



A lot can go wrong with a two-part plastic insulation that is essentially manufactured on the job site as it's being applied.

M Here's what to look out for

Most spray-foam insulation is installed correctly, but as an industry consultant I've inspected SPF projects that have left me scratching my head in wonder. Sometimes the foam is cracked or delaminated, indicating an improper mix or poor substrate preparation; in other cases, there's too much over-spray. Occasionally the foam is properly installed but applied in the wrong place or at the wrong thickness; sometimes there is a vapor retarder when one isn't required, or a required one is missing.

A decade ago, most SPF problems could be traced back to equipment issues. But with the recent expansion of the spray-foam industry, I'm also seeing a growing number of application defects made by inexperienced or poorly trained installers. Faced with job competition, some installers may be trying to cut

costs by taking shortcuts, or they may be trying to extend the window of application into risky climatic conditions in order to squeeze in more jobs.

Since a poor foam job can sabotage building-envelope performance, general contractors should know what can go wrong and learn how to evaluate the quality of their installer's work.

Spray-Foam Basics

There are two main types of spray foam used for interior insulation: $3/2$ -pound open-cell SPF and 2-pound closed-cell SPF. Thanks to ASTM and industry-wide standards, different foams from different manufacturers within these two categories have roughly similar physical properties, such as R-value and the amount of closed- and open-cell content.

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A few companies also offer 1.2-pound SPF, a kind of hybrid that shares some of the characteristics of both open-cell and closed-cell foam. But with no current industry standards or general code criteria for this type of foam available, installers will need to consult the manufacturers' literature, case studies, and ICC evaluation reports carefully to compare various products' physical properties and determine which is suitable for the application and meets local code requirements.

Stored in liquid form, SPF insulation consists of a petroleum-based "A" side (primarily methylene diphenyl diisocyanate) and a "B" side consisting of polyols, catalysts, fire retardants, blowing agents, and other chemicals.

Half-pound low-density open-cell SPF. Water is the blowing agent in low-density foam, which weighs between 0.4 and 0.6 pound per cubic foot of reacted material and expands to 100 to 150 times its liquid volume. This foam has an R-value range of 3.5 to 3.8 per inch and a vapor permeance of between 6 and

10 perms at a 3-inch application, which — according to current ICC building codes — qualifies it as a Class III vapor retarder.

Two-pound medium-density closed-cell SPF. Proprietary blends of HFC-245fa and water are the current blowing-agent packages used in medium-density foam, which weighs between 1.5 and 2 pounds per cubic foot of reacted material and expands to about 30 times its original volume. The foam has an R-value range of 5.8 to 6.8 per inch (depending on the blowing-agent formula) and a vapor permeance of less than 1 perm at 2 inches or more, qualifying it as a Class II vapor retarder. Unlike open-cell foam, 2-pound closed-cell foam is water-resistant and accepted by FEMA as a severe-flood-zone approved material.

Vapor retarder. Whether or not foam insulation requires an additional vapor retarder depends on the foam being used and its thickness, the climate, and local building codes. Closed-cell foam has a permeance averaging about 1.5 per inch, so as the average temperature goes down, more foam thickness is needed

to keep the temperature inside the wall or ceiling cavity above the dew-point and minimize the potential for condensation inside the assembly. The IRC allows a Class III interior vapor retarder — that is, latex or enamel paint — when at least R-15 of closed-cell foam is used in a 2x6 wall in climate zones 7 and 8. (For specific requirements for other climate zones, see 2009 IRC Table R601.3.1.)

With an open-cell content of over 80 percent, which allows liquid water to enter the foam, 1/2-pound SPF is considered a Class III vapor retarder. So, with a few exceptions, the IRC requires an additional Class II vapor retarder, such as the kraft-paper facing on batt insulation, on the warm-in-winter side of open-cell foam installed in climate zones 5, 6, 7, 8, and Marine 4.

Equipment

Good foam requires the correct combination of heat, pressure, and spray-gun configuration. Getting just one of these factors wrong can result in poor cell structure and dimensional instability, leading to such problems as



Open-cell foam can be installed in a single pass (above left), but because of its high expansion rate it must typically be trimmed after installation, which produces considerable waste (above). Trimming usually isn't necessary with closed-cell foam, but to avoid excessive exothermic heat, it should be installed in lifts no more than 1¹/₂ inches thick (left).

shrinking and cracking, voids and fissures, and poor adhesion.

