Avoiding Problems With Spray Foam

by Henri Fennell

To make sure you're getting a good spray-foam installation, choose a certified contractor and run regular material tests

I've been working with spray-applied and injected polyurethane foam for about 30 years, first as a manufacturer and architect and later as a foam-insulation contractor and consultant. I've insulated hundreds of buildings, from small homes to large commercial and industrial projects. For most of the time I've been in this business, foam has been seen as a high-priced specialty product — one specified only when cheaper, more easily installed materials, like fiberglass batts, couldn't provide the thermal performance needed. Over the past few years, however, polyurethane foam — particularly spray foam — has come into much wider use. Prices have fallen sharply, and the material has been embraced by builders and remodelers who see it as a way to have a single subcontractor provide high R-value insulation, air-sealing, and moisture control.

This surge of interest in spray foam isn't necessarily a bad thing, but it does have some important implications that builders who are now working with foam — or who are considering doing so — should be aware of.

Price and Quality

We've grown used to seeing prices for consumer goods like computers and cameras fall steadily as product performance improves and better features are added. It's easy to assume that cheaper spray foam is another example of the same trend. But in reality, the decline in foam pricing has almost nothing to do with market efficiencies and everything to do with demand, supply, and the miserable state of the housing economy.

Higher standards. A good portion of the increased demand for foam can be attributed to growing consumer interest in saving energy, as well as the emergence of net-zero and passive-house structures. "Green" certification systems like LEED that award points for improved air-sealing and high levels of insulation have also played a part.

The ongoing ratcheting-up of energy codes is another factor. Under the 2012 IRC, for example, all new homes will have to pass a blower-door test, and higher R-values will be required in most climatic zones. Foam's high R-value per inch — particularly that

Figure 1. This correctly applied closed-cell foam has been sprayed directly against the underside of the roof deck. To eliminate air leaks at the eaves, the foam has been extended beyond the top plate to form a seal against the attic floor. One minor omission: An additional shot of foam to each of the cracks between rafters and collar ties (arrow) would have prevented any possible air movement through that interface.

Figure 2. Defective B-rich foam, like that shown here, is characteristically soft and sticky and has a distinctive chemical odor. The material has not bonded to the sheathing beneath and can easily be pulled from the framing cavities by hand.

of closed-cell foam — makes it an attractive choice for contractors who want to comply with the new requirements without building deeper framing (**see Figure 1**).

Hard times. Of course, even while demand for spray foam was growing, the new-home industry was collapsing, leaving tens of thousands of contractors and subs from various trades with time on their hands. Many saw the spray-foam business as one of the construction industry's few remaining growth areas, and there has been a rush into the specialty. Unlike most established foam companies of the past — which were typically started by experienced foam installers who left existing businesses to strike out on their own — many of these startups are in the hands of owners with little or no experience with foam processing.

Predictably, increased competition has put a lot of downward pressure on prices, as new companies vie with one another to turn in the lowest possible bid. Their inexperience often shows in the bids themselves: I see prices on residential and commercial insulation jobs that barely cover the cost of materials and labor, let alone any overhead and profit. New foam installers who don't understand all of the costs either price themselves out of business or learn to price high enough to survive, but this takes time. And unfortunately, artificially low prices have driven many experienced installers out of business.

Causes of Foam Problems

The ongoing price wars have also been accompanied by a pronounced increase in bad installations. Industry experts tell me they've seen more foam quality problems in the last two years than in the preceding two decades.

In some cases, bad spray foam results from problems with the chemistry of the material. In others, the foam may be properly formulated as it emerges from the gun but later develops defects because it was applied incorrectly or under the wrong environmental conditions. And to further complicate matters, some foam-related problems are the result of bad building science, rather than any deficiency in the foam itself. Installing open-cell foam in a situation better suited to closed-cell foam, for example — or vice-versa — can lead to difficult-to-address long-term problems with moisture control.

