METAL ROOF COATINGS: 50 YEARS OF DEVELOPMENT

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Since the inception of practical and reliable paint systems, the metal roofing industry has offered a variety of different paint systems with varying levels of quality, performance and price. In the early days of painted steel and before the advent of superior substrates, paint acted as a barrier to prevent the metal from corroding. With the introduction of Galvalume, aluminized steel, galvanized G-90 and aluminum substrates, paint is no longer essential for corrosion protection. The paint systems today still help to protect the substrate but they have other features that now make metal and aluminum roofing substrates superior to other types of commercial and residential roofing. First, they come in a much wider range of colors. Second, they are more durable and resistant to fading. And third, even in the most non-corrosive environments they are likely to have a service life of 40 to 50 years or more.

One question that owners are practically guaranteed to ask about a new roof is "How long will it last?" For metal roofing, that question is often closely followed by another: "How long will it look good?"

Today's metal roofing systems are often a key design element, adding drama and color to new and existing buildings. But to look good for the long term, they need a finish that can withstand attack from acid rain, ultraviolet radiation and other environmental agents.

The durable, prepainted metal sold today was made possible by the development of coil coating lines that started to appear in the 1950's. These coating lines raised the quality of the product, lowered the cost with their automation and efficiency and allowed pre-painted metal roofing products to be competitively priced. In the ensuing years, the coatings industry developed a series of high-performing paints for coil coating, including enamels, acrylics, polyurethane and fluoropolymers, polyesters and siliconized polyesters,.

There are a few different kinds of coatings. Inorganic coatings, usually found on glass or ceramics, create superior barriers but are brittle and require a thicker metal substrate. The porcelain enamel on cookware is an excellent example.

Paints used on light-gauge architectural metal are organic or carbon-containing coatings. Organic paints have three basic components: resin, pigment, and solvents that evaporate during the curing process. Resin serves to bind the protein pigments and form a barrier over the substrate. Pigment creates the color, and absorbs the ultra-violet radiation that can destroy the resin and the underlying primer.

For exterior metals, paints are coil coated onto a primer suitable to the resin type. The two-coat primer and topcoat process yields a total thickness of about 1 mil. Paints are usually identified by a resin type such as polyester, urethane, latex, and etcetera. This generalization tends to obscure important variations in both the resin formula and pigment type. Tradeoffs in creating these systems are made to meet different price points for different needs. But, paints should also be considered as complete systems, rather than as a simple addition of a better or cheaper part of the product.

Distinct differences exist between coatings. There are three primary resins used for coil coating exterior metal. Polyesters have traditionally occupied the low end of the market. They offer a hard, scratch-resistant finish and a wide range of gloss. But polyesters are prone to chalking when exposed to UV or sunlight. Since their introduction in the 1960's, polyesters have been greatly improved with higher molecular weights and longer polymeric chains that create stronger, more UV-resistant bonds. Englert uses polyester paint systems to coat all our gutter products.

Silicone-modified polyesters, also known as silicone-protected and siliconized polyesters, use polymerized silicone to improve polyester chalk performance and gloss retention. Companies initially experimented with varying levels of silicone and marketed high levels as superior to lower levels. But silicone became less important as the polyester resins themselves improved. Most silicone-modified polyesters now contain 30% or less silicone.

Poly vinyl idene fluoride is acknowledged as the premium resin for coil coatings. Popularly known by its original trade name Kynar PVDF, it is a kind of fluoride, a family that includes such well known products as Teflon and Halar. Key to the toughness of these chemicals is the bond between carbon and fluorine, the strongest possible polymeric connection. PVDF resin has superior chalk resistance and gloss retention as well as stain and chemical resistance. It is softer than polyester and SMP, making it highly formable without risk of cracking. However, it requires some special handling during transport or installation because the product can scratch a little more easily than polyesters and silicone-modified polyesters.

The Penwalt Company brought PVDF to market in the mid 1960's, using fluoropolymer technology developed by the DuPont Company. Today, two companies, Arkema and Ausimont, manufacture PVDF under the trademarked names of Kynar and Hylar respectively. It is manufactured as a powder, and paint makers mix it with acrylic copolymer resins for coil coating. Years of testing have shown the PVDF is the most durable when it makes up 70% of the resin. Higher concentrations do not coat well. The two manufacturers of PVDF, Arkema and Ausimont allow paint companies to apply the trade names Kynar 500 and Hylar 5000 solely to 70% formulations. Several paint companies have 50% PVDF formulations. They are less costly than the 70% versions, but the performance drops off considerably.

