Performance Comparisons Between Water-Only Colorants and Universal Colorants

Jacob S. Donlon, *Mark W. Ellsworth*

Color Corporation of America

Abstract

The conversion of solvent-borne paints, stains, and coatings to water-based systems has increased noticeably in the past 10 years, with the performance of many of these water-based coating systems approaching that of the solvent-borne counterparts. With the continued shift to water-based coating systems, Point-of-Sale paint store and In-Plant tinting systems users are now faced with a decision to use Universal Colorants, or Water-Only Colorants. Through a series of benchmark tests, we have shown that CCA NovoColor® HP II 8600 Water-Only Colorants can provide important performance improvements such as lower VOC, reduced block and tack, lower surfactant leaching, improved standing water resistance, and lower impact on viscosity of tinted paints. These improvements provide manufacturers and retailers with additional support for converting their paint systems and colorants to Water-Only.

Introduction

Architectural paint and stain manufacturers typically distribute premixed paints and stains in a small number of popular colors. To accommodate consumer desires and enable matching of existing painted or stained surfaces, manufacturers typically also distribute a set of tintable base paints or stains and several liquid colorants. These are combined at point-of-sale outlets using volumetric colorant dispensing equipment and shaker mixing equipment to make small batch lots of custom-tinted paint or stain in a much larger array of colors than the limited color array available in premixed products.

Owing in part to industry custom and the available colorant dispensing equipment, the custom color systems from different paint or stain manufacturers tend to have somewhat similar components. For example, a typical custom color paint system may employ several (*e.g.*, 2 to 4) tintable base paints ranging for example from a bright white base that already contains a white pigment such as titanium dioxide and is intended to accept at most a small quantity of added colorant at the point-of-sale, to a relatively unpigmented clear base that is intended to accept a much larger quantity of added colorant at the point-of-sale. Base paints and stains may employ various binders (*e.g.*, natural or synthetic resins), binder forms (*e.g.*, solution polymers or latex polymers) and vehicles (*e.g.*, solvent-borne or water-borne versions), and may provide various dried surface finishes (*e.g.*, matte, semi-gloss or gloss finishes). Some manufacturers also sell colored base paints (*e.g.*, a red, a blue and yellow colored base) which are intended to be combined with additional colorant(s) at the point-of-sale when strongly-tinted custom paint shades with one coat hiding power are desired. The colorants in custom color paint or stain systems may for example be volumetrically metered from a multiple-colorant dispensing station, with 12 to 20 paint or stain colorants typically being employed in colorant dispensing stations for the U.S. market, and more (*e.g.* 16 or 24 colorants) sometimes being employed in other markets.

Years ago, paints and stains were virtually all solvent-borne. Although solvent-borne paints and stains continue to be used, nowadays 80% or more of architectural paints and a significant proportion of stains are water-borne. The overall percentage of water-borne paints and stains as a proportion of total sales is expected to continue to increase. Despite that, some workers or customers continue to prefer solvent-borne paints (for example, alkyd paints) or solvent-borne stains for their appearance and durability in some end-use applications, and may do so well into the future.

Universal colorants have been developed for use in point-of-sale tinting equipment. Universal colorants typically are formulated by modifying a water-borne colorant formulation to include appropriate surfactants, and optionally to include appropriate dispersing agents or co-solvents, so that the colorant can tint either a water-borne or solvent-borne base paint or stain using the same tinting machine. For proper dispersion, pigments are typically wetted in a vehicle by means of these surfactants and dispersants. The use of a humectant is also used to reduce the rate of vehicle evaporation and reduce the risk of colorant drying in the point-of-sale outlet dispensing equipment.

Unfortunately, these components, necessary in the colorant, can act negatively in tinted paints and tend to cause problems in the field. The use of most universal colorants especially requires compromises in paint performance in order to effectively bridge the colorant compatibility gap between water-borne and solvent-borne systems. For example, in water-borne paints tinted with universal colorants, the compromised performance factors may include one or more of higher volatile organic compound (VOC) content, surfactant leaching, increased tack, reduced blocking resistance and viscosity drop. As architectural paints are typically formulated to include associative thickeners, such as HEUR and HASE thickeners, it is common for the components in the colorant to negatively impact the effectiveness of the thickeners. The surfactants in the colorant tend to out-compete the associative thickener for the surface of the latex particle in the tinted paint, causing a notable, and often significant, decrease in tinted paint viscosity.