Off-ratio foam. Unlike most building materials — which come off the delivery truck needing only to be cut to size and fastened in place — spray foam is actually manufactured as it's used, in a mobile "factory" at the job site. It's this monolithic, formed-in-place quality that allows spray foam to far outperform prefabricated foam board in applications where gap-filling ability is required.

Ideally, the contractor's pumping equipment combines the A-side and B-side chemicals that make up the foam in a near-perfect 50/50 ratio. But partially clogged or incorrectly adjusted equipment can produce foam that's hard and brittle or sticky and soft, depending on the component imbalance (**Figure 2**).

The best way to ensure a proper mix is to use ratio-monitoring equipment, which will set off an alarm or turn off the pump when the mix ratio exceeds the manufacturer's tolerance range. Unfortunately, the equipment is so expensive few installers use it.

A lower-tech method of tracking the foam ratio is to periodically weigh the A and B drums — but by the time this is done, the material in place may already be off-ratio. Going off-ratio is typically a gradual process, and an experienced technician can usually spot it happening early in its development. New contractors, however, usually have to see bad installed foam to learn the lesson. There's also a tendency to cover up bad material once the equipment problem has been addressed, which can lead to complications later when the bad material is exposed to environmental stresses.

Shipment and storage. Improper shipping and storage of foam chemicals after they leave the factory can also lead to problems. As a contractor, I used to refuse winter shipments that arrived at our dock at temperatures well below freezing. Manufacturers' shipping documents usually stipulate that materials should be kept above freezing while in transit. Even so, it's a good idea to specifically request this, especially during swing periods of the year.

Overheating can be a problem too. The blowing agents used in most closed-cell foam systems will boil at temperatures that can easily be reached during shipment, in storage, or at the job site. Many shipments arrived at my facility in trucks that had been in the sun during hot weather for extended periods, resulting in overpressurized drums with the ends bulged out to the point that they wouldn't stand upright. I have never seen a training program that addresses the issue of temperature control during shipment; many potentially damaged shipments are probably accepted and used by contractors who don't realize that such improper handling can degrade the quality or yield of the resulting foam.

Errors in application. Even if foam is properly mixed with undamaged chemicals, success still isn't guaranteed. Improper application or failure to allow for environmental conditions can lead to a variety of "after the gun" defects.

Closed-cell foam gives off a lot of heat as it cures. That's not a problem as long as the foam is applied in relatively thin layers — or "lifts" — that allow excess heat to dissipate between layers. But if an inexperienced or careless operator piles up too much foam at one time, the heat can't escape. Once the temperature rises beyond a critical level, the resulting foam can shrink excessively after it cures (**Figure 3**). Overheating can also result in blowholes, hidden voids, or internal scorching, and even cause fire to break out (see "Massachusetts Fire Officials Urge Caution with Spray Foam," *JLC Report,* 10/11).

