Exploring and Comparing Factory-applied and

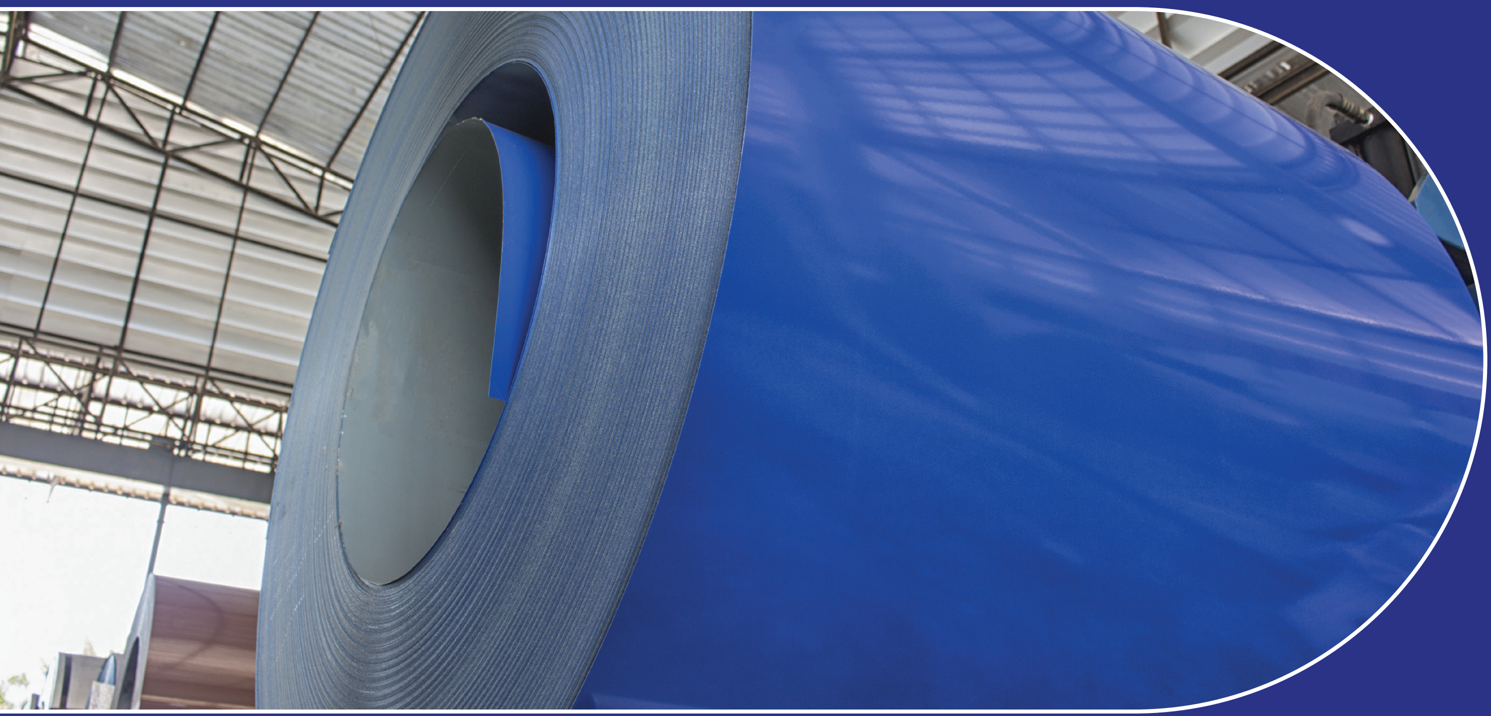
Full disclosure: My involvement in the coatings industry centers around the field of prepainted metals. These factory-applied coatings were always fascinating to me because metal coils of all types of substrate pedigrees could be unwound onto a paint line and all the processes needed for painting completed in a matter of minutes. These processes went all the way from cleaning the surface to curing the paint, resulting in pristine coils waiting to be formed into parts for almost every market.

Therefore, for purposes of this article, "factory applied" is defined as painted before forming, or prepainted. Conversely, "field-applied" refers to painting after forming—regardless of the application method or painting location.