Coward, et al describe in US 8,242,206 B2 compositions of universal paint colorants that comprise a surfactant package based on at least one alkyd-compatible surfactant and one latex-compatible surfactant. The combination of two or more surfactants at HLB values of both < 10 and > 10 allow the colorant to function universally, that is have compatibility in both solvent-borne alkyd and water-based latex paints.[1] Potential issues arise based on the type and level of surfactant needed for a colorant to function universally. The work presented here will focus on the performance comparisons between water-only and universal colorants. Specifically, we will investigate volatile organic content (VOC), tinted paint viscosity drop, surfactant leaching, standing water resistance, block resistance, and tack resistance.

Our observations and feedback from the industry prompted an in-depth review of the performance comparisons between CCA NovoColor® HP II 8600 Water-Only colorants, CCA NovoColor® II 8800 universal colorants, and a competitive commercially available universal colorant line.

Literature Review

Typical surfactants used in the formulation of colorants are common in the industry and described in detail in the literature. A simple classification of surfactants based on the ionization of the hydrophilic group is most commonly used and shown in Figure 1. Anionic surfactants are widely used where a negative head group, such as carboxylates, sulphates, sulphonates, and phosphates is paired with an appropriate counter ion, such as sodium, potassium, or ammonium salt. Non-ionics are also widely used based on a polar head group such as polyethylene oxide or ethylene oxide-propylene oxide copolymers or other multihydroxy based chemistries. Less common in the colorant industry are cationic and amphoteric or zwitterionic surfactants, where the former constitutes a positive head group such as quaternary ammonium compounds paired with an appropriate counter ion, such as chloride. Amphoteric or zwiterrionic surfactants contain both cationic and anionic groups, such as N-alkyl betaines, where system pH is very important and influences the functional performance properties.[2]

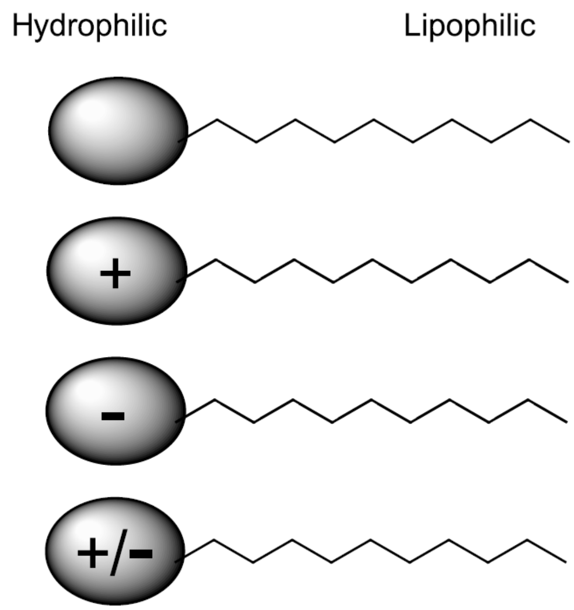

Figure 1: Simple classification of surfactants

Nonionic surfactants can be characterized by their hydrophilic-lipophilic balance (HLB) based on the relative percentage of hydrophilic to lipophilic groups in the surfactant molecule. Griffin's method described in 1954 calculates the HLB as $20 * M_h/M$ where M_h is the molecular mass of the hydrophilic portion of the molecule, and M is the molecular mass of the whole molecule. General guidance is an HLB value of < 10 is a lipid-soluble, or lipophilic surfactant, while HLB value of > 10 is a water-soluble, or hydrophilic surfactant.[3]

Surfactants play several roles in the formulation of colorants both mechanical and functional. Mechanically, surfactants help to wet, disperse, and stabilize dry pigments in a liquid medium. Wetting includes the lowering of surface tension and displacement of the solid-air interface with a solid-liquid interface. Dispersing includes the high shear mechanical step where media milling or high-speed dispersers are used to break apart the aggregates and agglomerates leading to comminution of the resulting particles and their subsequent stabilization. Functionally, surfactants play a role in compatibility and physical performance of colorants. Based on the HLB value of the surfactant(s) used, the compatibility range of the formulated colorant can be tailored for optimum performance in different paints and coatings systems, whether solvent-borne alkyd or water-based latex.

Systematic Study of Colorant Performance

Experimental

In an effort to understand and quantify the findings from the literature, experimental observations, and industry feedback, a study evaluating the performance of 3 commercially available colorant systems (Figure 2) comprising a total of 45 individual colorants in 6 commercially available paints (Figure 3) was conducted.

Colorant System	Compatibility
Competitive Colorant Line A	Universal
CCA NovoColor® II 8800	Universal
CCA NovoColor® HP II 8600	Water-Only

Figure 2: Colorant Systems

Commercial Paint	Sheen	Type
Paint A1	Flat	Deep Base
Paint A2	Satin	Deep Base
Paint A3	Semi-Gloss	Deep Base
Paint B1	Flat	Deep Base
Paint B2	Satin	Deep Base
Paint B3	Semi-Gloss	Deep Base

Figure 3: Commercial Paints

Colorants were analyzed for VOC by ASTM D-6886 using methyl palmitate as the boiling point marker. This method is a gas chromatography technique with higher precision in the low VOC range compared to EPA method 24.

