

## **The Case for PVDF Coatings on flexible Vinyl Substrates**

### **Introduction to PVDF**

Polyvinylidene Fluoride, or PVDF, is a non-reactive, thermoplastic fluoropolymer supplied in dry form under various trade names: KYNAR® or HYLAR®. PVDF is a specialty fluoropolymer that is used generally in applications requiring the highest purity, strength, and resistance to solvents, acids, bases and heat and low smoke generation during a fire.

Compared to other fluoropolymers, it has an easier melt process because of its relatively low melting point of around 177°C (350°F). PVDF has a low density (1.78) and low cost compared to the other fluoropolymers. It is available as piping products, sheet, tubing, films, plate and as a wire insulator. It can be injected, molded or welded and is commonly used in the chemical, semiconductor, medical and defense industries, as well as in lithium ion batteries.

Fine powdered grades of PVDF are also used as the principal ingredient of high-end paints for metals and other rigid architectural surfaces. These paints have extremely good gloss and color retention, and they are in use on many prominent buildings around the world as well as on commercial and residential metal roofing.

PVDF is the polymer of choice for 50-year architectural panels where it is usually baked or fused onto the metallic substrate. Other characteristics of PVDF finishes are outstanding resistance to humidity, color change, chalking, gloss shift and chemical attack.

### **PVDF coatings for flexible substrates**

While the use of PVDF in coatings for rigid surfaces is well established, its use in coatings for flexible substrates is relatively new. PVDF coatings are the most weather resistant of all finishes commonly used on flexible substrates but its widespread acceptance has so far been limited.

Leading Edge Coating Solutions (LECS) has over twelve years of experience with PVDF coatings for flexible substrates. Of these substrates PVC, the most common, is the substrate of choice for outdoor end-use applications like tents, awnings, signs, banners, roofing membranes, tension structures and others. Many generations of these coatings have been developed; the latest version is our PVDF-256.

When flexible PVDF coatings were first developed the goal was to find a replacement for Tedlar® film in a coating form. Tedlar®, another fluoropolymer had already found a niche in high end tension structures and other exterior applications where a protective over-laminate was needed, as in photovoltaic cells. Tedlar® exhibits similar, desirable properties to PVDF but is only available as an extruded film that requires the user to add an expensive and inconvenient lamination step in the manufacture of the product. A coating solution offering similar performance properties to Tedlar® would provide customers an attractive alternative.

The key technical challenge in developing a PVDF coating for PVC was adhesion since PVDF by itself will not adhere to PVC. This required extensive development and experimentation with modifying polymers

that eventually culminated in PVDF-256. In some cases the vinyl substrate's composition may have to be adjusted to work best with PVDF-256. LECS can also assist you with vinyl formulation questions.

### PVDF versus Tedlar ® and Vinyl Acrylics

The following is a summary of results obtained from a weathering study comparing vinyl acrylic, Tedlar ® and PVDF. The PVDF coating used in this study was an early predecessor of PVDF-256. The substrate was a 22 oz/yd<sup>2</sup>, yellow, flexible vinyl continuous laminate reinforced with woven polyester scrim.

QUV-A Hours	Control: Vinyl Acrylic (0.2 dry mils)			PVDF coating (0.2 dry mils)			Tedlar film (1.0 mils)		
	Color Delta E	60 deg Gloss	Observations	Color Delta E	60 deg Gloss	Observations	Color Delta E	60 deg Gloss	Observations
0	0	60+	Yellow	0	65+	Yellow	0	70+	Yellow
500	+1	20	Yellow	No change	No change	Yellow	No change	No change	Yellow
1000	+2	7	Yellow	No change	No change	Yellow	No change	No change	Yellow
2000	+5	3	Tan	No change	No change	Yellow	No change	No change	Yellow
3000	n/a	n/a	Dark tan	No change	No change	Yellow	No change	No change	Yellow
4000	n/a	n/a	Splotchy brown/tan	No change	No change	Yellow	+3	No change	Golden tan
5000	n/a	n/a	Brown	No change	No change	Yellow	+3	No change	Golden tan
6000	n/a	n/a	Dark brown/brittle/cracks	No change	No change	Yellow	Not tested	No change	Brown splotches
7000	n/a	n/a	Black, brittle, holes from shrinkage	+1.5	50	Yellow	Not tested	No change	Brown splotches
8000	n/a	n/a	Sample destroyed	+1.5	50	Yellow	Not tested	No change	Brown streaks and splotches

Several conclusions were drawn from this study:

- PVDF coated flexible vinyl applied at 0.2 dry mils will resist weathering, absorb UV radiation and block plasticizer migration for at least 8,000 hours of QUV weather testing. 8,000 hours of QUV-A exposure is roughly equivalent to eight years outdoors.
- The vinyl acrylic control exhibited major loss of gloss at 500 hours suggesting the coating offers no weather protection beyond that point. Color properties fail in a year and physical laminate failure occurs around 3 years.
- Tedlar®/vinyl laminate will start color properties failure in 4+ years as shown by its 4,000-hour color development.
- Tedlar® surface gloss was unchanged which suggests that the adhesive layer reacts with the vinyl surface to produce chromophores and/or the vinyl substrate is not sufficiently shielded from UV radiation. Tedlar itself weathers well as indicated by unchanged gloss level.

