

Developing and Evaluating Early Rain Resistance in Exterior Architectural Coatings

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High humidity and precipitation challenges the ability of exterior architectural coatings to properly cure and provide the necessary protection of exterior surfaces. To increase early rain resistance and decrease water sensitivity, different formulation techniques were investigated. Raw materials were evaluated in a standard starting point formula to generate an optimal formulation that reduces water sensitivity and surfactant leaching, while simultaneously increasing early rain resistance. Results for early rain resistance were determined by developing new testing methodology that varied environmental factors during the film curing process. We determined that using functional additives as well as increasing the hydrophobicity of the coating film can substantially increase early rain resistance.

INTRODUCTION

One of the most difficult parts of formulating exterior coatings is accounting for changes in weather. In the Pacific Northwest and Southeast United States, rainy seasons or extreme humidity can delay coating application or damage completed jobs due to precipitation during the film drying process. Not only can the paint appearance be negatively impacted by rain, but the film's protection properties can be reduced. As a latex paint film dries, the solid particles crowd and polymer latex particles coalesce as the water evaporates from

the film.¹ If precipitation interrupts this process, the latex may not be able to form a continuous film over the substrate, leaving film defects or areas unprotected from exposure.

Coating manufacturers need reliable testing procedures to be able to evaluate performance of paint films even under high humidity or precipitation. Formulation techniques to build early rain or moisture resistance are required to develop products that can withstand precipitation within one to two hours after application.

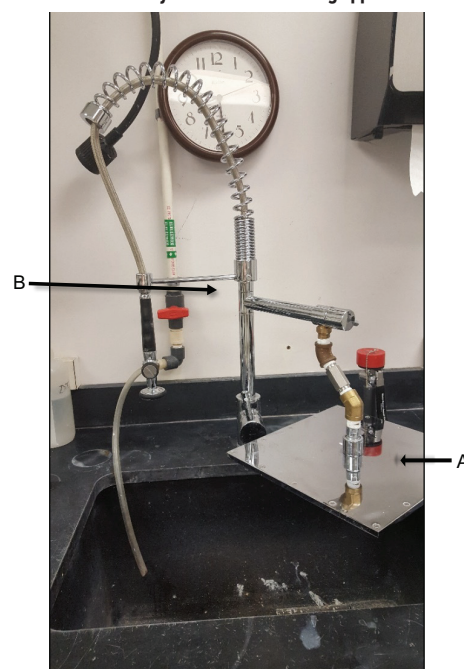
PART 1: PROCEDURE DEVELOPMENT AND TESTING

Testing early rain resistance requires a method of delivering controlled precipitation as well as ensuring high humidity during the film curing process. Procedure criteria included the ability to adjust for changing environmental conditions such as cure temperature and humidity, adjustable precipitation rate, and sufficient reproducibility and error control. Various testing techniques were reviewed including application on drywall then spraying the film with water, use of the QUV under condensation, and testing in a fog box. A test method adapted from roof coating applications gave the best and most consistent results. The test method discussed can be used to determine early rain resistance properties of a semi-dry film under harsh testing conditions.

Early Rain Resistance Testing Apparatus

Materials required include an environmental chamber capable of sustaining temperature at 40°F and 75% relative humidity (RH). The early rain resistance testing apparatus is shown in Figure 1.

FIGURE 1—Early rain resistance testing apparatus.



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The testing apparatus uses the following components:

1. Showerhead: Graff G-8464-PC 12 Inch Square Brass Showerhead
2. Faucet: Kraus KPF-1602 Single Handle Pull Down Kitchen Faucet Commercial Style Pre-rinse
3. Panel Rack (Optional): ACT Test Panels Stainless Steel Panel Rack 57187

Additional materials needed:

4. Divided 7 mil gap drawdown bar (see Figure 2)
5. 6 x 12 in. aluminum Q-panels
6. Environmental chamber set to requested conditions such as 75% RH and 40°F
7. Timer
8. Video camera (if requested)

Test Method

To prepare the test panel, the paints to be tested were drawn down using the divided Dow bar at 7 mil film thickness. Samples were cured in the environmental chamber set to 40°F and 75% RH for 30 min. The cure time allowed the film to reach the point at which the open time ended and drying was almost complete.

