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## Western Coatings Show 2017

# A Novel Acrylic DTM with Next Generation Corrosion Resistance at 50g/L VOC

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# Outline

- Project Background
- Structure/Property Study
- Next Generation Corrosion Resistance
- Solventborne & Waterborne Benchmarks
- Other Performance Properties
- Summary

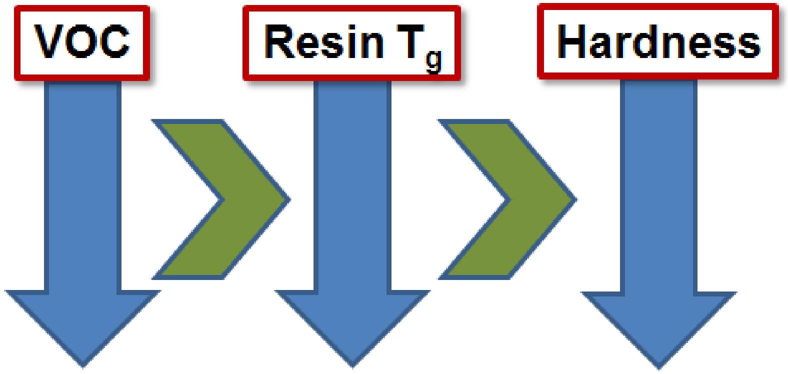
# Project Background

**Project Mandate**

Deliver best in class balanced, low VOC DTM resins

Lower VOC demands result in higher technical complexity in an effort to maintain full balance of properties

Interplay between adhesion and corrosion prompted in depth structure/property investigation



VOC

Resin $T_g$

Hardness

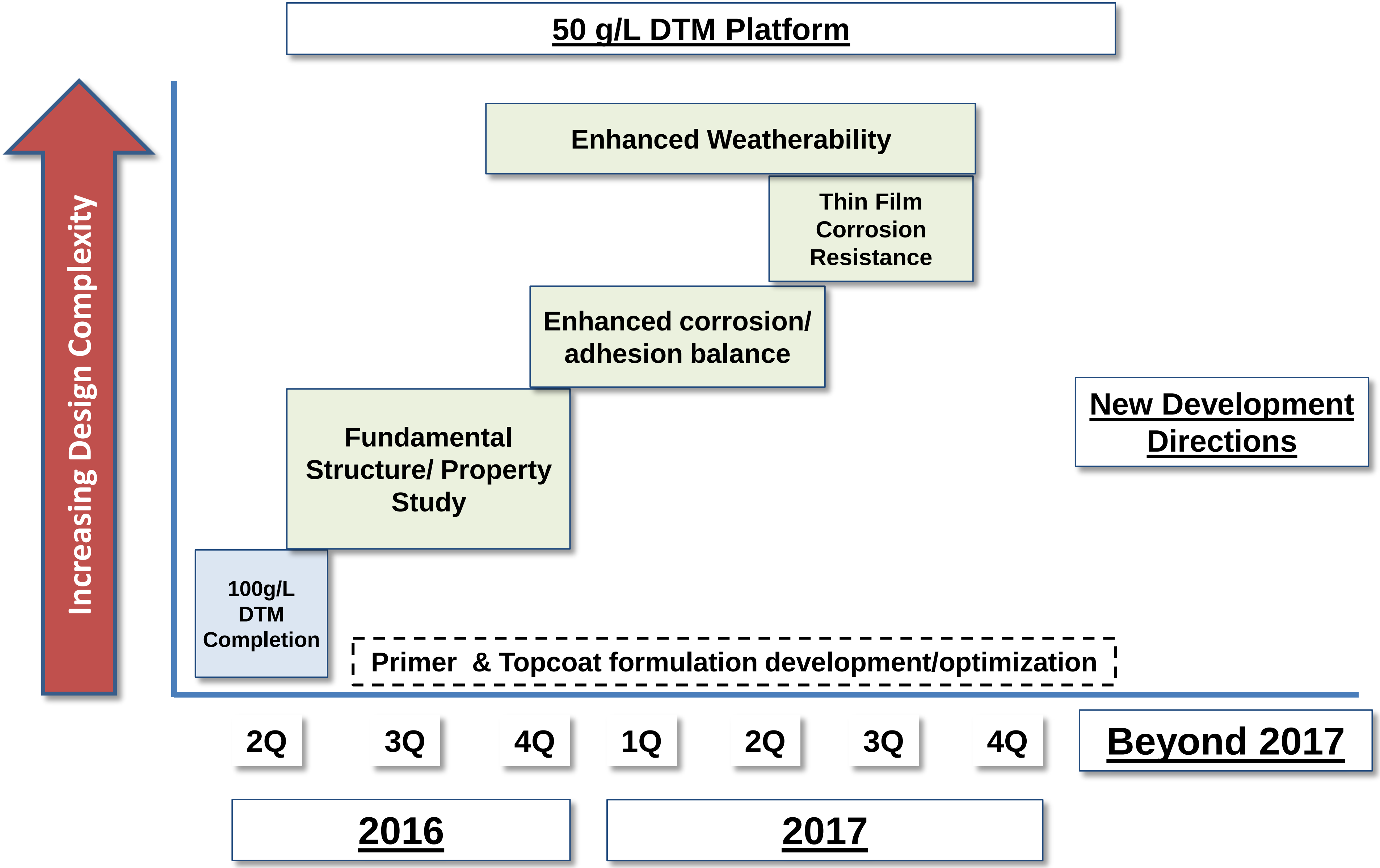
**Performance Tradeoffs**

Lower $T_g$ (or low VOC plasticizer) to lower VOC reduces hardness and block resistance

