In markets subject to volatile organic compound (VOC) regulations, single-ply roof membrane manufacturers supply alternative materials for solvent-based adhesives and primers. Among the VOC regulation-compliant materials that have emerged, low-VOC solvent-based and water-based adhesives are marketed as direct replacements for VOC-solvent-based contact adhesives.

Although intended as direct replacements, these materials should be considered apart from traditional solvent-based contact adhesives. For one thing, work and handling practices for low-VOC materials differ somewhat from those for traditional solvent-based materials. And water-based materials present some challenges that set them apart from both types of solvent-based materials. Additionally, depending on specific products and manufacturers, different recommendations for handling and use may apply for products within the same general category.

Where are VOCs regulated?

The California Clean Air Act of 1988 established the framework for the state’s air quality management efforts, including requirements for controlling ground-level ozone. To meet the requirements, in 1989, the South Coast Air Quality Management District, which is the air pollution control agency for Orange County and urban portions of Los Angeles, Riverside and San Bernardino counties, adopted Rule 1168. Rule 1168 limits VOC content of adhesives and sealants, including single-ply roof membrane adhesives and sealants. The VOC content limits introduced in Rule 1168 later were included in similar regulations adopted by a number of other California air districts.
The limits (in grams VOC content per liter [g/L] determined as the weight of volatile compounds, less water and exempt compounds) are: single-ply roof membrane adhesives—250 g/L; single-ply roof membrane sealants—450 g/L; and single-ply roof membrane adhesive primers—250 g/L.

More recently, the same VOC content limits have been used in regulations adopted by the states and districts that comprise the Ozone Transport Region (OTR) and are advised about air quality management strategies by the Ozone Transport Commission (OTC).

OTC is a regional advisory body of the Environmental Protection Agency (EPA) established in 1990 through amendments to the Clean Air Act (CAA). The amended CAA granted the EPA authority to establish air pollutant transport regions and corresponding transport commissions; specifically established OTR, which includes Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island,

Although low-VOC adhesives are marketed as direct replacements for VOC-solvent-based adhesives, there are significant differences

by Maciek Rupar
Vermont and parts of northern Virginia; and directed the EPA to convene OTC.

In 2006, OTC published its Model Rule for Adhesives and Sealants (OTC Model Rule). In 2009, OTR states and districts began to adopt local regulations based on the OTC Model Rule. The latest local regulations took effect at the beginning of 2012.

Currently, 12 of 35 California air districts, as well as Connecticut, Delaware, District of Columbia, Maine, Maryland, New Jersey, New York, Pennsylvania, Rhode Island and metropolitan districts in northern Virginia restrict the manufacture, distribution, sale and use of single-ply adhesives, primers and sealants to materials that comply with their regulations.

**Ground-level ozone and roofing**

VOCs subject to regulations affecting the roofing industry are hydrocarbons that have been shown to contribute to ground-level ozone formation. Some compounds have been used as solvents in roofing adhesives, primers and sealants. VOC emissions from materials used in roofing comprise a small portion of regulated emissions. Other sources and industries produce far more significant emissions.

Ground-level ozone is a harmful air pollutant and the primary constituent of smog. It is unlike the ozone found high in the Earth’s atmosphere, which screens out harmful ultraviolet (UV) radiation. Ground-level ozone can aggravate respiratory diseases and affect vegetation growth. It forms when VOCs react with nitrogen oxides (NOx) in the air in the presence of UV light. NOx present in the air are mainly the result of burning fossil fuels.

VOCs such as xylene and toluene are excellent solvents for polymers used as roof membrane adhesives and sealants. They allow good material workability over a broad range of temperatures encountered in roofing work and typically yield predictable open times and curing times. Replacement adhesives, primers and sealants, which roofing manufacturers have developed to comply with VOC regulations, rely on hydrocarbon solvents exempt from regulation or the use of water.

States that regulate VOCs include definitions of exempt compounds as part of the requirements. Many exempt compounds have been deemed negligibly photchemically active, meaning they do not significantly contribute to the production of ground-level ozone. However, because jurisdictions do not recognize all compounds the same way, the exemption lists are not the same. Additionally, a jurisdiction might amend its VOC regulations to modify its list of exempt compounds.

Consequently, a product designed to comply in one market may not meet the regulations in a different market. For example, some single-ply manufacturers have found it necessary to market low-VOC adhesives formulated specifically for use in California. Different low-VOC adhesive formulations are available from the same manufacturers in the Northeast and mid-Atlantic regions.

