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The best insulation you're not using?

Strategies for weatherproof windows

Air-sealing for energy savings

Tips for trouble-free plumbing

Tool Test

Track saws

Mineral wool makes a comeback, and for good reason p.48

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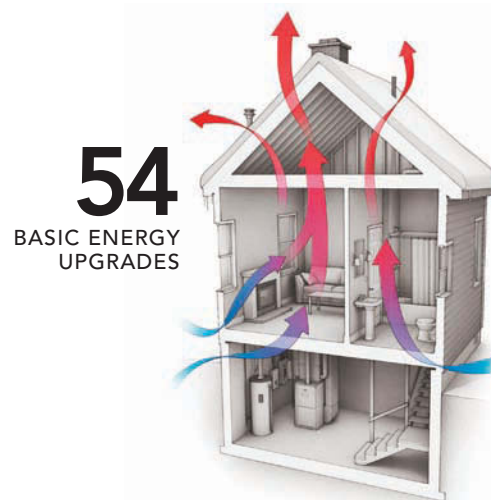
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breaktime



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Insulating an acrylic bathtub

SWISSCARPENTER ASKS: I've heard of some plumbers filling the interior voids of acrylic bathtubs with fiberglass and/or spray-foam insulation prior to installation. It sounds like a good idea for retaining heat in the tub. Is there any downside? I assume low-expansion foam is the way to go to prevent bulging or cracking of the acrylic, but I'm curious as to other people's experiences and techniques.

user-969819 replies: I recently tried this myself. I braced the edges and sides, filled most of the cavity with EPS, and went to town with low-expansion foam just to fill up the voids. It looked like it all stayed in position. But by the next day, the tub had sprung out in the middle by about 1 in.

Lying on my side, I spent three hours drilling, chiseling, scraping, and cussing to get all the foam removed. I ended up using a 30-in. crosscut saw to shave off layer after layer.

How did this happen? Apparently, the 6-in. block of foam that was attached at the factory to keep the front apron relatively in place had a weird chemical reaction with the spray foam, causing it to turn into a massive blob.

After restoring the tub to its proper shape, I filled the cavities with mineral-wool insulation. My wife just took a bath and said it was wonderful. Please, don't use foam.

DanH adds: Acrylic is a better insulator than cast iron and shouldn't really need added insulation.

junkhound replies: "Low expansion" does not mean "no expansion," and there is a huge surface area being pushed on. I tried the same thing with my tub, which moved enough to leave a puddle at the back. Like you, I spent a few hours with a crosscut saw getting the foam out from under the tub. My advice is to forget trying to use any spray foam.

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THE VOICES OF EXPERIENCE



MIKE LOMBARDI became interested in the mechanical trades while working on a dairy farm as a teenager. He began a plumbing/heating apprenticeship in 1972, earned his Master Plumbers license in 1984, and now owns his own business in Danbury, Conn. Mike has written for *Fine Homebuilding* on topics such as prepping and gluing plastic fittings (#229) and plumbing a bathroom (#234). In this issue, he explains how to install a toilet properly (pp. 66-67).

DOUG MAHONEY has been building in the Boston area since 2001. In that time, he has been a carpenter, a foreman, and a site supervisor, mostly in high-end residential construction. He also just spent nearly four years completely gutting and rebuilding his 100-year-old farmhouse—not an easy task with three kids under the age of 6. In addition, Doug has been writing about and reviewing tools since 2007. His review of track saws appears on pp. 74-79.



BRIAN KNIGHT ("A Weatherproof Window Installation," pp. 42-47) is the owner of Springtime Homes, a custom builder based in Asheville, N.C., specializing in indoor-air quality, energy efficiency, and building-science best practices. He received his bachelor's degree from Appalachian State University in construction, industrial, and appropriate technologies. Before starting Springtime in 2008, Brian managed construction projects in Asheville and in Greenville, S.C.

As a residential designer with a background in carpentry and engineering, **MIKE MAINES** pays attention to the practical, hardworking parts of a house, from materials such as mineral wool (pp. 48-53) to spaces such as laundry closets (pp. 92-94). For design inspiration, he draws on nature and traditional, vernacular architecture. When not designing, Mike likes to work in his woodshop or tend to his homestead in rural Maine.



write an article

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PRECISION

Filling a floor

Brent Kelosky wrote a fine article in the August/September 2015 issue about refinishing wood floors. Having done this job myself twice, I learned a great trick from an installer who was quite an artisan: After the final finish sanding, save all of the clean, fine sawdust, which is really a powder at that point, and mix it with a good sanding sealer into a medium-body paste. Trowel that mixture over the entire floor and let it dry, which usually happens pretty quickly. Do another light sanding of the floor before staining or coating with the final finish. The sanding sealer paste will fill every crack and crevice with the exact color of the surrounding wood and make the floor look like it did on the first day it was installed.

—RICHARD STUTSMAN
Malibu, Calif.

Author Brent Kelosky replies: Not all floors get filled, but this is a great trick that I have used, too. While the method works well, typically when I fill a floor, I use a premixed filler that is designed to match the wood species of the floor I am refinishing. These fillers are typically available from a distributor and are manufactured by the finish suppliers. I find that using a premixed filler is much less subject to user error, is easier to apply, and generally provides the same results. Premixed fillers also accept stains well.

I make an exception to this approach if I am refinishing an exotic species of wood that is not easily matched. In that case, mixing the dust and the sealer is better than using premixed filler. Additionally, some species of wood are very photosensitive and darken or lighten with age. Using the wood dust can work better in this application as well.

Spray-foam safety

While reading a back issue of *Fine Homebuilding*, I came upon the article “You Don’t Know Foam” by Justin Fink (*FHB* #241). While I found the article informative, I was disappointed to find that there was no reference to safety regarding this and other polyurethane products commonly found on job sites. The label on the can instructs users to protect eyes, skin, and surfaces. The user in the article, though, is shown without gloves.

More importantly, however, the label also warns against inhalation. I once accidentally knocked a foaming can onto my shoulder and later came down with a rash that was worse than one caused by poison ivy. I learned that I am allergic to the family of chemicals used as the curing agent in polyurethane products. Exposure to isocyanates gives me a condition called chemical-induced asthma, which can be fatal. I’ve noticed this reaction even days after commercial

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-Remodeler; Delmar, CA



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spray foam was used on one of my jobs.

I think it is important for your readers to be aware of the potential dangers that can result from using these products. I avoid using them completely when possible, and I wear a respirator with fresh cartridges when I must be near them.

—DAN QUILL
Southampton, Pa.

Fire ratings for exterior trim

I read with great interest Gary Katz's article "Today's Best Exterior Trim" in the last issue. One comparison that I found missing, though, was the fire rating on each of the products. Here in Colorado Springs, building codes for the hillside areas of the city require that a fireproof material be used for all fascia, soffit, and exterior trim. This is a result of the devastating wildfires of two and three years ago.

—BILL ROBERTSON
Colorado Springs, Colo.

Associate editor Patrick McCombe replies: This is an important issue. Fire-resistant and fireproof materials can minimize the damage done to structures by wildfire. Unfortunately, there are no universal approvals. States and municipalities with high wildfire potential determine the approved products in their respective areas. There is more than one test for determining a material's suitability, and just because one product is approved for one location doesn't necessarily mean that it's approved for all areas. The best thing to do is to contact your local enforcement officer to see if any product you're considering is on your area's list of approved fire-resistant products.

Draining outdoor showers

I was delighted to read the story about outdoor showers in the August/September issue. I've installed a few outdoor showers and would suggest that instead of capping the tub diverter, as depicted in the article's drawing, you attach a valve to it and make it accessible so that you can drain the plumbing completely come winter. Otherwise, even a little bit of water can end up freezing and cracking the cap, or in some cases, cracking the entire shower-valve body. I learned this the hard way.

—NIMA PARSI
Toronto

Solid gutter guards

Your article "Fixing Common Gutter Blunders" (*FHB* #253) recommends PlyGem and similar gutter guards. Those products work fine for large leaves, but they can create a situation worse than having no guard at all if your yard includes trees that produce tiny leaves and/or small seed casings. I've found that this small debris lies on top of the guards and completely clogs their small apertures. If I had it to do over, I would opt for a solid guard system similar to the LeafGuard product.

—ALLAN KAUTZ
via e-mail

Trim misrepresentations

Gary Katz's article "Today's Best Exterior Trim" (*FHB* #253) is well written. However, it makes representations of James Hardie trim products that are not correct.

First, neither James Hardie trim products nor its siding products contain fiberglass. Also, while the article recommends carbide-tipped tools to cut fiber-cement products,

James Hardie recommends the use of polycrystalline diamond (PCD) cutting tools. Next, the article says that personal protective equipment (PPE) and dust collection are a must when working with HardieTrim. PPE and dust-collecting tools can be used to manage dust, but they are not required.

Finally, on p. 63, a photo of HardieTrim is incorrectly used to represent the fly-ash product (see correction, below).

—MATTHEW SPENCER
Technology Assessment Manager
James Hardie Building Products

your safety

Home building is inherently dangerous. From accidents with power tools to falls from ladders, scaffolds, and roofs, builders risk serious injury and even death. We try to promote safe work habits through our articles. But what is safe for one person under certain circumstances may not be safe for you under different circumstances. So don't try anything you learn about here (or elsewhere) unless you're certain that it is safe for you. Please be careful.

—ROB YAGID
editor

Correction

In "Today's Best Exterior Trim" by Gary Katz (*FHB* #253), our photo of fly-ash trim on p. 63 showed the wrong material. (The correct material was shown in the photo on p. 64.) Here's the photo we should have run. We regret the error.



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BY JUSTIN FINK

Drain-waste-

Although hidden behind walls and in floors and ceilings, the pipes that make up a house's drain-waste-vent (DWV) system are the balance of the plumbing equation. They are the exit for the water provided through the supply lines, they carry waste from the toilet, and they connect to outside air for venting sewer gas and relieving pressure. These relatively large-diameter pipes rely solely on gravity, but they aren't easily routed through the structure of a house.

With three chapters in the IRC devoted to DWV systems, not to mention the tables and examples illustrated in the appendix, there is a lot to know about the layout and installation of such a system. Pipe sizes that vary based on usage; routes through framing bays that may already be packed with other mechanicals; pitch tolerances of plus or minus just $\frac{1}{4}$ in. per ft.; fittings with subtle differences in inlets, outlets, and applicability; and an array of minimums and maximums to consider when it comes to tying everything together are just a handful of the many situations, rules, and restrictions plumbers must understand.

The stakes are high, because an improper DWV setup can lead to slow drains, gurgling fixtures, sewer gas entering the living space, recurring clogs, and potentially hazardous overflows. When installed well, though, a DWV system will go unnoticed, with solids, liquids, and gases flowing smoothly. Here's how it works.

Justin Fink is Project House editor.

EVOLUTION OF THE MODERN DRAIN



Sewer gas

Air and water mix, breaking the vacuum, but sewer gas is allowed to enter the living space.

Unprotected If your sink, bathtub, and other fixtures were connected to drain lines that followed a straight, downward-sloping path to a main sewer outlet, water or waste would drain from each fixture with the help of gravity, air from the room would mix in and relieve the vacuum created by the draining water, and everything would flow without trouble. The problem with this setup is that air being allowed to flow into the drain system means that air also is allowed to flow out and into the room, bringing sewer gas with it.



Trap

Negative pressure siphons water from the trap, allowing sewer gas to enter the living space.

Trap To prevent the entry of sewer gas, every fixture is required to have a U-shaped section of piping, known as a trap. Located downstream of the fixture (or in the case of a toilet, as part of the fixture itself), the trap holds water, blocking sewer gas from coming up through the fixture's drain. The problem with a trap is that as water flows through a drain line, it creates a vacuum behind it (negative pressure) and pushes air in front of it (positive pressure). The flow of this "water slug" can cause water to be sucked out of a trap that it's passing near, and it may also cause air to push through and gurgle in nearby traps downstream of its path. To relieve this pressure differential, code requires vents.



Vent to outside air

Trap arm

Pressure is equalized by the vent, eliminating siphonage so that the water stays in the trap and blocks sewer gas.

Trap and vent Nothing more than a connection to exterior air, a vent neutralizes air pressure within the drain lines. This neutral pressure can be achieved with lots of different configurations: an empty (dry) pipe that connects to the top of a trap arm like a snorkel, a waste (wet) pipe that is oversize in order to provide enough room for both water and airflow, and variations on these setups.

vent systems

For sinks of any kind, the most common branch fitting is the sanitary T. The vent attaches to the top inlet, and the trap arm attaches to the branch inlet.

Vent pipes should be pitched to drain accumulated moisture.

Every DWV system is required to have at least one 3-in. pipe venting outside.

To avoid bottlenecking and clogging, no component of the drain system can be larger in diameter than the downstream parts that are attached to it.

Connections in a drain line should be made with a Y-fitting or TY-fitting, never a 90, to ensure a smooth and uninterrupted flow of waste.

Toilets have their own traps built in.

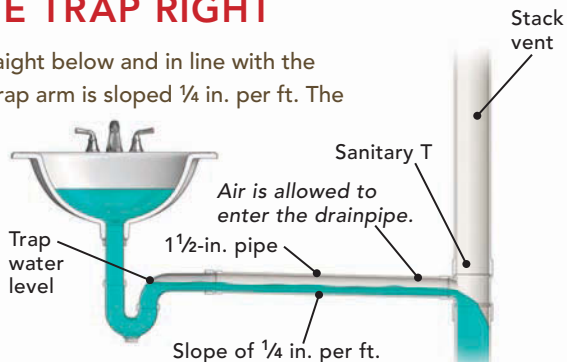
Drain pipes should be sloped $\frac{1}{4}$ in. per ft. If they are not pitched enough, the flow will be inadequate. If they are pitched too steeply, the water will flow too quickly, leaving behind solid waste or debris.

Cleanouts (and 18 in. of open space for access) are required by code for clearing clogs.

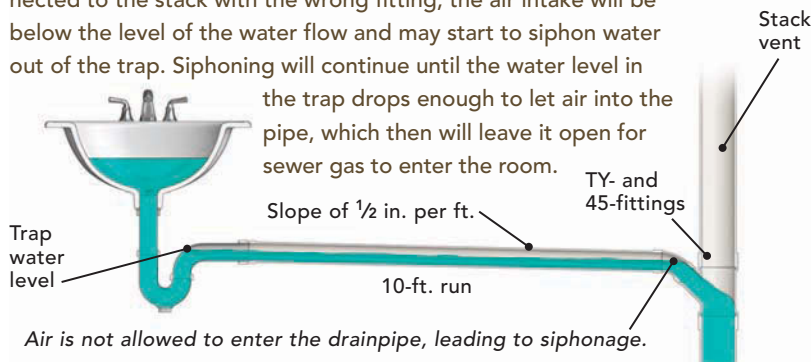
Changes from horizontal to vertical can be abrupt, but changes from vertical to horizontal should have a combination of TY-fittings and 45-fittings to avoid clogs.

GETTING THE TRAP RIGHT

Good The trap is straight below and in line with the fixture drain, and the trap arm is sloped $\frac{1}{4}$ in. per ft. The trap arm falls no more than the diameter of the pipe it's plumbed with, allowing adequate room for air to flow in from the vent pipe as water drains.



Bad If the trap arm is too long, pitched too steeply, or connected to the stack with the wrong fitting, the air intake will be below the level of the water flow and may start to siphon water out of the trap. Siphoning will continue until the water level in the trap drops enough to let air into the pipe, which then will leave it open for sewer gas to enter the room.



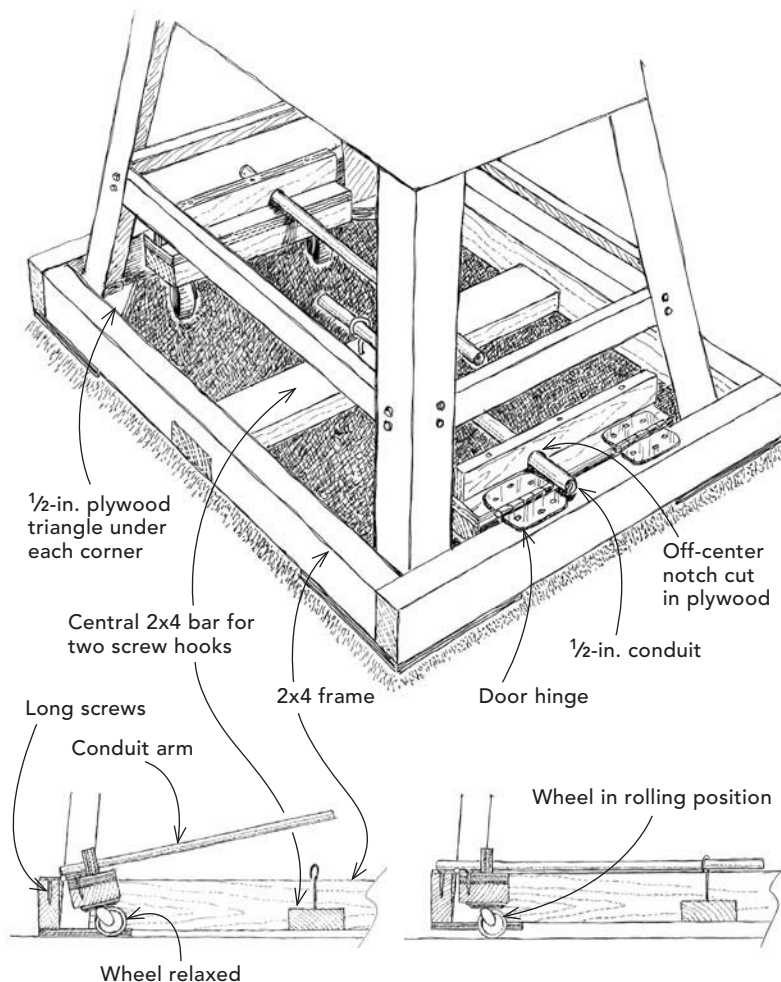
A rolling bandsaw base

I built a rolling base for my bandsaw using scrap wood and hardware-store parts. The base is made from 2x4 studs sized to fit around the saw's legs. Each leg is supported by a 1/2-in. plywood triangle fastened under each corner of the base.

The wheel assemblies are made from 2x4 scraps and pieces of 3/4-in. plywood. I attached caster wheels to the bottom of the 2x4s and added the 3/4-in. plywood pieces to the top of the 2x4 sections as spacers, so the total height of the wheels plus the wood is about 3/4 in. higher than the frame when the wheels are down. The required thickness of the spacers depends on the wheels used. I used door hinges to connect each wheel assembly to the base. The vertically mounted length of 3/4-in. plywood on top of each wheel assembly is notched to hold a lever made from 1/2-in. metal conduit. The notch needs to be about 3/4 in. wide so that the lever can swing back and forth. Finally, I installed a center 2x4 rail with two screw-in hooks large enough to hold the conduit arms.

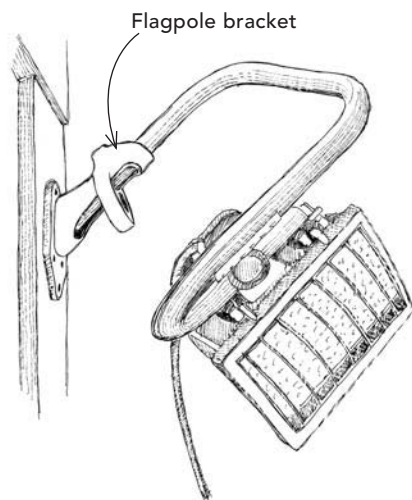
To move the saw, I simply push down on each conduit arm and slip it under its hook. This forces the wheel assemblies down and raises the saw base for rolling.

—TOM SCHAEFFER
Belleville, Pa.



submit a tip

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Flagpole bracket holds a lamp

My garage is also my workshop, so most of my projects involve hauling my tools to the driveway. Frequently, I am close to finishing a project as the sun sets. On one of those evenings, I found myself wanting to locate my shop light in a good spot. As I looked for a solution, I saw my flagpole bracket in a whole new light.

The bracket can receive the free end of my shop light's foot, leaving the light perched at a reasonable height above my head and inclined at an angle of about 45°.

—THOMAS S. AUCHTERLONIE
Leesburg, Va.

Keep the bugs out

When installing a soffit, staple nylon mesh or screen in advance. This prevents bees, wasps, or yellow jackets from building nests in your eaves.

—RON C. KERR
Wellsboro, Pa.



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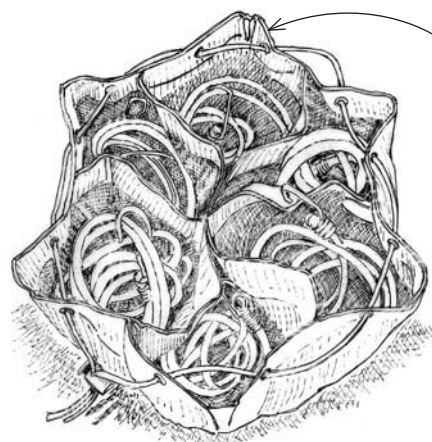
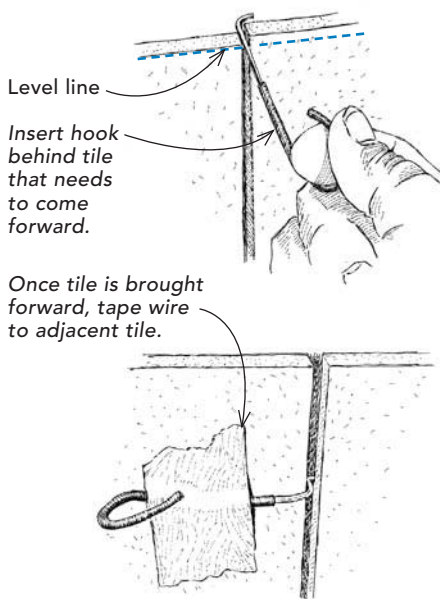
*Claim based on years/mileage (whichever occurs first) covered under the respective 2014 & 2015 New Vehicle Limited Warranty basic coverage. NV200[®] Taxi is covered under a separate limited warranty with a different level of coverage. Comparison based on *Ward's* Light Vehicle segmentation: 2014 & 2015 Nissan NV Cargo, NV Passenger vs. 2014 & 2015 Large Van class; 2014 & 2015 Nissan NV200[®] vs. 2014 & 2015 Small Van class. Comparison based on publicly available information on manufacturer's website. Claim current at time of printing. Nissan's New Vehicle Limited Warranty basic coverage excludes tires, powertrain coverage, corrosion coverage, and federal and California emission performance and defect coverage (applicable coverage is provided under other separate warranties). The powertrain coverage is 5 years or 100,000 miles (whichever occurs first). Other general exclusions, terms and conditions also apply. For complete information concerning coverage, conditions and exclusions, see your Nissan Dealer and read the actual New Vehicle Limited Warranty booklet. ©2015 Nissan North America, Inc.

Leveling big tiles

I used to have difficulty trying to level large tiles. I tried tile-leveling spacers, but I stopped using them out of frustration. Then while laying some 19-in. by 19-in.

porcelain tiles, I realized that all I needed was a hook to lift a tile that was sitting low. In the trash, I found a piece of 12-ga. cable, stripped its end, and bent one of the wires into a little hook. I made a loop on the other end of the wire in the same direction as the hook so that I would know which way the hook was facing. I slipped the wire between the tiles, made a quarter turn so the hook was under the tile, and lifted. The 12-ga. wire with that small hook was strong enough to pull the tile level without a problem. Once I pulled the low tile up to level, I bent the wire over and taped it to the adjacent tile until the thinset cured.

—VINCENT C. PIRRONE
Sparks, Nev.



Bungee cords are organized and stored in cloth nail bags.

Bungee-cord organization

I struggled to find a good solution for organizing bungee cords until a friend offered me a set of cloth nail bags. I accepted them, even though I didn't have a purpose in mind for them. And then it hit me. The bags keep the cords contained but easy to access. I can easily move the bags from vehicle to vehicle or to the tailgate when loading and unloading gear.

—MATTHEW SWETT
Langley, Wash.