Although they are not marketed for roofing or wall panels, it is impossible to track where the different percentage material ends up. The difficulty comes in the names: "Kynar" is shorthand for the unwieldy "Kynar 500/Hylar 5000" which allows 50% formulations to masquerade as the superior product.

There are two general classes of pigments. Organic or carbon-based pigments are generally synthetic and relatively inexpensive to make. They offer a broad spectrum of color. However, organics have fairly weak molecular bands that are easily broken down by moisture, UV and pollutants. And they are prone to fading. There is a great range in the effectiveness of organics. The organic pigments in cheap printer ink fades very quickly. Witness how long a newspaper left in the sun remains legible. The pigments used in Kynar 500 and Hylar 5000 are inorganic. Inorganic pigments are those that do not contain carbon, and may be naturally occurring or manufactured. They generally offer good fade resistance – with the notable exception of carbon-black, sometimes considered an inorganic. Many simple inorganics are metal oxides such as the widely used non-oxide and titanium dioxide. When several different metal oxides are fused, or calcinated, at very high temperatures, they become a new class of pigments called complex metal oxides, or complex inorganic color pigments. Known commonly as CICP's, these inorganics were first used to color tile and porcelain materials and are often called ceramic pigments. But those used in paints are much more finely ground. It takes high temperatures to create CICP's, so it takes a lot of energy to break them down. The UV, heat, moisture, and chemicals such as ozone, acid rain and industrial air pollutants that can break down organic and simple inorganics have little or no effect on CICP's. Some CICP's also have the ability to reflect high percentages of light energy from the non-visible infrared spectrum. CICP's with this ability have been developed to make paints that can reflect solar radiation outside the visible spectrum, thus allowing darker colored roofs to remain as cool as lighter ones. The major drawback of CICP's, aside from their expense, is their limited color range. They are largely confined to earth tones although they can be mixed with select inorganics and organics to extend their color range. Many paint systems will combine organics and inorganics to achieve both the desired color and to meet price points. Most two-coat paint systems with long warranties such as Kynar will use only CICP's and select inorganics. Some systems achieve long-lasting bright colors by using a third clear coat to extend the life of less durable pigments.

Architects and building owners are looking for specific performance characteristics. They expect the coating to act as a continuous barrier, adhere tightly to the substrate, and not fade peel or chip over its life. They expect it to be hard enough to resist incidental scratches from transportation, installation, and roof traffic and impact. They do not expect it to be so brittle as to crack during metal forming. They want it to resist damage from atmospheric chemicals and salt and not chalk, fade, lose gloss, or stain.

There are dozens of tests that paints can undergo to determine their performance characteristics. There are falling sand erosion tests, acid tests, adhesion after impact and bending tests and acid rain and salt spray simulations. The most reliable performance testing data comes from South Florida test fences, which subject painted strips to humidity and high UV radiation. Test fences in different climates are sometimes used for comparison. A number of accelerated tests using intensified UV, salt sprays, chemicals, etc. have tried to predict test fence performance. But they have largely been proven to be unreliable. Some UV tests, for example, have badly underrated the durability of certain paints. The best and most useful tests are the ones performed in a real live environment.

The paint manufacturers also own their own test sites or they lease space at approved test sites in different regions around the United States. There are a number of test sites in Florida. The most aggressive site in Florida for testing is the site that is owned by the Battelle Institute in Daytona Beach. At a 45-degree angle to the sun, steel and aluminum painted samples are installed on test racks. This complex is within 100 yards of the surf. This site is testing the paints' resistance to sun and its UV degradation, salt, heat and high humidity.

Fade, chalk and gloss are the most important characteristics measured in weathering tests. Chalk is the whitish powder that forms on the surface and is primarily paint resin and pigment that have been degraded by UV and moisture. Chalk is measured on a scale of 1 to 10, 10 being the best. Inferior coatings will chalk white. More superior coatings will chalk in their own color. For example, as a forest green roof ages and chalks, it will chalk in the color of forest green.

Color fade is largely the result of in situ pigment degradation by UV radiation. But color loss also occurs when pigment is washed out of a resin that is pitting or dissolving. To distinguish it from chalking, fade is only measured after cleaning surface chalking from weathered panels of with water, cheesecloth, and detergent. What appears to be a badly faded panel may in fact be merely chalked. Hence, it is important to conduct both measurements to differentiate. Fade is measured in National Bureau of Standards or Delta E Hunter units with a 1 Delta E being the slightest color differential perceptible by the human eye. A change of 5 units is therefore slight, and a problem to consider primarily when new and weathered material will appear near each other on a wall or roof. ASTM 2244 standard governs the measurement. The best performing paint won't change more than 6 units over 20 years or more.

