Melted frost on the new roof pointed to a problem during the first winter: Heat was escaping between the seams of the foam sheets. The author had used mastic and mesh tape to seal the seams, but that wasn't enough to keep in the heat. Turns out that the actual problem was a little more interesting. See p. 56 for the solution.

BY JOSEPH LSTIBUREK

Foam Shrinks, and Other Lessons

What we learned from updating a 16-year-old deep-energy retrofit

I did a deep-energy retrofit on my barn 16 years ago. Building Science Corp. was young and growing, and we needed a bigger office. The barn would be that office for the next 10 years. In fact, Betsy Pettit wrote about it in "Remodeling for Energy Efficiency" (*FHB* #194).

The first thing we did was to cut all the overhangs off the barn roof and wrap the outside of the building with plastic. Next, we applied 8-in.-thick expanded polystyrene (EPS) foam on the walls and 10 in. of EPS on the roof. On top of the roof, we installed a layer of plywood as a nailing base for the shingles. The plywood cantilevered

FINE-TUNE THE DETAILS THAT WORKED, AND OVERHAUL THOSE THAT DIDN'T

Peel-and-stick membrane was available when the author completed this retrofit, but it seemed like an excessive step when the air-control layer would be covered with foam anyway. Turns out that plastic, with its many holes, and a single layer of foam (that shrunk) didn't work so well at controlling air movement.

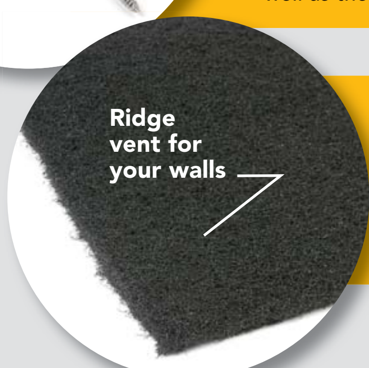
Solution: *The author covered the entire barn with peel-and-stick membrane.*

The biggest surprise was not that heat escaped between the joints of a single layer of foam, but that the gaps got bigger. Gaps are clearly visible above this window where the EPS foam panels shrunk, opening cracks in the mastic. On the house, where the author used XPS (drawing right), the panels stayed put, and the tape stuck tight.

Solution: *The author switched to a more stable type of foam and used multiple layers, offsetting and taping the joints.*

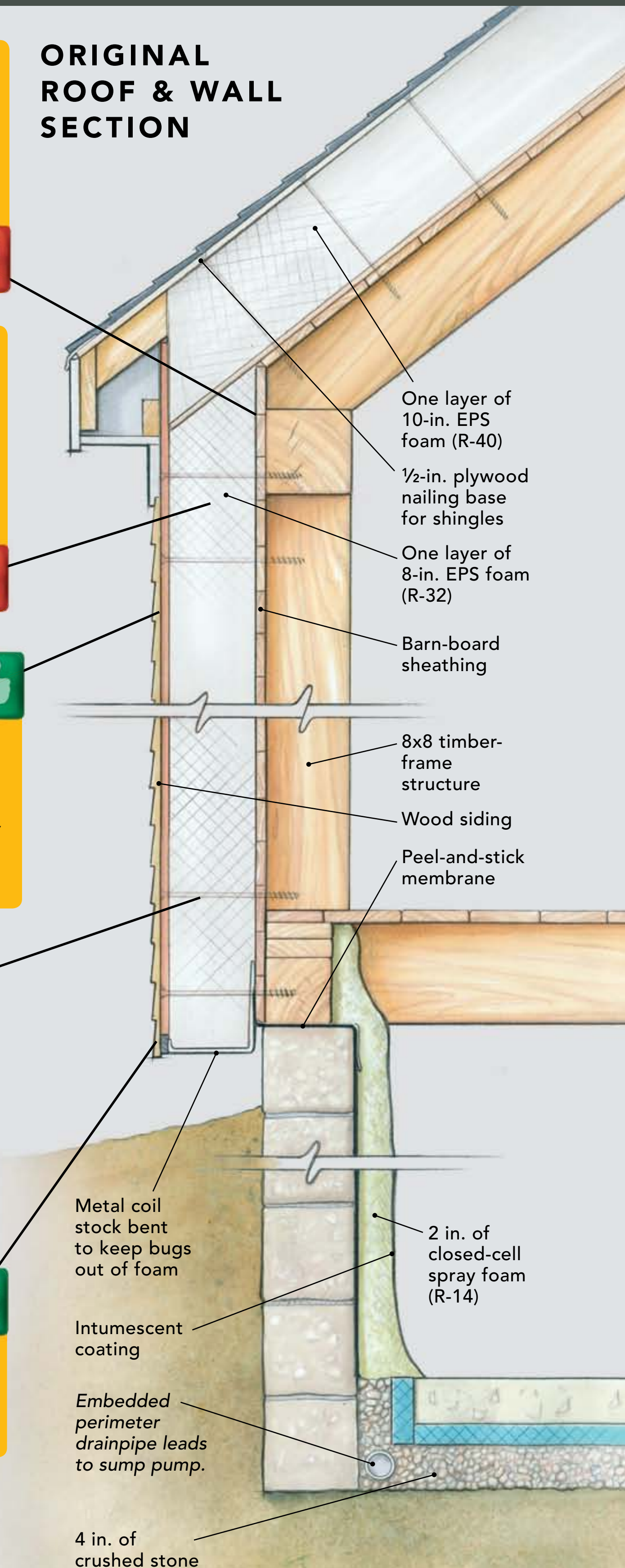
A common criticism of the author's wall assembly was that the furring strips needed to be pressure-treated or they would rot. Because the whole point of a vented airspace behind siding is to allow the siding to dry, the author reasoned that the furring strips ought to dry quickly, too. He was right. Not only did the paint job last 16 years, but the furring strips were in pristine condition as well.

