

High Performance Fluoropolymer Coatings

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Abstract

Highly durable fluoropolymers coatings have provided long-term beautification of metal building panels and components for over 30 years. Recent advances in fluoropolymer technology have brought newer and brighter colors and special effects. Derivatives of these new fluoropolymer finishes can now be site applied and cured under ambient conditions. This allows building restorers to use existing building metal components and to match new and old surfaces. Advances in colors and infrared reflective systems offer more variety and choices for the owner, architect, and specifier.

Fluoropolymers in Coatings: History

Some of the first fluoropolymers used as a protective layer for architectural applications were actually PVF (polyvinyl fluoride) films, for example, DuPont TEDLAR[®]. PVF was also supplied as a liquid coating in a pigmented solvent dispersion, however, the decomposition temperature was too near the “fusion temperature” of the PVF organosol to be practical on industrial coatings lines. Fortunately, parallel work on PVDF (polyvinylidene fluoride) offered a solution to the problem. DuPont held the first synthesis patent for PVDF in 1948. Pennwalt Chemicals acquired the rights in the 1950’s and developed a commercial licensing program that allowed the first widespread commercial use of PVDF pigmented liquid coatings (sold under the trade name KYNAR[®] 500) in the mid 1960’s. In the mid 1980’s, Elf Atochem (now Atofina) acquired Pennwalt. The Federal Trade Commission mandated that Elf divest one of its PVDF production sites. Ausimont, USA (now Solvay Solexis) acquired it and became the second major supplier of the Pennwalt PVDF coatings technology (sold under the trade name HYLAR[®] 5000). The first major entry into a “functional” or “thermoset” coatings-grade fluoropolymer was Asahi Glass in 1982 with a family of copolymers of fluoroethylene and alkyl vinyl ether (sold under the trade name LUMIFLON[®]). The coatings were recommended for architectural aluminum, coil, steel and masonry along with other applications. The polymer development continues today with waterbased and powder coating resin technology. There are a number of other resin/polymer suppliers too. This presentation will focus on the solvent-based liquid technologies that are in wide use today.

Fluoropolymer Coatings Chemistry

Any liquid coating is comprised of the following key ingredients:

1. Polymeric Binder
2. Pigment

3. Additives (flow, leveling, UVA, etc.)
4. Solvent or Water

The physical properties or the key performance features of the dry coating film such as exterior durability and chemical resistance are primarily derived from the polymeric binder and to some extent the pigments. The properties of polymeric binders are determined by their inherent chemical structure and their molecular weight.

Fluoropolymers like PVDF are very high molecular weight (MW) polymers. The polymeric films are thermoplastic and derive most of their properties from the high molecular weight PVDF. The KYNAR 500/HYLAR 5000™ technology is a 70%PVDF/30% acrylic organosol in which the cured film is obtained by melt/fusing the acrylic/PVDF dispersion into a film. Aside from the excellent physical properties, one consequence of this material is the 25-40-gloss restriction. The gloss is limited by the refractive index difference between the high MW fluoropolymer and the acrylic in the film.

Coatings that use functional polymers like FEVE and functional CTFE copolymers are lower molecular weight solution polymers. They must be crosslinked (infinite molecular weight) to obtain hardness and chemical resistance. Because the functional polymer coatings are true solutions, high gloss and brighter colors are possible. The solution polymers also offer opportunities for higher volume solids and for lower temperature cure systems, and even air-dry systems, with a two-component finish.

The following table summarizes some of the major fluoropolymer types and sources.

| Coating Types | Resin | Composition | Company |
|---|----------------------|--|----------------|
| Baked (Thermoplastic) (Thermoset) | KYNAR500/HYLAR5000 | PVDF | Atofina/Solvay |
| | Lumiflon/Fluoronate | FEVE/CTFE- functional copolymers | Asahi DIC |
| Air Dry | KYNAR ADS | VDF/TFE/HFP | Atofina |
| | LUMIFLON/FLUORONATE™ | FEVE/CTFE- functional copolymers | Asahi DIC |

Pigmentation

Pigments are solid materials that are used to impart color, control gloss, improve performance, such as infrared reflectance or corrosion resistance, or simply occupy space in a paint film. In general, pigments in fluoropolymer coatings are used for color and appearance. Color stability of the fluoropolymer coating is to some extent dependent on the light fastness of the pigment chosen. It is desirable to use polymers

that do not degrade, (lose gloss or chalk) and it is desirable to use pigments that do not change in color over time.

