Installing Exterior Insulation in Cold Climates

Airtight construction and a thick layer of exterior foam save energy and reduce the risk of rot and mold

by Thorsten Chlupp

As a custom home builder in Alaska, I've seen how poorly conventional wall assemblies perform in extremely cold weather. In Fairbanks, Alaska, where I work, a "typical" wood-frame wall might consist of 2x6 framing with R-19 batt insulation, OSB sheathing, and housewrap on the outside, and a 6-mil poly vapor retarder on the inside.

There are two problems with this construction. The first is that the wall framing members act as heat conductors between the warm interior and the cold outside. There's nothing to stop the transfer of heat. But the bigger issue is air leakage. It's nearly impossible to do a perfect job sealing all the penetrations in the vapor retarder, and just as hard to make the housewrap airtight. On cold winter days, warm, moist indoor air is driven into the wall cavities, where it hits the inside of the cold sheathing, condenses, and freezes. When the weather warms up, the moisture is trapped between the vapor retarder and the relatively impermeable sheathing, where it degrades the insulation and causes mold and even rot.

CCHRC Research

Moisture infiltration into wall cavities is a concern anywhere, but especially in climates like Alaska's, where extreme winter temperatures and a short drying season exacerbate the problem. To address the shortcomings of standard frame construction, my company has adopted an insulation and air-sealing method developed by builders and researchers

Figure 1. In a REMOTE wall, the sheathing is covered with a barrier membrane — either peel-and-stick (top), 6-mil polyethylene sheeting (above), or, in wet climates or beneath EIFS cladding, a wrinkled drainage material such as StuccoWrap (left). Installed before the roof is framed, the barrier membrane extends over the top plates and is later sealed to the poly air barrier on the ceiling of the house's top floor.

working with the Cold Climate Housing Research Center (CCHRC; cchrc.org) here in Fairbanks. Nicknamed the REMOTE Wall System (for Residential Exterior Membrane Outside Insulation Technique), it involves installing a barrier membrane on top of the structural sheathing, followed by several inches of rigid foam insulation (**see illustration, page 35**). The membrane provides an air seal, while the thick insulation keeps the sheathing and framing above the dewpoint temperature and so prevents condensation from occurring in the wall.

The rigid foam can be supplemented by installing a lesser amount of fiberglass batt insulation in the frame wall. The goal is to increase the wall's total R-value from the inside, but without allowing the sheathing to cool to the dewpoint. It's a balancing act: You have to put enough insulation on the outside to keep the sheathing membrane warm, but not too much on the inside else you'll isolate the sheathing and framing members from indoor heat. This is critical, because besides providing an air barrier, the membrane — either by itself or in combination with the sheathing and exterior insulation — acts as a vapor retarder. So there's no doubt that in a REMOTE wall, interior moisture vapor will be stopped at the sheathing plane.

Concerns With Exterior Membranes

Mindful of the dangers of a "wrong-side vapor barrier," the CCHRC has been monitoring REMOTE wall projects around Alaska, in both dry northern areas and the humid coastal region. Using HOBO data loggers (available from onsetcomp.com) that record temperature and humidity over time, the research has confirmed a rule of thumb long used by builders wishing to place vapor retarders inside of walls: It's generally safe to put approximately one-third of the total R-value to the inside of the vapor barrier. This holds true even for an extremely cold climate like that of Fairbanks, which has 14,000 heating degree days. (Keep in mind this is just a rule of thumb; the ratio may change somewhat depending on project specifics.)

Data loggers on some REMOTE projects have indicated short periods when humidity levels in certain wall cavities rose. The good news is that the cavities also dry out again as soon as conditions are right, because there's no poly vapor retarder on the inside face of the studs. So if condensation does occur in the wall — say, in extreme cold weather — it can dry to the interior.

I've used the REMOTE method on 14 homes to date, with excellent results. I learned years ago that to create a durable, energy-efficient home in a cold climate, you have to meet four goals: adequate insulation, airtightness, moisture control, and good indoor air quality. The REMOTE wall method allows me to meet all of these.