In addition, the liquid "A" and "B" components in SPF systems are designed to be mixed in a 1:1 ratio by volume (within 2 percent). Off-ratio "A"-rich foams tend to be hard, friable, and brittle, while "B"-rich foams tend to be soft and gummy and are more likely to have a high odor. Off-ratio foams can occur when the liquid components haven't been properly stored within the temperature range specified by their manufacturer — typically between 60°F and 80°F in a dry environment — or when the components are contaminated or out-of-date.

Faulty spray equipment can also lead to off-ratio foam. Sometimes, one of the two transfer pumps that send the "A" and "B" components to the proportioning pump fails, causing a crossover that can fill the spray gun and sometimes the whip hose with off-ratio or even reacted foam. If the proportioning pump fails to properly heat and pressurize the components to acceptable levels before pumping them in separate hoses to the spray gun, the foam may not get hot enough to react properly. And if the spray gun is dirty or the nozzle too large, the components won't mix well in the gun's mixing chamber when the installer pulls the trigger.

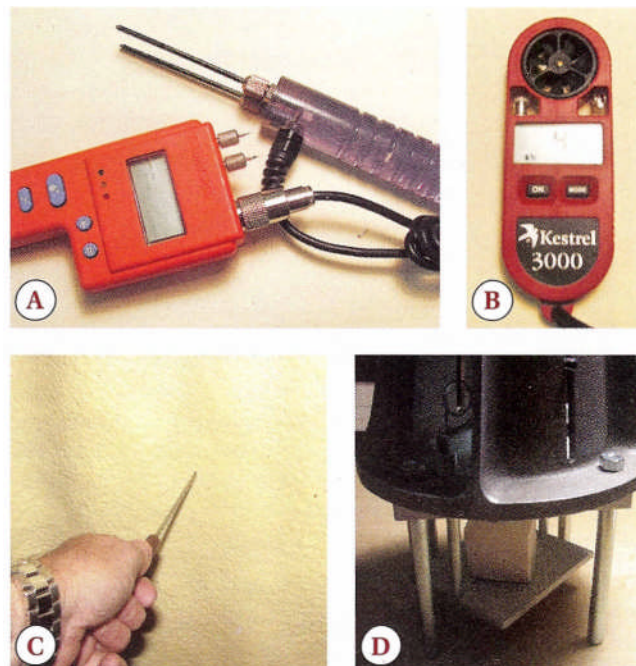
Substrate Preparation

SPF can be sprayed on wood, concrete, metal, asphalt, foam sheathing, and other substrates. But the substrate needs to be clean and dry — "paintable" is a reasonable benchmark — for the foam to adhere well. SPF shouldn't be installed when temperature and humidity levels fall outside the range recommended by the SPF manufacturer.

Moisture. When a surface is wet or damp, the moisture acts as a blowing agent that reacts with the "A" side of the SPF system, resulting in off-ratio foam with poor physical properties and poor adhesion. When foam is sprayed on wet framing or sheathing with greater than 19 percent moisture content, for example, there's a risk that the foam will have poor cell structure and won't bond well when the framing dries, leading to cracks between the foam and framing. For this reason, the spray-foam industry recommends that installers measure substrate moisture content with a moisture probe before applying foam — but many of them don't.

Safe moisture content is relatively easy to determine in wood, but trickier to do in masonry. Concrete may appear to be dry yet still hold quite a bit of moisture that will be brought to the surface during foam's exothermic reaction.

Currently, the SPF industry doesn't have any specific moisture-content recommendations for concrete, beyond allowing for a 28-day curing time if it's green. Some coating manufacturers



The author uses a Delmhorst moisture meter to measure substrate moisture content; this one (model BD 2100) has separate settings for different materials, including wood and foam insulation, and can be fitted with 6-inch-long contact pins (A). To calculate dewpoint, he uses a portable Kestrel 3000 temperature and humidity gauge (B). After installation, a simple probe confirms that the foam insulation has been sprayed at the proper thickness (C). Corn-Ten's compressive-strength tester (D) is useful if there are concerns about the quality and compressive yield strength of the foam.

consider MCs as high as 85 percent acceptable for paint, but I think this number is too high for foam. To be safe, tape an 18-inch by 18-inch sheet of clear plastic to the concrete, making sure it's sealed on all four sides. If condensation appears on the plastic or if the surface of the concrete darkens after 16 hours, the concrete is too wet for foam.

An experienced installer will often just spray a small section of concrete to see if the surface becomes damp and reacts with the rising foam. If it does, he'll wait until the concrete dries out before continuing to spray.

Temperature. While there is some variation among manufacturers, most SPF systems are designed to be installed when substrate temperatures are higher than 55°F. A few low-temperature foams can be used in colder conditions, but they're the exception. With most foams, spraying when temperatures dip below 55°F (or below the manufacturer's recommendation) can

Spray-Foam Problems



▲ Excessive moisture in the substrate can act as a blowing agent. Here, 2-pound SPF was sprayed on sheathing that was wet on the left side and dry on the right side. The foam on the wet side has increased in volume, compromising cell structure and substrate adhesion.



