in Climate Zones 1 and 2, houses must test at 5 ach50 or lower

See also the EERE Air Leakage Guide.

AIR-SEALING MATERIALS

A variety of materials may be used to form an air barrier, including lumber, drywall, plywood, special membranes, tapes, caulks, and spray foam. What's important is how these materials are applied, and how they are integrated with each.

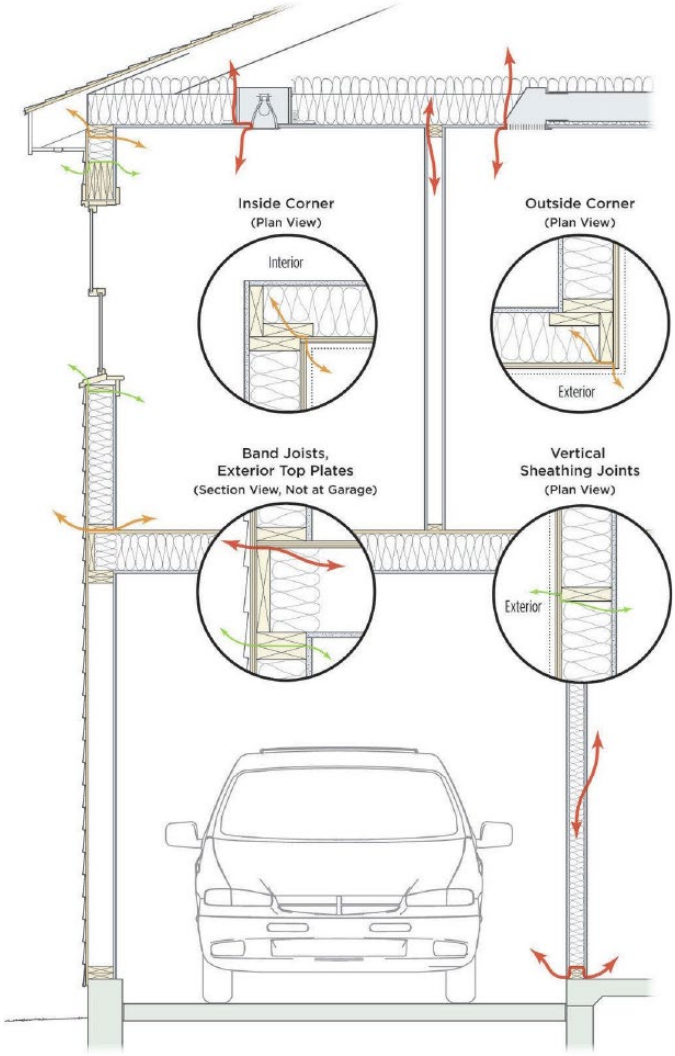
Here's a summary of the major groups of materials that can be used:

- **Sealant tapes.** High-quality tapes, such as those made by Siga, 3M and others, can form a tenacious bond and remain flexible over long periods of time. Tapes are more effective at creating a continuous seal at doors and windows than a canned foam sealant, which cures rigid and the seal may be broken when wood shrinks. It is also all-too-easy to apply with gaps and voids that will leak.
- **Membranes.** Housewrap, plastic sheeting, and specialized products such as Pro Clima DB+ all are examples of air barriers that come on a roll and are applied beneath concrete slabs, and in wall and roof assemblies. Some are vapor permeable and some aren't, so they aren't interchangeable. Where they are used depends on their particular properties.
- **Liquid-applied sealants.** Some are applied with a roller, others with a sprayer. They are especially effective at filling irregular gaps.
- **Sheet goods.** Drywall and plywood can become part of the air barrier. Joints between panels must be sealed. Some products, such as Huber's ZipSystem sheathing, come with sealing tape. OSB may or may not be an effective air sealing material, and should be avoided if aiming for a rigorous standard.

- **Caulk.** A number of readily available caulks make excellent air seals around penetrations for wires and pipes. Caulk is more durable than foam sealant when a wire or pipe is likely to be flexed or moved, although it must cure completely before being stressed in order to maintain its bond.
- **Spray foam insulation.** Both open-cell and closed-cell spray polyurethane foam can make an effective air barrier. One advantage of foam is that it fills gaps and seals leak in irregularly shaped and hard-to-reach places, such as the area around a band joist.
- **Canned foam.** Although some builders doubt its long-term effectiveness, foam sealant in a can is often used to seal windows and doors in place, and to fill gaps around pipes and wires.

COMMON AIR LEAKS

Just about any part of the building envelope will leak if given the chance, but the places where leaks are most likely to occur are where one material or part of the assembly meets another.



Tim Healey

The arrows represent common air leaks in a building, and their colors correspond to data in the chart at far right. Note that the leaks at the window represent those between the sheathing and the framing around windows (and doors). They are not those between the window unit and the rough opening. (It is assumed these gaps will be air-sealed without question.)

BASEMENTS AND BAND JOISTS

The area around the band joist has lots of potential for leaks because so many different materials come together here—the foundation wall, the mudsill, and wall and floor sheathing. The slab and the connection between foundation walls and slab also are potential leaky spots. Windows set in foundation walls are notoriously leaky.

FRAMED WALLS

Gaps between sheathing panels, and the spaces between door and window jambs and the rough openings are typical places for air leaks. Pay particular attention to where exterior walls meet the foundation and the top plate. These are both spots where dissimilar materials meet and where barriers from one plane to another must be joined together.

Any through-the-wall penetrations also are a common source of leaks. This can include gaps around electrical service entrances, water and drain lines, vent hoods and any other spot where the barrier is breached.

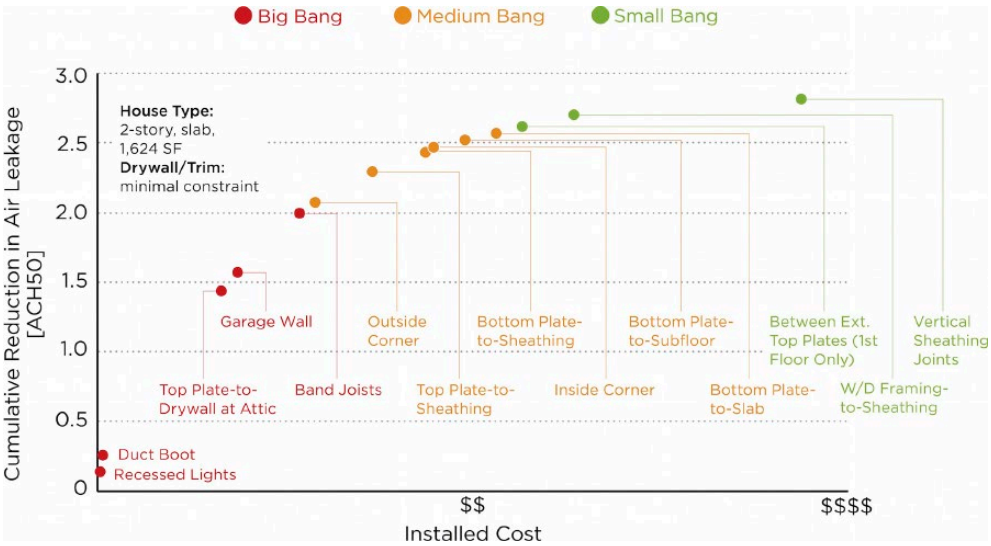
CEILINGS AND ATTICS

Ceilings are full of opportunities for air leaks, not only around the perimeter, where ceilings meet walls, but also via the many penetrations that are common in the ceiling. They include recessed light fixtures, electrical and plumbing chases, gaps around chimneys, and holes for wiring, pipes and ductwork.

