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Bright Ideas: Long-lasting Color Performance for Field-applied Coatings

by Kurt Wood and Lon Bauer

Photo courtesy APV Engineered Coatings

WHEN IT COMES TO EXTERIOR-USE ARCHITECTURAL AND PROTECTIVE COATING TECHNOLOGIES, THE IN-DEPTH SCIENCE AND THE CREATION OF PERFORMANCE STANDARDS BEHIND THE BEAUTY IS INCREDIBLE. POLYMER RESINS, PIGMENTS, AND ADDITIVE TECHNOLOGIES HAVE ADVANCED THROUGHOUT THE YEARS, CHALLENGING THE GOVERNING ASSOCIATIONS TO SET THE BAR EVEN HIGHER FOR WHAT TRULY MEANS 'HIGH PERFORMANCE IN CONSTRUCTION.'

Color fade or retention is one of the most visible indications of coating performance and many of the technological innovations are focused on improving this characteristic. ASTM International, the American Architectural Manufacturers Association (AAMA), Master Painter Institute (MPI), and the Society for Protective Coatings (SSPC) are four of the influential governing agencies advocating and setting standards for manufacturers and professionals in the industry.

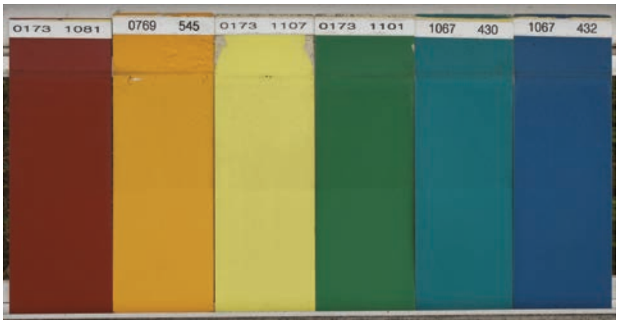
How are technology advancements proven? In short, by a lot of testing. However, when it comes to color fade the question to explore is whether pigmented coatings should be tested to the standard, or adapted to suit the chemistry and substrate. Moreover, what proper standards for color retention should be required for field-applied coatings?

Standard practice for testing weatherability and color retention

Being able to accurately predict service life through weathering testing allows coating manufacturers to estimate failure rates, establish warranty conditions, and set customer expectations. Prior to launching an exterior coating into the marketplace, accelerated weathering tests are conducted on the prototype coatings to assess their ability to perform under high ultraviolet (UV), elevated heat and temperature, humidity, oxygen, water, and atmospheric pollutants found in harsh climates. Test chambers can replicate or intensify outdoor environmental conditions with extreme UVA and UVB exposure, as well as wet-dry cycles.

To further validate the performance of new technologies, panels coated with prototype formulations are also tested at specific locations with challenging climatic conditions (*e.g.* south Florida below 27 degrees latitude) at specified angles (*e.g.* 45-degree angle facing south), maximizing the annual exposure to solar radiation. These natural weathering tests replicate real-world UV exposure and other environmental conditions, but they are typically more aggressive than the weathering conditions seen by most materials in their end-use environments. In both natural and accelerated weathering testing, new prototype materials are directly compared against previous iterations of the same chemistry, as well as against commercial formulations based on standard chemistries, to quantify improvements in performance. When it comes to measuring color change due to weathering, the most commonly used metric is Delta E (**ΔE**). It quantifies the total color difference between the exposed panel and the original color. Gloss change and chalking are also recorded and evaluated, as both these properties contribute to changes in coating appearance.

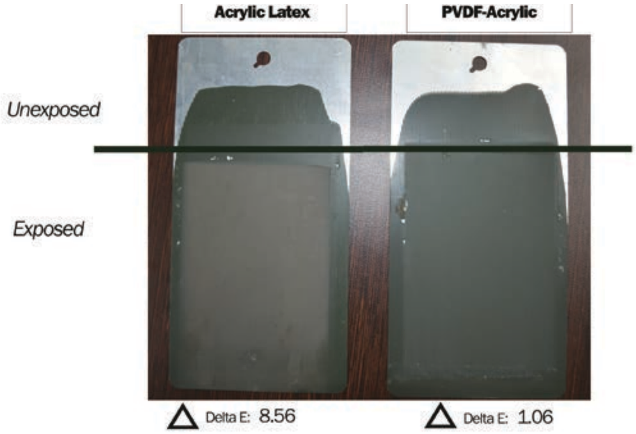
Figure 1



Early polyvinylidene fluoride (PVDF)-acrylic coatings, on exposure in Florida for more than 40 years. Unexposed portion of the coating is at the top. The number at the top left of each panel denotes the month and year of exposure. Typical coating thickness values are 25 μm (1 mils). The panels show gloss loss but no chalking.

