NEW ACRYLIC BINDER FOR HIGH PERFORMANCE WATERBORNE LOW VOC DIRECT-TO-METAL COATINGS: RESIN AND COATING FORMULATION INTERACTION

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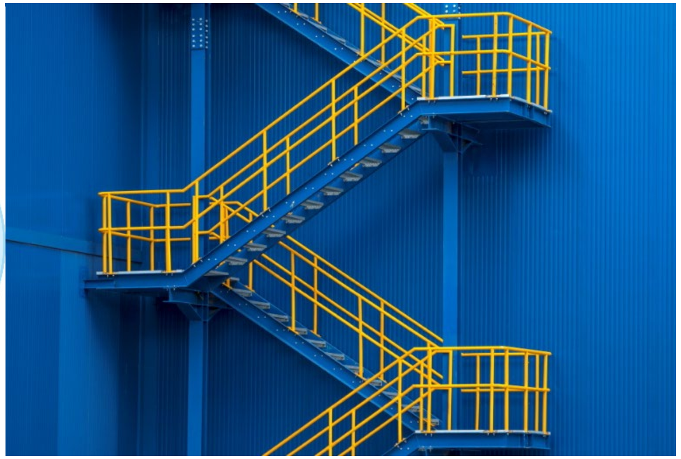
Agenda

1. Trends and performance challenges in waterborne direct to metal coatings
2. Market gap analysis on performance property balance
3. Performance objectives and experiment outline
4. Results and discussion
5. Conclusions

Direct to Metal Coatings
Industry trends

- Transition from solventborne to waterborne systems for light-duty applications
- Addressing new VOC* regulations to improve environmental and EHS profile
- Minimizing applied costs through 1 coat systems
- Addressing VOC regulations without sacrificing anti-blocking properties
- Balancing multisubstrate adhesion with high corrosion resistance





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***VOC** = volatile organic compound

Direct to Metal Coatings Trends

Solventborne transition to Waterborne

Solventborne Alkyd

Pros

1. Thin film corrosion resistance
2. Substrate tolerance
3. Low temperature applications

Cons

1. High VOC
2. Highly Flammable
3. High risk for Chemical exposure
4. Slower dry times with high solvent levels

Waterborne Acrylic

Pros

1. Low VOC
2. Low flammability
3. Low risk for chemical exposure
4. Quick Dry with low solvent

Cons

1.Lack thin film corrosion resistance

2.Need for substrate prep

3.Incapable of low temperature application

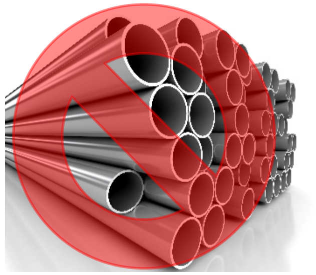
4.Low VOC thermoplastics tend to be soft

Legacy Solventborne

B117

Typical Waterborne

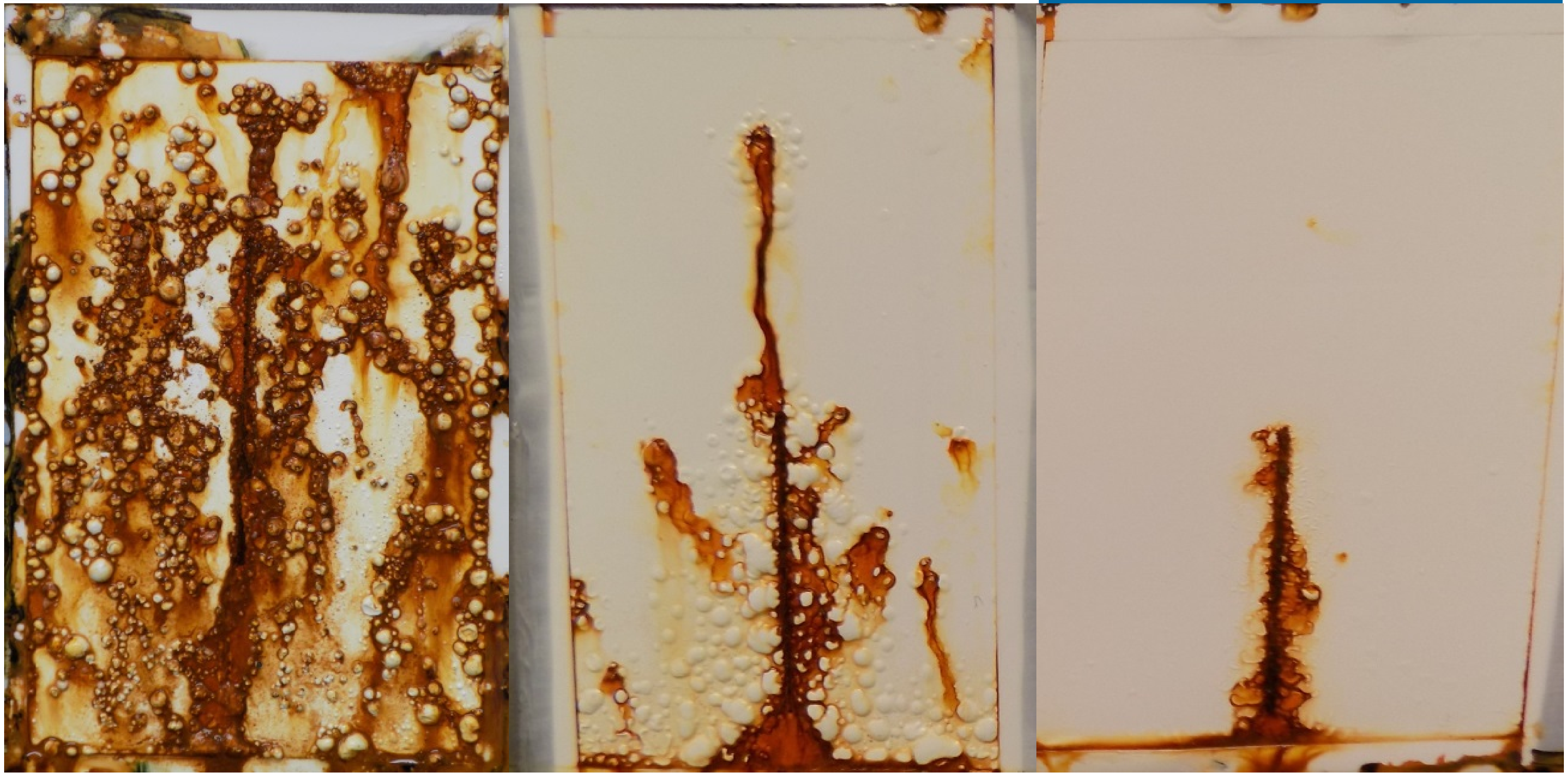
Block



Direct to Metal Coatings Challenges
(Corrosion and Block Resistance)

