A Practical Guide to WHITE COATINGS;

How to Talk to Building Owners about COOL ROOFS

By Steve Heinje and Tom Meyer

White coatings offer big benefits. As legislators and architects embrace the idea that building design has a huge impact on energy consumption and sustainability, white coatings are now in the spotlight. However, building owners do not often appreciate the immediate benefits of white coatings and convincing them of their value may still be challenging.

The best approach is combining two arguments: energy savings and the extension of roof life cycle. In the latter case, white coatings protect membranes with a chemical barrier and reflect sunlight, both of which contribute to a longer roof life cycle. The primary benefit, of course, is that the reflection of solar radiation significantly lowers air-conditioning costs, especially during hot summers in temperate climates and year-round in warmer climates.

Much has been written about white coatings. For example, in 2005, a conference hosted in part by the RCI Foundation was dedicated entirely to cool roofs [1-6]. Since then, California Title 24 legislation has begun to spread, the green building movement has grown, and much attention has been paid to white coatings.

This paper reviews and explains the major benefits of white coatings and summarizes the basic types of white coatings, as well as installation methods.

Watts and Areas

Any discussion of white coatings must begin with the sun. Solar energy impinges on the earth in astronomical amounts that far exceed any man-made energy production.

The vast power of the sun is best appreciated with respect to how its energy would compare to our own energy usage. According to the U.S. Environmental Protection Agency (EPA), in the Southwestern states, where the greatest solar resources are located, sufficient solar energy falls on an area of 100 miles by 100 miles to provide all of the nation's electricity requirements [7]. As we cover more and more of the earth's surface with buildings (and that means roof coverings), our choice of those materials determines how much of that heat and light will be absorbed and

White coatings can be applied on many roof types, including this old BUR on an apartment building in Spokane, Washington. The white coating is sprayed over a base coat on top of an old built-up roof.

White coatings are appropriate for buildings in temperate climates, such as Groton, Connecticut, where such a product was installed over the metal roof of a General Dynamics facility.

stored through roofing in our buildings.

On a clear day, solar energy reaches the earth at rates up to 1,200 watts per square meter; or, since one square meter is equal to about 10.76 square feet, the rate is about 100 watts per square foot.

If we round this down to one kilowatt per square meter, then 1,300 million kilowatts (or 1,300 gigawatts = 1,300 GW) fall on LA and 59 GW fall on Manhattan at any given moment on a clear day. (For comparison, China's Three Gorges Dam is predicted to have an electrical energy generating capacity of up to 18 GW.)

On a smaller scale, a football field with an area of 5,400 square meters intercepts solar energy on the order of a small power plant (5.4 MW). Multiply this by several thousands and the roofs across a large city or metropolitan area account for a significant amount of energy availability.

The Great HVAC Energy Sink

Unfortunately, this vast supply of energy is a burden as often as it is a boon. On hot summer days across the country, a peculiar situation exists in commercial buildings. As the sun pours its heat onto these buildings, roof temperatures soar and much of this energy is transferred inside. Large amounts of electricity are consumed by air conditioning systems to remove the heat from the building. Of course, that is not a very efficient way to manage energy that easily could have been reflected back into space in the first place.

The most remarkable property of a white surface is that no energy is used in the process of moving energy. Light from the sun is scattered by white surfaces through a physical process that is much more efficient than pumping heat by using air conditioners. In this sense, a white surface is equivalent to a renewable resource for cooling buildings.

Moreover, since air-conditioner use peaks at the same time in various regions, providing electric power to air conditioners will determine the energy generating needs of a region. The bottom line is that peak electric loads are often the criteria on which electricity is priced.

California Title 24

California is noted for taking the lead in environmental regulation, particularly in clean air and energy conservation. Recent activity in California underscores the merits of using white surfaces on commercial buildings to reduce energy costs. California Title 24 is exemplary for its support of white surfaces. Exempting buildings with high reflectance roofing from energy audits makes sense because white surfaces dramatically decrease the need for air conditioning and in cooler climates can decrease the need for insulation.

Alleviating solar heating loads directly affects peak electricity requirements. California Title 24 legislation requires a detailed energy audit on a new building to show that solar heat is dissipated or removed in an energy-efficient manner; e.g., through insulation and climate-control systems, unless the building uses highly reflective roofing with reflectance values above 0.70. Hence, Title 24 sends a strong message to building owners: The best way to cool a building is to divert the solar energy before it raises temperatures.

