

Defining High Performance at Low VOC: Waterborne Acrylic DTMs under 25g/L

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ABSTRACT

Waterborne coatings have been used to protect steel and concrete infrastructure for decades, and recent technical developments have led to materials with lower VOC content and higher performance. One-component waterborne acrylics are often considered for light to medium duty service environments, but what level of performance can be expected from these systems? This paper will describe recent efforts to formulate waterborne acrylic coatings for steel protection below 25 g/L VOC and exemplify high performance over steel substrates. The very low VOC levels are facilitated by an innovative acrylic latex polymer that can be formulated at low coalescent levels and still demonstrate the highest standards of corrosion resistance and exterior durability. A comparison to a currently available low VOC resin and direct-to-metal (DTM) coatings will be described to highlight the advantages of the innovative binder and to demonstrate the high level of performance possible with waterborne acrylic coatings.

Key words: Acrylic, Direct-to-metal (DTM), Latex composite formation, Low VOC, Self-crosslinking, Waterborne coatings

INTRODUCTION

Today, the push to find more environmentally friendly solutions for paints and coatings has become very important. Paints contain volatile organic compounds (VOCs), that contribute to ground level ozone and smog and can be harmful to human health and air quality. VOC limits for formulated coatings have been instituted by local governments to meet the highest air quality standards. One such regional regulation set a limit of 100 g/L for industrial maintenance coatings in the South Coast Air Quality Management District (SCAQMD) of Southern California in 2007.¹ In parallel, consumers and end-users continuously seek greener and more sustainable coatings as populations are becoming more aware of their effect on the environment. There is also a demand for safer coatings with lower odor and flammability, which is helping drive the industry to find alternative solutions to solvent based technologies. As a result, paint manufacturers continue to develop low VOC products to meet these environmental regulations and consumer needs.

To get a better idea of the current VOC landscape for gloss and semi-gloss light duty DTMs, products from twenty-four leading paint manufacturers in North America were analyzed using information from their technical data sheets (TDS). Only waterborne acrylic, styrene acrylic, and acrylic-modified paints were analyzed. Figure 1 shows a VOC break-down of fifty-four paints from those manufactures with levels ranging from 250 g/L to 0 g/L. Many of the offerings (48%) fall in the < 150 and < 100 g/L VOC space. Currently, there is only a small percentage of coatings formulated at ultra-low VOC, < 25 and 0 g/L. There are two probable reasons why ultra-low VOC coatings are not often formulated in the North America industrial maintenance market today: there are no current regulations requiring VOCs to be at these levels, and the performance of products at ultra-low VOCs have shown poor performance in comparison to higher VOC offerings. Examples of poor performance include lower film hardness, decreased dirt pick-up resistance, and accelerated corrosion in unfavorable environments.

This paper describes the performance of a waterborne acrylic binder that can be formulated at < 25 g/L in a DTM coating. This resin shows best-in-class corrosion resistance and exterior durability, with the right balance of hardness properties. A comparison to a currently available low VOC resin and commercial direct-to-metal (DTM) coatings will be shown to highlight the advantages of the binder and to demonstrate the high level of performance possible with low VOC waterborne acrylic coatings.

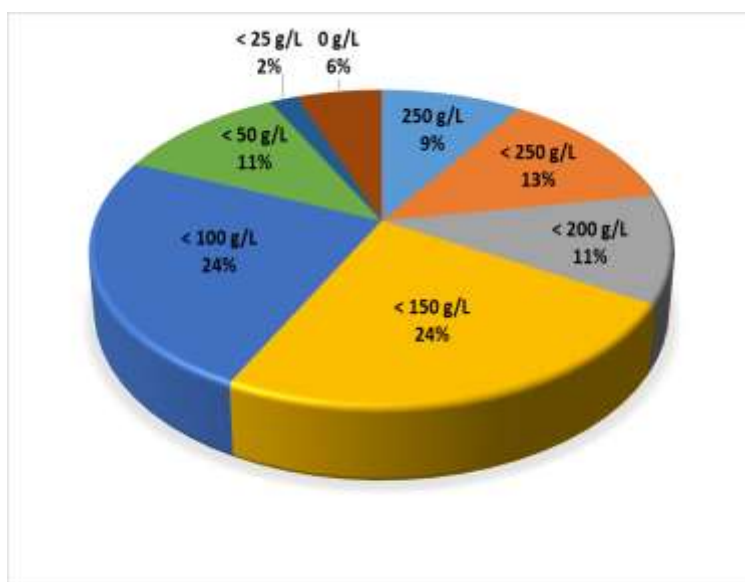


Figure 1: VOC level percent break down of Gloss/Semi-Gloss light duty DTMs for twenty-four leading paint manufacturers in North America.