Gloss retention, a feature of the paint's resin, affects the tonal appearance and stain resistance of a coating. Specular gloss is measured by the ASTM D 523 standard, by using an instrument mounted at an angle to the surface, typically 60 degrees, or at 85 degrees for low glosses. Measurements range from low sheen with less than 20%, semi-gloss ranging from 20 to 60%, glossy from 60 to 85% and full gloss which is more than 85%.

Four companies – BASF, Akzo Nobel, PPG and Valspar – make all the PVDF-based coil coatings used in the United States and most of the polyesters and silicone-modified polyesters as well. These companies collect the various chemicals necessary for paints from other suppliers. Pigments come primarily from the Ferro Corporation or Shepherd Color Company. PVDF resins for Kynar/Hylar paints come from either Autofina or Arkema. And the various solvents, resins, flattening agents, binders and other ingredients come from a variety of manufacturers. The paint companies are responsible for their products, doing the bulk of testing and research, and issuing coating warranties. The reason is simple. While a particular ingredient's qualities can be known, how it works in combination with others is not. Therefore, the companies extensively test every paint system in a wide range of colors before it is brought to market.

Polyester systems have improved greatly over the years, but they remain the lowest tier for price and performance for coil-coated exterior metal. Scratch resistance is their strong suit. In years past polyesters were recommended for soffit, rainware, entry doors and other applications without full sun exposure. Modern polyesters can take the sun better, but will never match the performance of PVDF's or silicone-modified polyesters. Polyesters offer a wide range of glosses from 5 to 80 at 60 degrees. However, weathering quickly degrades high gloss levels. The low cost of these resins make them suitable partners for inexpensive, organic pigments. Consequently, polyester generally offers a broader color spectrum than PVDF's – but the brighter and darker colors, especially reds, blues and bronzes, are those most prone to fade. Their tendency to chalk ranges from fair to poor. Even with their long-term fade, chalk and gloss issues, when formulated with stable pigments in light colors, polyesters offer a versatile and inexpensive coating that can look good for ten years and more. Modern systems often carry a 10 or 15 year film integrity warranties, and boast of decent weathering performance results.

Silicone-modified polyester systems vary greatly in quality. As noted, polyester quality outweighs silicone content in importance, but silicone-modified polyesters or SMP's as they are known, still outperform straight polyesters in chalk resistance. A more important difference is in pigment type and quality. Some formulations use the same ceramic pigments as PVDF's. Others rely on simple inorganics or organics. Since the better resin does little to prevent an organic pigment from fading, paying for silicone is no excuse for going cheaper with pigments. SMP's vary in gloss from 20 – 60 and at 60 degrees for semi-gloss to medium-gloss. Warranties for SMP's vary between 10 and 20 years, and can contain impressive chalk, fade, and gloss retention promises. Like polyesters, SMP's are harder than PVDF resins – about one pencil harder – making them more resistant to rough handling. They are also more brittle, and tiny fractures can appear on bends during forming. Manufacturers have generally considered these microscopic fractures insignificant; however one company, Everlast Roofing, warms its SMP coil before sending it through the rollformer.

Kynar 500/Hylar 5000 systems, which are required to contain 70 percent PVDF, do not vary greatly between manufacturers. Since the paints carry 20 to 35-year warranties that allow for extremely little fade, the companies all use ceramic and appropriate inorganic pigments. Also available in PVDF are metallic coatings, in which aluminum flakes are embedded into the resin. These coatings have a metallic sparkle and shimmer. They must be topcoated to protect the flakes from oxidation, and so they are more expensive. Coil coated in a metallic paint is also highly directional due to metallic "flop". It can look very different from slightly different angles, and must be marked and installed in the same direction to avoid a checkerboard look. More popular are pearlescent paints, which use a natural substance called mica in place of metal flakes. They do not require topcoating. The mica particles reflect only some of the light that hits them, so the appearance is less metallic and more iridescent, conveying more of the pigment color. The use of these special paint systems is growing in popularity. Beyond polyesters, SMP's, and PVDF's, one other coil coating system is showing up on roofs. Plastisols, usually employing PVC resins, are thick, soft coatings that have abrasion resistance generally superior to Kynar and comparable chemical resistance. Because they are applied in thick coats of 4 mils or more, Plastisol finishes can be textured. They have generally poor chalk and fade performance, particularly in high UV areas. Yet they are as expensive as PVDF. In the United States, plastisols are primarily specified for highly corrosive environments such as chemical plants and animal confinement operations. In Canada and Northern Europe, however, they are widely used for architectural roofing and siding. Manufacturers who use this system consider it appropriate for climates with low UV levels, and report no particular problems. U.S. based manufacturers, accustomed to judging paints by South Florida weathering data, generally recoil at the thought of using plastisol paints for roofing anywhere.

