# Quality Assurance in Sprayed Polyurethane Insulation: Water and Its Effects

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WHILE A NUMBER of factors affect the quality of installation of a spray-applied polyurethane foam roof, perhaps none are more important to understand and control than water, moisture, and humidity.

Fundamental to understanding the effects of water is: Water acts as a reactive blowing agent. The reaction between water and the isocyanate component of the polyurethane foam chemical system generates $CO_2$ gas.

The chemist uses this effect to develop water-blown or partially water-blown foams. That is, water can be blended into the resin mix to react with the isocyanate component, generating $CO_2$, which becomes a blowing agent. Foams utilizing water as a blowing agent are precisely formulated by the manufacturer to meet stringent requirements of compressive strength, density, reactivity, etc.

## THE EFFECTS OF MOISTURE

Moisture, for the sake of this article, is defined as trace or small quantities of liquid water, often not easily observable.

Moisture contamination on a roof surface to be sprayed will act as a localized blowing agent. The result will be a layer of elongated, weak cells at the foam-substrate interface. This weak cell layer may fracture under stress resulting in delamination. What appears to be an adhesion failure is actually a foam structural failure.

A thin, fuzzy-surfaced layer of polyurethane foam remaining on the substrate is characteristic of this mode of failure. Prevention is easier than correction, because the problem is often not recognized until months or years later when delamination occurs.

Moisture detection paper (MDP), a chemically treated paper which turns



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purple when contacted with water, is used to detect surface moisture. This indicator paper is very sensitive to small amounts of moisture that are otherwise unobservable (the applicator and the project monitor should use it liberally, particularly early in the day when dew is more likely to be present).

Polyurethane foam spray guns use air to keep accumulations of foam from building up around the gun tips. Depending on the spray gun type, this purge will be continuous or at the end of a triggering (spray) cycle. Moisture contamination in spray gun purge air generally yields pin holes in the foam (vertical voids which may penetrate the entire foam pass thickness).

Usually pin holes of this type are relatively large in diameter (up to1/8″). Pin holes violate the waterproof integrity of the foam mass and make coating the foam difficult.

Pin-holed foam should be removed and the area resprayed. To prevent occurrence, air dryers should be installed and functioning properly on the incoming air to the spray equipment. Spray gun purge air may be checked with moisture detection paper to verify dryness.

## HUMIDITY

The water vapor in humid air can react with the curing foam surface resulting in a weakened bond with the next pass of foam. This effect is worsened if the foam cure rate is slowed by spraying thin passes (i.e., less than 1/2 inch thick). These weakened bonds, or knit lines, may delaminate and blister.

Manufacturers of spray foam systems have established ambient humidity application limits. These limits must be honored to insure well-bonded polyurethane foam. (Caution: Some references will offer a "rule of thumb" to define maximum ambient humidity such as 85% relative humidity or 5°F above the dew point. Don't accept these rules; insist on manufacturer specified limits.)

Field monitoring humidity is best accomplished with a psychrometer. Readings should be taken before spray operations commence, and regularly (e.g., every 2 hours) while spraying. Record these readings in the project log book or log sheets.

As foam application is in progress, slit samples of foam should be cut regularly for visual inspection of the foam cross section. Foam should be of uniform color, with small, uniform cells. Knit lines should be well adhered with uniform cell structure above and below the knit lines. Foam pass thicknesses should be a minimum of 1/2 inch. (Examination of foam slit samples may reveal a variety of conditions other than moisture—more on this in upcoming articles.)

## WATER IN QUANTITY

Gross amounts of water not only will act as a blowing agent but also will consume large amounts of isocyanate. The resulting resin rich foam will be soft and spongy with a cell structure that has open, irregular, large cells; color will not be uniform. Foam such as this will be obvious: the surface will rise above the surrounding foam; it will be rougher, often discolored, and will likely blister the same day. Spraying onto a sweat drop, for example, can produce a rising column of foam resembling a mushroom on a lawn after a rain.

Prevention is obvious: don't apply foam to wet surfaces; don't apply foam in the rain. Corrective action: cut out the offending foam and re-spray.

## LONG-TERM EFFECTS OF WATER

The traditional fix for a wet foam roof was to tear it off—a wet foam roof was a failed foam roof. This approach is under challenge.

The bugaboo of the industry was that freeze-thaw cycling and other long-term effects of water in polyurethane foam would rupture the cell structure and render the foam incapable of waterproofing.

Recent empirical and laboratory experience refutes much of this bugaboo.

Fundamental to understanding this problem is the need to understand how good quality, closed-cell polyurethane foam can become wet—the phenomenon is water vapor diffusion followed by condensation.

Research [1,2] shows that foams can accumulate water when vapor drives act in concert with thermal gradients and/or vapor restrictions on the cold side. Thus polyurethane foam, which is otherwise perfectly functional, may become wet. But the same phenomenon will also dry polyurethane foam. Moisture accumulation is reversible. A foam roof wetted via diffusion-condensation can be dried out by changing the conditions that promoted the wetting.

As an example, a textile mill near Asheville, North Carolina had several wet, flat polyurethane foam roofs. The roofs were coated with a vapor-retardant coating that had been hail damaged. In 1988, the coating system was stripped off and minor maintenance items completed. Three weeks later, the foam was dry and the roof no longer leaked. Gravel was installed for ultra-violet light protection.

Another example was a coated ten-year-old polyurethane foam roof in Grand Rapids, Michigan that had become wetted and leaked. The vapor-retardant coating was opened up and existing blisters repaired. The roof stopped leaking in two days; gravel was installed three weeks later for UV protection.

So the foam will dry out: What about freeze-thaw and the potential problems that long-term wetting might cause? Both of the cases were amply exposed to freeze-thaw cycling and long-term wetting. The fact that both roofs are now fully functional—and stopped leaking—suggests that the supposed damage affected by freeze-thaw cycling and long-term wetting is minimal.

Regarding thermal resistance ($R$ values), work by Ascough, Bomberg, and Kumaran [3] indicates that long-term thermal resistance is affected minimally, if at all, by environmental factors including freeze-thaw cycling. These researchers showed that short-term aging rates were affected by environmental factors but stabilized $R$ values of samples exposed to freeze-thaw cycling, vapor and/or thermal gradients were approximately the same as for stabilized $R$ values for samples aged isothermally at room temperature.

Rumors of failure seem greatly exaggerated.

Not all wet polyurethane foam roofs can be rehabilitated. But if the roof has a sound foundation of thick closed-cell foam and if the conditions that permitted water accumulation are reversible, restoration may be an attractive, economical alternative to tear off and replacement of the roof.

## CONCLUSION

Water, moisture, and humidity play important roles in polyurethane insulation. Testing and measuring techniques are readily available to prevent and correct water-related problems. An understanding of the effect of water—be it in gross or trace quantities or in air as humidity—is essential to successful polyurethane foam roofing.

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## BIOGRAPHY

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