TIP FROM THE ARCHIVES

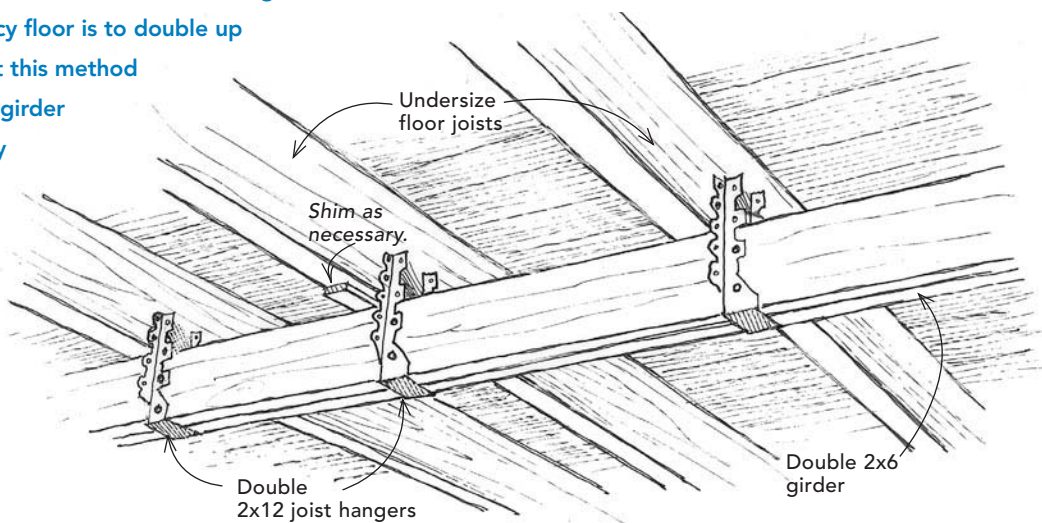
Fixing a bouncy floor

Ever walk across a living-room floor that flexed enough to make the record player skip a track? Although record players may be a thing of the past, those bouncy floors are still with us. Whenever one of my customers asks me to remedy this sort of situation, I install a 4x6 girder (or double 2x6s, if I'm working alone) to support the centers of the joists. As shown in the drawing, the girder is attached to each joist by a double 2x12 joist hanger. This new girder runs the length of the floor, supported at both ends, with additional posts that are added as necessary.

Joists aren't always uniform in depth, so to make sure I've got solid bearing for each joist, I add shims where appropriate, such as the one illustrated in the center of the drawing.

Another way to beef up a bouncy floor is to double up each existing joist. I've found that this method takes a lot more lumber than the girder approach. Also, there are typically wires, pipes, ducts, and bridging in the way. The girder solution avoids all those problems.

—DAVID R. NICHOLSON
Lewisburg, Pa.



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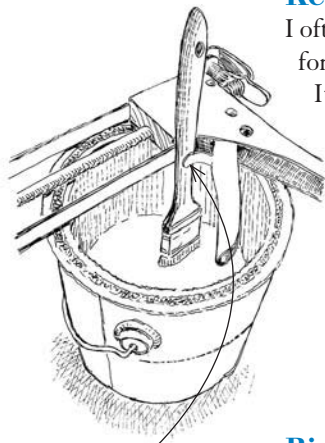


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Secure the brush between the caulking gun's trigger and frame.

Keep your paintbrush wet

I often have found myself looking around the job site for a way to store my brush temporarily in wet paint.

It occurred to me recently that there's almost always a caulk gun nearby at the painting phase. Caulk guns are large enough and have the proper strength to hold the brush, and they adapt easily to brushes of different sizes and paint cans of various depths.

—MIKE ALEXANDER
Monrovia, Md.

Big sound from a small speaker

To get more bass and a fuller sound from my small Bluetooth speaker, I simply put it inside a 5-gal. plastic bucket. With the speaker facing outward, I can tilt the bucket on a piece of scrap wood and have the sound directed toward where I am working.

—ROB FRIEDRICH
Lomita, Calif.

Trimming jambs

Whenever I install an interior door over a floor that has already been laid, there's a good chance that the floor is not perfectly level. To accommodate an uneven floor and achieve an even reveal at the top, I trim one side of the jamb.

I set up my laser level so that it casts its beam across the rough opening. (Alternatively, I could use a spirit level and make a pencil mark on each side of the opening.) Starting at one side of the jamb, I make a pencil mark on a story pole at the line. Moving to the other side, I make another mark. The distance between the two marks is the amount I need to trim off the high side of the jamb.

I align the lower mark on the story pole with the bottom edge of the jamb and transfer the upper mark to the jamb, which becomes my cutline. If I haven't assembled the jambs yet, it's simple to trim the piece on a miter saw. On prehung units, I simply square a line and trim the end with my jigsaw.

—MIKE PATTERSON
Gaithersburg, Md.

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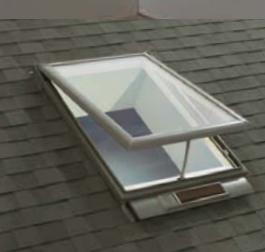
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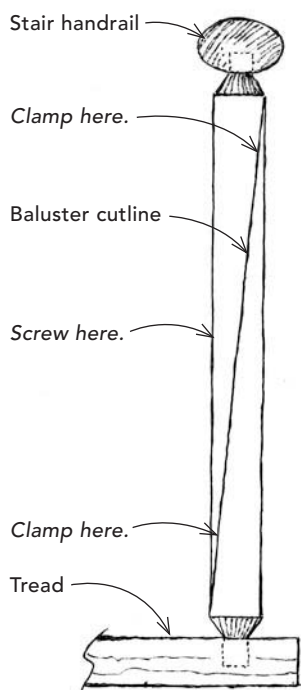
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Easy baluster replacement

I once had to replace a number of balusters in a cedar railing. The challenge was to do it without having to take apart the entire railing section to insert the tenons on the balusters into the holes in the handrail. After thinking of a variety of schemes, I came up with this simple system. I used a bandsaw to cut a narrow and slightly irregular diagonal kerf in each baluster. I applied waterproof glue to the cut surface of one of the halves and inserted the piece into the hole in the tread. After sliding the other half of the baluster up and into its hole in the handrail, I matched it up with its mate. To hold the pair in alignment, I clamped the thin ends together and drove a screw into the middle of each baluster.

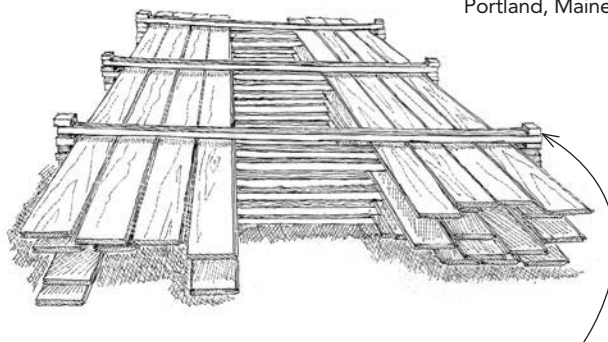
When the glue dried, I removed the clamps and cleaned up the gluelines. The balusters were ready for filling, sanding, and painting.

—KEITH OJALA
Hancock, Mich.

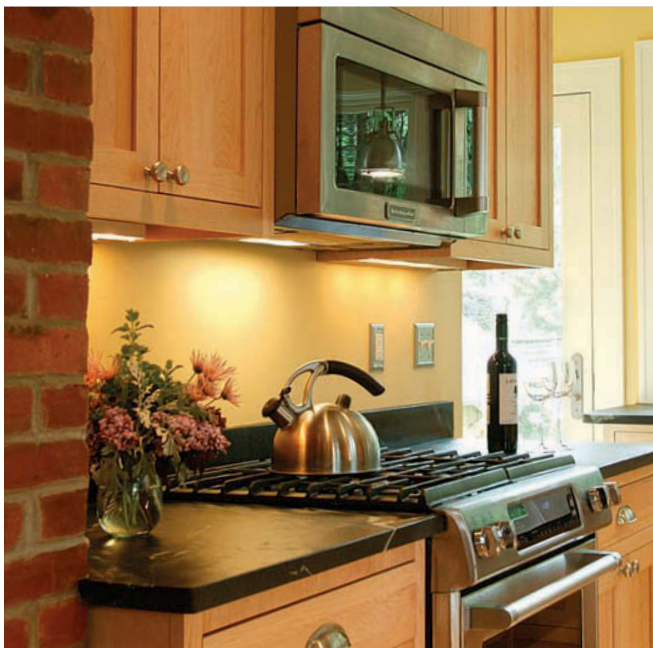
Drying racks for finishing

My painting contracting business specializes in custom homes and restorations, and we finish a lot of siding and trim prior to installation. In order to dry large deliveries, we build simple drying racks by cutting a 2x4 into small blocks and screwing them onto the ends of 8-ft. 2x4s. This allows large amounts of material to dry with minimal contact points.

—TONY D'AGOSTINO
Portland, Maine



Drying rack of 8-ft. 2x4s with short blocks screwed to their ends creates a stackable drying rack.



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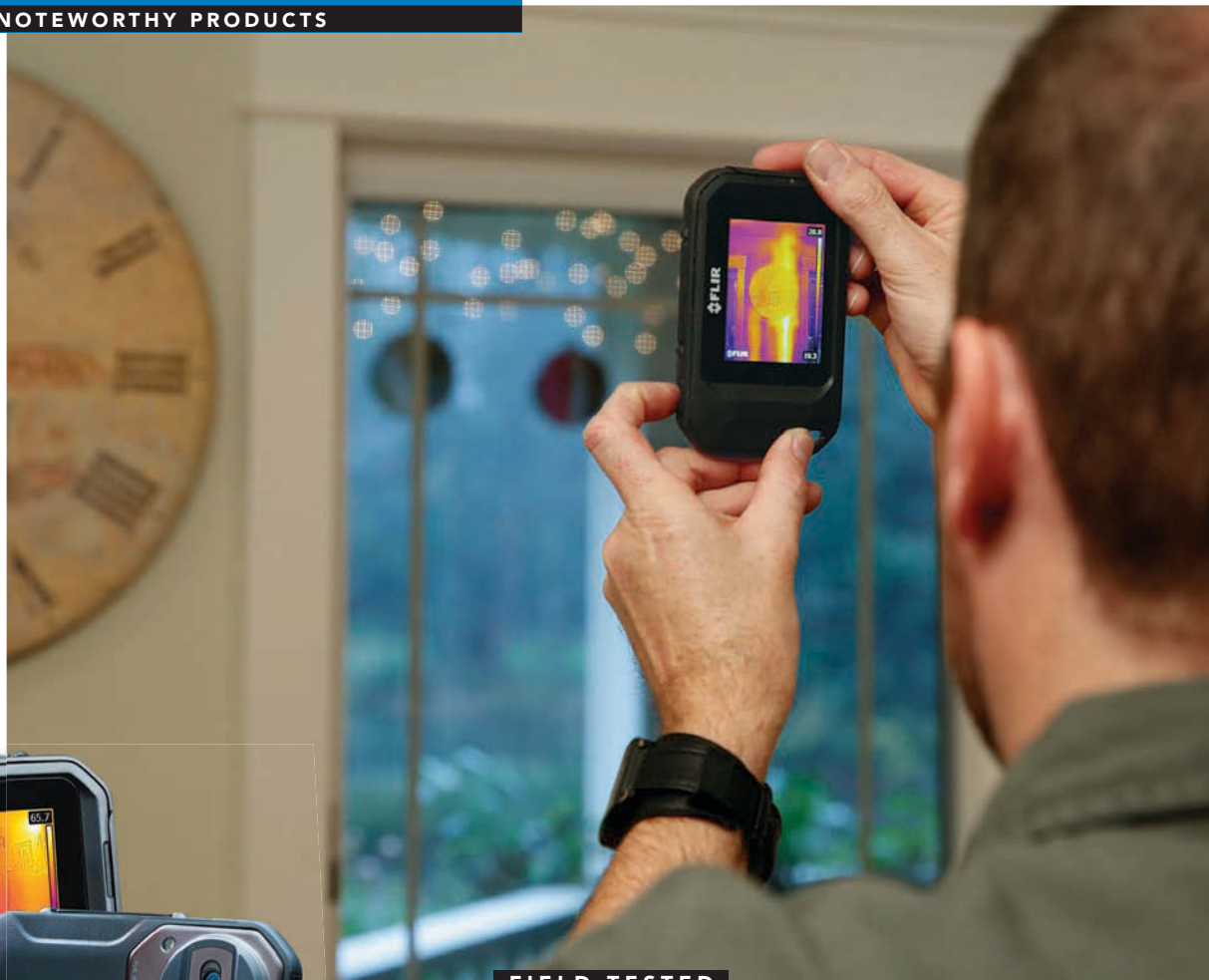


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FIELD TESTED



Thermal camera

A good thermal camera is indispensable for diagnosing problems in buildings. You can use it to track down leaks in roofing and flashing, pinpoint insulation voids, and locate air leaks. You can also spot leaky ductwork and faulty electrical components. A good thermal camera suitable for these tasks used to cost thousands of dollars, but not anymore. Now there's the \$699 Flir C2.

About the size of a typical smartphone, the C2 is compact, is easy to use, and has excellent image quality for an entry-level thermal camera. It also has what Flir calls MSX. With MSX turned on, an outline of the visual image is overlaid onto the infrared image. The combined image makes it much easier to tell exactly what you're looking at.

The C2 comes with 165MB of storage. At the camera's thermal resolution of 4800 pixels, I found this to be

enough space for 500 paired (visual and thermal) images. You can download the images for project files and customer reports using the provided USB cable. Images also can be postprocessed using Flir Tools software. Other features include an adjustable color pallet, emissivity and distance settings, onboard flash, and auto orientation.

I wish the C2 had a removable memory card and built-in WiFi or Bluetooth connectivity, but considering that this very functional thermal camera sells for just \$699, I shouldn't complain. I think that plumbers, electricians, HVAC contractors, builders, and remodelers interested in expanding their diagnostic and troubleshooting capabilities should add a C2 to their toolbox.

Flemming Lund, owner of Infrared Diagnostic (infrareddiagnostic.com)



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Frustration-free hammer tacker

If you've ever used a hammer tacker to fasten felt paper to a roof, you're probably familiar with the sound of its spring-loaded follower skittering down the roof toward the ground. This is not my favorite sound, because it means a trip down the ladder in search of the follower while leaving the partially fastened felt paper to flap in the breeze.

And never mind the fussy process of aligning sticks of staples to fit in a hammer tacker's magazine, particularly when it's cold. Either you have to try to handle the fragile staples while wearing gloves, or you freeze your bare hands to the cold metal sides of the tool. It's even worse when you're trying to clear a jam in those conditions by removing a couple of tiny cotter pins that always seem to break or snap rings that require a tool to remove. I've used tackers from several manufacturers over the years and have found these problems to be endemic to the tool—until now.

I recently tried out a Milwaukee tacker, which accepts readily available T50 staples in lengths from $\frac{5}{16}$ in. to $\frac{1}{2}$ in. and sells for \$40. The first thing I noticed is that

the follower never leaves the tool, so you can't drop it. Loading it requires no alignment of staples and guides; you hold the tacker upside down, withdraw the follower, and drop a stick of staples into the tool's bottom-loading magazine. Push the follower back in place, and you're ready to go. The housing above the driver end is reinforced with a steel plate that you can use to hammer staples flat, and there's a staple puller on the front. I've run a few thousand staples through the thing, and it hasn't jammed yet.

Andy Engel, senior editor



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Good-looking vent caps

The typical plastic and aluminum vent caps for clothes dryers and exhaust fans found at hardware stores and home centers are not noted for their good looks or durability. If you want a step up in aesthetics and performance, consider the roof and wall caps from Luxury Metals. They're available in copper, stainless steel, and galvanized steel for round ductwork from 3 in. dia. to 12 in. dia., and for rectangular ducts from 3¼ in. by 10 in. to 6 in. by 10 in. The company also manufactures roof vents, soffit vents, and plumbing-vent flashings. Prices range from \$29 for a galvanized 4-in. round dryer vent to \$139 for a 6-in. by 10-in. stainless-steel wall vent.

Patrick McCombe, associate editor



How wood you know?

Wood gutters look great on historic homes, but they need annual maintenance to keep them free of rot. You can get the same traditional look with low-maintenance fiberglass gutters from The Fiberglass Gutter Company in Pembroke, Mass. (fiberglassgutters.com). Available in standard and custom profiles in lengths up to 40 ft. (longer runs can be field-seamed), the gutters are produced individually in molds made from traditional wooden gutters. Straight gutters typically sell for \$35 to \$85 per ft., installed. The company also makes fiberglass gutters for turrets and curved walls.

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USB charger

I am cheap and mostly analog by nature, so I generally don't get all giddy about electronic gadgets. I'll make an exception for DeWalt's DCB090 USB power source (\$29), though, because I use it a lot.

Having to walk to the truck to charge a dying phone or missing calls because of a dead phone can be a big hit to your efficiency, but you can keep your phone or tablet charged with this great little device that slides onto a DeWalt 20v battery pack. It has a fuel gauge for monitoring the pack's remaining life and two USB ports that can provide up to 1.5 amps of charging power. When two USB devices are connected, it splits the 1.5 amps between the two devices. In addition to charging, it keeps my phone functioning in frigid weather. Because the device is so small and I'm not tethered to a wall outlet or extension cord, I can stash my phone wherever I find a spot that's safe from the hazards of a construction site.

Mark Clement, licensed contractor and co-host of the MyFixitUpLife podcast



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Better electrical box

Conventional electrical boxes don't do much to prevent the movement of air through wall and framing cavities. This air leakage wastes energy, leads to comfort complaints, and creates condensing surfaces where mold and rot can get a foothold. Many versions of airtight electrical boxes designed to control air leakage are notoriously finicky and slow to install. However, the new FastCap Air Tight Box is the most promising way to control air leakage through electrical devices that I've seen. Employing an adhesive flange that adheres to both polyethylene and smart vapor-retarder air barriers (such as CertainTeed's MemBrain), the box has rubber grommets that seal around the wires and built-in square-drive screws for fastening. Currently, it's available only in 24-cu.-in. single-gang sizes, but the manufacturer promises that multiple-gang and fan-rated boxes are coming soon. The box sells for \$3 each or \$142 for 50.

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difference?

■ HAMMER-ACTION DRILLS

Hammer drills vs. rotary hammers

There are times when a conventional drill just won't get the job done. For example, when you're installing a deck ledger against a concrete foundation and need to drill lots of holes, you need a more specialized tool. That's when you might pick up a hammer drill or a rotary hammer. While the names are often used interchangeably, they are not the same tools.

Matt Higgins, assistant editor



HAMMER DRILL

As the name implies, this tool delivers a hammering action as it drills. This action is created by two internal metal disks with ridges. As the disks spin against each other, the ridges ride up and down and cause the chuck to move in and out. Hammer drills can have the hammering action turned off; with the flip of a switch and the swap of a bit, you can go from drilling in concrete block to boring into wood framing. Typically, these tools can use up to a 1/4-in.-dia. bit when working on poured concrete. A 3/8-in.-dia. or smaller bit can be used in block and masonry.

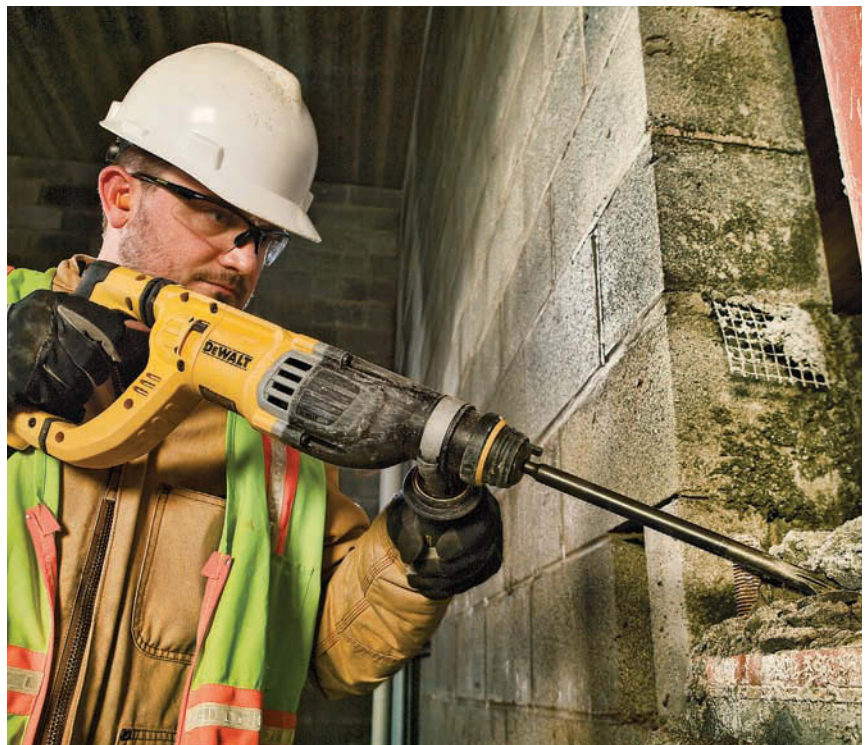
Because of the mechanics needed to create the hammering action, a hammer drill is typically more bulky than a traditional drill. That said, many of today's hammer drills aren't shaped and sized all that differently from traditional drills. A standoff handle to keep the tool steady is one telltale feature of a hammer drill.

ROTARY HAMMER

For larger holes, a rotary hammer is the go-to tool. A rotary hammer uses a piston to compress air that moves a striker to create the hammering action. The rate of the blows is slower than with a hammer drill, but those impacts are far more powerful. Think of the hammer drill as delivering numerous jabs and the rotary hammer as hauling off with haymakers. The power of the rotary hammer means less work for the user, but it also means that the rotary hammer is not suitable for use on wood or metal.

While hammer drills typically are outfitted with a standard adjustable chuck, rotary hammers have a spring-loaded chuck that corresponds directly to the size of the bits being used. This means that you must use only bits that fit that specific chuck. SDS-plus are the most popular bits and are designed for drilling holes with diameters from 5/32 in. to 3/4 in. SDS-max bits step the capability up to a range of 3/8 in. to 2 in.

Since the hammering force isn't created by a spinning mechanism, as it is with hammer drills, rotary hammers can be switched to hammer-only mode. This is useful for light demolition work such as tile removal. Rotary hammers are generally bigger, weigh more, take on bigger tasks, and require less work from the user. They do, however, cost more, so if the job doesn't call for it, purchasing a rotary hammer might be overkill and wasted dollars.





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Integrity employee Larry T. at the Wood-Ultrex factory in Fargo, ND.



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■ SCREW BITS

Phillips vs. Pozidriv

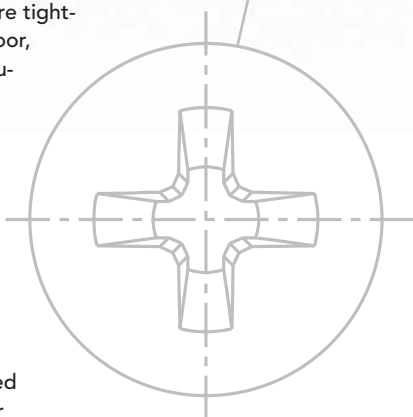
There's a wide variety of drive systems in the hardware world, and most of us have a healthy collection of bits, ranging from star-drive to square-drive to hex. It's easy to spot the differences between most of the styles, but two that are commonly mixed up—even by the more experienced—are the Phillips and Pozidriv bits. Despite their similar appearance, these two systems are not interchangeable. Here's how to tell the difference between them.

M.H.



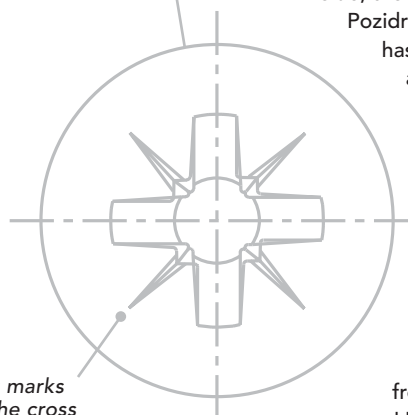
PHILLIPS

It makes no difference when you're tightening a cup hinge on a cabinet door, but the Phillips design wasn't actually invented by someone named Phillips. Rather, John Thompson sold his design to Henry Phillips, who then formed a new company, improved the design, and worked to get the drive system to become the standard in numerous industries, especially automotive. The key improvements of the Phillips system over the slotted system are that its bits self-center and will cam out (slip out) when a fastener is sufficiently seated. On a production line, these features are huge time savers. The most common Phillips sizes are 1, 2, and 3 (from smallest to largest), and the bits typically have "ph" indicated on them. The patent on the Phillips design expired in 1966, but the Phillips Screw Company has continued to improve on the cruciform-shaped drive, which has led to other drive systems from the same company, such as the Pozidriv.