Insulation

I generally use R-Tech IV EPS (expanded polystyrene) on the exterior. It's made by Insulfoam (800/248-5995, insulfoam.com) and has an R-value of 4.8 per inch at 40°F. (The R-value actually increases as temperatures drop.) I typically install 6 inches — two layers of 3-inch. R-Tech has a polyethylene facing that helps it shed water, though the edges are unfaced. This has led to some concern that moisture might get into the foam board at joints and be unable to get out. But CCHRC tests in the rainy southeast of Alaska have shown that R-Tech performs well in REMOTE walls and that moisture entrapment is not a problem.

Some builders have used XPS (extruded polystyrene) foam, which has a slightly higher R-value and has also performed well on monitored projects.

Note that in cold Fairbanks, I can carry the EPS below grade with no fear of insect damage. Although some foams contain a borate additive intended to repel insects, the treatment may leach out over time in wet soils. In situations where insect damage poses a threat, holding the exposed foam above grade and using a termite shield is a safer option.

On the inside, I supplement the exterior foam with fiberglass batts.

Airtightness and Blower-Door Test

Covering the house with rigid foam board creates a potentially tight structure, but it's the barrier membrane applied to the sheathing that does most of the work (**see Figure 1, facing page**).

The earliest REMOTE walls used peel-and-stick membranes; this produced an incredibly airtight, waterproof shell but it was expensive. So most builders switched to less expensive materials — 6-mil poly or, in very wet zones, vapor-permeable drainage wraps such as Tyvek StuccoWrap or DrainWrap. Poly works fine in Fairbanks, which is fairly dry; in rainy southern Alaska, the Tyvek products are the usual substitute for peel-and-stick. The

Figure 2. The author's crew applies a 9-inch-wide peel-and-stick flashing to the top plates, adhering it to the inside edge of the plates (top) and lapping it onto the 6-mil poly membrane on the sheathing (above).

Figure 3. When installing recessed windows, the author uses sill and jamb extensions bent from coated sheet metal. The flanges at the outer edges (left) are carefully placed to allow for the thickness of the foam, ¾-inch strapping, and the vinyl siding, which will tuck underneath. Note the lines of black acoustical caulk used to seal the jamb extensions to the poly membrane and the poly seams (above).

reason is that rainwater might travel through a nail hole and get trapped behind poly, whereas using a housewrap will allow for evaporation to the outside. (StuccoWrap or something similar is also used on REMOTE houses that receive an EIFS cladding, per the EIFS manufacturer's specifications.)

On the inside, the 6-mil poly continues across the ceiling below the attic. To avoid stack-effect exfiltration, we refuse to install recessed light fixtures in the ceiling poly and even avoid putting sealed electrical boxes there, pushing customers to put upper-floor lighting fixtures in the walls instead. On most of our jobs the plumbing stack is the only thing that penetrates the lid. Access to the attic is through a gable wall, preferably above an attached garage.

Performance test. Installing the barrier membrane and exterior foam doesn't in itself guarantee that the structure is airtight. The only way to do that is to do a blower-door test. This is a critically important step in achieving a tight shell, and you have to do it when you can still access the leaks. If you hold off doing the blower-door test until the insulation and drywall are installed, it'll be too late.