Factory-applied painting was very different from what some call "the traditional" method of applying coatings, which involves forming the parts, putting them together, and then cleaning and painting the end product. This method of painting after parts are formed could be done in an immersion or spray painting section of a facility, outsourced to another company, or painted on location during construction.

Joseph L. Hunter, an early pioneer in the paint and coatings industry, invented the first coil coating apparatus to streamline the very time-consuming chore of painting venetian blind slats in 1930. This coating method was quickly adopted by the venetian blind industry. In the 1950s, coil coating lines were designed to handle large steel and aluminum coils and the industry grew by leaps and bounds.

Since those first rudimentary coil painting lines, technology has advanced significantly to the point where prepainted metal has become a preferred



Field-applied Coatings

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coating method for a wide variety of commercial, industrial, consumer and residential products.

Applications range from automobile parts, appliances, HVAC units, lighting fixtures, metal roofing, interior and exterior wall panel systems, mullions, soffits, gutters, truck trailers, food and beverage containers—in short, anything that can be made from a flat sheet of metal.

In the appliance market today, customers tend to gravitate toward color. The days of the standard white refrigerator, washing machine and dryer are gone. Consumers want durability and beauty in their homes. Appliance manufacturers adopted prepainted metal about 30 years ago. At that time, white was still the "in" trend.

Today, the finish on a refrigerator door or washer/dryer set is a high-value differentiator, and it is not only color where prepainted metal plays a role. Yes, a rainbow of colors does exist for home appliances for those who want bright pops of color to brighten their home.

However, for those who enjoy the look of stainless steel, but don't want to constantly remove fingerprints, consumers now have the choice of coatings with fingerprint resistance that retains the industrial look. Thin glittery metallics or translucent coatings reminiscent of holograms are also available. Because of the consistency and excellent color match provided by coil-coated metal, some manufacturers even tout custom color matching for the kitchen and laundry room.

Coil lines have grown in size and capacity to accommodate speeds of up to 800 ft/min, with a few lines stating capabilities inching toward 1000 ft/min for some applications. There are anecdotes that some of the accumulator towers used for unwinding and winding at either end

of the line at high speeds were so tall that they required air-traffic control clearance! A typical coil coating line schematic is shown in *Figure 1*.

Conversely, when metal is formed into a shape or final product before painting (known in some circles as extrusion coating), a slower and very different batch coating process is needed. Some common examples of extruded products include tubing, weatherstripping, fencing, deck railings, window frames, and curtain wall framing. A typical paint line schematic for formed and extruded products is shown in *Figure 2*.

The uniformity of each applied layer is one of the key attributes that makes coil-coated products perform so much better than brushed or sprayed coatings. Steel and aluminum can be painted on both sides with as many layers as needed for the durability of the final application. The diagrams in *Figures 3* and *4* illustrate typical pretreatment and coating layers possible for zinc-coated steels and aluminum respectively.[2,3]

Aluminized steel is another metallic coated steel that has been used in the manufacture of building panels. The illustration for coating of that product is the same as that of zinc-coated steels albeit it the alloy layer is aluminum and the conversion coating would be of a different chemistry.

Stainless steel prepainted material would appear very similar to the coated aluminum diagram. Both substrates have protective oxides on the surface that inherently prevent corrosion in the uncoated state. Therefore, these types of substrates require conversion coatings that interact with, rather than eliminate the surface oxide.

Paint technology advances mirrored and drove many applications. Both pre- and postpaint systems use similar resins for the same type of final product. The coating formulations, however, are very different as they are tailored to accommodate the specific application system. This maximizes final properties, durability and the required aesthetic characteristics.

