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Metal Adhesion and Corrosion Resistance of Coatings

GOLDEN GATE SOCIETY FOR COATINGS TECHNOLOGY

HALF DAY SEMINAR

JANUARY 28, 2019

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Corrosion Control

The chemical or electrochemical reaction between a material and its environment that produces a deterioration of the material and its properties

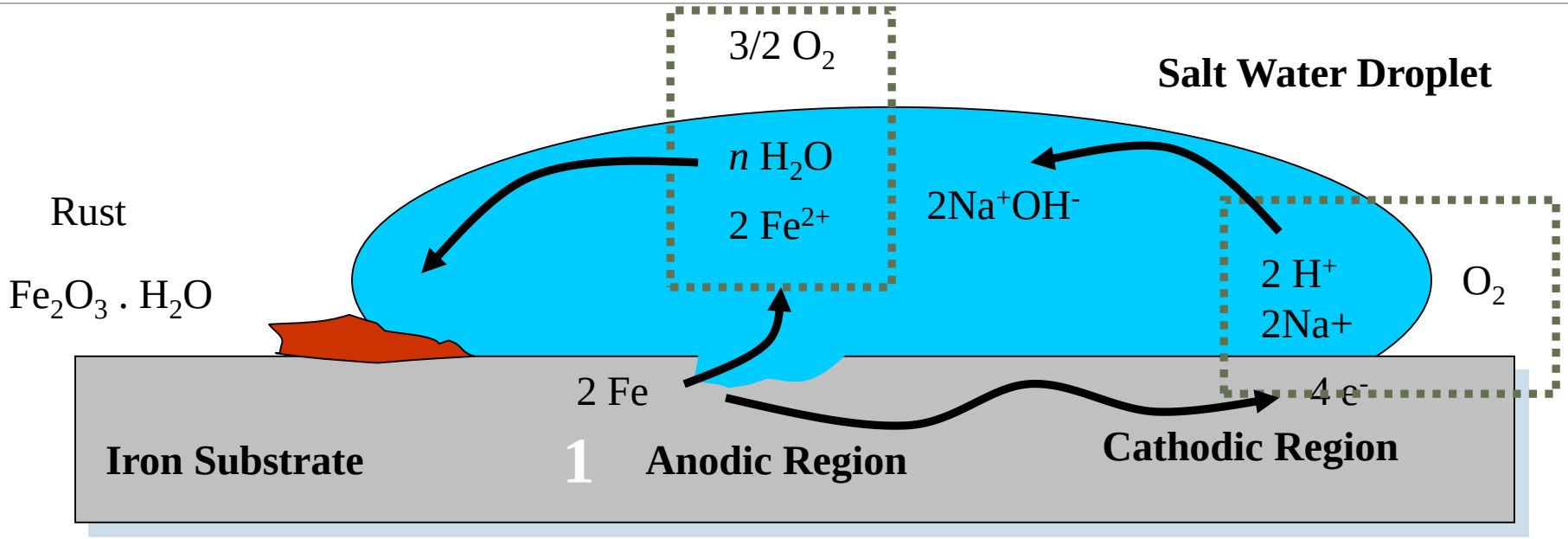
In the United States, costs associated with corrosion estimated between 1% and 3 % of the gross domestic product*

Cathodic Protection Protects one metal by connecting it to another metal that is more anodic, according to the galvanic series

Barrier Protection Provided by a protective coating that acts as a barrier between corrosive elements and the metal substrate

*Orman, S. (1976): 'Economic Aspects of Corrosion', ed., by Shreir L. L. in Corrosion, Vol 2, Corrosion Control, Newnes – Butterworths, London, pp 10: 3 – 6.

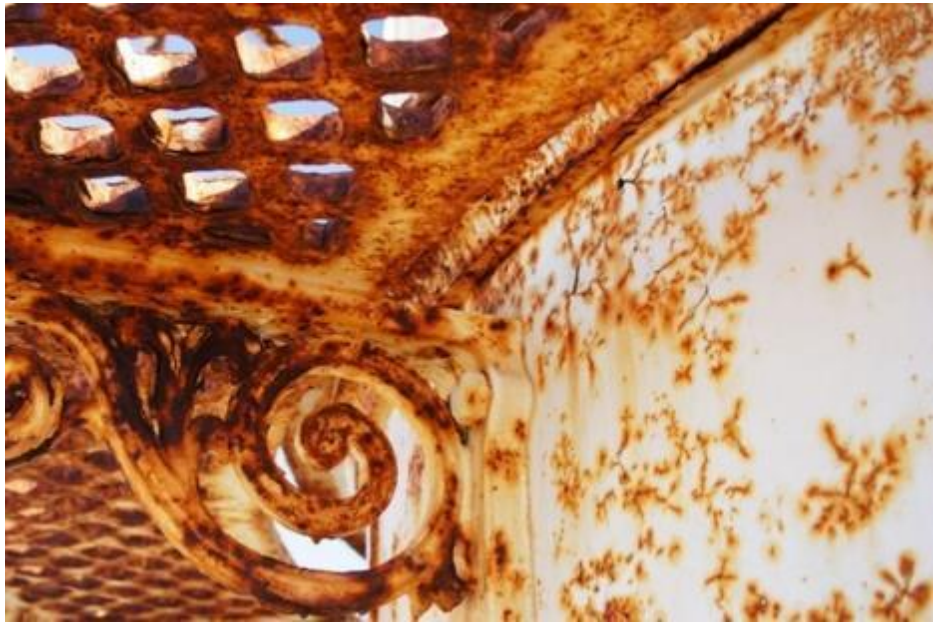
Chemistry of Corrosion



1. **Oxidation of Fe yields electrons which travel through the metal.**
2. **Electrons at the Fe (inactive) cathode reduce O_2 to OH^-.**
3. **The Fe^{2+} migrates through the drop and reacts with OH^- and H_2O to form rust.**