To minimize these kinds of problems, most high-end

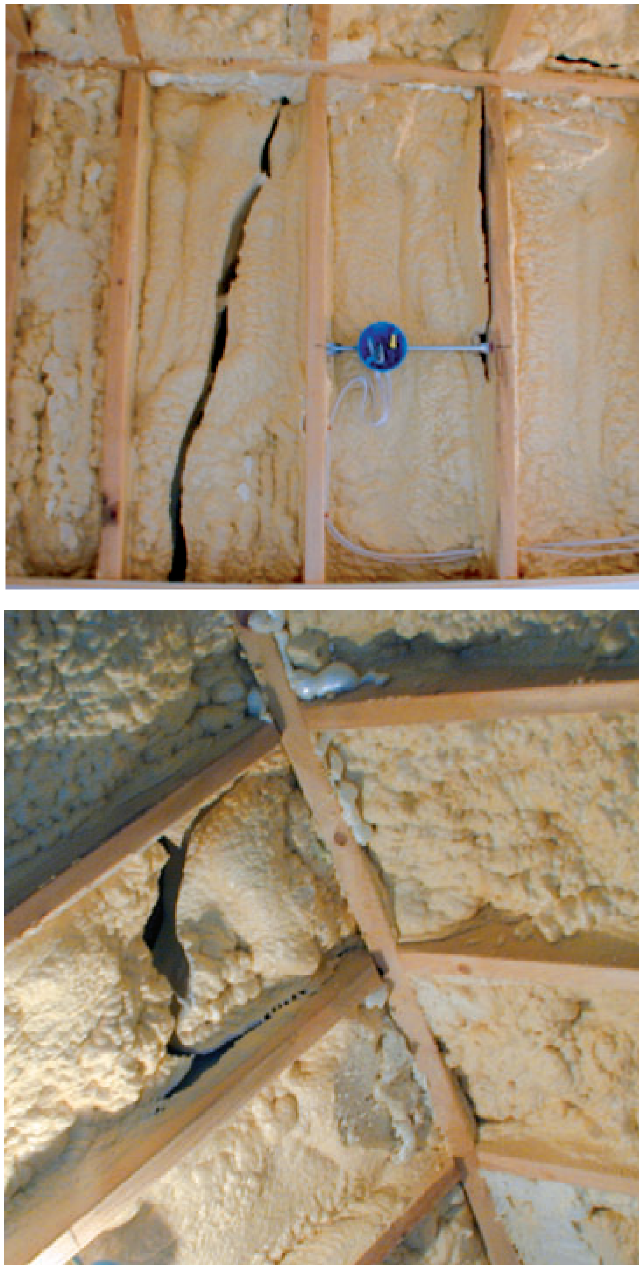

Figure 3. Closed-cell foam applied in lifts that are too thick is subject to overheating, which can lead to subsequent shrinkage and cracking — a problem that may not become evident until months after the applicator has packed up and left. The lighter-colored areas of foam mark the location of cracks that had been filled in an earlier attempt at repairing the still-ongoing shrinkage (top). Cracks in the foam sprayed against the roof sheathing precisely matched melted areas of frost on the roof exterior in cold weather. Because such cracks may extend all the way to the sheathing, humid indoor air that moves through them may condense on the cold underside of the sheathing, promoting mold growth or rot (above).

manufacturers of closed-cell foams offer summer and winter formulations of their products, and some even have spring/fall formulations for the swing seasons.

Choosing the right foam formulation is a good start — but it's important to realize that summer-like conditions can occur on a job site even in midwinter. A roof deck covered with black roofing felt, for example, may be hot to the touch in cool weather. A skilled applicator will compensate for this by spraying a very thin first pass to "prime" the area and insulate subsequent lifts from the heating effect of the sun. Omitting this step could result in an area of unacceptably low-density foam, which can shrink and crack dramatically when first exposed to cold weather — even months after installation — as the resulting "thermal shock" causes encapsulated gas bubbles to contract. Foam that's sprayed under conditions that are too cool, conversely, will not shrink, but will fail to bond correctly to the substrate material.

Because water is a blowing agent for polyurethane foam, the substrate the foam will be sprayed against must also be clean and dry. Foam blown against a damp surface will be "overblown" where it contacts the substrate, and adhere poorly. Using an open-flame gas heater to bring a job site up to temperature is a common cause of such moisture-induced problems, because the water vapor it gives off may condense on cool surfaces. Hygroscopic materials like OSB and plywood can feel dry to the touch while still holding a lot of moisture, so if there's any doubt, it's a good idea to use a moisture meter to be sure the substrate moisture content is within the manufacturer's specs.

Choosing a Subcontractor

For builders, supervising tradespeople is all in a day's work. But foam is so new, most builders don't yet have the experience to know when the foam installer is making a mistake. While component ratio, mix quality, and processing temperatures are not the GC's responsibility, there are steps he or she can take to improve the odds of getting a quality job.

Figure 4. A cheap kitchen knife — with graduated inch markings added to the blade with a permanent marker — is a handy tool for cutting samples and confirming material thickness.