FIGURE 1—Coil paint line schematic of a typical coil coating line. This diagram is for two layers of paint application; some can apply three layers in one pass through the line.[1]

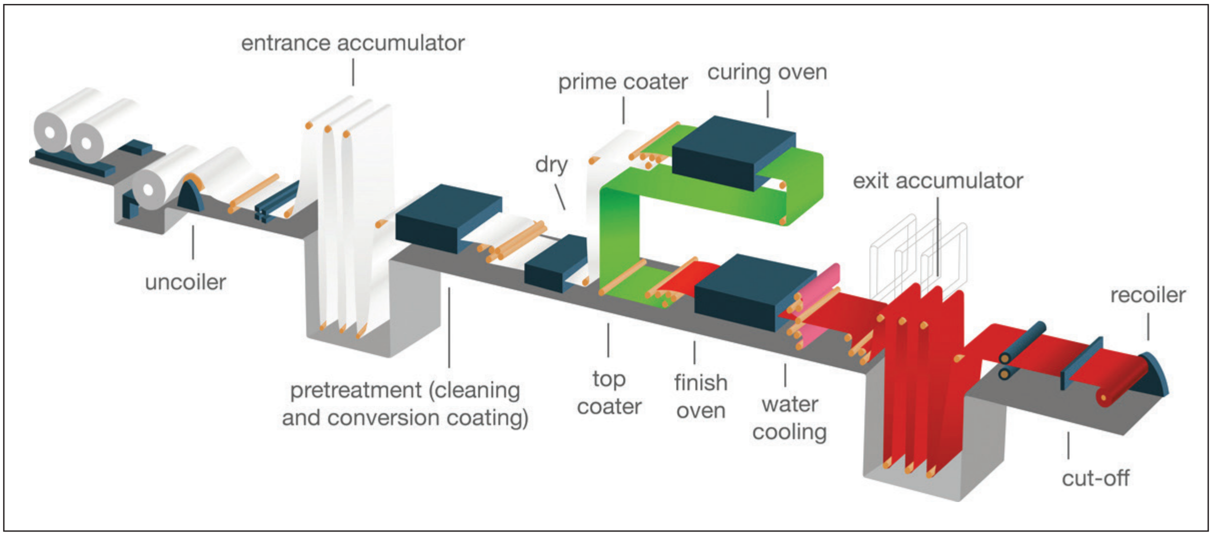
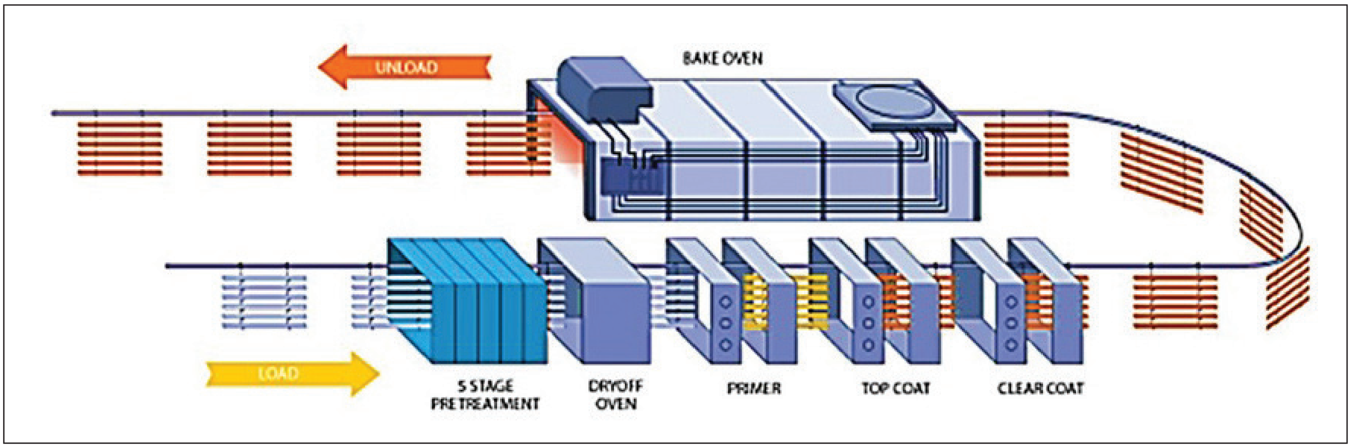


FIGURE 2—Schematic for a paint line coating formed and extruded products.[1]



PREPAINT COATINGS ATTRIBUTES

Postpaint systems generally have two jobs—good adhesion and appropriately sufficient durability for adequate service life. Prepaint coatings, by contrast, have a whole host of additional characteristics and functions.