AIR-SEALING PRIORITIES

What to tackle first? Tests at the Owens-Corning research facility provide a good idea of where you will get the biggest bang for your air-sealing buck.

BANG FOR YOUR AIR-SEALING BUCK



Air leaks are ranked on the basis of CFM50 reduction for the amount of effort required, and the amount of material needed, to complete each air-sealing task. Owens-Corning grouped the results in three categories: those that provide a "big bang for a builder's air-sealing buck" (red); those that provide a "medium bang" (orange); and, as the return tapers off, those that provide only a "small bang" (green). Certain leaks — like vertical sheathing joints and the sheathing joints around windows and doors — require a lot of sealant for only a modest reduction in airflow, which is why they are "small bang" leaks.

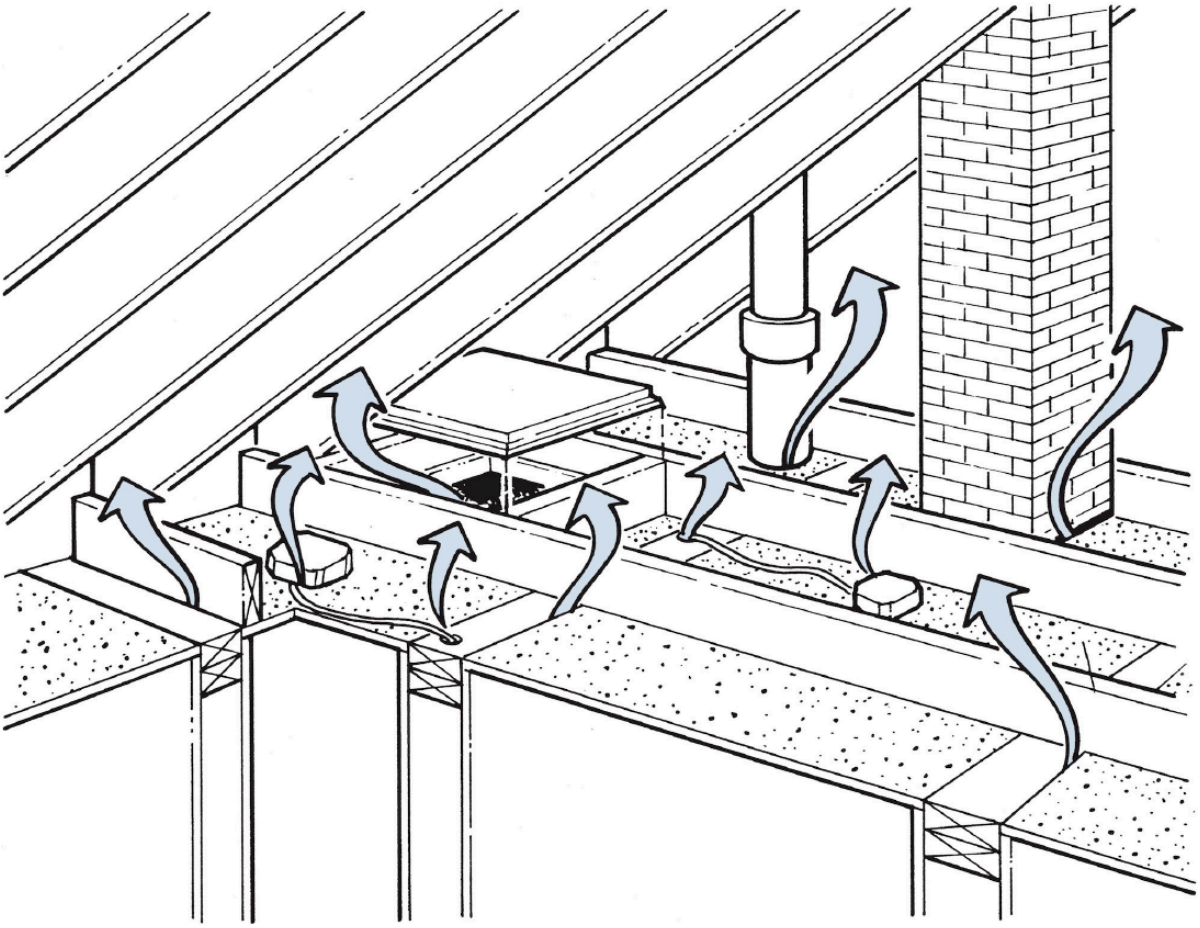
These guidelines should be a starting point. Keep in mind the Owens-Corning research applies to a relatively small, two-story house on a slab, and results may not translate to every other house type or size. Other potential leaks that weren't specifically studied, such as rough-in mechanical penetrations through interior wall plates, aren't covered.

AIR-SEALING ATTICS

The ceiling plane between the conditioned space and the attic is typically a large area, and there's a big payoff in beefing up the insulation and sealing air leaks here simply because there's so much real estate.

All of the penetrations for wires, ducts, and pipes must be sealed with caulk, foam, or building tape.

COMMON ATTIC LEAKS

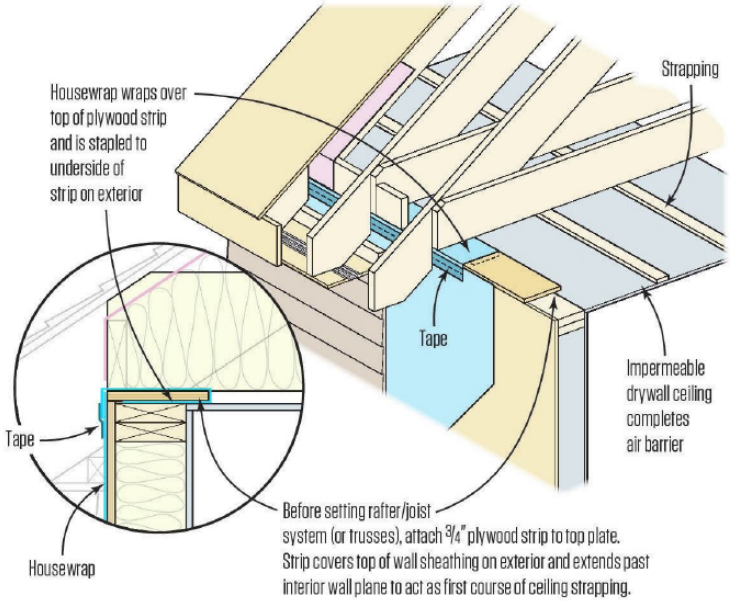


Recessed light fixtures and duct boots are often big offenders (see **Air-Sealing Priorities** above). If the light fixtures will be used in a **cathedral ceiling**, read that section below.