The tinted paint viscosity drop for each combination was measured by tinting 116 fluid ounce per gallon deep base with 12 fluid ounce per gallon colorant. After mixing, the tinted samples sat overnight to allow for equilibration.

Surfactant leaching for each combination was measured by tinting 116 fluid ounce per gallon deep base with 12 fluid ounce per gallon colorant. After mixing, 6 wet mil drawdowns on white sealed charts were prepared and allowed to air dry until tacky. The drawdowns were then hung vertically and spray misted with water to provide an appropriate environment for exudation to occur. Samples were rated on a 0-10 scale with 10 being no visible streaking, change in gloss, blistering, swelling or discoloration. The full rating scale is noted in Figure 4. An example photo of this test is presented in Figure 5 where the surfactant exudate shows as shiny streaks on the coated drawdown.

Rating	
10 No Effect	No visible streaking
9	Trace streaking
8 Very Good	Minimal streaking
7	Minimal to slight streaking
6 Good	Slight streaking
5	Slight to moderate streaking
4 Fair	Moderate streaking
3	Moderate to heavy streaking
2 Poor	Heavy streaking
1	Heavy to severe streaking
0 Failure	Severe, prominent streaking

Figure 4: Surfactant Leaching Rating System

Figure 5: Surfactant Leaching

Standing water resistance for each combination was measured by tinting 116 fluid ounce per gallon deep base with 12 fluid ounce per gallon colorant. After mixing, 4 wet mil drawdowns were prepared and allowed to air dry for 24 hours. Once dry, a 1 square inch cloth swatch was placed on each section and water was titrated until saturation. A watch glass was placed over each swatch to prevent water evaporation and left covered for 1 hour. After 1 hour, the watch glass and swatch were removed and underlying coating inspected. The coating was evaluated for blisters, softening of film, loss of adhesion, and discoloration initially and after an additional hour of recovery. The rating scale for standing water resistance is presented below in Figure 6.

	Initial Rating
5 No Effect	No bubbles, no wrinkling, no surface distortion
4 Very Good	No bubbles, no wrinkling, slight ring
3 Good	Some small bubbles, no wrinkling
2 Fair	Many small bubbles, no wrinkling
1 Poor	Many small bubbles, moderate to high wrinkling
0 Failure	High wrinkling and lifting of paint film
	Recovery Rating
5 No Effect	No ring, darkening may be present
4 Very Good	Very slight ring and darkening present
3 Good	Slight ring and darkening present
2 Fair	Some wrinkles
1 Poor	Many wrinkles
0 Failure	Paint film did not adhere to substrate

Figure 6: Standing Water Resistance Rating System

Block resistance for each combination was measured by tinting 116 fluid ounce per gallon deep base with 12 fluid ounce per gallon colorant. After mixing, 4 wet mil drawdowns were prepared on mylar scrub charts and allowed to air dry for 1 week. Testing was conducted using ASTM D4946-89 Standard Test Method for Blocking Resistance of Architectural Paints. Tack resistance was conducted following the Cotton Ball Tack Resistance procedure described by Bell, et al in Quantification of Surface Tack of Next-Generation, High-Gloss, Low-VOC Architectural Binders study published in *Paint & Coatings Industry Magazine*.[4] Figure 7 displays the rating system used in the tack resistance method. A higher rating signifies less cotton residue adhered to the coating after testing and thus less tack.