POZIDRIV

When trying to tighten up that previously mentioned cup hinge with a Phillips bit, you probably should be using a Pozidriv. The Pozidriv also has a self-centering design, but the shape is modified for improved engagement. The sure sign that a screw is Pozidriv is the four tick marks or indentations around the cross. Viewed from the side, the difference between Phillips and Pozidriv bits is unmistakable. A Pozidriv has ribs between each of the four arms of the cross. This adds the increased grip. A Phillips bit fits in a Pozidriv screw head, but it will most likely cam out before the fastener is fully tight. This can damage the fastener and is why that cup hinge loosens up so quickly when a Phillips bit is used. A Pozidriv bit does not fit in a Phillips screw. Pozidriv bits are available in driver sizes from 0 to 5 (from smallest to largest) and have "pz" marked on them.



Four tick marks around the cross indicate Pozidriv.



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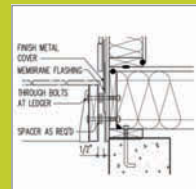
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A Weatherproof Window

Layers of redundant flashing and sealant ensure that the most expensive part of your house is also the best protected

BY BRIAN KNIGHT

As the building industry tightens up on air-sealing and improves energy efficiency, we need to be more aware of the risks associated with air and water intrusion. Materials that get wet won't dry out as quickly or easily as they used to do in leaky, poorly insulated houses, and many of the materials being used to build houses aren't as resistant to moisture as their predecessors. There's no doubt that with windows accounting for such a large part of the building budget, and being one of the most direct connections to the elements, their installation deserves extra attention.

Windows are complicated, and so is their installation

Compared to solid areas of wall and roof, windows and their interface with the air barriers and water-resistive barriers (WRBs) of a house are complicated and vulnerable. Many builders and designers are confused about best practices, and inferior techniques are rampant. As windows, tapes, sealants, and WRBs evolve, so do the installation guidelines for these products. It's not uncommon for products that are typically used together to have conflicting installation instructions. When in doubt, I follow the window manufacturer's instructions as a bare minimum, and add improvements from there.

The best window installations include redundant layers of protection for keeping water out, incorporate measures for blocking the air movement that can draw that water in through weak spots, and provide an escape path for water that enters before it has a chance to cause damage.

Not all windows are created equal, of course, and it's tough to predict long-term performance. But I don't discriminate or try to predict. Every window I install—regardless of brand, material, or price—gets the same belt-and-suspenders treatment to ensure that air and water leaks aren't going to be an issue.

Aim for waterproof, but plan for leaks

We should always assume that water will find its way into a window opening. Even if the installer does a per-

IT STARTS WITH THE SILL



Create your own sloped sill. Remove stock from the rough sill to provide drainage in the case of leaks. Draw one line 3 in. from the outside face of the opening, and another about 1/4 in. down from its outside edge. To create the slope, use an angle grinder equipped with a rough-grit flap disk.

Installation



Width plus 12. Cut a piece of flashing tape 12 in. longer than the width of the opening, which allows 6 in. of tape to extend up each side.

FHB'S
PROJECTHOUSE



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www.finehomebuilding.com



Keep the transition tight. Use a rafter square to press the tape tightly into the corners where the sill meets the sides of the rough opening, eliminating bubbles under the tape that are vulnerable to puncturing.



Continuous outside corners. You can buy flashing tapes made for curves, but they're expensive. Protecto Wrap tape is far more affordable and has enough flexibility to be stretched down onto the sheathing, where I tack it in place with button-cap nails.

fect job with sealing and flashing, water can still leak through the window unit itself—especially as the materials, transitions, and sealants go through many cycles of expansion and contraction over time. Gravity, capillary action, blowing rain, and pressure differences can push and pull water into these weak points.

Water leaks from windows usually show up at the sill. Because this is the most vulnerable area of a window, it's also where the weatherproofing efforts begin.

As long as there is an air gap in place, a sloped and flashed rough sill is the best way to protect this vulnerable area. Creating a back dam along the rear edge of the sill flashing is one way to ensure that leaks under the window can't reach the interior of the opening, but I typically don't use back dams unless specifically required by the window manufacturer. I've found that they can complicate rough-opening dimensions, interfere with shimming the window off of the sill pan, and make it difficult to air-seal the bottom of the window.

A piece of bevel siding laid across the rough sill of the opening is the

traditional choice for creating a slope, but it requires planning to make sure there is adequate height in the rough opening to fit the siding and layers of flashing tape. Manufactured sill pans are another option and are certainly better than nothing, but I don't like them. The ones I've tried don't have the amount of slope I prefer; can make shimming, air-sealing, and trim installation more difficult; and often are two halves that need to be pieced together and are then never visible for inspection. I prefer to avoid questionable joints or seams in this vulnerable area.

My favorite method is to add the slope right to the rough-sill framing. Sloping the sill after it has been framed eliminates any

worry about reducing the height of the rough opening because you're actually enlarging it.

In addition to the sloped sill, the opening is protected with flashing tape, with the weakest interface being the spot where the sill meets the jack studs on each side. There are many ways of cutting flashing tape to fit this situation, but I prefer to stretch the sill flashing around the corner, eliminating the seam altogether.

If the window manufacturer allows it (some require continuous support at the sill), install the window atop spaced shims to increase the drainage and drying potential underneath the window unit and above the sloped, flashed sill.

The biggest obstacle in the drainage path is typically the window's bottom nailing fin. Do not caulk it, do not tape it, do not seal it in any way. Some window manufacturers call for a dashed bead of caulk, but I believe this is just asking for trouble. It's also much easier to tell my crew "No caulk at the bottom" and get consistent results rather than "X lengths of Y diameter caulk with Z amount of space



Easy air-sealing opportunity

Regardless of window brand, material, or type, I eliminate the possibility of hidden air leaks through joints and seams in the window frame with vapor-permeable Pro Clima Uni-Tape before the window is installed.



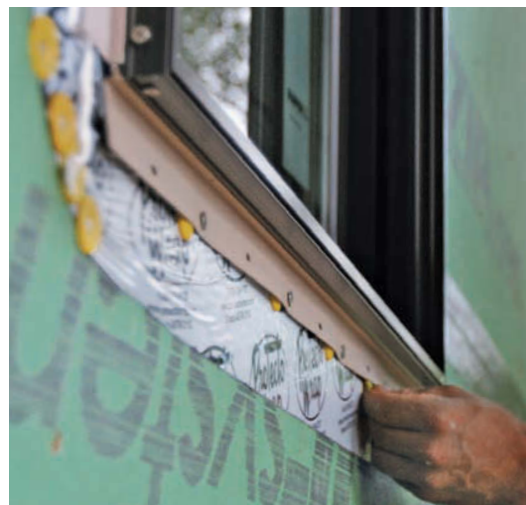
Sides are simple. Cover each side of the opening with a piece of flashing tape that bridges the gap between sheathing and framing and that extends down to and over the top of a horizontal piece of the same tape, reinforcing the seam where the sill flashing adheres to the wall. I like Zip System Tape or 3M All Weather Flashing Tape 8067.

Caulk three sides. Lay a bead of high-quality caulk along the sides and top of the opening, keeping it close enough to the edge so that the nailing fin will compress it. Never caulk across the bottom. If the corners of the nailing fin are designed to receive a piece of manufacturer-supplied adhesive flashing, skip the caulk in the top corners, as shown here.

BUT LET THE BOTTOM DRAIN



Bottom first. Rest the window on the edge of the sill, tip it upright, and slide it straight in against the caulked sheathing.



Caps make a gap. To promote drainage, slide caps from button-cap nails under the bottom nailing fin, pressure-fitting one next to each nail. These caps are thick enough to create a gap but not so thick that they will complicate trim installation.



Reinforce the fin. Zip System Tape is $3\frac{3}{4}$ in. wide, which is wide enough for it to be adhered to the sheathing, across the nailing fin, and onto the side of the window frame.

between them” and then hope for no problems. I like to go even one step beyond by providing a gap behind the nailing fin to promote further drainage.

Deal with air from the inside

In an ideal world, the window unit and any manufacturer-installed jamb extensions have airtight joints, but a builder’s best method for assessing airtightness is the blower door, and that means the window is already installed. I’m sure that some manufacturers seal this connection, but it’s safer not to assume. I eliminate the possibility of a leaky unit by applying tenacious acrylic-adhesive flashing tape over any seams and joints in the window frame before it’s installed. It pays to seal the joints in the rough opening as well to eliminate short circuits or air leakage from surrounding stud cavities. Control the window unit, control the rough opening, and then you can confidently address the space that’s left between the two.

Canned spray foam is probably the most common way of sealing between the window unit and the framing. My biggest gripe with this method is that it’s difficult to inspect for quality without a blower-door test. On a house I tested recently, I was surprised to find air coming through the spray foam around windows and doors, most likely in the area of a shim, which I’ve found to be the most vulnerable leakage point.

There are many variables to consider if you’re relying on spray foam as an air barrier in this location—the size, shape, and consistency of the bead; whether the can was shaken adequately; if the humidity is suitable; and the texture and temperature of the substrate—so I prefer to think of this spray foam only for insulating purposes. Backer rod and caulk followed by a layer of vapor-permeable flashing tape is what I use as my air-control layers.

I buy several packets of backer rod in diameters of $\frac{3}{8}$ in., $\frac{1}{2}$ in., $\frac{5}{8}$ in., and $\frac{3}{4}$ in. to accommodate the different-size gaps I typically encounter, and I always use a rod that is slightly fatter than the gap being filled. For gaps smaller than $\frac{3}{16}$ in., I skip the backer rod and simply caulk the gap. In all cases, I use a high-quality elastomeric or polyurethane sealant made for windows and doors, such as Sonneborne’s NPI, Sika’s Sikaflex, or Dap’s 3.0. These sealants have better adhesion than typical silicone but still allow for plenty of expansion and contraction.

Flashing tape doesn’t receive enough attention for use in this location. It’s fast, durable, effective, and easy to inspect. Plus, it’s the one air-sealing layer that’s guaranteed to clear the shims installed around the window.

I prefer a tape that is vapor permeable—I use Pro Clima Uni-Tape—to eliminate it as a potential barrier should any moisture around the window need to dry toward the interior, but I would use something impermeable in a pinch. Tape is typically applied to the rough framing and the jamb-extension edge, but it’s important to keep in mind the exposed reveals of the trim when placing the tape.

When followed by careful installation of the drywall, the exterior trim, and the head flashing (all of which are areas that should be handled with care to avoid damaging flashing tapes and air-sealing tapes), you’ve improved the performance of one of your building’s weakest links. □

Brian Knight is owner of Springtime Homes in Asheville, N.C.
Photos by Justin Fink.

AIR-SEAL FROM



A conservative bead of foam. A thin bead of low-expansion spray foam offers limited air-sealing and insulation, but avoid filling the entire cavity, especially toward the bottom, to allow for drainage in the case of water entry.



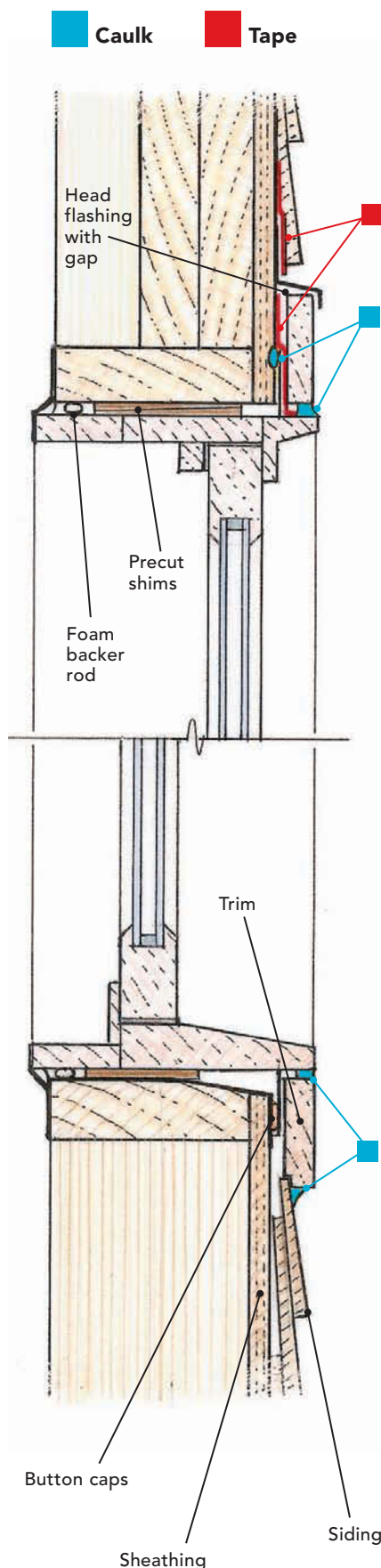
A caulk joint that will last. Foam backer rod cut and pressed in around the window jamb creates a flexible base for the bead of caulk that follows it. Use a wet finger to smooth the bead against the backer rod, creating the ideal hour-glass shape that allows the sealant to expand and contract without cracking or debonding.

THE INSIDE



Tape is the innermost air-seal. Applied so that it bridges the gap between rough frame and window jamb, flashing tape provides an easily inspectable air barrier that, like the backer rod and caulk, isn't affected by the shims along the four sides of the window.

Finish strong on the exterior



The exterior weatherization—the tape, the head flashing, the caulk, and their integration with the trim and the siding—is the last step in a well-detailed window installation. It's fairly common for people to unknowingly seal the crucial water exit points while missing some of the important leak-prone areas. Here are some general guidelines.

- Wherever there is flashing or a shingle-style transition in which one piece laps over another, such as clap-board over the head flashing, don't caulk. Any transition other than a lap, such as a butt joint where siding meets trim, should be caulked.

- Whatever the material, seal the top and bottom pieces of trim to the nailing fin or window frame to prevent water running behind it, even if the wall includes a vented or ventilated rain-screen assembly.

- Don't let installers place siding directly on top of the head flashing, and never add caulk in this location. Space the siding off the flashing to achieve a gap of $\frac{1}{8}$ in. to $\frac{1}{4}$ in.; otherwise, paint can seal this water-drainage pathway.

Mineral Wool Makes a Comeback

This natural spun-stone insulation is enjoying a resurgence in popularity—and for good reason

BY MIKE MAINES

Mineral-wool insulation has been in use since the late 1800s, so it's nothing new. But as the market shifted in the 1960s to less-expensive and better-promoted fiberglass insulation, the mineral-wool industry shifted its focus to industrial and manufacturing applications, where mineral wool became a perfect replacement for the asbestos materials being phased out due to health concerns. Yet over the last 25 years, the cost of energy, the public's awareness of health and environmental impacts, and building-science research have led to a renewed interest in mineral wool for the residential market also.

It's not hard to see why mineral wool is regaining lost ground. It's got an R-value of 3.8 to 4.3 per in., it's chemically inert, it contains almost no VOCs, it's fireproof, it absorbs sound, and its embodied energy is lower than that of most petroleum-derived foams. Sold most commonly as batts, it's also available as boards and as loose fibers for blown installations, and it can be used in all the critical locations: walls, floors, ceilings, roofs, exteriors, and even below grade. It is vapor permeable—which has its disadvantages as well as its advantages—and is fairly easy to install well. In a category that has long been dominated by fiberglass batts, mineral wool is worth a fresh look. □

Mike Maines is a residential designer in North Palermo, Maine.

THE OPTIONS LOOK FAMILIAR



BATTS

Mineral-wool batts come in widths and thicknesses typical for residential construction, but only in 48-in. (or sometimes 47-in.) lengths, and never in rolls. Batts are formed slightly wider than typical 16-in. or 24-in. framing cavities to create a tight friction fit, and they don't move or change significantly over time or with changes in temperature. Mineral wool is dense, ranging from 2 lb. to 4 lb. per cu. ft. versus 0.4 lb. to 1.4 lb. per cu. ft. for fiberglass.



BLOWN

Mineral wool is available for blown installations either by itself as loose fill (generally for attics), or mixed with a binder and sprayed into framing cavities or onto foam as a fire retardant.

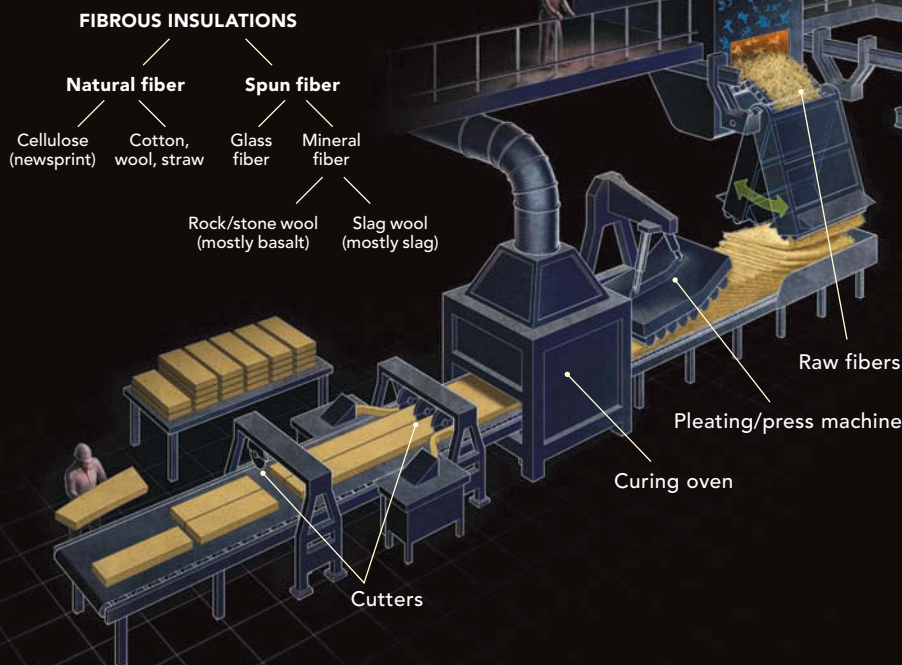


BOARDS

Mineral-wool boards are almost as stiff as rigid foam and are always about 48 in. long, between 16 in. and 96 in. wide, and between 1 in. to 3 in. thick. Denser than mineral-wool batts as well as rigid-foam boards, which have a density of between 0.75 lb. and 3 lb. per cu. ft., these boards range from 4.4 lb. to 8 lb. per cu. ft. (and up to 15 lb. per cu. ft. for commercial grades). They can be used both for interior and exterior applications.

YES, IT'S MADE OF ROCKS

Ranging from tannish-yellow to greenish-brown, mineral wool has a matted-wool texture that's coarser and denser than fiberglass, thanks to its main ingredient: rock. Part of the fibrous insulation family of products, mineral wool is made by spinning molten basalt and/or blast-furnace slag (a by-product of the processing of iron ore and other minerals) to form short, multidirectional fibers.



SUPPLY AND DEMAND Although more available than ever before, mineral wool still competes for shelf space. Batts are typically 60% to 70% more expensive than fiberglass, and boards are at least 80% more expensive than rigid-foam boards.

Johns Manville

Thermal batts (TempControl) and sound-control batts (Sound & Fire Block); no board insulation for the residential market
AVAILABILITY Widely available at Lowe's from the Southeast to the West Coast
COST PER SQ. FT. R-15 batts = 63¢

Owens Corning/Thermafiber

Thermal batts, also good for sound and fire control (UltraBatt); no board insulation for the residential market
AVAILABILITY UltraBatt distributed in the north-central United States through Menards.
COST PER SQ. FT. R-15 batts = 77¢ to 93¢, R-23 batts = \$1.08 to \$1.16, R-30 batts = \$1.53 to \$1.58

Roxul

Thermal batts (ComfortBatt) and sound-control batts (Safe'n'Sound) in widths designed for 16-in. and 24-in. framing cavities; board insulation (ComfortBoard IS insulating sheathing) in 1¼-in., 1½-in., 2-in., and 3-in. thicknesses, and in 24-in.,

36-in., and 48-in. widths (also available is the 1-in.-thick ComfortBoard FS firestop product, sold in 16-in. and 24-in. widths)

AVAILABILITY Batts commonly available nationwide; board insulation typically special ordered and only in large quantities, but internet retailer Small Planet Workshop stocks smaller quantities

COST PER SQ. FT. R-15 batts = 66¢ to 79¢, R-23 batts = \$1.00 to \$1.15, sound-control batts = 74¢ (3 in. thick), board insulation = \$1.80 (2 in. thick) and \$2.79 (3 in. thick)

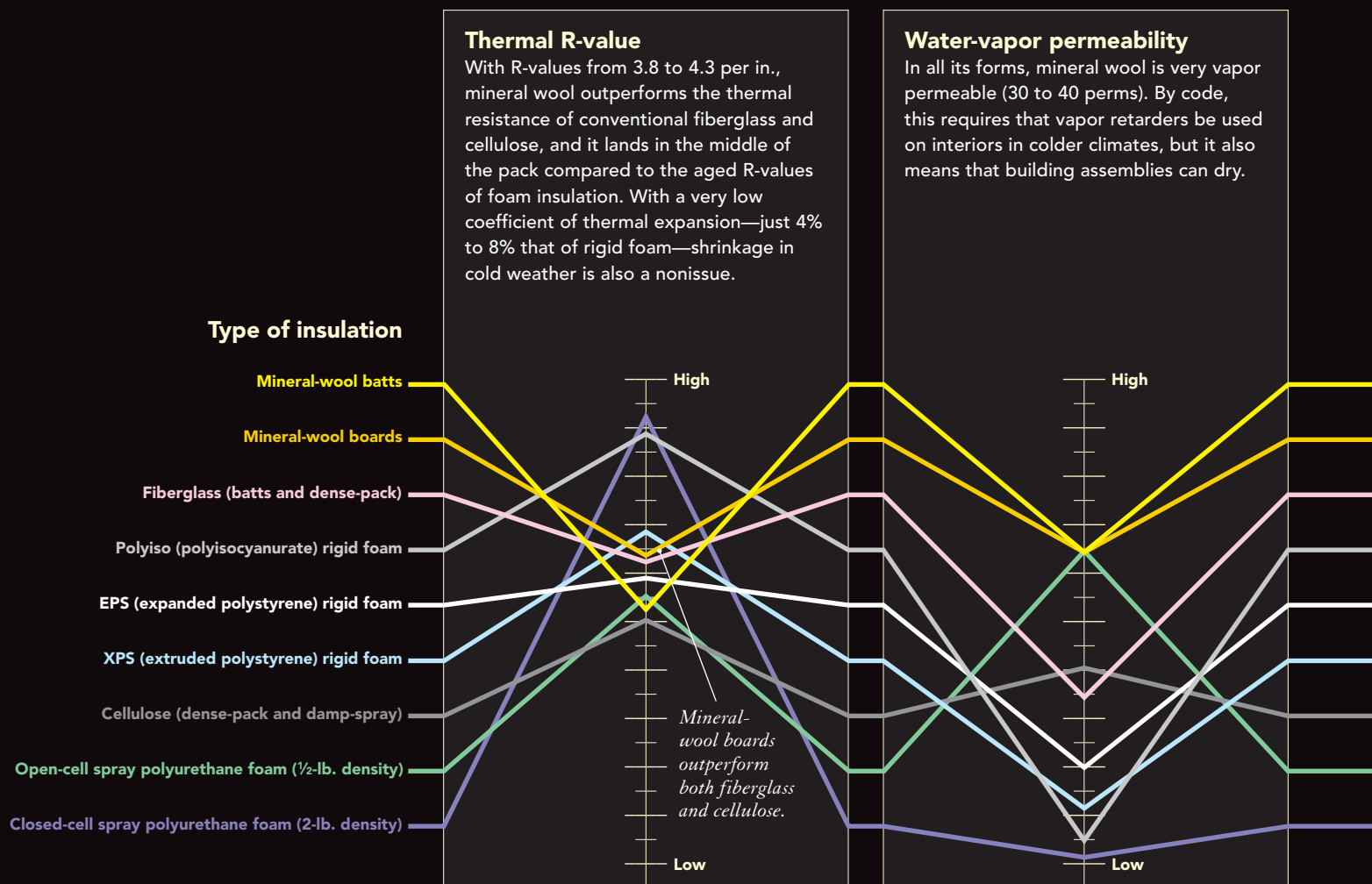
Amerrock

Loose mineral wool for blown installation (Rockwool Premium Plus) and FireStopTB sprayed thermal barrier; no boards or batts
AVAILABILITY Nationwide through insulation distributors, or direct from the manufacturer

COST PER SQ. FT. R-38 = \$2.40 installed (\$8.50 for a 30-lb. bag), which is about 30% higher than cellulose but less than half the cost of closed-cell foam

HOW MINERAL WOOL STACKS UP

Although it's not easy to do a direct comparison, mineral wool proves to be a strong



MORE POINTS OF COMPARISON

Health concerns

Although mineral wool is chemically inert and contains essentially no VOCs (the products with formaldehyde binders are cured before leaving the factory), respirators and other personal protective equipment are still recommended during installation, as with installations of other types of fibrous insulation. Some people find the fibers itchier than fiberglass, but others consider them less so. According to manufacturers, the fibers settle out of the air quickly due to their relatively heavy weight, so the itch factor may depend on the individual and whether the itch is from contact or airborne fibers. MSDS documents list mineral wool as “not classifiable as carcinogenic to humans.” Although products with a mineral-oil additive may create some smoke in the presence of fire, there is no danger of the thick, toxic smoke that accompanies burning foam.