Block Rating
0-10 where 10
represents no tack

8	4	0



300hr B117 @ 2mil
DFT

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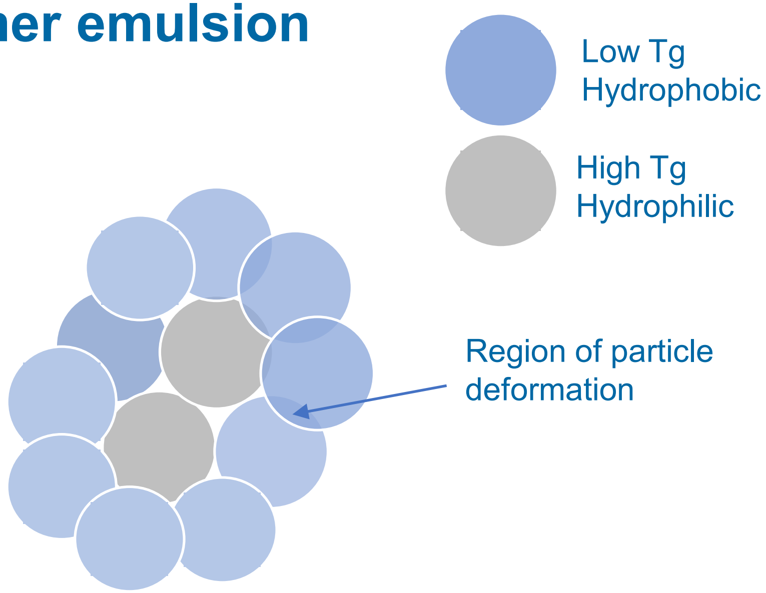
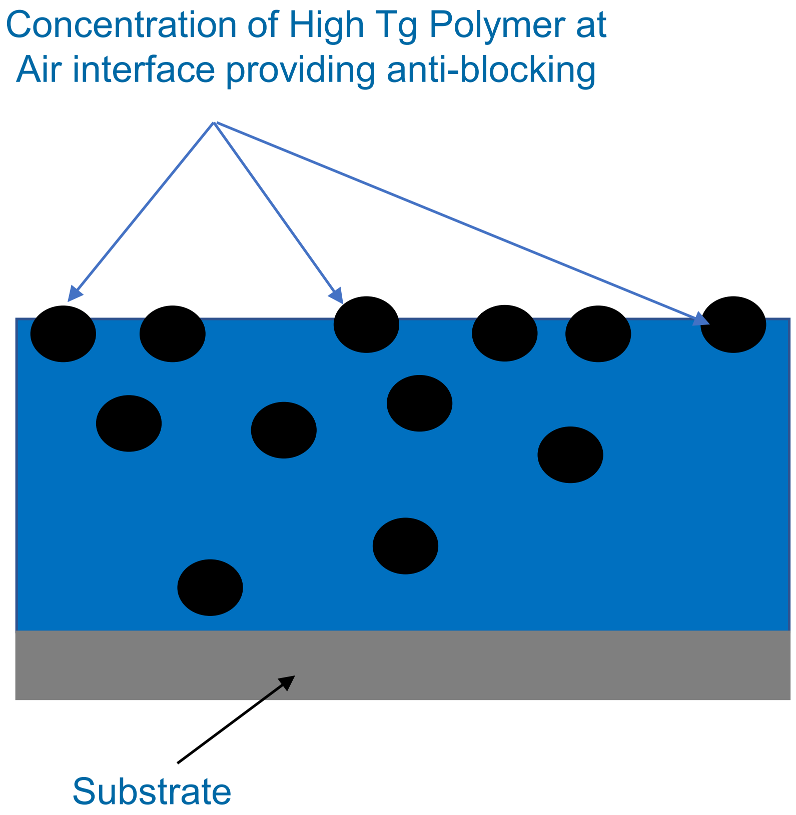
Direct to Metal Coatings Challenges
(Film Formation Process)

Multi-Phase polymer emulsion



Stage 2 of latex drying process subsequent to water evaporation coincides with the evolution of high and low Tg domains in film resulting in a heterogenous Tg distribution.



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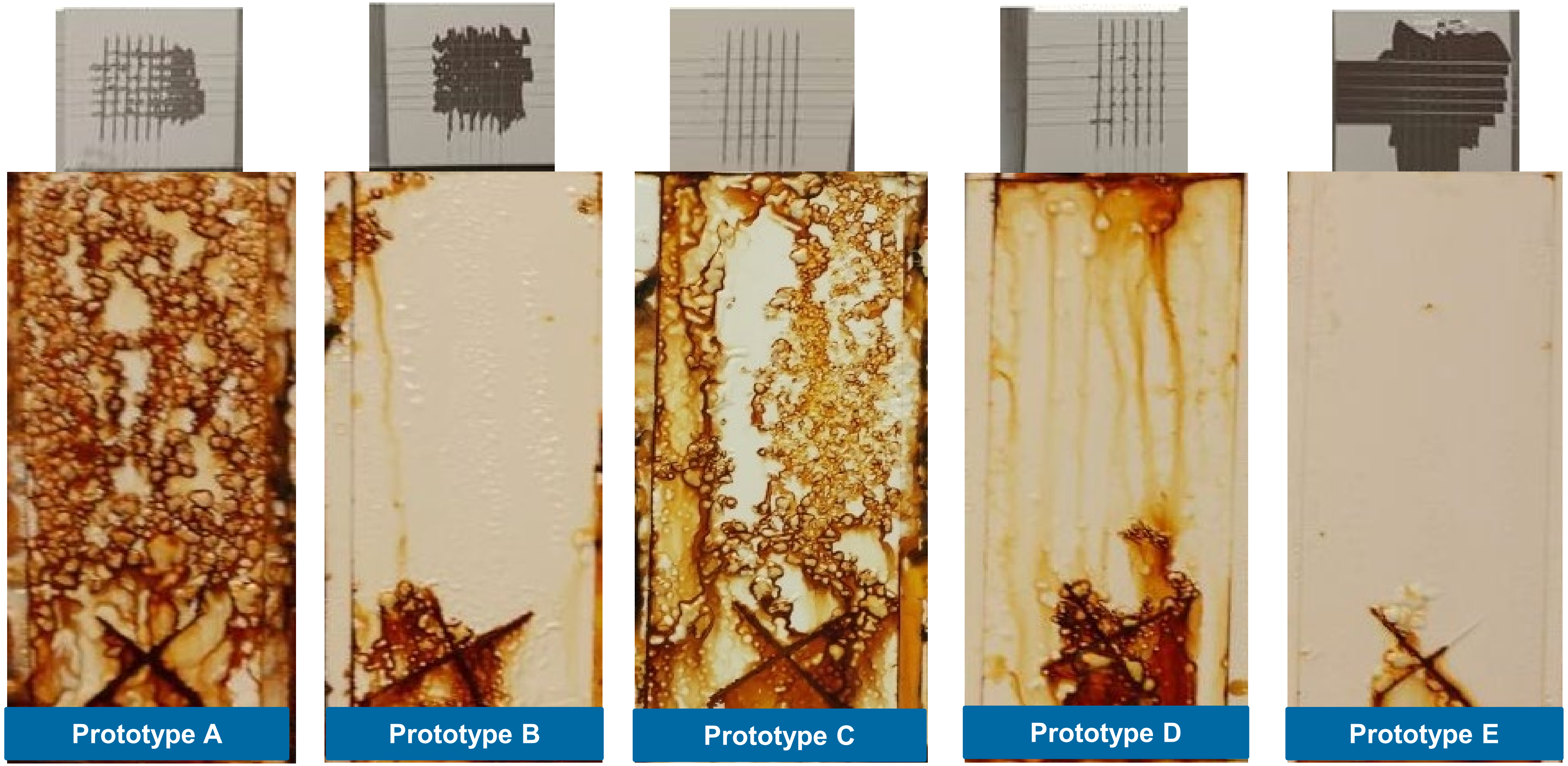
Direct to Metal Coatings Challenges
(Corrosion and Adhesion)



Aluminum adhesion

300hr B117

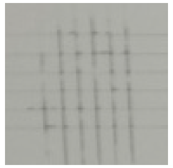
Challenges arise due to surfactant aggregation at interfaces and the need to incorporate specific polymer functional groups

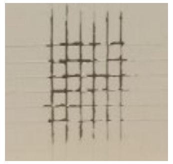
Direct to Metal Coatings Challenges
(Corrosion and Wet Adhesion)