MATERIALS AND EXPERIMENTAL PROCEDURE

The water-based acrylic resin designed for < 25g/L formulations will be designated as IC-1. This is a self-crosslinking acrylic copolymer with a weight solid content of 45% and a pH of 9.0. It has a minimum film formation temperature (MFFT) of 8 °C and is made without APEO surfactants. The IC-1 resin was formulated into a white, gloss DTM finish (DTM-1) at 18% pigment volume concentration (PVC) and 35.5% volume solids (VS) and is shown in Table 1.² The coating was formulated at < 25g/L VOC using 3% dipropylene glycol n-butyl ether (DPnB) and 2% plasticizer based on polymer solids. This coalescent package was selected after performing a low-temperature film formation (LTFF) study looking at varying plasticizer levels in combination with 3% DPnB. LTFF was measured by applying a film to a chart (Form 1B Penopac) and drying at 4.5 °C / 40% relative humidity. Cracking is rated on the dry film over both the sealed and unsealed areas of the chart. A “fail” rating was given if any cracking was seen in the film. If no cracking was noticed, the formulation was considered passing. Table 2 shows the results of this study, where 3% DPnB and 2% plasticizer was the optimal coalescent package for DTM-1 to pass LTFF.²

IC-1 was compared to another low VOC-capable resin, designated as IC-2, to demonstrate the importance of resin design when trying to achieve high performance at an ultra-low VOC. This is also a self-crosslinking acrylic copolymer synthesized at 49% weight solids with a pH of 9.0. The resin has a MFFT of 14 °C and is also prepared without the use of APEO surfactants. IC-2 was formulated in the < 25 g/L DTM formulation found in Table 1 while maintaining PVC and volume solids and is designated as DTM-2. IC-2 was also prepared using the same formulation, but the coalescent package was changed to the recommended VOC level of < 50 g/L utilizing 6% DPnB and 2% plasticizer (designated as DTM-3).

In a separate study, IC-1 was prepared in an optimized formulation designated as DTM-4 which can be found in Table 3. DTM-4 was compared to four DTM commercial paints currently available in the market. The commercial paint controls varied in VOC level according to the technical data sheets from 0 g/L (COM-1), < 50 g/L (COM-2), < 100 g/L (COM-3), and < 200 g/L (COM-4); the descriptions and properties of each are shown in Table 4.

Table 1
White Gloss DTM Formulation DTM-1

DTM-1		
Ingredients	Pounds	Gallons
Grind:		
Water	61.04	7.31
Dispersant	7.63	0.86
Surfactant	2.03	0.22
Defoamer	1.02	0.12
Ammonia (28%)	2.03	0.27
Titanium Dioxide	213.67	6.40
<i>Grind for 30 min. before adding:</i>		
Water	22.38	2.68
Grind Sub-Total	304.50	17.57
LetDown:		
IC-1 Resin	571.78	65.50
Water	50.87	6.10
<i>Add grind from above</i>		
Dipropylene glycol n-butyl ether	7.70	1.02
Plasticizer	5.14	0.64
Sodium Nitrite (15%)	9.16	1.01
Water	63.04	7.55
Rheology Modifier	2.75	0.32
Total	1020.24	100.00
Paint Properties		
PVC	18.0%	
Volume Solids	35.5%	
VOC (calculated)	~ 24 g/L	

Table 2
LTFE with Different Coalescent Packages for IC-1 Resin

Coating #	DTM-1	DTM-1	DTM-1
Resin	IC-1	IC-1	IC-1
Coalescents	3% DPnB	3% DPnB 1% plasticizer	3% DPnB 2% plasticizer
VOC (g/L)	< 25	< 25	< 25
Low Temperature Film Formation (4.5 °C / 40% RH)	Fail	Fail	Pass