Before the samples were tested, the water flow rate was measured and adjusted to ensure testing consistency between panels. The water flow rate was set to simulate a light rain. A 1 L beaker with a diameter of 108 mm was centered beneath the showerhead and used to collect water over a 30-sec time period. It was determined that a flow rate of 400 mL water per minute simulated a light rain, and only cold water was used

in testing. The height of the showerhead was set for 12 in. above the test panel.

After the test panel cured, the panel was placed in the panel rack centered under the showerhead, and the timer was set to begin at the same time as the shower. The time at which the film first broke through was recorded. The breakthrough time is important because when the continuous film is interrupted, such as from damage from precipitation while curing, the substrate protection properties are significantly reduced. At this point, the substrate becomes exposed to elements, which can lead to further damage such as blistering, microbial attack, and potential cracking.

Reproducibility

Panels were tested in duplicate for an average with the samples drawn down in different positions, as shown in Figure 3.

FIGURE 2—Divided 7/12 mil gap drawdown bar.

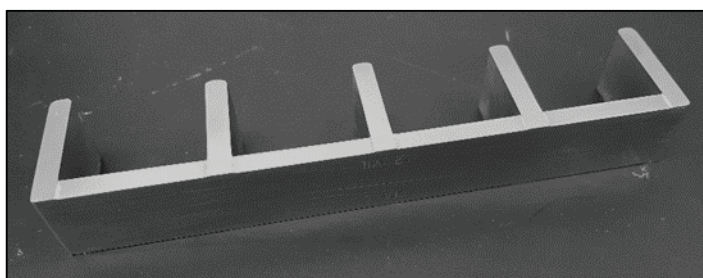


FIGURE 3—Examples of sample positions on panels.

Panel 1	Sample A	Sample B	Sample C	Sample D
Panel 2	Sample C	Sample D	Sample A	Sample B

TABLE 1—Exterior Commercial Flat Paint Breakthrough Time in Seconds

SAMPLE	EARLY RAIN RESISTANT CLAIM	PANEL POSITION				AVG	STD DEV	3 σ LIMIT	
		A	B	C	D			LOWER	UPPER
COMMERCIAL 1	1.5 H	50	51	54	48	50.75	2.17	44.25	57.25
COMMERCIAL 2	12 H	36	33	33	30	33	2.12	26.64	39.36
COMMERCIAL 3	1.5 H	36	43	39	39	39.25	2.49	31.79	46.71
COMMERCIAL 4	1 H	56	50	55	53	53.5	2.29	46.63	60.37
COMMERCIAL 5	NO CLAIM	27	27	27	23	26	1.73	20.80	31.20

Commercial paints were tested to determine reproducibility in early rain resistance results using the test method detailed above. The paint samples included those with various marketing claims for early rain resistance. Each paint was tested in all four positions on the panel to determine result accuracy. The results were recorded as time to first film breakthrough in seconds. The testing results are shown in *Table 1*.

From the data, the average and standard deviation were calculated. The 3 σ upper and lower limits were calculated to determine if the individual panel

results fell within the 6 σ range to indicate result reliability. For each of the samples, it was noted that the results did meet the 6 σ requirement. Also, there was a significant difference in early rain resistance times for commercial paints 1–4 compared to commercial paint 5, supporting the marketing claims for early rain resistance compared to the commercial paint without claims.

PART 2: EARLY RAIN RESISTANCE FORMULATION TECHNIQUES

Latex Hydrophobicity

Several formulation components were investigated to determine their effect on early rain resistance. We first evaluated the hydrophobicity of the latex and the effect on early rain resistance. A proprietary acrylic latex (referred to herein as

Acrylic Latex A*) and a commercial latex were tested using contact angle analysis (*Figure 4*). The latexes were then tested for early rain resistance in a commercial exterior flat starting point formula.