In addition, some California air district rules do not exempt tert-butyl acetate, which is exempt where local regulations recognize EPA’s definition of VOCs. Tert-butyl acetate is used in low-VOC single-ply adhesives available from some manufacturers.

Manufacturers take a different approach with water-based materials. Exempt compound definitions in these cases are made irrelevant because water replaces the hydrocarbons as a carrier but at a cost: Switching to water-based single-ply adhesives involves a different set of work practices that need to be observed to obtain acceptable performance.

**Low-VOC bonding adhesives**

Single-ply adhesives marketed as low-VOC materials are similar to traditional solvent-based products they replace in that both types of materials are hydrocarbon solutions of synthetic rubber compounds. Both are contact adhesives, meaning adhesive material applied to two surfaces bonds the surfaces by adhering to itself after most of the solvent has evaporated.

Manufacturers’ recommendations for storage and application conditions generally are similar for both types of materials. Several manufacturers recommend low-VOC adhesives be stored in original sealed containers at temperatures between 60 F and 90 F. Others recommend a range of 60 F to 80 F.

Storage in temperatures above these ranges shortens material shelf life. Storage in temperatures below the recommended ranges causes solids to separate over time, and manufacturers recommend returning materials to the recommended temperature range before mixing for use, which can take a few days. Application when ambient temperatures are 40 F and rising typically is recommended. Solvent-based single-ply contact adhesives become too
Solvent-based adhesives, water-based adhesives also are based adhesives used in similar applications. Unlike most with water-based adhesives as compared with solvent-based adhesives. Some manufacturers report better coverage rates function as contact adhesives, similar to solvent-based used with smooth-backed membranes, these materials branes typically are acrylic polymer emulsions. When Water-based bonding adhesives for single-ply roof mem-

Early in a project’s planning stage.
involving the manufacturer’s field technical representatives a working knowledge of these materials. Also, consider in the manufacturer’s recommendations as you develop adhesives is limited, pay close attention to the language of low-VOC adhesives. If your experience with low-VOC 

Because acetone-based adhesives tend to dry quickly, it may be necessary to coat surfaces in smaller increments as ambient temperatures increase to mate the surfaces before the adhesive dries completely. Other substitute solvents take longer to dry, and drying times are less predictable as conditions change. It is necessary to manage the reduced productivity and less predictable flash-off times.

When used with EPDM membranes, some adhesives containing exempt compounds may cause membranes to swell or blister, especially when application is not uniform.

These trade-offs need to be considered and managed when a single-ply roof membrane application calls for use of low-VOC adhesives. If your experience with low-VOC adhesives is limited, pay close attention to the language in the manufacturer’s recommendations as you develop a working knowledge of these materials. Also, consider involving the manufacturer’s field technical representatives early in a project’s planning stage.

Water-based bonding adhesives

Water-based bonding adhesives for single-ply roof membranes typically are acrylic polymer emulsions. When used with smooth-backed membranes, these materials function as contact adhesives, similar to solvent-based adhesives. Some manufacturers report better coverage rates with water-based adhesives as compared with solvent-based adhesives used in similar applications. Unlike most solvent-based adhesives, water-based adhesives also are

Other VOC mandates

LEED* 2009 and the 2012 International Green Construction Code (IgCC) contain provisions affecting VOC content in construction adhesives and sealants used on the interiors of building envelopes. You should be aware of the LEED 2009 and IgCC provisions because they may be specified for roofing projects, including those in jurisdictions that have not adopted local VOC content limit regulations.

LEED Indoor Environmental Quality (IEQ) Credit 4.1—Low-emitting Materials—Adhesives and Sealants can be used to earn one point toward a LEED rating for new construction (NC), core and shell (CS) design, or schools. IEQ Credit 4.1 is intended “to reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.”

The credit states:

“NC & CS

All adhesives and sealants used on the interior of the building (i.e., inside of the weatherproofing system and applied on-site) must comply with the following requirements as applicable to the project scope:

• Adhesives, Sealants and Sealant Primers must comply with South Coast Air Quality Management District Rule #1168. Volatile organic compound (VOC) limits listed in the table below correspond to an effective date of July 1, 2005 and rule amendment date of January 7, 2005. (A table is provided.)

• Aerosol Adhesives must comply with Green Seal Standard for Commercial Adhesives GS-36 requirements in effect on October 19, 2000. (A table is provided.)

SCHOOLS

All adhesives and sealants installed in the building interior (defined as inside the weatherproofing system and applied on-site) must meet the testing and product requirements of the California Department of Health Services Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers, including 2004 Addenda.”