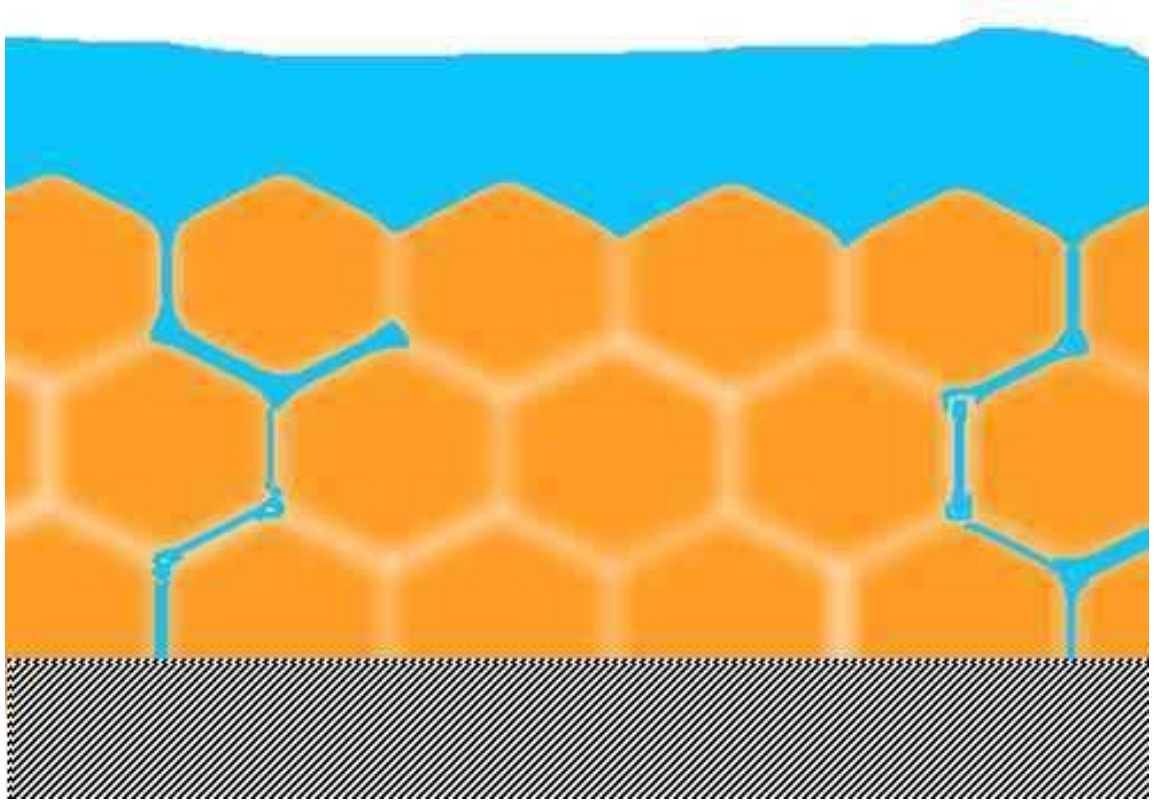
Corrosion: Coated Steel

- Water and Oxygen can penetrate most organic coatings fairly easily
- Water can create channels for ions to travel through the coating
- Water, ions and oxygen are then in direct contact with the steel, corrosion can start

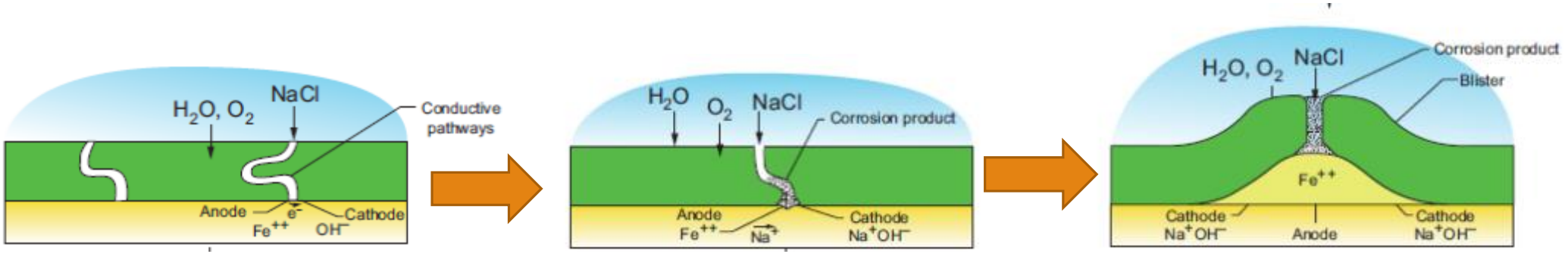


Conductive Pathways

- Water attack on hydrophilic regions
- Pathways develop along boundaries of polymer structure units
- Allows the ions to penetrate the coating