Image courtesy Arkema Inc.

Figure 2



Acrylic latex coating on left and PVDF-acrylic coating on the right, both in dark green, after exposure in accelerated weathering for 10,000 hours. Unexposed portion of the coating is at the top. The number at the bottom of each panel denotes the total Delta E color change difference from the top of the panel versus the tested portion. Typical coating thickness values are about 25 μm. The PVDF-acrylic show gloss loss but no chalking.

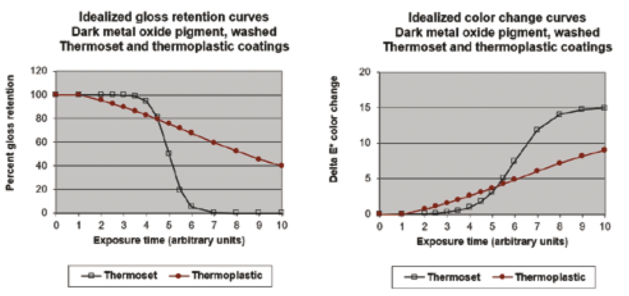
Image courtesy APV Engineered Coatings

Understanding the testing standards for high-performance coatings

It is important to give an overview and comparison of a few of the important standards produced by the aforementioned governing agencies impacting the specifications of color retention.

According to AAMA, the purpose of 2605, *Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing*

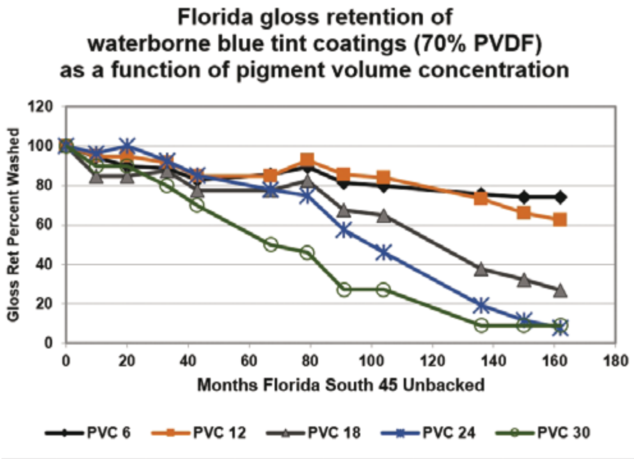
Figure 3



Gloss and color change behavior for thermoset and thermoplastic coatings, made with a color stable dark metal oxide pigment. The coatings have identical 80 percent gloss retention times, but the time to significant color change associated with chalking differs by more than a factor of two.

Images courtesy Arkema Inc.

Figure 4



South Florida gloss retention (south-facing unbacked panels, 45 degrees, washed) for PVDF-acrylic hybrid water-borne coatings, with inorganic pigments, as a function of pigment volume concentration.

Organic Coatings on Aluminum Extrusions and Panels (with Coil Coating Appendix), is to "…assist the architect, owner, and contractor to specify and obtain factory-applied organic coatings, which will provide and maintain superior [2605] level of performance in terms of film integrity, exterior weatherability, and general appearance over a period of many years."

Coatings with high fluoropolymer resin content, typically 70 percent of total polymer weight, meet AAMA 2605. Under this standard, there are 17 ASTM test methods with criteria for compliance. For the weathering section 7.9, this standard specifies a maximum of 5 ΔE (Hunter) units of color change as per ASTM D2244, *Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates*, after an exposure time of 10 years in south Florida at a south-facing, 45-degree angle. However, AAMA 2605 outlines "new colors, whether formulated by a paint manufacturer or blended by an applicator according to a paint manufacturer's specifications, may be qualified without the exposure test…provided they are produced with the same pigments in the same coating resin system on a color on which acceptable ten (10) year test data is available and which is within the ± Hunter Units in lightness (L)."

