

SSPC: The Society for Protective Coatings Technology Update No. 12

Ambient-Curing Fluoropolymer Finish Coats Applied to Metal Substrates

1. Scope

This technology update provides a fundamental discussion of ambient-curing fluoropolymer finish coats applied to metal substrates, including recent developments. It is intended as a resource for architects, specification writers, facility owners, and others charged with the selection and field application of coating systems requiring superior weathering resistance and appearance retention in both architectural and industrial applications. It includes background information about the development of fluoropolymer materials, a basic description of fluoropolymer coating technology, the different types of fluoropolymers used in coatings today, application methods, and performance testing procedures.

2. Description

“Ambient-cured fluoropolymer finish coats” describes a class of coating materials based on resins (i.e., polymers) with a high fluorine content that have been formulated into liquid applied finishes that “air-dry” or cure under ambient conditions. Finish coats based upon fluoropolymer resin technology are designed to retain color and gloss after years of direct sunlight (UV) exposure. The two principal fluoropolymer resin types for finish coatings used at the time of publication are polyvinylidene fluoride (PVDF), and fluoroethylene-vinyl ether (FEVE).

Fluoropolymer resin-based coatings are most frequently selected as finish coats to be applied over compatible primers or intermediate coats in service environments where long-term color and gloss retention and chalking resistance are required. Additionally, the barrier properties of fluoropolymer resin-based coatings provide corrosion resistance, making them suitable for use as finish coats in marine and offshore environments. The chemical resistance of thermoset fluoropolymer resin coatings is similar to that of standard polyurethanes (such as SSPC-Paint 36)¹, and their application in severely corrosive environments may be limited.

3. Fluoropolymer Technology

3.1 HISTORY OF FLUOROPOLYMERS: Thermoplastic fluoropolymers are a family of hydrocarbon polymers having high fluorine content, first developed by the DuPont Company in the 1930s, that were initially limited to the production of extruded or molded plastic parts. As a family of materials,

these thermoplastic fluoropolymers offered extremely high performance in severe environments, primarily due to their resistance to a widely diverse range of harsh chemicals, resistance to elevated temperature, low surface energy and low coefficient of friction (i.e., “non-stick” capability).

3.1.1 Original Development of Ambient-Cured Fluoropolymers: The first generation fluoropolymer-based coating materials were produced in the 1960s. They were solvent-borne liquid dispersions of polyvinylidene fluoride (PVDF) thermoplastic resin (see Figure 1). These PVDF dispersions were later formulated into coatings by blending with acrylic resins typically at a 70:30 PVDF:acrylic ratio by weight as finish topcoats for exterior metal substrates on commercial buildings. Formulations with less than 70% PVDF in the resin are generally regarded as having reduced gloss retention and increased levels of chalking.

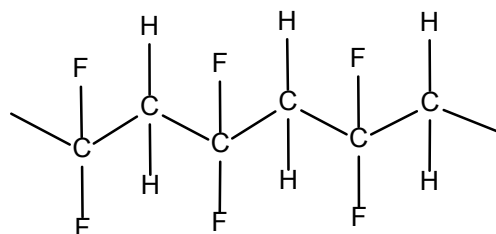


Figure 1. Polyvinylidene Fluoride Chemical Structure.

The need to bake these coatings at high temperatures limited their applicability to uses that could accommodate factory application and high-temperature bake processes. They were not an alternative to more conventional air-dry finish coats. The PVDF finish coatings were factory-applied to thin-gauge steel sheets coated with zinc or its alloys using a coil-coating process, or spray-applied to extruded aluminum. The coatings were then baked in an oven at 230-250 °C (approximately 450-500 °F) to develop the final properties of the thermoplastic coating.

A coating that offered comparable performance to the baked PVDF coatings that would air dry under ambient conditions and could be applied by conventional application methods was highly desirable. This led to the development of solvent-borne PVDF-acrylic coatings that formed a dry film by solvent evaporation without a high-temperature bake. These early air-dry coatings began to approach the performance of the baked coatings, but exhibited relatively lower adhesion, lower tensile strength and limited scratch and wear resistance.

¹ SSPC-Paint 36 (latest revision), Two-Component Weatherable Aliphatic Polyurethane Topcoat, Performance-Based.

when compared to the baked PVDF coatings.

3.1.2 Development of Second-Generation Ambient Cured Fluoropolymers: The second advancement in ambient-cured fluoropolymers occurred in Japan circa 1980. These newer resins were designated fluoroethylene vinyl ethers, or FEVE (see Figure 2). They were also formulated with solvents, but could undergo thermosetting reactions during ambient temperature cure. Early FEVE thermosetting coatings show marked improvement in many physical properties (such as higher gloss capabilities) compared to the earlier PVDF thermoplastic solution coatings.