To attach the furring strips, the author used two kinds of screws—not to test the efficacy of each, but because that's what was available at the hardware store at the time. A couple of epoxy-coated screws in a place with water-management problems developed rust, but in general, the epoxy-coated screws fared as well as the stainless-steel screws.



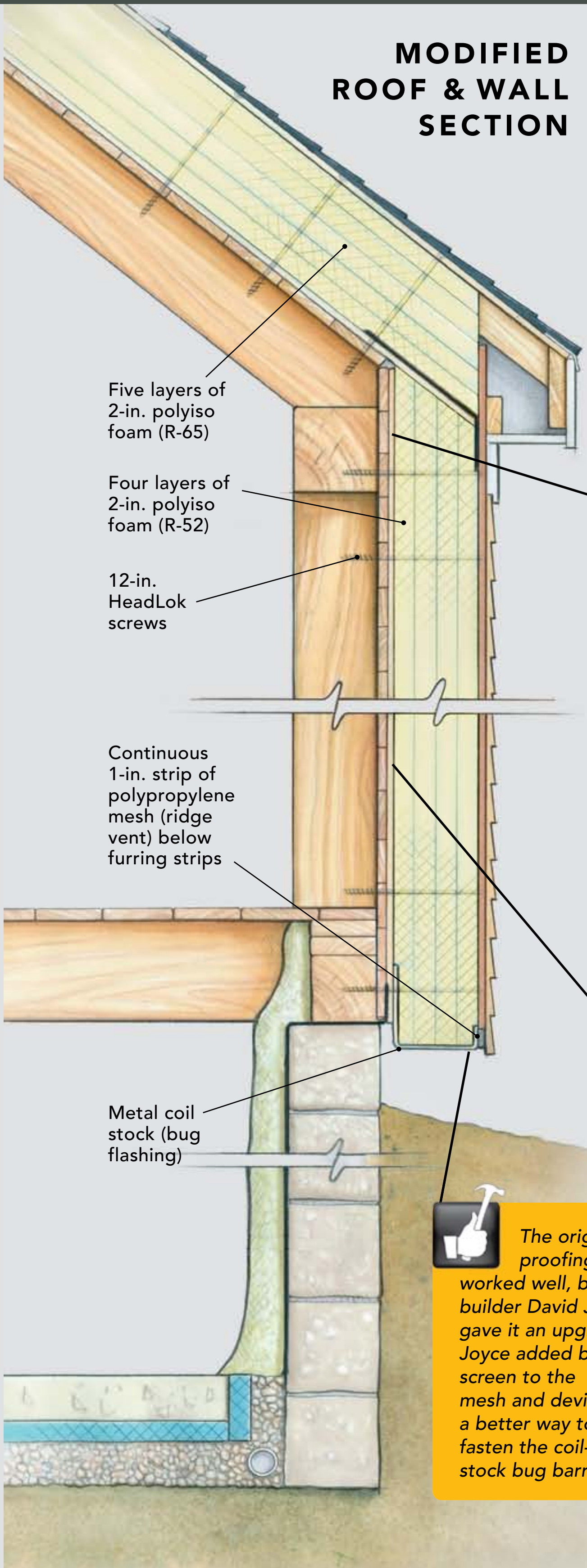
The most common use for polypropylene mesh is for ridge vents on a roof, but it also works well at keeping bugs out of the airspace behind siding.