Experience and training. Most foam manufacturers claim to restrict sales of their products to qualified contractors who have been through their in-house training programs, but I speak from experience when I say this is not always true. In addition to checking on the financial stability of the company, take the time to find out what types of training a prospective subcontractor — as well the technician who will actually be spraying the material on your job — has received. Ideally, the technician will have completed a general spray-foam training program that includes an introduction to air barriers and building science. He should also be certified by both the manufacturer of the spray equipment and the foam supplier.

Check references. Rather than relying on a list of preselected references, ask for the name and phone number of the GC on the foam contractor's largest project. Large commercial projects are often supervised by an architect and include a formal quality-assurance program, so it's a good sign when this kind of job appears on a contractor's resume. Big commercial jobs also tend to reveal the variations in quality you can expect from an installer: Sprayers get tired, equipment gets dirty, out-of-date inventory tends to be used up, and it is unlikely that only the installer's most experienced workers will do the entire project. So a commercial GC will likely have seen the best and the worst the installer has to offer.

It's also a big plus if a foam contractor is certified by the Air Barrier Association of America (ABAA). Contractors on ABAA projects are required to complete the association's comprehensive spray-foam training, which includes a building science overview, and they are required to perform quality-assurance protocols during the work. This is primarily a commercial qualification that's fairly uncommon among contractors who specialize in residential work, but it doesn't hurt to ask.

Defining the scope of work. Another way to ensure high-quality work is to provide a clear scope of work as part of your bid process, and to include a submittals requirement. While this might seem unnecessarily formal and applicable only to commercial work, it's definitely worth having the proper documentation on file. Submittals should include the following:

- MSDS sheets for both the raw material and cured foam
- product data sheets
- ICC-ES reports
- certificates of insurance
- a written safety plan (required by OSHA)
- an air-quality management plan
- a quality-assurance plan

Finally, it's a good idea to develop a list of standard operating procedures (SOPs) that clearly define the foam sub's responsibilities in writing. For example, you can specify that all foam shall be trimmed flush with the framing in areas that will receive an