The large void and delaminated area on this core sample indicate that the low-density foam was sprayed on a substrate that was too cold.



In this example of off-ratio foam, the darkened layer at the top has very high compressive strength, an indication of an "A"-rich foam caused by a cold "B"-side component. Equipment malfunctions can also lead to off-ratio foam.



▲ Excessive exothermic heat can actually scorch foam, as shown here, and in extreme cases cause it to catch on fire.

lead to the formation of a high-density shellac-like coating on the surface of the substrate that reduces the adhesive quality of the foam. In some cases, the foam can actually separate from the substrate, because of the difference in temperature between the two materials.

Humidity. When relative humidity levels are high, moisture can combine with the liquid components of rising foam and affect the foam's cell structure. To avoid problems like low density, low compressive strength, and too many open cells, foam shouldn't be sprayed when the ambient temperature is within 5°F of dewpoint. Since dewpoint is based on relative humidity and air temperature and can vary widely over the course of a day, these conditions should be measured and recorded a few times daily with a humidity and temperature gauge, such as a Kestrel 3000 (800/891-8493, kestrelmeters.com).

Application

Once spraying begins, it's a good idea to check foam regularly for quality, thickness, and yield, particularly when temperatures

are cool or the humidity high. Quality-control samples — taken periodically during the job by either the installer or the GC — can indicate problems with foam thickness, adhesion, and cell structure, and can help document that a foam installation meets specifications.

Lifts for closed-cell. To avoid problems, closed-cell foam should be installed in lifts less than 1½ inches thick, with breaks of about 10 to 15 minutes between lifts to allow exothermic heat to dissipate. A certain amount of exothermic heat is needed to properly cure SPF foam, but excessive heat can result in cracks and shrinkage. Unusually strong odors after foam application can be an indication of this problem.

A good rule of thumb is to size the spray gun's mixing chamber and nozzle so that passes overlap by more than 60 percent. This will allow the foam to grow at a uniform rate from one side to the other during a lift. When spraying studwall and ceiling cavities, for example, the installer should picture-frame the cavity, allow the foam to set a few minutes, and then fill in the middle, spraying parallel to the direction of the studs.



A Cracks, fissures, and voids in closed-cell foam indicate either a poor mix or excessive lift thickness.



- High exothermic heat can also cause blowholes and discoloration in closed-cell foam.



I Closed-cell foam was sprayed too thickly into this stud bay and has shrunk away from the framing as a result of exothermic heat build-up. The foam should be removed and replaced.



A This foam has pulled away from the truss chord due to excessive exothermic heat. Closed-cell foam should be installed in lifts that measure less than 2 inches thick, and with enough time between lifts to allow exothermic heat to dissipate.

On a masonry wall, an experienced installer should be able to spray 2 or 3 inches of closed-cell foam in two or three lifts within a $\frac{1}{4}$ -inch tolerance. In framing cavities, the variation is typically greater due to the thicker application against rafters or studs.

One shot for open-cell. Half-pound SPF is typically installed in a single lift, starting at the bottom of a studwall or ceiling cavity and working up. To prevent gaps and voids, hard-to-reach areas or spaces behind the studs are usually picture-framed first.

You can expect considerably more thickness variation with open-cell foam due to its greater expansion rate. A $\frac{1}{2}$ -inch tolerance when spraying 3.5 to 5.5 inches of foam would be considered exceptional, while a more typical $\frac{1}{2}$ -pound foam installation would have a $\frac{3}{4}$ -inch to 1-inch tolerance between studwall cavities. As a result, trimming is usually necessary after the foam has been sprayed.

job-site protection. SPF insulation can drift a few hundred yards on a windy day if the doors and windows have been left open, and it sticks tenaciously to any surface it lands on. Therefore, every job should have a comprehensive overspray plan that includes careful masking and the removal of any items in the immediate vicinity that might be damaged by overspray. And since the fumes and mist produced by an installation can be harmful, SPF contractors are responsible (per OSHA regs) for a written respirator plan for employees, and for a safety plan that protects all nearby occupied areas and prevents nonworkers from entering the work area during spraying. (GCs are responsible for a safety plan as well.)

Fumes and mist usually dissipate within a few hours to a few days, depending on the amount of ventilation available. Since off-spec foam can create odors that linger much longer, any odors that last longer than a week may indicate a problem with

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the foam and should be investigated.