300hr B117 @ 2mil DFT

Prototype F

CRS Dry

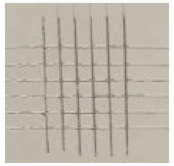


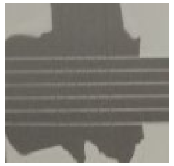


CRS Wet

Prototype G

CRS Dry

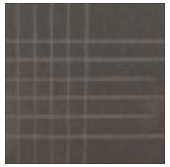


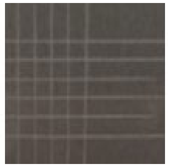


CRS Wet

Prototype H

CRS Dry





CRS Wet

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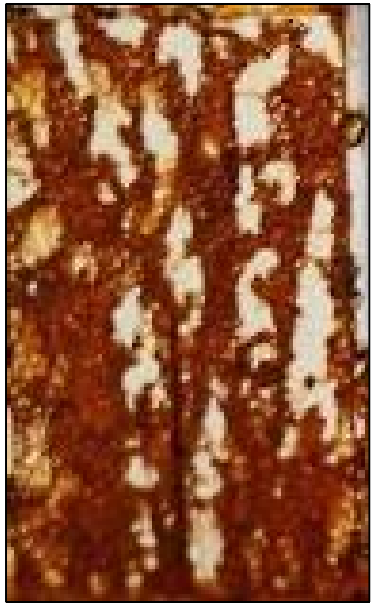
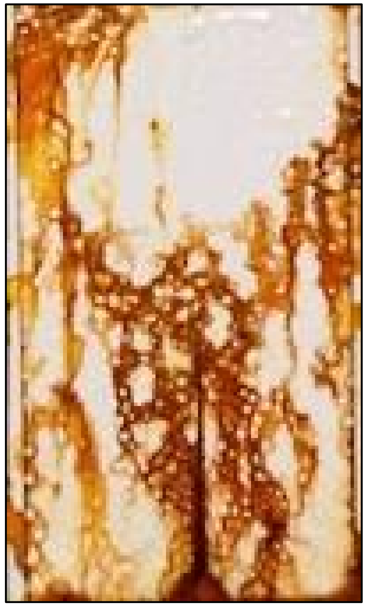
Direct to Metal Coatings Challenges
(Thin Film Corrosion)

Corrosion resistance at 300hrs in B117

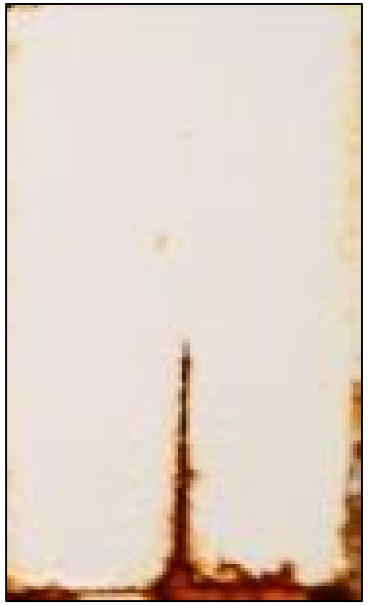
Benchmark 50g/L product



1mil

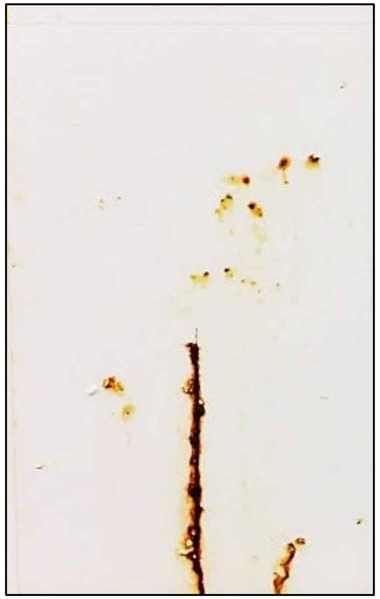


2mil

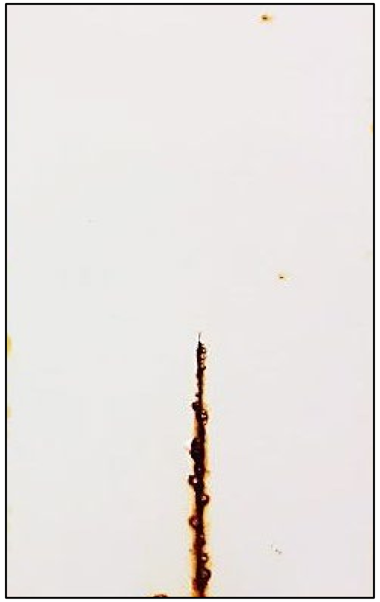


3mil

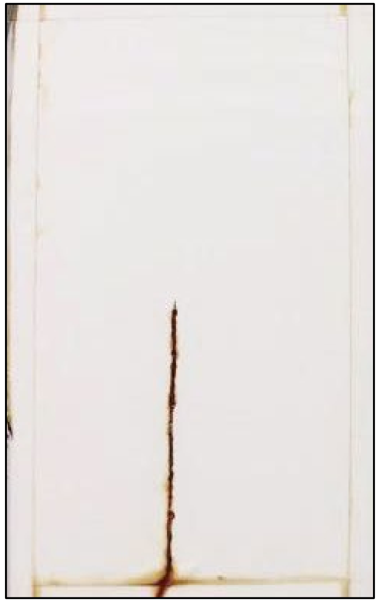
EPS® 2580



1mil



1.5mil



2mil

Market Gap Analysis

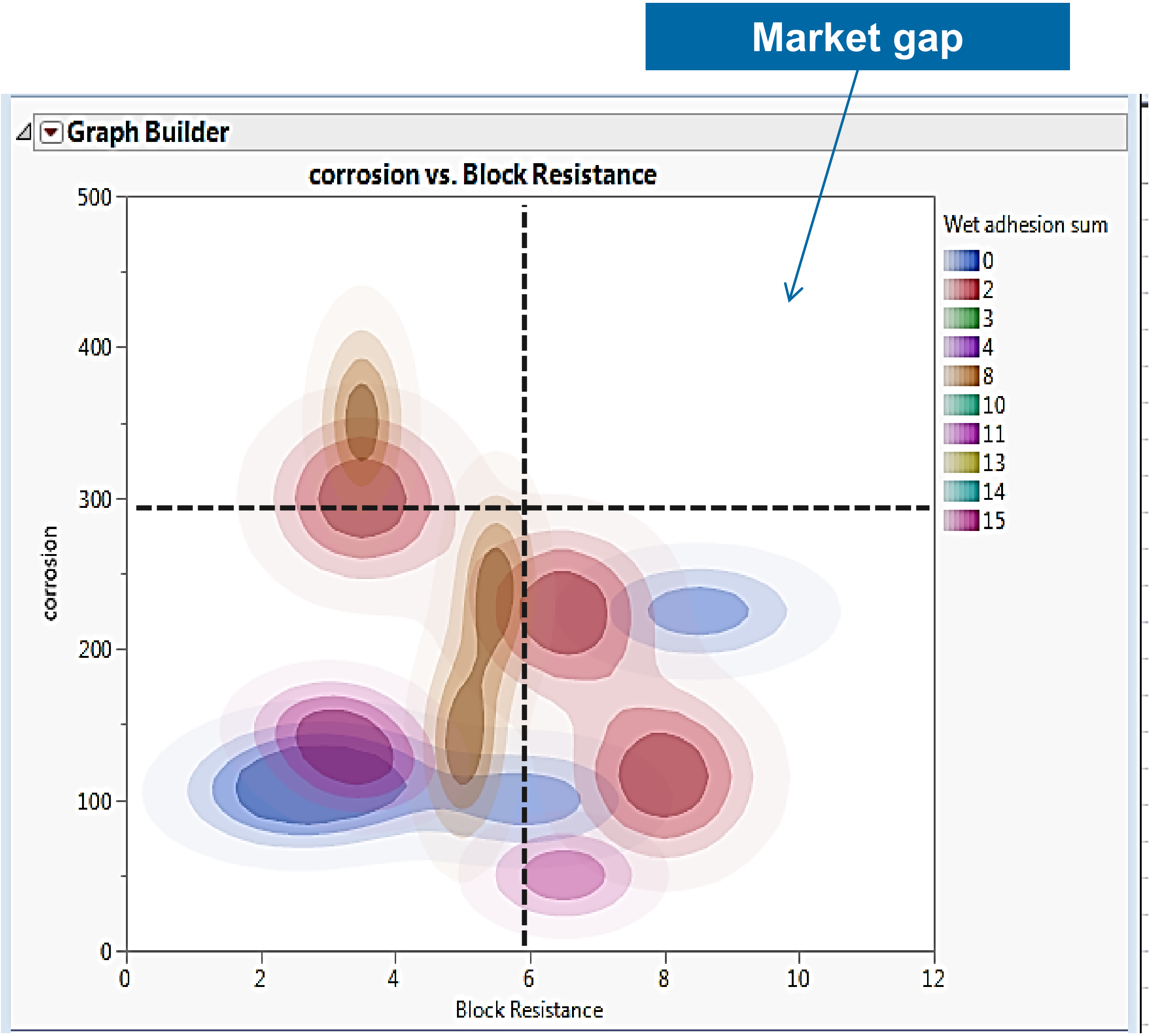
Performance Attribute Balance Resolution