In terms of chalking, AAMA 2605 stipulates testing per ASTM D4214, *Standard Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films*, Method A after natural weather testing has been completed with 10 years of exposure data. To comply, coatings must have a minimum rating of eight for colors and six for whites, on a scale of zero to 10 (10 equals no chalking). Gloss is read at 60 degrees on unexposed and exposed areas of the test area per ASTM D523, *Standard Test Method for Specular Gloss*, and the coating must retain a minimum of 50 percent of the original gloss, after the 10-year exposure period.

While AAMA 2605 was originally written around the performance of 70 percent polyvinylidene fluoride (PVDF) fluoropolymer finishes, SSPC Coating Specification No. 36, *Two-Component Weatherable Aliphatic Polyurethane Topcoat*, was published to address this polymer type. In terms of color and gloss retention, this standard allows for weathering testing using either UVA fluorescent cabinet accelerated testing (ASTM G154, *Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials*), or natural weathering (ASTM D1014, *Standard Practice for Conducting Exterior Exposure Tests of Paints and Coatings on Metal Substrates*). The coatings are assigned to one of three performance levels based on the number of hours or months of exposure meeting a maximum of 2 ΔE (C.I.E 1976 L*A*B*)[1]. Like AAMA 2605, SSPC Paint 36 specifies chalking is measured per ASTM D4214 Method A, but all colors are required to chalk at a minimum level of six.

It is important to note SSPC Paint 36 section 12.4.2 says, "Performance results from accelerated weathering do not necessarily correspond to those from the corresponding level of atmospheric weathering. It is left to the discretion of the specifier whether to accept natural outdoor weathering data from a similar color or to use UVA data in lieu of natural outdoor weathering data."

Further, section 12.4.3 goes on to add, "Test results for color and gloss of deeper colors (*i.e.* having a Munsell value below nine) will vary significantly due to differences in pigment weathering properties, and may not meet the requirements of section 7, "Weathering Requirements," without use of additional procedures such as clear coating. Alternatively, the specifier may accept a greater change in gloss and color for deeper colors."

MPI 311, *Latex, Exterior, High Performance Architectural, Semi-Gloss*, covers "…a high performance white or colored semi-gloss, latex-based paint intended for use on new or previously painted exterior wall surfaces…not intended for application on un-primed wood surfaces."

For conformance to weathering performance under this specification, the coating must only pass 2000 hours of UVA fluorescent cabinet accelerated weathering testing as per ASTM D4587, *Standard Practice for Fluorescent UV-condensation Exposures of Paint and Related Coatings*, (similar to SSPC Paint 36 Level 2A), with "no blistering, chalking, checking, cracking, flaking, or loss of adhesion."

It is important to note these last two standards for field-applied coatings only use white or light-colored coatings to evaluate weatherability. AAMA 2605, which does have the same 10-year natural weathering requirement for all colors, is primarily a voluntary standard for original equipment manufacturer (OEM) topcoats on aluminum. There are currently no standards for field-applied coatings to address the needs of specifiers who want to validate color retention in high chroma or saturated and bright colors. Raw material suppliers and the coating developers have found that the common practice in the industry is to focus on meeting the specification, but not necessarily exceeding or adapting it.

Color retention under the microscope

Several factors determine the length of an exterior coating's color lifetime and it is important to take a closer look at the chemistry and photodegradation modes of the coating's polymer(s) (the 'binder'). The resin chemistry, pigment grades, and the volume of pigment concentration, all determine the impact of radiation, extreme temperature, salt, and the atmospheric moisture on the coating's gloss and color. In pigmented coatings, reducing the rate of binder loss is an important goal of the formulator, since significant loss leads to chalking, which in darker colors also brings about a change in hue.