The contact angle of Acrylic Latex A is significantly higher than the commercial latex. When tested in the paint formulation, the paint with Acrylic Latex A had an early rain resistance of 46 sec compared to paint made with the commercial latex with an early rain resistance of 38 sec. The hydrophobicity of the latex contributed to reduced film wetting which, in turn, enhanced the early rain resistance of the paint film.

Formula Optimization

After examining the surfactant, coalescent, rheology modifier, and zinc oxide levels, we then evaluated the effect on low shear (KU) rheology development as well as early rain resistance as average time to film break through. We wanted to see how the paint viscosity could potentially attribute resistance to deformation of the paint film under stress from precipitation. The formula components were evaluated using Umetrics MODDE Pro in a response surface model with an optimization objective. Using the four-factor design of experiment (DOE) with two responses, 20 sample runs were made. Within the DOE, each formulation component was evaluated at a low loading (–1), nominal loading (0), and high loading (1). The nominal loading is the amount found in the starting point formula presented in *Table 2*.

The samples were tested for early rain resistance in duplicate for an average. The early rain resistance and KU were modeled to determine which formulation component influenced the film breakthrough time. We mapped the variable importance to determine the driving formulation component to increase early rain resistance (*Figure 5*).

*Acronal® EDGE 4247, by BASF Corporation

EARLY RAIN RESISTANCE FORMULA EXTERIOR FLAT WHITE

DISPERSION	LBS.
KRONOS® 4311	294
WATER	50
DISPEX® CS 4320	8
FOAMSTAR® ST 2420	2
HYDROPALAT® WE 3320	2
PROXEL™ BD20	3
KTPP	1
MINEX® 4	230
ZOCO® 101	10
ATTAGEL® 50	4
MIX 15-20 MIN LETDOWN	
WATER	152
POLYPHASE® 663	10
AMMONIUM HYDROXIDE	1.4
FOAMSTAR ST 2420	2
ACRONAL® EDGE 4247	365
VELATE™ 368	7
RHEOVIS® PE 1331	35
RHEOVIS PU 1191	2
MIX 20 MIN	

TABLE 2—Early Rain Resistance Starting Point Formula with DOE Component Loading Levels

FORMULATION PROPERTIES				
WEIGHT SOLIDS, %		58.7		
PVC, %		46.6		
VOC, G/L		<25		

Variation				
FORMULATION COMPONENT	LOW LOADING	NOMINAL LOADING	HIGH LOADING	UNITS
SURFACTANT	1	2	4	#/100 GAL
ZINC OXIDE	8	10	15	#/100 GAL
COALESCENT	3%	4%	5%	%OPS
KU DRIVER	1	2	3	#/100 GAL

FIGURE 4—Contact angle of neat latex.

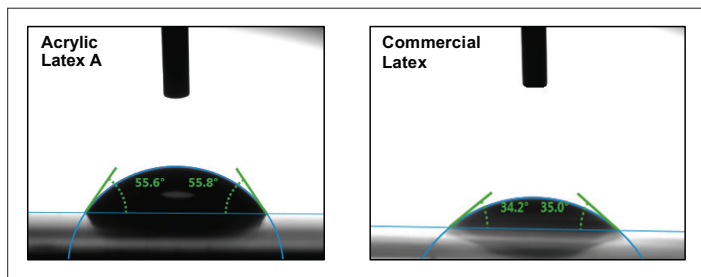


FIGURE 5—Formulation component importance on early rain resistance.