You can reduce leaks around light fixtures by making a box from foil-faced rigid foam insulation and sealing it in place with expanding foam. Seal around the electrical feeds and the mounting brackets with expanding foam.

In new construction, an effective strategy for sealing the ceiling is to bring the housewrap on exterior walls up and over a strip of 3/4-in. plywood attached to the top plate.

WALLS TO CEILING



Tim Healey

The top of the sidewall is a notorious place for air leaks. Connecting the interior ceiling plane to the sidewall can solve lots of problems.

Apply a continuous layer of drywall before interior walls are built, and apply a strip of sealing tape to the outside of the wall as shown. The advantage here is that the potential leaks where the ceiling meets the top plates of each room are eliminated.

Another approach is to seal the perimeter of the ceiling with expanding spray foam after the ceiling panels have been hung but before the wall panels have been installed. This will make a more reliable seal than paper drywall tape and joint compound.

Foam sealant can be sprayed over gaps around light fixtures, fan boxes and duct boots.

Foam sealant can't be used, however, around chimneys, where leaks can be significant. Instead, use sheet metal sealed with a high-temperature caulk that meets the ASTM 136 standard.

SLIDESHOW: AIR-SEALING RETROFIT FOR A CHIMNEY CHASE

Ted Cushman/JLC

Weatherization tech Scott Pillips air-seals a framing joint with gun foam before starting to install air-sealed metal flashing over the gap between the brick chimney and the wood-framed chimney chase.

Ted Cushman/JLC

Phillips measures the length of the chimney chase opening.

Ted Cushman/JLC

Cutting a piece of coasted aluminum coil stock flashing to length.

Ted Cushman/JLC

Phillips trims a piece of flashing to width using Cutco hardened steel shears.

Ted Cushman/JLC

Phillips displays his Cutco Su per Shears. "I can cut anything with these," he says. "I can cut a penny in half. They're like 85 dollars."

Ted Cushman/JLC

Phillips snips a corner off the strip of flashing to create room for a cable that leads out of the chimney chase into the attic.

Ted Cushman/JLC

To protect data cabling from damage from the sharp edges of the cut flashing, Phillips bends scraps of flashing over the cut edges at locations where the flashing may touch the wires.

Ted Cushman/JLC

Working at close quaters, Phillips wiggles a piece of metal flashing into place at the opening where the brick chimney penetrates the ceiling framing. With the roof sheathing removed and the ceiling exposed from above, according to Phillips, this is a relatively easy situation: often, the chimney-to-framing gap is less accessible.

Ted Cushman/JLC

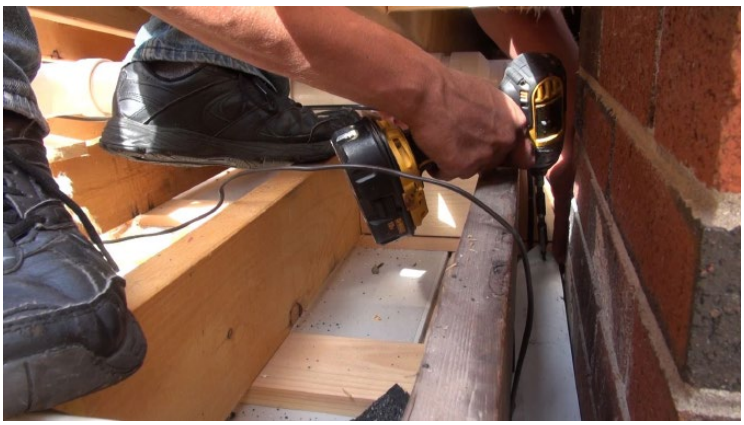
Working by feel as much as by sight, Phillips eases a strip of metal flashing into place between the chimney and the framing.

Ted Cushman/JLC

After noting the location of some data cable by feel, Phillips bends a piece of metal around the sharp edge of the flashing in order to protect the wire insulation from damage.

Ted Cushman/JLC

Phillips works the metal into position in the small gap.



Ted Cushman/JLC

Phillips screws the metal flashing down onto the chimney chase framing.

Ted Cushman/JLC

Phillips applies high-temperature sealant caulk to the underside of a piece of flashing before setting the flashing in place. To achieve a good seal, caulking is installed between the metal and the wood framing, as well as at the joint between the metal and the brick chimney.

Ted Cushman/JLC

Phillips sets another screw to fasten the metal flashing securely to the ceiling framing.

Ted Cushman/JLC

Field expedient: to extend his driver bit to the length required to reach the awkward location, Phillips attaches several magnetized bit holders together and secures them with a temporary wrap of aluminum foil.

Ted Cushman/JLC

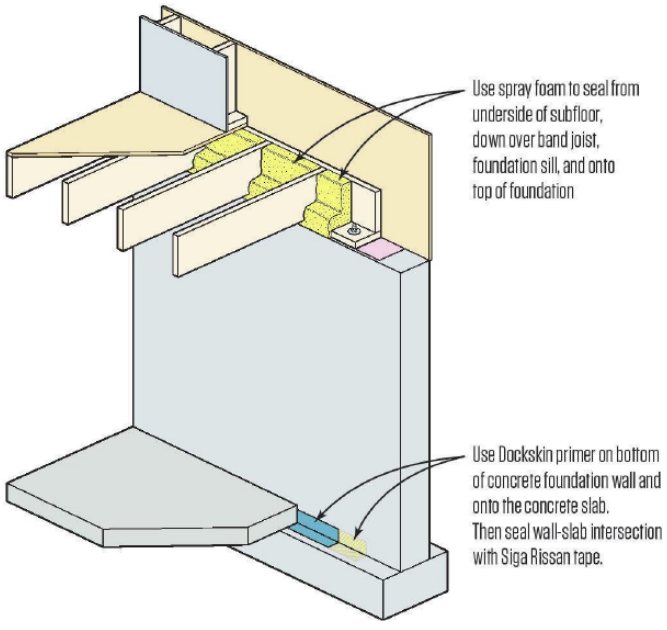
Once all the flashing has been screwed into position, Phillips caulks the joints between the flashing and the brick chimney with high-temperature sealant.

AIR-SEALING FOUNDATIONS AND CRAWLSPACES

Slabs. The air barrier should begin beneath the slab with a product such as Stego Wrap, a vapor and radon barrier as well as a hedge against air leaks.

Poured concrete foundations are relatively airtight by themselves. However, the joint between the wall and the footing, and between the footing and the slab, are potential leaks and should be sealed.

AIR-SEALING RETROFIT FOR A CHIMNEY CHASE



Tim Healey

A concrete foundation is air impermeable, but on the interior, you must air-seal where the foundation meets the framing and where the foundation and slab meet.