When selecting paint pigments, it is important to understand the conditions under which the coating will be used. The pigment must maintain its original color under the conditions to which the coating will be subjected. If the coating will be used outside, then the pigment must be capable of withstanding UV light and humidity. If the coating will be subjected to heat, either in-service temperature or during a bake or cure cycle, then the pigment must be heat resistant. The pigment must also be selected to be sufficiently chemical resistant, either toward solvents in the paint or chemicals to which it will be exposed.

Other important properties, such as color, opacity, tint strength, brightness, toxicity, and oil absorption are important factors that must be considered in selecting a pigment.

As a general rule inorganic oxide pigments are more durable (UV resistant) than organic pigments, but the organic pigments give a wider range of bright colors. Many different chemistries exist for organic pigments. The choice of pigment depends on the color desired and durability and performance needed.

Metallic pigments, such as aluminum, stainless, copper and bronze pigments, can impart special effects, chemical resistance and/or color to a coating. Aluminum flake is widely used in fluoropolymer coatings to impart a metallic look. Coloring pigments are often used in combination with the aluminum pigments.

Aluminum pigments are classified as leafing or non-leafing. Leafing aluminum flakes migrate to the surface of the coating forming a very reflective layer. Leafing aluminum pigments are used where high reflectivity and corrosion resistance are desired. Non-leafing aluminum flakes tend to disperse evenly throughout the paint film, not just on the surface. It is these non-leafing aluminum flakes, which are used in fluoropolymer coatings to give a metallic appearance and polychromatic effects (also known as “flop” or “travel”). Aluminum-containing coatings usually require a clearcoat to maximize durability and prevent oxidation of the metal pigment.

Metal oxide-coated mica pigments are a form of nacreous or pearlescent pigments. Their color can vary from a white pearlescence to a variety of transparent colors. These products are made by depositing a layer of a metal oxide (titanium dioxide most commonly) on the transparent mica flake. These pearl pigments have a white pearl background. Colors can be produced by varying the metal oxide layer thickness and type. These pigments are made from a mineral and metal oxide so they are very durable. Mica pigments do not offer the same degree of “flop” or metallic look seen in aluminum pigmented systems, but their unique appearance combined with outstanding durability make them a good choice as a special effects pigments for fluoropolymers.

Pigments that reflect infrared energy are of particular interest for use in energy-saving coatings, especially for roofs. Pigments, which historically have been used in whites,

light colors, and metallics, are inherently IR reflective. However, recent advances in dark colored pigments, have tremendously improved the reflectivity of coatings using these “reflective” pigments. In some dark colors, the reflectance values can triple with these new reflective pigments compared to matching colors made without using reflective pigments.⁷ The table below illustrates this comparison.

| <u>Color</u> | <u>Reflectance w/Standard Pigments</u> | <u>Reflectance w/IR Reflective Pigments</u> |
|--------------|--|---|
| Off- White | 61% | 66% |
| Medium Green | 34% | 43% |
| Dark Bronze | 8% | 25.1% |
| Metallic | 49% | 53% |

There are many benefits to using a highly reflective roof coating. Such coatings can reduce the roof temperature thereby reducing building cooling requirements. Low roof temperatures can extend the life of the roof. More reflective roof coatings can reduce smog formation, and contribute less heat to the Urban Island effect. In many cases, building owners using reflective roof coatings may qualify for tax credits and rebates from Federal, State, and local governments. It is estimated that a 1% increase in coating reflectivity produces a 1°F reduction in surface temperature.

The EPA has established the Energy Star labeling program to encourage the use of energy efficient household items. Included in this program is the Energy Star Roof Products Labeling Program. To qualify, coatings must meet the following criteria, initially and after 3 years :

STEEP SLOPE ROOFS (greater than 2:12 inches)

- Initial Reflectance \geq 25%
- 3-Year Reflectance \geq 15%

LOW SLOPE ROOFS (2:12 inches or less)

- Initial Reflectance \geq 65%
- 3 Year Reflectance \geq 50%

AAMA Standards

The American Architectural Manufacturers’ Association known as AAMA has three voluntary performance based specifications for coatings on aluminum extrusions and building panels. These are AAMA 2603, 2604, and 2605. AAMA 2605, entitled “Superior Performing Organic Coatings on Aluminum Extrusions and Panels” represents the most rigorous performance specifications. The specifications differ in requirements for documented coating performance after specified years of South Florida exposure. AAMA 2605 requires documented coating performance after exposure of the coating for 10 years in South Florida at an exposure angle of 45 degree from the vertical facing

south. AAMA 2604 requires 5 years South Florida exposure, and AAMA 2603 requires 1-year minimum South Florida exposure. Accelerated weathering test methods are not included in the AAMA standards and cannot replace real time weathering in Florida. Generally, fluoropolymer coatings are designed to meet the higher standards of AAMA 2604 and 2605.