Various models exist for computing energy savings based on cool roofs for various climates across the U.S. For example, calculators for estimating the energy savings from reflective roofs have been developed by the U.S. Department of Energy's (DOE) Oak Ridge National Laboratory [8] and the EPA [9].

Of course, the savings will be greatest in California and southwestern states, which enjoy more sunny days and more intense sunlight than other regions of the country; but savings can also be realized in northern climates.

Studies by the Building Envelopes Group, Engineering Science and Technology Division, Oak Ridge National Laboratory [10], indicate that in most U.S. climates, summer air-conditioning energy savings significantly exceed any winter penalty, so there is little or no concern that energy costs will increase with a cool roof.

Moreover, temperatures can soar in temperate climates as well. Air-conditioning systems are often based on requirements for the hottest days. The total cost of not having a cool roof, including cooling systems and insulation, could be considerably higher than the immediate cost of energy for running the air-conditioning systems.

But lower energy use is not the only benefit that accrues from the use of white surfaces. Just as the main reason for using sunscreen is to prevent burns, but secondarily they prevent premature aging and diseases of the skin, white coatings can extend the life expectancy of many different types of commercial roofing systems simply by avoiding the high roof temperatures associated with exposure to the sun.

California lawmakers deserve applause for encouraging the use of white surfaces to reduce energy costs, but that is only part of the story.

Long Live Cool Roofing

Unfortunately, uncontrolled, unharnessed solar energy creates more problems than benefits for buildings.

Most people appreciate that white surfaces result in savings on cooling costs, but enhanced roof longevity, especially in northern states, can be another major benefit that results in at least as much savings. Without white surfaces, roof temperatures skyrocket in the summer months, especially for buildings with insulation to help keep in the heat during the winter months.

The technical term for exposure is "insolation," and it is measured in terms of the rate of solar radiation received per unit area (typically expressed in Watts per square meter). As mentioned above, under very clear skies, up to 1,220 W/m^2 of solar radiation reaches the rooftop.

Insulated roof systems block this heat from penetrating the building as heat; however, in summer months, convective heat transfer to the surrounding air and radiant heat transfer are inefficient. Consequently, the heat has nowhere to go, and roofing membrane temperatures can soar.

Membrane Thermodynamics

The Arrhenius equation expresses an exponential relationship between chemical reactions and temperature. As found in chemistry textbooks, it has the general form of $k = A \exp(-Eo/RT)$, where Eo is the reaction activation energy.

Predictions of life cycle often are based on accelerated aging using models typically developed in terms of an acceleration factor that is an inverse of the Arrhenius equation; i.e., the acceleration factor increases with temperature. As an example, Meeker showed that polyurethanes nicely follow such an exponential trend with respect to aging [11].

In general, to predict life cycle, the limiting factor or the mode of failure must be ascertained. Once the mode of failure is established, then that specific property generally follows an exponential trend with respect to temperature. The Arrhenius model can be simplified to an acceleration factor that increases by a factor of two to three times for every increase in temperature of 10˚C. This simplified relationship fits the classical Arrhenius model. We have found this useful as a rule-of-thumb. Some of the best temperature-life-cycle data are from the field of electronics, but this example using a polymer applies to roofing as well.

For commercial roofing systems made from organic materials, high temperatures can shorten the life of the roofing system. Rubber, as well as other synthetic polymers and especially asphalt, are susceptible to damage at these elevated temperatures. Roof temperatures can rise above ambient air temperatures by as much as 90 degrees Fahrenheit (50 degrees Celsius). Meanwhile, the rate of degradation of the roofing materials begins to accelerate at modestly elevated temperatures, for example at 140˚F (60˚C). Significant damage can begin to occur at these elevated temperatures, causing both short- and long-term performance issues.

As temperatures rise to the peak of this range, degradation of roofing systems increases exponentially. Lighter, and hence more volatile organic compounds, may evaporate into the atmosphere, and chemical reaction rates with water, oxygen, and contaminants also increase. As a result, roof life expectancies are shortened. Based on the polyurethane roofing example above and other accelerated aging tests for polymers, a rule of thumb for thermal aging is that service life is cut in half for every 10˚C (18˚F) increase in temperature (weighted and averaged over time).

High Reflectance, Low Watts

A key property of a white coating is its reflectance (sometimes also called "reflectivity"). Imagine a 100-watt light bulb with its total intensity reflected downward on one square foot of roof surface. Then imagine a two-dimensional array of these light bulbs spaced one foot apart over a large expanse of roof, and you will begin to appreciate the potential for solar damage on a rooftop.