Block foundations (CMU walls) can be leaky. They need to be sealed with a coat of plaster or a fluid-applied air barrier. Basement windows also are known for air leaks. If they're not essential for egress, try to avoid them in the first place.

Vented crawlspaces. Crawlspaces have traditionally been vented to the outside and left as unconditioned space. In this case, the floor between the crawlspace and the conditioned interior becomes the location for the air and thermal barriers. This floor assembly can be sealed with a combination of rigid foam insulation applied to the bottom of the joists, taped at the seams and foamed at the perimeter. The rim joist area can be sealed with open- or closed-cell foam.

Another option for sealing the rim joist area suggested by Energy Star's Thermal Bypass Checklist (PDF) is to install a small structural insulated panel in place of conventional 2x material. The SIP acts as both an air and thermal barrier.

Conditioned crawlspaces. Increasingly, crawlspaces are treated as conditioned space. In this case, outside walls are insulated with rigid foam in an amount appropriate for the climate zone. Panels should be taped at the seams, and the band joist area sealed with spray foam. The foam should be lapped over the top edge of the rigid insulation to create the seal.

SLIDESHOW: SEALING A CRAWLSPACE

Workers from Energy One America start to lay a ten-mil poly ground cover in the crawlspace of a new house on Daniel Island in Charleston, South Carolina.

Air-Sealing Foundations and Crawlspaces

The installer fastens the poly to the block wall with pneumatic-driven nails and metal washers.

Seams in the poly ground cover are sealed with tenacious vapor-barrier tape. Gun foam fills the gap between the poly and the concrete block in this picture; for air-tightness and vapor control, the crew installs a bead of the expanding adhesive foam at the top seam where the poly meets the block wall around the entire perimeter of the crawlspace.

Penetrations where plumbing passes through the ground vapor barrier receive particular attention. This joint will be thoroughly sealed with vapor-tight tape.

Air-Sealing Foundations and Crawlspaces

Air-driven masonry nails and metal disks hold the poly ground cover to the concrete block walls at the perimeter. The crew seals the joint between the poly and the masonry using adhesive foam sealant.

A crew member installs a poly-faced fiberglass insulation blanket around the block wall perimeter of the crawlspace.

A crew member fastens the fiberglass insulation blanket to the block wall using gun-driven masonry nails with metal disk washers. The space between the top of the insulation blanket and the framing above is required by code, to allow inspection for termite tubes. Termites are a significant risk in coastal South Carolina.

Energy One America operations manager Seth Harris points out surface mildew on the floor trusses in a new house during a crawlspace sealing and conditioning job. In the South Carolina climate, mold tends to grow quickly, even in a very well-ventilated crawlspace — a strong reason to prefer a sealed, conditioned crawl. (Atmospheric humidity, not wood moisture content, is the culprit: Harris measured the moisture content of the trusses at only 16%.) Once this crawlspace is airtight and vapor-tight, and with mechanical dehumidification operating, Energy One will return to scrub away the mildew with a sanitizing cleanser. Given dry conditions, the problem should not re-occur.

AIR-SEALING WINDOWS

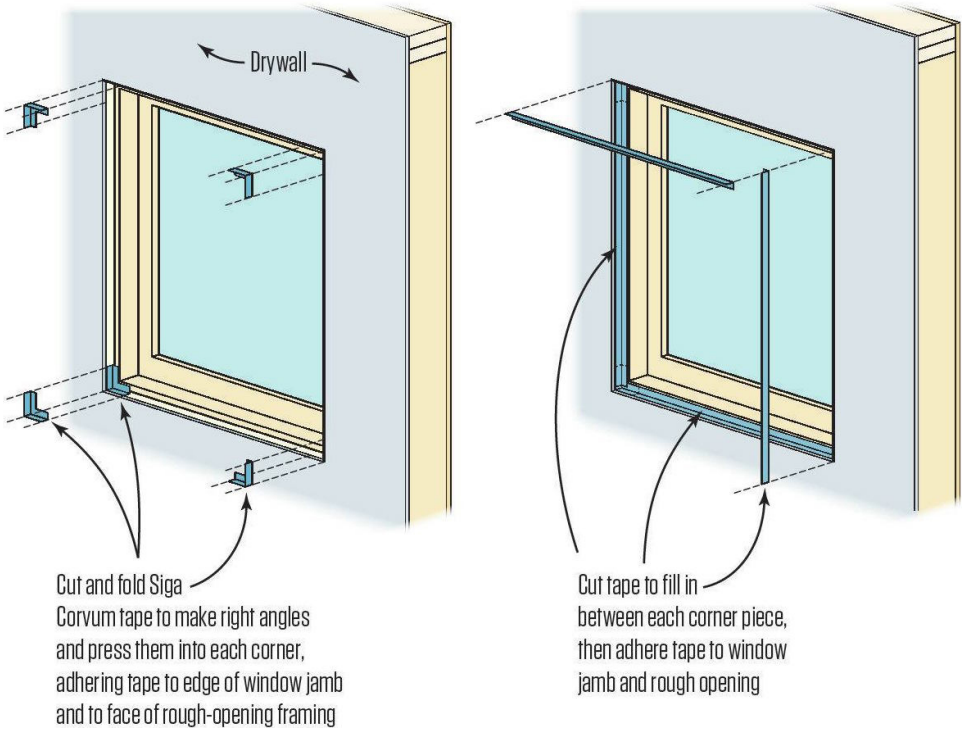
Windows are part of a building's air barrier, and they must be connected to other components of the air barrier in order to keep air leaks to a minimum.

The Building America program recommends applying the air seal between the window unit and the rough opening toward the interior edge of the window frame. This creates the least interference with drainage. And this way, the seal is pressure equalized with the outdoors, so there's no air pressure difference to push moisture into the joint.

The window should be sealed into the rough opening with an impermeable material—fiberglass insulation stuffed into the crack is not an effective air barrier.

Air barrier tape, caulk (used in conjunction with backer rod for large gaps), and low-expansion foam sealant all are materials that can be used.