Formation of Blisters

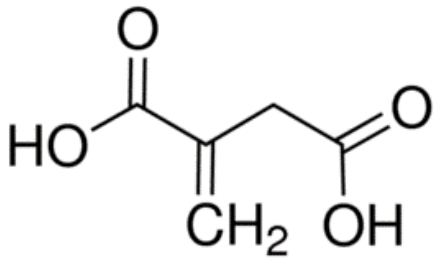


T. Nguyen, J.B. Hubbard, and J.M. Pommersheim, Unified Model for the Degradation of Organic Coatings on Steel in a Neutral Electrolyte, J. Coating. Technol., 1995

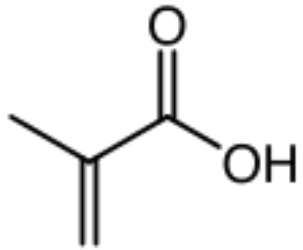
Improving Corrosion Resistance

- Water resistance
  - Hydrophobic polymers & films
- Wet and dry adhesion
- Alkali resistance
- Barrier properties
  - Highly crosslinked system

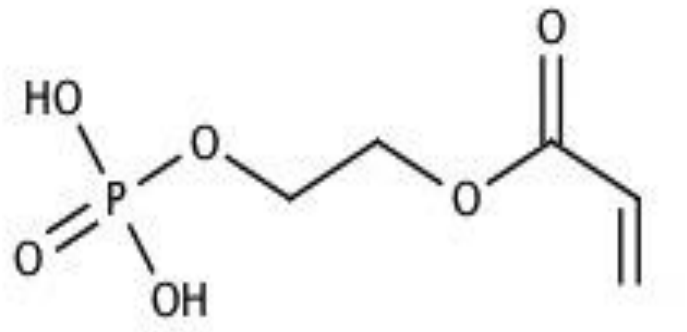
Metal Adhesion & Crosslinking



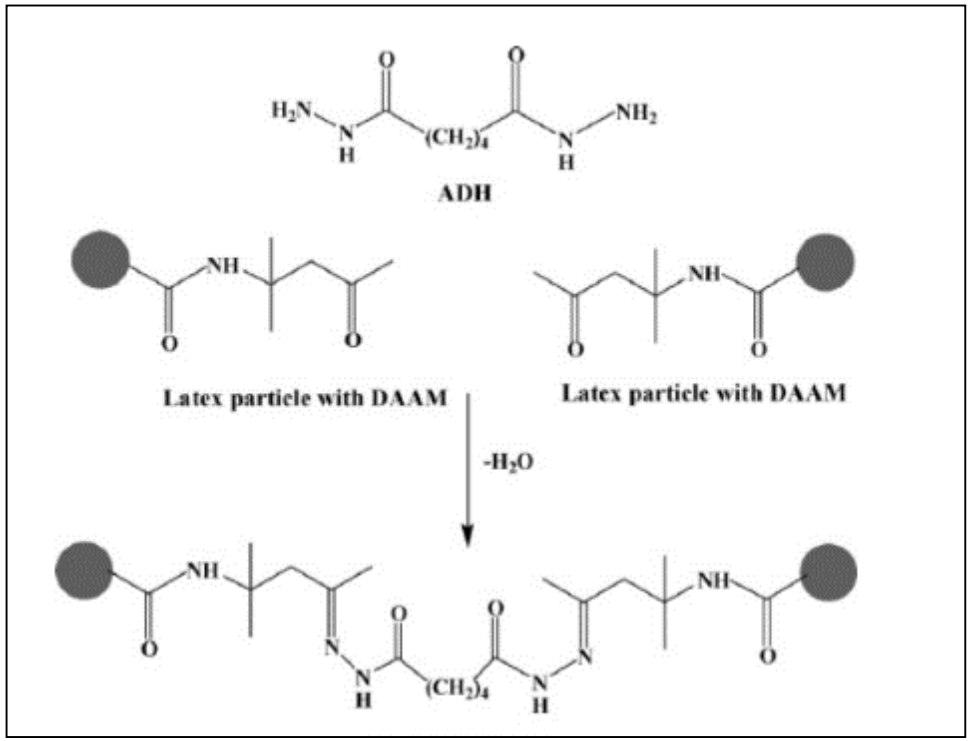
Itaconic



Methacrylic



Phosphate Monomer



DAAM / ADH Crosslinking

Needs – Low VOC Water Based DTM

- Improved chemical resistance
- Improved corrosion resistance with good adhesion
- Improved gloss retention

Hybrid Polymerization with Hydrophobic Resins

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Hybrid vs Cold Blend

- Phase Compatibility
- Coating Stability

Potential

- Improved Barrier Properties?
- Improved Chemical Resistance?
- Better film alkali resistance?