Test Protocol

- Block Resistance tested after 24-hr cure at 50°C
- Corrosion tested at 1.5mil DFT after B117hrs
- Colors represent crosshatch wet adhesion on three substrates

Analysis

- Benchmarked 21 resins
- No polymer could achieve 300hrs B117 and pass the rapid block development test



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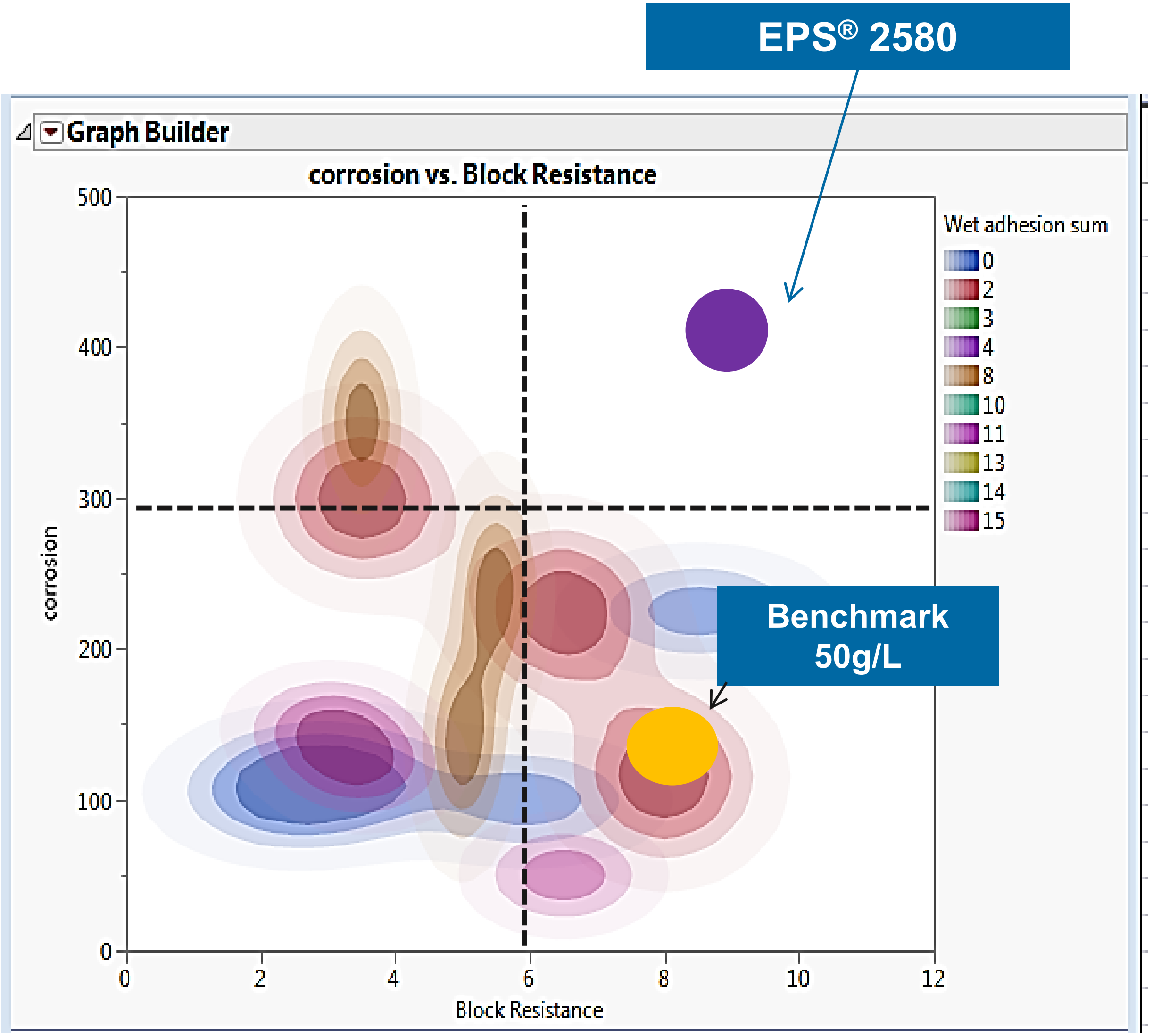
Market Gap Analysis
Performance Attribute Balance Resolution

Careful polymer design and rigorous formulation work filled the market need for a low VOC, block resistant, and thin film corrosion resistant coating.