AIR-SEALING WINDOWS AND DOORS

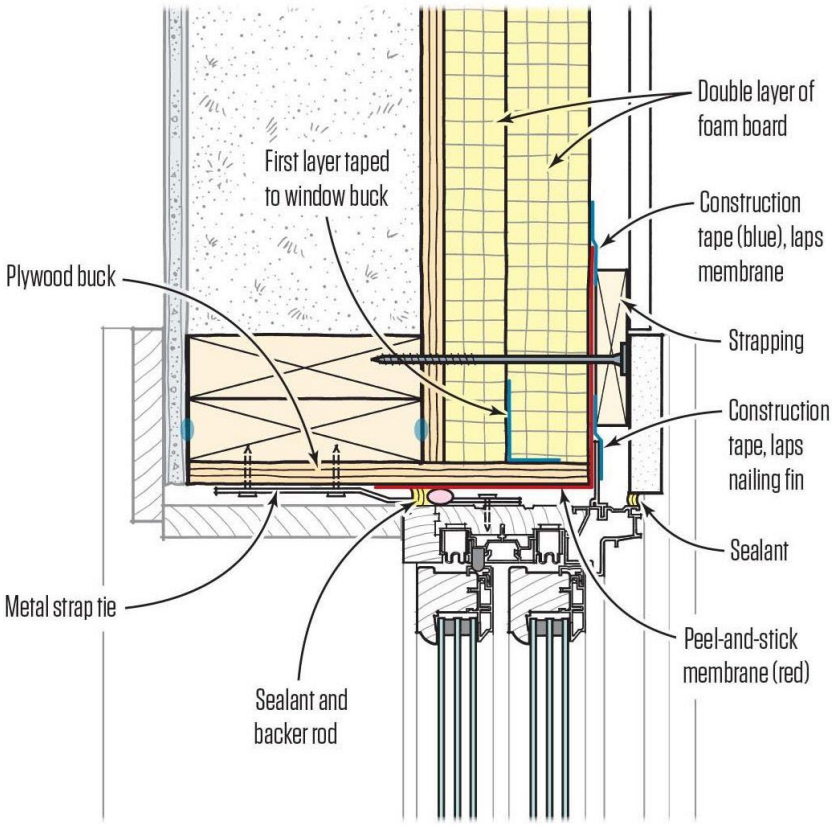


Tim Healey

Stuffing fiberglass in the space between a window frame and its rough opening won't block air movement, and it can be problematic to get foam in there, especially if the space is narrow. Tape works better to air-seal a window in the interior.

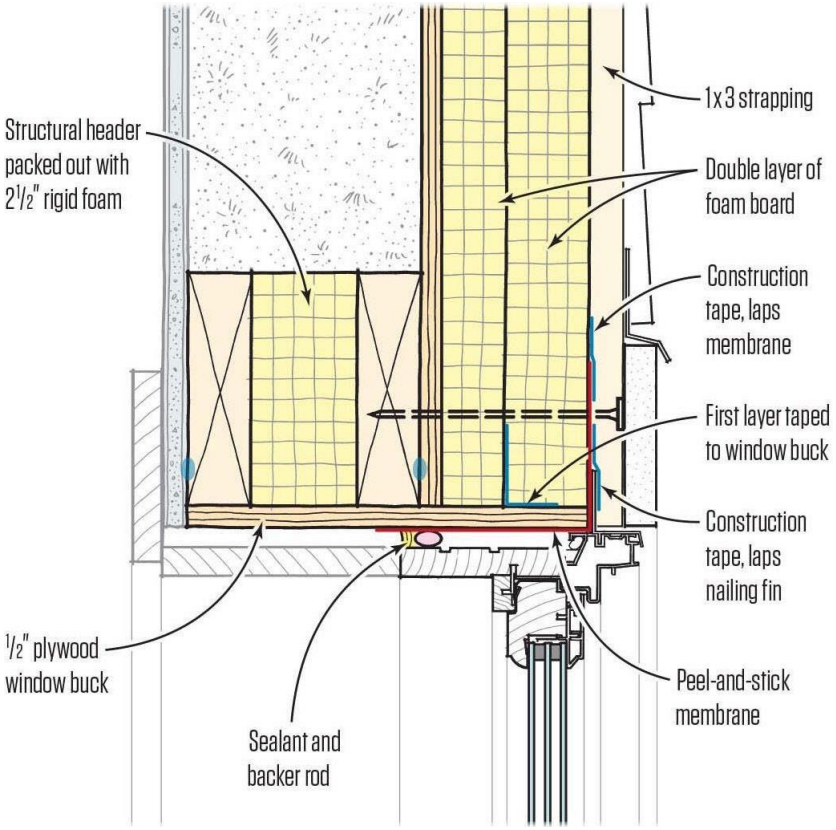
Openings in a wall with continuous exterior foam. The use of rigid foam on the building exterior complicates air sealing around windows.

WINDOW JAMB (PLAN VIEW)



Most builders line the rough openings with 1/2-inch plywood bucks that project beyond the framing by the thickness of the foam. This window buck gives you the option of installing the windows recessed to the inside or flush to the outside. Note: strap ties may be needed to secure the window to solid.

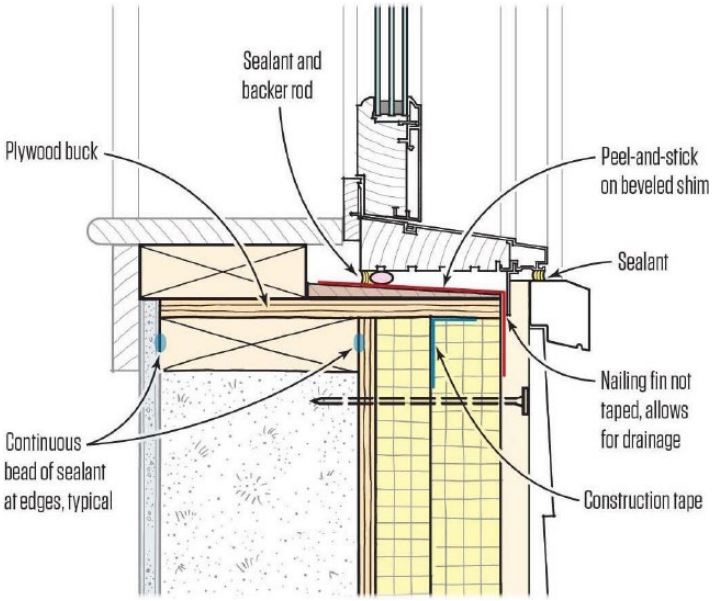
WINDOW HEAD



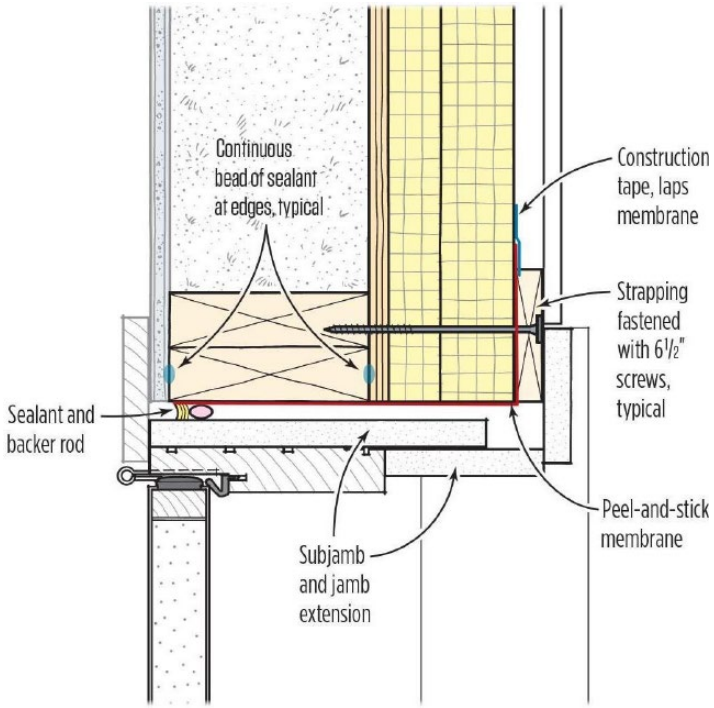
Tape the outside edge of the plywood buck to the first layer of foam before the window is installed. Also tape the nailing fins to the foam—first at the jambs, then at the head—but leave the bottom fin untaped for drainage.