Formulation

Raw Materials	Weight (lbs)	Volume(gals)
Water	40.00	4.80
Ammonium Benzoate	1.00	0.10
Flash Rust Additive	1.00	0.09
Ammonia	1.00	0.12
Dispersant 35%	10.00	1.10
Wetting Agent	1.50	0.19
Defoamer	1.00	0.12
Titanium Dioxide	200.00	6.00
Water	30.00	3.60
Cowles grind for 20 minutes		
Experimental Hybrid Acrylic EXP-1	**590.71**	**68.06**
Water	96.03	11.53
Hydrophobic Coalescent	30.00	3.96
Rheology Modifier	2.00	0.23
Glycol Ether	0.78	0.10
Totals	**1,005.02**	**100.00**

Typical Physical Properties

Weight per Gallon	10.05
Weight Solids, %	49.99
Volume Solids, %	39.30
PVC, %	15.55
VOC, gm/L	93.23
Coalescent, %	10.42

Polymers:

1. Exp-1 Hybrid Sty/Acrylic w Hydrophobic Polymer
2. Variant #1 No Hydrophobic Polymer

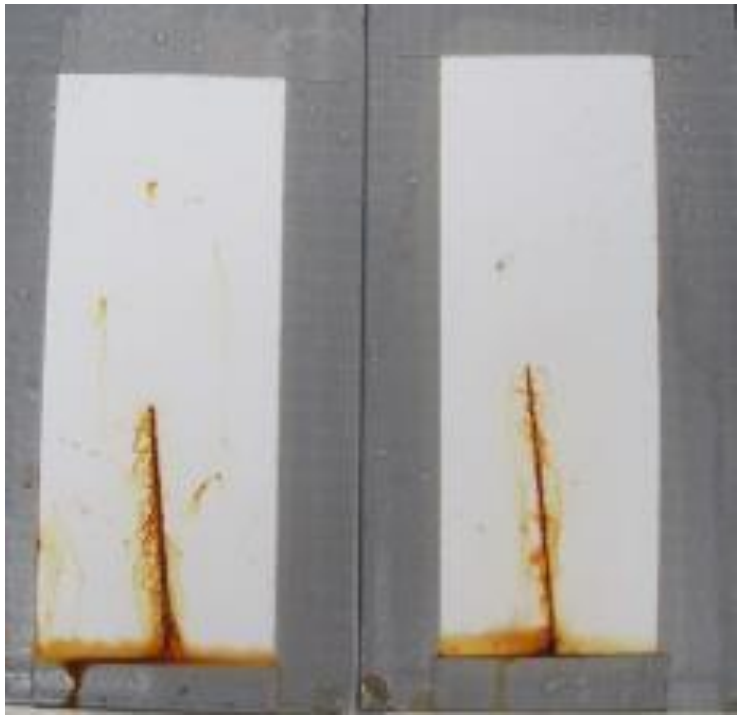
Property	EXP-1 Hybrid	Variant 1 No Hydrophobic Polymer
Volume Solids	39.31	39.31
PVC	15.62	15.62
VOC (gm/L)	90	90
Gloss		
20 Deg Gloss	45	60
60 Deg Gloss	77	89
Adh to **Matte CRS** Dry Time 1 Week Dry, 1 Hour Soak		
Adh to CRS Wet Knife Peel (1 - 10, 10 Best)	4	4
Adh to CRS Wet X Hatch % Removed	0%	0%
Adh to **Polished CRS** 1 Week Dry, 1 Hour Soak		
Adh to CRS Wet Knife Peel (1 - 10, 10 Best)	4	4
Adh to CRS Wet X Hatch % Removed	0%	0%
Salt Fog : B117, Matte CRS, 200 Hours		
Field Rust (1 - 10, 10 Best)	9	3
Undercut at Scribe, mm	3	6
Blistering (Size 1 - 10, 10 Best)	5F	8D