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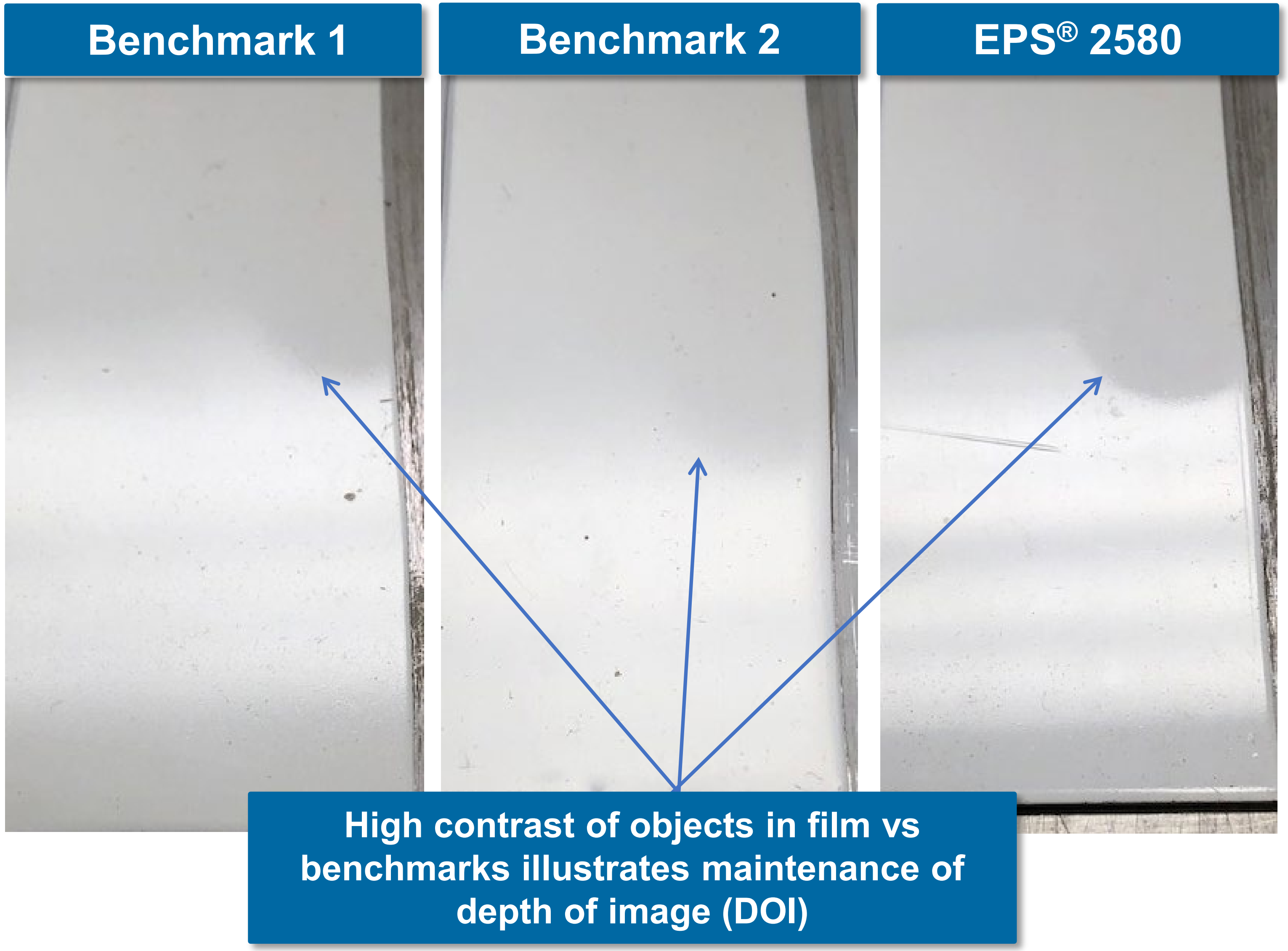
Performance Objectives

16PVC high gloss white direct to metal

Performance Category	Testing Protocol	Target Range	Real World Correlate
Corrosion resistance	B117	500-1000hr with minimal rust/blistering	Substrate Protection
Adhesion composite (aluminum, galvanized, CRS)	Crosshatch 24hr cure	4B – 5B wet/dry on 3 substrates	Long term barrier protection
Block resistance	24hr cure 50°C on a scale of 1-10	6-8	Return to service times and line speed
Gloss Retention	QUV A	1,000-2,000hr 90% gloss retention	Long term aesthetic properties and barrier property retention
Humidity	Cleveland 24hr cure	500-800hr no rusting 50% gloss retention	Long term aesthetic properties and barrier property retention
Hardness	Konig oscillations	15-20	Scratch resistance

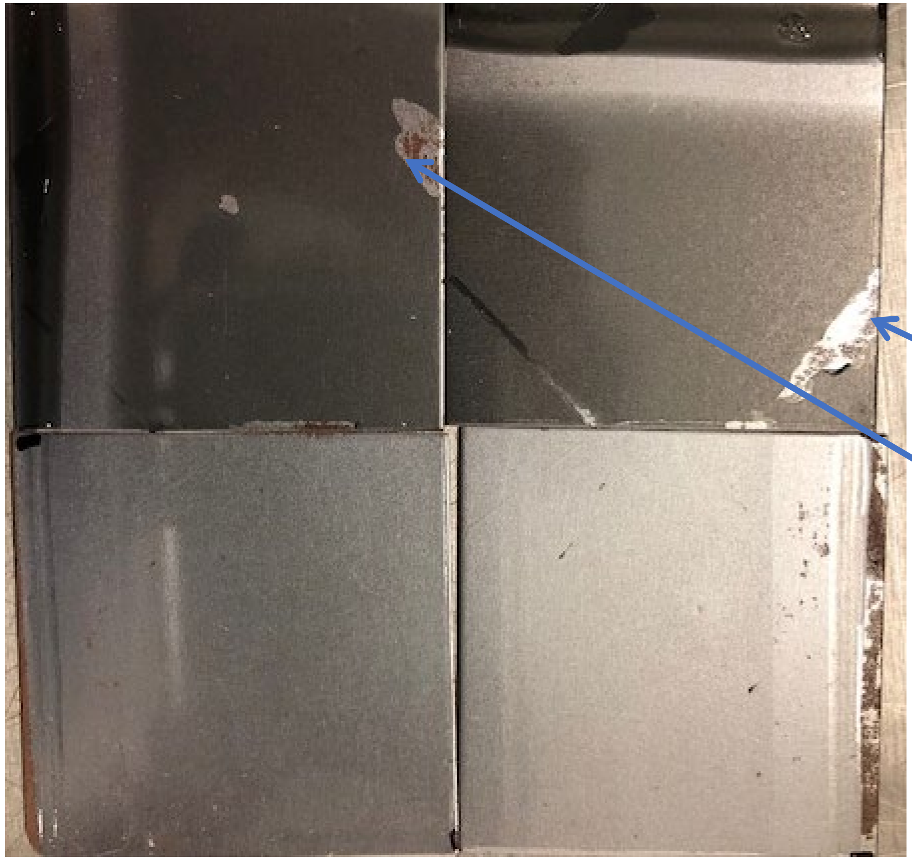
Performance Overview
Cleveland humidity

Coatings applied on aluminum and exposed to humidity for 30 days



Performance Overview

High Temperature Blocking



Benchmark

Delamination indicating film failure

EPS® 2580

Procedure

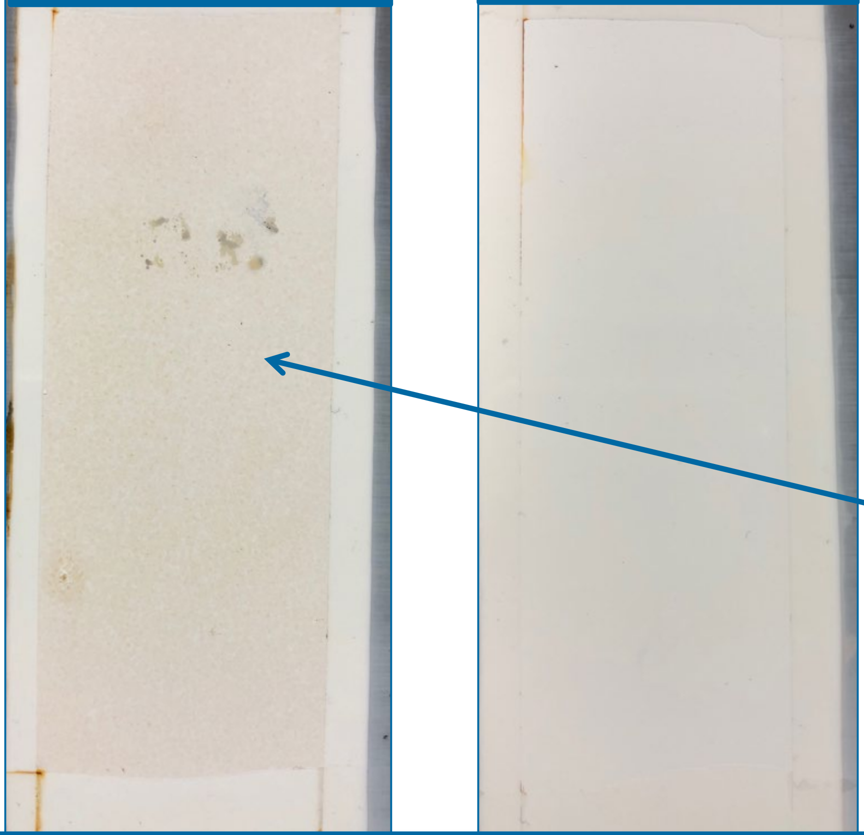
Formulations applied (10mil WFT) and dried for 24hrs. Films were then placed in 60°C Oven for 30min with 1kg weight applied. After 30min, specimens were removed from oven and left at room temp. for 30min with weight still applied. After this the films were separated and assessed for blocking.