Mold

As do the manufacturers of many building products, mineral-wool producers exercise care with the phrasing “does not support mold growth.” In other words, the insulation itself does not provide a food source for mold or other fungal growth, but if temperature and humidity levels are high enough, mold could still appear in framing cavities. In fact, one of mineral wool’s other markets is as a growing medium for plants.

TO OTHER TYPES OF INSULATION

contender in many areas.

Airflow resistance

Although dense enough that wind washing (diminished insulating value due to movement of air) is not a big concern for board products or in attics, mineral wool is still air permeable, and even when it's tightly fit, there still may be some gaps in the installation. For this reason, batts in framing cavities should be combined with some form of air barrier.

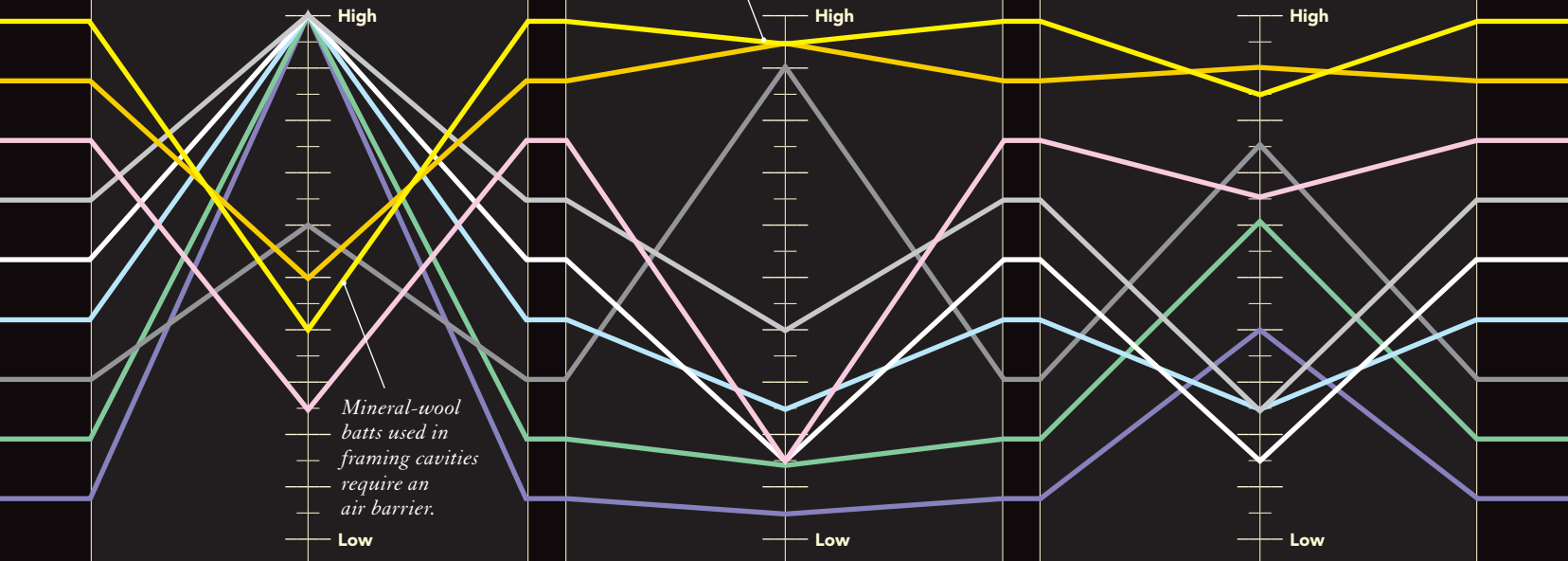
Fire control

Naturally fire resistant and noncombustible without relying on chemical additives, mineral wool has a melting point of over 2000°F and is code approved for use as both draft stopping and as fire blocking. Its flame-spread and smoke-development ratings are low to zero, depending on the specific product.

Mineral wool has a melting point nearly twice that of fiberglass.

Sound control

The physical characteristics of mineral wool make it excellent at absorbing sound. "Sound batts," made somewhat denser and in different sizes than batts intended solely for thermal use, can be installed in interior framing cavities to minimize sound transfer. Manufacturers note that mineral wool is only one part of a sound-attenuation strategy, though; for the best performance, refer to assemblies rated for sound-transmission class (STC).



Environmental impact

Considered green for its typically high recycled content (although some brands use all virgin material), fire resistance, low formaldehyde content, high thermal resistance, and vapor-permeable composition, mineral wool compares favorably to most other insulation products in terms of environmental impact. According to a Building Green report, mineral wool's lifetime global-warming potential is lower than that of most foam products and about the same as fiberglass. The only insulation material that scored significantly better than mineral wool was cellulose.

Liquid water

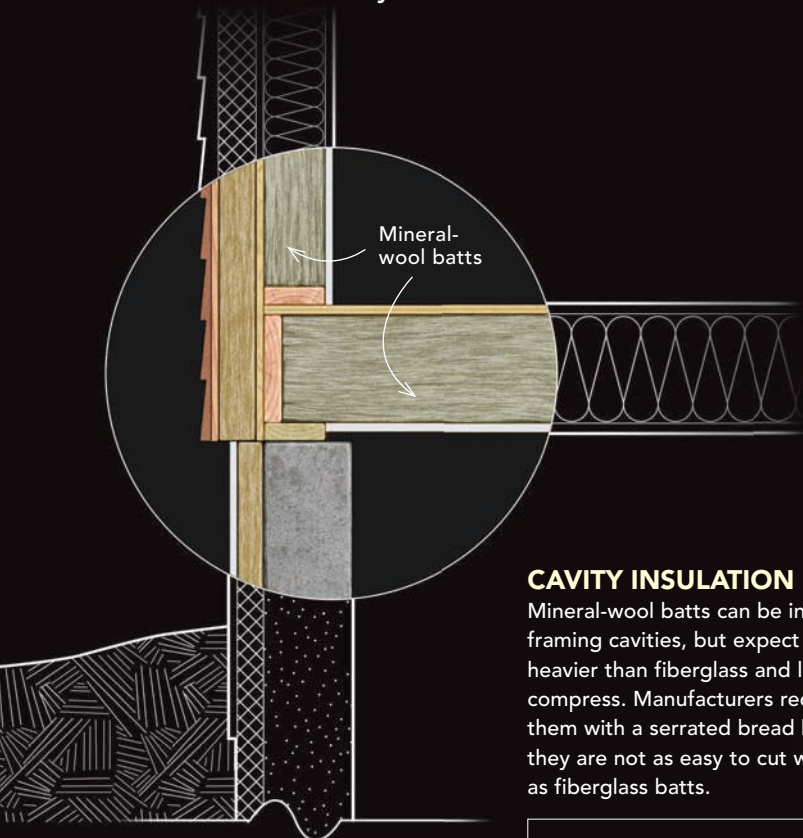
Thanks both to a light-bodied oil added during the manufacturing process and to the nonporous nature of its fibers, mineral-wool insulation is highly resistant to water absorption. Mineral-wool fibers are stocky, allowing liquid water to drain without harm, even in batt products.

Pests

Other than its density, there is nothing in mineral wool to deter rodents or insects, and birds have been known to nest in exposed exterior mineral wool. As with most types of insulation, care should be taken in other ways to keep pests out.

AT HOME IN MOST APPLICATIONS

Manufacturers and insulation contractors cite sound attenuation and fire safety as the two major reasons for using mineral wool, but the product has plenty of thermal advantages as well. Here's what you need to know about installing it in various applications.

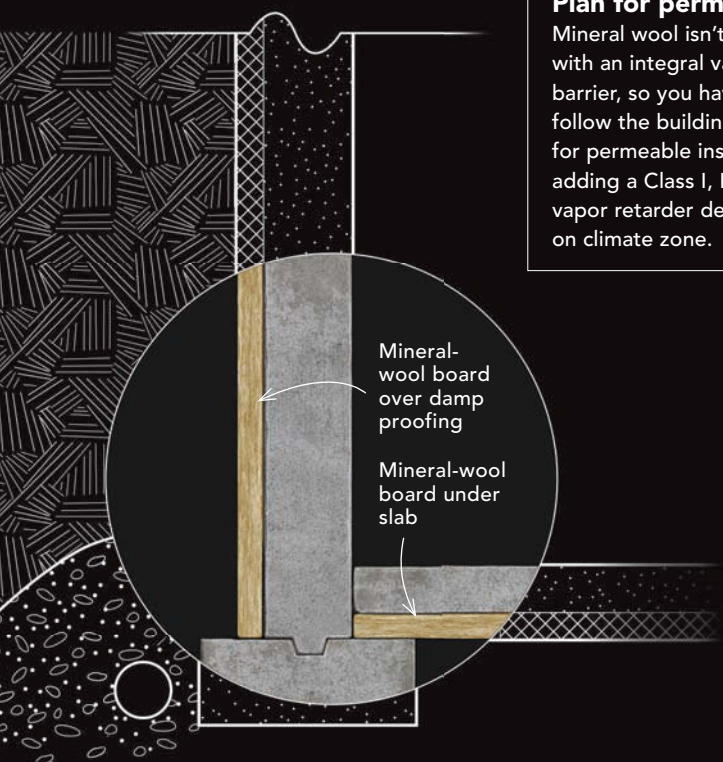


CAVITY INSULATION

Mineral-wool batts can be installed in framing cavities, but expect them to be heavier than fiberglass and less likely to compress. Manufacturers recommend cutting them with a serrated bread knife because they are not as easy to cut with a utility knife as fiberglass batts.

Plan for permeability

Mineral wool isn't available with an integral vapor barrier, so you have to follow the building code for permeable insulation, adding a Class I, II, or III vapor retarder depending on climate zone.



BASEMENTS AND FOUNDATIONS

When insulating first-floor joists, or the ceiling of a crawlspace or basement, keep the batts tight to the floor sheathing, and add a vapor retarder. Because of the risks involved, avoid using mineral wool or any permeable insulation on the interior face of a basement wall.

A study by the Danish Technological Institute found that mineral wool installed below grade remained effective and unaltered by compression over 30 to 35 years. Damp proof or waterproof the exterior face of the concrete before installing the mineral wool, backfill with well-draining soil and filter fabric, and extend the insulation to the top of the foundation wall. Cover it with cementboard, stucco, or another material.

Roxul's ComfortBoard IS is approved for use below slabs at non-load-bearing locations, but it is not approved for use under frost-protected shallow foundations.

Keep joints tight

Unlike foam (whose joints can be sealed with tape or spray foam) or faced fiberglass batts (which can be stapled into place), mineral wool relies on tight physical contact to avoid thermal "short circuits."

Plays well with others

Used regularly in flash-and-batt applications, mineral wool is a cost-effective companion to a thin layer of spray foam applied against the interior side of wall sheathing. This approach is also appealing for its acoustical performance, as closed-cell foam does little for sound control.

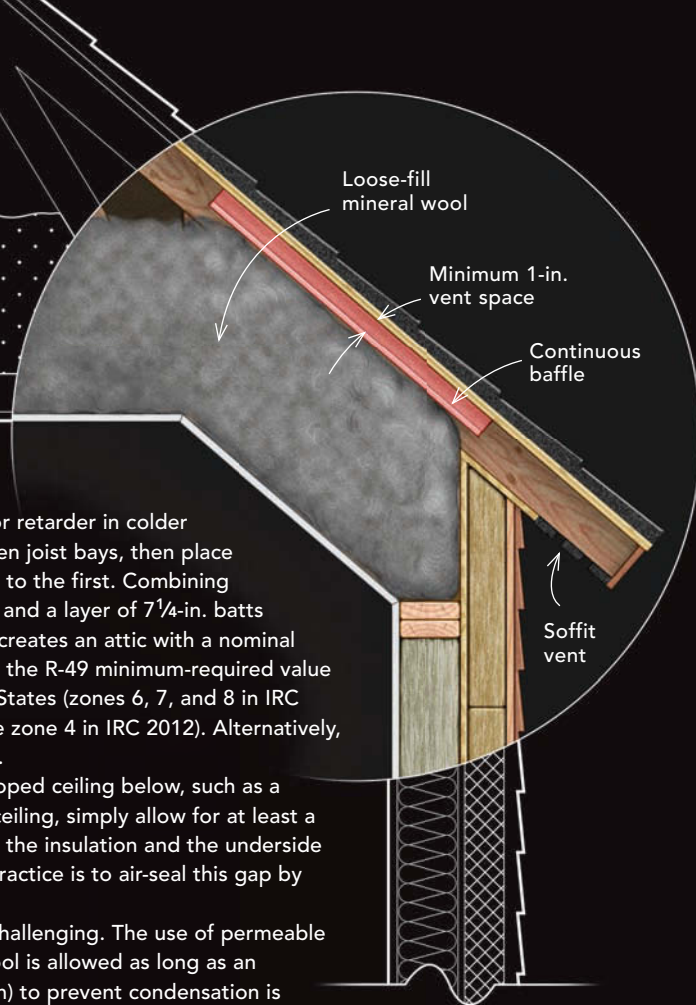


ATTIC AND ROOF

On attic floors (above a vapor retarder in colder climates), install batts between joist bays, then place a second layer perpendicular to the first. Combining a layer of 5½-in. batts (R-23) and a layer of 7¼-in. batts (R-30), with all seams offset, creates an attic with a nominal R-value of 53, which exceeds the R-49 minimum-required value for cold zones in the United States (zones 6, 7, and 8 in IRC 2009, plus zone 5 and marine zone 4 in IRC 2012). Alternatively, use the loose-blown product.

For a vented roof with a sloped ceiling below, such as a typical vaulted or cathedral ceiling, simply allow for at least a 1-in. gap between the top of the insulation and the underside of the roof sheathing. Best practice is to air-seal this gap by using continuous baffles.

Unvented roofs are more challenging. The use of permeable insulation such as mineral wool is allowed as long as an impermeable insulation (foam) to prevent condensation is installed either directly above or directly below the roof sheathing. Generally, a greater proportion of impermeable insulation is required the farther north you are.

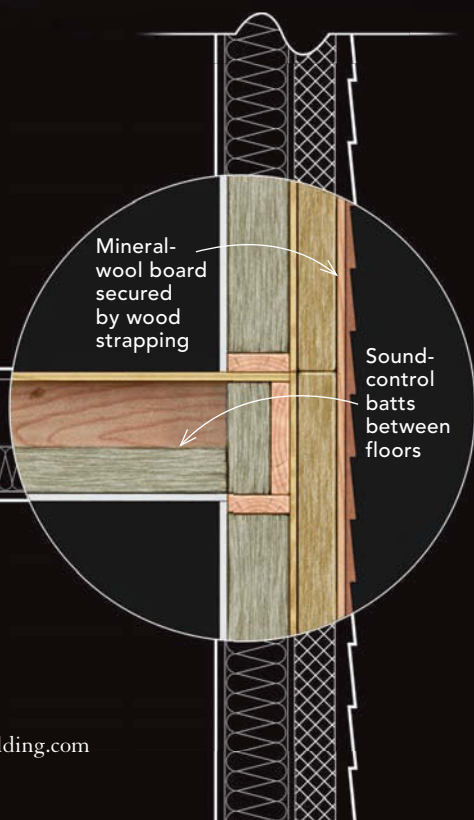


EXTERIOR INSULATION

According to Building Science Corporation, the water-resistive barrier (WRB) should go on the face of the sheathing when installing exterior mineral-wool board insulation. You also can use a sheathing with an integral WRB, such as Huber's Zip System product. The WRB or sheathing layer is also a good location for the air barrier in all climates as long as the framing cavities allow drying toward the inside (i.e., no closed-cell foam). It is also a good location for the vapor retarder, when required, as long as the proportion of exterior insulation to interior insulation keeps the vapor retarder above the dew point. Keep in mind that because of its lower R-value per inch, a thicker layer of mineral-wool board insulation is required to reach the same R-value as foam.

Heavy hanger

Although commonly attached like rigid foam—with screws driven through wood strapping—mineral wool tends to compress slightly, so creating a flat plane for siding takes finesse. HECO screws (smallplanetnetworkshop.com) designed to attach strapping without overly compressing the insulation is one option; thermally broken fiberglass standoffs to support strapping are another.





Air Sealing Basics

Look high and low to find and plug air leaks that cost you money and comfort

BY MIKE GUERTIN AND ROBERT SHERWOOD

While you might think that air leaks are a problem only with older houses, we've tested old homes that are pretty airtight and brand-new homes that leak lots of air. Air leaks occur wherever there is a joint, gap, or hole in the rigid building materials that enclose a house, such as wall sheathing, framing, and drywall.

Making an existing house more airtight is pretty straightforward: Find the holes and seal them up. Many air leaks can be found just by looking for spaces between framing and chimneys, electric boxes and drywall, and the mudsill and foundation. The fixes are often simple and use common materials—rigid foam, caulk, acoustical sealant, and spray foam—which are selected based on

THE PATH TO A TIGHTER HOUSE

HOW HOUSES LEAK AIR

Warm air rises, creating a zone of higher pressure at the top of a house that forces air out of any hole it can find. This escaping air creates a zone of lower pressure at the bottom of the house that sucks in air through holes and cracks. This is the stack effect. Sealing leaks at the top and bottom of the house is the most effective approach for stopping it. The colder it is outside, the stronger the stack effect, so air-sealing can have a big impact in cold climates (zones 4 to 8) and a lesser one in mixed climates (zone 3). It is not as important in warm climates (zones 1 and 2).

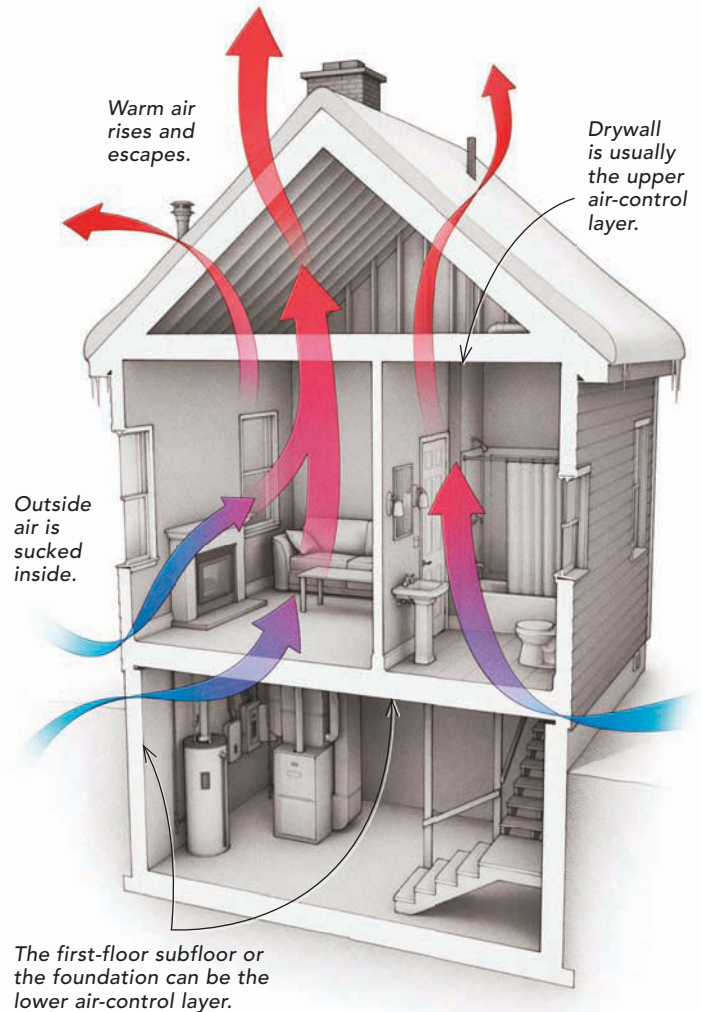
TWO TOOLS FOR FINDING AIR LEAKS

SMOKE GENERATOR

The Wizard Stick works like an old Lionel locomotive, generating vapor by heating glycerin. It runs on 6 AA batteries and costs \$25 from Amazon.com.

HOMEMADE BLOWER DOOR

Some scrap plywood and a \$150 fan create a blower door that's adequate for finding air leaks.



THREE MATERIALS FOR STOPPING AIR LEAKS

RTV SILICONE

Sold for use as an automotive sealant, RTV is rated to 650°F. It's more flexible than so-called fire caulk, which tends to dry and fall out, so it can be a good choice for use around chimneys. Small quantities can be bought at auto-supply stores, but for caulk-gun tubes, Amazon.com is a good source.

ACOUSTICAL SEALANT

Meant for soundproofing, acoustical sealant never hardens, and it accommodates the normal movement of building materials without cracking. You might have to go to a commercial drywall supplier to find it.

SPRAY FOAM

Ranging in price from about \$50 to over \$100, foam guns make applying spray foam easy. Cans of foam for guns come in several varieties, from minimal-expanding for use around doors and windows to gap-filling for higher-volume applications. It's widely available online and at lumberyards and home centers.



SEAL THE BASEMENT WALLS OR THE

Whether to seal the foundation walls and slab or the subfloor above depends on factors unique to each house. When the basement is conditioned, the foundation walls and slab must be sealed because even though they are underground, air still can leak through the soil. If there are insulated foundation walls or ducts in the crawlspace or basement, use the wall and slab as the air barrier. If the subfloor consists of lumber planks, which leak a lot of air, it's probably easier to seal the foundation walls and slab. Bulkhead doors to the outside are big leaks, but it still might be easier to install a weatherstripped and insulated door at the bottom of the stairs than to seal the subfloor above.



CONCRETE PENETRATIONS

Apply spray foam around sump-pump pits as well as where utilities such as water lines, waste pipes, gas pipes, and oil fills enter the space.



RIM JOIST

The rim joist is prone to air leaks from the multiple gaps: mudsill to rim joist, rim joist to subfloor, and butt joints in the rim joist itself. Install rigid-foam insulation in each joist bay, and seal its perimeter with spray foam.



MUDSILL TO FOUNDATION

Even mudsills set on foam gaskets have gaps. Seal the perimeter with caulk from either the inside or the outside.



BASEMENT WINDOWS

Basement windows are often loose-fit sashes in cast-in-place frames. Use foam gaskets and foam rod to block air leaks.



SLAB TO FOUNDATION

Seal this gap, as well as any cracks in the walls or floors, with masonry sealant.



CHIMNEY CLEANOUT

Seal the perimeter of the door to the frame with high-temperature silicone caulk. The sealant can be cut away and then replaced when the door is opened for cleaning.

BASEMENT CEILING

Use the first-floor subfloor as the air barrier if it's plywood or OSB, if the joist cavities are uninsulated, and if there are few ducts in the basement or crawlspace. If the basement or crawlspace is damp, has dirt floors, or has walls built of unmortared stone, air-sealing the subfloor helps control moisture. In houses with those issues and leaky board subflooring, seal the subfloor with several inches of spray foam. You may also need to dry out the foundation. In all cases, the door to the first floor requires weatherstripping.

TUB OR SHOWER DRAIN

Piece in rigid foam around the pipes, gluing it to the subfloor with caulk or sealant. Fill the gaps with expanding foam.



PIPE AND WIRE HOLES

Seal the space between the framing and the wire or pipe with foam or acoustical sealant.



DUCT BOOTS

Seal to the floor with foam or acoustical sealant.



CHIMNEY TO FRAMING

Bridge the space with metal. Fasten it to the framing, and seal it to the chimney with high-temperature sealant or fireblock caulk.



SUBFLOOR GAPS

Apply acoustical sealant or a flexible caulk to the joints.



the hole size and surrounding materials. The energy savings usually pay for the cost of air-sealing within a few years—almost immediately, in fact, if you do the work yourself.