Installing a coating with a reflectance of 0.60 would have the same effect as replacing the 100-watt bulbs with 40-watt bulbs. A coating with a reflectivity of 0.70 would have the same effect as changing the bulbs to 30-watt bulbs.

Reflectance is measured according to strict standards. A perfect reflector would have a value of 100 percent for all wavelengths of light. When just one value of reflectance is given, it usually represents an average value weighted according to intensi-

THE WHITE COATINGS COUNCIL

The White Coatings Council of the Roof Coating Manufacturers Association (RCMA) serves the producers and suppliers of acrylic or elastomeric (non-bituminous) coatings. The council has implemented an industry promotional program and is actively planning programs to respond to targeted governmental and regulatory issues, technical matters and activities, and membership services and programs.

The White Coatings Council focuses on describing and promoting the benefits of white coatings in terms that directly and positively motivate targeted end users through a plan to increase awareness and product promotion. The council now has 18 members who are committed to promoting to commercial building owners and designers that white coatings are easy to understand, easy to apply, and cost-effective.

For more information, call RCMA at (202) 207-0919 or visit www.roofcoatings.org.

White coatings can provide reflectivity of 70 percent or more.

ty across the solar spectrum.

The Cool Roof Rating Council provides reflectivity data online for 295 brands of factory-applied and field-applied coatings and membranes from 111 manufacturers, including data for 601 models of roofing products, according to recent tabulations [12]. Of these 601 models, 301 boast initial reflectivity above 0.70, with some as high as 0.92.

Besides reflectance, another important material property for roof surfaces is emissivity. Since not all of the incident photons are scattered, some heating of the roof is inevitable. And what goes in must come out! Emissivity is the ratio of radiation emitted by a surface and the theoretical radiation predicted by Planck's Law. Black body emissivity is frequently referred to as a single number; but, like reflectance, it varies with wavelength.

This property is often referred to in product literature as "thermal emittance." Emissivity is not nearly as important as reflectance, since roofs can cool by other means than radiative heat transfer (for example, convective cooling by the surrounding air). Nonetheless, this property is typically listed in the specifications for white coating, and consultants should understand what it means.

Surfaces with low thermal emittance tend to absorb infrared into the bulk of the material rather than to emit the radiation to its surroundings. Emittances for white coating products can range from below 0.10 to above 0.95. In selecting coatings, much greater weight should be given to reflectance than emittance. In other words, it is often better to choose a product with a higher reflectance even though it might have a lower emittance. Products should not be chosen based on emittance alone. Fortunately, there are many white coatings on the market with high values for both of these properties.

Why White Coatings are White

With the growing recognition of reflectance as an important design parameter, reflectance values are being thoroughly measured across the entire solar spectrum (including infrared wavelengths) and accurate values for specific materials and coatings are becoming readily available.

The beauty of a white coating is that pigments such as zinc oxide (ZnO) or titanium dioxide (TiO_2) scatter a large fraction of the incident photons back into the sky, optimizing for reflection in the visible and near infrared bands. Metal-oxide pigments used in white coatings scatter light by the same mechanism that light is scattered by the water droplets in a cloud or fog; the scattering is due to the tiny particle size. Except for the small particle size, these materials would be transparent to light, because the metal atoms are oxidized; i.e., the valence electrons of the metals are held by the oxygen and do not interact with the incoming photons.

From the roof's perspective, the effect of scattering is the same as if the photons never arrived on the roof. This ability to scatter photons is characterized by the reflectance of a coating. Most white coatings have a very high reflectance across all visible wavelengths and also have a high reflectance for near infrared radiation (NIR). Typical reflectance values averaged over these wavelengths are in the neighborhood of 70 or 80 percent.

Interestingly, it is also possible to make a coating that has good reflectance but is not white. In this case, the coating strongly reflects infrared wavelengths, while it absorbs some light in the visible range. Also, the property of blocking ultraviolet radiation is not related to the color of the roof. In general, a bright white coating provides excellent reflectivity in the visible light range.

Binders and Pigments

A white coating consists of a binder blended with pigments and other additives. Most white coating products can be conveniently classified according to the binder they use.

Binders usually are made of an organic or silicone compound. Most binders are elastic polymers with elongation and tensile characteristics; i.e., elastomers, which have the ability to return to their original shape after being stretched or deformed. In white coatings, the elastomer binder is the viscous, pliant material that bonds the pigments and makes them adhere to the surface. Common elastomers used as binders in white coatings include acrylic, silicone, rubber, vinyl, and urethane.

