

NEW LONG SERVICE LIFE TOPCOATS FOR PAD-MOUNTED TRANSFORMER ENCLOSURES

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ABSTRACT

This paper describes recent work to develop 2-component aqueous topcoat formulations, based on PVDF-acrylic hybrid dispersions crosslinked with polyisocyanates, which meet the requirements of the new SSPC Paint 47¹ standard for highly weatherable fluoropolymer topcoats, and when combined with conventional primer and midcoat technology, also meet the requirements of IEEE⁽¹⁾ standards C57.12.28² and C57.12.29³ for pad-mounted transformer enclosures. Enhanced weatherability is primarily conferred by having relatively high levels of fluoropolymer in the coating binder. Chemical resistance is obtained by a combination of high fluoropolymer level plus crosslink density. Barrier properties contributing to corrosion resistance depend on both these compositional factors, as well as on other formulation details.

Key words: “Polyvinylidene fluoride” PVDF fluoropolymer topcoats “SSPC Paint 47” C57.12.28 C57.12.29

INTRODUCTION: TYPES OF SERVICE LIFE, AND SSPC DURABLE TOPCOAT STANDARDS

Typical service lifetimes for protective coating systems range from 10-50 years, depending on how extreme the service environment is, as well as on all the details of substrate preparation, coating composition, and coating application.⁴ While the primary consideration for specifiers of protective coating systems is the service life related to *corrosion* protection, there is often also a requirement of durability of *decorative* properties, e.g. color and gloss. This is true not only for monumental steel structures, but also for instance for industrial and offshore structures where “safety colors” are used. This segment

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therefore has many similarities to the “architectural coatings” segment (coatings for monumental buildings), where the substrates may be different, but where a multi-layer system approach is still used, and owners expect the durability of both the protective and decorative functions.

Unlike the protective coating service life, which is a system property, the decorative service life often depends almost exclusively only on the system topcoat or finish coat. As a result, in the protective coatings standards world, it is often the case that standards for individual coating system layers do NOT have include corrosion-related tests (corrosion resistance being a system property), while decorative durability requirements are most commonly seen in finish coat requirements. The SSPC⁽²⁾ protective coatings standards, widely used in North America, illustrate this point. The SSPC Paint 36 standard⁵ for 2-k urethane topcoats has only three main performance requirements: weathering, solvent (methyl ethyl ketone) resistance, and adhesion (to the primer over which it is specified).

The cost/year of coating system protection can often be reduced by the judicious choice of high performing materials, even if those materials themselves are more expensive on a per liter, per kg, or per m² basis. In cases where both the decorative and protective service life is important, it will often be most cost effective to match the protective service life and the decorative service life. In this respect, it was long recognized within the SSPC membership that there was a kind of gap in the topcoat standards. The most weatherable level recognized in the SSPC Paint 36 standard requires 4 years Florida gloss and color retention (in a white), or similar performance in 4000 hour fluorescent cabinet testing using UVA-340 bulbs, but these topcoats are not known to retain gloss and color for 10, 20 years or even longer, particularly in darker and saturated colors. Fortunately, field-applied fluoropolymer topcoats meeting much longer decorative durability targets have been available since the 1980s.⁶ As a result, the SSPC established a technical committee to develop a performance-based fluoropolymer topcoat standard. This standard issued in December 2020 as SSPC Paint 47.¹

The SSPC Paint 47 topcoat standard is structured along the same lines as SSPC Paint 36, with requirements for weathering, adhesion to primer, and methyl ethyl ketone resistance (Type 2 only). Like Paint 36, coating weatherability may be demonstrated either by natural weathering in south Florida, or by accelerated testing. A key challenge for the committee was to identify a set of accelerated weathering test conditions allowing for the reliable qualification of fluoropolymer topcoat formulations, much faster than the 10-50 year outdoor service life of the fluoropolymer paint. Using a round-robin weathering study of 13 resin systems (fluorinated and non-fluorinated) from 10 different manufacturers, in four reference colors, it was found that 4000 hours of fluorescent testing with UVB-313 bulbs was highly differentiating for identifying high-performing fluoropolymer topcoats, capable of meeting 10-year south Florida gloss, color, and chalk resistance requirements.