Some formulation mitigations available, but not ideal

- Fluorosurfactants

# Development Cycle



**50 g/L DTM Platform**

Increasing Design Complexity

Enhanced Weatherability

Thin Film Corrosion Resistance

Enhanced corrosion/ adhesion balance

Fundamental Structure/ Property Study

100g/L DTM Completion

Primer & Topcoat formulation development/optimization

**New Development Directions**

2Q 3Q 4Q 1Q 2Q 3Q 4Q **Beyond 2017**

**2016** **2017**

# Literature Review

**Barrier Properties**

S. Guruviah, *JOCCA*, 53, 1970, 660; P. Kresse, *Pigment Resin Tech,* 2(11), 1973, 21

- $O_2$ transport limiting factor in corrosion protection

**Impedance**

J. Mayne, *Corrosion*, 1976, pp15:24-15:37; Bacon, et al, *Ind Eng Chem*, 40(1), 1948, 161

- Films generally too permeable for barrier properties to be important
- Inhibition of galvanic cell via a high film resistance which impedes electrolyte transport most important factor

**Adhesion**

W. Funke, H. Haagen, *Ind Eng Chem Prod Res Dev*, 17, 1978, 50; E. Parker, H. Gerhart, *Ind Eng Chem*, 59(8), 1967, 53

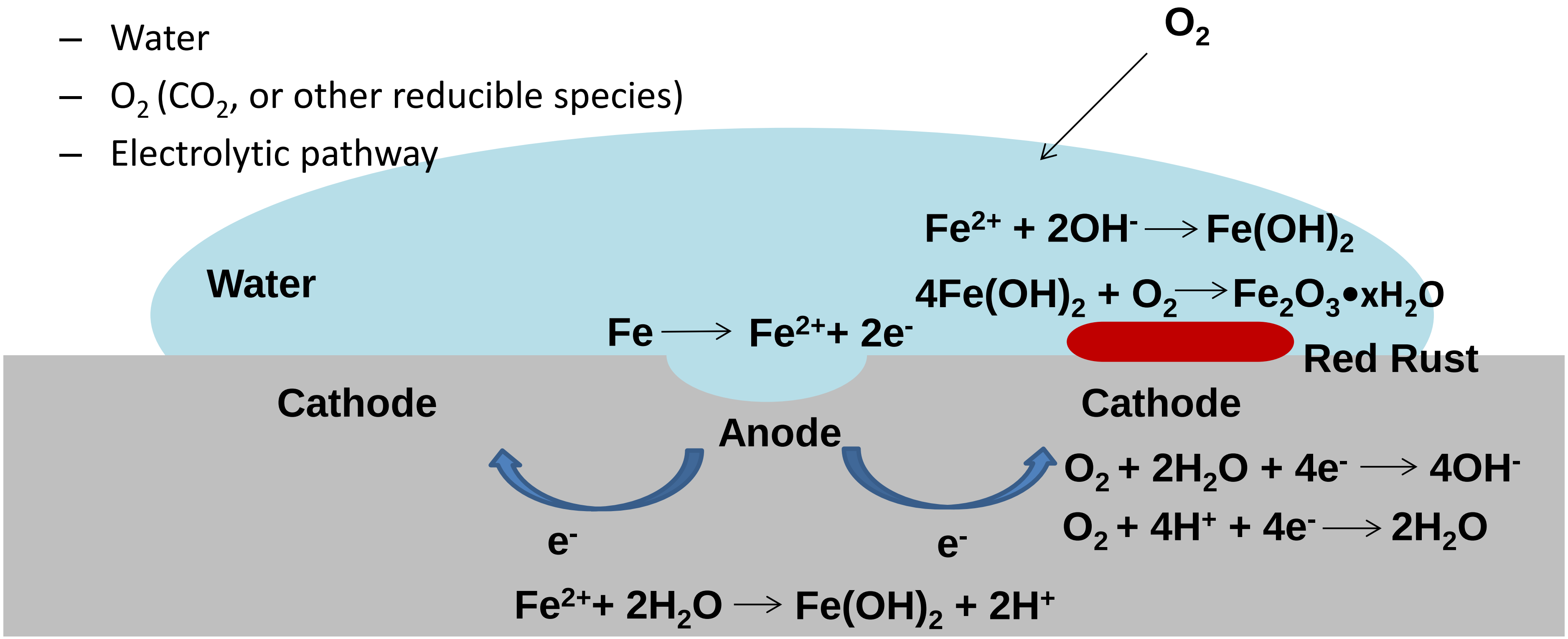
- Loss of adhesion leads to onset of corrosion