The longest lasting and best quality coating that you can put on metal is Kynar. Today more and more manufacturers are using finishes formulated with poly vinyl idene fluoride (PVDF) for their premium systems.

The resin is a 70% Kynar 500 based material that was developed, produced and patented by the Penwalt Company of Philadelphia. The real strengths of a Kynar 500, 70% full strength Kynar paint system are excellent color and gloss retention, superior film adhesion and film flexibility, unmatched general stain and chemical resistance, unparalleled fade resistance, superior abrasion resistance and excellent salt spray resistance.

Kynar 500 has an extremely long life and is a baked-on finish applied on a coil coating line at 475 degrees Fahrenheit. The key to Kynar’s success across so many different functional areas can be traced to its basic foundation. The carbon/fluoride bond that is the basis of Kynar is the strongest chemical bond known to man. Kynar is available in a wide range of colors. Almost any color can be duplicated within the Kynar system. The development of Kynar was perfected by Penwalt, but the discovery of Kynar was a by-product that was developed when DuPont was inventing Teflon. Kynar 500, being a country cousin of Teflon and like it, has great non-staining characteristics. Since Kynar's coefficient of friction is extremely low, heavy rains can help wash and keep a Kynar-coated building clean. Some of the more popular finishes today such as siliconized coatings do not have the low coefficient of friction of a fluorocarbon and do not shed dirt, grime, and stain as readily. Kynar 500 is somewhat graffiti-proof. Paint thinners or removers can be applied using a soft, non-abrasive cloth to remove graffiti, with no harm to the coating itself. Fresh cement can be easily washed off without concern for staining.

Kynar is always the product of choice when the architect and building owner are looking for a product with an extremely long life and where color retention is required. With the use of Kynar 500, the owner can feel safe that the roof and coating product that he has chosen will be aesthetically coated with a finish that will not only protect the metal substrate, but will hold its colors for may years. An additional Kynar 500 coating can safely be added to an earlier coat in five to ten years without any checkerboard effect due to color fading and chalking. With Kynar 500, there would be virtually no objectionable color variance.

Kynar 500 PVDF coatings are applied to the following substrates: aluminum, galvalume, galvanized steel, aluminized steel, and now with new developments in the Kynar 500 technology--stainless steel. Stainless steel represents another category of substrate now being coated with 500 Kynar 500 systems on the principle that premium substrates demand premium finishes. Kynar 500-based coatings add value and versatility to this substrate by broadening architectural options. A Kynar 500 finish, for example, can soften the glare of stainless steel roofing and trim. And a wide variety of accent colors enables architects to complement a broader color motif while gaining a lifetime of protection.

In one scientific test, twelve panels coated with Kynar 500 resin-based coatings and other coating systems were exposed at a south Florida test fence for 10 to 17 years. The panels were evaluated periodically during this exposure for chalk, gloss, and color change. Kynar 500 resin-based coatings outperformed polyester powder, urethane, silicone polyester and acrylic coatings in every category including better color retention, better gloss retention and better resistance to chalking.

Continuous exposure testing in harsh environmental conditions have repeatedly demonstrated the superior weatherability of PVDF over anodized metal, PVC plastisols, porcelain enamels, acrylics and silicone polyester–based materials. A 70-percent mix PVDF finish was subjected for 160 months to continuous exposure in a subtropical environment at a 45 degree angle facing south. The metal panel with the 70-percent mix

PVDF finish showed very little change, even when examined at 1,000 times magnification under a scanning electron microscope.

In addition to its durability, PVDF is environmentally friendly and nontoxic. PVDF – exclusive of any additives – has had a listing in the Federal Register since the 1960's for reported food contact use. It's also listed in USDA for "Food and Dairy" use and for "Meat and Poultry." In addition, it meets the purity requirements of USP, Class VI, the most stringent of the classes. It is currently undergoing the test series mandated by the National Science Foundation for potable water. In fact, PVDF components are used in the food and beverage fields, in pharmaceutical applications and in the semiconductor industry.

PVDF, and components made of PVDF, are approved for disposal in sanitary landfill sites. The PVDF polymer does not contain any Chloro fluorocarbons components, a compound once used widely as aerosol propellants and refrigerants. Nor does it emit any carbon monoxide fragments under normal or decomposition conditions, and is not considered to be a danger to the ozone layer.