Wet Adhesion to CRS…All Equal

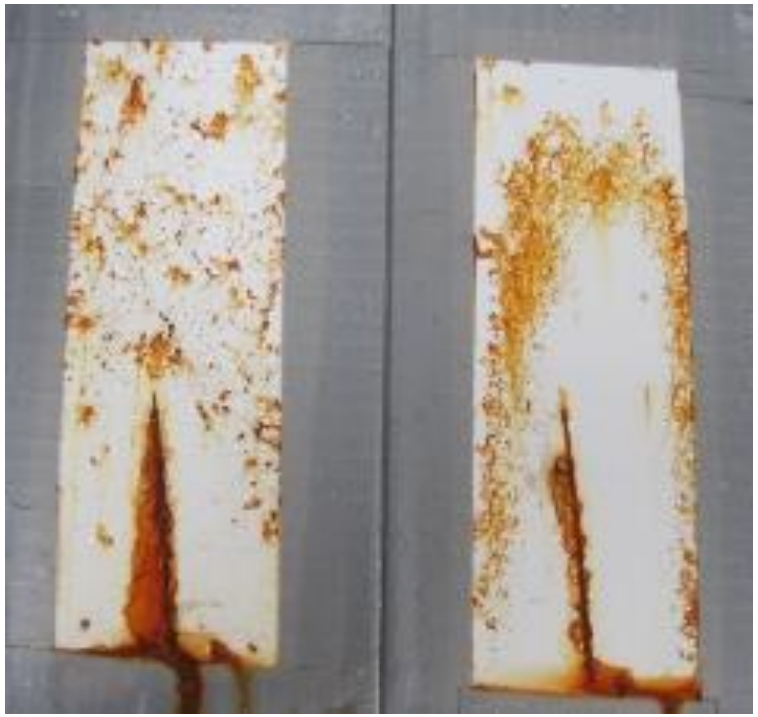
But Corrosion Significantly Improved

Comparison to Non Hybrid Analogue 200 Hours B117

Experimental
Hybrid Sty / Acrylic EXP-1



Variant 1
Sty / Acrylic
No Hydrophobic Polymer



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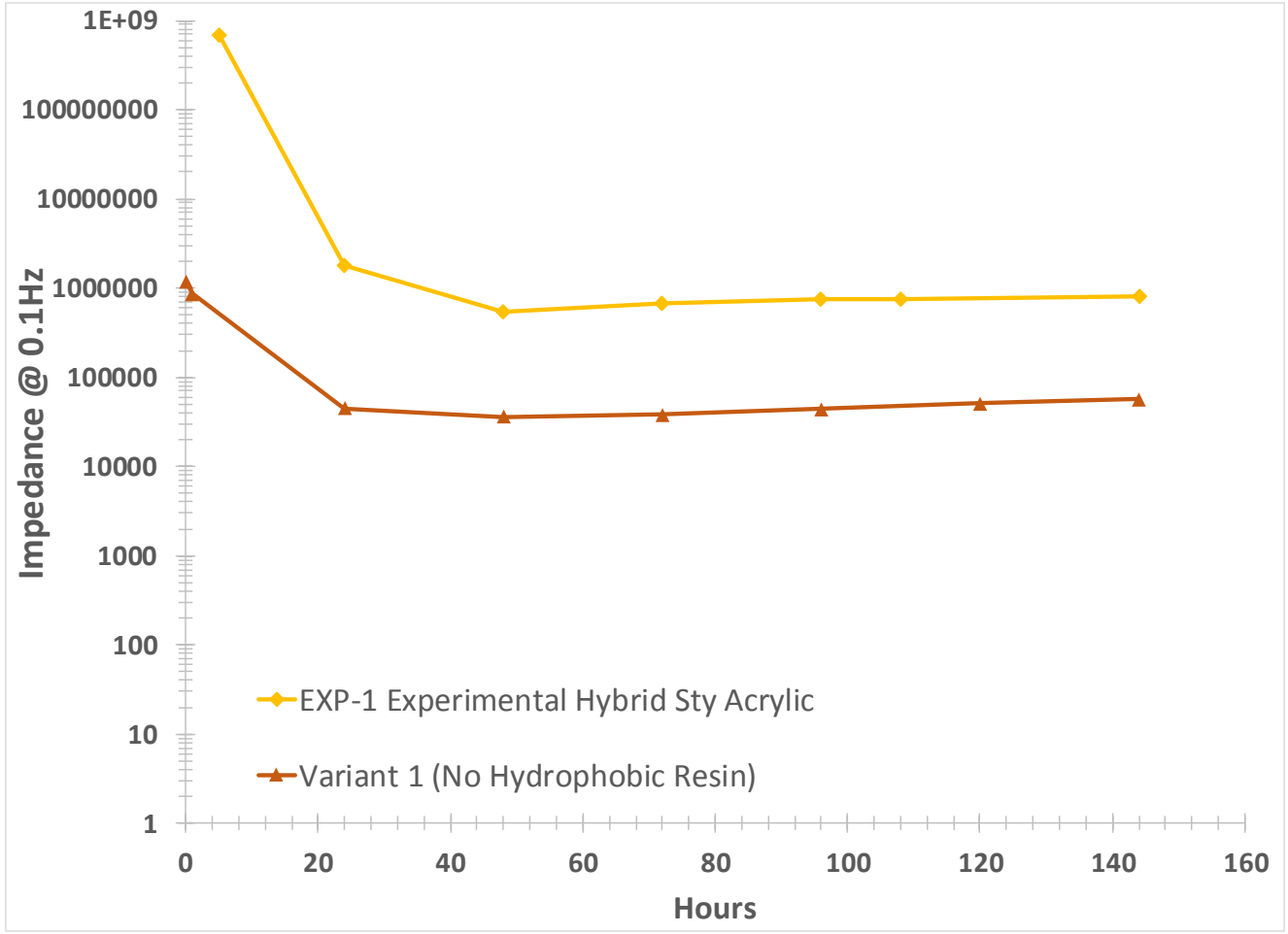


