ENGINEERED POLYMER SOLUTIONS

Science Simplified

color corporation of america

Bridging the Development Gap with Low VOC DTM Emulsions

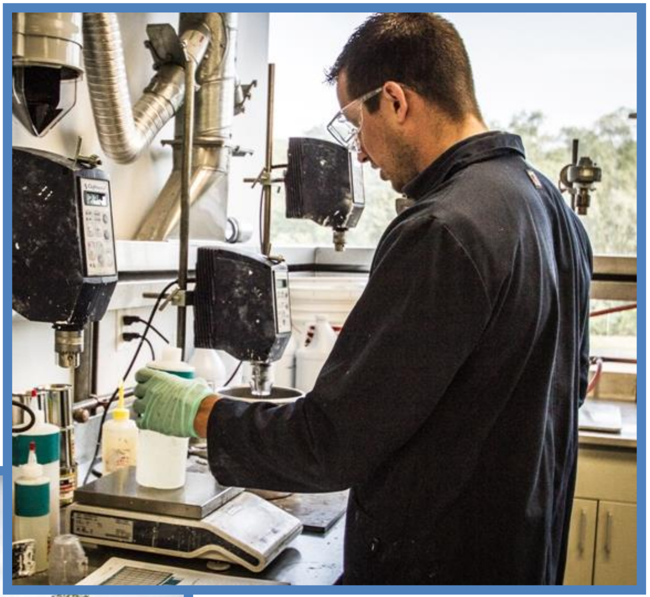
Presented by: Dr. Allen Bulick

Agenda

- EPS Overview
- Innovation Drivers in Coatings
- National Volatile Organic Content (VOC) Restrictions
- Challenges of Lowering VOC
- Hardness/Block/Corrosion Performance Survey
- Adhesion/Corrosion Mechanisms & Tradeoffs
- Other Properties
- Summary

Engineered Polymer Solutions (EPS)

A leading supplier of compliant acrylic emulsion technologies as well as conventional resins to supply the Architectural, Industrial, Construction, Adhesives and Sealants markets.



Products

Water Based/Acrylic Emulsions

Solvent Based

- Polyester
- Alkyd
- Polyurethanes
- Other resins

Low VOC coalescent

Colorants

Capabilities

Fully equipped labs in USA and Netherlands

- Synthesis
- Formulation
- Application Support

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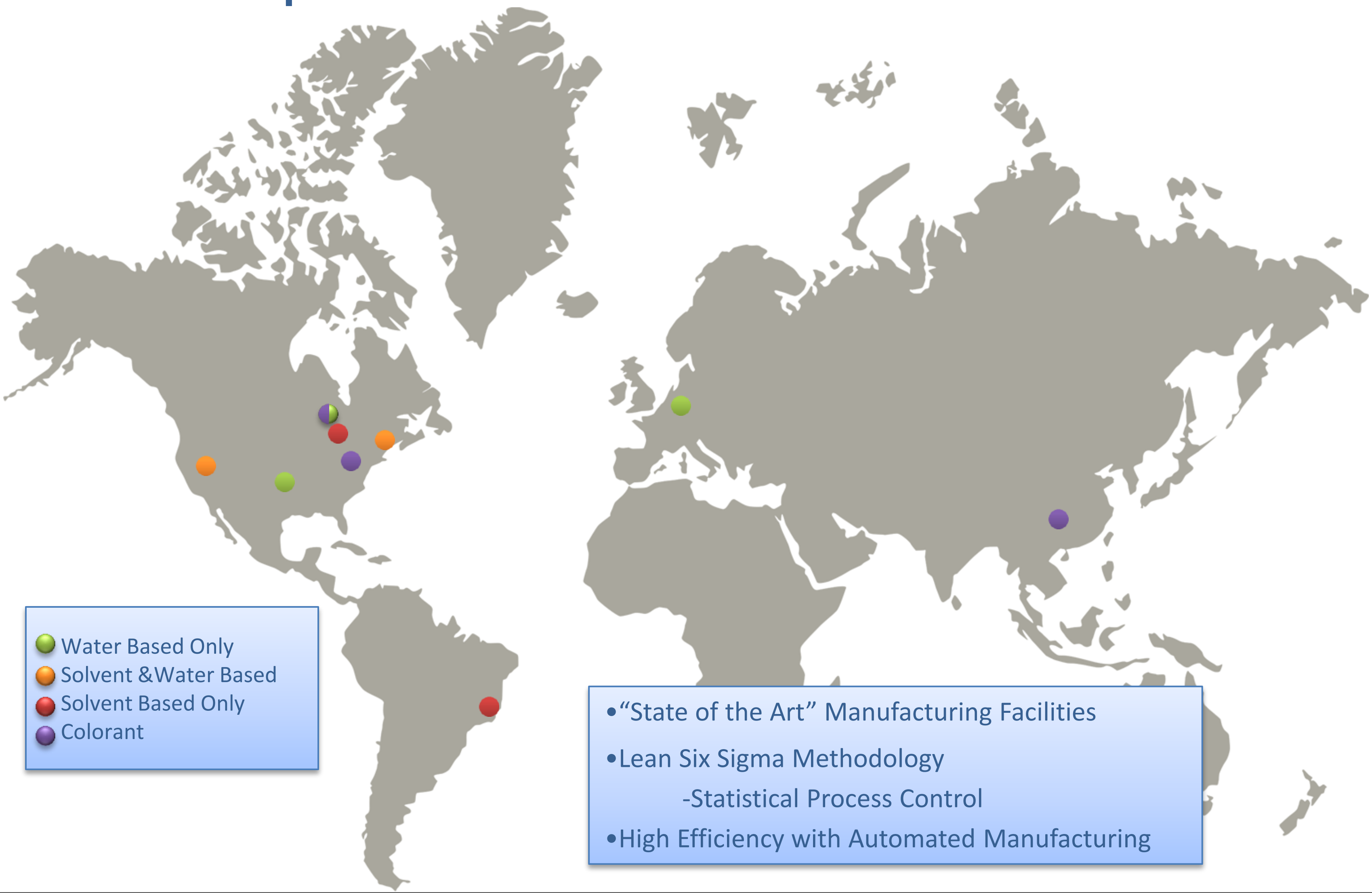
Global Operational Excellence



- "State of the Art" Manufacturing Facilities
- Lean Six Sigma Methodology
  - -Statistical Process Control
- High Efficiency with Automated Manufacturing

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Technology Offering

- Architectural Coatings
- Industrial Coatings
- Construction
- Adhesives and Sealants
- Colorants

Innovation Drivers

- All about EHS – many examples driving technology changes some by regulation, some by market demand
  - **VOC reduction**
    - Reduction/elimination of coalescing solvents
  - Low maximum incremental reactivity (MIR)
  - Low hazardous air pollutants (HAPs)
  - APEO-free
  - Chromate-free
  - Isocyanate-free
  - BPA-free
  - Other green and sustainability initiatives (eg LEED)