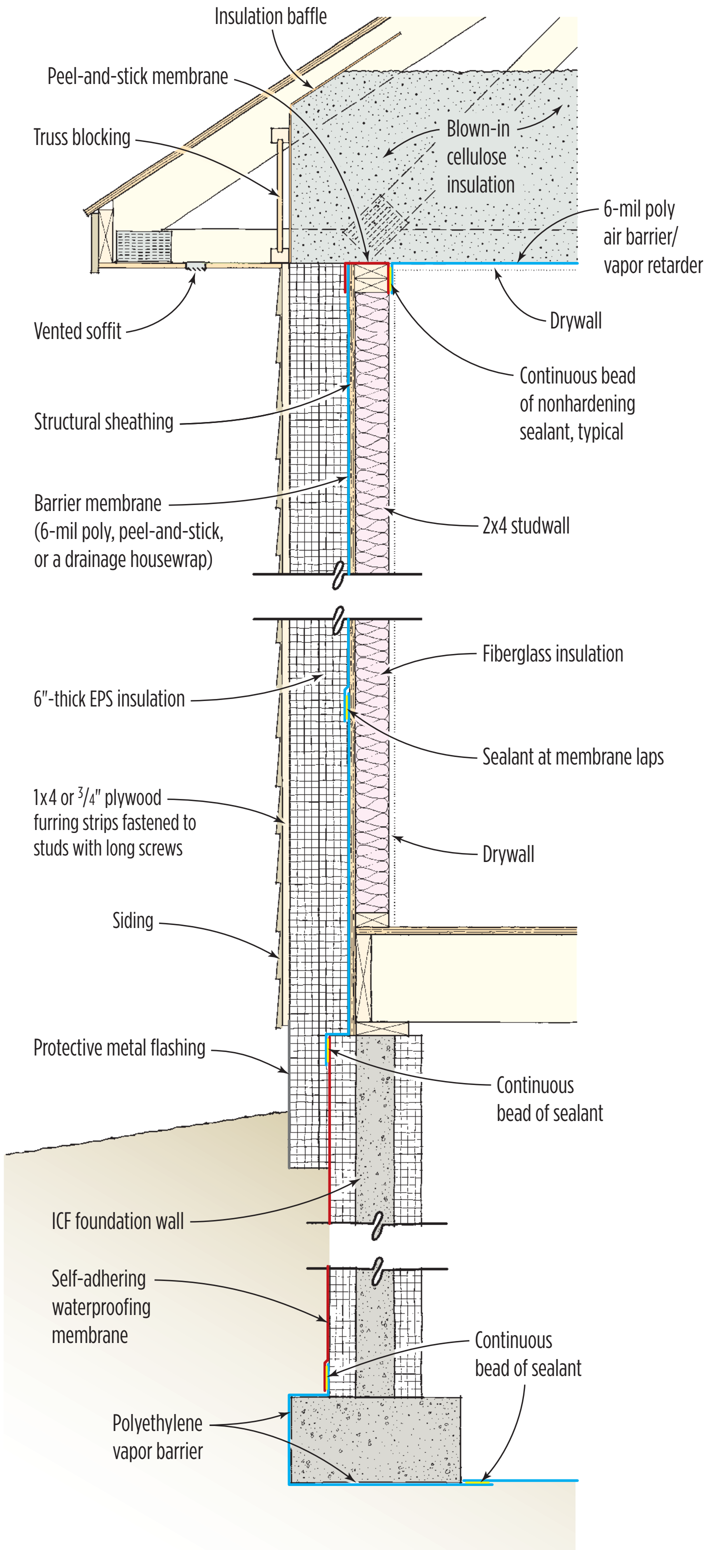
We wait until the electrical, plumbing, and mechanical subs have done their rough-ins, then hang the drywall over the ceiling air barrier. The blower door depressurizes the interior and shows us where the leaks are. There's no insulation in the stud bays at this point, so it's easy to seal wall leaks from the inside, using spray foam and acoustical sealant. The attic has not yet been insulated, so we can plug those leaks working from above. When the house is finished, an independent energy rater performs a second blower-door test as part of an energy audit.

Our goal is an airtightness of 0.6 air changes per hour at a pressure of 50 pascals (ACH50) — the same standard required for a Passive House. We've achieved this with the 6-mil poly barrier and have gotten down to 0.3 ACH50 with a peel-and-stick membrane. The best we've done with StuccoWrap is 0.8 ACH50.