Electrochemical Impedance Testing

3 mils Wet Film on CRS
5% NaCl; 0.1 Hz; 24 Hr Intervals

Chemical Resistance – 1 Hour Spot Test

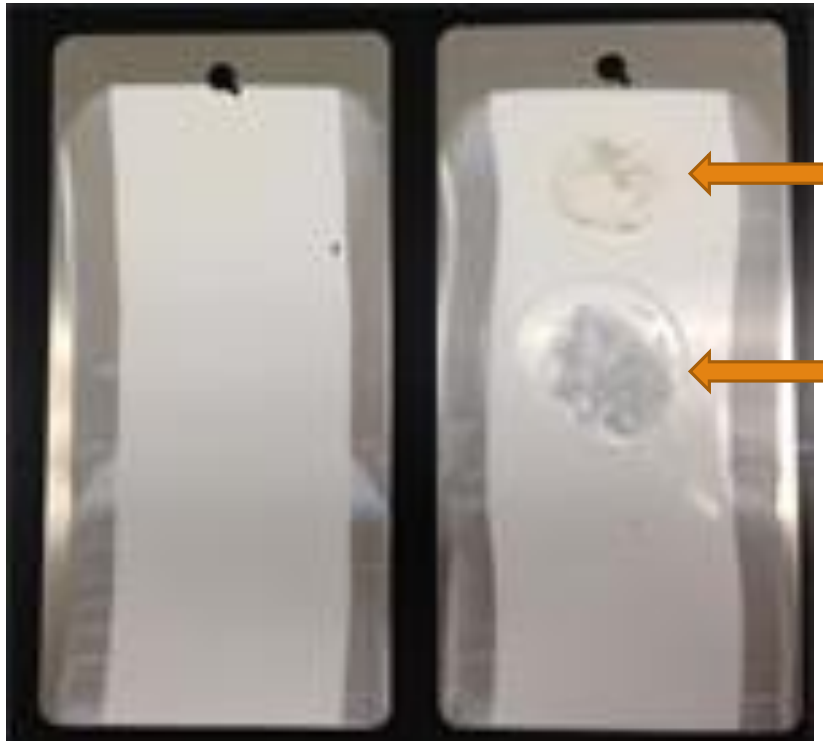
EXP-1 Hybrid
Sty Acrylic

Variant 1
No Hydrophobic
Polymer

Gasoline

MEK

2% NaOH



Blistered and Soft

Dissolves

Comparison to Commercial Polymers (34 VS, 17.7% PVC Gloss White DTM)

- EXP-1 Hybrid Styrene Acrylic, Tg 17C, MFFT 11C
  (100 VOC Formulation)

- Comp1: Low VOC Self Crosslinking S/A, Tg ~20C
  (100 VOC Formulation)

- Comp2: Low VOC Acrylic, Tg 27, MFFT 14
  (100 VOC Formulation)

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Gloss, Scrub and Chemical Resistance

Property	EXP-1 Hybrid Sty Acrylic	Comp 1 Low VOC Sty Acrylic	Comp 2 Low VOC Acrylic
Volume Solids	35.00	36.00	35.00
PVC	17.71	17.71	17.71
VOC (gm/L)	95	95.00	95.00
Gloss			
20 Deg Gloss	53	28.40	59.50
60 Deg Gloss	79	69.20	82.90
Scrub Conditions			
Scrub Cycles to First Break	915 / 1104	540 / 753	620 / 615
Scrub Cycles to Cut Through	1172 / 1340	880 / 900	700 / 675
Scrub First Break % of Control	Ctrl	64	58
Scrub Cut Through % of Control	Ctrl	71	52
Chemical Resistance: 2 Week Dry, 1 Hour Spot			
Gasoline (Rated 1 - 5. 5 Best)	4 (Sl. Softer)	4 (Sl. Softer)	4 (Sl. Softer)
MEK (Rated 1 - 5. 5 Best)	4 (Sl. Softer)	4 (Sl. Softer)	4 (Sl. Softer)
2% NaOH (Rated 1 - 5. 5 Best)	5 (Exc.)	5 (Exc.)	5 (Exc.)

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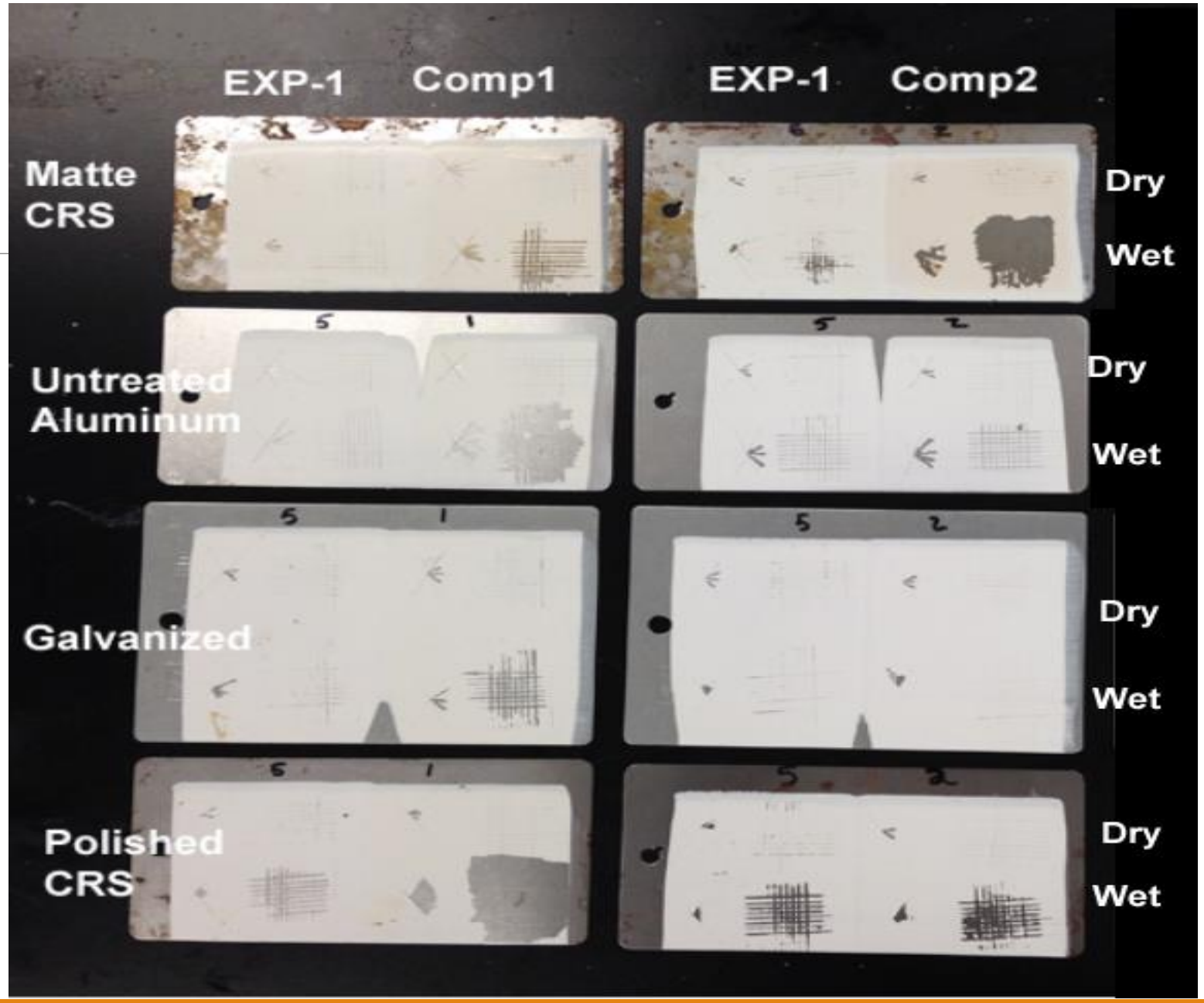
Wet Adhesion to Metal