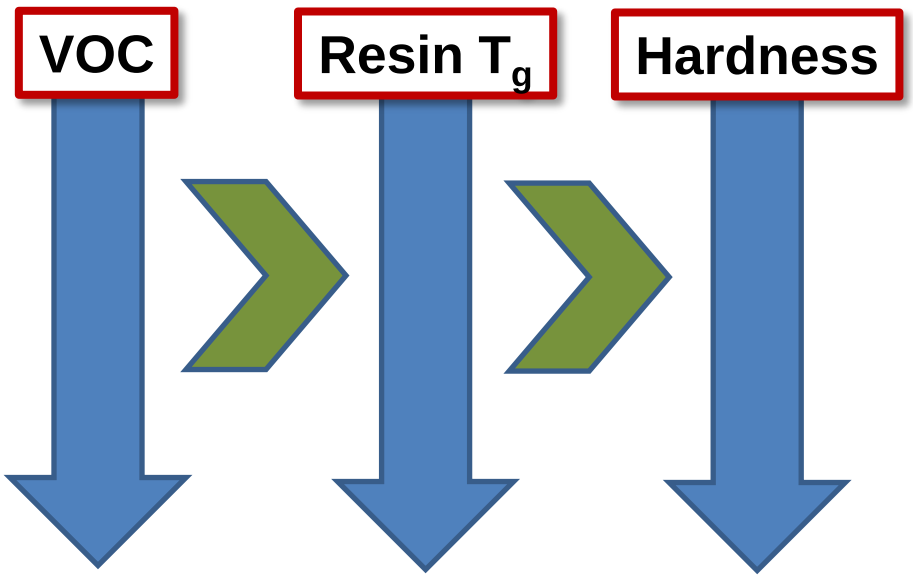
NA VOC Restrictions

Regulatory Body	Industrial Maintenance VOC Limit (g/L)	Rust Preventive Limit (g/L)
EPA	450	400
CARB	250	150
South Coast (SCAQMD)	100	100
OTC	250	250
Canada	340	400
LADCO	340	400

Elimination of quart exemption may result in the reduction of VOCs of legacy products and SKU reduction for national suppliers.

Balance of Properties

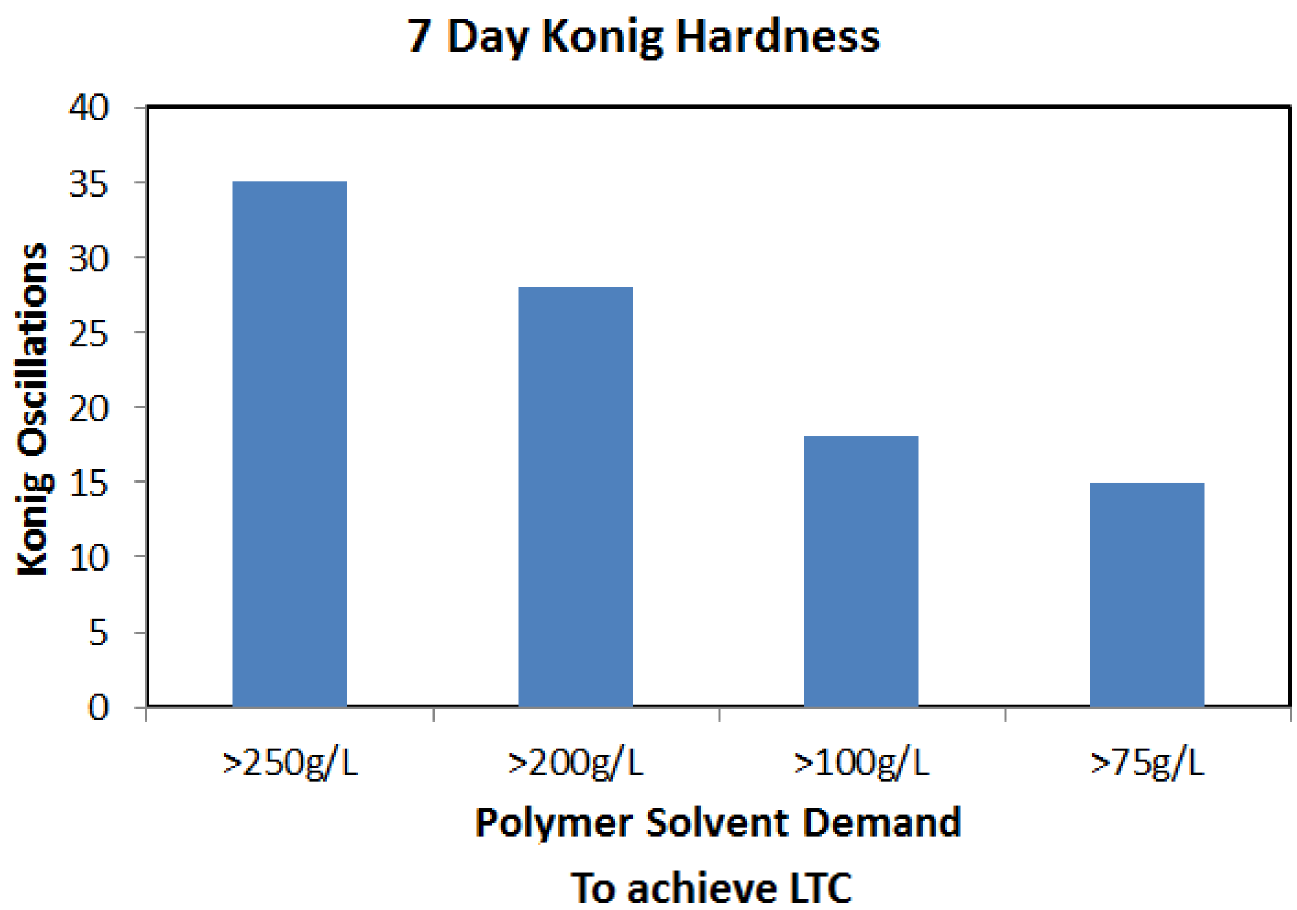
- Direct to metal (DTM) coatings must balance a larger number of performance properties
  - Corrosion resistance, adhesion, block resistance, gloss, hardness, chemical resistance, early water resistance, weatherability, etc
- Lower VOC demands result in higher technical complexity in an effort to maintain these properties