ORIGINAL ROOF & WALL SECTION



Drawings: Bob La Pointe. Photos this page: second from top, Joseph Lstiburek; bottom two: Dan Thornton. Top photo, facing page: Joseph Lstiburek.

Most of the details worked well, but some could have worked better. Three main changes were incorporated: adding plywood for structural stability, switching to a better air-barrier layer, and adding multiple layers of foam.



To provide racking resistance to the vertical barn boards, the author added a layer of ½-in. plywood to the outside of the barn. He first put down a layer of felt paper so that the new plywood wouldn't be visible from the inside, where barn boards are the finished wall surface.

Rather than wrap the barn in plastic again, the author chose to dig deep into his bank account and spring for peel-and-stick membrane as a first-line air barrier.

The original bug-proofing detail worked well, but builder David Joyce gave it an upgrade. Joyce added bug screen to the mesh and devised a better way to fasten the coil-stock bug barrier.

past the edge of the barn's roof to form the new overhang.

Our first lesson came about four months after the retrofit was complete: When the first frost hit the roof, I discovered an obvious melting pattern. At the seams between the foam panels, warm air was escaping and melting the frost. Rather than installing one thick layer of foam, I should have installed multiple layers, offsetting the joints and staggering the seams. I decided to fix that when I replaced the shingles.

I was curious about a few other things:

1. We had carpenter ants, which indicated a water problem. I couldn't figure out where they came from exactly, but I knew that I wanted to hunt them down and find out what was going on.

2. The air-leakage test revealed that the barn wasn't as tight as I thought it should be. I wanted 1.5 air changes per hour (ACH) at 50 pascals, but what I got was 3 ACH. We haven't retested with a blower door yet, but testing on similar buildings with this same retrofit system have netted excellent results: 0.1 ACH at 50 pascals.

3. I wanted to know whether I had any other bugs living in the furring-strip space between the siding and the foam sheathing.