Although color and gloss retention are the primary focus when highly durable fluoropolymer coatings are specified, AAMA specifications and performance requirements also include tests for film hardness, adhesion, and chemical, corrosion, impact, and abrasion resistance. Resistance to chemicals such as mortar, detergents, window cleaners, and acids are included in these standards. The requirements for the three AAMA specifications are presented in the table below.

| Test | AAMA 2603 | AAMA 2604 | AAMA 2605 |
|---------------------------|------------------|------------------|------------------|
| Dry Film Hardness | √ | √ | √ |
| Dry Film Adhesion | √ | √ | √ |
| Wet Film Adhesion | √ | √ | √ |
| Boiling Water Resistance | | √ | √ |
| Impact Resistance | √ | √ | √ |
| Abrasion Resistance | | √ | √ |
| Muriatic Acid Resistance | √ | √ | √ |
| Mortar Resistance | √ | √ | √ |
| Nitric Acid Resistance | | √ | √ |
| Detergent Resistance | √ | √ | √ |
| Window Cleaner Resistance | | √ | √ |
| Humidity Resistance | 1500 hrs | 3000 hrs | 4000 hrs |
| Salt Spray Resistance | 1500 hrs | 3000 hrs | 4000 hrs |
| South Florida Weathering | 1 Year | 5 Years | 10 years |
| Color Retention | Slight fade | 5ΔE Hunter | 5ΔE Hunter |
| Chalk Resistance | Slight chalk | < No. 8 | < No. 6/8 |
| Gloss Retention | NA | 30% | 50% |
| Coating Erosion | NA | <10% | <10% |

Primers, Surface Preparation, and Coating Application

Primers typically are required for bake and air-dry systems. In heat-cured coating systems, primers are required to provide adhesion and corrosion resistance to metallic substrates, such as aluminum and steel. Steel substrates include hot-dipped galvanized, GALVALUME and ZINCALUME substrates. The chemistry of the primer can be based on PVDF, epoxy, acrylic, or polyester polymers depending on substrate and performance requirements.

Air-dry systems are, in many cases, retrofitted to existing buildings. The primer chosen will depend on the substrate and existing paint system. Buildings may have older paint systems ranging from alkyds to factory-applied fluoropolymer coatings. Substrates can include anodized aluminum, porcelainized metals, and galvanized and carbon steel. Generally, 2-component epoxy based primers are used. This will be the case for most metal substrates. Because fluoropolymer coatings are chemical and solvent resistant, special primers are required if the existing paint system is a fluoropolymer. Surface preparation can range from thorough cleaning to extensive abrasion and sanding. In all cases, the manufacturer of the air-dry fluoropolymer must be consulted for primer and surface preparation recommendations.

When corrosion resistance is a primary concern, primers must be capable of not only good adhesion to the substrate but corrosion protection as well. Highly corrosion resistant zinc-rich primers, with epoxy mid-coats, can be used under fluoropolymers if superior corrosion protection of steel substrates is required.

Fluoropolymer coatings typically are applied by spray or roll coat (coil) application techniques. Spray application techniques, electrostatic or conventional, are used for extrusions and retrofit using air-dry coatings. Roll coating is used to apply coatings to coil stock. Very often it can be quite a challenge for coatings manufacturers and applicators to duplicate the color and special effects appearance on parts coated by different application methods.

Applications/Case Histories

Fluoropolymers are used when the highest level of exterior durability is demanded. The colors and special effects appearance can be duplicated in other polymer technologies, such as polyurethanes, but the color and gloss retention of fluoropolymers is unmatched. Fluoropolymer coatings have been used primarily on the exterior of commercial metal buildings. Coating costs have limited the use of these highly durable coatings, which can be up to 10 times the cost of other paint systems. With regard to total cost, this may only double the total painting cost when application and installation costs are included. If the use of fluoropolymer coatings can double or triple the repaint schedule, then the added cost of the fluoropolymer paint can be easily justified.

Fluoropolymer coatings have been used on 80-story skyscrapers, storefronts, movie theater facades, gasoline service stations canopies and building panels, and road and traffic signs. They are used on building panels, walls, roofs, doors, window frames, handrails; practically any sound surface where long-term weather resistance is needed.

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