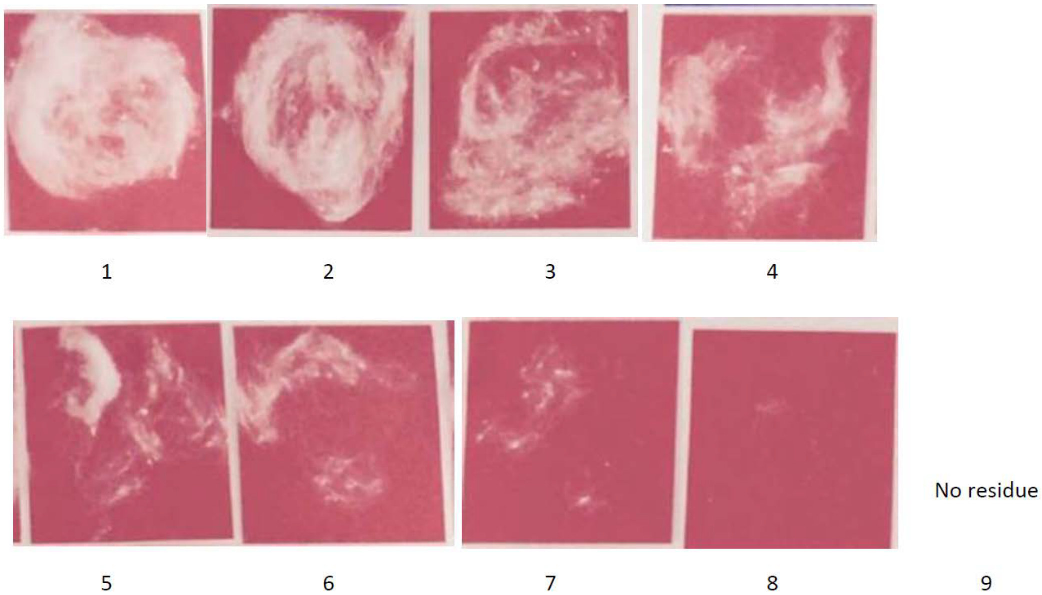

Figure 7: Cotton Ball Tack Resistance Rating System

Results and Discussion

The results in Figure 8 show the comparative VOC results for selected colorants of each of the commercial options and can be logically extrapolated for other colors or pigment types in the respective colorant lines due to formulating with common components. With the industry shift to lower VOC technology and more precise analytical measurement techniques an understanding of the current state of the art technology was required. A cross section of commercially available colorants were analyzed (see those listed below in Figure 8) for VOC by ASTM D-6886 using methyl palmitate as the boiling point marker. This method is a gas chromatography technique with high precision in the low VOC range. Using methyl palmitate as the boiling point marker, common polyglycol ether co-solvents, such as tri-, tetra-, and penta-ethylene glycols which years ago were considered low or no VOC, are now considered VOC by regulatory agencies in many jurisdictions.

By this analysis, CCA NovoColor® HP II 8600 water-only colorants overall show lower VOC than commercially available universal colorants.

Colorant	Competitive Colorant Line A	Colorant	CCA NovoColor® II	Colorant	CCA NovoColor® HP II
Compatibility	**Universal**		**Universal**		**Water-Only**
Yellow Oxide	93 g/l	Yellow Oxide (8878N)	21 g/l	Yellow Oxide (8678N)	1.5 g/l
Phthalo Green	127 g/l	Phthalo Green (8821N)	17 g/l	Phthalo Green (8621N)	1.9 g/l
Phthalo Blue	127 g/l	Phthalo Blue (8832N)	18 g/l	Phthalo Blue (8632N)	0.9 g/l
Red	119 g/l	Red (8847N)	13 g/l	Red (8651N)	0.8 g/l
Average	116.5 g/l	Average	17.3 g/l	Average	1.3 g/l

Figure 8: Volatile Organic Content (VOC) results of commercial colorants

As shown below in Figure 9, the mean tinted paint viscosity drop results incorporating all 45 colorants show a significant increase in resistance to viscosity drop using CCA NovoColor® HP II 8600 water-only colorants. Less of a viscosity drop means easier formulation of latex emulsion paints as less of the expensive associative thickeners are needed for proper rheology.

The increased mean resistance to viscosity drop of tinted paints is evident for the CCA NovoColor® HP II 8600 water-only colorants over the CCA NovoColor® II 8800 universal and Competitive Colorant Line A universal colorant lines. The mechanism for this increased resistance points to the level and type of surfactants used in the water-only colorant platform having less of an impact on the associative thickeners in the architectural paints. As was discussed earlier, typically less surfactant is needed in water-only colorants than in universal colorants due to the range of application. Most universal colorants need extra surfactant to provide the full range of compatibility between solvent-borne alkyd systems and water-based latex systems. The type of surfactant required also varies based on application, where lower HLB surfactants are needed to provide a colorant universal compatibility.