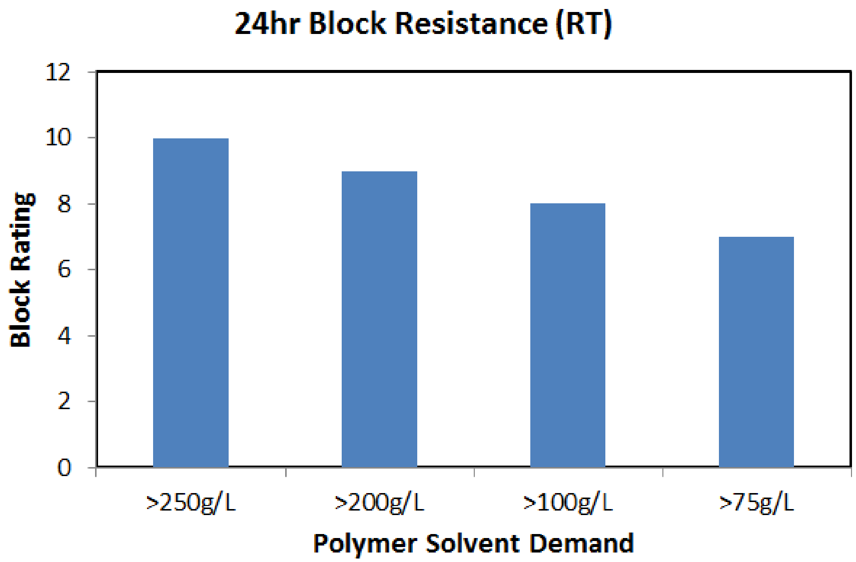
<u>Performance Tradeoffs</u>

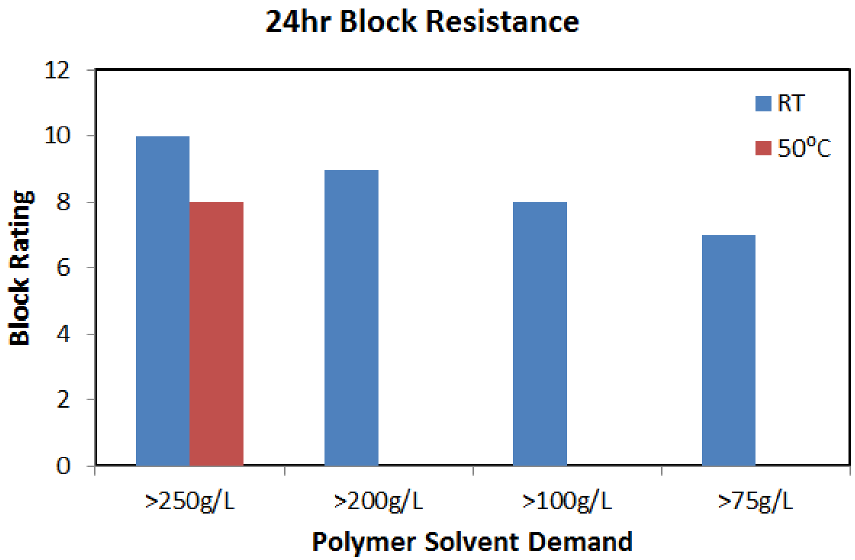
- Lower T_g (or low VOC plasticizer) to lower VOC reduces hardness and block resistance
- Some formulation mitigations available, but not ideal
  - Fluorosurfactants