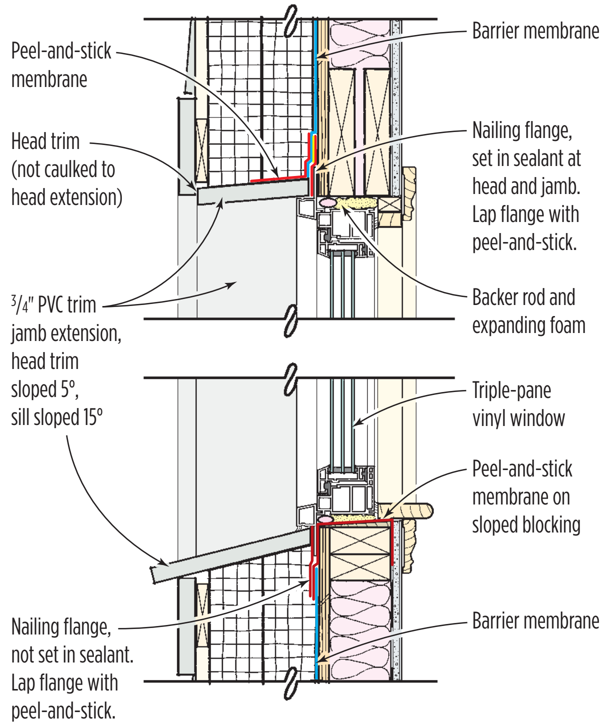
Moisture and Air Quality

In buildings this tight, relying on passive ventilation by natural infiltration or even exhaust-only fans (which require makeup air) would be a mistake. The home would

REMOTE Wall Details



Window Installed Flush With Sheathing



Window Installed Flush With Outside Face of Wall

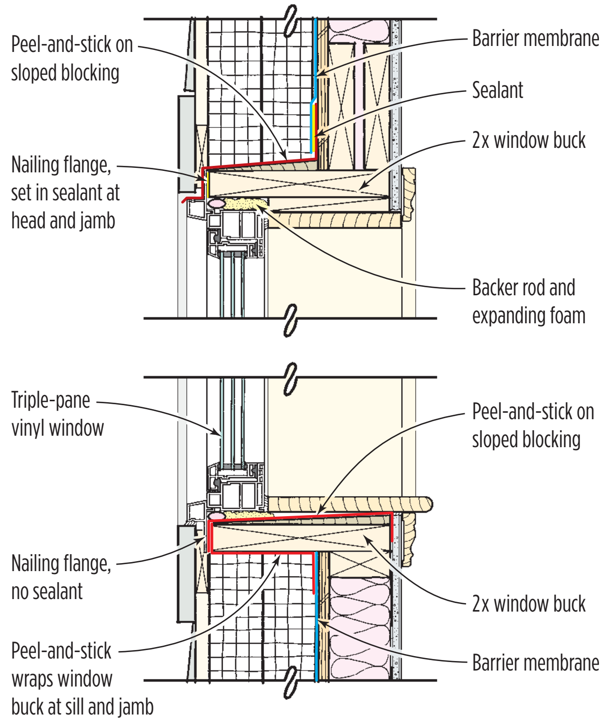


Figure 4. On past jobs, the author installed windows at the face of the wall by setting them in solid lumber bucks protected with peel-and-stick flashing (top). The bucks are attached to the inside of the rough opening and taped or flashed to the wall membrane (above left). Bucks are sized so that when foam insulation and furring are installed, the siding will be in the proper plane (above right).

have poor air quality and moisture and condensation problems. So I put a heat-recovery ventilator (HRV) in every house I build. The HRV provides a measured supply of fresh air and recovers much of the heat that would be lost with a simple fan system. HRVs also address the issue of indoor humidity by replacing stale humid air with drier outside air.

Installing the Membrane

Most of the houses I build have wood or vinyl siding; on those jobs we typically install a 6-mil poly barrier membrane, lapping the seams shingle style and sealing the laps with a nonhardening acoustical sealant.

Poly is slippery to walk on and will tear if you drag trusses across it, so when we get to the top of the wall we switch to a strip of 9-inch peel-and-stick flashing. The flashing adheres to the top plate and laps an equal distance onto the poly and the inside face of the plate (**Figure 2, page 33**).

Pencil marks will not show on this material, so we use a white marker to lay out truss locations. Once the trusses are set, we install the ceiling membrane, lapping its edges onto the peel-and-stick flashing and sealing the lap with acoustical sealant.

Installing Windows

Windows can be installed either at the face of the sheathing — in a recess — or out at the face of the wall. From a performance standpoint, a recess is better, because the window is somewhat protected from wind-washing and the interior glass is more easily warmed by the heat in the room. By contrast, windows installed at the face of the wall are in an interior recess, separating them from the warm air inside (especially if a curtain is drawn) and exposing the outer layer of glass to cold wind. I've observed that in extremely cold weather — when it's 25°F below zero, for example — frost tends to form inside windows installed at the face of the wall, whereas frost rarely occurs on inset windows.