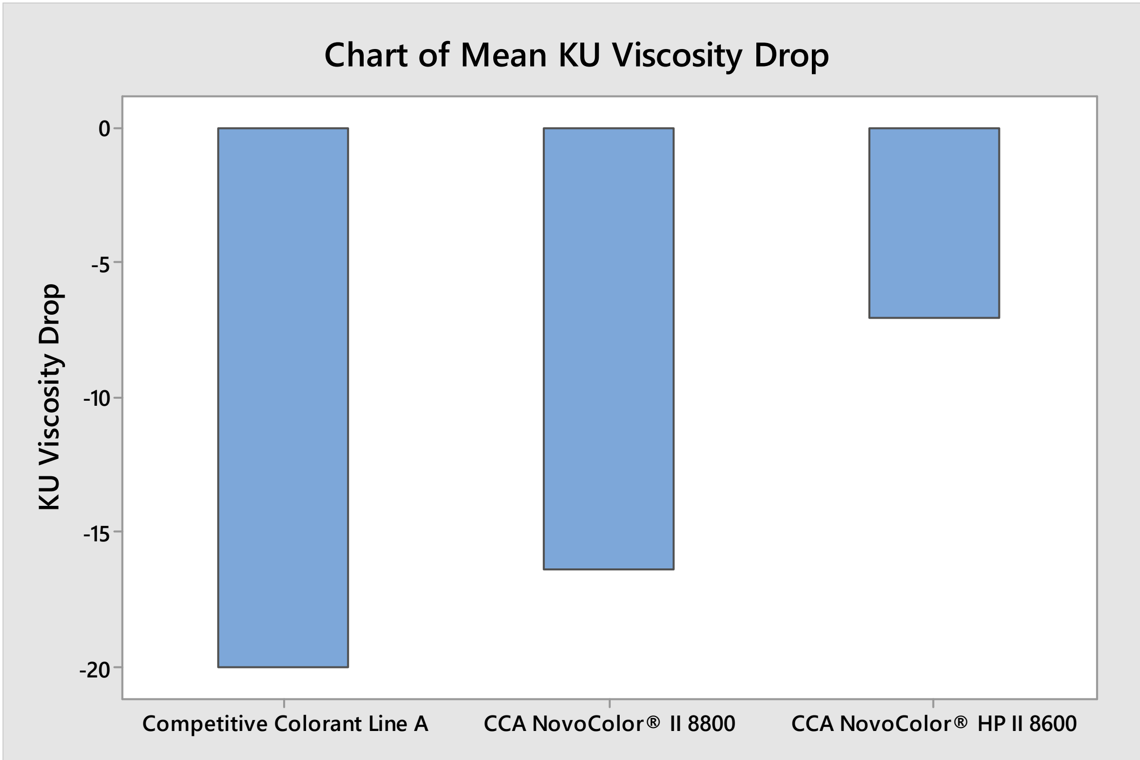

Figure 9: Viscosity Drop Plot

A series of plots (Figures 10-13) were generated to summarize the correlations between colorant systems and tinted paint performance, using all 45 colorants. The quantitative results for each of the 6 commercial paints were aggregated by colorant system for ease of analysis, where a higher rating corresponds to better performance for a given, tested performance characteristic. Figures 10 and 11 show surfactant leaching and water resistance comparisons where it is evident that less spread or scatter in data exist between commercial paint bases when using water-only colorants compared to universal colorants. This signifies there is a reduction in variability when using water-only colorants. Similarly, Figures 12 and 13 show comparative block and tack resistance where block and tack resistance on average were higher and there was less scatter, meaning more consistent block and tack resistance, when using water-only colorants.