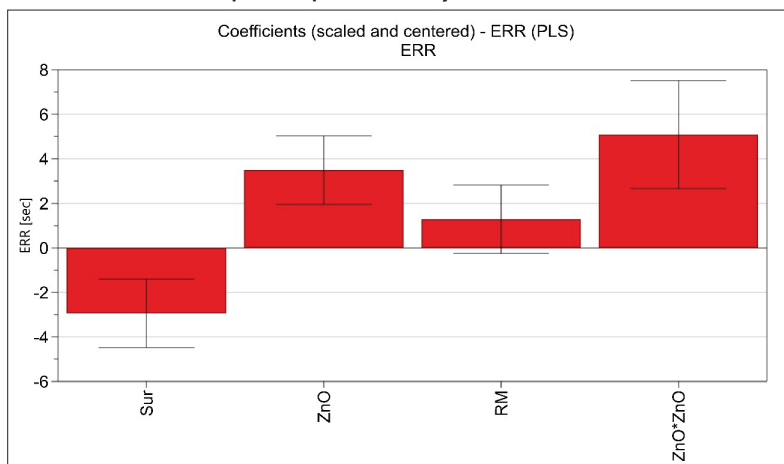


TABLE 3—Early Rain Resistance Optimized Formula

OPTIMIZED EARLY RAIN RESISTANCE FORMULA	
DISPERSION	LBS.
KRONOS 4311	294
WATER	50
DISPEX CX 4320	8
FOAMSTAR ST 2420	2
HYDROPALAT WE 3320	1.5
PROXEL BD20	3
KTPP	1
MINEX 4	230
ZOCO 101	15
ATTAGEL 50	4
MIX 15-20 MIN LETDOWN	
WATER	152
POLYPHASE 663	10
AMMONIUM HYDROXIDE	1.4
FOAMSTAR ST 2420	2
ACRONAL EDGE 4247	365
VELATE 368	6
RHEOVIS PE 1331	35
RHEOVIS PU 1191	2.5
MIX 20 MIN	

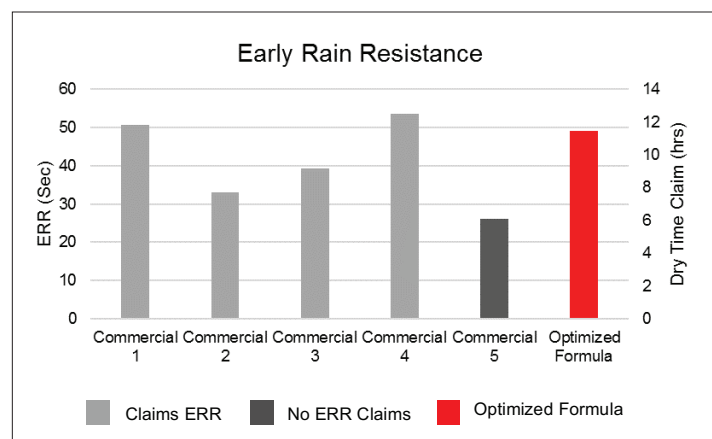
The results indicated that zinc oxide influenced the early rain resistance breakthrough time significantly more

than the other formulation components. Zinc is used in the formulation to improve exterior durability, but it can be theorized that the zinc oxide enhanced the crosslink density of the film, which reduced sensitivity to moisture during film cure.² When the MODDE analysis tools were used to predict an optimized formulation, it was determined that zinc oxide had a contribution factor of 46.1% and rheology modifier had a contribution of 31.8%. Surfactant and coalescent, while not necessarily significant for early rain resistance in lighter bases, should not be ignored as they may negatively impact other formulation performance properties as well as early rain resistance in deeper bases with a higher colorant loading.³ When formulating with zinc oxide or adjusting raw material amounts, the formulation should be re-assessed for in-can stability.

Our optimized formulation had a model projection of 46.5 sec for early rain resistance and a KU of 100, as shown in Table 3.

The optimized formula was tested for early rain resistance, which resulted in 49 sec and a KU of 106. When the results were compared with the commercial paints, the optimized formula

FIGURE 6—Comparative early rain resistance results.



performed similarly to the paints with early rain resistance claims (Figure 6).

CONCLUSION

Early rain resistance is an important parameter to consider when formulating exterior architectural coatings. Not only can the painting season be extended, but the film's performance can be enhanced. The testing procedure outlined enables the coating formulator to reliably test and categorize the early rain resistance of a film. We found that some of the coating components, such as zinc oxide and rheology modifier levels, can have a significant impact on rain resistance. The hydrophobicity of the latex can also significantly influence the early rain resistance properties of the paint film. It has been shown that by optimizing the levels of surfactant, coalescent, zinc oxide, and rheology modifier, the development of early rain resistance and performance properties of a paint film can be maximized. *

Acknowledgments

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