First, the prepaint coating must be compatible with an application technique that runs at several hundred feet per minute. It must cure or dry in less than 30 seconds while traversing through the continuous processing line.

Each of the material properties needed to stamp, cut, punch, pierce, or join the final product must also be incorporated into the paint formulation. The coatings must also possess the same formability as the substrate without thinning excessively. All these characteristics must be present while acting as the lubricating agent during forming. Compatibility with joining technologies appropriate to the final product is another critical attribute.

Of course, aesthetics cannot be compromised. The surface must remain perfectly unmarred during all of these processes. And finally, cut-edge-corrosion resistance is paramount to service life durability.

All this is possible because coil coating methods offer nearly 100% processing efficiency. To begin with, substrates can be aggressively cleaned and uniformly pretreated much more consistently when the substrate is still a flat sheet. Those first two steps provide the basis for successful long-term durability.

The coating process is highly efficient and precise as well, with a uniform and reproducible finish from one end of the coil to the other that enhances surface quality and aesthetics on both sides of the strip. Every inch of the surface can be cleaned, pretreated and coated when the substrate is flat—a general impossibility when parts are formed and/or joined before painting. Curing or drying of the flat sheet is also extremely uniform and fast—usually 30 seconds or less at prescribed peak metal temperatures.

Coil coatings are tailored to meet the aesthetics and service needs of the final product even while essentially acting in concert with the substrate during product manufacturing.

FIGURE 3—Schematic illustration of a metallic coated substrate painted with a conversion coating (chemical pretreatment), primer and topcoat during the coil coating process.[2]

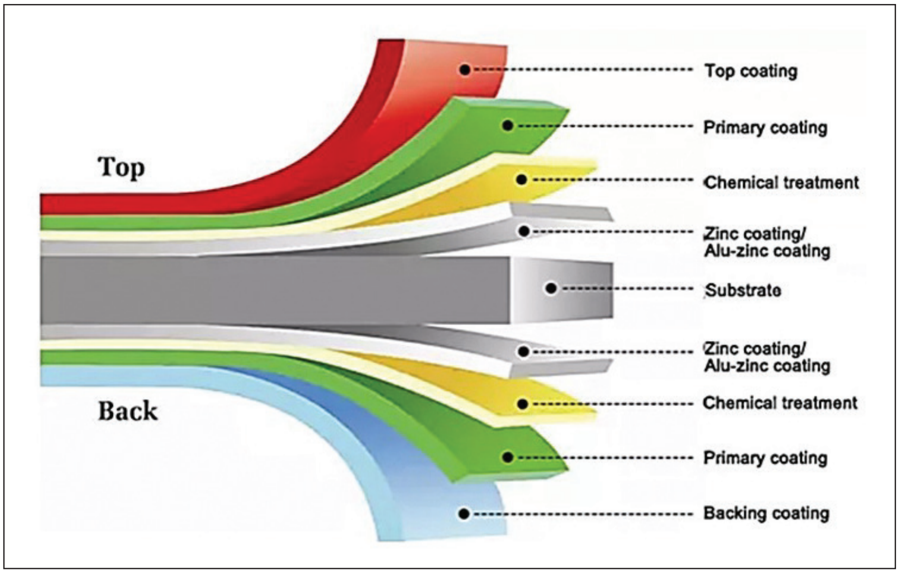
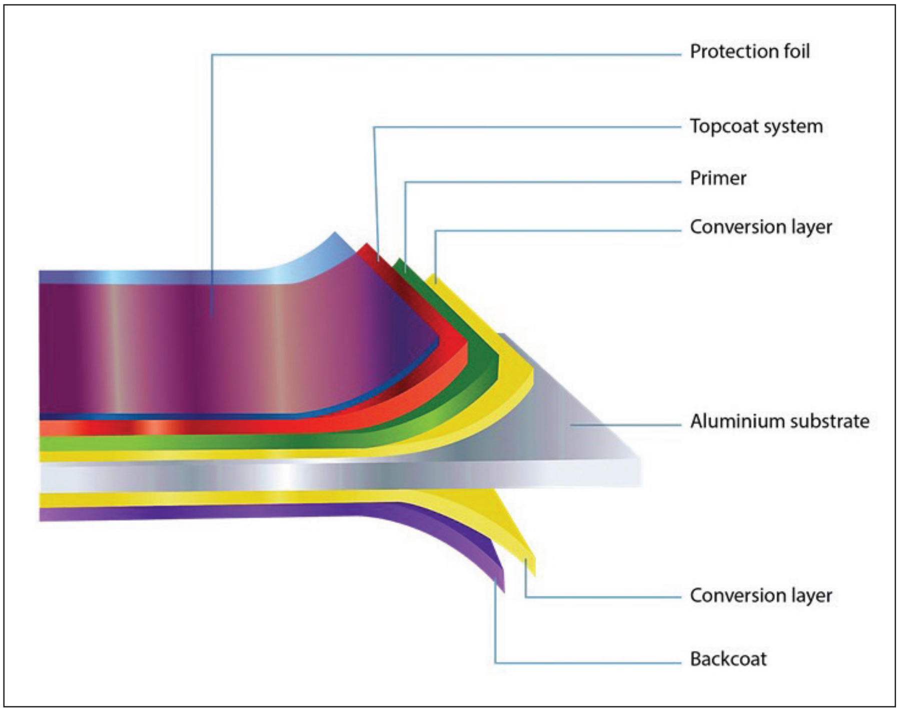