Property	EXP-1 Hybrid Sty Acrylic	Comp 1 Low VOC Sty Acrylic	Comp 2 Low VOC Acrylic
Adh to Matte CRS 1 Week Dry, 1 Hour Soak			
Adh to CRS Wet Knife Peel (1 - 5, 5 Best)	4	2	0
Adh to CRS Wet X Hatch % Removed	0	35	100
Adh to Untreated Al 1 Week Dry, 1 Hour Soak			
Adh to Al Wet Knife Peel (1 - 5, 5 Best)	3	0	3
Adh to Al Wet X Hatch % Removed	10	100	10
Adh Galvanized Steel 1 Week Dry, 1 Hour Soak			
Adh Wet Knife Peel (1 - 5, 5 Best)	4	2	3
Adh Wet X Hatch % Removed	0	50	0
Adh to Polished CRS 1 Week Dry, 1 Hour Soak			
Adh Wet Knife Peel (1 - 5, 5 Best)	0	0	0
Adh Wet X Hatch % Removed	40	100	60

Adhesion to Metal



QUV and Corrosion

Property	EXP-1 Hybrid Sty Acrylic	Comp 1 Low VOC Sty Acrylic	Comp 2 Low VOC Acrylic
Volume Solids	35.00	36.00	35.00
PVC	17.71	17.71	17.71
VOC (gm/L)	95	95.00	95.00
QUV 300 Hours			
QUV 60 Deg gloss	75	78	88
% 60 Degree Gloss Loss 300 Hrs	-4	8	5
Salt Fog ASTM B117, Matte CRS, 96 Hrs			
Field Rust (1 - 10, 10 Best)	9/9	0/0	9/9
Undercut at Scribe, mm from scribe	5/5	4/4	5/5
Blistering (Size: 1 - 10, 10 Best)	8F/8F	2D/2D	8F/8F