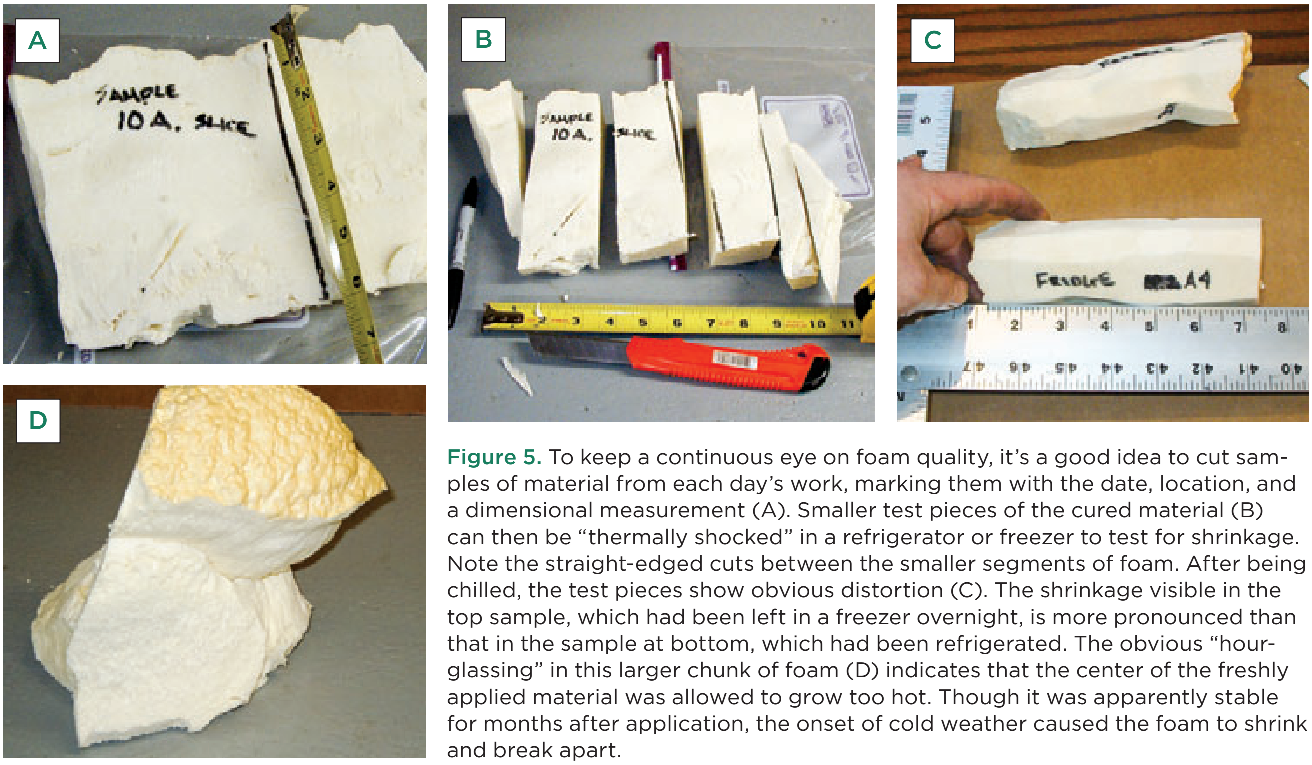

Figure 5. To keep a continuous eye on foam quality, it's a good idea to cut samples of material from each day's work, marking them with the date, location, and a dimensional measurement (A). Smaller test pieces of the cured material (B) can then be "thermally shocked" in a refrigerator or freezer to test for shrinkage. Note the straight-edged cuts between the smaller segments of foam. After being chilled, the test pieces show obvious distortion (C). The shrinkage visible in the top sample, which had been left in a freezer overnight, is more pronounced than that in the sample at bottom, which had been refrigerated. The obvious "hourglassing" in this larger chunk of foam (D) indicates that the center of the freshly applied material was allowed to grow too hot. Though it was apparently stable for months after application, the onset of cold weather caused the foam to shrink and break apart.

interior finish, or that the foam applicator is to provide an air seal between his or her own work and any adjoining surfaces.

By telling installers in advance that they will have to meet these requirements, you will weed out many of the new, unproven foam products, as well as unqualified foam contractors who are new to the industry or do not have safety and quality-assurance programs in place.

Your in-house SOP list will evolve as you gain experience working with foam. The goal is to make sure that you don't make a given mistake more than once.

Monitoring foam quality. A simple way to verify that the foam installer is using the right materials is to check the labels on the drums. Parts A and B should be from the same manufacturer and should be identified as components of the same foam "system," if the manufacturer has multiple foam products. It's also a good idea to systematically check samples of the foam as the job progresses. This doesn't have to be a difficult or complicated procedure. Basically, it involves cutting out a chunk of foam about 6 inches square — tapered slightly inward for ease of removal — at the end of each work day (**Figure 4, previous page**). The sample should be bonded to the substrate to the point that it must be broken out of the hole. Foam that separates easily from the sheathing without leaving a layer of material stuck to the surface was likely applied to a substrate that was wet or too cold.

Compare the first test piece with the sales samples the manufacturer's salesman hands out, and use it as a benchmark for the subsequent test shots. Mark each with the date and the area of the building it represents, measure its dimensions, and write that information directly on the sample. Don't forget to have the installer patch the hole with more foam the following day.

For projects in climate zones 3 and lower, wait until the recommended cure time for the foam — typically 24 hours — has elapsed, then put the labeled and bagged sample in a refrigerator overnight to assess its reaction to thermal shock (**Figure 5**). In climate zones 4 and above, double the minimum cure time, then put the sample in the freezer overnight. The next day, remove it, check its dimensions, and compare any shrinkage with the acceptable range listed on the manufacturer's product data sheet.