Air-sealing keeps conditioned air inside the house, but it also improves the performance of insulation such as fiberglass, cellulose, and mineral wool by stopping air from moving through it. In addition, because moisture vapor piggybacks on leaking air, air-sealing reduces the possibility of condensation developing in building cavities, which can lead to mold and decay. It's also a first step to adding fibrous insulation to an attic in a cold climate. This type of insulation alone does not prevent warm, moist air from escaping the living space. Finally, air-sealing can block gasoline or CO fumes from an attached garage, or moldy air from a crawlspace. Air-sealing does make it more important to vent bathroom exhaust fans and clothes dryers to the outside.

Air moves in and out of houses due to pressure differences between the inside and the outside. The three main forces driving pressure differences are the stack effect, wind, and mechanical fans. Although wind and fans may be important drivers in warmer climates, the stack effect is often the dominant cause of air leaks in heating climates. The stack effect happens when warm air rises and escapes through holes high in the house, much like how a chimney works. Although it's a weak force, it operates constantly, so it can account for a lot of air movement and energy loss.

Determine your air barrier

Air-sealing starts with deciding which building planes to use as air barriers. A building plane can be the exterior sheathing, subfloor, or drywall. One way to visualize the air barrier is to look at a section drawing of the house and find a continuous line that encloses the living quarters. The insulation should directly contact the air barrier. Generally that means the air barrier is the drywall or sheathing along the exterior walls, the top-floor ceiling or roofline, and either the foundation wall and slab or the first-floor sheathing. Once you've identified the air barrier, look for leaks in it and seal them up, starting with the biggest ones in the attic and the crawlspace or basement.

Finding the holes

Although a visual inspection can find plenty of leaks, it's easier to pinpoint them by pres-

surizing or depressurizing the house and feeling for drafts with your hand or using a handheld smoke puffer. The smoke moves toward a hole if the house is being pressurized, or away from a hole if the house is being depressurized. It's better to pressurize the house when you are using smoke inside to find leaks, and to depressurize the house when you are using smoke outside the living space. Professionals use a blower door for this, a tool that combines a high-capacity fan with a fabric-covered frame that fits in an exterior doorway. A manometer attached to the fan measures the air-leakage rate of the house to predict its performance or to determine rates of air leakage and assess the progress of air-sealing work.

Blower doors cost about \$2600, though, and they aren't commonly available to rent. You can sometimes depressurize a house enough to find air leaks by turning on the exhaust fans, central vacuum, and clothes dryer all at once. But in very leaky houses, that may not create a noticeable pressure difference. Another option is a powerful (5000 to 10,000 cfm) drum fan. One can be had for under \$150 (I have a 24-in. shop fan from Harbor Freight) and can be fit into a piece of plywood that mounts to a door or window, creating a low-tech, homemade blower door.

Close all windows, doors, chimney dampers, and attic hatches to maximize the pressure difference. Exhausting air from a house may suck air down chimneys, so turn off combustion appliances such as gas ranges, furnaces, boilers, water heaters, or clothes dryers. Make sure that fireplaces or woodstoves have been out for 24 hours. Clean the ashes out of the firebox to avoid sucking them into the house, and wash potentially lead-contaminated dust from around windows in pre-1978 houses. If you have vermiculite insulation in the walls or attic or otherwise think there may be asbestos in the house, consult an asbestos-abatement specialist before doing any air-sealing. Remember to turn the appliances back on and to relight pilot flames when the work is done. □

Editorial adviser Mike Guertin is a contractor in East Greenwich, R.I. Rob Sherwood is a senior project manager with Conservation Services Group in Westborough, Mass. Photos by Andy Engel, except where noted.

SEAL THE ATTIC

In most homes, the drywall ceiling dividing the living space from the attic is the best air barrier at the top of the house. Seal leaks from above, and cover attic accesses such as stairs or scuttles with a foam box such as the Battic Door or ones available at home centers. We sometimes encounter ceilings covered with tongue-and-groove planks or acoustical tiles and no drywall behind them. These ceilings are nearly impossible to air-seal, so it's easier to seal these houses at the rafter plane by spraying a layer of foam against the underside of the roof and sealing off any attic ventilation. When there is no attic, such as with many sloped ceilings, the drywall still can be used as the air-control layer, but air leaks have to be sealed from inside the living space.



DUCT BOOT

Holes in the ceiling for duct penetrations are usually oversize and can leak significant amounts of air. Seal around them with spray foam or acoustical sealant.



RECESSED LIGHTS

These are notorious for leaking air. The first option is to replace a recessed can with an airtight model or a ceiling-mounted fixture, but you also can build an airtight box around lights that have thermal cutoffs as long as you observe the manufacturer-required clearances.



FRAMING AROUND CHIMNEYS

Insulate the space between the chimney and the framing with mineral wool, then bridge the space by bedding sheet metal in acoustical sealant and screwing it to the framing. Seal the metal to the chimney with RTV silicone or fireblock caulk.





DRYWALL GAPS

Added up, the gaps between the wall and ceiling drywall and the top plates can amount to a large open area. Seal gaps up to 1/4 in. with acoustical sealant and larger gaps with spray foam.



BALLOON FRAMES

Often found on gable walls, open stud bays can conduct air from inside the house into the attic even when they are filled with fibrous insulation. Block the bays with wood or rigid foam sealed to the framing.



UTILITY BOXES

Foam or caulk the gap between drywall and electrical boxes, duct boots, and bath fans. Seal holes in electrical boxes, or encase smaller boxes with expanding foam.



PENETRATIONS IN WALL PLATES

Fill holes in the plates and gaps around wires and pipes with spray foam or acoustical sealant.



CHASES AND SOFFITS

Large breaks in the ceiling drywall often occur at utility chases, at corbeled chimneys, and above soffits. Block these holes with rigid materials (foam, plywood, OSB, drywall), and seal them to the surrounding framing and drywall.



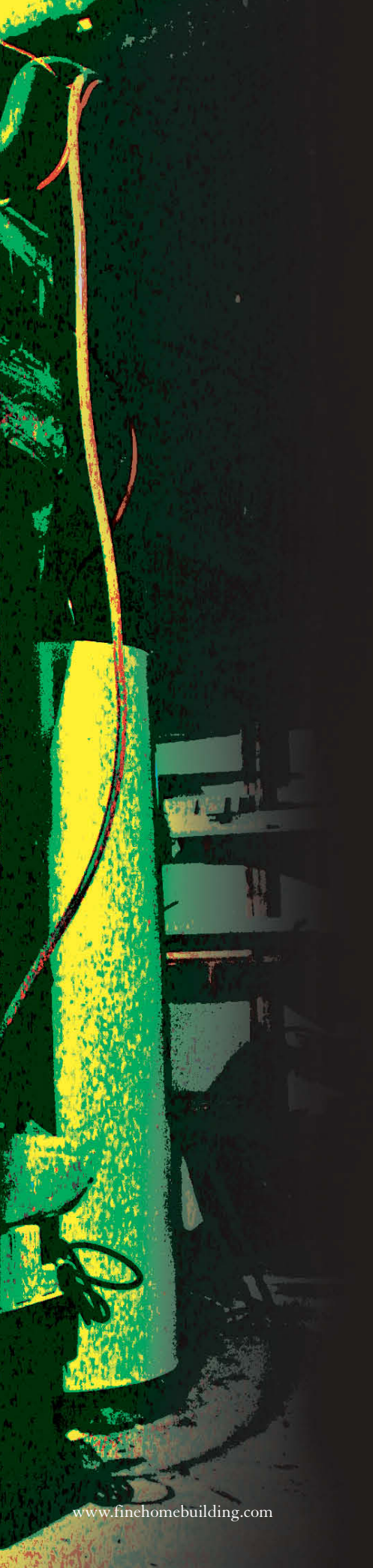
Dedicated combustion air. In tight houses, boilers and similar appliances should be supplied with air through a duct leading directly to the outside.

Can you make a house too tight?

After air-sealing, have a knowledgeable HVAC technician or energy specialist make sure that your house has enough fresh air for your combustion appliances. Air-sealing can tighten a house to the point where combustion appliances don't receive enough make-up air to perform well. Atmospheric combustion appliances can be a health hazard in a tight house. The exhaust gases from a fireplace, woodstove, furnace, or water heater can be sucked down the flue by exhaust fans. Combustion appliances, or the area they operate in, should be outfitted with air intakes ducted from the outside. Broan makes a motorized damper that can be wired to open when the boiler or furnace fires, providing combustion air when needed while otherwise keeping outside air where it belongs. Intake ducts can connect directly to the burner on some models.

Tight houses can suffer from poor indoor-air quality if water vapor, VOCs, CO₂, and odors build up. You may need mechanical ventilation to bring in fresh air and exhaust stale air. In a balanced ventilation system, fans draw in and exhaust air at the same rate. An improvement to a basic balanced ventilation system is to use an energy-recovery ventilator (ERV) or a heat-recovery ventilator (HRV), both of which transfer a large percentage of the energy from the air being exhausted to the incoming fresh air.





Getting to Know The Beast in Your Basement

A forced-air heating system
isn't as scary as it seems

BY MARTIN HOLLADAY

Many different appliances can be used to heat a house, including boilers, water heaters, heat pumps, and woodstoves. According to the Department of Energy (DOE), however, most homes in the United States are heated by forced-air furnaces.

A forced-air furnace is connected to ducts that deliver heated air to registers throughout the house. Different types of furnaces are manufactured to burn a variety of fuels, including natural gas, propane, oil, and firewood. The most common furnace fuel in the United States is natural gas.

Even though the smallest available furnaces are often too big for a high-performance home (see “Heating Options for a Small Home,” *FHB* #217), furnaces still have virtues that are hard to ignore. They are inexpensive, widely available, and easily serviced by local HVAC contractors. For many North American homes, they are a logical way to supply space heat.

A furnace is only as good as its installation, though, and research has shown that new furnaces and their distribution systems (ducts) often aren't sized correctly. According to a 2013 report prepared for the DOE, the problem is even more widespread when it comes to replacement furnaces. An oversize furnace often costs more than a right-size furnace, and improper duct installation results in reduced operating efficiency.

Efficiency drives the decision

When it comes to fuel efficiency, furnaces are grouped based on their annual fuel-utilization efficiency, or AFUE. These efficiency ratings are calculated using a laboratory method that tells you how much of the fuel going into the furnace is being converted to usable heat. AFUE is expressed as a percentage, and higher is better. Residential furnaces in the United States are divided into just two main categories: medium-efficiency furnaces (80% to 82% AFUE) and high-efficiency furnaces (90% to 97% AFUE). The

CHOOSE AN EFFICIENCY

Understanding AFUE

The efficiency of a furnace is calculated using a laboratory procedure that measures an appliance's annual fuel-utilization efficiency, or AFUE. This calculation tells you what percentage of the energy in the fuel is being converted to heat, so higher is better.

What's calculated

- Heat losses up the chimney
- Heat losses through the appliance jacket
- Heat losses due to on-and-off cycling

What's not calculated

- Electricity use (energy required to run fans and controls)
- Heat losses through ductwork connected to the furnace

Efficiency categories

75%

LOW

LESS THAN 75%

Although a low-efficiency furnace has traditionally been any model less than 75% efficient, the technology used in these older furnaces is now considered obsolete. The new minimum AFUE, mandated by the federal government, is 80%. Even though furnaces operating at low efficiency are no longer being manufactured, many are still in use throughout the country.

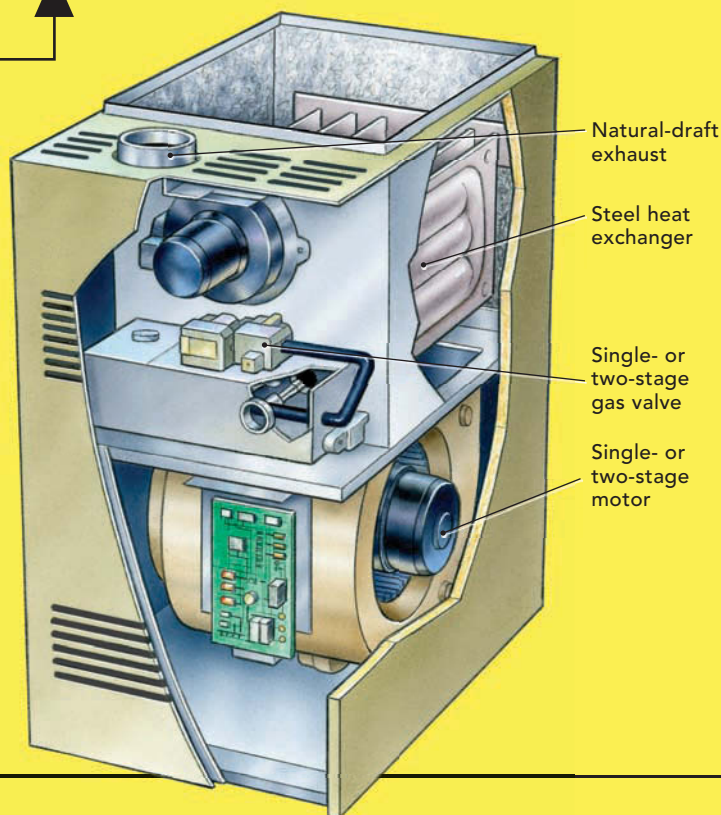
80%

MEDIUM

80% TO 82%

Single- or two-stage (sometimes called "standard") furnaces can be equipped with either a single- or a variable-speed blower. They usually have a steel heat exchanger and rely on a natural draft to create a flow of exhaust gases up a chimney.

85%



CHOOSE A TYPE

Single-stage These are the simplest furnaces because they only have one heat-output setting. If a furnace is rated with an output of 60,000 Btu/hr, that is the furnace's output whenever it is running, regardless of exterior temperature or differences in temperature in different parts of the house.

reason that you can no longer buy a low-efficiency furnace is that the federal government now requires residential gas-fired furnaces to have a minimum efficiency of 80%.

The line between medium- and high-efficiency furnaces isn't arbitrary or driven by marketing campaigns; it's a function of the inner workings of those furnace types. Medium-efficiency furnaces are designed

to keep flue gases hot enough to avoid condensation of flue-gas moisture, while high-efficiency furnaces deliberately encourage this condensation. Furnaces with an efficiency of at least 90%, sometimes known as condensing furnaces, draw so much heat out of the flue gases that the furnace exhaust can be vented through PVC pipe. PVC costs less than the stainless-steel pipe that would have

to be used to vent hotter flue gases at risk of depositing corrosive condensate.

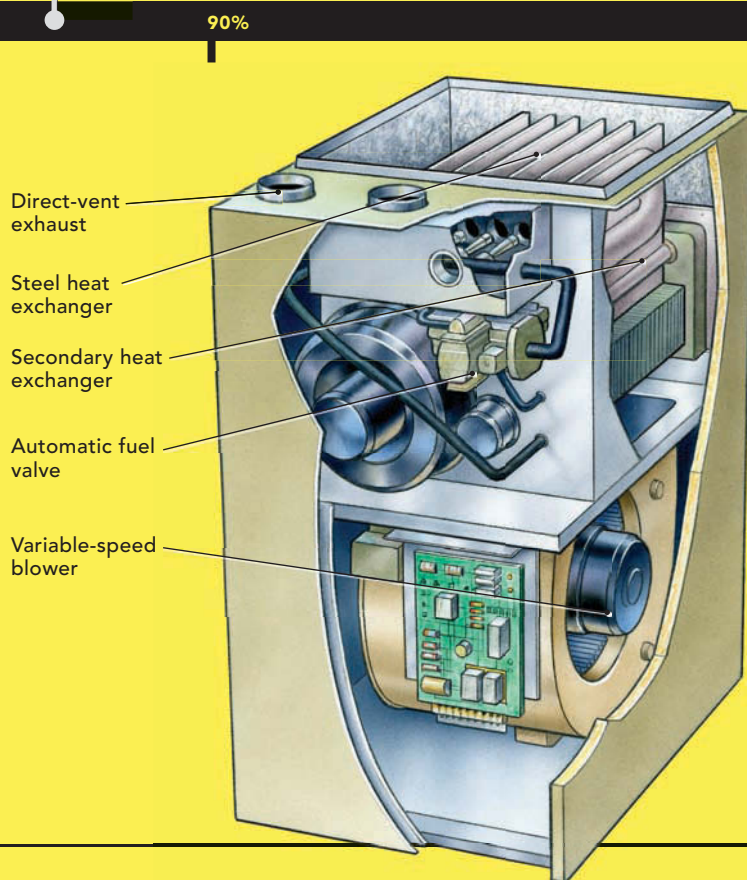
Single-stage, two-stage, and modulating furnaces

The simplest furnaces are single-stage models with single-speed blowers; they're either on or they're off. By contrast, two-stage furnaces can operate at two different output

WHAT ABOUT 83% TO 89%?

From a technological standpoint, it's difficult to manufacture a furnace with an efficiency rating between 83% and 89%, so none are available in that range. A furnace with this rating would have sporadic condensation of flue gases, which would lead to corrosion problems. You either want dependable condensation (so that it can be dealt with and the thermal benefits of it can be harvested) or no condensation at all (to avoid the need for a condensate drain). Any condensation requires

expensive features, including a method of collecting and disposing of the condensate; if the efficiency gains are small, the investment in these features isn't worth it. Also, very-high-efficiency furnaces with dependable levels of condensation lower the temperature of the flue gases to the point where PVC can be used as a flue; intermediate levels of condensation result in hotter flue gases, and hotter flue gases require a stainless-steel flue pipe, which costs more than PVC.



HIGH 90% TO 98%

These furnaces can be either single-stage or two-stage models, but most have a variable-speed blower. Also, in addition to the standard steel-tube heat exchanger, high-efficiency furnaces have a secondary heat exchanger, which condenses the moisture in the escaping flue gases, turning it from vapor to liquid and squeezing out even more available heat in the process. These furnaces require a drain hookup to dispose of the condensate from this process. So much heat is drawn out of the flue gases that the exhaust can be vented safely through a PVC pipe going out the wall.

Two-stage A bit more sophisticated than single-stage models, these furnaces can operate at two different output levels. Most of the time, they operate at a lower Btu/hr output—typically around 65% of full capacity. The higher output is needed only on the coldest days of the year.

Modulating These furnaces include an automatic fuel valve that varies the amount of fuel delivered to the burner. Since modulating furnaces can match the heating demand precisely, they provide heat more evenly than single-speed furnaces, which operate with a stop-and-go jerkiness.

levels—either a high or a low Btu/hr setting depending on the demand. This is helpful because most of the time, a furnace only needs to operate at a low Btu/hr output to do its job. The higher output is needed only on the coldest days of the year.

Slightly more sophisticated than two-stage furnaces, modulating gas furnaces include an automatic fuel valve that varies the amount

of fuel delivered to the burner. Many modulating furnaces also include a variable-speed blower motor—usually an electronically commutated motor (ECM)—that, like the automatic fuel valve, adjusts the airflow of the warmed air up and down in response to heating demand.

While it's fairly easy to design a gas valve that varies the amount of fuel delivered to

the burner, it's harder to design such a valve for delivering oil, so these furnaces are usually optimized for a single firing rate at a fixed Btu/hr output. That's why oil furnaces are usually single-stage furnaces.

Efficiency leads to direct venting

Condensing furnaces are power-vented, so they include at least two fans: an air-handler

GET YOUR DUCTS RIGHT

Choose the right ducts

Use rigid galvanized ducts wherever possible, and keep runs as short and straight as possible to enhance airflow. Flexible duct is hard to support and to keep straight, and its corrugations can cause turbulence that reduces airflow. Never use stud bays or other framing cavities as plenums to move supply air or return air. It's not only bad practice because it allows air to leak through miscellaneous gaps and cracks; it's also a code violation.

Plan for return air

Return air has to have a path from every conditioned room back to the furnace's return plenum. You can ensure this either by including grilles in every room that are connected to the return-air duct system, or by installing jumper ducts or transfer grilles to connect rooms without a return to those with a return. Avoid a single, central return-air grille, which can cause bedrooms with closed doors to become pressurized, forcing conditioned air into walls and ceilings. Size return-air ducts to be as large as or larger than supply-air ducts. When in doubt, make them bigger.

A central location is best

To make sure that duct runs are as short as possible, locate the furnace in the center of your basement or in a mechanical room near the center of your house. Both the furnace and the ductwork should be located inside of the thermal envelope, not in an unconditioned attic or crawlspace.

Seal everything

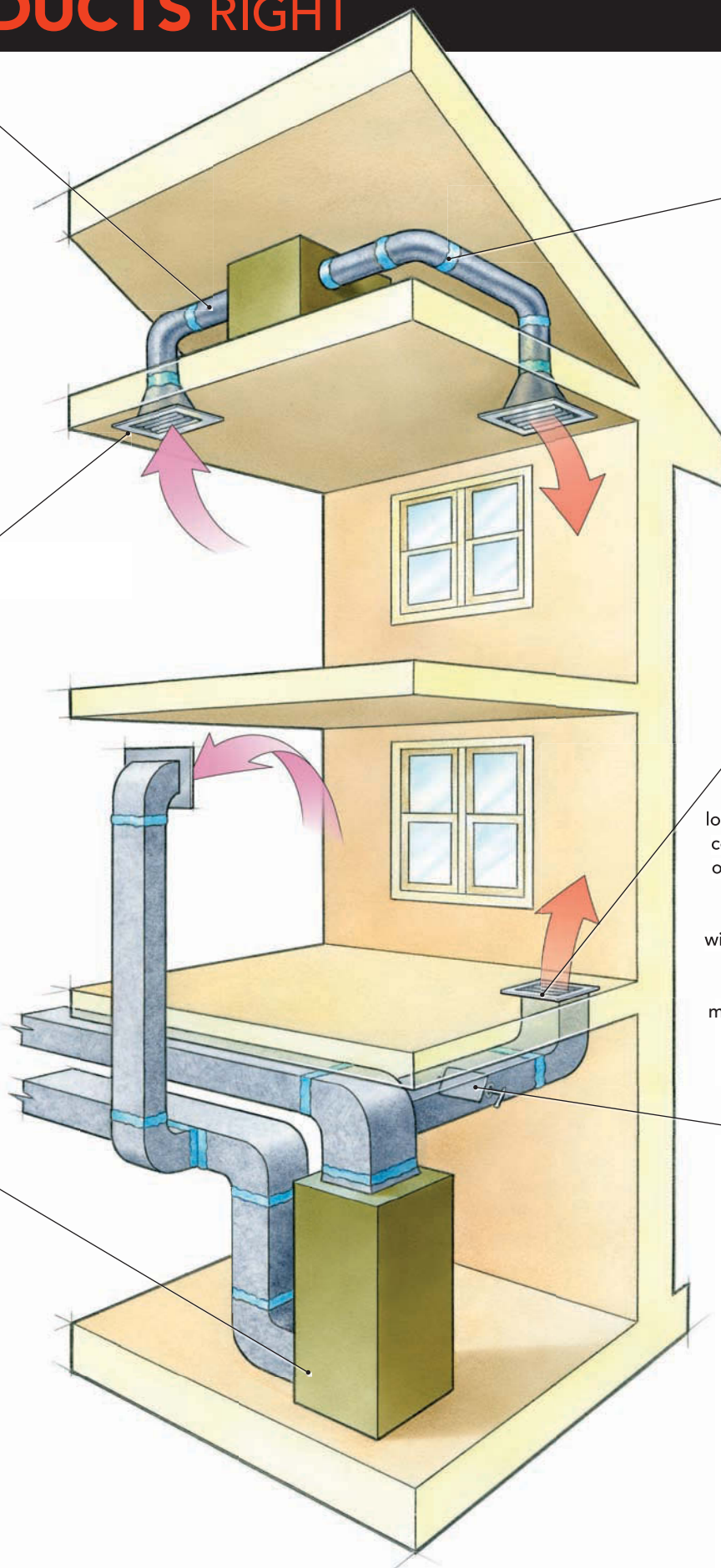
It's crucial to seal duct seams with mastic to prevent leakage, and you should apply foil tape or mastic to the plenum seams, too. If your furnace is located inside your home's conditioned space, these leaks may not matter very much, but if your furnace is located in a garage or vented attic, it can mean a substantial energy loss. Once sealed, the airtightness of the entire system should be evaluated with a Duct Blaster or similar duct-leakage tester.

Reconsider register placement

Although traditionally located near exterior walls to counteract the chilling effect of windows, supply registers can be placed on interior walls if high-performance windows have been specified and the house is tight and well insulated. This method means shorter duct runs that operate more efficiently.