With the windows sealed to the foil-faced sheathing, any water that gets past the trim and siding will drain to the outside.

WINDOW SILL

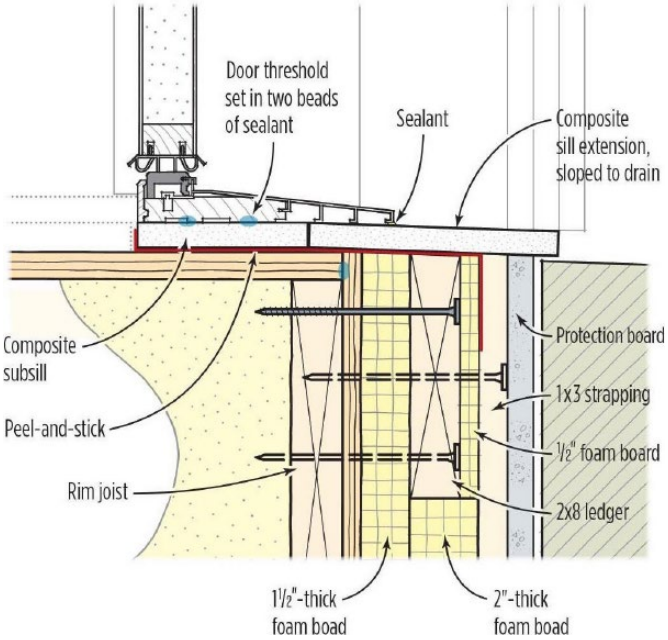


DOOR JAMB (PLAN VIEW)



Exterior doors typically swing inward, so the door unit needs to be installed to the interior. A two-step jamb extension will often work to trim out a standard exterior door in a thick wall. Best practice calls for using cellular PVC for the jamb extensions and other exterior trimwork. (see Exterior Trim: PVC and Composite Trim)

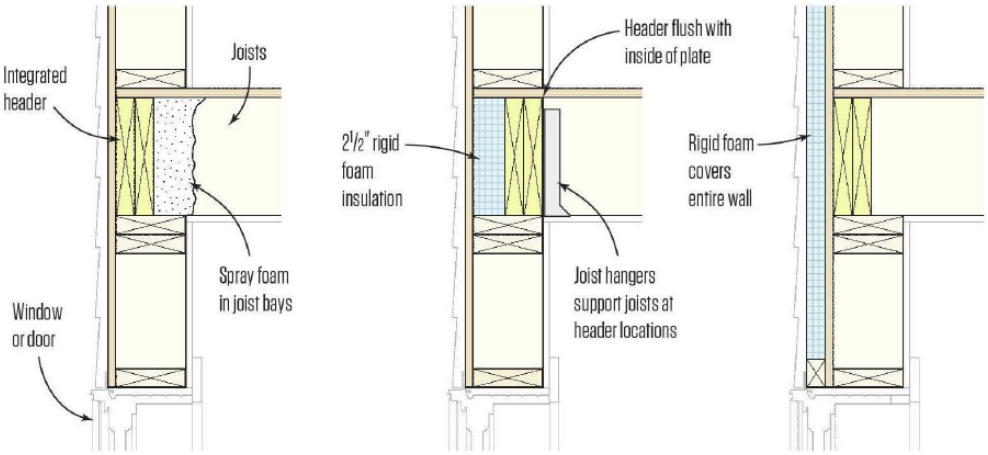
THRESHOLD



SEALING THE RIM JOIST

Rim joists at the first-floor level and band-joists between stories, are difficult place to seal because a number of components come together here—sill plates or top plates, the rim joist and subflooring.

INSULATING BAND JOISTS



Three options for insulating the band-joist (shown here as an integrated header):

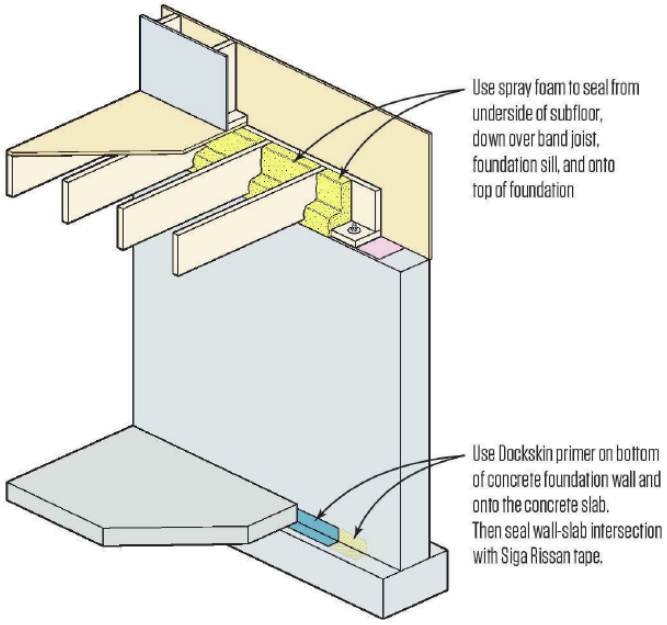
- Spray foam between joist bays.
- Offset band and inset pieces of rigid of insulation.
- A layer of rigid foam insulation on the exterior. This option helps reduce thermal bridging.

In each case, use a continuous bead of high-quality subfloor adhesive on the top edge of the band joist joist before the subfloor is installed.

Alternately, a layer of closed-cell spray polyurethane foam that encases the mudsill/foundation connection and covers the back of the rim joist provides an excellent air barrier. Low-density, open-cell foam also can be used here, but it may need an additional vapor retarder in Climate Zones 6 and higher.