- Tedlar may not be suitable for use over flexible vinyl laminates. Automotive type "W" flex studies show early failure (8 cycles) with Tedlar®/flexible vinyl laminates as compared to the vinyl-acrylic-coated control and PVDF samples (10,000+ cycles).
- PVDF provides an excellent barrier to plasticizer migration, UV degradation and staining. No stain resistance testing failures have been reported. Coated surfaces remain "self cleaning" and will not support the growth of "pink stain" bacteria, molds or fungus.
- PVDF top coated laminates are "self cleaning" due to unique surface energy properties. The natural accumulation of organic surface debris is blown off by wind and/or rinsed from the surface by the development of dew and rain fall.
- PVDF top coated test samples (uncoated back side) were consumed from the back side by "pink stain" bacteria, mold and fungus in one year. Back coated specimens remained clean and unchanged.
- PVDF is a thermoplastic which can be heat welded. More on this in a later section.
- PVDF outdoor weather exposure studies conducted in South Florida, using generic calendered white 4.0 mil flexible vinyl and samples of the yellow laminated lot used in the accelerated study above, confirm the data from the accelerated studies. PVDF will keep a flexible vinyl laminate "fresh" for more than eight years.

### **Heat Sealing and Welding**

One observation made in our comparative study was that laminates coated with our PVDF are heat sealable. This is not the case for Tedlar® laminates. It was observed that Miller hot air heat sealers performed well. Dielectric sealers may require a 2 second increase in cycle time. PVDF-coated vinyl can also be thermally laminated and embossed.

However, heat sealing performance may be affected by many factors including the type of welding equipment, training of personnel, coating thickness and other factors. Lack of control of these factors may result in field failures. To mitigate this risk LECS has developed PAP-127, a heat-activated laminating adhesive designed to produce excellent bonds when used to weld PVDF-256 coated vinyl substrates. PAP-127, when used to heat seal PVDF-256 coated vinyl substrates, will yield excellent bond strengths at temperatures as low as 170F. It can be supplied as a liquid or dry film. For more information see our PAP-127 data sheet.

### **Comparison to Urethanes**

No urethane coatings were included as part of this comparative study. However, LECS also has extensive experience with polyurethane coatings. Based on this experience we expect urethane coatings to fall somewhere in between the performance of vinyl acrylics and PVDF, more likely closer to vinyl acrylics. Urethanes, even when fully crosslinked, tend to yellow upon exposure to UV and typically do not resist plasticizer migration, the chief culprit of vinyl degradation. Hence they will not exhibit the superior self-cleanability and stain resistance of PVDF or Tedlar®. Furthermore, crosslinking of urethanes will greatly compromise heat weldability by making the crosslinked film thermoset instead of thermoplastic. Urethanes are generally a good choice in applications where high flexibility and abrasion resistance are demanded.

### **Solvent or Water Based?**

PVDF-256 is only available in solvent based form. Considerable effort has gone into finding a water-based version of a PVDF coating and such efforts will continue. However it has been our experience that the surfactants required to provide the required film coalescence will compromise coating performance. In

addition, a solvent-based version will be easier to apply and cure and will result in a coating with superior film integrity. PVDF-256 is usually supplied in ethyl acetate or propyl acetate and n-methyl pyrrolidone (NMP). It can also be supplied in acetone/NMP for customers wanting a non-HAPS, zero-VOC solution.

**Relative Cost Comparison**

The main difficulty in comparing the cost of competing coatings is the problem of “apples versus oranges.” How does one correct for the fact that coatings are of different chemistries and must be applied at different thicknesses in order to get similar performance? The only true solution is to compare the applied cost of competing coatings at the thickness required to produce a targeted service life.

We have already established that PVDF-256, applied at 0.2 mils, would yield an outdoor service life of at least eight years. Vinyl acrylics, acrylics and urethanes, even when applied at thicknesses of 0.5 mil are unlikely to last beyond 3 years in outdoor service life.

For the sake of comparison let’s choose a target service life of five years, a generous assumption for vinyl acrylics and urethanes but a conservative one for PVDF-256. From calculations derived from our weathering study we estimate that PVDF-256 applied at an estimated dry film thickness of 0.155 mils would yield a service life of five years <sup>1</sup>. Now we are in a better position to compare this to vinyl acrylics and urethanes applied at 0.5 mils.