FIGURE 4—Schematic illustration of an aluminum substrate painted on a coil paint line. In this illustration, a conversion coating, primer, topcoat, and removable protective layer are applied.[3]



Coil coating is also environmentally attractive compared to postpainting alternatives such as spraying. With the nearly 100% application transfer efficiency while applying the paint, there is virtually no loss of coating. The emissions profile is also excellent thanks to the contained operation and highly sophisticated emissions abatement systems. Coil lines can also treat their own effluent for reuse or before discharge into public systems.

Manufacturers that move from an in-house post paint process to prepainted alternatives can dramatically reduce production cost and time. Specially tailored painted coils allow manufacturers to essentially eliminate continuous costs of operation associated with those post-paint lines. Energy savings, waste minimization and less onerous regulatory compliance can also be realized. Further, by employing supply chain logistics best suited to the business, lead times are reduced, and material logistics become less complex.

Housekeeping is also greatly improved as oils and other lubricants that attract dust and dirt are eliminated because of the inherent lubricity of the coatings. Die maintenance is minimized, leading to more uptime and fewer maintenance costs.

Coil-painted materials are often used to solve an existing problem, improve quality and/or in-service durability. Ford New Holland manufactures heavy duty agricultural equipment. The need was to improve corrosion protection on shielding and cosmetic components of their most popular balers. In this case, capital intensive fabrication processes were in place that could not be altered.

The biggest concern was welding. Formulation of weldable primers for coil coating solved that problem. By using weldable preprimed metal, Holland was able to meet the enhanced corrosion resistance objectives not achieved by post painting *and* keep their core manufacturing in place. This even included no significant changes to their existing top coating processes.[4]

In industries such as automobile manufacturing, where it is not logistically practical to employ fully prepainted or preprimed materials, temporary protective prepainted coatings have played a large role in enhancing substrate formability irrespective of the inherent surface roughness characteristics of the substrate.

Metal alloy surfaces range from the very smooth, such as stainless steel and aluminum to moderately rough (galvanized) to highly microtextured (galvanneal). While temper rolling serves to control the surface roughness to the required levels for optimal aesthetics, the inherent roughness of the alloy surface can increase sliding friction within the stamping dies, reducing the ability to optimally stretch the material during forming.