Sealing The Rim Joist

FOUNDATION



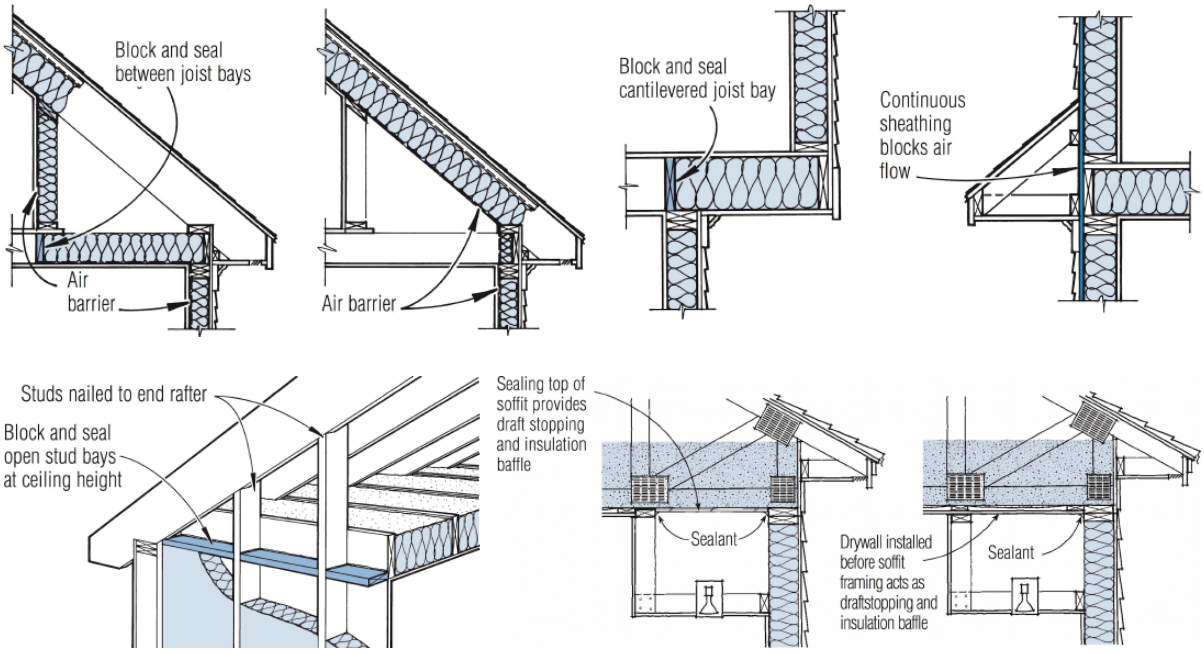
Tim Healey

A concrete foundation is air impermeable, but on the interior, you must air-seal where the foundation meets the framing and where the foundation and slab meet.

Fiberglass batt insulation stuffed into joist cavities against the rim joist will not block the flow of air between the basement and the rim joist. This can increase the risk of condensation, leading to mold growth in this area.

AIR-SEALING WALLS

CRITICAL AIR-SEALING DETAILS



Knee-wall cavities are best insulated before the knee wall is framed. If insulated after the knee wall is framed, be sure to include ceiling blocking to stop airflow through the cavity (A). Cantilevered floor sections will create a thermal short-circuit unless blocked with 2x or rigid foam (B). Blocking in balloon-framed exterior walls will reduce convective air currents in the walls that can short-circuit the ceiling air barrier and insulation (C). Before framing eyebrow roofs and other framing projections, sheathe the exterior walls first. The sheathing will air-seal the wall cavity. Similarly, extend the ceiling above soffits or seal with plywood, as shown (D).

Knee walls. A common problem with knee walls is a lack of blocking below the knee wall's bottom plate. This allows cold air from the attic or the outside to move through the insulation and into the ceiling and attic. Install blocking between joists, and seal the perimeter of the blocking with caulk or foam sealant.

When knee walls contain ducts and pipes that make effective insulating and air-sealing impossible, shift the thermal and air barriers to the slope of the roof. Add a layer of rigid foam insulation to the bottom of the rafters and seal all of the seams and the perimeter. Fill the cavities with blown-in cellulose or fiberglass. Or, use closed-cell spray-foam insulation to insulate and provide an air barrier.

Balloon-framed and gable walls. In a balloon-framed wall, studs run all the way from the sills to the rafters. At the attic line, there's typically a gap between the first ceiling joist and the exterior walls on the gable ends. These must be blocked and sealed to prevent air from leaking into the attic. The blocking can be made from a variety of rigid materials, as long as the perimeter is carefully sealed.

Cantilevers. At the wall line, add blocking between the joists and seal the edges to prevent air from moving into the ceiling. Blocking can be made from solid wood, plywood or rigid foam with the edges foamed or otherwise sealed in place. In addition, the sill plate of the upper wall should be sealed to the subfloor. Seal any seams in the subfloor, and seal any penetrations through the subfloor for wires or pipes.

SLIDESHOW: AIR-SEALING TIPS AND TRICKS

Drywall corners can be sealed with caulk before application of corner bead and joint compound

Depending on the situation, air-sealing can call for caulk, canned foam, tape, sheet material, or a combination of materials. The author's jobsite arsenal covers all the bases.

Air-Sealing Walls

High-performance bulk caulk, applied with refillable pneumatic caulking guns, is a useful alternative to canned foam for many applications.

If air-sealing is going to be done right, someone has to sweat the details. The author's shirt leaves no doubt as to who that person is.

Small-diameter pipe penetrations through drywall or plywood are efficiently sealed with two short pieces of tape.

Air-Sealing Walls

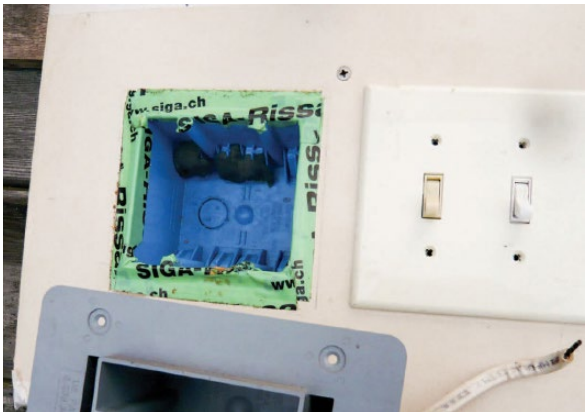
Larger pipes, like this rangehood exhaust vent, may require a dozen pieces or more.

Floor penetrations that will be enclosed in a partition wall are best sealed at the level of the subfloor, rather than where they pass through the plate.

In retrofit applications where that's not an option, air leakage under the plate can be reduced by sealing the area with duct mastic.

Floor openings around bathtub P-traps can leak as much air as an open window. They're best closed off with a piece of polystyrene — notched on one edge to fit around the pipe — set in a fresh bead of canned foam.

A small filler piece at the drainpipe is foamed in place to complete the seal.



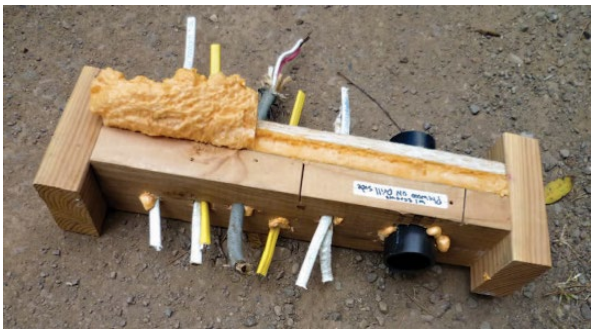
Conventional plastic electrical boxes can be sealed to partitions by sticking a strip of tape against each of the inner walls of the box and folding the portion that extends beyond it against the drywall. The width of the flange has been sized to fit under a oversized outlet cover, or "goof plate." The manufactured airtight box below is easier to seal but expensive; for economy, the author uses this type of box mostly on outside walls.