Include dampers

Balancing dampers should be included on every branch duct running to a register to allow for airflow adjustments, a critical portion of the commissioning process.





A low thermostat setting may void your furnace warranty

fan that distributes warm air through the home's ductwork, and a power-vent fan to move exhaust gases through the flue pipe.

Most condensing furnaces are sealed-combustion furnaces, which means that the burners pull outside air into the combustion chamber through plastic ducts to feed the fire's needs. Sealed-combustion furnaces don't use any indoor air for combustion. The main advantage of a sealed-combustion furnace (compared to an old-fashioned atmospherically vented furnace) is that it is much less likely to suffer from backdrafting problems. Backdrafting occurs when a powerful exhaust fan—for example, a range-hood fan—depressurizes a house enough to draw combustion fumes down the chimney and back into the house. (For more information on this issue, see “How to Provide Makeup Air for Range Hoods,” *FHB* #232.)

Sizing matters

The most accurate method for determining the required size of a furnace is to do what's called a Manual J calculation. In its simplest form, a Manual J calculation takes into account the shape and orientation of a house, its insulation levels and airtightness, its square footage and surface area, and the various amounts of heat lost through all of the exterior surfaces. This information is then plugged into a Manual D calculation, which helps determine duct sizing.

Sounds easy, right? Well, it isn't. It can be difficult to find a residential HVAC contractor who is willing to perform Manual J, Manual D, or code-compliant alternative calculations, even though they're required by code. You should not assume that an HVAC contractor who agrees to do a “heat-loss calculation” will perform an actual Manual J calculation. (When in doubt, ask to see the paperwork.) Because heat loss and heat gain through building envelopes is governed by many factors, an accurate Manual J calculation requires many inputs, as well as dedicated computer software. Those who do perform the calculation need to be diligent and accurate about the details, because taking any guesses about building components and other fudge factors used to cover unknown defects in construction will push

heat-loss estimates higher, leading to furnaces that are oversize.

You could argue that a pinpoint-accurate Manual J isn't necessary when furnace-size options aren't that numerous, but it's not uncommon for rule-of-thumb calculations to miss the mark by more than a little. Even if you aren't sold on the idea of conducting an accurate Manual J calculation to size a furnace, you should consider one for the room-by-room calculations it provides, which are necessary to perform a Manual D calculation. Failure to take Manual J seriously means that Manual D calculations suffer.

The dos and don'ts of ductwork

During the 1950s and 1960s, fuel was so inexpensive that most heating contractors routinely installed ductwork without much attention to airtightness. In many areas of the country, contractors still install ductwork in vented crawlspaces or vented attics. These locations are outside of a home's conditioned envelope, and any air that escapes from leaky ductwork running through these areas is money wasted.

In the 1980s, energy-efficiency advocates responded to this issue with training programs to encourage HVAC installers to seal duct seams. After three decades of training, these programs are beginning to bear fruit in some areas of the United States. Unfortunately, the gospel of airtight ductwork hasn't reached every corner of the country, and many HVAC contractors are still installing ductwork the way their grandfathers did.

To make up for the fact that leaky duct systems waste large amounts of energy, many HVAC contractors install oversize furnaces with huge blowers. According to the DOE, 40% of contractors in one large-scale survey indicated that they purposefully oversized equipment, citing reasons such as “To reduce callbacks,” “To allow for future expansion,” or “Customers demanded it.”

Designing a duct system properly and installing it carefully costs more than doing sloppy work, but it provides two important benefits to homeowners: better comfort and lower energy bills. □

Martin Holladay is a senior editor.

Energy columnists routinely advise owners of vacation homes to turn down their thermostats when the homes are unoccupied. As it turns out, homeowners following this advice not only are at risk of damaging their furnace; they are also at risk of voiding their furnace warranty.

If you read the fine print on the installation instructions for Carrier condensing furnaces, to take one example, you'll find this statement: “This furnace is designed for continuous return-air minimum temperature of 60°F ... or intermittent operation down to 55°F ... such as when used with a night setback thermometer [thermostat]. Failure to follow these return air limits may affect reliability of heat exchangers, motors and controls.”

When I asked the Carrier Corp. whether setting one's thermostat to 50°F would void the warranty, the company had this response: “For optimal performance, Carrier Corp.'s 58MXB gas condensing furnace should be operated with return-air temperatures no lower than 60°F and no higher than 80°F. To support appropriate return-air temperatures, Carrier recommends that the 58MXB furnace be set within the range of 55°F to 80°F. Return-air guidelines and detailed operating instructions are included in the 58MXB owner's manual. Failure to operate the furnace according to the owner's manual could affect the furnace's reliability and void the factory warranty.”

The bottom line: Condensing furnaces are more efficient than noncondensing furnaces, but their efficiency comes with the added risk that low return-air temperatures can contribute to the condensation of corrosive flue gases in the primary heat exchanger.

Trouble Free Toilets

The floor, flange, and sealant can mean the difference between success and failure

BY MIKE LOMBARDI

I've installed, removed, and replaced more toilets than I care to count. In some cases, a toilet has to be replaced because the necessary repairs to the inner workings of the tank aren't worth the effort when compared to the cost of upgrading to a new fixture. There's not much I can do to predict how long these internal components of a toilet will hold up, but I certainly can ensure that the plumber or homeowner who pulls the toilet isn't faced with additional repairs to the bathroom. I've pulled lots of toilets that have been in service for 50 years or more yet had no evidence of wax-ring failure, leakage, or rot. The difference isn't in the quality of the toilet, but in the quality of the installation.

In my experience, the three essential aspects of a long-lasting and trouble-free toilet installation are a stable floor frame, a closet flange that's installed at the right height, and a bead of sealant or grout around the base of the toilet where it meets the floor.

Mike Lombardi is a plumber in Danbury, Conn. Photos by Justin Fink.



Hole centered on joist depth, with at least 2 in. above and below

Pipe slopes $\frac{1}{4}$ in. per ft.

$3\frac{5}{8}$ -in. hole for 3-in. PVC pipe

Closet flange

Street 90 elbow slides directly into closet flange, allowing for a compact change in direction.

Reinforcement may be required on 2x8 and 2x10 joists and often can be achieved with gussets or additional framing.

THE FLOOR FRAME MUST BE STABLE

From a framing perspective, there isn't anything special about the floor under a bathroom. If things go wrong, it's usually because somebody has reduced the strength of the floor by notching or drilling where they shouldn't, or because water damage has led to decay. Either of these problems will lead to movement in the floor, and that will affect the seal between the toilet and the closet flange.

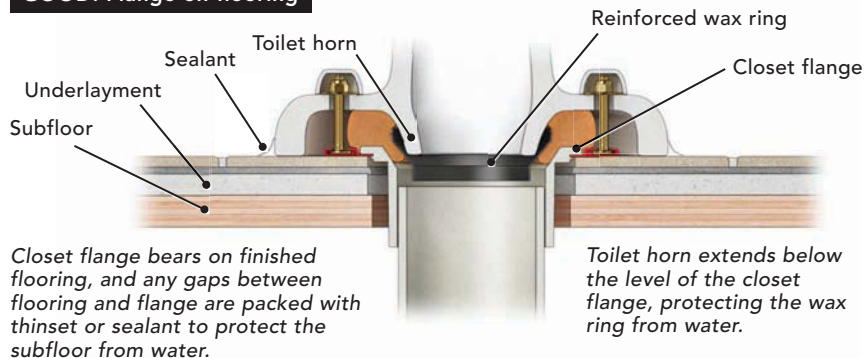
Assess the condition of the floor by looking for loose tiles or feeling for sponginess. If there's access, always go below and look up for notched or drilled joists or for softness in the wood, which indicates rot. If the subflooring around the flange is rotten, it's best to cut out the old closet flange—either from below using a reciprocating saw, or from above with a specialty tool such as the Flange-off (keco.com) or the Ram Bit (pascospecialty.com)—and replace it along with the section of flooring.

If you have to drill holes in the floor joists to route the waste line, do so through their center, and be mindful of the structural restrictions. Although not permitted by a strict interpretation of the building code, drilling waste-line holes through 2x8 and 2x10 joists is often approved by building inspectors if you agree to reinforce the joists. Reinforcement options include doubled joists, plywood gussets, angle iron, headers for transferring the load, and a support wall.

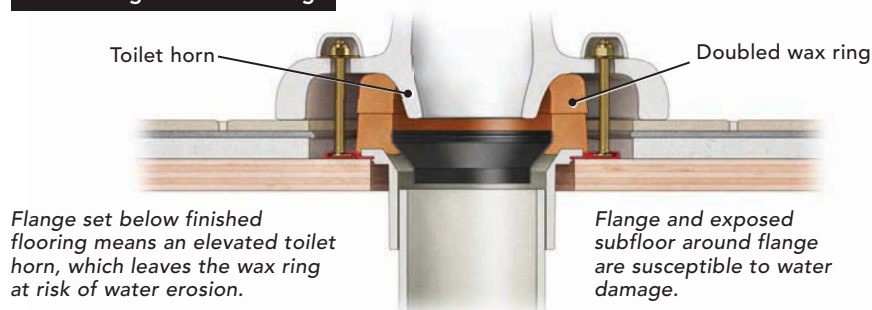
FLANGE OVER THE FLOORING

The underside of the closet flange should sit level and bear evenly on top of the finished floor. If new flooring has been added on top of the existing flooring, use spacer rings to extend the flange up. Although common, it's never OK to stack up wax rings to span the gap between a recessed closet flange and the horn of the toilet. A correctly installed wax ring is there to prevent sewer gas from entering the bathroom, not as a waterproof seal.

GOOD: Flange on flooring



BAD: Flange below flooring



FIX: For an oversize hole



DON'T SKIP THE SEALANT

Some plumbers argue that applying sealant where the toilet meets the floor will trap water and lead to rot if the wax ring ever fails. But sealant in this area is required by code, and for good reasons. The sealant prevents condensation on the outside of the bowl from wicking between the toilet and the floor, where it won't easily dry out. More importantly, it seals against soiled water following the same path if the toilet ever overflows. I always flush a newly installed toilet multiple times before sealing it to the floor with Phenoseal adhesive caulk.

All-Around



Pairing a proven net-zero strategy with conscious material choices

BY STEVE BACZEK

I see two paths to being green. (I don't like that term, but lack of a better one forces me to use it.) Path 1 is designing a typical code-built house and then applying a degree of recycled materials and site-generated energy in an attempt to make up for building-performance inadequacies. Path 2, my preference, is to integrate performance strategies with scrutinized building practices to develop a house where all the decisions are in harmony with each other. While energy efficiency is always a concern, conceptually I don't solve for it. I concentrate on durability, comfort, and health, making sure to align them with environmental responsibility, particularly in terms of material choices—and then energy efficiency comes along for the

ride. The result is a comfortable, healthy home that is durable enough to last a long time, that will remain a high-performance home for decades, and that will have a minimal impact on the environment.

I recently had a great opportunity to design a home in this way with Don and Amy Bowen. If you ask them to describe their lifestyle, you'll hear words such as *simple*, *environmentally thoughtful*, *minimalist*, *uncluttered*, and *free*—which is to say free from a burdened conscience, the trappings of high energy bills, and arduous home maintenance. They live this way in part to have the time and money to pursue their favorite leisure-time activities, but mostly because they are passionate about the fight against climate change.

Efficient



With that philosophy in mind, Don and Amy came to me. Their goals were clear: First, the house had to generate at least as much energy as it consumed. Second, all materials had to be considered for their environmental impact, including both their recycled content and their recyclability. Local materials were to be given the highest priority, and domestically manufactured materials were to be chosen before products from abroad. Third, the house had to strive for a nearly maintenance-free exterior.

The Bowens' passion for this house was personal. They were not interested in a plaque, so I didn't design the house to meet LEED or Passive House or any other standard. Despite that, it is easy to see the

influence that the LEED and Passive House standards had on the design. Meeting net-zero energy is a relatively easy concept to succeed at in theory: You build a house, determine the loads, and then design a PV system to balance them out. Although many find it as simple as that, my scrutiny extends a bit further. Developing a net-zero-energy home based only on the economics of energy used/purchased/generated is missing half of the equation. The home's performance should be elevated in an effort to reduce the burden of site-generated energy.

With the generating power of PV panels on the rise and their cost constantly being reduced, net-zero energy is becoming fairly easy

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A FORTRESS OF EFFICIENCY

POWERED BY PV The house creates enough energy through its 14.6kw PV system for the house, the studio, and the Bowens' two electric cars. The PV panels are set at 20°, which helps to prevent them from shading each other. The 3.5kw battery system stores excess energy for times when there's no other energy input. The low-slope roof provides a large field for the PV system. Its pitch is a hip-style configuration achieved with tapered pieces (1/4 in. per ft.) of rigid polyiso insulation.

DURABLE ENVELOPE

The Bowens wanted a low-maintenance building, so the cladding materials were chosen for their longevity. At the same time, their high recycled content reduces their environmental impact. Firestone Una-Clad aluminum trim coil, made from over 50% postindustrial material, was used for the fascia and soffits. The cladding is a combination of Reynobond, a composite material comprised of aluminum sheets thermobonded to a polyethylene core, and EcoClad XP, a highly durable, nontoxic material made from bamboo and recycled paper bonded together with a corn- and cashew-based resin.



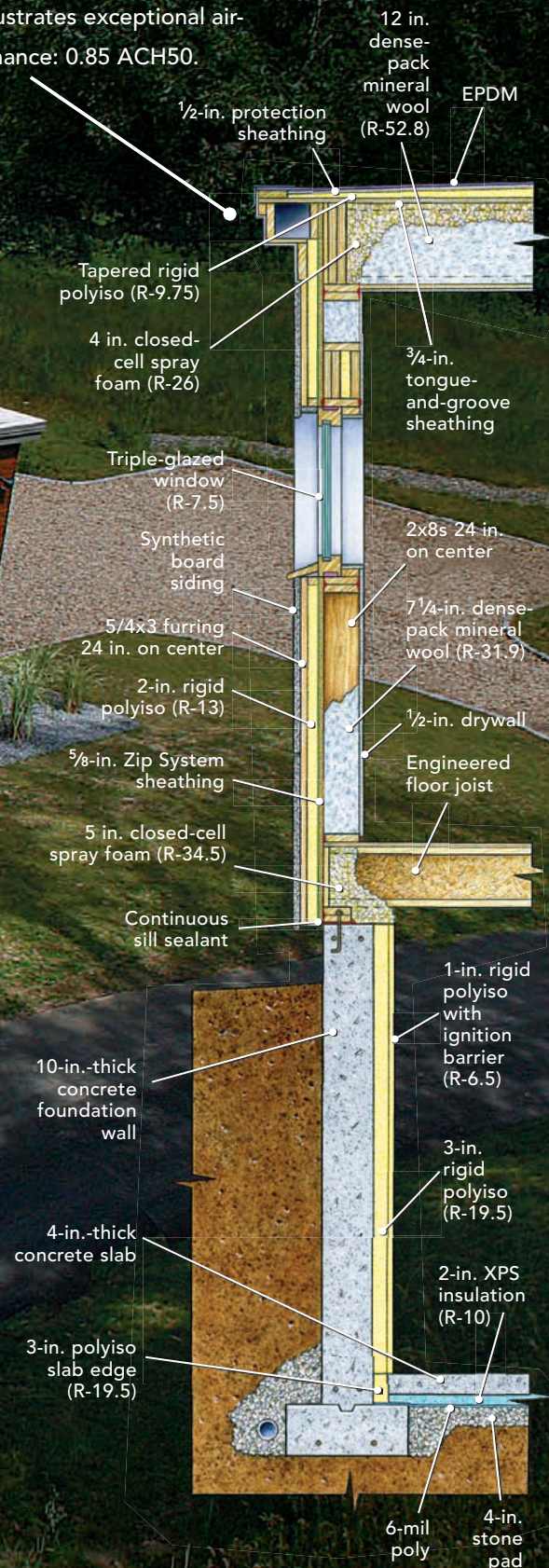
- 1 Entry
- 2 Office
- 3 Powder room
- 4 Kitchen
- 5 Great room
- 6 Porch
- 7 Dining area
- 8 Master bedroom
- 9 Master bath
- 10 Deck
- 11 Studio
- 12 Garage



A BACZEK WALL ASSEMBLY Basic framing can accommodate the goals of a performance wall. When you don't have to provide special instructions to the framing crew for an exotic wall assembly, that helps with time, energy, money, and accuracy. In all houses the author designs, he strives for exceptional airtightness. The goal of 1.0 ACH50 for this house, while not quite the 0.6 ACH50 of a certified Passive House, still illustrates exceptional airtightness. The final blower-door test revealed even better performance: 0.85 ACH50.

PERFORMANCE MECHANICALS

The house and studio both are outfitted with independent high-efficiency heat pumps, ERVs, and tankless water heaters.



Continued from p. 69

to achieve. That also means it's becoming easier to build a lower-performance house and throw a truckload of PV panels on the roof. While I could meet net-zero energy by building that way, I would not satisfy my basic tenets of shelter, in which comfort, health, and durability play the primary and decisive role in determining the right amount to invest in the home's performance.

Working with Don, who served as general contractor, I developed a Passive House-inspired design that guided us to a high-performance ideal. With the 10/20/40/60/5 insulating rule (R-10 underslab, R-20 basement wall, R-40 above-grade wall, R-60 roof, and R-5 windows) as a guide, I set out to design the building assemblies. The airtightness goal was the high-performance minimum of 1.0 ACH50, which is only slightly above the Passive House standard of 0.6 ACH50.

For health reasons and because we planned to use site-generated solar, we eliminated all combustibles and agreed to an energy-recovery ventilator (ERV) as part of our mechanical ventilation. For durability reasons, we eliminated thermal bridging and used a cladding system and rain-screen concepts to provide sound water management. Our assemblies were in pretty close alignment with the insulating rule, although because of certain framing-material choices, the R-values for the above-grade walls and the roof deviated somewhat. We also decided to elevate the R-value of the windows. The Bowens wanted a modern-looking house and the above-average amount of glazing that is part of that style. More windows mean less efficiency, however, so the R-5 window value needed to be elevated 150%. The final 10/26/45/88/7.5 design proved to be the best and most cost-effective assembly for lowering the home's energy load.

Net-zero energy—a unique challenge every time

The site was purchased in part because of its exposure. It is a large open lot with a tree-filled perimeter. The Bowens wanted from the start to have a low-slope roof, which proved advantageous for integrating a 14.6kw PV system ballasted with blocks to prevent penetrations in the roof. The house is set about 10° off due south to provide the desired views both to and from the house, but that doesn't hamper the PV system's overall production. With a low-slope design, the entire roof can have PV panels as long as none are shading any adjacent panels. This does mean giving up some of the roof area, but what remains still exceeds what would be achieved on half of a gable roof.

The house creates enough energy not only for itself but also for two electric cars. Coupling the PV system with a 3.5kw battery-storage system means that excess energy can be stored for times when there is no other energy input, such as in the evening or during power outages of up to 12 hours. Should the need arise for more storage capacity, extra battery units can be added to the existing system.

Recycled and resourceful material choices

Environmental impact drove all of our decisions. We balanced the presence of recycled content and the recyclability of the home's materials with the durability of those products; if a product has a life twice

THREE LEGACIES

Comfort, health, and durability should all be factors in the development of the net-zero-energy equation; actually, there is no excuse for these concepts not to be part of every decision we make in the building industry. They are legacies that will serve the main goal of building a house: to provide shelter that will be around for a long time without being a burden to the environment.

as long as an alternative, its environmental impact is halved. Flooring is locally sourced or reclaimed. Countertops are largely made up of recycled glass, and water fixtures are low-flow models. Because the Bowens did not want to provide any scheduled maintenance, the cladding materials were chosen for their longevity, and as it turns out, the metal panels and the plank siding have a high recycled content.

Always concentrating on durability, comfort, and health, I aligned environmental responsibility with each concept to ensure that our decisions kept us on the path to shelter that's built to last, which is still the greatest measure of green, whether I like the term or not. □

Steve Baczek is an architect in Reading, Mass.



SPECS

Bedrooms: 1, plus studio

Bathrooms: 3

Size: 2034 sq. ft., plus 320-sq.-ft. studio

Cost: \$265 per sq. ft.

Completed: 2015

Location: Hamilton, Mass.

Architect: Steve Baczek

General contractor: Don Bowen



Conscious choices. The kitchen features an EcoStone recycled-glass countertop and reclaimed beams from a barn in Falmouth, Maine. The flooring, which extends into the master bedroom, is locally harvested hickory finished with a water-based, no-VOC sealer. The glazing throughout the house is triple-pane Yaro windows (below).



A man with a beard and safety glasses is using a track saw to cut a piece of wood on a workbench. The saw is black and green, and the track is visible on the wood. The man is wearing a blue button-down shirt and khaki pants. The background shows a wooden wall and some outdoor equipment.

TOOL TEST

Track Saws

These versatile tools make fast, precise cuts and weigh a lot less than your tablesaw

BY DOUG MAHONEY

Clamp-free cutting. High-friction tape on the underside prevents the aluminum track from moving during straight and angled cuts. All track-saw manufacturers offer clamps for their tracks, but they're unnecessary for most materials.

Combining a plunge-cutting circular saw with an aluminum guide rail, track saws have gone from obscure woodworking tools to common job-site problem solvers in less than 10 years. Their unsurpassed accuracy, ease of use, and clean cuts make them perfect for cutting everything from veneer plywood for cabinets and built-ins to plywood and OSB for wall and floor sheathing. Track saws are also great for trimming doors and cutting off overhanging deck boards.

In the past, I used a regular circular saw along with a clamped straightedge for guided cuts. But after getting my first track saw four years ago, I find that method sloppy and tedious. On a conventional circular saw, the blade is seldom parallel to the edge of the base, so cuts are rough and sometimes burned. Track saws are built so that the track and the blade are parallel, resulting in accurate cuts free of burning and saw marks. In addition, the aluminum tracks have flexible edges that prevent splinters, so the cuts are smooth with little or

ALL THE SAWS SHARE THE SAME BASIC DESIGN AND OPERATION

Track saws have two components: a plunge-cutting circular saw and a track that's available in various lengths. The track has a flexible edge that aligns with the path of the blade to aid setup and to prevent splintering.



Cuts are precise. The track's flexible splinter guard follows the cutline exactly, so you don't have to compensate for the width of the saw's base, which speeds setup and reduces mistakes.



Bevel cuts are easy. Unlike with a conventional circular saw, the path of the blade isn't altered when a track saw is set to make a beveled cut. This makes a track saw the perfect tool for mitered corners on tapered columns, range hoods, and built-in cabinets made from sheet goods.



Plunge cuts are accurate. All the saw motors plunge by way of a spring-loaded hinge, so you have to push down on the handle to make a cut. This makes plunge and stopped cuts easy and accurate. Marks on the blade housing show where the blade is positioned within the housing.



no chipping. The improved quality of cut is especially noticeable on materials prone to chipping, such as melamine. Track saws also can plunge cut, which is more difficult and less accurate with a traditional circular saw.

I recently tested track saws from DeWalt, Grizzly, Festool, Mafell, Makita, and Triton. Surprisingly, most track-saw kits come with a single length of track that's only long enough for a 4-ft. cut. I think ripping a full sheet of plywood is an essential task, so I wanted 8 ft.

of track. Although a few manufacturers offer a single 8-ft. track, the hassle of transporting and storing such a large and easily bent piece of aluminum seems like an unreasonable burden. Instead, I prefer to make 8-ft. rips by joining two 4-ft. tracks with a manufacturer-provided connector. When offered by the manufacturer, this is the setup I requested.

One thing I learned during testing is that blade sizes vary slightly in diameter from model to model, so you should stick with blades made

THE BEST SAWS STAND OUT FOR THEIR USER-FRIENDLY CONTROLS



Enclosed blades, rising knives

The DeWalt, Festool, and Grizzly saws have rising knives to prevent kickbacks. All the saws have shrouded blades to aid in dust collection, which was effective on all models when connected to a vacuum.



TOOL TECH

To see a track saw in action, visit FineHomebuilding.com/extras.



Smooth sliding action

Adjustable with a top-side thumbwheel, cams ensure that the saw slides easily without wobbling on the track. Festool's adjustment system has large, low-friction pads for smooth operation. Other saws use small cams, which don't operate as smoothly.



by the saw manufacturer or confirm that a replacement is exactly the right size. I think it's a good idea to have extra blades on hand before you need them because track-saw blades can be hard to find at home centers and lumberyards.