Recessed installation. I've installed windows both ways, but because of the frost problem I now do only recessed installations. A recessed installation is more complicated because the sides of the recess must be covered with exterior jamb extensions. On vinyl-sided homes, we make the extensions from 20-gauge metal coil stock (**Figure 3, page 34**). The bottom is sloped to shed water, and there are flanges on both edges — an inner flange that gets fastened to the sheathing and an outer flange that laps over the 1x4 strapping that we install on top of the EPS around the window.

We've also made extensions from wood and cellular PVC. These solid extension jambs are glued and screwed at the corners and fastened to the wall over a thick bead of sealant. We either toe-screw them to the framing or fasten them from the inside with metal clips.

Window bucks. Because it's less expensive, many of my past customers chose to have doors and windows installed at the outside face of the wall. We did this by extending the rough openings with bucks ripped from 2-by lumber. The buck fits inside the opening and extends from the inside face of the frame to the outside face of the furring that goes over the foam.

The window is installed in the buck and the fins lapped with peel-and-stick flashings that extend back to the wall membrane (**Figure 4, facing page**). Though this method is less expensive than fabricating jamb extensions, it requires more care with the flashing. From the standpoint of moisture intrusion, I felt comfortable doing it around Fairbanks because we don't get a lot of rain, but in a wetter climate I would recommend recessing the windows. As I mentioned above, I no longer use this technique because of the icing problem my customers experienced. But for builders in a warmer climate, it could still be a reasonable approach.

Installing the Exterior Insulation

The EPS insulation can be lightly attached with framing staples or nails because the furring strips, which get screwed through into the studs, will securely hold it in place. We stagger seams and lap corners in successive layers so that air doesn't have a direct path through to the wall. The boards are butted to the sides of window bucks and jamb extensions, and gaps between sheets and around windows and doors are filled with minimally expanding spray foam.

Some areas have to be insulated and sealed before the framing is complete. For example, where the roof of an unheated attic butts to a sidewall, we'll insulate that wall before framing the roof (**Figure 5**).

We insulate attic gables at least as high as the top of the attic insulation. The area above does not have to be insulated, but

Figure 5. To ensure the continuity of the barrier membrane and exterior insulation, the wall to the right of this garage roof was covered with poly and foam before the roof was framed (top). Moving truss blocks in line with the outer edge of the exterior EPS will allow the cellulose in the attic to completely cover the full thickness of the exterior walls (above).

Figure 6. The EPS insulation is first tacked in place, then secured with long screws fastened through furring strips into the framing (top left). Wide furring members are needed at corners (top right) and around openings (above) to provide backing for trim.

it needs to be built out to the plane of the foam below, which we often do with scrap pieces of insulation.

If the inspector and engineer will allow it, we push the truss blocks along the eaves out to the face of the foam so that the blown-in attic insulation will cover the entire top of the wall, including the EPS. Otherwise, we carry the insulation boards up to the top of the attic insulation by fitting them around the rafter tails.

Furring

We provide nailing for siding by installing 1x4 furring or strips of $^3/_4$-inch plywood over the foam, fastening through to the studs with long screws (**Figure 6**). We space the screws about 12 inches on-center and make sure we penetrate at least $1^1/_2$ inches into the framing. These long fasteners have to be mail-ordered; we use Wind-Lock W-SIP screws (800/872-5625, wind-lock.com) and FastenMaster HeadLok and OlyLog screws (800/518-3569, fastenmaster.com).

Screws are very heat-conductive and can cause condensation where they miss the studs. We always check from the inside for missed fasteners, reinstall them, and use spray foam to seal the holes.

Cost and Payback

Though the REMOTE method is more expensive than conventional construction — EPS costs more than fiberglass and there's extra labor involved — the added costs are offset by reduced energy use and a longer building life cycle. The CCHRC has estimated a three- to five-year payback period from energy savings, and there's no question that a building free of moisture problems will have a considerably longer life. But what's equally important is that good insulation, tight construction, and proper heat-recovery ventilation add up to a comfortable, healthy house to live in.

Thorsten Chlupp *owns REINA, LLC, in Fairbanks, Alaska.* *Special thanks to Ilya Benesch of the CCHRC for providing technical advice.*