In all of the construction markets in which PVDF is used, the number one reason for using this material is cost-effective performance. PVDF-based systems are more expensive than many competing systems and may not be appropriate for every project. However, when specifying projects in which long-term weatherability and aesthetic appeal must go hand-in-hand, PVDF-based systems represent the most cost-effective alternative.

Now that we've focused on the different kinds of coatings historically available in the marketplace, let's take a look at what the coating manufacturers are doing to meet the needs of the environment.

There is a quiet revolution going on not only in America, but all over the world and it is very complex. But, for our purposes, we will refer to it as the Green Building Worldwide Movement. When people are polled about their major concerns, two that always show up in the top four concerns are energy and the environment.

To address these needs, some roofing manufacturers in the United States have switched their entire roofing product lines to Ultra-Cool, the new heat reflective coating from BASF. These low-gloss, ultra-cool roofing products meet the requirements of the Department of Energy's Energy Star program for reflectivity and more recently, the United States Green Building Council or USGBC LEED program for heat emissivity.

Meanwhile, regulators across the country, seeking to lower peak energy consumption and reduce heat island effect caused by dark urban surfaces, are writing specifications into building codes and other public policies that call for reflective roof surfaces. This new generation of metal oxide pigments notably BASF's, Ultra Cool line, allow darker colored roofs to reflect like lighter ones. This gives metal an edge over other materials in a market where dark colors are usually preferred. Add to this the material's longevity and recyclability, and metal is well positioned to become the greenest cool roofing material of choice.

The architectural community has embraced the concept of sustainability using the U.S. Green Building Council's LEED program as an economic and environmental standard for measuring construction products and systems conducive to green building. Other ad hoc organizations and standards are pushing their way into the marketplace with variations of standards. But, more than 20,000 building and design professionals have earned LEED certification which uses known standards and other qualification programs to provide the necessary data for qualification.

The LEED program uses a credit or point system to establish an overall building performance. Rating points are given for various sustainable features in five categories: building site; water efficiency; energy and atmosphere; materials and resources; and indoor environmental quality. Ratings, categorized as platinum, gold, silver or certified, are based on the number of points earned. A building rated platinum needs at least 52 points out of a total of 57 to qualify, while a gold rating would mean it has scored between 39 and 51 points. Between 33 and 38 points are needed to achieve the silver level while a certified rating requires between 26 and 32 points. A platinum-rated building would be able to effectively reduce its environmental impact by over 70 per cent, while a gold-rated building by an estimated 50 per cent. Used as a guide toward environmental design, LEED standards were the collaborative brainchild of the U.S.

Green Building Council members. They include government, architects, interior designers, builders, manufacturers and several branches of the military which conceived, tested and voted on the rating criteria.

Metal roofing products contribute importantly to the sustainable building movement. Metal's energy efficiency, high recycled content and total recyclability allow it to qualify for points in the LEED program.

The cost efficiencies of green building have been widely questioned and debated. But for those interested in building environmentally sound structures, the LEED program can result in economic and social incentives. And metal roofing is a path in earning those incentives.

Monitoring of over 10 buildings in California and Florida demonstrates that cool roofs save residents and building owners 20 to 70% in annual cooling energy use. These products reduce heat transfer to the indoors, thereby lowering air conditioning costs.

President George W. Bush's signing of the Energy Policy Act of 2005 allows cool metal roofing to receive preferential tax treatment.

The Air Force requires the use of LEED for new or major renovations for MILCON projects. It has developed a LEED Application Guide for lodging projects and has conducted LEED training seminars for its design and construction personnel. It has also created an online design guide for sustainable development structured after LEED. And it is developing an online Sustainable Training course. The Army has also adopted LEED into its Sustainable Project Rating Tool also known as SPiRiT. And all of the EPA's significant new facility construction and new building acquisition projects must meet the U.S. Green Building Council's LEED silver standard. The federal General Services Administration requires that all new GSA building projects meet criteria for basic LEED™ certification. The U.S. Navy stresses that submission to the USGBC for

LEED™ certification is not a requirement, but is recommended for high visibility and showcase projects. The State Department has committed to using LEED on the construction of 180 new embassies worldwide over the next 10 years.

Eighteen states have or are considering tax rebate and incentive programs tied to LEED certification. And dozens of major cities and counties throughout the United States require LEED certification for government structures or offer incentives for LEED-compliant construction.

The most widely known credit for roofing is the LEED Credit. 7.2 for roofs that reduce the heat islands effect. This is worth one point in the Green Building Council LEED code. The intent, according to LEED, is to “reduce heat islands characterized as thermal gradient differences between developed and undeveloped areas. It is hoped this will minimize impact on microclimate and human and wildlife habitat.”