Titanium dioxide and zinc oxide are the common pigments that impart a bright white color to the coatings. However, other pigments can be combined with these to yield a variety of pastel colors. Some cool-colored pigments reflect heat in much the same manner as chlorophyll reflects heat from plants. They are dark but don't get that hot. Such "IR white" pigments are made of multi-metallic oxides rather than traditional metal oxides such as chrome oxide and iron oxide, which are IR-black.

The majority of white coatings in use today are water-based. These products, often referred to as latex coatings, are available in a variety of polymer types.

The water in latex coatings serves as a liquid carrier, allowing the pigment and binder to be spread onto the surface as a thin coating. For some white coatings, organic solvents are used as the liquid carrier; while others, often referred to as reactive coatings, may have sufficient flowability to eliminate the need for a liquid carrier. Reactive coatings are generally prepared with multiple-part resins often blended onsite, before curing.

Selecting and Installing White Coatings

With so many products on the market and so many roofing substrates, climates, and environments, it is no wonder that building owners and even contractors may be reluctant to experiment with white coatings.

A roof consultant with experience and training in this subject could provide a valuable service to a building owner by selecting the right coating for a given roof and ensuring that it is properly installed and maintained.

White coatings can be applied to practically any roofing membrane or system. They are commonly applied to sprayed polyurethane, metal, single-ply rubber, and modified bitumen roofs. They can even be applied to certain kinds of asphalt, built-up roofs. It is important to establish compatibility between the white coating and the underlying roof surface. Manufacturers' recommendations should be consulted for detailed information about specific coatings.

Primers are useful for improving adhesion between roof surfaces and coatings or for imparting additional properties to the roof coating systems. For example, a rubber roof coating may provide better adhesion to a rubber roof membrane or a coating intended for sprayed polyurethane might provide a better permeability ("perm") rating needed on such a roof. Most white coatings impart greater reflectivity and UV protection to the system.

Manufacturers' literature should be consulted and followed to properly prepare the surface for the coating. Professional roofing contractors should be employed for installations. For certain systems, contractors may need to be specially trained by the manufacturer in the application of the coating. Proper application strongly influences the subsequent life and performance of the coating.

Surfaces should be clean and dry and they must have a positive slope-to-drain. Application of white coatings over dirty, wet, or contaminated surfaces may produce unsatisfactory results. Acrylic latex coatings are sensitive to dew, rain, and other moisture during curing. It is important that the application be done with strict adherence to the manufacturer's recommendations.

Coatings are typically applied by airless spray, rolling, or brushing. Due to the variety of coating types, climatic conditions, and surfaces to be coated, it is important to consult the manufacturer for proper application rates and related recommendations.

Permeability

A few words should be said about the permeability of white coatings. There are many purposes besides reflectivity for roof coatings. Many white coatings are waterproof, but some are not. The property of permeability (perm rating) to liquid water, water vapor, and gases varies greatly, depending on the type of coating.

- Acrylic coatings are breathable, which means they have a high moisture vapor transmission rate or permeability.
- Silicone coatings, as well as many urethanes, are also classified as breathable types.
- Butyl rubbers, Hypalons, and Neoprenes have a very low permeability (i.e., they are highly resistant to moisture transmission). The same applies to asphalt-extended, moisture-cure polyurethanes and SEBS-modified, cut-back, asphalt coatings.

The perm rating should not be confused with weatherability or resistance to weathering. A coating with low permeability still may require a protective topcoat to ensure satisfactory weathering resistance.

The granulated modified bitumen roof on this Intel facility in Chandler, Arizona, was coated with an elastomeric white coating.

An elastomeric white coating is sprayed on this metal roof in Japan.

Opportunities for Consultants

The application of white coatings to commercial roofing is a fairly new technology. Relatively few contractors have developed expert knowledge about coating properties and installation methods. Many products are rather new and have not benefited from long-term field experience.

Product quality and contractor workmanship can have a significant effect on the success of the white coating project. Consultants who can identify reliable white coating products and qualified installers can expect to expand their businesses as the demand for white coatings increases.

Today there are scores of companies who manufacture white coatings and they are eager to develop networks of contractors and consultants who are familiar with their products. There are also a growing number of building owners eager to extend the life cycle of their roofs and save on energy costs.