Today, most FEVE products are cross-linked with polyisocyanates, yielding coatings with superior transparency, gloss, and hardness, with many FEVE systems now demonstrating outdoor weatherability comparable to the 70% PVDF technology.

3.1.3 Third-Generation Water-borne Ambient-Cured Fluoropolymer Systems: Environmental concerns have led to severe restrictions in the amount of volatile organic compounds (VOCs) that can be released to the atmosphere as solvent-borne coatings cure. Considerable work has been done to adapt both the FEVE and the PVDF resin technologies for use in water-borne fluoropolymer coatings to reduce the amounts of solvent released, and hence the VOCs emitted to the environment. The FEVE technology can be adapted to water, either in an FEVE emulsion form (higher molecular weight), or in water dispersion form (lower molecular weight). The PVDF technology can be adapted to water by making PVDF-acrylic hybrid dispersions (latex), which incorporate a miscible blend of fluoropolymer and acrylic polymer in each latex particle. Either resin chemistry can be adapted to make either thermoplastic (non-crosslinking) or thermoset (crosslinking) coating systems. Generally speaking, higher molecular weight fluoropolymers are used for thermoplastic systems, and

lower molecular weight fluoropolymers are preferred for thermosetting systems.

3.2 CURING MECHANISM OF ARCHITECTURAL AND INDUSTRIAL FLUOROPOLYMERS: Most fluoropolymer products for thermosetting systems are hydroxy functional. This means that they can be cross-linked with the same products used with standard acrylic or polyester polyols. Examples of cross-linkers include oligomers of isophorone diisocyanate (IPDI), hexamethylene diisocyanate (HDI), and hydrogenated methylene diphenyl diisocyanate (HMDI). Ambient-curing coatings of this type are generally two-component or "2-k." For water-borne thermosetting systems, a number of specialized crosslinker products have been developed, which are adapted to better incorporate the hydrophobic crosslinker into an aqueous medium.

Thermoplastic systems do not "cure" via crosslinking, but rather develop their properties by means of increasing polymer chain entanglements during and after a physical drying, a process known as "coalescence." Solution coatings and dispersions have different mechanisms for film formation. Thermoplastic systems are generally single-component or "1-k."

3.3 FACTORS AFFECTING THE FINAL COATING PERFORMANCE

3.3.1 Resin Structure and Fluorine Content: Fluoropolymer resins derive their weatherability from their chemical structure. The unique properties of fluorine atoms not only make the resin much more hydrophobic (important for both corrosion resistance and weathering), but also impart increased chemical and UV resistance to the resin, including nearby non-fluorinated segments on the polymer chain. For instance, the regularly alternating structure of FEVE resins allows the fluorinated segments of the molecule to protect

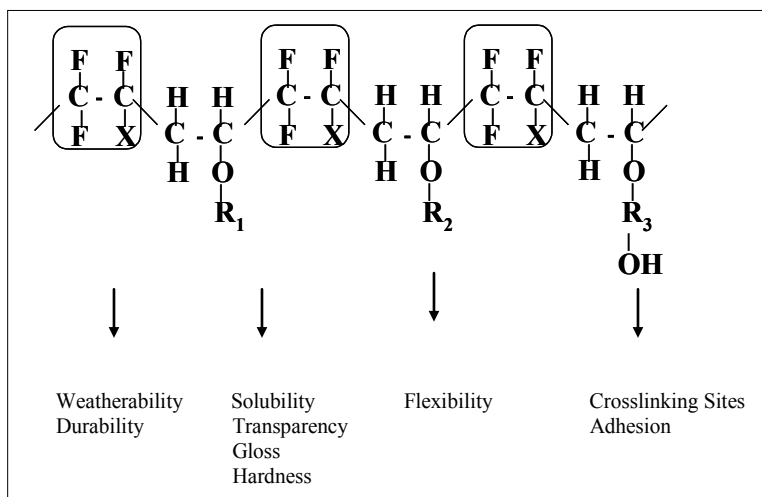


Figure 2. Structure of Fluoropolymer Resin Polymer. The fluoroethylene segments (enclosed by boxes in figure above) provide weatherability, durability and chemical resistance. Each of the vinyl ether segments (not enclosed by boxes) contributes different attributes: clarity; gloss and hardness; flexibility; and crosslinking.