Urban areas produce what is called the urban heat island effect with dark, heat-absorbing roofs being among the chief culprits. The temperatures in the air above heat islands and their heat-absorbing roofs can be as much as 12 degrees Fahrenheit hotter than the surrounding suburbs. This leads to higher air conditioning costs, greater use of electricity, and discernable, unhealthy levels of smog and ozone.

The LEED program had required that in order to achieve a credit, the product must have a minimum emissivity of 0.9 for 75% of the roof surface. LEED also made it clear it was not acceptable to round up the emissivity value in order to achieve this credit under LEED standards.

The solar reflectance of cool roofs tends to decrease over time. This is because surface particles like dew, dust, and air pollutants accumulate. Another factor that affects long-term solar reflectance is slope – the greater the angle of roof slope, the more dirt and particles dislodge and fall off the roof surface. Studies done at the Florida State Energy Center show that during the first two years of a cool roof's life span, solar reflectance can deteriorate up to 11% for a membrane roof if regular maintenance is not provided.

However, studies by various Kynar paint manufacturers show that the solar reflectance of metal roofing material remains almost constant.

Regardless of their material, cool roof materials have two important surface properties: a high solar reflectance and a high thermal emittance. Solar reflectance is a measure of the ability of a surface material to reflect sunlight. This includes the visible, infrared, and ultraviolet wavelengths – on a scale of 0 to 1. Essentially, it is the percentage of solar energy that is reflected by a surface. Solar reflectance is also called "albedo."

Thermal emittance is defined as the percentage of energy a material can radiate away after it is absorbed. *Solar* emittance of a material refers to its ability to release absorbed heat. Scientists use a number between 0 and 1, or 0% and 100%, to express emittance. With the exception of metals, most construction materials have emittances above 0.85 or 85%.

Cool roofs reflect heat well across the entire solar spectrum, especially in the infrared and visible wavelengths. The less solar radiation materials absorb, the cooler they are. In addition to absorbing less heat, the coolest roofing materials radiate away any absorbed heat.

Solar reflectance and thermal emittance have noticeable effects on temperature. Conventional roof surfaces have low reflectance from 0.05 to 0.25 and high thermal emittance typically over 80%. These surfaces can heat up to 150 to 190°F at midday during the summer. Bare metal or metallic surfaced roofs have a high solar reflectance of 0.5 or higher and may have low thermal emittance anywhere between 20 to 60%, depending on their surface treatment. These surfaces warm to 140 to 170°F. Cool roofs with both high reflectance and high emittance warm to only 100 to 120°F in the summer sun.

EPA's ENERGY STAR ® Roof Product Program has cool roofing specifications for both low-sloped and sloped roofs. Low-sloped roofs, those below 2:12, and flat roofs, must have an average initial albedo of at least 0.65. Steep sloped roofs must have an average initial albedo of 0.25 or more. While thermal emittance is not a qualifying criterion for the ENERGY STAR ® label, a rating of .70 or more further reduces heat transfer to the indoors.

Department of Energy research has shown that one additional percent of reflectivity in a coating will reduce the roof temperature on average by one degree. The ultimate result is that heat is reflected away from buildings, smog is reduced, energy costs are lowered and the life expectancy of the roof will be increased due to less expansion and contraction.

LEED Version 2.2 requires that roofing materials used on low slope roofs with a slope of less than 2:12 must meet a solar reflectance index or SRI of 78. Steep-sloped roofs with a slope of more than 2:12 must have an SRI of 29.

According to the U.S. Green Building Council's new requirements, an SRI is defined as "a measure of the constructed surface's ability to reflect solar heat as shown by a small temperature rise. It is defined so that a standard black with reflectance of 0.05 and emittance of 0.90 is zero, while the SRI for a standard white with reflectance of 0.80 and emittance of 0.90 is 100."

To calculate the SRI for a given material, it is necessary to obtain the reflectance and emittance values for the material. SRI is calculated according to ASTM E 1980, a standard practice for calculating the solar reflectance index of horizontal and low-sloped opaque surfaces with emissivity greater than 0.1. Reflectance is calculated according to any one of three ASTM standards—ASTM E 903, ASTM E 1918 or ASTM C 1549.

ASTM E 903 has been discontinued and ASTM E 1918-97 is a Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field. It covers the measurement of solar reflectance of various horizontal and low-sloped surfaces and materials in the field, using a pyranometer. The test method is intended for use when the sun angle to the normal from a surface is less than 45 degrees.