VOC Performance Tradeoffs



VOC Performance Tradeoffs





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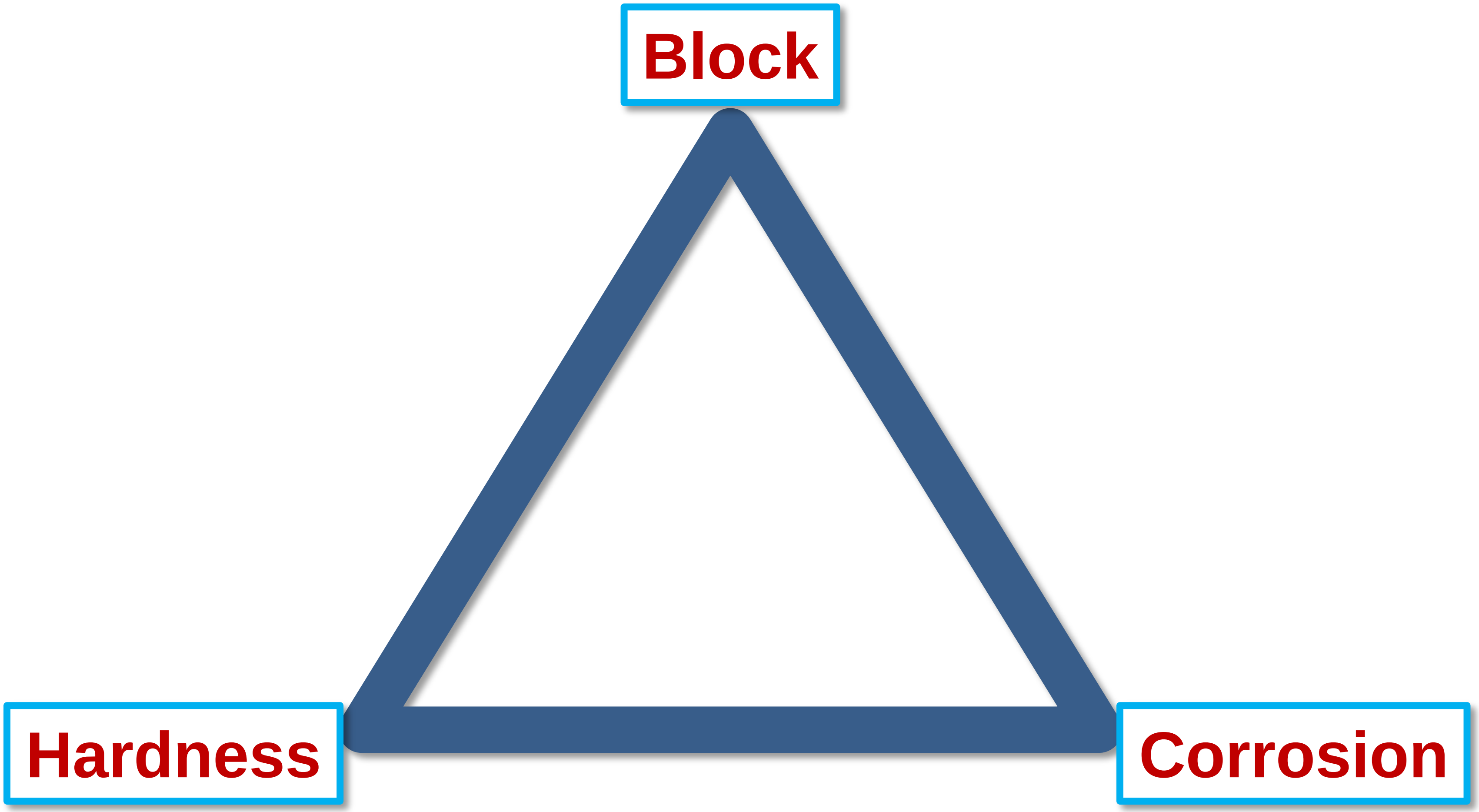
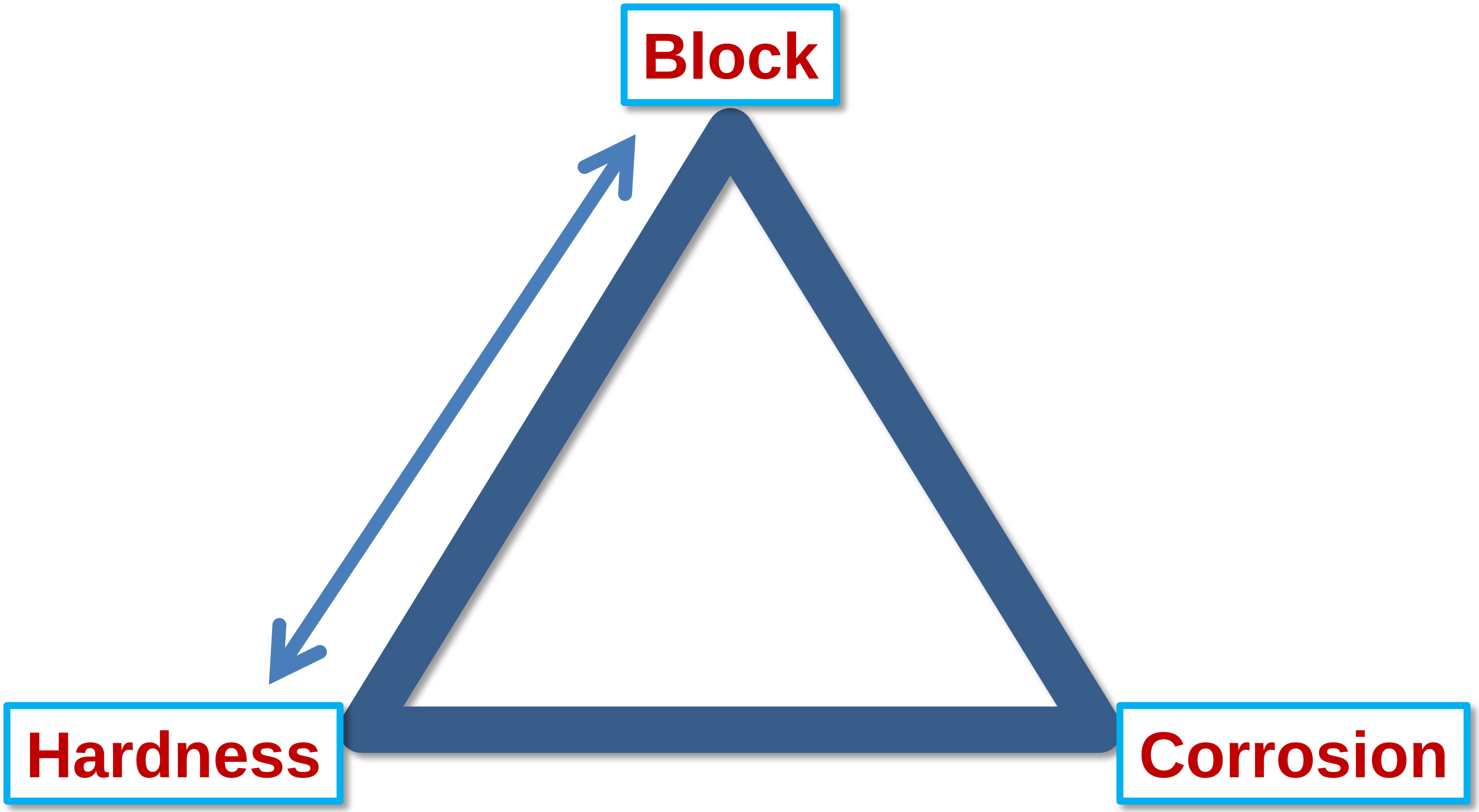