Another useful quality-assurance technique is to use a sharp knife to cut several shallow lengthwise slits down the center of a few randomly selected framing bays after the foam has finished curing. If there are any tensile stresses in the not-yet-shrunken foam, slitting the material will relieve them, in some cases causing the foam to separate at the cut line with a dramatic "pop." In less severe cases, the cracks may gradually open up over the course of several days. Foam that doesn't open up within a day or two is likely to be permanently stable.

The slitting technique can sometimes be used to salvage foam that's generally adequate in quality but shows minor density-related shrinkage. It involves systematically slitting all affected

Figure 6. The closed-cell foam on the stone foundation wall at right has been extended a foot or so onto the interior concrete wall at rear to reduce conductive heat loss; the concrete wall was masked before spraying to provide a neat termination. Depending on soils, climate, and other factors, such below-grade applications are sometimes limited to the above-grade portion of the wall — or graduated in thickness, with a thinner layer below grade — to reduce the danger of freezing the footing.

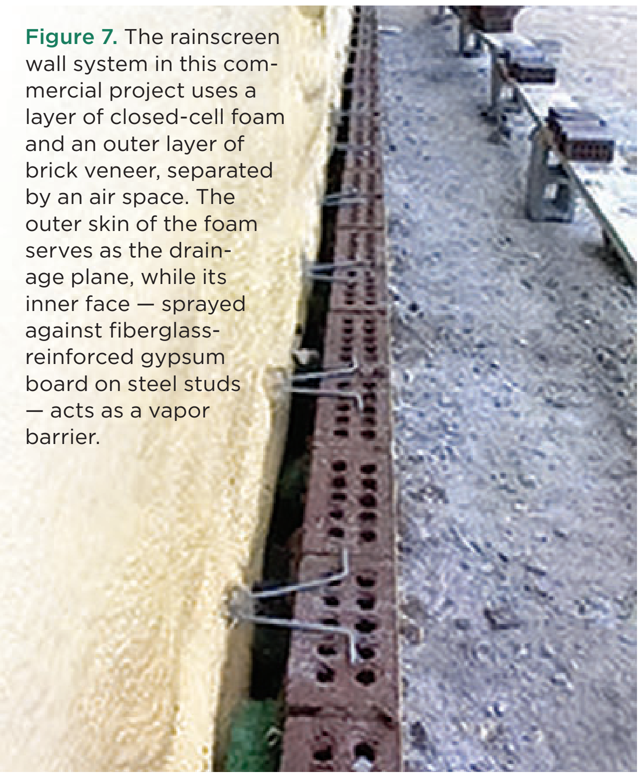

Figure 7. The rainscreen wall system in this commercial project uses a layer of closed-cell foam and an outer layer of brick veneer, separated by an air space. The outer skin of the foam serves as the drainage plane, while its inner face — sprayed against fiberglass-reinforced gypsum board on steel studs — acts as a vapor barrier.

material, waiting until the cracks have stopped opening, and filling them with additional foam. In either case, any slits that do not open up need not be sealed.

Fixing defective foam isn't always so simple, of course. Badly off-ratio foam or foam with serious shrinkage problems may need to be completely removed and replaced. Regularly checking on foam quality greatly increases your chances of catching any problems before they're sealed behind the wall or ceiling finish, at which point they become much more expensive to repair. Equally important, it lets the foam contractor know that you're serious about the quality of the product.

Spray Foam and Building Science

Spray foam does several things well. It serves as an air barrier, a high R-value insulator, and — in the case of closed-cell foam — an excellent vapor retarder. But turning to foam as a one-stop solution to building-envelope problems can backfire if you don't understand its effect on dewpoints and vapor drive. The most important choice facing a builder in this regard is whether to specify open- or closed-cell foam.

Foam below-grade. Fully cured closed-cell foam is almost impervious to water, which means it can be applied directly to below-grade masonry walls. If wire mesh or some other suitable material is mechanically fastened to the masonry base — eliminating the need for a physical bond between the masonry and foam — closed-cell foam can even be successfully applied to a damp or wet substrate, though adequate drainage must be provided (**Figure 6**).