Temporary protective coatings allowed for uniform stretching and thinning of a panel, yielding sharper feature lines and more complex shapes. The reason for this was that the temporary organic coating was a solid film applied to the surface that uniformly exhibited a very low coefficient of friction (COF), essentially “smoothing out the rough edges” of the alloy microsurface.

Because of the low and more importantly consistent COF, body panels with features designed outside the “safe zones” of stress and yield point could be formed without breakage. The extremely uniform organic coating acted as a consistent lubricant, generating the maximum ability of the metal to reach full mechanical properties. Oil-based lubricants that could be smeared into the microvalleys associated with the surface roughness of many metallic coatings could not provide the same lubricating consistency.

These temporary protective coatings also enhanced die performance because abrasion and dirt were minimized by the clean, smooth organic surface. At the same time, housekeeping and maintenance costs were reduced in the stamping areas.

Another important characteristic of a temporary coating was that the metallic surface was “covered” throughout the entire stamping and assembly processes. This kept dirt and other soils away from the metal surface. Therefore, at the pretreatment stage, the surface was uniformly activated for optimal conversion coating deposition. This is important because under normal circumstances there are instances when embedded soils cannot be removed from the body panels, ultimately leading to paint delamination in critical cosmetic areas.

Once assembled, automobiles were staged through the traditional post painting process. During alkaline cleaning, the protective coating was removed, and a perfectly pristine surface was presented for pretreatment. Any fingerprints, oils, greases or other contaminants were never in contact with the substrate surface. With an even more consistent pretreatment deposition, the already excellent automotive paint system became an even higher-quality product.

THE CUT EDGE QUESTION

All prepainted metal has a cut edge. But because of the extremely uniform pretreatment applied to the flat surface and the specially tailored paint formulations, prepainted metal performs much better than postpainted parts in the long term.

In a now-famous seminal case, the National Coil Coating Association, PPG Industries, and the NA Zinc-Aluminum Coaters Association conducted a study where G60 and G90 hot-dipped galvanized (HDG) prepainted louvers with exposed cut edges were subjected to exposure to corrosive elements in Daytona Beach, FL.[5,6]

Control parts included both G60 and G90 HDG post-painted with either electrocoat, powder coating or a spray finish. Following 16, 44, and 68 months of exposure to the Daytona Beach elements, the prepainted metal—complete with cut edges—exhibited significantly better corrosion resistance irrespective of galvanized coating weight.

In fact, as illustrated in *Figure 5*, the parts prepainted onto the lower galvanized coating weight (G60 HDG) outperformed the G90 HDG component that had been spray coated. The ability to reduce the galvanized coating weight *and at the same time* achieve superior corrosion performance with prepainted metal represents a significant cost savings to HVAC and other manufacturers.

BUILDING AND CONSTRUCTION

Today, metal building and construction products have taken the most advantage of prepainted-coil technology, comprising roughly 75% of the coil coating market. Eighty percent of metal roofing is coil coated. All other market applications combined pale in comparison to the sheer surface area of painted metal in building and construction. These products are a perfect match for the high speed, precise, and most importantly, consistent coil coating operation.

Many architects around the world enjoy the innovative way that color can bring metal to life as the products have wonderful aesthetics. As a result of this interest, paints have evolved to look beautiful, mesmerize the senses, and even improve the environment.

In the field, the options for applying paint to metal generally include spray or brush applications. However, while these field techniques are adequate for certain applications that have built-in maintenance intervals, they do not allow for the long-term durability of 50-plus years routinely expected of many products used for metal building construction.

Early work in coating technology for the building and construction market began with silicone polyesters for weathering applications. Highly durable fluorocarbons for the most demanding settings and maximum color strength were developed next. Both are still in use today.

Specific performance and cost needs were addressed by modifying those systems with other materials. Organosol and plastisol coatings were also excellent for long-term durability and where fabrication of the painted panel was extremely critical.

Now, because of advances in both application methods and paint chemistry, there are a wide variety of interior and exterior systems that can be chosen to provide excellent long-term performance. Chemistries can be selected to provide 15 to 60 years (or more) of exterior performance, specially tailored to geography, environmental conditions, and desired special functionality.