See appendix for further reading suggestions

# Corrosion Process - Steel

**Requires**

- Water
- $O_2$ ($CO_2$, or other reducible species)
- Electrolytic pathway



$O_2$

**Water**

$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$

$4Fe(OH)_2 + O_2 \rightarrow Fe_2O_3 \bullet xH_2O$

$Fe \rightarrow Fe^{2+} + 2e^-$

**Red Rust**

**Cathode**

**Anode**

**Cathode**

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

$e^-$

$e^-$

$Fe^{2+} + 2H_2O \rightarrow Fe(OH)_2 + 2H^+$

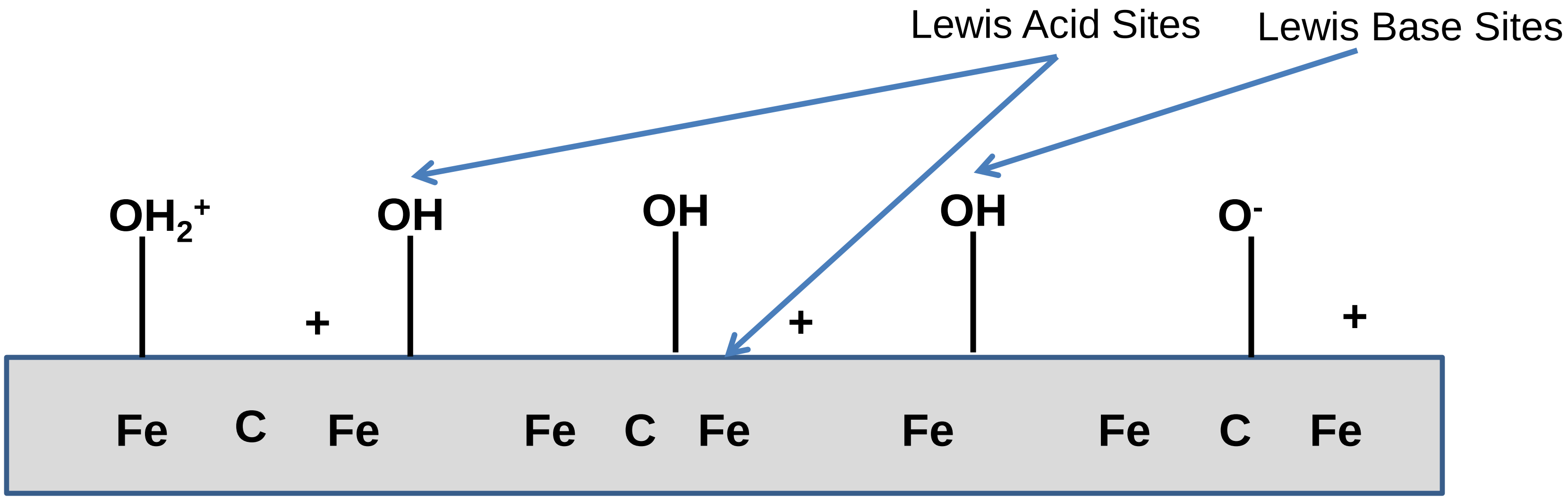
**Possible mechanisms of corrosion prevention**

- Block water penetration
- $O_2$ transport inhibition

**Barrier Properties**

- Adhesion – surface passivation, exclusion of water, etc
- Interference with electrolytic pathway – coating resistance