ASTM C 1549 is a standard test method for determining solar reflectance of flat opaque materials in a laboratory or in the field. The test employs a portable, commercial solar reflectometer and does not replace and is supported by comparison of measurements gained from E 903.

Emittance is calculated according to ASTM E 408 or ASTM C 1371. ASTM E 408 is a standard test methods for total normal emittance of surfaces using portable inspection-meter techniques. ASTM C 1371 is a standard test measure for determining emittance of materials near room temperature using a portable, differential thermopile emissometer to evaluate temperatures, heat flows and the thermal resistances of materials.

Tests have shown that on a 90-degree day, a white roof will only have a temperature of 110 degrees at its surface while a black roof will have a reading of 190 degrees. However, it would be a very dull country if architects and builders could not enhance the appearance of their products and were restricted to white, despite the energy savings. Consequently, roof coatings manufacturers have been developing cool roof coatings that increase heat reflectivity and reduce emissivity without sacrificing color choices.

New infrared-reflective pigments incorporated into paints used on architectural metal roofing products allow them to achieve higher reflectivity values, even in darker colors such as black and brown. This improved reflectivity — black changes from 0.07 with normal pigments to 0.32 with infrared-reflective pigments, for example — can mean a much cooler surface temperature and thus greater energy savings for the building below. This allows facility executives to select a sustainable roof without having to sacrifice color choices and aesthetics.

Another technology may be emerging that will further enhance the effectiveness of new cool roof coatings. While its presence in metal roof coatings is still down the road, a new micro encapsulation technology that reduces energy costs and increases room comfort in wall materials may also provide an answer to roof heating and cooling problems. BASF's Micronal phase-change microcapsules (PCM) apply an established technique used in space exploration technology for interior temperature management in buildings. The technique is simple: plastic capsules are filled with a wax that absorbs and releases energy by melting and solidifying. The technology holds microscopic wax droplets inside hard acrylic polymer shells. The small, 2 to 20 micrometer sized microcapsules are impervious, making them safe to process, and far too small to be damaged by sanding, drilling or cutting of the construction material.

Just as ice melts to form water when warmed and then freezes again when the temperature drops below 32 degrees Fahrenheit, the wax microcapsules work in the same way. However, the melting and freezing occurs at 78.5 degrees Fahrenheit. The key with the Micronal capsules is that a lot of heat energy is needed to fully melt the wax. For example, the energy required to melt one pound of ice at 32 degrees Fahrenheit to form water at 32 degrees Fahrenheit is actually equivalent to the amount of energy needed to heat the same pound of water from 32 degrees Fahrenheit to about 175 degrees Fahrenheit. The wax used in Micronal also absorbs a large amount of heat energy during its melting. When used in a building material, room heat is readily absorbed when interior temperature starts to climb just above the wax's melting point. While the wax is absorbing the room's heat to melt, the room temperature stays constant, thus modulating temperature swings in the room. This system works in daily cycles so that at night, when the room temperature drops below 78.5 degrees Fahrenheit, heat energy stored in the microcapsules' liquid wax is released as the wax freezes. Consequently, Micronal provides a dampening effect on the room's temperature during the day and night because it reversibly absorbs energy from the air and sunlight, stores it, and later releases it as the ambient air temperature drops

These tiny capsules are expected to add a new and innovative tool to address the growing 'green building' trend. While phase-change microcapsules are not a replacement for insulation, Micronal enhanced coatings could enable a reduction in air conditioning needs and allow the equipment to be run at a more constant level. It can also slightly reduce the need for heating at night.

We have talked a lot about the ability of existing cool roof products to meet Energy Star and LEED requirements for reflectivity and emissivity.

Most of the cool roof coatings and colors available today have little or no trouble meeting the reflectivity standards. Some, however, would fall short in meeting emissivity requirements if the entire roof surface required it.

However, utilizing the weighted average calculation as defined by LEED in one of its recent Credit Interpretation Rulings (CIR), only 75% of the roof surface must have 0.90 emissivity. The remaining 25% can be anything. There are many LEED Credit Interpretations Rulings that have allowed a lower emissivity or solar reflectance—but not both—where 100% of the roof surface is covered by one material, including a painted metal. The following calculation results when using the thermal emittance requirement of .9 on 75% of the roof surface requirement:

> 75% minimum coverage X .9 Emissivity plus 25% X .1--the emissivity of bare Galvalume-- equals .70 over all emissivity for 100% of a roof surface *excluding* parapets, skylights and equipment

This means any prepainted metal covering 100% of the roof, meeting the Energy Star Solar Reflectance specification, and having a thermal Emittance of .70 or greater meets or exceeds the LEED 7.2 credit criteria.