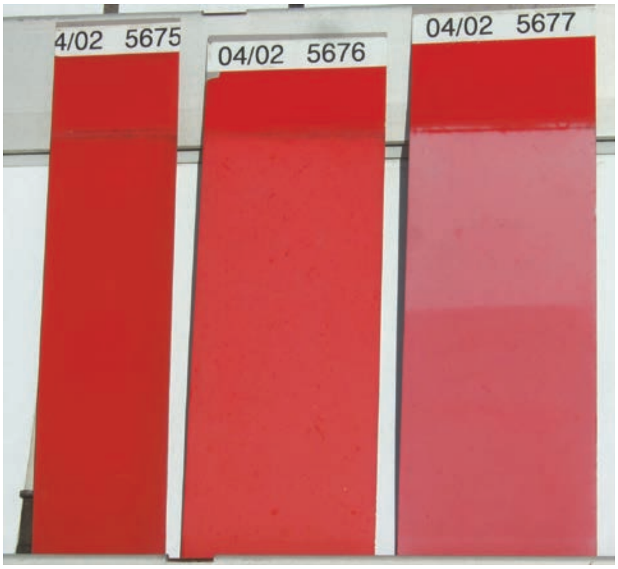
It is very important to consider the difference in photodegradation failure modes between coatings made with the highly crosslinked thermosetting resin systems and thermoplastic resin systems with little or no crosslinking. Thermoset materials, such as polyesters and fluoroethylene vinyl ether (FEVE) resins, are low in molecular weight and achieve many of their properties from crosslinks. Once crosslinked, thermoset coatings can maintain many properties very well during weathering. However, as the crosslink density drops below a critical threshold during the weathering process, binder integrity is abruptly lost, resulting in chalking on the surface.

Thermoplastic coatings with little or no crosslinking are based on higher molecular weight resins and achieve binder integrity through physical entanglements. These thermoplastic coatings often degrade through a surface contraction mechanism through which properties gradually change, without any abrupt transition. While some thermoplastic resins (*e.g.* one-component acrylics) eventually chalk, high PVDF-based thermoplastic coating systems withstand chalking over multiple decades of outdoor exposure (Figure 1, page 33).

Figure 2 (page 33) illustrates the result of an accelerated weathering study conducted on two thermoplastic coatings in dark green, a one-component acrylic latex and another one-component PVDF-acrylic, after 10,000 hours of exposure. This study validates the actual performance of the PVDF formulation when comparing the accelerated results to the natural weathering study in Figure 1. It also demonstrates the more rapid changes in color and chalking of the thermoplastic one-component acrylic in comparison to the PVDF.

Figure 3 depicts idealized versions of how the evolution of gloss and color retention can differ for coatings with thermoset and thermoplastic binders. The two systems have about 80 percent gloss retention after four units of exposure time. For the thermoset system, chalking occurs at about five to six time units, leading to rapid gloss loss and color change. Chalking for the thermoplastic system in this instance may occur closer to the 10 time units point.

Figure 5



Appearance of coatings made with a red pigment and different resins, after seven-and-a-half years of exposure in south Florida. From left to right: 70 percent PVDF (solvent), 2K FEVE (solvent-based), and two-component acrylic urethane. Panel sections from top to bottom: original color (covered by flap) and unwashed and washed portions.

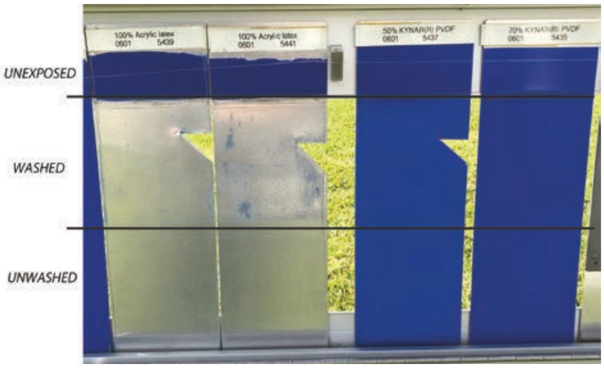


Photo of a cobalt blue natural weathering study taken on August 12, 2018, after weathering in south Florida for more than 17 years. From left to right, the first two panels are 100 percent acrylic latex, approved by Master Painters Institute (MPI) 311, *Latex, Exterior, High Performance Architectural, Semi-Gloss,* and now eroded and no longer on the test panel, followed by 50 percent PVDF-acrylic (American Architectural Manufacturers Association [AAMA] 2604, *Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels [with Coil Coating Appendix]*), and 70 percent PVDF (AAMA 2605, *Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels [with Coil Coating Appendix]*).