# Adhesion to Steel



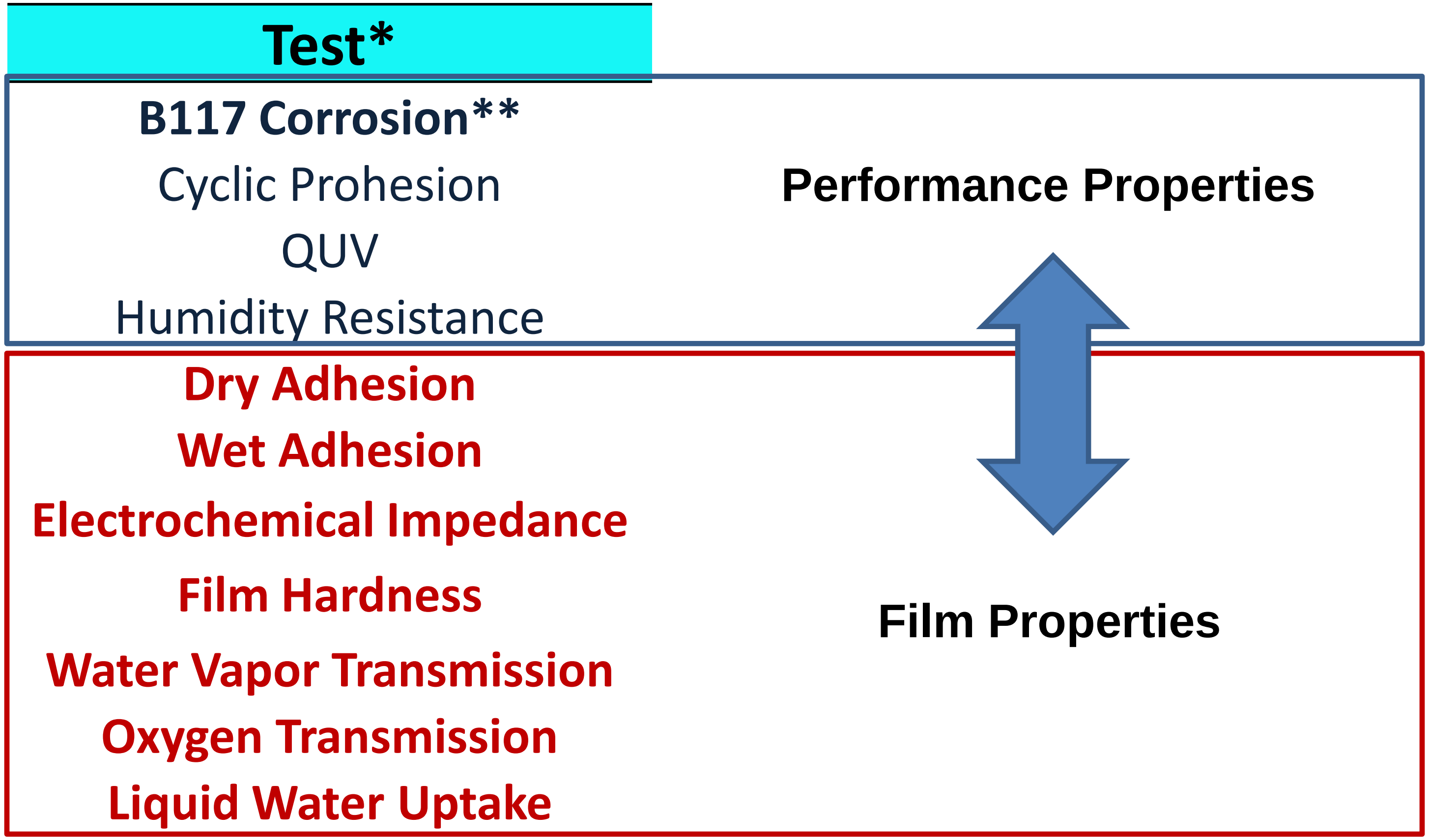
- Provided sufficient wetting is present, acid/base interactions, ionic interactions and van der Waals forces considered of primary importance[1]
- Isoelectric point of steel difficult to pinpoint, but likely around pH ~8-9
- As ammonia evaporates and pH drops, cationic sites arise allowing for electrostatic interactions
- Mechanical interlocking also significant in blasted substrates

[1] Fowkes, F.M., *J Polym Sci J Polym Chem Ed,* **1984**, 22, 547

# Study Description

- 21 internal and external styrenated acrylic systems
- Wide variety of performance capabilities, Tg’s, MFFTs, etc
- Formulated into single clear formulation – adjusted coalescent level for MFFT
- Evaluated in a number of performance tests to develop a film property/corrosion model