4. I wanted to know how my water management actually worked. You can't really tell with computer simulations.

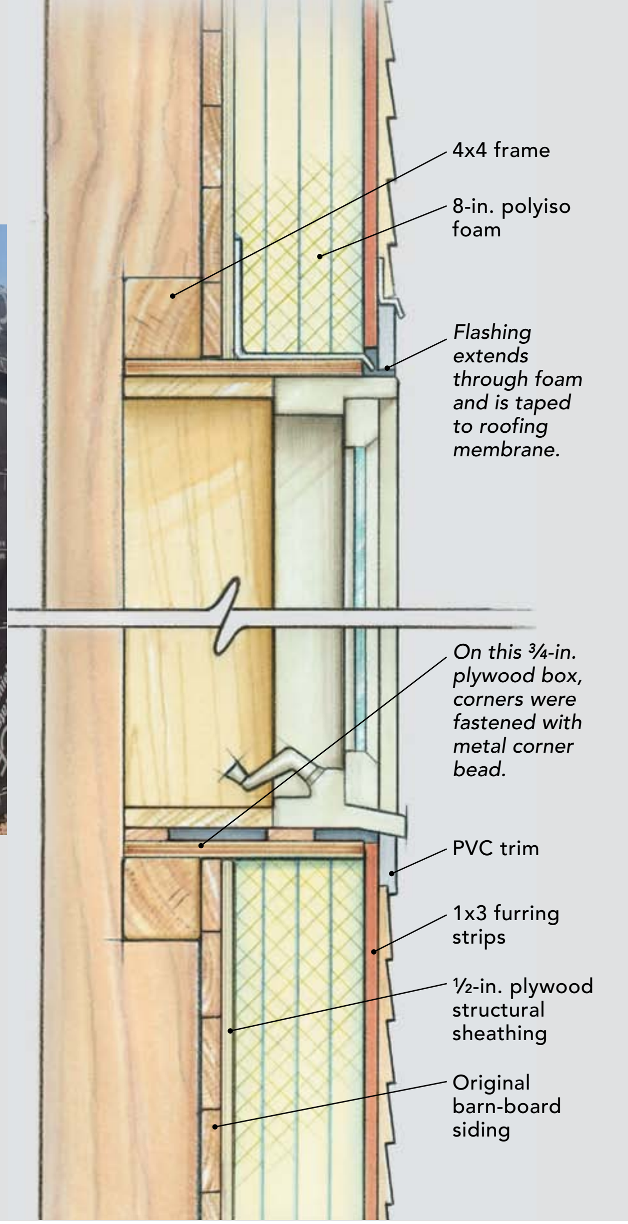
Clearly, there were more issues with this building than just the shingles and the foam, and they have been nagging at me for more than a decade. I decided to look at the project like an experiment—take the barn apart, see how the components performed, and then put it back together again using the best off-the-shelf technology available now.

Beginning at the outside, I'll take you through what we learned.

Paint can last a very long time

There was nothing special about the siding we had chosen for the barn except that it was installed over a vented rain screen and we were meticulous about sealing cut ends. The siding is lodgepole pine from Alberta. It was shipped to New Brunswick, where it was kiln-dried and then coated on all six sides with a penetrating wood preservative. Next, it was coated on all six sides with an oil-based primer and painted with acrylic-based latex paint. It was then shipped to Massachusetts as "Cape Cod" siding. We installed it over ¾-in. furring strips, which allowed air circu-

CANTILEVERED PLYWOOD BOX DID NOT SAG



When thickening walls by 8 in., one of the difficult design details is how to install and trim windows. The author chose to cantilever plywood boxes past the frame and to install the windows with masonry straps. Naysayers cautioned that the boxes would sag under the weight of the windows, but time told a different story.

lation behind it. This meant that the siding could dry evenly in front and in back.

When we took the siding off the barn, it was pristine. The trim, also lodgepole pine treated the same way, did not hold up as well in some places. The trim was not back-vented like the siding. Instead, it was nailed directly to ¾-in. plywood strips.

The bug screen worked perfectly

Installing siding over furring strips is a water-management strategy that keeps siding and walls dry and free of rot. I can't tell you how many times over the past 16 years that someone has said to me, "You can't do that. There will be animals and bugs up there, and they'll eat your house." When we took the wall assembly apart, however, there was absolutely no evidence of bugs, bees, or other critters living in the space between the 1x4s.

We kept critters out by wrapping a ¾-in. strip of attic ridge vent called Cobra Vent (www.gaf.com) at the bottom of the siding. We're rebuilding it in much the same way, but with slightly more advanced materials.

Epoxy-coated screws perform as well as stainless steel

We used two kinds of screws to fasten the thick foam panels to the barn boards: stainless steel and epoxy-coated steel. When we opened the walls, all the screws looked brand new except for two of the epoxy-coated screws. Those two screws were in a place where we had some water-management problems, and the heads had rusted out.

In the past 16 years, the technology of epoxy coatings has improved significantly, so I have no reservations about using epoxy-coated screws on the rebuild. At about 35¢ per screw versus $1.50 for stainless steel, this is an easy choice. I have absolutely no hesitation in recommending epoxy-coated steel screws and non-pressure-treated furring strips.