FIGURE 5—Comparison of cut edge corrosion performance of prepainted and postpainted hot-dip galvanized steel after 68 months of exposure at Daytona Beach.[6]

Prepainted G60 HDG after 68 months of exposure at Daytona Beach

Postpainted G90 HDG after 68 months of exposure at Daytona Beach

The entry-level product in the building and construction market is standard polyester. It is used for rainware, doors, windows and liner panel-type applications. Simple polyesters are designed to last up to 15 years without refinishing or replacement.

Silicon-modified polyesters (SMPs) are more durable, harder, less flexible and are prone to water spotting. But they are successfully used for postframed buildings, pre-engineered metal buildings, and for many industrial/commercial components. These coatings are available in a wide variety of colors and have good durability, lasting more than 20 years.

Super-durable polyester systems have grown substantially during the past 15 years. Because of their superior color and gloss retention in harsh conditions, they command much of the coastal and southern U.S. markets. Normally, the flexibility of these coatings is a bit less than other polyesters, but they make up for that with robustness and greater outdoor durability.

Recently, new super-durable polyesters have been introduced with a 40-year limited warranty. These modified high-end polyesters do not lose flexibility like SMP products. They are formulated to maintain gloss and color retention and have excellent weatherability and durability.

These super-durable polyesters meet all the AAMA 2604 criteria for durability and corrosion resistance as well. In fact, some colors have met the more stringent AAMA 2605 specifications which have long been the purview of fluoropolymer technologies.[7] Super-durable polyester coatings are used for building panels, aluminum composite material, roofing and all types of highly exposed architectural systems.

The top-of-the-line coating for architectural applications remains the fluoropolymer polyvinylidene fluoride (PVDF). This paint was first synthesized and introduced in 1948 and is still viable today.

An additional acrylic resin is needed to formulate PVDF into the paint system used in coil coating. Typically, optimal physical and performance properties are obtained with a formulation of 70% PVDF and 30% acrylic resin. At lower PVDF-to-acrylic ratios, paint performance suffers. Interestingly, this paint is a thermoplastic. Gloss is limited to approximately 35 and the acrylic addition limits the color pallet. Achieving bright colors, while possible, can still be a challenge.

In 1982, a new fluoropolymer paint was introduced called fluoroethylene vinyl ether (FEVE). It is a chemically cross-linked thermoset resin. FEVE is a clear resin, with gloss as high as 70, yielding smoother, brighter, and more vibrant finishes. Both PVDF and FEVE systems meet the stringent criteria of AAMA 2605 and are used in large architectural projects.

TESTING AND VERIFICATION

Three American Architectural Manufacturers Association (AAMA) standards govern testing and performance requirements for many of the components in the architectural manufacturing industry.[8] These specifications apply to all high-performance architectural coatings, irrespective of application technology or whether the coating is formulated as a liquid or powder.

Many of the test procedures embedded in AAMA are governed by ASTM standards. This allows for a consistent evaluation of old and new coatings over decades, lending confidence to coating selections. ASTM standards are reviewed every five years to respond to new coating technologies, coating or coating component obsolescence, advances in testing equipment, and changes due to environmental regulations.

AAMA 2603 is for interior applications such as facades and commercial storefronts in malls and other interior applications where color retention is not required. It is considered the least stringent specification for this market. Baked enamel (acrylic/polyester) coatings can generally meet this specification. They are generally harder (less flexible) than other architectural coatings and have poor resistance to chalking and fading but are also much less expensive.

Weathering performance standards are relatively low, requiring only one year of exposure to be suitable proof of key performance criteria. Most of these applications are not in high corrosive or harsh weathering environments. In truth, most systems considered for use under this specification have undergone testing longer than one year, as most architects would not be comfortable with only one year of testing.

AAMA 2604 is an intermediate specification for storefront doors, windows, low-rise curtain wall, or other high-traffic areas. This coating provides good color and gloss retention and good hardness and abrasion resistance. A typical paint system that meets this standard is a 50% fluoropolymer resin-based coating. Even though there is a five-year weathering requirement in the specification, these coatings on aluminum usually are sold with a 10-year warranty and therefore easily exceed the specification.