This paper will explore one particular kind of structure needing protection, pad-mounted electrical transformer enclosures. Distribution transformers and their enclosures have a designed service life of decades. The IEEE standards C57.12.28 and C57.12.29 governing transformer enclosures include an extensive series of tests aimed at assuring multi-decade corrosion resistance in all but the most corrosive environments. However the UV resistance requirements of these standards are minimal (no cracking or checking after 500 hours of ASTM⁽³⁾ D4587⁷ fluorescence testing with an FS-40 bulb, a lower irradiance earlier version of modern UVB-313 bulbs⁸). While many of the protective coating systems used for these enclosures actually employ SSPC Paint 36-type acrylic- or polyester-based polyurethane topcoats, which as noted above are expected to show 1-4 years south Florida weathering, even these materials cannot be expected to maintain topcoat binder integrity, over the multi-decade service life of the enclosure.

Polyvinylidene fluoride (PVDF)-based topcoats, by contrast, can easily meet multi-decade service life requirements for both functional and even decorative properties, and are already used for this purpose

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in diverse areas of the energy industry including photovoltaic module backsheets. Aqueous hybrid dispersions of PVDF and acrylic resins, in particular, offer a way to achieve highly weatherable topcoats while meeting increasingly stringent VOC requirements. This paper describes recent work to develop 2-component aqueous topcoat formulations, based on PVDF-acrylic hybrid dispersions crosslinked with polyisocyanates, which both meet the weatherability requirements of the new SSPC Paint 47 standard, and when combined with conventional primer and midcoat technology, also meet the requirements of IEEE standards C57.12.28 and C57.12.29.

OVERVIEW OF PVDF HYBRID TECHNOLOGY

Polyvinylidene fluoride (PVDF) based topcoats⁹ have been used for decades on monumental buildings around the world, to the point that they have become the gold standard for decorative property durability and substrate protection. In these coatings, the polymer binder is typically a blend of 70-80 wt% PVDF resin with 20-30 wt% of a miscible acrylic resin. In the last century, PVDF-based coatings were used little outside of factory baked coatings on metal, because of the need for a high temperature bake (230-250 °C) to alloy the polymer components. However, about the year 2000, water-based hybrid resin technology became commercially available,¹⁰ combining PVDF copolymers and acrylic resins in pre-alloyed form.¹¹ The new water-based technology allows for the application of durable PVDF-based coatings under field-applied and low temperature bake OEM conditions, with dramatically lower levels of emitted volatile organic compounds (VOCs). Hydroxy-functional products in this class were soon added, which could be used with crosslinkers such as water-reducible polyisocyanates.^{12,13} These systems show enhancements in certain key properties such as early hardness, solvent resistance and adhesion, with performance contributions coming both from the entangled polymer network and from the network formed by crosslinking reactions.

Like the other PVDF-acrylic hybrid latex products, the particles of the hydroxy-functional version are structured as an intimate mixture or “IPN” (interpenetrating network) of the two thermodynamically miscible polymers.¹¹ Because the chemical inertness of the PVDF makes it difficult to functionalize, the hydroxyl functionality is on the acrylic component only. Following predictions of the standard model of latex film formation for thermoplastic systems,¹⁴ the latex particle morphology should be maintained during the film formation process. In the 2-k systems, when crosslinking of the hydroxyl groups is occurring later in the film formation process, the expected polymer morphology in the final coating film should be a bi-continuous network of fluoropolymer and acrylic-urethane. In such cases, contributions to certain properties such as mechanical properties, and chemical resistance would be expected both from the PVDF fluoropolymer backbone and from the urethane network formed by the crosslinking reaction.

The weatherability of PVDF-acrylic waterborne hybrid coatings has now been studied extensively,¹⁵ with a special focus on understanding the factors important to connecting long-term outdoor weathering, with accelerated test cycle results.¹⁶ Like earlier generations of weatherable fluoropolymer coatings, it is the inherent superior photostability and chemical stability of the fluoropolymer backbone which is the primary factor conferring excellent durability. At the same time, careful attention to the choice of pigment grades and other formulation components, as well as to application requirements, are essential to achieving superior results, just as they are for other kinds of high-performing industrial coatings.

RESULTS

Accelerated weathering testing

Consistent with the results of the SSPC round-robin weathering study, parallel studies in our laboratory have confirmed that both 1-k and 2-k PVDF-acrylic hybrid formulations can meet the accelerated weathering requirements of SSPC Paint 47, in multiple colors. Generally speaking, formulations with at least 50% or more PVDF on total binder weight are able to meet the UVB-313 gloss retention requirement, when formulated with suitable pigment grades. At these higher PVDF levels, chalk