Performance Overview

Water Immersion

Benchmark 50g/L

EPS® 2580



Water Immersion panel after 96hr

- Water immersion resistance is critical to protective coatings performance
- Provides insight into ponding water resistance

Benchmark materials not only blister during immersion but also allow the substrate to corrode

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Binder Formulation Interactions
Clear and pigmented coatings

- Formulation components have a profound influence on the final properties of the film.
- Factors manipulating final film properties in clear and pigmented coatings were evaluated.
- Care should be taken in selection of filming aids and pigmentation

Formulation Variation

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Clear Coatings
Coalescent Impact

The use of a hydrophobic (polymer miscible) solvent is recommended

Use of Hydrophilic coalescents can impact field rusting

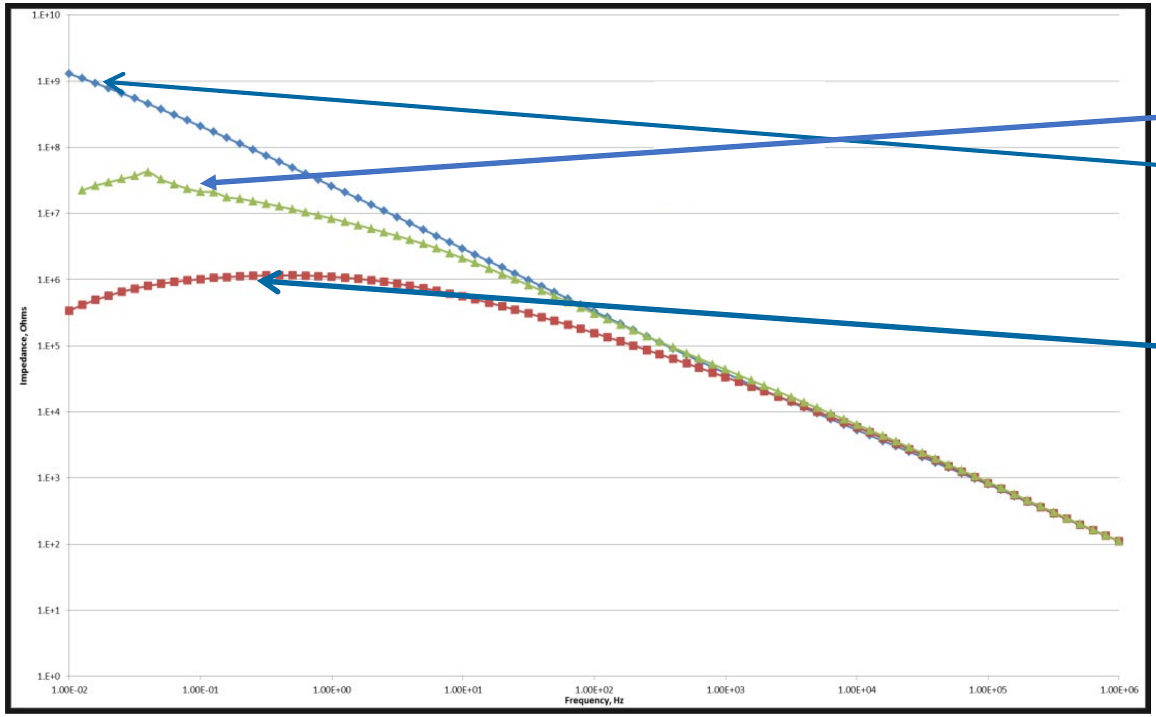
10% Water Miscible A

10% Water Miscible B

10% Polymer Miscible

Binder Formulation Interactions

Clear and pigmented coatings



*Bode plot courtesy of Niteen Jadhav

Polymer Miscible solvents

Water Miscible solvent

- **Impedance of hydrophobic solvent coalesced film is orders of magnitude higher than one with water miscible.**

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Pigment Binder Interactions
Experiment Design Factors

Hypothesis: By manipulating pigment particle size, pigment oil adsorption, pigment chemistry and latex particle size. There will be a shift in packing behavior and thus a reduction in water uptake and corrosion susceptibility

- Experiments evaluating extender pigment influence on water uptake, corrosion, and electrochemical impedance.
- Factors investigated
  - Pigment particle size
  - Oil adsorption
  - Pigment chemistry
  - Latex particle size
- Sought to elucidate main effects and two way interactions between these variables.
- Evaluating differences between 15PVC (Moderate packing) and 35PVC (Dense packing) systems in their response to variables.

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Experimental Design 1
2 latex with pigmentation variation

- 5 Variables investigated (31runs)
- Polymer Particle size
- PVC 15 or 35
- Pigment oil adsorption
- Pigment
  - $CaCO_3$
    - 3 and 5 micron
  - $BaSO_4$
    - 1 and 3 micron
  - SiO_2
    - 2.4 and 3.5 micron
- Experiment was designed to perform the minimum number of runs to establish a significant statistical model.

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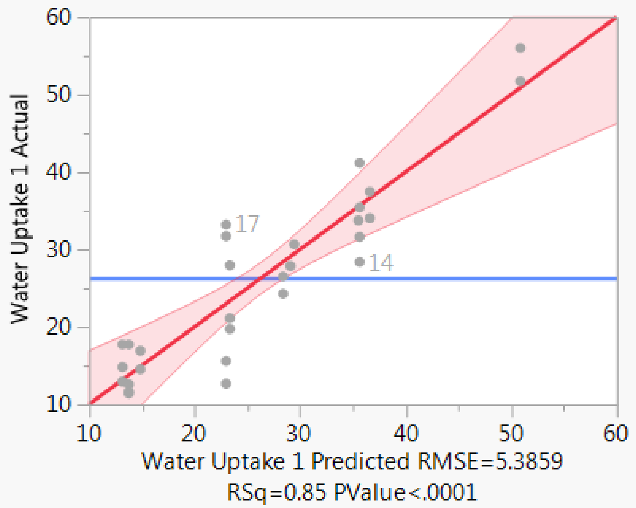
Experimental Results and Modelling
All run model for water uptake

Response Water Uptake 1

Actual by Predicted Plot



Effect Summary

Source	LogWorth	PValue	
PVC(15,35)	6.895	0.00000	
Pigment*Polymer particle size	2.035	0.00923	
Polymer particle size	1.912	0.01224	^
PVC*Pigment	1.857	0.01391	
Pigment	1.602	0.02499	^

Remove Add Edit Undo ☐ FDR ('^' denotes effects with containing effects above them)

- P values indicate that PVC, polymer particle size, pigment particle size and polymer particle size/pigment interaction term and a PVC pigment interactions term are the significant factors.

- Low residuals from the prediction model
- 85% of the variation in water uptake is explained by these variables.