Leaky metal boxes exposed in the course of a retrofit can be sealed to the back of the drywall with tape.

Leaky metal boxes exposed in the course of a retrofit can be sealed to the back of the drywall with tape.

Where a new metal box is called for, tape provides a more reliable seal around the cable than foam, which is prone to cracking when the electrician installs the fixture or receptacle.

Air-Sealing Walls



A scrap of pre-drilled plywood or OSB can be used to create an air-sealing "sandwich" where closely spaced pipes or wires penetrate wall framing at a plate.

A strip of foil tape seals an air leak in an "airtight" ceiling can.

The much larger — and often overlooked — leak between the fixture and the ceiling drywall has been sealed with tape.

On a can with an integral trim ring that prevents the use of tape, a rolled "shoelace" of duct putty forms a seal.

Excess putty that squeezes out is removed later.

When wall sheathing is set in beads of polyurethane foam, temporary blocks at the base make it easier to position the sheet without smearing the sealant.

Air-Sealing Walls

For extra insurance, seams between panels are also sealed with tape.

An intentional 1/4-inch gap below the drywall on exterior walls is easily filled with canned foam. In a retrofit project, it's a good idea to protect the finish floor with paper or tape first.

Warm air venting from the attic above sucks a protective plastic sheet against this single-layer T&G ceiling, illustrating its extreme permeability to moving air.

Air-Sealing Walls

To stop air penetration at the gable overhang of a T&G cathedral ceiling, a 3/4-inch bit is used to bore holes where the boards cross the outermost pair of rafters.

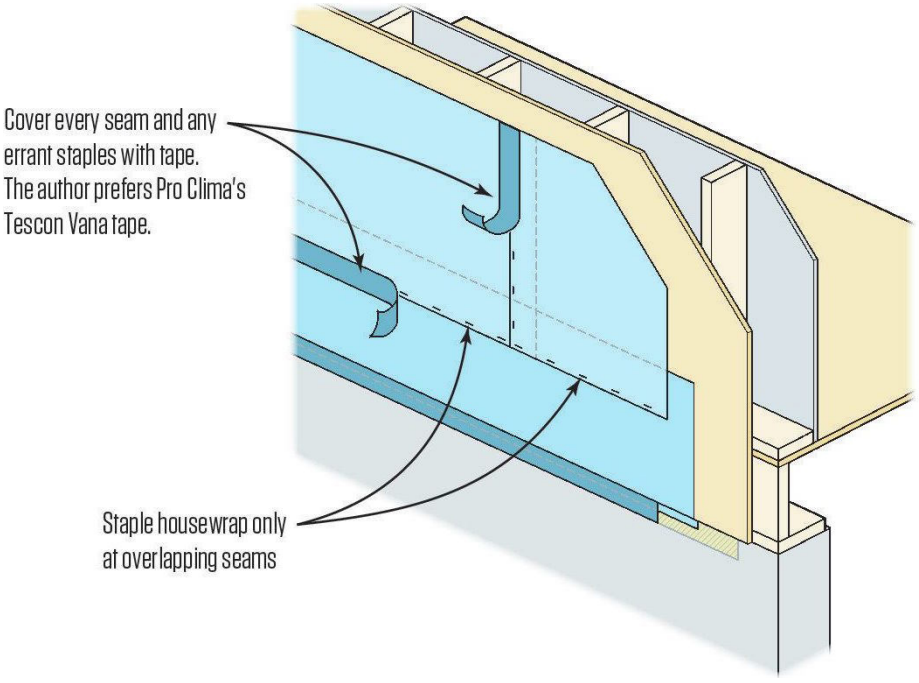
The holes are then injected with foam.

Plywood bedded in polyurethane foam seals air leaks between blocking and rafter tails. A stucco wall finish will cover the raw bottom edge of the plywood. A nearby rafter bay has been sealed with tape instead of foam — a time-consuming but more positive solution.

The excess foam that marks an injection hole for dense-pack cellulose will be trimmed off, and the tape covered with a plywood trim piece.

Air sealing at the sheathing layer. Huber's Zip Wall System, in which all seams are sealed with a proprietary tape, or taped housewrap can be an effective air barrier on conventionally framed exterior walls.

When using housewrap, fasten it to the wall with cap fasteners, or use staples at seam overlaps only.



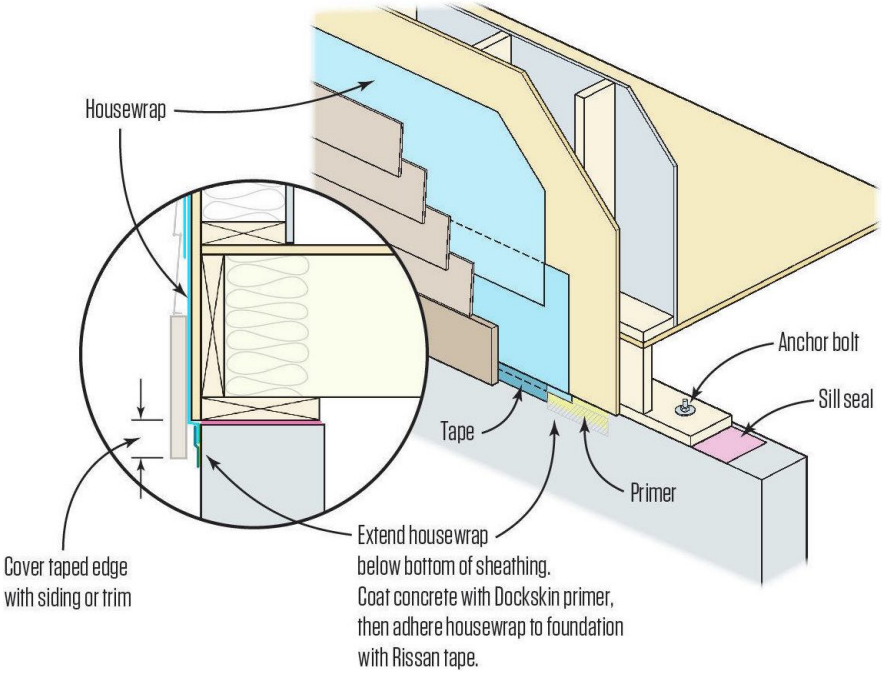
Tim Healey

Holes in the housewrap, even small ones from staples, compromise the air barrier.

All seams and edges must be taped (particularly at the base of the wall), and all holes for vents, electric and water service must be sealed. (See Weather Barriers and Flashing.)

Air-Sealing Walls

FOUNDATION TO FRAMING



Tim Healey

Traditional sill seal doesn't do a very good job, plus foundation J-bolts through the sill seal and pressure-treated sills can leak lots of air. On the building's exterior, use housewrap to seal the framing-to-foundation intersection.