The resin-pigment relationship

Premium fluoropolymer topcoats have been used for decades in outdoor environments because of their color-retention property and the absence of chalking. High PVDF-content systems with a relatively low pigment volume concentration (PVC) allow the pigment to remain encapsulated, even if all the acrylic co-resin is compromised by exposure, as seen in Figure 4 (Page 36) where gloss retention is visible for a series of water-borne paints made with a 70 percent PVDF-acrylic hybrid latex binder, after 10 years of exposure in Florida.

This minimal color change is attributed to the absence of chalking (when a high PVDF: pigment volume ratio is employed), along with the use of color-stable inorganic pigments in the formulation. The color service life of such coating systems can be measured in decades.

Since color-stable inorganic pigments are unavailable in a full palette of bright, saturated colors, many coatings makers turn to organic pigments. While color change is greater for coatings made with organic pigments, the use of a PVDF resin can help ensure the visual effect of the color change is minor (Figure 5). The much greater color change for the non-fluorinated acrylic urethane system is due to both the pigment bleaching and chalking of the binder.

The 'false positive' conundrum

Accelerated weathering testing is the fastest way to acquire information on the service life of a coating. However, an inappropriate reliance on accelerated testing can increase risk, if materials perform well in accelerated testing, but not in natural weathering. These cases are known as 'false positives.'

The reason why accelerated weathering test methods cannot be correlated with outdoor weathering, independent of material considerations, is rooted in the fact coatings based on different resin chemistries have varied failure modes. It is impossible to equally accelerate all the factors contributing to different failure modes, in any specific test.

Due to these differences, material-agnostic standards, such as AAMA 2603, *Voluntary Specification, Performance Requirements and Test Procedures for Pigmented Organic Coatings on Aluminum Extrusions and Panels (with Coil Coating Appendix)*, 2604, *Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels (with Coil Coating Appendix)*, and 2605 for pigmented organic coatings on aluminum extrusions and panels, do not allow alternatives to natural weathering. When accelerated testing is involved, differences in failure modes for dissimilar materials imply there will almost unavoidably be an increase in risk. In such cases, one powerful way to reduce risk is to limit the scope of the standard to a narrower range of materials, where there is a strong defined correlation between field performance and the accelerated test(s) to be used.

This strategy goes against the trend toward material-agnostic standards, but there is a precedent for this kind of approach within the current SSPC standards. For example, SSPC Paint 36 limits its scope to resins as defined by ASTM D16, *Standard Terminology for Paint, Related Coatings, Materials, and Applications*, Type 5. To that end, identifying an appropriate performance-based standard for low-color-fade fluoropolymer coatings should be restricted to specific fluoropolymer resin chemistries with proven performance, and the accelerated testing criteria for each chemistry type should be selected based on available historical data for how commercially relevant coatings perform under natural as well as accelerated conditions.

Formulations for factory versus field application

There are some differences between the composition of factory- and field-applied engineered coatings using fluoropolymer technologies. Formulating a factory-applied fluoropolymer coating incorporates a catalyzing and backing system to ensure uniformity and proper cure using controlled OEM or plant conditions. Engineered fluoropolymer technologies for field-applied applications use wetting and drying chemistries in the formula to promote proper cure under fluctuating atmospheric conditions to produce quality coatings.

Figure 6

A college building in Vacaville, California, eight years after installation of an acrylic latex. The photo of the north-facing exterior wall shows significant chalking and erosion, exposing areas of the concrete façade. Board members of the college expressed the need for recoating as a key effort to build their brand and attract students.

Image courtesy APV Engineered Coatings

Factory-applied coatings also have many advantages including:

- controlled environmental conditions with clean areas;
- uniform coating thicknesses;
- precise drying; and
- curing temperatures to promote proper crosslinking.

The biggest problem with field-applied coatings is surface preparation before application of the engineered coating. The surfaces need to be properly cleaned and prepped for the coating to have proper adhesion and weathering resistance. Atmospheric conditions such as temperature, humidity, and wind introduce unique drying conditions for the field-applied engineered coating to overcome. Also, the lack of controlled higher curing temperatures produces slower crosslinking times. It may take more than a month to ensure a complete cure for a field-applied engineered coating.