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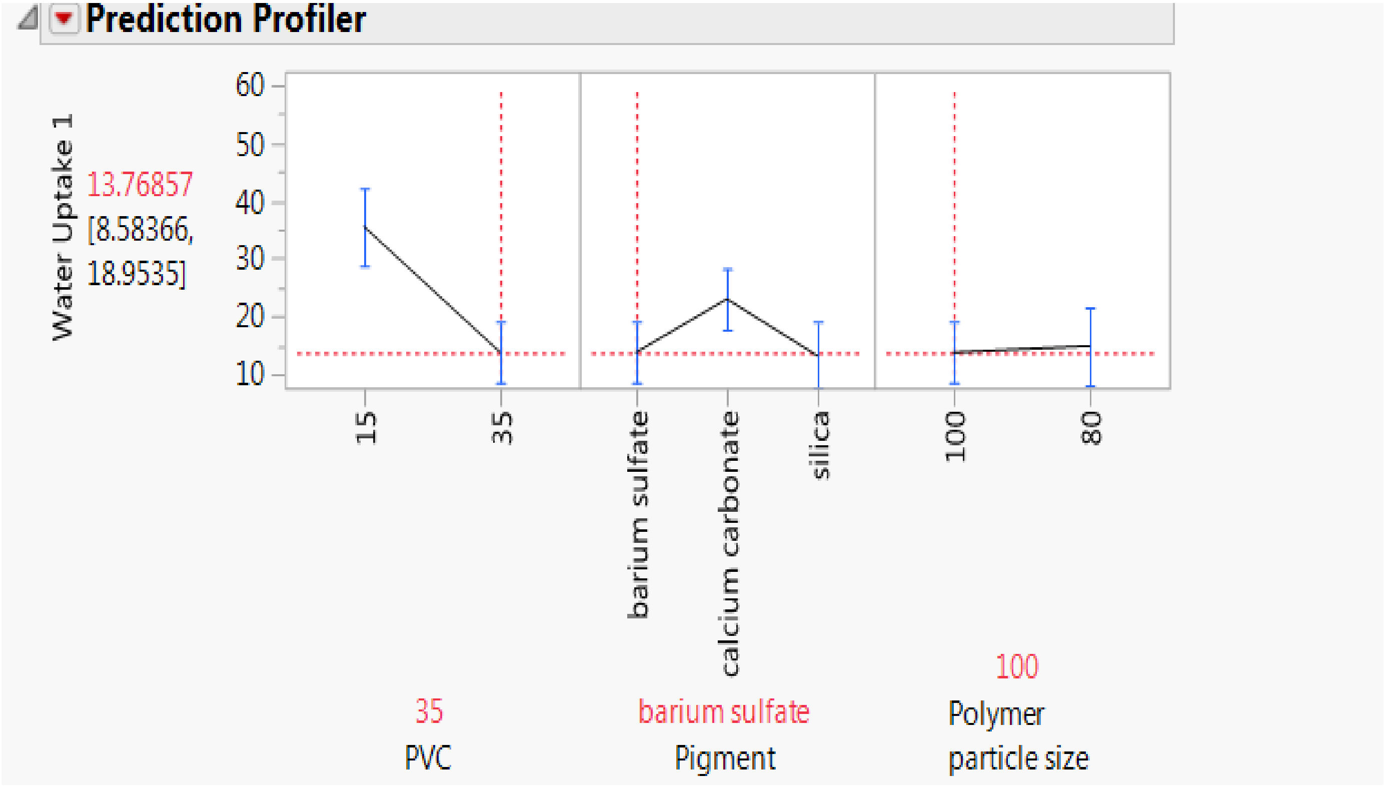
Experimental Results and Modelling
All run model for water uptake



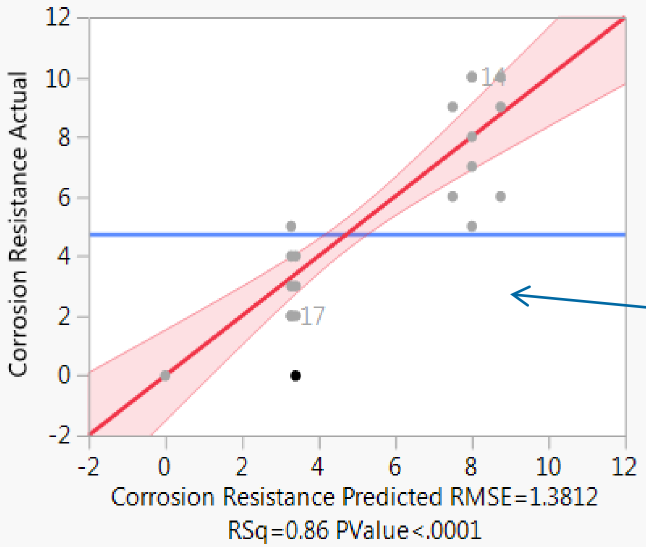
- Performance optimizer tool allows you to minimize or maximize a response.
- Minimizing water uptake provides variable set points seen here.
- 35PVC barium sulfate and 100nm emulsion provide for minimal water uptake. (13.76%)

Experimental Results and Modelling

All run model for corrosion resistance

Response Corrosion Resistance

Actual by Predicted Plot



Effect Summary

Source	LogWorth	PValue
PVC(15,35)	9.540	0.00000
Pigment	2.037	0.00919
PVC*Pigment	1.600	0.02509

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- P values indicate that PVC, Pigment type, and a PVC/pigment type interaction term are the significant variables.
- Low residuals from the prediction model
- 86% of the variation in the corrosion is explained by these variables.

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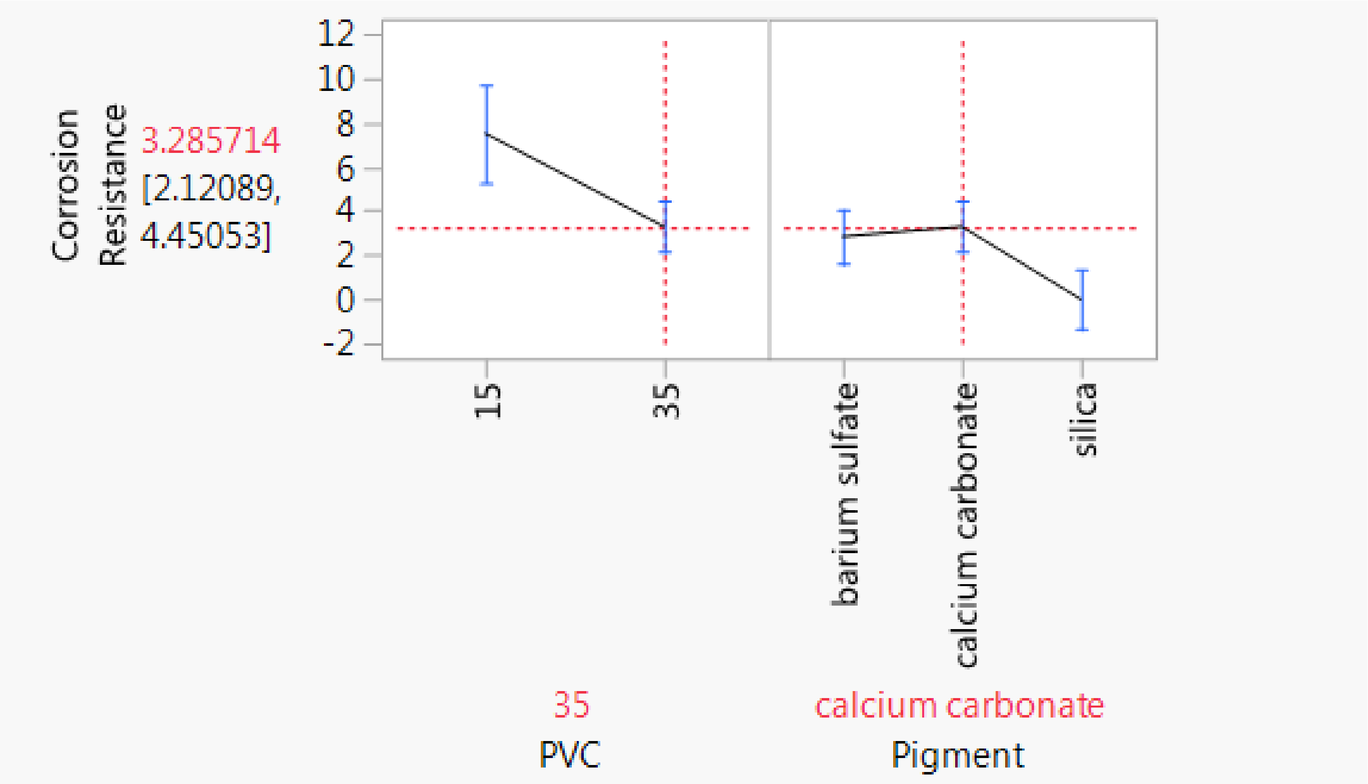
Experimental Results and Modelling