Furring strips will not rot

I can't tell you how many times I have heard, "You've got to use pressure-treated furring strips," but it is absolutely untrue. When we took the walls apart, the furring strips looked brand new. Why does this detail work? Because the vent space is designed to dry. That is its whole job.

Why not use pressure-treated furring strips as an added measure of protection? One reason is that it means having to use stainless-steel siding nails, which has proven to be an unjustified extra expense.

Stagger the sheets and choose the right foam

When I took the photo of my frosty roof on p. 55, I thought the heat loss was the result of using a single layer of foam, which meant that I couldn't stagger the sheets and offset the seams. That is what I've been telling people all these years in my confessional speeches about deep-energy retrofits. That, however, was only part of the problem. Now I know the rest of the story.

When we installed this foam, we covered the joints with mesh tape and mastic. Over time, the panels shrunk, and the tape/mastic combination cracked, opening the seams. This is where the heat came through to melt the frost on my roof.

Because we used XPS on parts of the main house, we dug into that siding to compare the EPS with the XPS, which was sealed at the seams with Tyvek tape. After 16 years of service, the XPS and Tyvek tape were in perfect condition (photo p. 56).

Peel-and-stick membrane sags

Interestingly, we also learned something about Bituthene membrane (peel and stick). Some of the peel-and-stick membrane that we used to flash windows wrinkled over time. Specifically, the pieces running horizontally above window head flashings sagged along their top edge. Anywhere that we didn't seal the top edge with contractor's tape, the peel-and-stick membrane sagged. This meant that water could get in and cause

MULTIPLE LAYERS OF FOAM OUTPERFORM A SINGLE LAYER

The second line of defense against air leaks was staggering and taping the seams of the many layers of polyisocyanurate foam.

problems. Wherever we taped the top of the membrane, water couldn't get in. Some folks in commercial construction call this a termination layer and use glue, sealant, or some type of tape. Now we specify that all the tops of this membrane should be taped.

Plastic is a dumb air barrier

In the 1980s, I was preaching all over Canada about plastic being a dumb air barrier. What did I choose to wrap my barn with? Plastic. It was cheap, and I was overconfident. The blower-door test years later didn't specify where, but it told me that there were a lot of holes. Rather than try to figure out where all the holes were and detail the plastic layer better, I switched to covering the barn in peel-and-stick membrane as the first line of defense in my air-barrier system.

Note: This plastic air barrier is different from a plastic vapor barrier that is commonly (and often wrongly) installed in roof and wall assemblies.

Window film is a poor substitute for the right glazing

At the time of the deep-energy retrofit, we used the best windows we could buy: triple-glazed Heat Mirror windows from Hurd. The third layer of glazing is a film suspended between the two layers of glass. The performance was pretty good, but the longevity of the inner layer of film was not so great. After 16 years, I can see fish eyes on the film—not enough to make me want to replace the windows, but enough to keep me from specifying window film in the future.

Ants can tunnel easily through foam

Flashing matters

One of my missions was to hunt down the carpenter ants that I knew were chewing up my foam. I found ant galleries in three distinct locations. Each place was adjacent to an area with a water-management problem. In two places, there was reverse-lapped flashing. The third place was up on the roof: The cupola's windows are at the same height as the roof peak. This is a dumb design detail. The windows should have been placed higher than that, and they are now.

How did the ants get to these areas? They crawled up. Ants crawl all over the place on reconnaissance missions. When they find a water source, they dig in. As irritated as I was that the ants were eating my foam, I was glad to find the ants localized in places with water problems. I am absolutely embarrassed about the water-management details. Two of the spots were reverse-flashed on a day when neither my architect nor I was on the job site.

Bottom line: If you don't screw up your water management, then you're not going to have ants.

Cantilevered window boxes won't sag over time

Here's another question that I have been bombarded with for the past 16 years: Won't those window boxes sag? When I talk about this window detail (called *outies* by the energy nerds), I often get questions about whether the boxes will sag under the constant weight of the window. I have always answered this question by saying that the window boxes on my house hadn't seemed to sag so far. Now, after having had the barn stripped of its siding and foam, which gave me the opportunity to measure the deflection, I can say unequivocally, "No, they will not sag." □

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