Block
Hardness
Corrosion


Block
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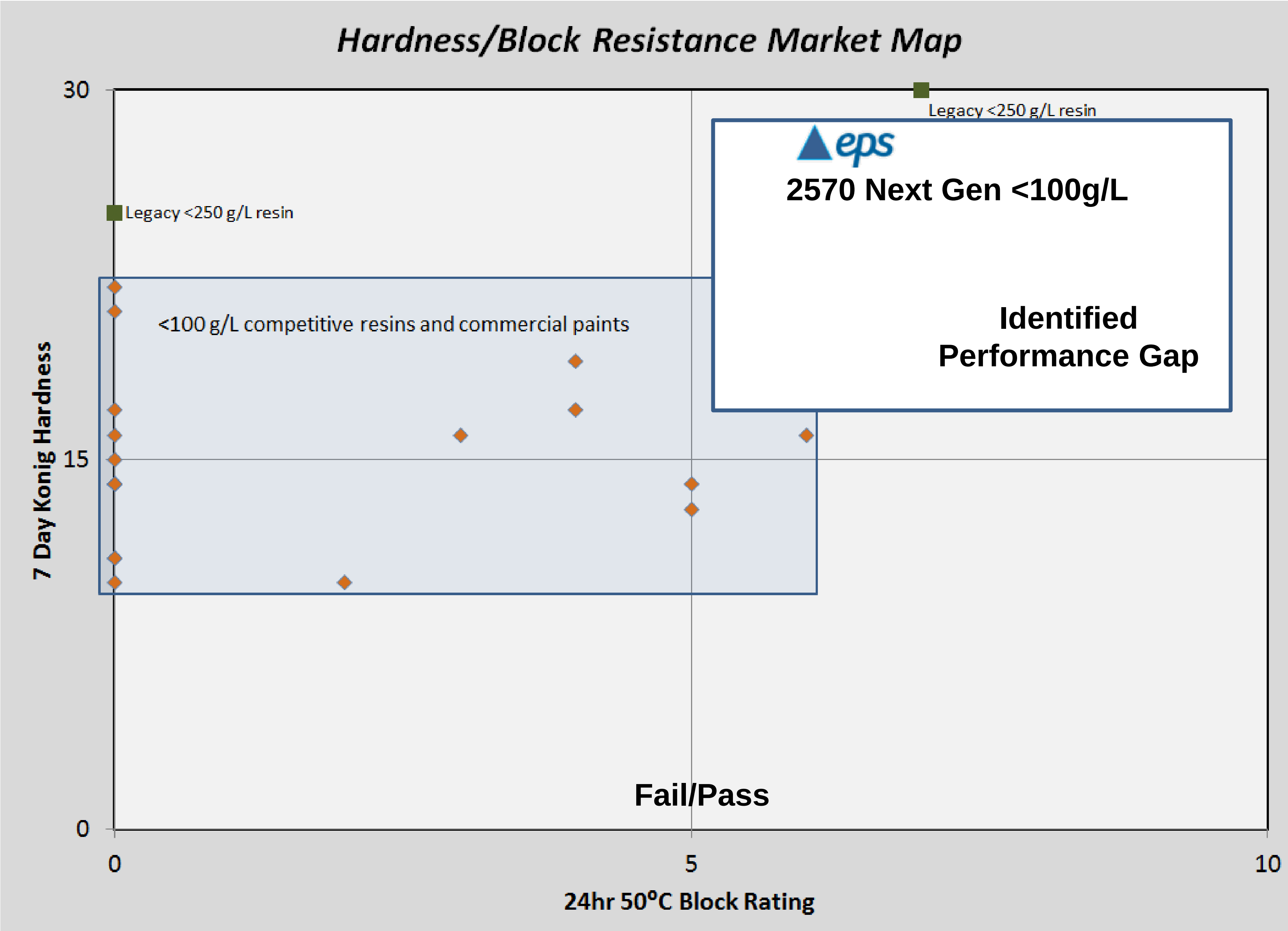
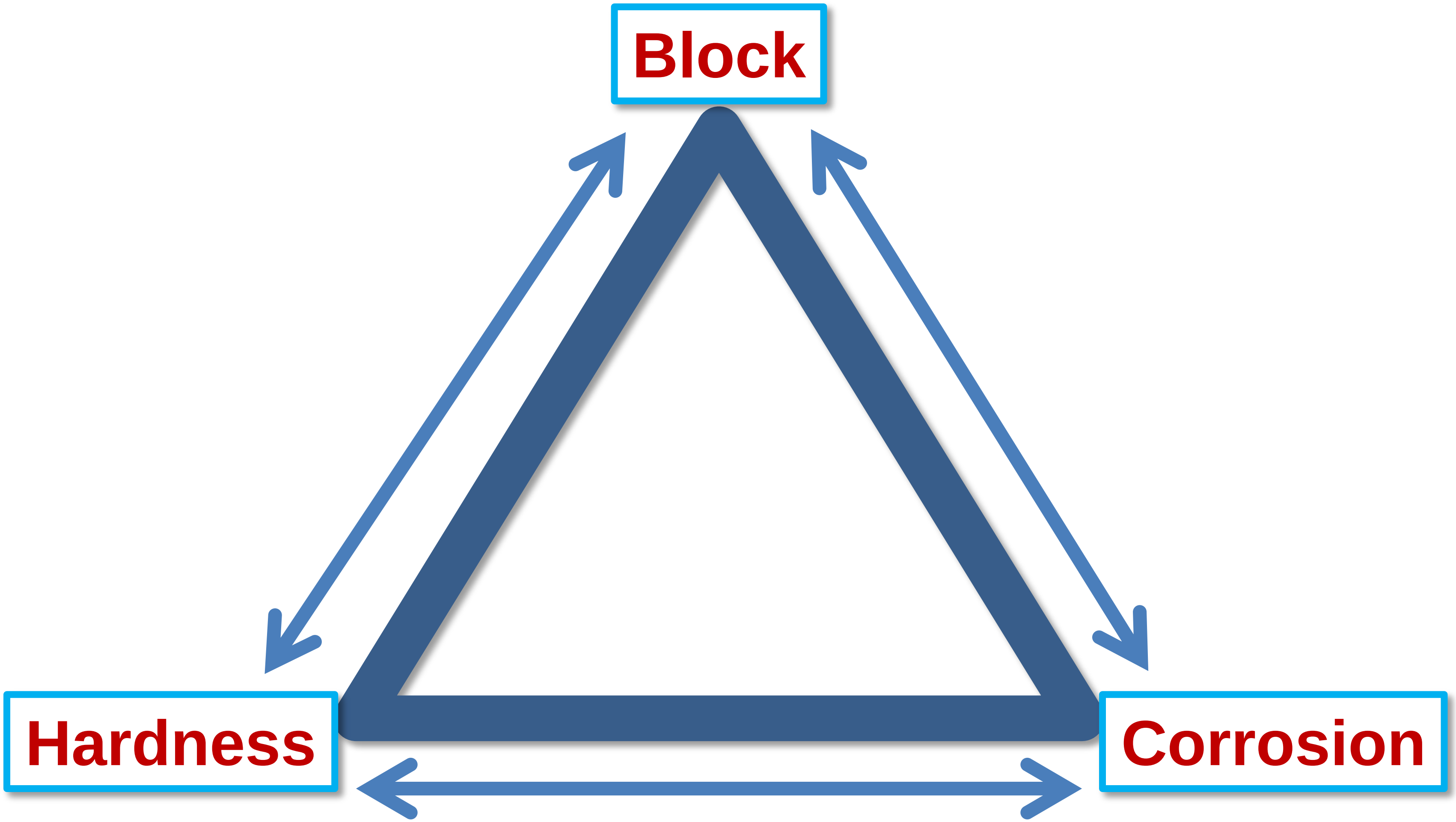


- Market survey (17 resin and paint systems) showed difficulty in achieving >20 Konig and hot block resistance, even in high VOC resins


Block
Hardness
Corrosion

Corrosion Performance

B117 Salt Fog, 2-2.3mil DFT, Flat CRS

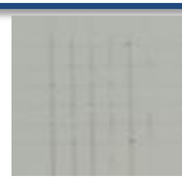
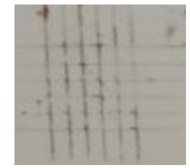
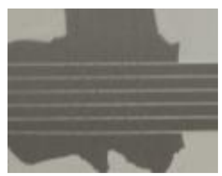
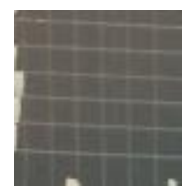
100g/L Incumbent Resin