How we tested

In addition to using the saws in my shop and on job sites for a variety of tasks, I ran them through a number of tests using the supplied

manufacturers' blades. I ran each tool through $\frac{3}{4}$ -in. melamine to judge the quality of cut through the material's brittle plastic-coated surface. As a power test designed to simulate how the saws would perform when trimming an exterior door, I cut through 2 ft. of 2-in.-thick oak. Finally, to assess the gripping power of each track, I ripped a $\frac{3}{4}$ -in.-thick piece of plywood at a 45° angle without using clamps. During all of these tests, I had the saws hooked up to a Festool CT 26 vacuum so I could assess their dust collection.



Score-setting for veneer

The Mafell, Makita, and Triton have a one-touch scoring feature that sets the blade to take a very shallow pass for clean cuts in difficult materials such as veneer plywood and melamine. The scoring feature is more convenient than setting the blade depth manually.



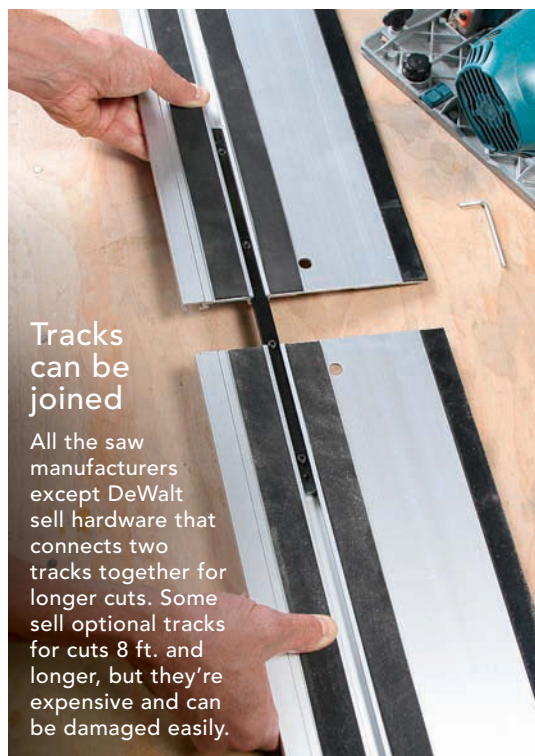
Safety brake

Festool, Grizzly, and Mafell have stop blocks that clamp to the track to prevent the saw from moving backward during plunge cuts. The blocks are preferable to Triton's and DeWalt's systems, which prevent the saw from moving backward at all times. DeWalt's can be turned off, but Triton's requires an override every time you reverse.



Easy blade changes

Pull the lever on the top of the Mafell, and it opens the blade cover and locks the arbor for easy blade changes. Although track-saw blades are close to 6½ in. dia., conventional 6½-in. circular-saw blades have a ⅝-in. arbor hole that's too small for a track saw's 20 mm arbor.



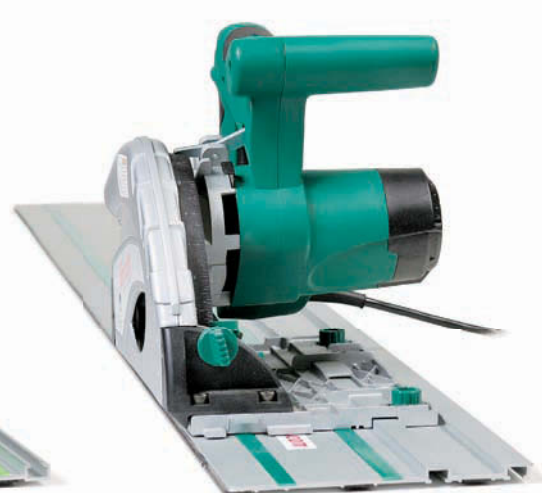
Tracks can be joined

All the saw manufacturers except DeWalt sell hardware that connects two tracks together for longer cuts. Some sell optional tracks for cuts 8 ft. and longer, but they're expensive and can be damaged easily.

Standard features

The six saws I tested all share a few features. Each baseplate has a set of cams that snug the saw to the track, eliminating any side-to-side movement, and every saw has a thumb-operated safety trigger that needs to be engaged before the sawblade will spin and the housing will plunge. Bevel adjustments are similar to those on a regular circular saw, but the baseplates are engineered so that the track always aligns with the blade regardless of the bevel angle. Beyond these con-

sistencies, I was surprised how the features and safety mechanisms varied from saw to saw. Many of the saws have some means of preventing kickback during plunge cuts. The DeWalt and the Triton have a setting on the base that allows the tool to move forward on the track but not backward. Festool's stop block prevents the saw from moving backward during plunge cuts. Grizzly includes a similar device in its accessory kit, and Mafell sells a similar device as an accessory (\$23). The DeWalt, Festool, and Grizzly saws have a riving



DeWalt DWS520CK

The DeWalt's track is the only one with a splinter guard on both sides, so I didn't need to constantly flip the track, an advantage when working in tight quarters. The DeWalt is also the only saw that uses a linkage connection rather than a single pivot point for the saw's plunge mechanism. This means you have to push the handle forward as well as down to make a cut. I found it tricky to make this motion with one hand. In addition, the depth-of-cut dial is too small and is difficult to operate with gloves on. Unfortunately, DeWalt does not sell a track connector, so for cuts longer than 4 ft., the only option is to get a 102-in. track. The DeWalt is built tough, but ergonomically, it's not the strongest of the bunch.

Festool TS 55 REQ

Perhaps it's not surprising that the Festool is the track saw I see most often on job sites. This tool is the complete package of power, precise cutting, and easy adjustments. In a single pass (without scoring), it left a nearly perfect edge when cutting melamine. In the power test, the motor maintained a constant speed while slicing through the thick oak. The depth-of-cut adjustment is excellent, and the track has a thick and effective splinter guard. The Festool also has great dust collection. The depth scale is in metric, but Festool includes a sticker with Imperial measurements to place over the millimeter scale. Power, ease of use, and overall cut quality made this tool stand out above the rest.

Grizzly T25552

The least expensive track saw I tested, the Grizzly has enough power and ability to get basic tasks done at a decent level of quality. The simplicity of the tool makes it easy to use, but it has the smallest motor of all the saws and lacks both variable speed and a soft start. It's also not a very comfortable saw to use. The safety switch is tough to reach with your thumb, and the plunge mechanism has a very strong spring that makes cutting tiring. Also, when I tried to dial in a specific angle, I found the bevel markings to be unclear. The dust collection was good but not great. For occasional use, this tool will get the job done, but if you plan on using your track saw often, it's worth upgrading.

Model	Base cost	What you get	Weight	Riving knife	Anti-kickback
DeWalt DWS520CK	\$613	Saw, 59-in. track, 102-in. track	11 lb., 8 oz.	Yes	Yes
Festool TS 55 REQ	\$640	Saw, 55-in. track	10 lb., 1 oz.	Yes	Yes
Grizzly T25552	\$245	Saw, 55-in. track, clamps, connector	10 lb., 9 oz.	Yes	Yes
Mafell MT55cc	\$836	Saw only	10 lb., 2 oz.	No	Yes
Makita SP600J	\$406	Saw, 55-in. track	9 lb., 6 oz.	No	No
Triton TTS1400	\$300	Saw only	11 lb., 9 oz.	No	Yes

knife to keep the blade from binding while cutting. The knife deploys when the blade is plunged into the material.

Depth-of-cut adjustments

With all of the saws, the depth-of-cut adjustment is more precise than you'll find on a regular circular saw. On the high-end track saws (Festool and Mafell), the adjustment is made by squeezing the depth stop and sliding it up and down the gauge. The rest of the saws use

locking dials. The squeeze adjustment is more ergonomic and more precise. The dials can be tricky, especially when the depth of cut is bottomed out and the dial is hard up against the saw's baseplate and bevel gauge, leaving little room for fingers. One feature I especially like—which can be found on the Mafell, Makita, and Triton saws—is the setting for making a shallow scoring cut. Using the scoring setting before making a full-depth pass creates a much cleaner edge on finicky surfaces such as melamine or veneer plywood. While all of the



Mafell MT55cc

The Mafell backs up its high price tag with precise adjustments, easy-to-read gauges, and the simplest blade change I've seen on any circular saw: Pull a lever, and the entire blade shroud pops open. The Mafell track is only 5 in. wide—over 1½ in. narrower than the rest—so it's easy to work with narrow material. Using the scoring feature, the Mafell made a perfect cut through the melamine and, like the Festool, kept constant power while cutting the thick oak. On the downside, the Mafell doesn't have a front handle, which I kept trying to reach for, especially when cutting at an angle. Overall, the Mafell is a nice tool with superior dust collection, but I wish it had a front handle for better control.



Makita SP600J

The Makita's handles are comfortable, and the plunge spring offers just the right amount of resistance. The thumb safety switch is the easiest to use, and I like how the saw's base locks into the track for added stability during beveled cuts. When I used the scoring setting, the Makita made an almost flawless cut in the melamine. The dust collection was also very good. The Makita weighs at least ½ lb. less than the other saws and easily plowed through ¾-in. plywood; however, it struggled a little with the thick oak, leaving burn marks as it cut. I was surprised to see that the depth-of-cut scale is in millimeters. Because it was so comfortable and easy to use, though, the Makita was my favorite midpriced saw.



Triton TTS1400

The Triton toggles easily between cutting, scoring, and blade-change mode. It also has an anti-kickback mechanism and can lock into the track—handy for steep bevel cuts—with the turn of a dial. Unfortunately, when using the scoring function, I could never get the second cut to line up perfectly with the first. I also didn't like how the kickback stop needed to be manually overridden every time I slid the saw backward. It's especially tedious because the knob is located in a hard-to-reach spot under the motor. The Triton has a good selection of features, but its overall design makes it a difficult and frustrating saw to use. On the plus side, it's the second-least-expensive saw in the test.

Depth of cut	Amps	Bevel	Scoring feature	Setup for 8-ft. rips	Connectors	Available track lengths (in.)
2½ in.	12	0° to 47°	No	\$613	Not offered	59, 102
2 in.	10	-1° to 47°	No	\$787	\$18	32, 42, 55, 75, 106, 118, 197
1½ in.	9	0° to 45°	No	\$295	Included in kit	55
2 in.	10	-1° to 48°	Yes	\$1211	\$76	32, 43, 63
2½ in.	12	-1° to 48°	Yes	\$520	\$27	55, 118
2½ in.	12	0° to 48°	Yes	\$400	In optional \$100 kit	59, 27.5

saws can be set manually to scoring depth and then reset to the cutting depth, the ability to toggle between the two settings saves time.

The bottom line

The saws are priced at three levels. At the top (about \$800 and up for a setup for 8-ft. rips) are Festool and Mafell. These two saws stood apart from the rest due to the smoothness of their motors, excellent dust collection, and overall build quality. The middle range (about

\$400 to \$620) includes saws by Makita, DeWalt, and Triton. I had some issues with the Triton, but even though the DeWalt and Makita are missing some of the finer points found on the upper-tier tools, they would both perform admirably on a job site. The Grizzly costs roughly a quarter of the most expensive saw, so it's no surprise that it lacks the features of the other saws and has poor ergonomics. □

Doug Mahoney is a carpenter in Harvard, Mass.

Mudroom's the name—organizing's the aim

We all have things that we drag in and out of our homes just about every day: coats, purses, mail, shoes, sports equipment, books, backpacks. Without a mudroom—that dedicated space between the house's entry and the rest of the rooms—the essentials that accompany us each day can end up being strewn throughout the house. Kitchens, family rooms, and hallways all become drop-off zones. The resulting clutter throughout the house is unsightly, but what's worse is trying to remember where you left your shoes, keys, and cell phone the night before when you're running 10 minutes late.

Originally designed as a place for removing wet coats and dirty shoes, mudrooms have evolved to handle much more. Mudrooms come in all shapes and sizes, and many are now custom-designed to meet the specific needs of the homeowners. But all good mudrooms have what it takes to stand up to daily use: durable yet easy-to-clean flooring; sturdy cabinetry; ample racks and hooks for hanging clothing and backpacks; drawers and cubbies; and a place to park a package temporarily or to sit while putting on or taking off shoes.

The mudrooms pictured here show how beauty combined with purpose helps to ensure a well-organized household.



A MUDROOM WORTH FLIPPING FOR

Renovations to this 1926 stone Tudor-style home included a 90° flip of what was once a steep, narrow back staircase. This change allowed for optimum use of the space for the kitchen, the dining room, the mudroom, a storage area, and a dog-washing area while staying within the existing footprint of the house. To complement the Benjamin Moore Knoxville Gray walls, the custom cabinetry, trim, and beadboard were painted with Benjamin Moore Simply White. The cubbies' bench is walnut, and the stair treads and handrail are oak. The Belgian-bluestone floor, which is easy to clean and maintain, completes the crisp, clean look of the back entry.



To view or post projects,
click on the Gallery tab at
FineHomebuilding.com.

Design Period Architecture Ltd., Chadds Ford, Pa.; periodarchitectureltd.com

Construction E.C. Trethewey Building Contractors, Downingtown, Pa.; ectbuilders.com

Photograph Angle Eye Photography, angleeyephoto.com



SHOES AND SPORTS STORAGE FOR SIX

This mudroom was designed to meet the needs of an active family of six. While the family members enjoy all seasons and sports, they are most enthusiastic about cold-weather activities, especially hockey. The “hockey locker” portion of the mudroom stores all their gear in one convenient place. Rows of adjustable, angled shelving in the adjacent area keep everyone’s shoes ready and easy to locate. Once shoes have been stored in their designated spot, the radiant heating installed under the Belgian-bluestone floor keeps toes toasty warm. Painted poplar was used to construct the shelving.

Architect Archer & Buchanan Architecture, West Chester, Pa.; archerbuchanan.com

Builder Norcini Builders, Devon, Pa.; norcinibuilders.com

Photograph Tom Crane, Tom Crane Photography, tomcranephotography.com



MAIL CALL AND MORE

The owners of this beach home requested that their mudroom not look like a mudroom. Family members and guests see nothing but a row of closets opposite a welcoming bench. Behind the closed doors are cubbies, shelves, and sections for hanging garments. At the far end is a telephone and mail station. Behind the station’s upper doors are cubbies for sorting the mail; the lower portion of the station houses a recycling drawer for junk mail. Dark-brown corkboard was used for the station’s backsplash, and the counter is solid mahogany with a natural satin finish. Closets and cabinets are furniture-grade prefinished maple plywood with solid paint-grade poplar doors. Flooring is 12x12 gray ceramic tile.

Cabinet design Jennifer Burr, Simmons Quality Home Improvement, Clinton, Conn.; simmonsquality.com

Construction Simmons Quality Home Improvement

Photographs Craig Freeman, craigfreemanphotography.com, courtesy of Simmons Quality Home Improvement



askthe experts

YOUR QUESTIONS—PRO ANSWERS



experts

Senior editor **Andy Engel** is a former carpenter and builder as well as the author of two Taunton Press books: *Building Stairs* (2007) and *Carpentry Complete* (2012).

Editorial adviser **Mike Guertin** is a builder and remodeler who has written over 100 articles for *Fine Homebuilding* and appeared in dozens of videos.

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Ceiling-fan height



Q Is it OK to install a ceiling fan in a 12-ft. by 17-ft. living room with an 8-ft. ceiling?

—ALAN
via email

A I grew up in a house with 7-ft. 6-in. ceilings. There was a ceiling fan in the living room that, for obvious reasons, we called the “guillotine fan.” I don’t know how many times I stuck my arm into that beast while putting on a jacket. That said, I couldn’t find a code reference for a minimum ceiling-fan height from the floor. Online sources say there should be at least 7 ft. from the blades to the floor and that more is better. While not ideal, there are many houses with both 8-ft. ceilings and ceiling fans. Follow the manufacturer’s instructions, and choose a low-profile model to preserve as much clearance as possible. —*Andy Engel*

Adding walls on I-joists



Q I want to finish the basement of a home I recently purchased. The first floor is built with I-joists, and I’m wondering if I can attach the top plates of the new basement walls to the flanges of the joists. Will that compromise the strength of the I-joists?

—TONY HILL
Middletown, Del.

A Yes, you can secure the new framing to joists without weakening them. Carefully drive the nails near the middle of the flange; nailing too close to the edge could split it. To further reduce the chance of splitting, use smaller diameter nails (0.131 in. or less), driving no more than two nails into each joist. —*Mike Guertin*

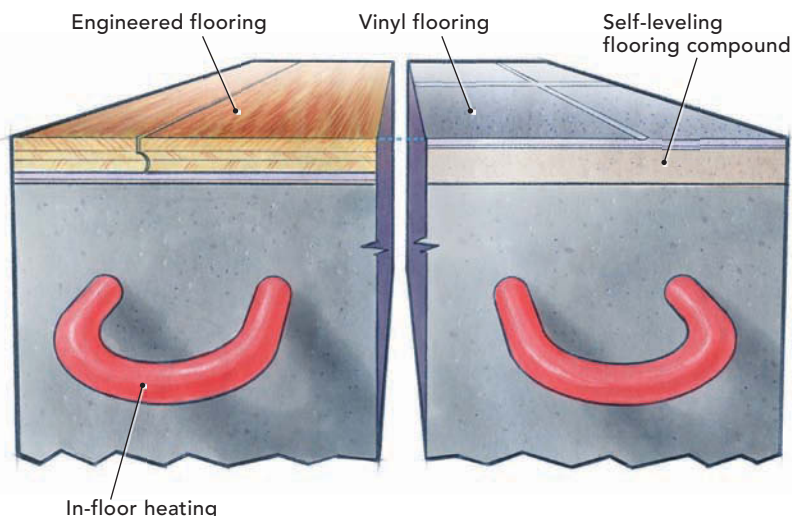
Raising floors a little bit

Q I plan to build a small bungalow in the near future. The foundation will be slab-on-grade with in-floor heating. Most of the

flooring will be engineered wood except for wet areas such as the laundry room and the mudroom, which will have vinyl flooring that’s significantly thinner than the wood. What is the best way to raise those two areas so that they are level with the engineered-wood flooring?

—RON PERCY
via email

A You could use plywood, but with in-floor heat, any wood-based panel can diminish heat transfer. It’s best to raise those areas using a conductive material such as a self-leveling flooring compound. Several types can be poured over existing concrete slabs in depths up to 1½ in., but be sure to use an in-floor, heat-compatible compound. You can buy the dry materials by the sack and mix them with water on-site. It’s not the easiest approach, but for larger areas, you can hire a specialty contractor who will use mixing machines and pumps to deliver the compound to the floor. —*Mike Guertin*



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Lstiburek's ideal double-stud wall

After posting an article at GreenBuildingAdvisor.com titled “Is Cold Sheathing in Double-Wall Construction at Risk?” which covered a study of moisture in double-stud walls in a Massachusetts home, I was contacted by *Fine Homebuilding* contributing editor Joe Lstiburek. Joe is principal of Building Science Corporation (BSC), and his company had done the cited research as part of the Building America program. The reason he called was to make it clear that BSC had only monitored the project. Some readers of my article had gotten the mistaken impression that BSC had at least endorsed, if not designed, that double-stud wall. Joe considers the wall design too risky, and the excessive moisture content in the exterior sheathing confirmed his misgivings. Although the sheathing didn't show damage when the wall sections were deconstructed after three years, the amount of moisture detected during winter and spring was a concern.

As for where the moisture came from, the perfect correlation between indoor relative humidity (low in the winter of years 1 and 3, high in the winter of year 2) and the moisture content of the sheathing (also low in the winter of years 1 and 3, high in the winter of year 2) indicates that the moisture was from indoors. “None of this is unknown,” Joe told me, “and none of it is a surprise.” The problem is the lack of adequate vapor control. Both cellulose and open-cell spray foam, the two types of insulation BSC looked at in the Massachusetts home, are Class 3 vapor retarders (1 to 10 perms), which means they are vapor semipermeable. With lots of insulation in the walls (the house in this study had 12 in.), the exterior sheathing stays colder. Cold materials are generally wetter than warm materials.

Ideal double-stud design

The drawing shows Joe's preferred double-stud wall design, which Joe said solves the problems of inside and outside moisture. (For more details, see “High R-Value Wall Assembly: Double Stud Wall Construction” at buildingscience.com.) This wall has two layers of framing, which is why it's called a double-stud wall, but there's

an important difference between this wall and the one in the BSC study. Joe specifies a layer of OSB or plywood on the outside of the inner wall when using air-permeable insulation such as cellulose or fiberglass.

“Plywood or OSB works in every climate zone,” Joe said. This layer of sheathing serves as the primary air-control layer as well as the vapor-control layer. Its permeance changes with relative humidity, which permits drying to occur. When taped, the sheathing is airtight, but it can reduce moisture accumulation and damage by increasing its permeance with increased humidity. Some builders in

cold climates put a layer of 6-mil polyethylene inside a double-stud wall instead of OSB or plywood. I asked Joe for his thoughts on that technique. “In terms of the physics, it's great,” he replied. “In terms of practicality, it's a very fragile way of doing things. We did this in the early '80s, and it was difficult to build. That's why I like sheet goods.”

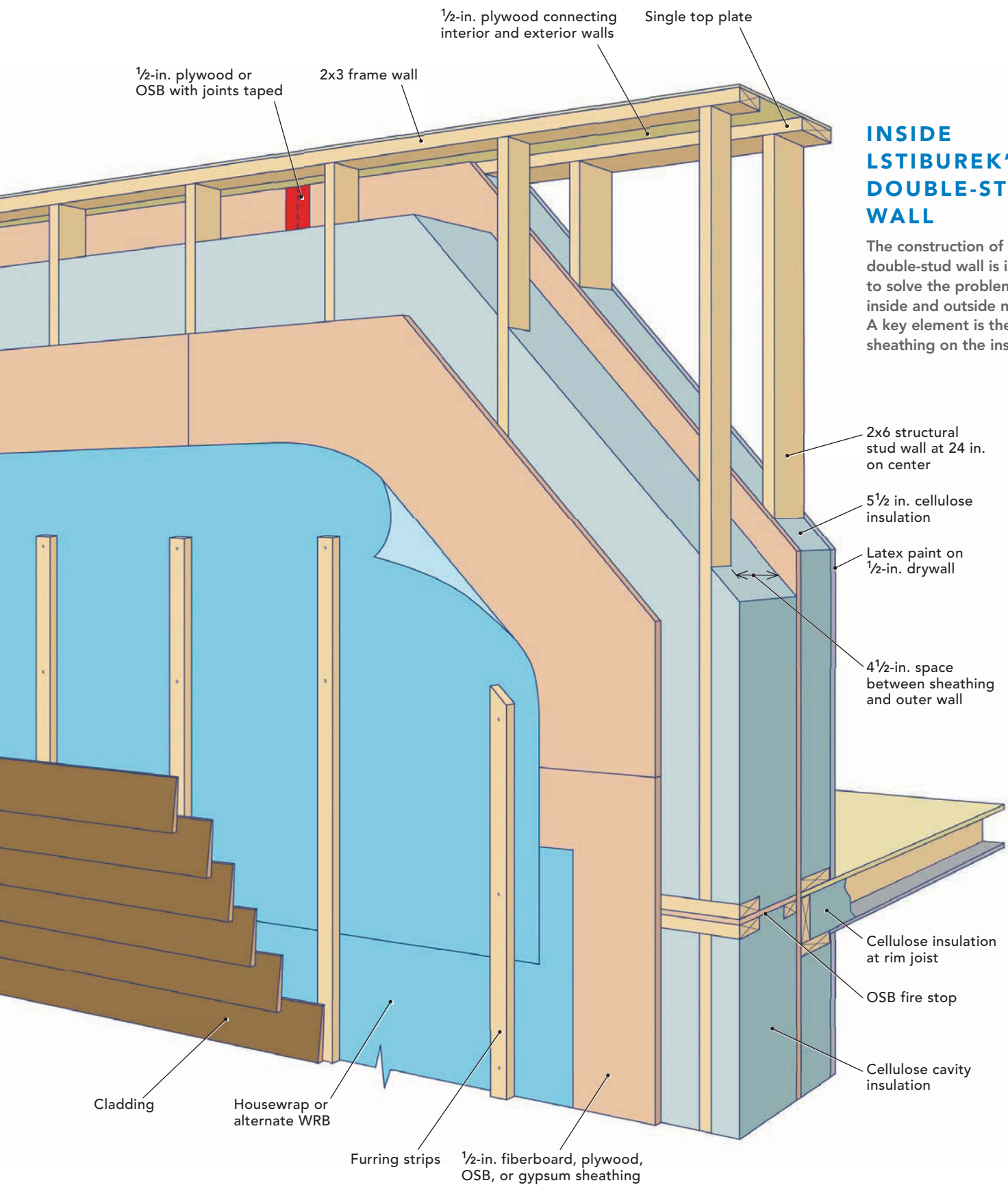
Another thing Joe likes is to have the structural part of the double-stud wall be the inner wall. Similar to a Larsen-truss wall, the inner wall is built at the edge of the framed floor and sheathed. The outer part of the wall is hung from the studs. “I think it's colossally stupid to have the second wall of a double-stud wall be on the inside of the structure,”

Joe said. “That's an incredible waste of floor area and materials and very, very difficult from an airtightness perspective.”