Open-cell foam, on the other hand, absorbs water readily and should never be used on below-grade masonry that is damp or subject to seasonal wetting or moisture intrusion. Nor should it be installed in a roof structure that is not yet weathertight. Whether this type of foam dries out over time depends on the conditions. If, for instance, it is in a leaky roof cavity between plywood and a polyethylene vapor retarder that was installed a day after the foam, it may never dry out, especially if the roof is unvented.

Moisture and vapor drive. Open-cell foam typically requires a vapor retarder in climate zones 4 and above. Most open-cell foam manufacturers specify the number of heating degree days beyond which one is needed. Both open- and closed-cell foam need vapor protection if they are in a location where there is a high vapor drive for long periods of time, the general rule being that the drying potential of an assembly must exceed its wetting potential.

So, for example, if you have an indoor pool or greenhouse with foam insulation in the enclosure, the warm, humid indoor conditions will usually be constant for the life of the structure. Open-cell foam can be used in this sort of application, but only if a vapor-permeable exterior sheathing is also used, so that moisture can dry to the outside.

A riskier option is to use a wall system designed to dry to the inside. I've seen several installations where an architect or designer specified open-cell foam directly against rainscreen masonry, the idea being that any water absorbed by the foam can evaporate harmlessly to the inside of the building. That approach can work if the interior wall finish is permeable enough, but if the building's occupants later hang vinyl wallpaper — or even apply several coats of paint — the moisture can become trapped inside the wall. It's best to avoid open-cell foam in this situation, unless you can add an exterior rainscreen at the same time. Even then, closed-cell foam is a safer choice (**Figure 7, previous page**).

No matter what kind of foam is to be used, exterior masonry cladding should be evaluated ahead of time to ensure that spalling, freeze/thaw damage, and efflorescence won't be a problem.

Incidentally, don't count on the foam sub to understand such moisture-control issues well enough to keep you out of trouble. My own recent experience suggests that many installers are happy to spray foam wherever the GC tells them to.

Calculating cost. Where moisture isn't a factor, the choice of foam will usually be determined by the size of the framing. Open-cell foam is typically less expensive than closed-cell for a given R-value. But in a structure that has only 2x6 rafters, open-cell foam may not allow you to meet current code and performance standards because its per-unit R-value is too low. In an existing building with 2x8 studs, on the other hand, you can likely use open-cell foam — with or without a vapor retarder, as the climate zone demands — and still meet or exceed code or energy-program requirements.

If framing size does not dictate the choice, a simple calculation of the installed cost per unit of R-value will give you the most cost-effective option, although this can be tricky at times. If you have 2x6 studs and the specification is for R-21, for example, you might need to install $5^1/2$ inches of open-cell foam in a $5^1/2$-inch framing cavity. This isn't difficult to do, since open-cell foam is designed to be sprayed to the full depth of the framing and beyond, then trimmed back flush after it cures (**Figure 8**). However, you'll have to spray $6^1/2$ inches initially — and pay for both the excess material that's trimmed off and discarded and the labor to do the trimming.

With closed-cell foam, a 2- to 3-inch layer will provide the same R-value. The bottom line is that 3 inches of closed-cell in a 2x6 wall, with no trimming and no waste, may be more cost-effective than open-cell foam, even though closed-cell foam itself costs more. Obviously, in deep roof framing members, open-cell foam will cost less than closed-cell because neither will require trimming.

Henri Fennel *is president of Building Envelope Solutions in North Thetford, Vt.*

Figure 8. Depending on the R-value required, open-cell foam can be applied to a depth greater than the framing before being trimmed back flush (top). Denser closed-cell foam is much more difficult to trim. By allowing the foam to extend beyond the plane of the framing (above), this installer has created a major headache for the drywall crew. The author's tool of choice for trimming limited areas of closed-cell foam is an angle grinder fitted with a coarse 6-inch steel cup brush.