Table 3
Optimized White Gloss DTM Formulation DTM-4

DTM-4		
Ingredients	Pounds	Gallons
Grind:		
Water	60.00	7.19
Dispersant	7.50	0.85
Surfactant	2.00	0.22
Defoamer	1.00	0.12
Ammonia (28%)	2.00	0.27
Titanium Dioxide	210.00	6.29
<i>Grind for 20 min. before adding:</i>		
Water	22.00	2.64
Grind Sub-Total	304.50	17.57
LetDown:		
IC-1 Resin	562.00	65.81
Water	50.00	5.99
<i>Add grind from above</i>		
Dipropylene glycol n-butyl ether	7.57	1.00
Plasticizer	5.05	0.63
Sodium Nitrite (15%)	9.00	0.99
Defoamer	20.40	2.42
Silicone Additive	10.20	1.22
Rheology modifier	8.00	0.92
Rheology modifier	3.00	0.34
Water	25.32	3.03
Total	1005.04	100.00
Paint Properties		
PVC	18%	
Volume Solids	35%	
VOC (calculated)	~ 24 g/L	

Table 4
Description and Property Details of Commercial Controls

Paint ID	Resin Type	Paint Type	Volume Solids	VOC (Calculated)
COM-1	WB Urethane Modified Acrylic	Gloss DTM	39.0%	0 g/L
COM-2	WB Acrylic	Gloss DTM	40.0%	< 50 g/L
COM-3	WB Acrylic	Gloss DTM	41.0%	< 100 g/L
COM-4	WB Acrylic	Gloss DTM	37.0%	< 200 g/L

Test Methods

Corrosion Resistance: Corrosion resistance was tested using a salt fog chamber in accordance with ASTM B117.³ The coatings were applied to 4 x 12 in. panels of 16-gauge abrasive blasted hot rolled steel (BHRS) with a 2.0 mil profile and smooth, dull matte cold rolled steel (CRS). The coatings were applied by draw down to achieve an approximate dry film thickness (DFT) of 3.0 mil for BHRS and 2.0 mil for CRS. The coated panels were allowed to cure for 1 week at 21 °C / 50% relative humidity. The bottom half of the panels were scribed with a single vertical 2-inch scribe prior to being placed into the salt spray cabinet. The panels were rated for percent rust and blistering (ASTM D714) approximately every 168 hours up to 1000 hours or until failure was seen.⁴

Humidity Resistance: Humidity resistance was evaluated over cold rolled steel using a Cleveland condensation cabinet according to ASTM D4585.⁵ The cold rolled steel panels were prepared following the same procedure found in the corrosion resistance test method. The panels were rated for percent rust and blistering (ASTM D714) approximately every 168 hours up to 500 hours.

Hardness: König pendulum hardness was measured according to ASTM D4366 using a pendulum hardness tester.⁶ Pencil hardness was measured according to ASTM D3363.⁷ For both tests, coatings were applied by draw down to 4 x 12 in. chromate-treated aluminum panels targeting a DFT of approximately 2.0 mil. Measurements were taken after one day cure at 21 °C / 50% relative humidity, and then every 7 days up to 21 days.

Oil Softening Resistance: Panels for oil softening resistance testing were prepared according to the same procedure found in the hardness test method. The coated panels were dried for 7 days at 21 °C / 50% relative humidity, and then initial König hardness measurements were taken. Vegetable oil and hand cream with lanolin were applied to a 1.5-inch-wide strip of cheesecloth at two separate areas on the film, and they were allowed to sit for 24 hours. After 24 hours, the cheesecloth was removed, and any residual oils were wiped clean. The coatings were visually inspected for swelling and measured for König hardness. The delta König hardness was then reported for each sample to evaluate how much the oils had softened the film.

Block Resistance: Panels for block resistance were prepared by draw down of the coatings onto a plain white chart (Form WB) at approximately 1.0 mil DFT. The coatings were cured for one and seven days at 21 °C / 50% relative humidity before block resistance was evaluated. Two 1.5-inch x 1.5-inch squares were cut from the chart, and the coated side of the two squares were placed facing together on a flat surface. A #8 rubber stopper was placed on top of the cut-out squares and a 1-kg weight was placed on top of the stopper. Block resistance was rated after 30 minutes at 50 °C and 30 minutes at 21 °C. The two face-to-face pieces were pulled apart and rated for film damage and tack according to the following 0-10 scale: 10 = no tack/perfect; 9 = trace tack/excellent; 8 = slight tack/very good; 7 = slight tack/good; 6 = moderate tack/good; 5 = moderate tack/fair; 4 = severe tack, no seal/ fair; 3 = 5-25% seal/ poor; 2 = 25-50% seal/ poor; 1 = 50-75% seal/ poor; 0 = complete seal/very poor.

Accelerated Dirt Pick-up Resistance: Panels for dirt pick-up resistance (DPUR) were prepared by draw down of the coatings on 3 x 6 inch chromate-treated aluminum substrates targeting approximately 2.0