What to Look For

Ideally, every completed SPF installation should be inspected, by a manufacturer's representative, an owner's representative, or a third-party inspection company. (For a list of inspectors accredited by the Spray Polyurethane Foam Alliance, call 800/523-6154

or go to sprayfoam.org.) With the cost of a third-party inspection on most residential projects ranging from \$1,000 to \$2,500, the most realistic option for a GC with an already-stretched insulation budget is to request an inspection by the SPF manufacturer's or supplier's rep - especially if there are any concerns about the quality of the insulation sub's work.

When I inspect an SPF installation, my inspection report includes the name of the material supplier, the type and product number of the foam, the lot number, the specified thickness, photos, and a sketch of the sprayed areas. I measure and record foam depths at a minimum of 15 locations to verify that the contractor met thickness requirements and to evaluate his ability to uniformly install the foam. I also examine the foam quality and look for problems like poor adhesion, density irregularities, and voids, cracks, or gaps in the foam.

Cell structure and quality. Foam should have a consistent cell structure without significant color changes, cell deformation, or other anomalies. Dark or scorched areas in the middle of the foam indicate high exothermic heat, which can result in cracks and shrinkage.

Density. I've inspected enough foam to be able to tell whether it's approximately the right density simply by pressing it with my thumb. But when I'm in doubt, I take a sample and test it. For 2-pound foam, the density should be between 15 and 25 psi; for 1/2-pound foam it should be between 2 and 5 psi. Anything softer or harder is an indication of an off-ratio or poor mix.

Adhesion. Adhesion problems on closed-cell foam can usually be found by randomly pounding the foam. Delaminated foam will have a hollow sound and compress slightly.

When I find a suspicious area, I use a coring tool, a saw, or a knife to take a sample. If the sample is hard to remove and leaves little bits of foam on the substrate (the industry term is "cohesive foam failure") there is no adhesion problem. Another acceptable result is when the sample comes away from the substrate with some force but is clean; this is called a mechanical bond. But if the sample is easily removed from the substrate, I know that the adhesion is poor and the affected area must be removed, since poorly adhered foam can lead to blisters, delamination, and shrinkage of the foam - all of which will affect the foam's insulating, air-sealing, and condensation-control qualities.

Repairs

Usually, cracking and other problems in a foam installation affect only small areas, and repairs can be made without a total tearout of the existing insulation. Unless the whole application is off-ratio, most repairs require the removal of 5 percent to 15 percent of the existing foam.

| Manufacturgs | | | |
|---|----------------------------|-----------------|------------------|
| Manufacturer | Product | Density (lb/cf) | R-value per inch |
| Arnette Limited 816/776-3005 arnetteid.com | Amthane PUOC R | 0.45 | 4.32 |
| BASF 800/888-3342 basf-pfe.com | Enerlite | 0.5 | 3.7 |
| | Spraytite/Comfort Foam 158 | 2 | 6 |
| | Spraytite/Comfort Foam 178 | 2 | 6.7 |
| BioBased Technologies 800/803-5189 biobased.net | BioBased 501w | 0.5 | 3.6 |
| | BioBased 1701s | 1.7 | 5.9 |
| Corbond Corp. 406/586-4585 corbond.com | JM Corbond III | 2 | 6.6 |
| Demilec 877/336-4532 demilecusa.com | Sealection 500 | 0.45-0.5 | 3.81 |
| | Heatlok Soy | 2.1-2.3 | 7.2 |
| | Heatlock Soy 200 | 2.1 | 7.3 |
| Henry Company 800/486-1278 henry.com | Permax RT 3090 | 0.5 | 3.61 |
| | Permax RT 2045 | 1.8 | 6.47 |
| | Permax RT 2045 | 2 | 6.45 |
| Icynene 800/758-7325 icynene.com | LD-C-50 | 0.5 | 3.7 |
| Lapolla Industries 281/219-4100 lapolla.com | Foam-LOK FL500 | 0.4-0.6 | 3.9 |
| | Foam-LOK FL2000 | 2 | 6.3 |
| North Carolina Foam Industries 800/346-8229 ncfi.com | Sealite | 0.5 | 4.1 |
| | InsulStar | 2 | 6.4 |
| Spray Foam Polymers 800/853-1577 sprayfoampolymers.com | ThermoSeal 500 | 0.5 | 3.83 |
| | ThermoSeal 1200 | 1.2 | 4.89 |
| | ThermoSeal Soy 2000 | 2 | 6.9 |

After the off-spec foam has been identified, it should be cut back at a 45-degree angle to where it exhibits good adhesion and good physical properties. After the substrate has been cleaned and - if necessary - reprimed, the area can be resprayed.

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