300 hrs

Initial Prototype

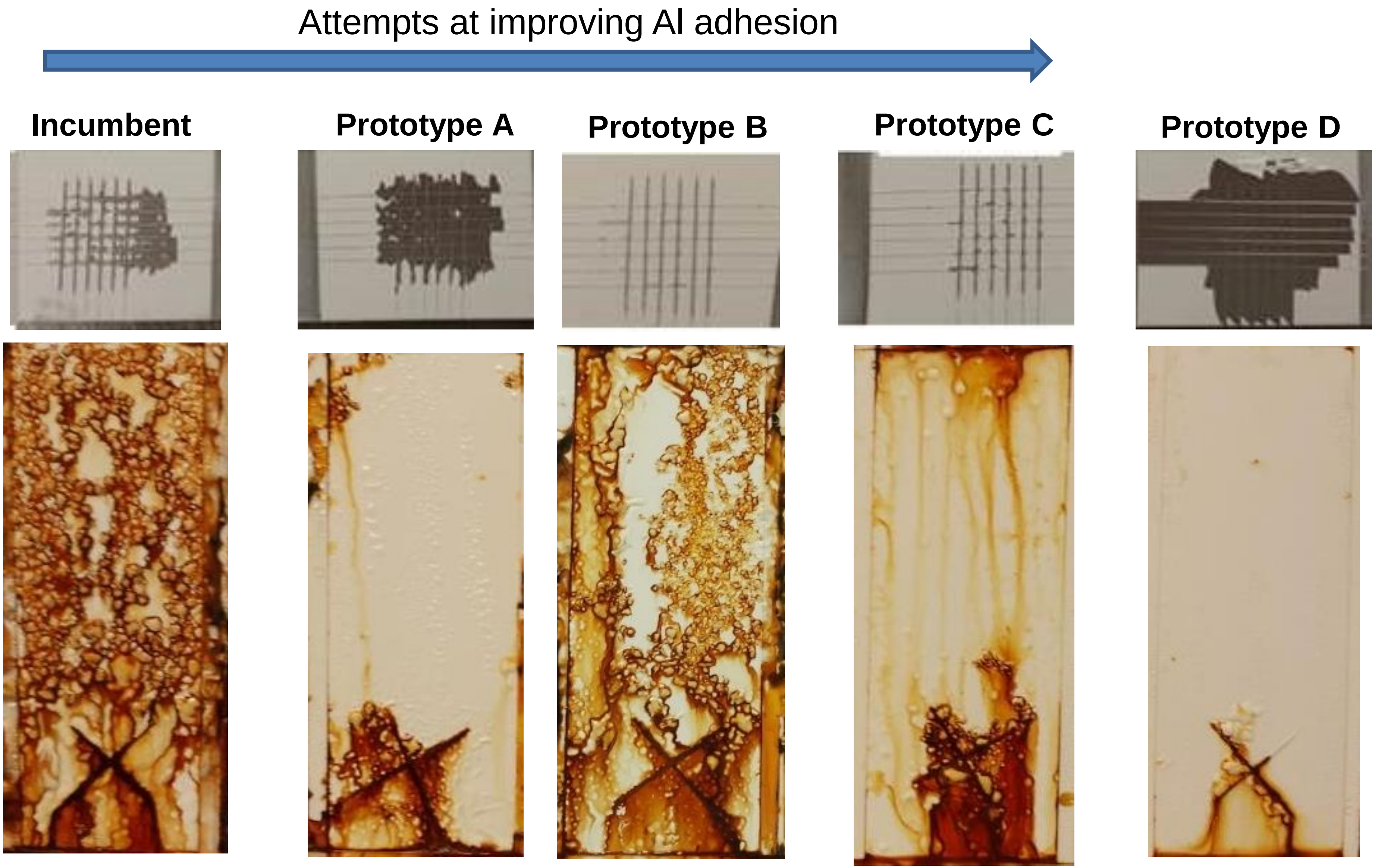
300 hrs

Adhesion Properties

		100g/L Incumbent	Initial Prototype
CRS	dry		
	wet		
Aluminum	dry		
	wet		
Galvanized	dry		
	wet		

Adhesion vs. Corrosion Resistance

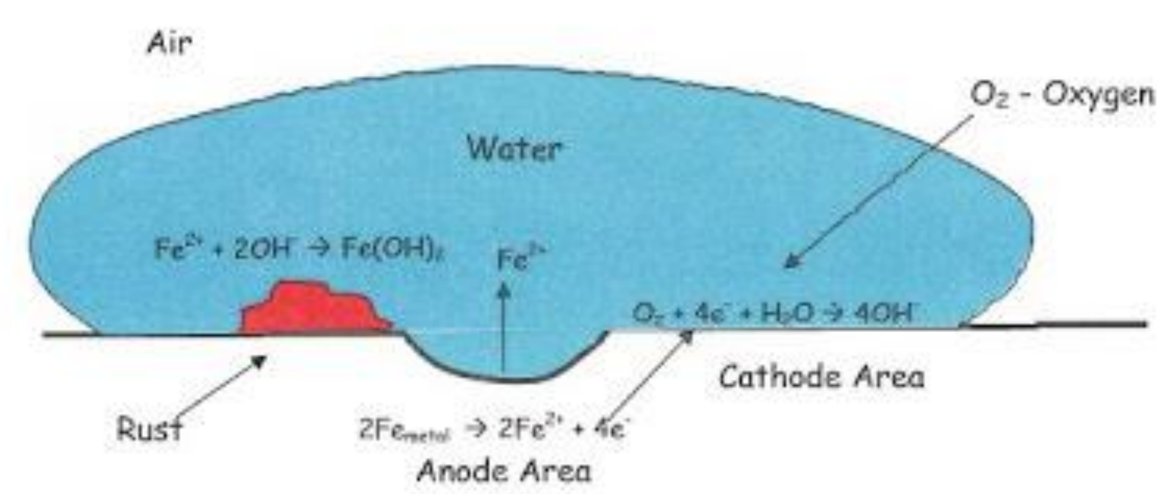
2-2.5mil DFT, 12PVC High Gloss, 400hr B117



Accelerated Testing Methods

- ASTM B117 Salt Fog
  - 5% NaCl, constant fog
  - Rapid screening tool
  - Excessively harsh vs. exterior exposure
- Cyclic Prohesion
  - Cycles humid/dry cycles in salt fog cabinet with QUV (condensation/UV exposure)
  - Introduces more representative conditions
  - Tests more failure modes
  - Long cycle times vs. B117

Corrosion on Steel Substrates



http://acnosite.blogspot.com/2011/11/water-corrosion.html

<u>Requires</u>

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

<u>Possible mechanisms of corrosion prevention</u>

- Block water penetration
- O_2 transport inhibition

→ **Barrier Properties**

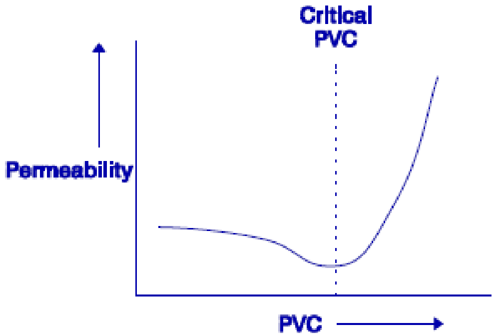
- Adhesion – surface passivation, exclusion of water, etc
- Interference with electrolytic pathway – coating resistance

Barrier Properties

Coating Type	Water Vapor Permeability[1,2] ($g/m^2/25\mu m/day$)	O_2 Permeability[1,2] ($cm^3/m^2/25\mu m/day$)
Chlorinated rubber	30	50
Coal tar epoxy	75	213
Al epoxy mastic	105	110
Read-lead oil	535	734
Pigmented Alkyd	645	595
Acrylic primer	1800	500

[1]Thomas, NL, *Prog Org Ctgs*, 19, 101, 1991
[2]Thomas, NL *Proc Symp Advances in Corr Prot by Org Ctgs, Echem Soc,* 1989, 451

- What about pigment considerations – ie tortuosity?