IgCC’s Section 806.2—Adhesives and Sealants requires a minimum of 85 percent of site-applied adhesives and sealants used on the interior of a building envelope to comply with specific VOC content limits provided in the code. The section also directs as to the methods of determining VOC content and which materials are not subject to its requirements. The VOC content limit provided for single-ply roof membrane adhesives is 250 grams per liter (g/L). No VOC content limit for materials specifically designated as single-ply roof membrane sealants is provided.

A material category designated “architectural sealants” is limited to 250 g/L VOCs.

Do these requirements apply to single-ply roof membrane installations? It depends on the mandates’ interpretations applied to projects. For instance, LEED 2009 IEQ Credit 4.1 language requires its VOC content limits be met by all adhe-
sives and sealants used “inside of the weatherproofing system and applied on-site.” The interface between an adhered single-ply roof membrane and its substrate certainly fits the description.
used in felt-backed membrane applications where adhesives are applied to substrates only and membranes are rolled into wet adhesives.

Versatile though they may be, water-based materials have a significant temperature limitation. They do not tolerate below-freezing temperatures in storage and after application before fully curing. If materials are allowed to freeze in storage, they typically cannot be restored to a usable state. Also, the adhesive bond can be compromised if materials are exposed to below-freezing temperatures before fully curing.

Most manufacturers recommend storage at temperatures between 60°F and 80°F. This is the same temperature range manufacturers typically recommend for solvent-based single-ply adhesives. In addition to storage temperature range recommendations, manufacturers point out water-based materials should never be exposed to temperatures below 40°F or allowed to freeze.

Application when ambient temperatures are 40°F and rising typically is recommended. This is in line with manufacturers’ recommendations for applications using solvent-based adhesives. One manufacturer recommends application temperatures of 50°F and rising for installations using its PVC membrane and water-based adhesive.

Recommendations from some single-ply membrane manufacturers suggest monitoring roof system temperatures during curing following application. One of a list of precautions provided on a water-based adhesive product data sheet reads: “Do not apply if ambient temperature will drop below 32°F (0°C) before adhesive completely dries.” A water-based adhesive installation guide from another manufacturer contains the following caution: “Do not apply when ambient temperatures are expected to drop below 40°F within 48 hours after application.”

It makes sense to keep water-based adhesives from freezing and limit them to warm-weather months. However, in many parts of the U.S., a window of only a few months may be available. Also, during periods of borderline-acceptable conditions a phenomenon called nighttime radiative cooling needs to be factored into decisions about using water-based roof membrane adhesives.

Nighttime radiative cooling is the radiation of heat into space from Earth’s surface. It affects all surfaces exposed to the nighttime sky, including roofs. Heat is radiated from Earth’s surface toward much colder outer space. Under the right conditions—clear view of cloudless sky and low humidity—radiative cooling causes surface temperatures to fall below ambient air temperature.

The effect most easily is noticed during cool spring and fall mornings on some mechanically attached reflective membrane roof systems. Condensation on the membrane’s underside turns to ice, which makes a characteristic crackling sound when someone walks upon it. Reflective roof membranes are more susceptible than dark-colored roof membranes because they do not get as hot during the day and do not effect as much downward drying.

Consider the possibility of water present in curing single-ply membrane adhesives being affected the same way. One study of nighttime radiative cooling of white membrane roofs recorded temperature differentials as large as 18°F between ambient air and roof surfaces. When conditions conducive to nighttime radiative cooling are expected, allow for an appropriate temperature buffer above freezing during curing of water-based roof membrane adhesives. This may result in a decision to avoid using water-based adhesives.

Flash-off times can be significantly longer for water-based adhesives as compared with solvent-based materials under the same conditions, especially at low temperatures and/or during periods of high humidity. Shading also affects flash-off times according to one manufacturer’s warnings. Water trapped under a membrane as a result of incomplete or nonuniform drying may prevent bonding and cause blisters.

Learn the issues

VOC regulations likely will affect increasing numbers of roofing projects in the future as more jurisdictions follow the examples set by some California districts and OTR states. Provisions in the 2012 International Green Construction Code also likely will drive increased use of low-VOC and water-based adhesives in the roofing industry. The roofing industry will have to include these uses into the canon of accepted practices and most likely will experience a period of adjustment just as it has with every other major product introduced to the industry.

If you are involved with adhered membrane applications, invest time to learn and understand the reasons behind manufacturers’ recommended work practices for low-VOC and water-based adhesives. You will benefit by more quickly developing expertise using the materials and save yourself from learning many critical lessons the hard way.

Maciek RupaR is an NRCA director of technical services.