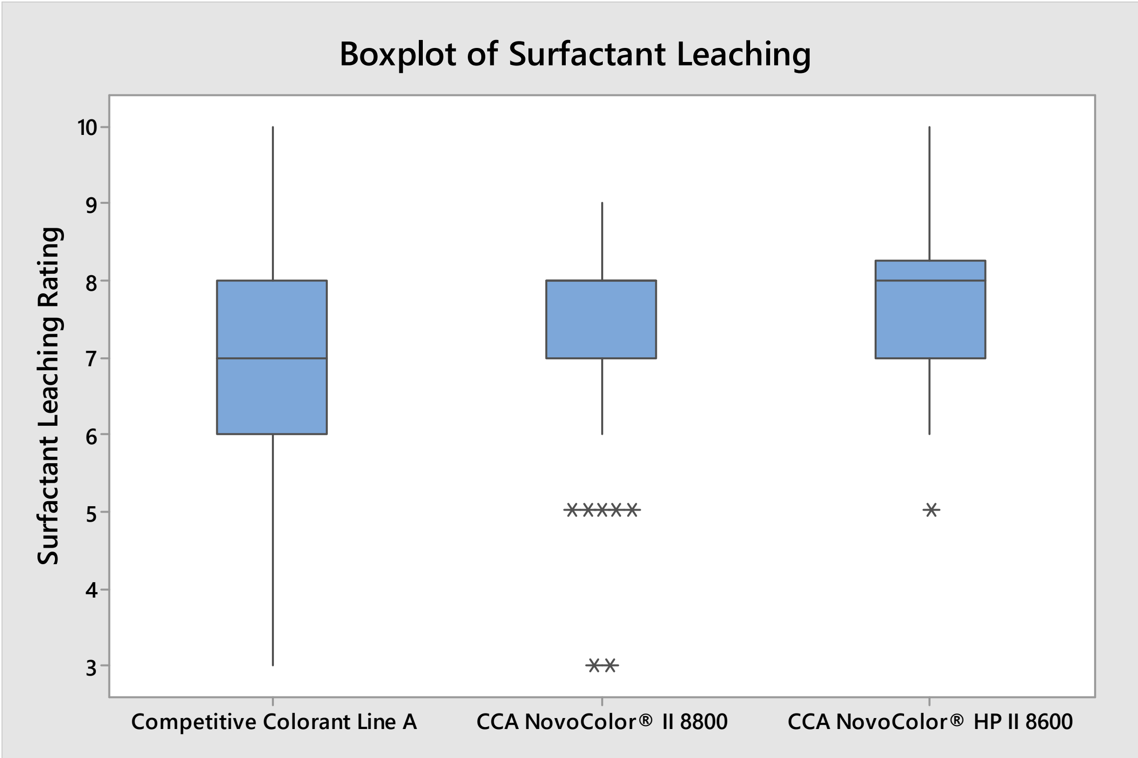

Figure 10: Surfactant Leaching Plot

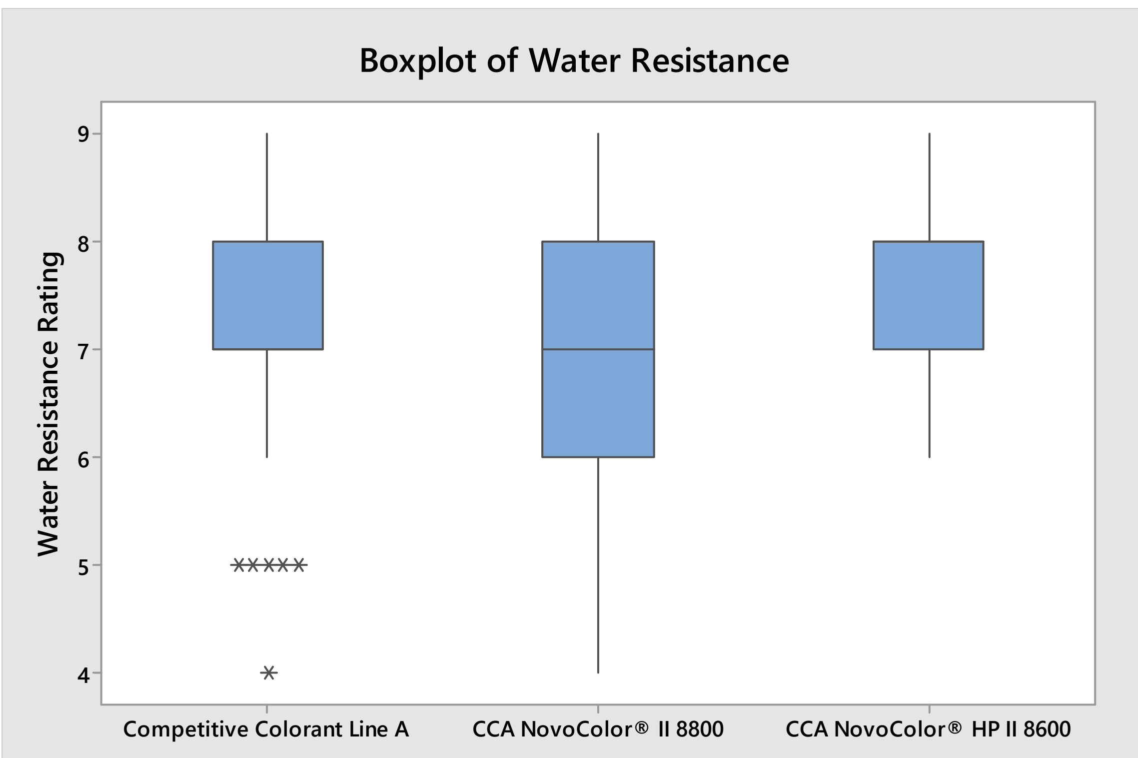

Figure 11: Water Resistance Plot

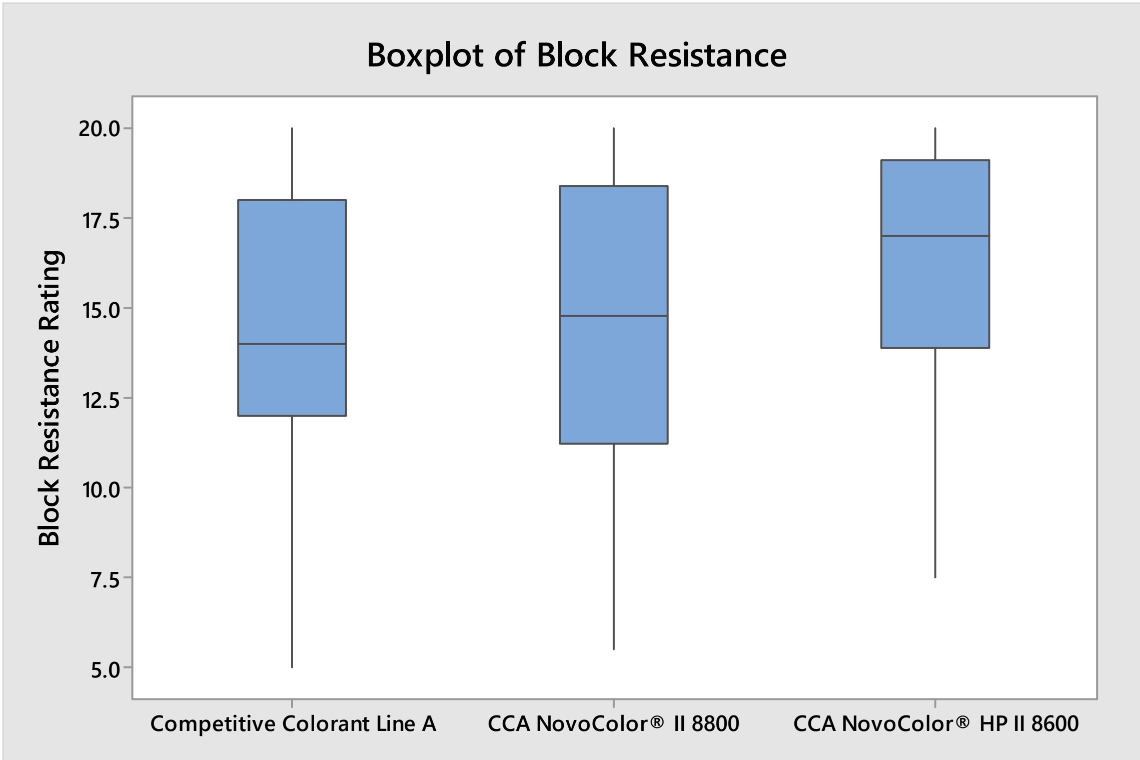

Figure 12: Block Resistance Plot

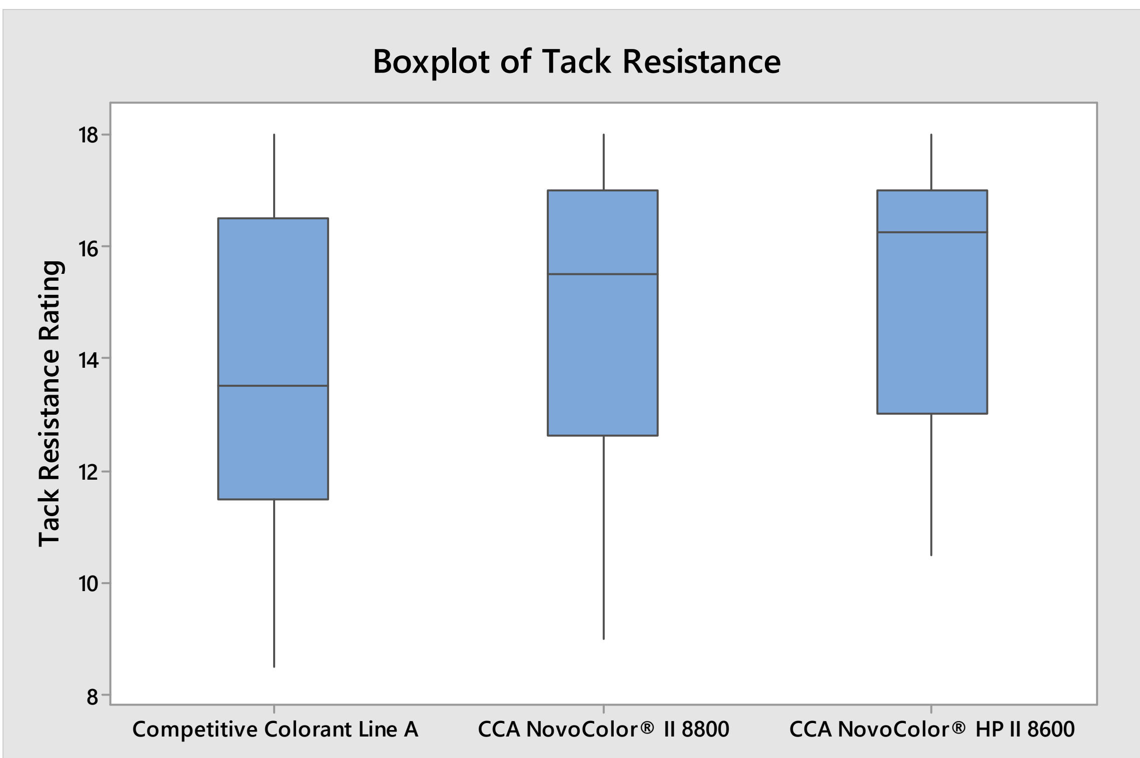

Figure 13: Tack Resistance Plot

A composite plot (Figure 14) was generated to summarize the overall performance comparison between CCA NovoColor® II 8800 universal colorants to CCA NovoColor® HP II 8600 water-only colorants to Competitive Colorant Line A universal colorants. The composite results show a significant reduction of VOC and greater resistance to viscosity drop using water-only colorants to universal colorants. Moderate increases are evident in surfactant leaching and water resistance, with less variability in these tests being observed for the