Longer curing times impose problems with testing proper adhesion and weathering resistance for field-applied engineered coatings. Factory-applied coatings would have achieved proper cure due to their controlled baking system. In the end, there should be no difference with the overall quality and performance of a factory- and field-applied coating.

Is a new standard required?

Many believe the industry needs a new standard. SSPC's C.1.8 fluoropolymer coatings committee has been active over the past years and has produced a technical update (SSPC-TU 12) describing the two major fluoropolymer resin types mentioned earlier, PVDF and FEVE. These two chemistries are used for highly weatherable topcoat applications. While they differ in some important details, both these resins can be used in several different kinds of coatings, including solvent- and water-borne versions. These coatings can offer, in many cases, service lifetimes for gloss and color retention, which are longer than those attainable with non-fluorinated organic polymers, such as the two-component acrylic urethane systems described above in SSPC Paint 36, or acrylic latex paints as described in MPI 311.

This committee has been collaborating to develop a new specification for fluoropolymer topcoats. The architectural restoration coatings sector has expressed this as a need for a standard that can be used when long-term color retention is important. To-date, standards bodies have been challenged to create new material-agnostic, performance-based standards eliminating the false-positive problem associated with the accelerated testing of a wide range of materials.

From microscope to market

Fortunately for project specifiers, outdoor and accelerated weathering data does exist for high-chroma, PVDF-based coatings. Developers of this technology have tested saturated and dark colors beyond the requirements of specifications and have adapted accelerated studies to help evaluate new and improved prototypes. Until a new formalized standard is in place for pigmented, field-applied systems, some developers and manufacturers are doing their due diligence to ensure the data provides a much needed and reliable source for identifying a high-performance coating's color retention in field applications for architectural restoration.

The coatings manufacturer can provide this data. Often, product data sheets list test results per the standard, but specifiers can request the test reports to back up the data the specification calls out, such as section 8, "Test Reports," of AAMA 2605. Many manufacturers, especially developers of premium fluoropolymer-based coatings, have natural and accelerated data on a broad range of saturated and dark colors that have been tested beyond the spec until signs of failure (*i.e.* significant color fade, loss of film integrity, chalking, etc.). PVDF-based chemistries offering warranties for color retention are a safe and low-risk option for long-term performance for the building owner.

What does this mean for building owners?

From a cost perspective, re-coating structures every few years can get expensive and cause disruption to the occupants of the building during the process. Hospitality properties, office buildings, schools, and other commercial properties can face major disruption-induced costs from a renovation project. There are also soft costs associated with the negative curb appeal of a structure's faded or chalky appearance (Figure 6, page 37).

From a coatings expert's perspective, the most important risk to eliminate is the damage of the buildings substrate after the aged coating has been compromised from the elements. Failing to maintain a new protective coating on a surface can cause damage to the underlying substrate, an even more costly issue to resolve. After long-term exposure to the elements, standard latex-acrylic and urethane coatings break down and eventually wear away entirely. Although the initial cost of commodity paint may be low, the life-cycle costs will far exceed those of implementing a high-performance coating system.

Conclusion

As one of the most visible indications of performance, the advancements in color retention for exterior-use architectural and protective coating technologies have resulted from the evolution of in-depth science and test standards. Manufacturers and governing associations are continuing to work together to set the bar higher for what 'high performance' truly means. Technological advancements must be proven through validated and trusted test protocols taking into consideration the resin and pigment types, material to be coated, and field or factory application. Every entity in the supply chain plays a critical role in bringing long-lasting color performance to the field. **CS**

Note

[1] This is the color system used in the Society for Protective Coatings (SSPC) Coating Specification No.36, *Two-Component Weatherable Aliphatic Polyurethane Topcoat*. It defines color slightly differently from the Hunter system that is used in the American Architectural Manufacturers Association (AAMA) 2605, *Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels (with Coil Coating Appendix)*.

ADDITIONAL **INFORMATION**

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Key Takeaways

Color fade or retention is one of the most visible indications of the performance of exterior-use architectural and protective coatings. Many of the technological innovations are focusing on improving this characteristic. These advancements must be proven through validated and trusted test protocols taking into consideration the resin and pigment types, material to be coated, and field or factory applications.

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