All run model for corrosion resistance



- Running 35PVC maximization exercise for corrosion yields set point seen left.
- 15PVC and barium sulfate provide the optimal corrosion resistance

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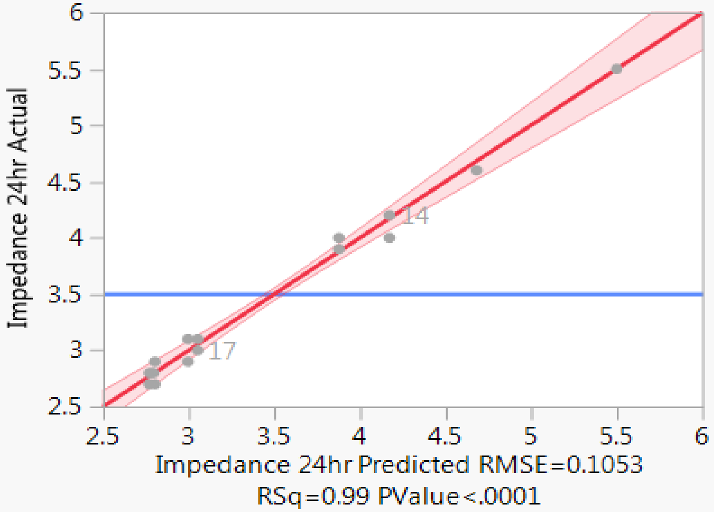
Experimental Results and Modelling

All run model for Impedance

Response Impedance 24hr

Actual by Predicted Plot



Effect Summary

Source	LogWorth	PValue
PVC(15,35)	8.738	0.00000
Pigment	5.697	0.00000
PVC*Pigment	4.800	0.00002
PVC*Particle size	3.014	0.00097
Particle size	2.871	0.00135 ^

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- Modelling Impedance of the films provided the best possible model.
- Significant factors were PVC, Pigment type, Pigment particle size, PVC/pigment type interaction and a PVC/ pigment particle size interaction term.
- 99% of the variability is explained in the model.

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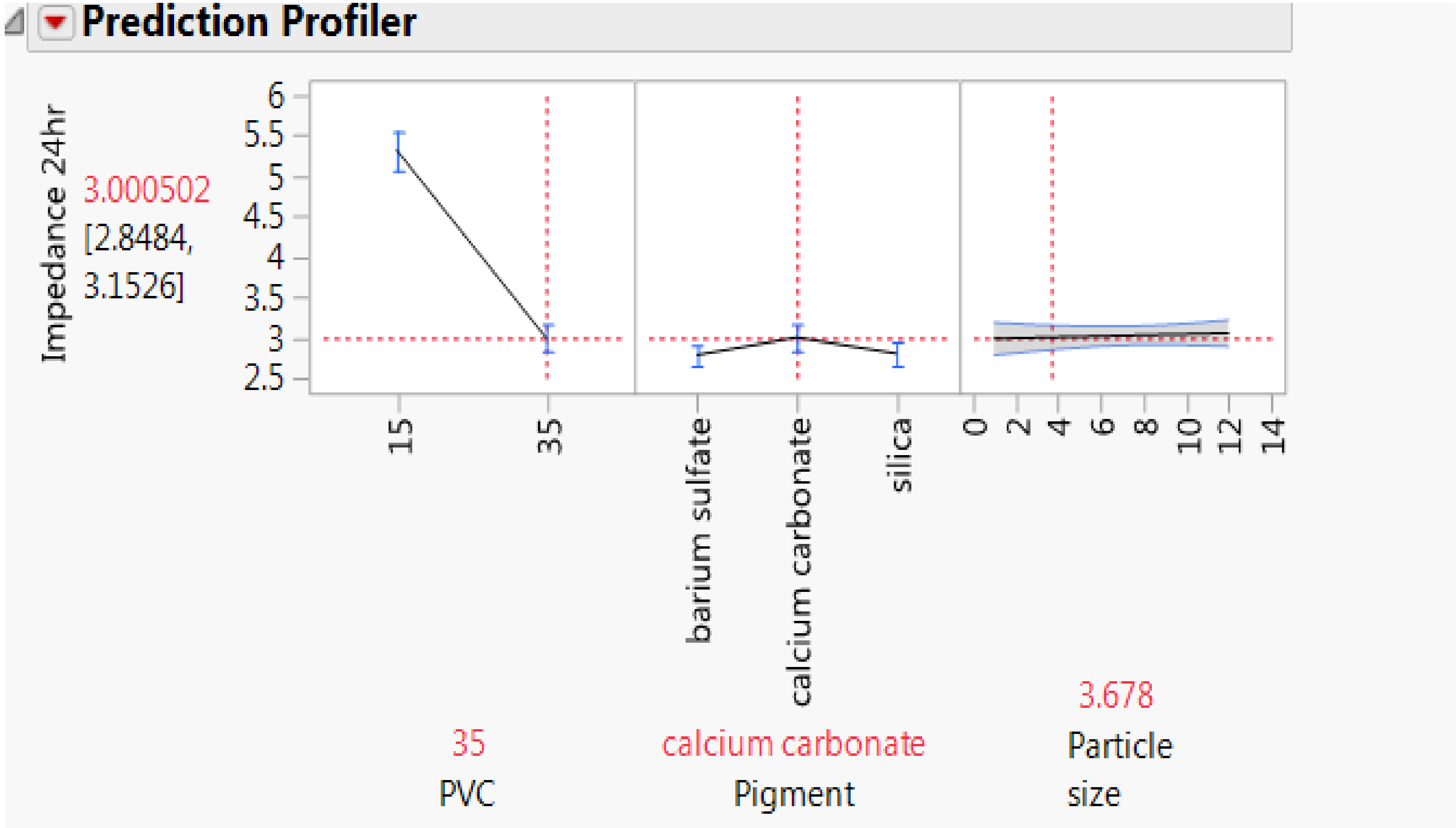
Experimental Results and Modelling

All run model for Impedance



- Running 35PVC maximization exercise for impedance yields set point seen left.
- 15PVC and calcium carbonate at 3microns provides the highest impedance of the film.
- 35PVC films were found to have minimal fluctuations in impedance from the experimental variables.

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Pigment Binder Experiment
Findings, Conclusions and future work

The experiment elucidated a number of interesting phenomena

- 35PVC films took up less water than did comparable 15PVC formulas
- However the 35PVC formulas did not provide improved corrosion resistance suggesting other factors are at play.
- Barium sulfate extenders provided both the lowest water uptake and the best corrosion performance irrespective of PVC.
- 35PVC films showed variation in corrosion and water uptake but not in impedance behavior.
- Findings provide an impetus to further the understanding of packing behavior in latex films. (morphology or interfacial surface area)

New DTM Resin Platform

In Conclusion

- Waterborne topcoats, and direct to metal coatings present numerous challenges to modern formulators
- Formulating in lower sheens and in primer formulations adds additional complexity to polymer design
- Developing an understanding of the binder/formulation interactions is critical to achieving optimal performance in these demanding applications

Development and Experimental
Technology Team

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QUESTIONS

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