water only colorants. The comparative data for block and tack resistance indicates that the paint formulation influences the block and tack resistance more than the colorant, although a slight increase in block and tack resistance using CCA NovoColor® HP II 8600 water-only colorants was still observed.

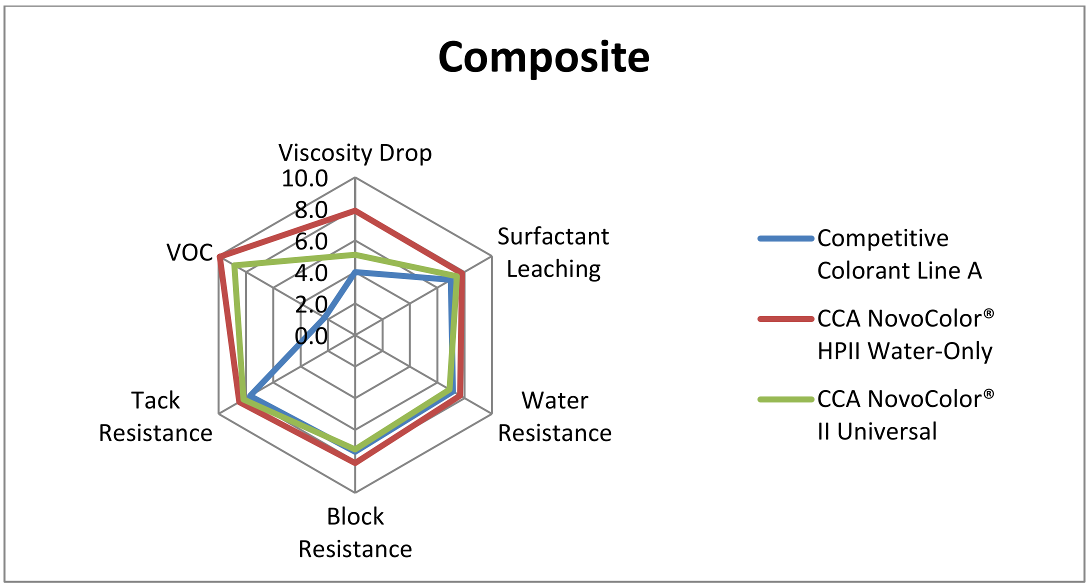

Figure 14: Composite Plot

An important takeaway from the performance comparison results is the magnitude and significance colorant has on the physical and functional performance of tinted paints. For the characteristics tested in this report, CCA NovoColor® HP II 8600 Water-only colorants provide less negative impact on tinted paint performance than the universal colorants tested. These physical performance improvements are attributed to the level and type of surfactant technology used to formulate the CCA NovoColor® HP II 8600 colorant platform. With the increasing shift from solvent-borne coatings technology to water-borne, there is less of a need now for a universal colorant than there was in years past. This comparison provides additional information for paint providers who are considering switching from universal colorants to water-only colorants.

Works Sited

[1] Coward et al United States Patent US 8,242,206 B2, “Low VOC Universal Paint Colorant System” (2012)

[2] T. Tadros, *Applied Surfactants*, Wiley-VCH, Germany (2005)

[3] W. Griffin, “Calculation of HLB Values of Non-Ionic Surfactants”, *Journal of the Society of Cosmetic Chemists*, (1954)

[4] T. Bell et al, “Quantification of Surface Tack of Next-Generation, High-Gloss, Low-VOC Architectural Binders”, *Paint & Coatings Industry Magazine*, (2017)