Adhesion in B117 Cabinet

<u>Styrenated Acrylic Emulsion</u>

<u>Clear Formulation</u>

Easy film delamination
out of salt fog cabinet

2k Epoxy Primer
Salt Fog Wet Adhesion (300hrs)

Solventborne Epoxy Ester
Salt Fog Wet Adhesion (300hrs)

<u>Solventborne Sytems</u>

Cross hatch failure

Corrosion without Adhesion

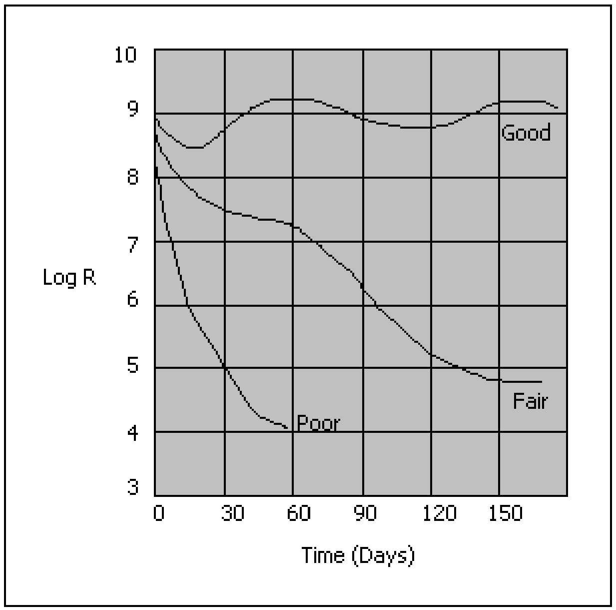
B117, Clear formulation, ~1mil DFT

500hrs

0b – CRS Cross Hatch

Electrolytic Resistance

Likely most important film property in corrosion resistance



Ind Eng Chem, 40(1), 1948, 161-167

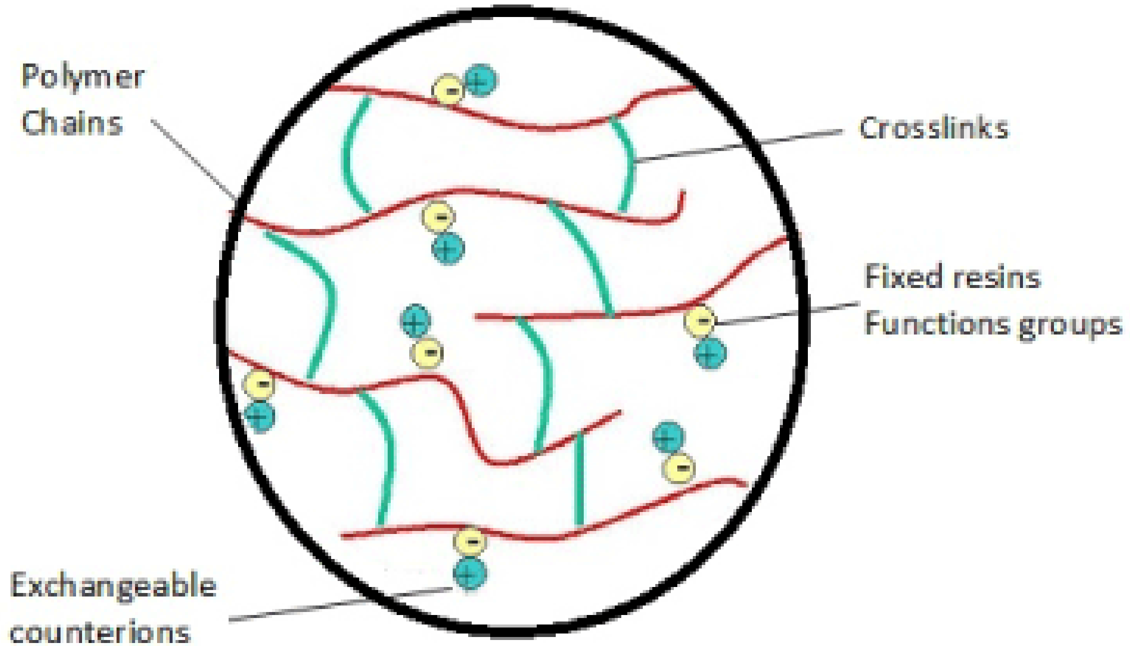
- Study of 300 coatings showed resistance thresholds of ~10^8Ohm for the best coatings and at least ~10^6 Ohm for fair performance[1]
- Coating resistance falls with increasing electrolyte concentration