# Study Design



**Test***

**B117 Corrosion****

Cyclic Prohesion

QUV

Humidity Resistance

**Performance Properties**

**Dry Adhesion**

**Wet Adhesion**

**Electrochemical Impedance**

**Film Hardness**

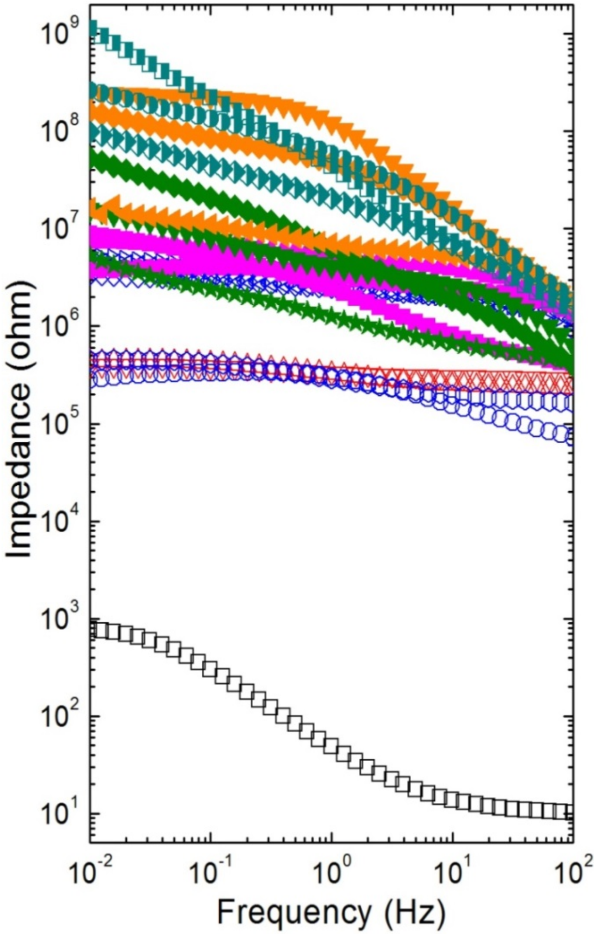
**Water Vapor Transmission**

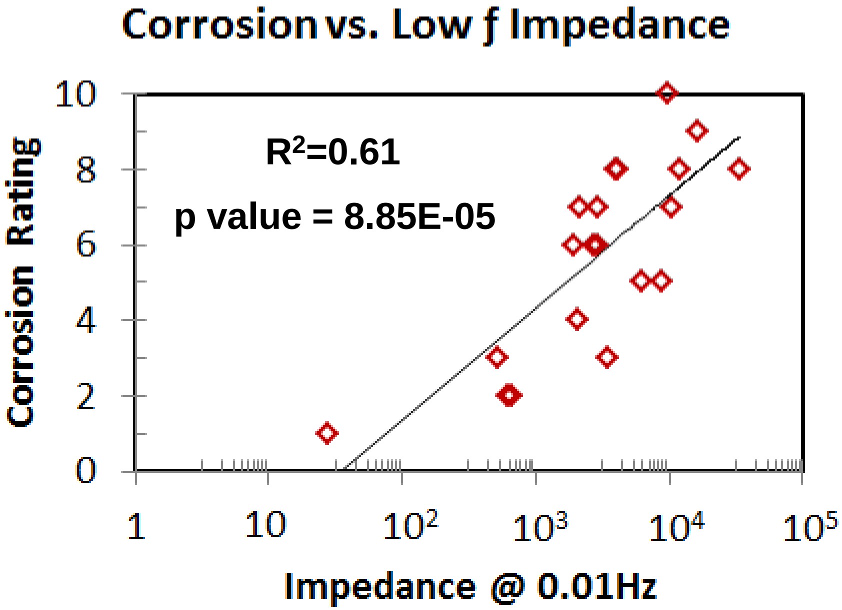
**Oxygen Transmission**

**Liquid Water Uptake**

**Film Properties**

# Impedance Studies




Corrosion vs. Low f Impedance

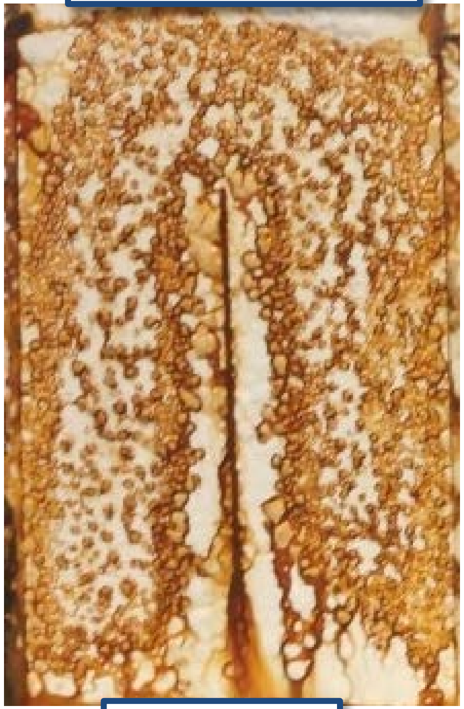
$R^2$=0.61

p value = 8.85E-05

# Corrosion Progression

B117, 2mil DFT, Smooth CRS

**Incumbent**



**300hrs**

**100g/L DTM**

**300hrs**

**50g/L Prototype**

**700hrs**

# Thin Film Corrosion Resistance

B117, Smooth CRS

**100g/L DTM**
**1mil DFT**

**300hrs**

**50g/L Prototype**

**1mil DFT**

**300hrs**

**0.65mil DFT**

**540hrs**

**0.5mil DFT**

**265hrs**

# Next Generation Development

B117, 2mil DFT, Smooth CRS

**50g/L Prototype**

**700hrs**

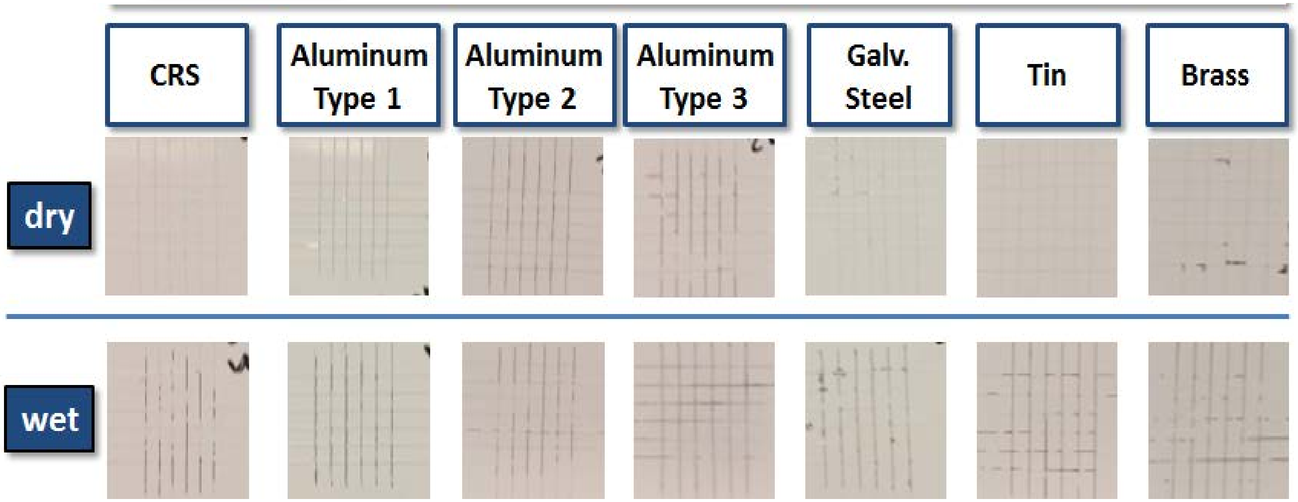
**< 50g/L DTM Prototype**

- Self-crosslinking styrenated acrylic
- Market leading corrosion resistance
- Excellent humidity resistance
- Good block resistance