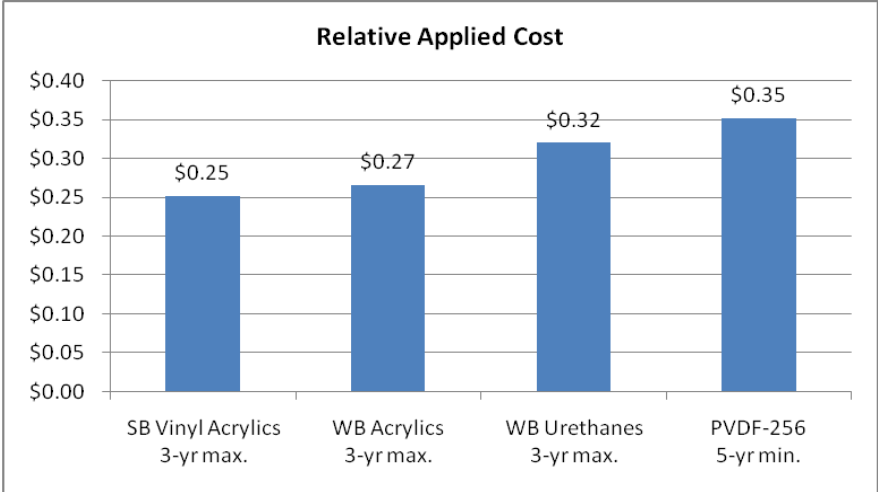
Using typical prices we can now compare the relative applied costs of vinyl acrylics, acrylics, urethanes and PVDF-256 summarized in the following table and chart <sup>2</sup>.

	SB Vinyl Acrylics 3-yr max.	WB Acrylics 3-yr max.	WB Urethanes 3-yr max.	PVDF-256 5-yr min.
Typical % solids by weight	15%	30%	30%	16%
Typical wet coating price (\$/lb)	\$1.50	\$2.25	\$3.25	\$5.00
Applied dry film thickness (mils)	0.5	0.5	0.5	0.155
Applied cost (\$/sq meter)	\$0.25	\$0.27	\$0.32	\$0.35

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<sup>1</sup> This calculation is for comparative purposes only. We do not recommend applying PVDF-256 at less than 0.2 dry mils.

<sup>2</sup> The price shown for PVDF-256 is not intended to be a price quotation. Price quotes are based on a variety of factors including volume requirements.



The first conclusion is that PVDF-256 applied at less than one third the film thickness of competitive coatings will perform far better in outdoor service. The second conclusion is that the moderate increased cost of applying PVDF-256 would produce a dramatic increase in service life.

**Benefit Summary**

We can now summarize benefits of PVDF-256 against competitive coating options in long-term outdoor applications:

	SB Vinyl Acrylics	WB Acrylics	WB Urethanes	PVDF-256
Weatherability/UV resistance	Poor	Good	Fair to good	Superior
Stain Resistance	Poor	Poor	Fair to good	Superior
Self Cleanability	Poor	Poor	Poor	Superior
Resistance to plasticizer migration	Poor	Poor	Poor	Superior
Heat weldability	Good	Good	Fair	Good
Relative Cost	Low	Low	Moderate	Moderate

## **Application Summary**

PVDF-256 is also thermoformable and may also be used in interior applications needing a combination of stain resistance and formability. The following table summarizes the many applications, both exterior and interior, where PVDF-256 would be an excellent choice:

Application	Comment
Roofing membranes	As a protective varnish for long-term weatherability, self-cleanability. Alternative to Tedlar® film.
Tents; Awnings; Banners	Topcoat or varnish to provide a weatherable, self-cleanable protective layer.
Commercial graphics; Signs	Use as an overprint varnish. PVDF-256 is pigmentable and would make an excellent ink in its own right. May also be used as a system with PAP-127 as the pigmented under layer and PVDF-256 as the over-print varnish.
Convertible tops; press polish vinyl	Use as a weather-resistant protective varnish for vinyl convertible tops.
Vinyl wallcovering	Overprint varnish to provide stain resistance and cleanability. Ideally the topcoat should be applied in an earlier stage and embossed last. May be used as a system in combination with pigmented PAP-127 ink.
Thermoformable, bladder press	Use as a topcoat on semi-rigid films for kitchen cabinet or similar thermoformable applications. Provides a stain resistant, protective layer.
Automotive interiors	Would make an excellent coating for automotive instrument panels or other formable parts where a combination of high stain resistance and weather resistance is needed. May be difficult to achieve glosses less than 4-5.

## **Conclusions**

- PVDF-256 offers a highly attractive cost-benefit combination for coating flexible vinyl products in applications where long-term exterior durability and service life are required. In applications that demand superior weathering, self-cleaning and stain resistance its performance will far surpass traditional alternatives.
- PVDF-256 may also be worth exploring for selected interior applications where a combination of stain resistance, thermoformability and weatherability are needed.

If you still have questions please contact us. You may also refer to our PVDF-256 data sheet and MSDS for more information.