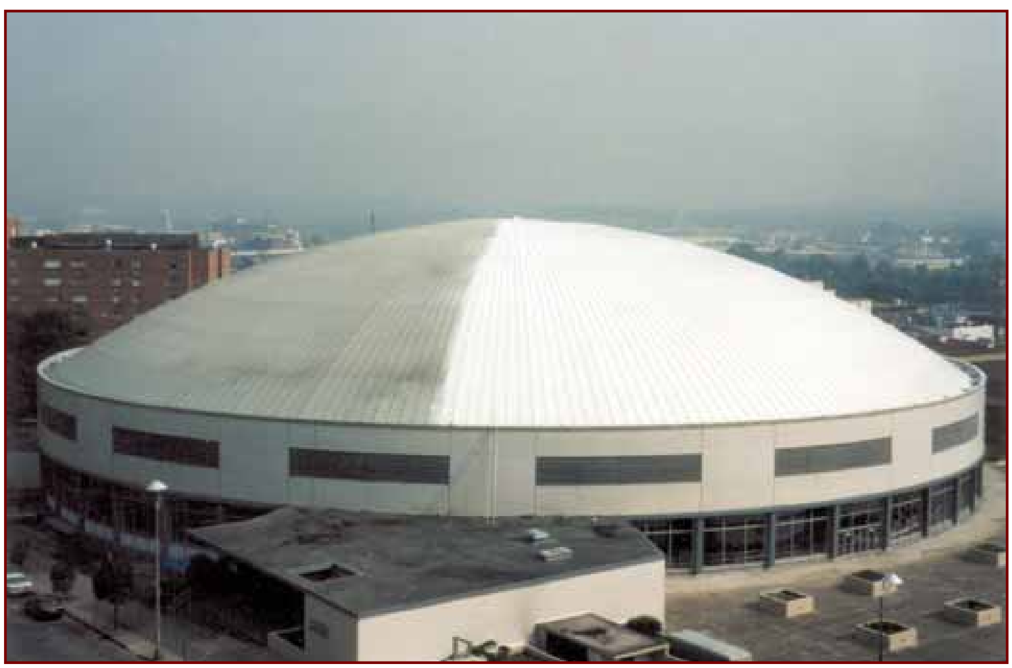
The successful use of white coatings is a team effort, involving manufacturers, roof

Cleanliness and Aging

Roofs that have white coatings in arid, dusty regions, or in places where farm plowing or construction exposes the earth to wind, are likely to accumulate dirt more than in areas with greenery or where occasional rainfall washes away the dirt. The frequency and intensity of precipitation and slope of the roof also affect cleanliness of the coatings over time. As with other white surfaces, white coatings discolor and darken slightly after several years of service.

Two values of reflectivity are often quoted to represent the performance of new coatings and three-year-old weathered white coatings, respectively. Generally, a small decrease in reflectivity occurs over time, depending on several factors. Wind-blown dirt and dust can decrease the reflectivity of white coatings, depending on the age of the coating and regional climate characteristics. UV radiation tends to be blocked rather than reflected by a white coating. A white coating still protects against UV radiation, even when foreign particles reduce the reflectivity.

To maintain their reflectivity, roofs may be periodically refreshed with a new topcoat, typically for less than the cost of the initial coating. The maintenance schedule depends on the type of coating, type of roof, the purpose of the coating, and regional climate differences. Typically, white coatings should be refreshed every three to seven years.



This metal roof at Eastern Tennessee State University is partially covered with a white coating. The coated half of the dome contrasts sharply with the uncoated half mid-way through the application process.

consultants, roofing contractors, and building owners. When these parties – each with a good understanding of white coating technology – are brought together, then the chances for success are high.

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Tom Meyer

Tom Meyer is co-chairman of the RCMA White Coatings Council and technical manager, Technical Roof Solutions, Brookfield, Wisconsin. He began his career as a tool and die maker and then went to Mexico to run a manufacturing plant. Five years later, he entered sales for fiberglass raw materials and roofing materials. After another five years, he became owner of Polydyne, a manufacturer of polyester gel coats and roof coatings. Three years ago, he sold the gel coat business to Ashland Chemicals and the roof coating business to Technical Roofing Solutions, where he remains as technical director.

Fricklas, Henshell Honored by ASTM D-08

Above: Justin Henshell, FAIA, (left) receives a plaque recognizing 30 years of active ASTM membership from Dr. Walter Rossiter, awards chairman of ASTM Committee D-08.

Left: Dick Fricklas (left), was granted the William C. Cullen Award by ASTM Committee D-08 in "recognition of his distinguished contributions and personal commitment to Committee D-08 and to the field of roofing and waterproofing through his dedication and leadership in the industry." Dick is an honorary member of RCI and was previously active in RIEI. Here, Dick receives congratulations from Jim Thomas, president of ASTM.

(Photos, courtesy of Dick Fricklas.)