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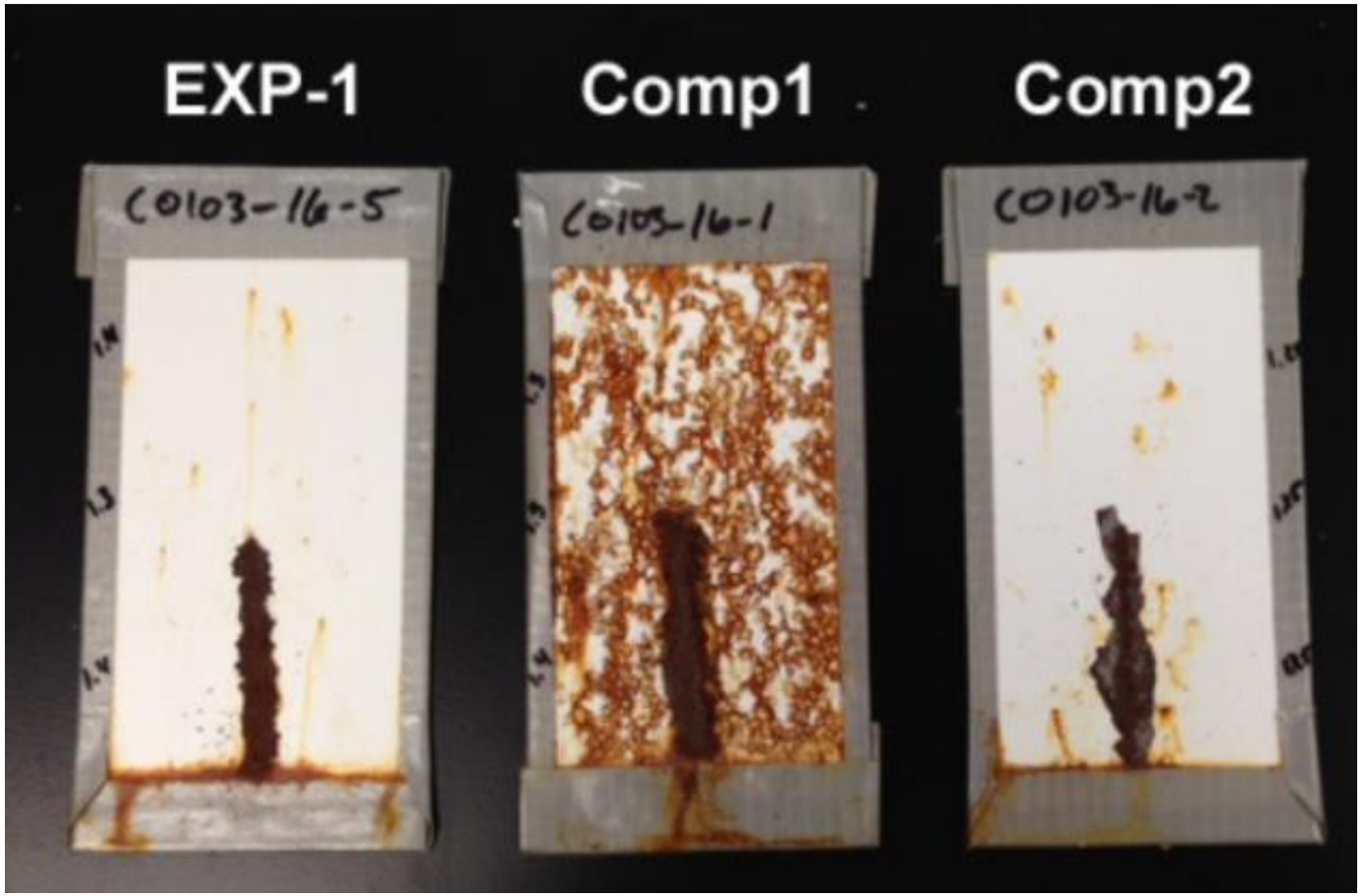
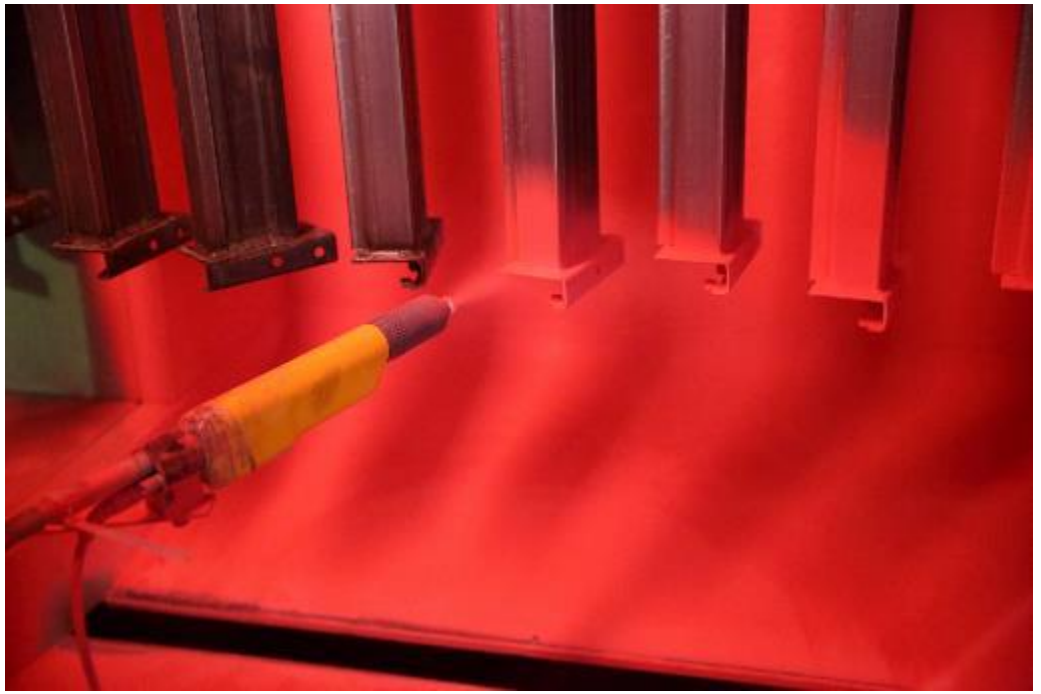
Salt Fog: 100 Hrs B117 (Matte CRS)



Comparative Evaluation – Hybrid DTM

Advantages

- Very good corrosion resistance (B117 Salt Fog)
- Excellent wet and dry adhesion to most metal substrates
- Very good QUV-A Gloss Retention



Conclusion

A hydrophobic polymer hybrid of a styrene acrylic DTM significantly improved the corrosion resistance and chemical resistance

- **Corrosion resistance** is better than one of the competitive low VOC DTM polymers
- **Adhesion** is better than the two competitive low VOC DTM polymers

Work is continuing on optimizing the performance balance for DTM coatings

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Thanks

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