On the exterior of the outer wall, he specifies a vented rain screen to aid drying. The drawing shows furring strips, but any method that provides at least a $\frac{3}{8}$ -in. gap should work. A ventilated cladding, such as vinyl siding, will also work. Lstiburek's ideal double-stud wall has all the thermal, air, and vapor control that it needs to ensure good performance and to avoid moisture problems. “I think the walls that I'm recommending are not risky, regardless of whether we're talking about interior or exterior moisture,” Joe said.

Allison A. Bailes III, Ph.D., is an energy consultant (energyvanguard.com). Drawing by Dan Thornton.

This wall has all the thermal, air, and vapor control that it needs to ensure good performance and to avoid moisture problems.



INSIDE LSTIBUREK'S DOUBLE-STUD WALL

The construction of this double-stud wall is intended to solve the problem of inside and outside moisture. A key element is the layer of sheathing on the inside wall.

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Remodeling carpenters routinely set large beams in cases such as the one shown here, where the beam replaces a bearing wall. Whether a beam is made from engineered lumber or regular old 2x12s, the challenge is weight. Here, a new beam was made from three 16-ft.-long 1 $\frac{3}{4}$ -in. by 11 $\frac{7}{8}$ -in. LVLs. It would have been difficult to raise the assembled beam, but the trick is to raise one piece at a time and then fasten the three together in place.

Replacing a wall with a beam requires carrying the loads while the old wall is being removed and the new beam is being installed. I built a temporary wall about 1 ft. beyond the old wall before removing it. I was lucky in that the joists above overlapped by several feet and so the temporary wall could be held back that far, which provided more room to work. In most cases, a temporary wall has to be built much closer to the existing wall, or even in contact with it, to catch the joist overlap and to support the floor.

This beam was engineered for its loads. (Lumberyards often provide this service for free.) Each end of the beam imposes a substantial load that requires a direct path through the framing to the foundation. Here, one end of the beam landed above the foundation wall, while the other was directly over a column in the basement. To complete the load path, all I had to do was place squash blocks (double or triple studs cut to the depth of the floor joists) between the bottom of the subfloor and the main beam below. In other cases, I might have had to add new columns and footings to carry the newly concentrated loads.

Senior editor Andy Engel is a longtime carpenter. Photos by Justin Fink, except where noted.

Installing a big beam

STEP BY STEP

1 Install kings and plates. King studs tie the beam ends to the existing framing. Cut a new bottom plate long so that fasteners don't split it, screwing it to the framing below where the king and jack studs will go. Cut the plate flush to the jack studs later.



2 Mark the beam location. To keep the beam straight, snap a chalkline on the joists between the edges of the king studs for a guide.



3 Use the beam depth to size the jacks. Measure the depth of the beam stock, and mark that on the king studs. Measure up to the mark from the bottom plate to determine the height of the jacks.



4 Install jack studs and stop blocks. Two jacks were required at each end, but only one was installed at first to ease setting the beam. Temporary blocks on the jacks guide the beam placement.

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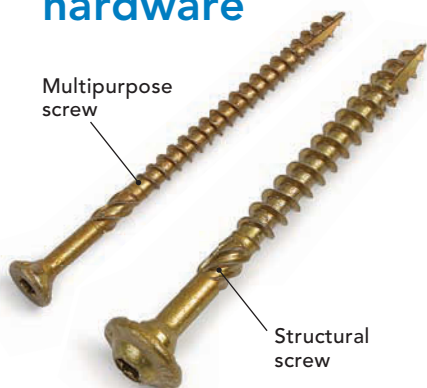


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In combination with an impact driver, structural screws by manufacturers such as FastenMaster, GRK, Screw Products, and Simpson Strong-Tie are increasingly used in place of nails and lag bolts. Although they're more expensive than those options, structural screws have some advantages. The GRK RSS screws used here require no pilot holes to minimize wood splitting, and they are configured to draw layers together as they are driven. Although multipurpose screws are not as strong as structural screws, they are useful for toe-screwed connections and temporary assemblies.

In areas where seismic and wind-uplift forces are big concerns, specific hardware such as hurricane ties are required to connect the beam to the rest of the framing.



STEP BY STEP



5 Measure the beam length. Pull a tape between the king studs to determine the beam length. Deduct $\frac{1}{4}$ in. from that number so the beam members don't bind while being installed.



6 Slip the plies into place. With the top leaning in, place both ends of the first ply at once onto the jack studs. A few sledgehammer taps along the bottom face stand the ply up.



7 Install the remaining plies like the first. Nails can be used to join the plies, but structural screws set with an impact driver are better at drawing them into full contact with one another. Follow the designer's fastening schedule.



8 Fasten to the joists. Join each joist to the beam with a $3\frac{1}{2}$ -in. #10 multipurpose screw driven at an angle. In some circumstances, framing hardware is required to resist seismic or uplift loads.

9 A wide opening. With the second jack studs placed, the bottom plates trimmed, the squash blocks placed below, and the temporary wall removed, the new beam is ready for drywall.





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Laundry closets

Laundries are one of the harder-working spaces in a house, yet they rarely receive the same design attention as kitchens or bathrooms. It may not make sense to allocate a large percentage of prime real estate to a chore that is only done once or twice a week, but that doesn't mean laundry facilities should be relegated to damp, dark utility spaces.

Having designed and installed many laundry areas in narrow closets and alcoves, I've found that you can carve out a fully functional laundry where it's most convenient, either near the working areas of the home or near the bedrooms.

Wherever you place a laundry, it needs adequate ventilation to remove moisture-laden air and replace it with fresh

air. If the house has an energy-recovery ventilator (ERV) or a heat-recovery ventilator (HRV), it should exhaust from the laundry area. Alternatively, a continuous or intermittent bathroom exhaust fan can promote rack-drying and remove stale odors.

The volume of air exhausted by dryers varies, so check manufacturers' recommendations

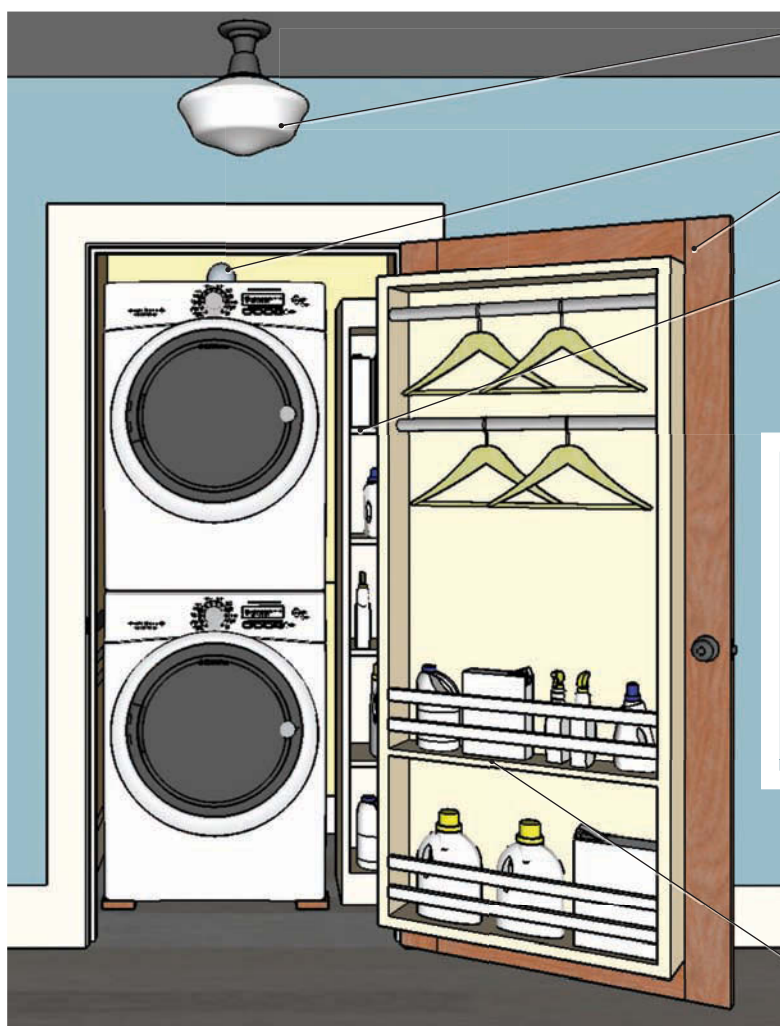
for makeup air. Code requires an opening of at least 100 sq. in. for dryers that exhaust more than 200 cfm.

In a tight closet, dryer venting can be problematic. If space is particularly tight, consider a recessed dryer vent.

Front-loading (horizontal axis) washing machines are popular for closets because they can be installed either stacked

A NARROW CLOSET

A narrow laundry closet should be at least 32 in. wide to allow for hoses (when the supply is located to the side) and machine vibration, and 40 to 50 in. deep (about twice the depth of a standard closet). Units in this type of laundry closet are stacked. One problem that can arise with this configuration is that an unbalanced load can cause the machines to jump around. I've tamed wild machines by drilling holes in small squares of $\frac{3}{4}$ -in. plywood, setting the legs in the holes, and screwing the squares to the floor. If there is not enough room to access the dryer vent from the side, it should be routed up the wall to exit above the dryer. This allows rigid ducting to be installed and for the vent to be cleaned regularly.



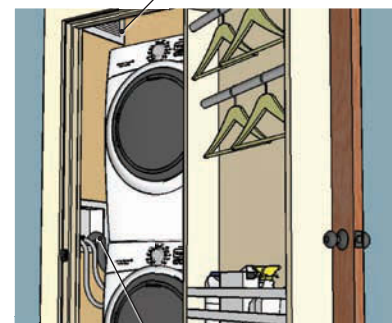
Overhead light should be outside the closet, where it will not be blocked by the machines.

Accessible rigid dryer duct

Doors should be at least 30 in. wide by 80 in. high to accommodate the machines.

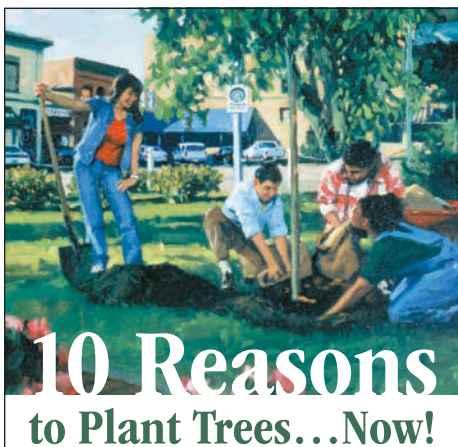
Extra width creates space for a tall, narrow set of shelves next to the machines.

Vents allow air circulation. They are most effective when placed both high and low in a wall or door.



Plumbing drain and supply shutoffs should be installed where accessible near the front of the closet, not at the back where they can't be reached.

Extra depth allows shallow shelves (with keeper rails) to be installed on the back of the door.



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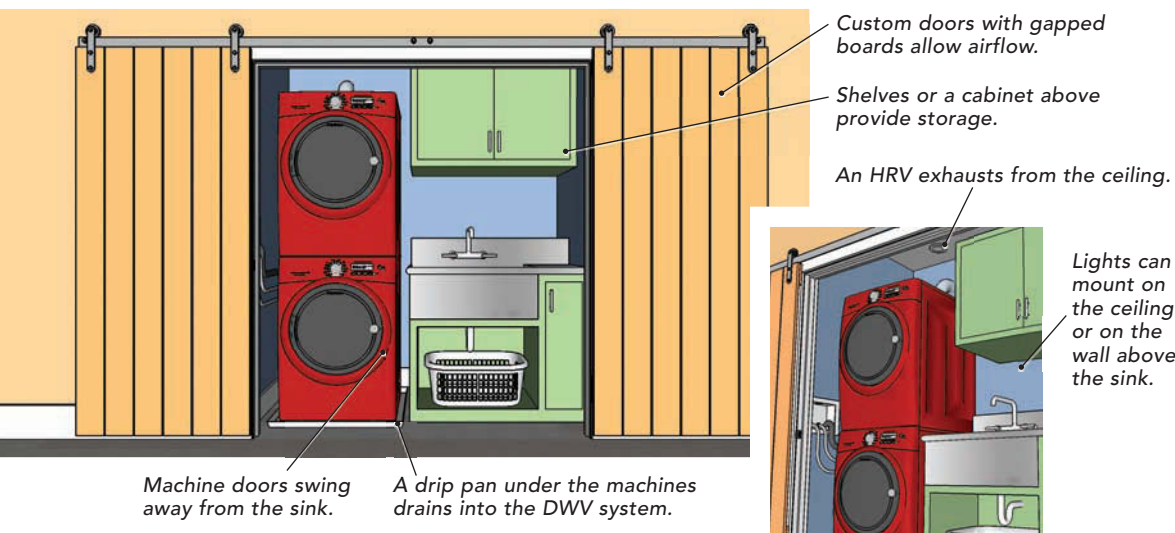
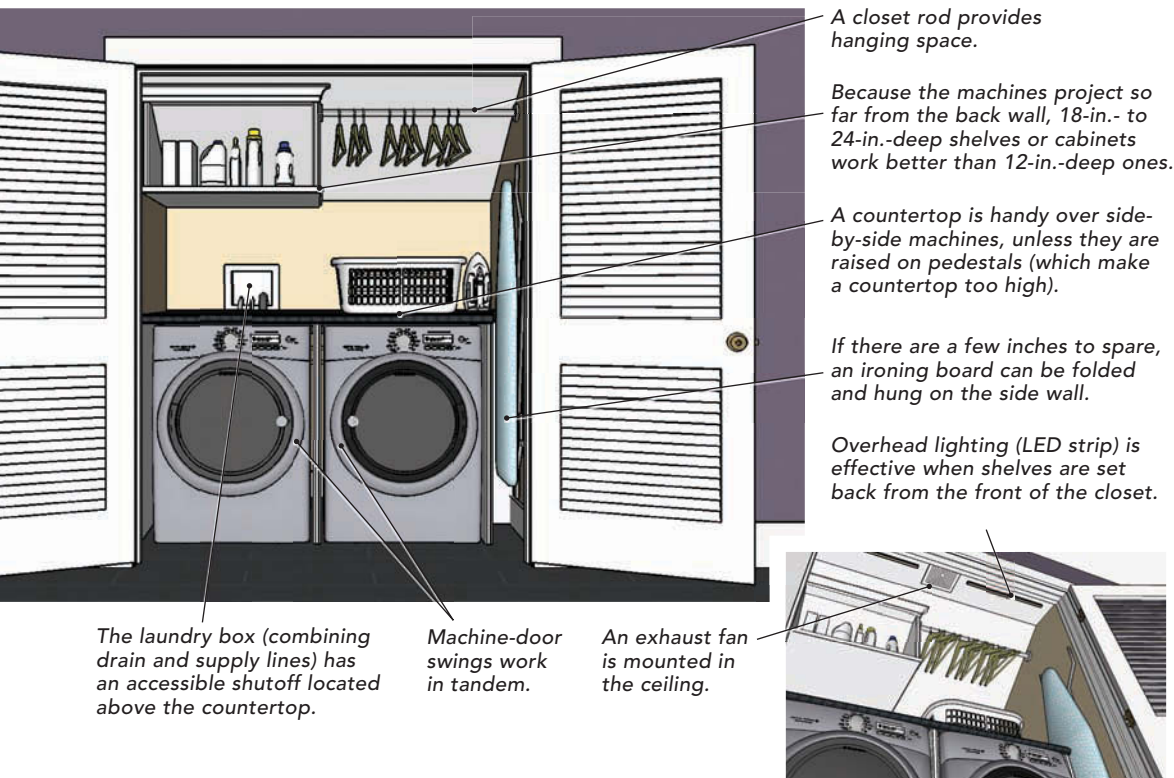
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A WIDE CLOSET, SIDE BY SIDE

A minimum width of 5 ft. is usually required to fit two machines side by side and provide the wiggle room needed for vibration during use. This design works well when tucking a laundry closet under a sloped ceiling. Having a countertop over the machines is a nice option with this configuration, but be aware that it will be higher than a kitchen counter—usually between 38 in. and 42 in. high.



A WIDE CLOSET, STACKED

If the ceiling is high enough, you can install stacked machines in the same 5-ft.- to 6-ft.-wide closet. This allows for a laundry tub or a section of countertop with or without a sink. An integrated sink allows laundry-basket storage underneath if the sink is not too deep and the drainpipe is carefully routed. A stainless-steel countertop with integral sink offers an easy-to-clean surface.

or side by side with a dryer. Other options include condensing dryers or combination washers/condensing dryers, which don't need an exhaust duct and are sometimes recommended for airtight homes; one-piece stacked units with top-load washers; and in wide closets, traditional top-loaders placed side by side with dryers. The designs shown here focus on front-loading machines, but the concepts hold true for other options as well. Consider also that machines come in several sizes: full-size units are 27 in. to 30 in. wide and from 28 in. to 34 in. deep. Compact machines are 24 in. wide and 25 in. deep.

Regardless of which appliance you choose, consider a drip pan under the washer. Plumbers have told me that upgrading the supply hoses to braided stainless steel is the best insurance against a leak, but a drip pan isn't a bad idea, and some jurisdictions require them on upper floors. An accessible shutoff is usually required by code.

Finally, functional laundry rooms typically include a number of features and accessories to make the task of doing laundry less onerous, any of which can be added or eliminated based on space constraints. Here's what my clients ask for, in order of popularity: shelves or cabinets for storage; storage or a staging area for dirty clothes; a countertop for folding; rods and/or hooks for hanging; a sink or laundry tub; and room for an ironing board and iron. With planning, it's possible to fit many of these features into a small, efficient space.

Mike Maines (michaelmaines.com) designs everything from laundry closets to Passive Houses. Drawings by the author.



Need assistance?

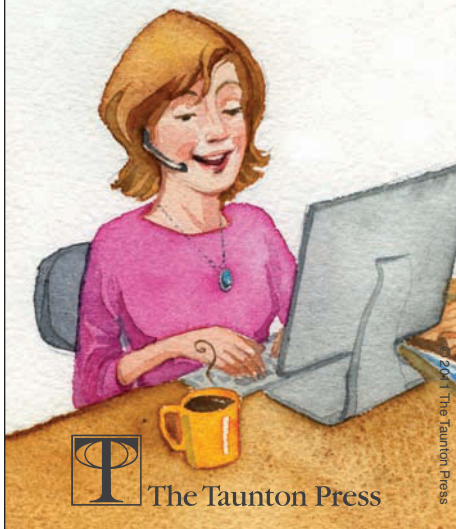
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KATHERINE BOORMAN, Designer This operations director for the firm OneButton specializes in making technology an unobtrusive part of home design.

At what stage in the design/build process do you get involved?

The earlier I get involved, the better. By making technology decisions up front, everyone from the builder to the homeowner knows what we are ultimately working toward on a job. For example, if you know you are going to have a motorized shade, you would choose window hardware that accommodates it without interfering with its operation. That said, if there is a project that does not address technology up front, an array of retrofit solutions is now available in the home-automation field.

If technology is part of the vision, it won't read as an afterthought.

Exactly. You wouldn't start framing without knowing where the kitchen or the bathrooms are, and I feel like technology is entering that realm of importance now.

Do you have a specific area of focus?

I love lighting and shading because it's detailed, challenging, and constantly evolving. Light affects our health and impacts how we live. I take pride in creating ideal light environments, and I'm driven to demystify technology in the home. Technology should add an elegant layer of comfort, not work. I often tinker with new equipment at my own home before recommending it to clients.

It's immensely rewarding to touch base with clients once they have spent a night or two in their new home and to hear how the ease of a lighting keypad or motorized shade has improved their home experience.

Is there a learning curve in executing the details of your designs?

It's more of a wall than a curve. We put together clear plans and wiring labels for our electricians, but working on the control system can be a wall for our partners in the field to leap over. We are there from the beginning, however, to explain how the sys-

tem infrastructure is created and to ensure that the process moves smoothly.

Tell us about Savant.

Savant is the most sophisticated software platform we utilize. It's a centralized system that is capable of tying many elements of the home together—temperature, security, television remotes, music, gates, garage doors, and so forth. We like Savant because it's incredibly reliable, flexible, and powerful while being elegant and easy for the homeowner to use. It pairs beautifully with

I think we have been normalizing technology in the home for quite a while now ... More and more we live through it as a medium.

the Lutron Homeworks QS lighting and shading hardware, and it also has a sleek thermostat offering that keeps total control as simple and centralized as possible.

Will technology integration become the new normal?

I think we have been normalizing technology in the home for quite a while now. It's how we stay connected to the outside world. It generates an emotional and intellectual response, because more and more we live through it as a medium. Consumers have a precedent based on their interaction with smartphones and tablets. We take all of those aspects into consideration when determining how to design a space for a client.

What are some of the other platforms you use for automation?

Sonos is our go-to for sound systems and speakers throughout the home. Again, Savant does a fantastic job of tying everything together on its software platform. Right now, many of our systems are proprietary, but some—and hopefully more over time—are in the process of developing more-open standards for integration devices on the market such as the Apple Watch.

Have you encountered any visionary concepts?

One item that we have been using recently is the August Smart Lock, which can be accessed by a smartphone from anywhere. Having the peace of mind and a sense of security about their house being locked is important to many people.

Is information security a concern?

All high-end control systems provided by a controls design firm like OneButton have security protocols in place. Multiple layers of security settings help protect our clients' information and make their systems readily available to appropriate users. For example, even with a fully integrated system that taps into a homeowner's alarm system, an authorized user would still need to type in the security code in order to arm and disarm the system.

Do you see a wireless future?

I think we will find the world more connected to all of its devices through the internet. We will see a migration away from proprietary systems and toward adding specific items (locks, shades, lights) to a pool of connected items throughout the home. Homeowners will be able to tailor their technological environment to their unique tastes.



For the complete interview, visit FineHomebuilding.com/extras.

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Where concrete is king

In the summer of 2012, Andrey Rudenko began toying with the idea of creating a 3D printer capable of constructing homes. An experienced contractor with a background in engineering and architecture, Rudenko's prototype was a small 3D printer that created plastic objects. For two years he experimented with enlarging the printer and producing objects using different types of concrete mixes. In May 2014, Rudenko put his printer to the test to create a castle playhouse. Its design allowed him to experiment with creating a variety of shapes from the concrete. The castle was printed completely outside in his yard, where the custom concrete mix set quickly in the summer sun. The castle is 12 ft. high, 16½ ft. long, and 10 ft. wide. Construction of this castle took one month, during which

time printing was often stopped to make adjustments to the printer. If the printer were to run nonstop, it would take only a week to print a second one.

Rudenko's 3D printer is "centered on simplicity, easy maintenance, and parts replacement." Transporting such a large rig would seem to be problematic and expensive, but Rudenko says that "the printer's complicated knots are simplified so they can be taken apart, shipped, and then put together at any time." He credits his success to design engineer Mikhail Tikh, input from the RepRap (replicating rapid prototype) community, and those who helped him with the manual labor. Given the success of the preliminary testing, Rudenko is confident that he can now print a medium-size house. —Maureen Friedman



Like icing from a pastry bag. The 3D concrete printer lays down row after row of concrete directly onto the building site.



For more information on the 3D concrete printer, visit FineHomebuilding.com/extras.

DESIGN AND CONSTRUCTION Andrey Rudenko, Total Kustom, Shorewood, Minn.; totalkustom.com

DESIGN AND 3D MODELING Mikhail Tikh, RFA Engineering, Eden Prairie, Minn.; rfamec.com **PHOTOGRAPHS** courtesy of Andrey Rudenko

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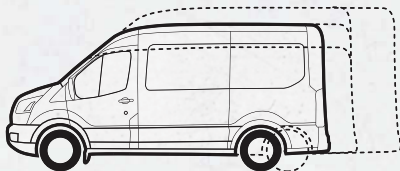
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