These Credit Interpretation Request (CIR) rulings can be critical when planning a LEED-compliant building and are available from the U.S. Green Building Council in a catalog of questions formally asked of the U.S. Green Building Council by registered LEED projects. They provide important guidance not found in the LEED reference manual.

Most industry experts agree that reflectivity has a greater impact than emissivity on the energy performance of the roof during hot weather. If a majority of the initial solar radiation is reflected, then a smaller portion is left for infrared emittance. Many cool roofs have reflectivities of 75 to 80 percent, or 0.75 to 0.80, which means that only 20 to 25 percent of the sun's energy is absorbed into the roof.

According to the Lawrence Berkeley National Laboratory, at an ambient temperature of 98 degrees, a change in a roof's emissivity from 0.75 to 0.90, with constant reflectivity, results in a surface temperature reduction of two degrees. Conversely, raising a roofs reflectivity from 0.25 to 0.40 while keeping emissivity constant, results in a surface temperature reduction of 13 degrees, a substantial difference.

Still, the combination of high reflectivity using light-colored or white surfaces, with high emissivity during hot summer months, results in a surface temperature sometimes as much as 60 to 70 degrees cooler than a non-reflective roof. The reduction in heat energy means less need for air conditioning and lower energy costs.

While the reflective and emissive properties of a roof are important concerns, they are not the be all and the end all. Other factors such as insulation, roof orientation and roof pitch are equally essential to a building's overall energy efficiency. Cool roofs save more energy when installed on buildings with low roof insulation. Attic radiant barrier can be used to reduce the energy saving potential of cool roofs. Buildings with low attic ventilation see a greater benefit from a reflective roof. And local climate plays a huge role, particularly in areas with long, sunny, hot summers where cooling energy savings are typically greatest.

In addition, building owners should never agree to a roof based solely on its color. The long-term performance characteristics of metal roofing should be strongly considered, particularly its low maintenance costs and durability.

The question remains however, if a cool roof will be a thermal detriment in traditionally cooler climates characterized by cool summer evenings and cold winters.

A roof designed with specific reflective and emissive properties can't change its properties with the technology currently available in the marketplace. Perhaps a decade from now we shall see acrylic-wax coatings that can repulse heat in summer and absorb it in winter. But for now, the effectiveness of a cool roof must be gauged by energy saved during the hot summer months versus energy consumed during the cold season. Some critics of the LEED prescription for cool roofs contend that geographics are missing from the standard and must be included to accommodate environmental considerations unique to cold climates where the cost of energy required to compensate for heat loss would make a cool roof counterproductive.

Some experts contend the summer cooling savings even in cold climates are able to counteract the winter heating losses. They argue that days during the winter months are shorter and the solar angle is lower so less total energy is hitting the roof to be absorbed or reflected over the same period of time as during the summer. They also contend that white roof snow piled up on the roof during the winter reflects the sun's energy and that resources like natural gas and oil have been traditionally cheaper than electricity to heat buildings in the winter.

Arguments like these have been a key reason why some critics of the LEED standard are arguing for revisions or looking to other organizations to emerge with their own criteria for judging what is green.

LEED does stipulate that products and their manufacturers meet standards before they can be designated Energy Star or LEED compliant products. In the case of Energy Star and LEED, any qualified laboratory can determine the solar reflectance required by the program. The laboratory does not need to be independent of the material manufacturer; therefore both third party and manufacturer laboratories can be used to provide data to the EPA.

However, the Cool Roof Rating Council, an independent non-profit industry association, requires that the laboratory conducting the measurement be accredited. Either the lab must be listed as an Accredited Independent Testing Laboratory (AITL) by the CRRC or it must be an Accredited Manufacturers Testing Laboratory (AMTL) to perform the determine reflectivity and emissivity. Both the AITL and the AMTL must meet the requirements of the CRRC, which includes ISO certification of the lab, as well as additional required CRRC training.

There are no fees for having products listed as being Energy Star compliant. Therefore, there is no fee for the LEED compliant evaluation of roofing products. However, associated fees may be required for obtaining recognition of the complete facility construction through the LEED program.

The non-profit CRRC does have a fee structure, which is based upon the volume of all roofing products manufactured or applied by the licensee. The association also charges a label fee for each product type. That label fee is broken down into two categories; one that relates to frequently produced products and one that relates to custom colors, applicable to metal roofing applications

Whatever the standard for heat island effect in environmental building one thing is clear. A metal roof is a natural choice. And architects and builders already working with metal have a clear opportunity to add yet another reason for choosing it over other surface materials.