**Competitor 50g/L DTM**

**350hrs**

**Broad spectrum adhesion properties**



# Commercial Benchmarks

## B117, 2mil DFT, Flat CRS

**Benchmark 1**
**<100hrs**

**Benchmark 2**
**<100hrs**

**Benchmark 3**
**<100hrs**

# Commercial Benchmarks

B117, 2mil DFT, Flat CRS

**Benchmark 4**
**<100hrs**

**Benchmark 5**
**<100hrs**

**Benchmark 6**
**<100hrs**

# Waterborne DTM Benchmarks

B117, 1mil DFT, Flat CRS, 300hrs

**50g/L Prototype**

**Benchmark 1**

**Benchmark 2**

**Benchmark 3**

**Benchmark 4**

**Benchmark 5**

**Benchmark 6**

**Benchmark 7**

# Benchmarking Solventborne Alkyds

B117, CRS, 1mil DFT, 300hrs

**50g/L Prototype**

**50g/L Styrene Acrylic Emulsion**

**Alkyd 1**

**High Solids Short Oil CS**

**Alkyd 2**

**Short Oil CS**

**Alkyd 3**

**Long Oil**

**Alkyd 4**

**W/R Short Oil CS**

**Alkyd 5**

**W/R Short Oil CS**

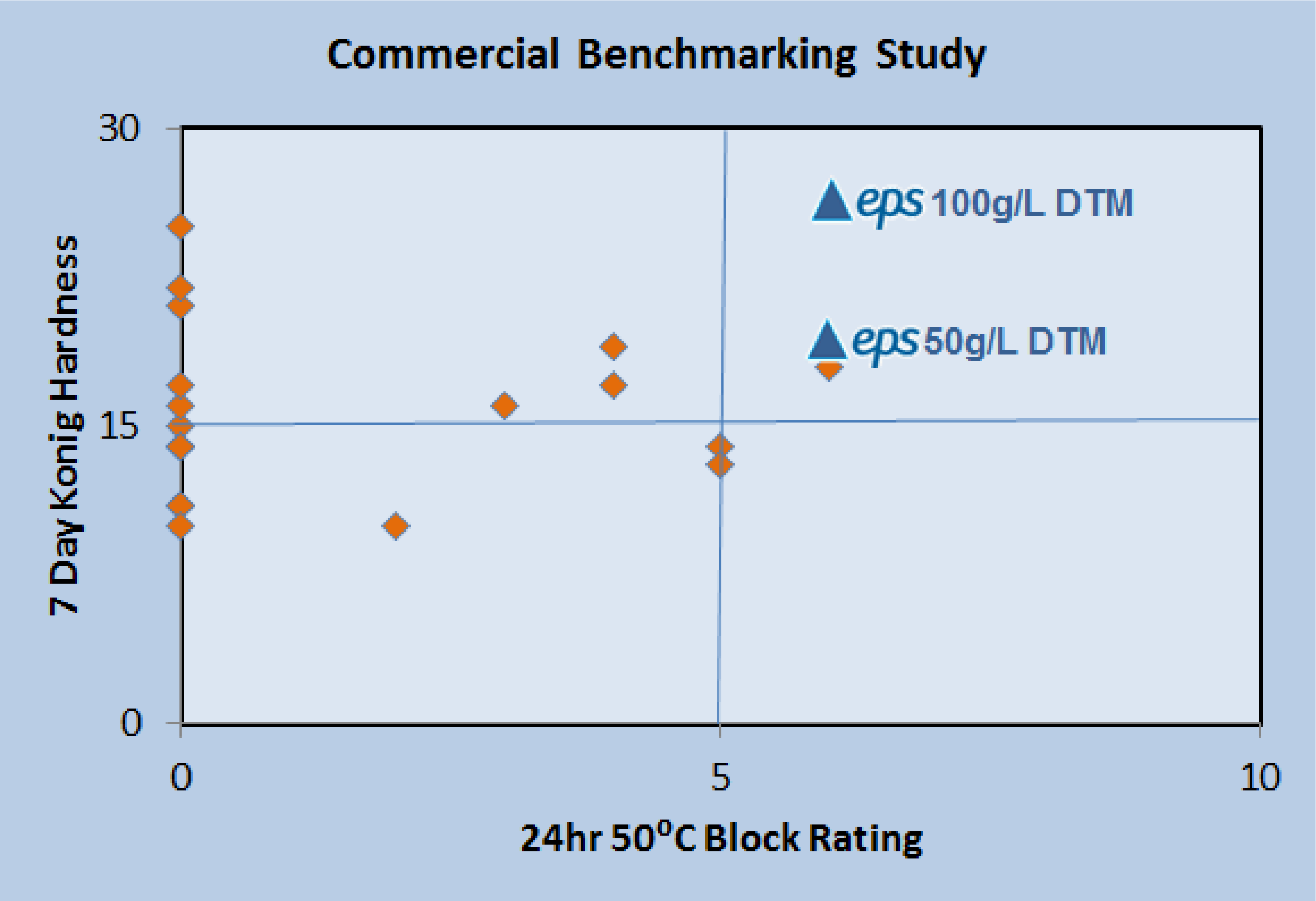
**Solventborne Alkyd Paint**

**Commercial Product**

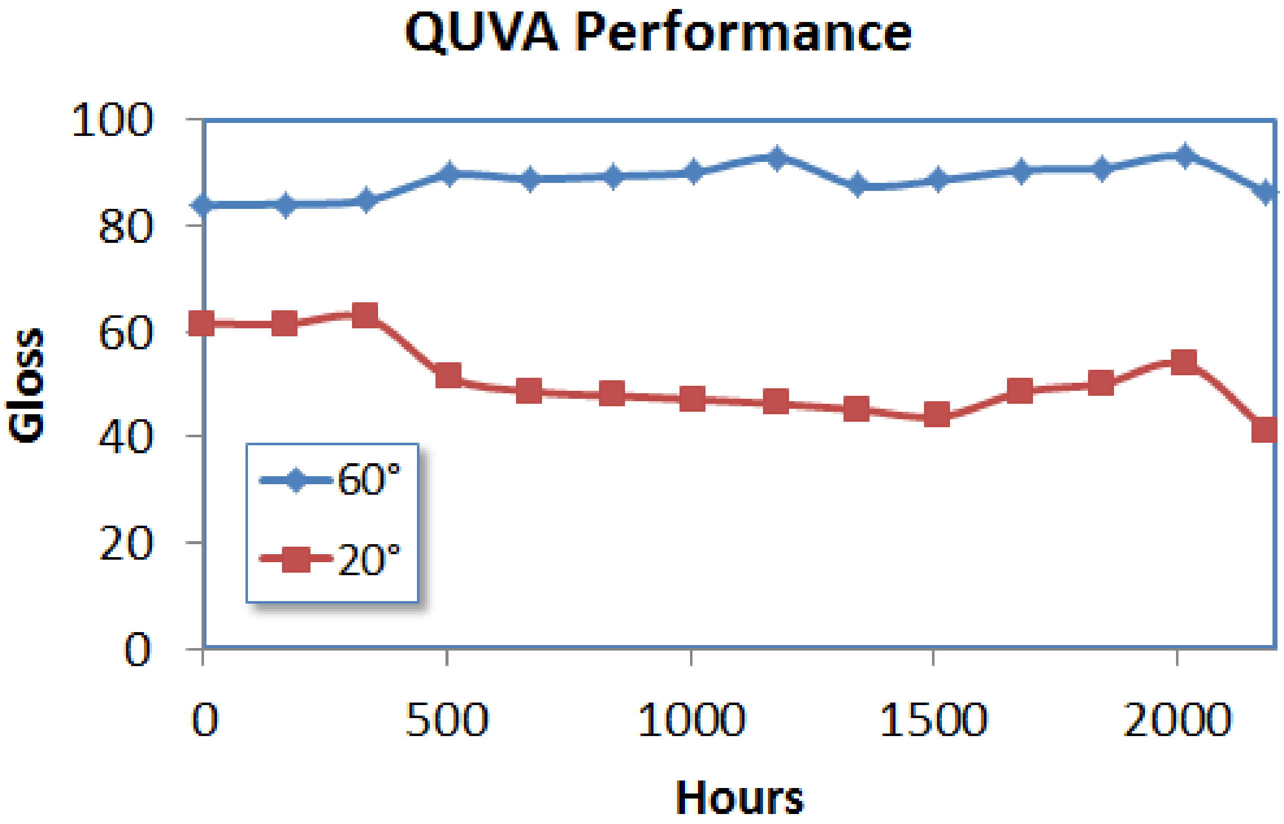
**Solventborne Alkyd Paint**

**Commercial Product**

# Hardness/Block Survey



# Extended Weatherability



# Summary

- Protective action of coatings on steel is a complex process with multiple modes of action
- Experimental observations and more recent studies point towards impedance as primary predictor of corrosion protection in B117 salt fog