AAMA 2605 is the mainstay of liquid paint options for high-performance exterior applications. One of the popular paint systems that meet this specification is the 70% fluoropolymer (PVDF) resin-based coating. Almost every major paint supplier has its version of this paint chemistry. These finishes exhibit outstanding resistance to humidity, color change, gloss loss, and chemicals.

Applications for this finish would include exterior curtain wall, facades for windows and doors, and large architectural projects such as stadiums and high-value residences that require long-lasting surfaces and long-term durability performance in a large diversity of

TABLE 1—Testing Criteria for AAMA Specifications for Architectural Coating

TESTING CRITERION	AAMA 2605	AAMA 2604	AAMA 2603
South Florida Weathering*	10 years	5 years	1 year
Color retention	ΔE <5	ΔE <5	Slight change
Chalk resistance	No more than 8 rating 6 rating for white	No more than 8 rating	Slight change
1 year "slight" Chalk	50% retention	30% retention	No specification
Erosion resistance	10% loss	10% loss	No specification
Dry film thickness	1.2 mils minimum	1.2 mils minimum	0.8 mils minimum
Pretreatment System	Chrome or chrome free	Chrome or chrome free	Chrome or chrome free
Accelerated Testing			
Salt spray resistance	4000 hours or 2000 hours aggressive cyclic testing	3000 hours	1500 hours
	1-2 mm creepback from scribe	1-2 mm creepback from scribe	1-2 mm creepback from scribe
	Size 8 blisters	Size 8 blisters	Few blisters
Humidity resistance	4000 hours	3000 hours	1500 hours
	Size 8 blisters	Size 8 glisters	Few blisters
Gloss retention	Minimum 50%	Minimum 30%	Slight change
Warranty	10 years	5 years	1 year

environments. Warranties of these products routinely exceed 20 years and have even been offered up to 50 or 60 years.

AAMA requires well-established testing to verify that architectural coatings are properly positioned. There are more than 20 different tests that address a wide variety of material properties and system performance. Mechanical and chemical testing and certification is geared primarily toward the metal substrate. The remaining testing is aimed at paint system performance on specified substrates. *Table 1* is a compilation of some of the key AAMA paint testing criteria related to long-term durability and aesthetics of architectural coatings under consideration.[9]

ENVIRONMENTAL FOCUS

Many of the coatings mentioned in this article have been on the forefront of responsible environmental considerations. Not only is coil coating itself an environmentally friendly manufacturing process, but products generated through this precise application technology are being used to clean the air and lower energy costs.

Solar-reflective coatings for prepainted metal roofing help reduce energy costs. These coatings cut down on heat buildup on metal roofs, campers, shipping containers, refrigerated trailers, storage units, and shipping containers. The "cool-roof coatings" reflect infrared radiation, decreasing heat buildup within buildings.

On the flip side, the coil coating process is ideal for the special multilayer coatings used for solar energy because of the unique, continuous, precise control of coating thickness. Thin layers of functional coatings containing nanoparticles, metal particles, metallic oxides and pigments can be uniformly applied. Each ingredient has a specific purpose within the solar reflectance system. Additional coats provide protection from humidity and temperature. Some topcoats are self-cleaning, making the solar panels more efficient for much longer.

Another architectural coating on aluminum is formulated to break down pollutants in smog and convert them into harmless compounds that wash away when it rains.

Nitric oxide and nitrogen dioxide is broken down into simple nitrates. In combination with solar energy (sunlight), the special titanium dioxide coating acts as a catalyst to break down organic pollutants and sulfur oxide from diesel exhaust. These also wash away in rainwater.

When exposed to UV light, the coating becomes super hydrophilic, so rainwater hits the surface and collapses flat instead of beading up. This allows organic particles, dirt, grime and smog to slide off the panels. This natural cleaning of the building also reduces maintenance costs and preserves the aesthetic appeal of the structure. It is reported that 10,000 square feet of building panel surface coated area with this type of paint system removes as much pollution as 80 trees.[10] ❇

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