- Learnings leveraged toward development of 50g/L DTM with previously unachieved corrosion resistance
- Performance is comparable to and/or exceeding that of solventborne and water reducible alkyds at thin films
- The new low VOC DTM delivers a balance of properties including corrosion resistance, humidity resistance, multi-substrate adhesion, block resistance, and weatherability
- Performance optimization continues through formulation development and exploration of functional additives

# Acknowledgements

- Howard Killilea
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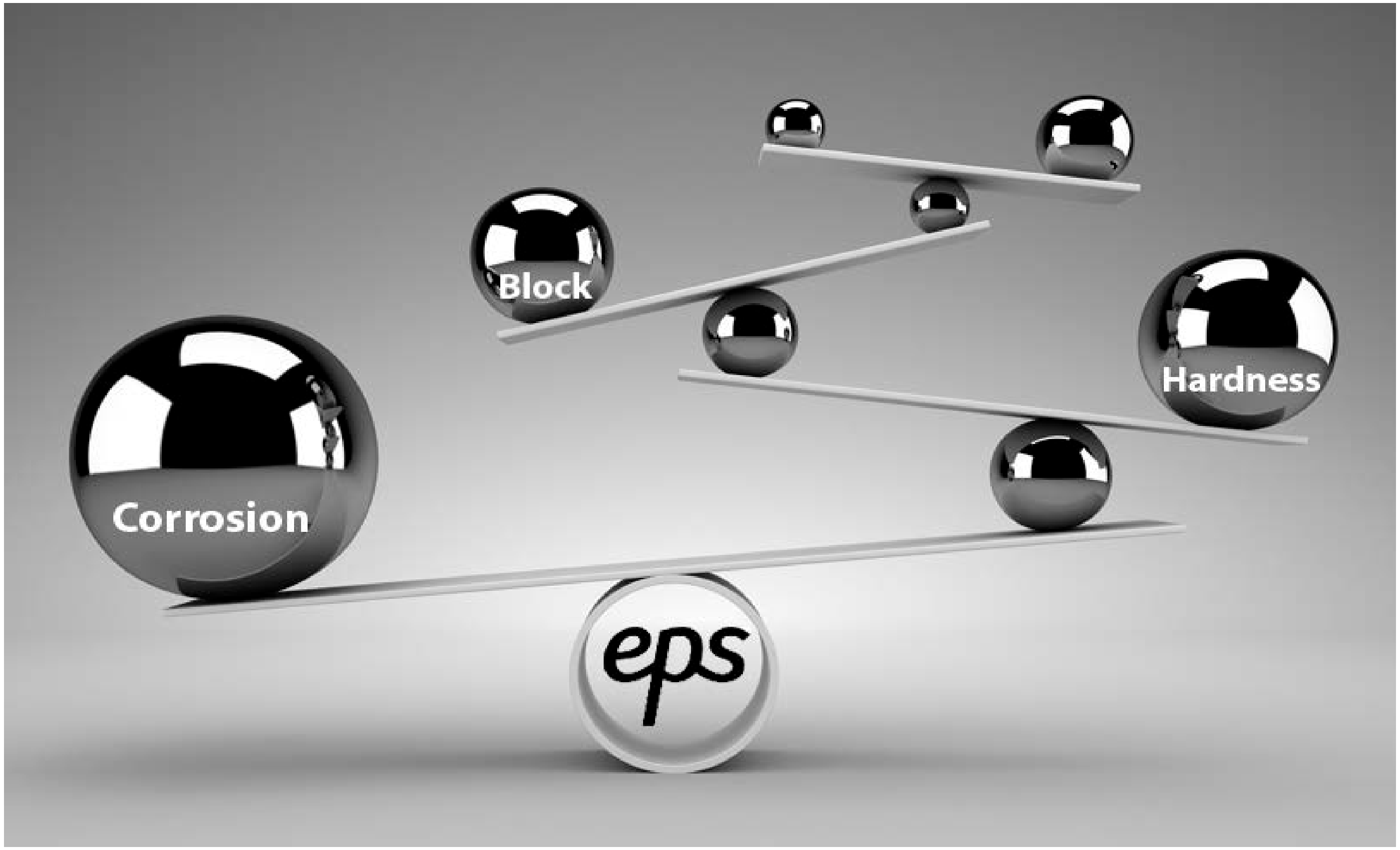
- Morgan DeWall
- MJ Hibben

# Questions?



# Further Reading

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