Maitland CC, Mayne JEO, *Official Digest, Sept 1962*

- Inverse study between ion exchange capacity and corrosion resistance of film

Ulfvarson, U and Khullar, M, *JOCCA*, 54, 604, 1971

Styrenated Acrylic Emulsions as Ion Exchange Systems

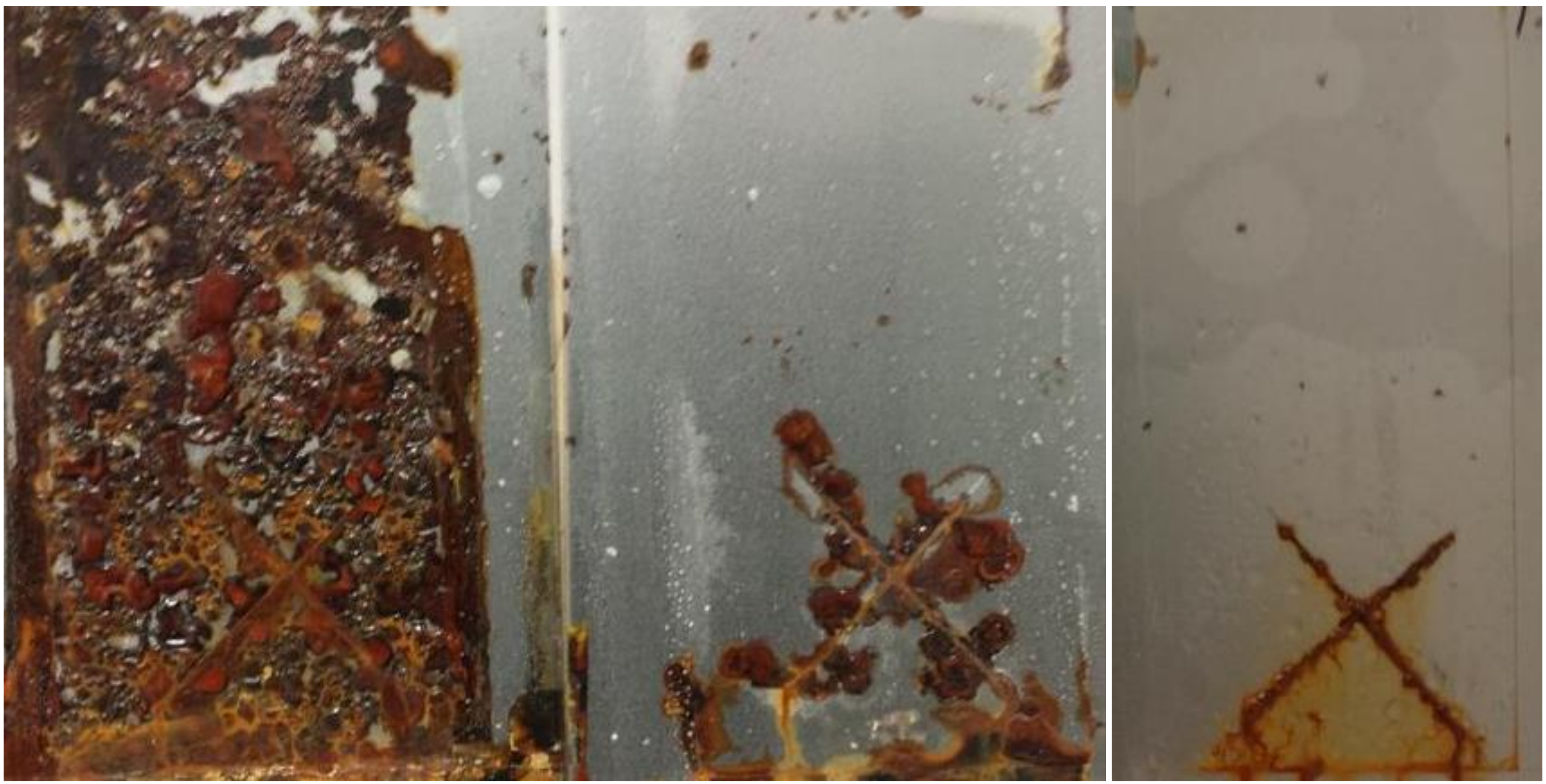


http://esciencecentral.org/ebooks/advances-in-protein-chemistry/new-protein-approaches.php

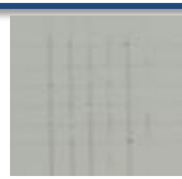
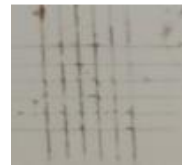
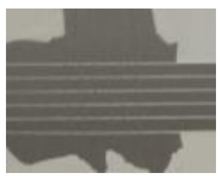
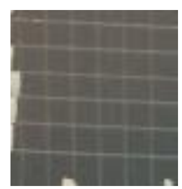
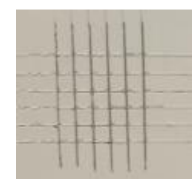
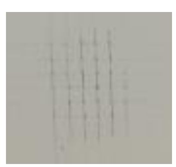
Corrosion vs. Acid Content

Clear films, 1.2mil DFT, 300hrs B117

Decreasing Acid Content



Adhesion Properties

		100g/L Incumbent	Initial Prototype	EPS® 2570 Next Gen <100g/L
CRS	dry			
	wet			
Aluminum	dry			
	wet			
Galvanized	dry			
	wet			

Corrosion Performance – B117

2-2.5mil DFT, Flat CRS

Panel Label:

Resin System
7day Konig/24hr 50^{0}C Block

EPS® 2570
28/6

350 hrs

Resin A
21/0

Full field blistering

100 hrs

Resin C
15/0

48 hrs

Corrosion Performance – B117

Panel Label:

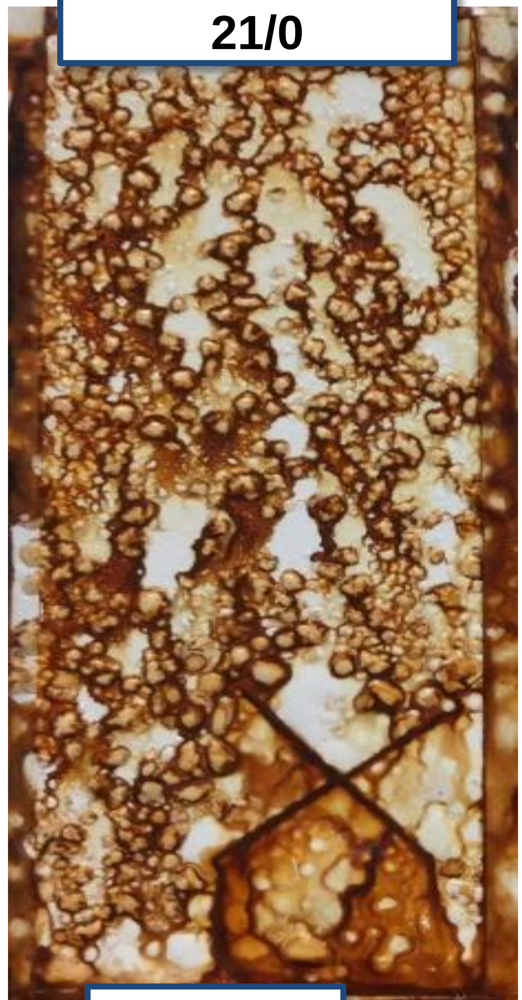
Resin System
7day Konig/24hr 50^{0}C Block

2-2.5mil DFT, Flat CRS

EPS® 2570
28/6

350 hrs

Resin A
21/0



300 hrs

Resin C
15/0

300 hrs

Corrosion Performance – B117

2-2.5mil DFT, Flat CRS

Panel Label:

Resin System
7day Konig/24hr 50^{0}C Block

Resin C
15/0

48 hrs

Resin D
11/0

500 hrs

Resin E
11/0

500 hrs

Corrosion Performance – B117

Panel Label:

Resin System
7day Konig/24hr 50^{0}C Block

2-2.5mil DFT, Flat CRS

Resin F
19/4

200 hrs

Resin G
16/0

500 hrs

Commercial Paints – Corrosion Resistance

2-2.5mil DFT, Flat CRS

EPS® 2570
350hrs

Paint A
<100hrs

Paint B
<100hrs

Commercial Paints – Corrosion Resistance

2-2.5mil DFT, CRS

Paint C
<100hrs

Paint E
<100hrs

Paint F
<100hrs

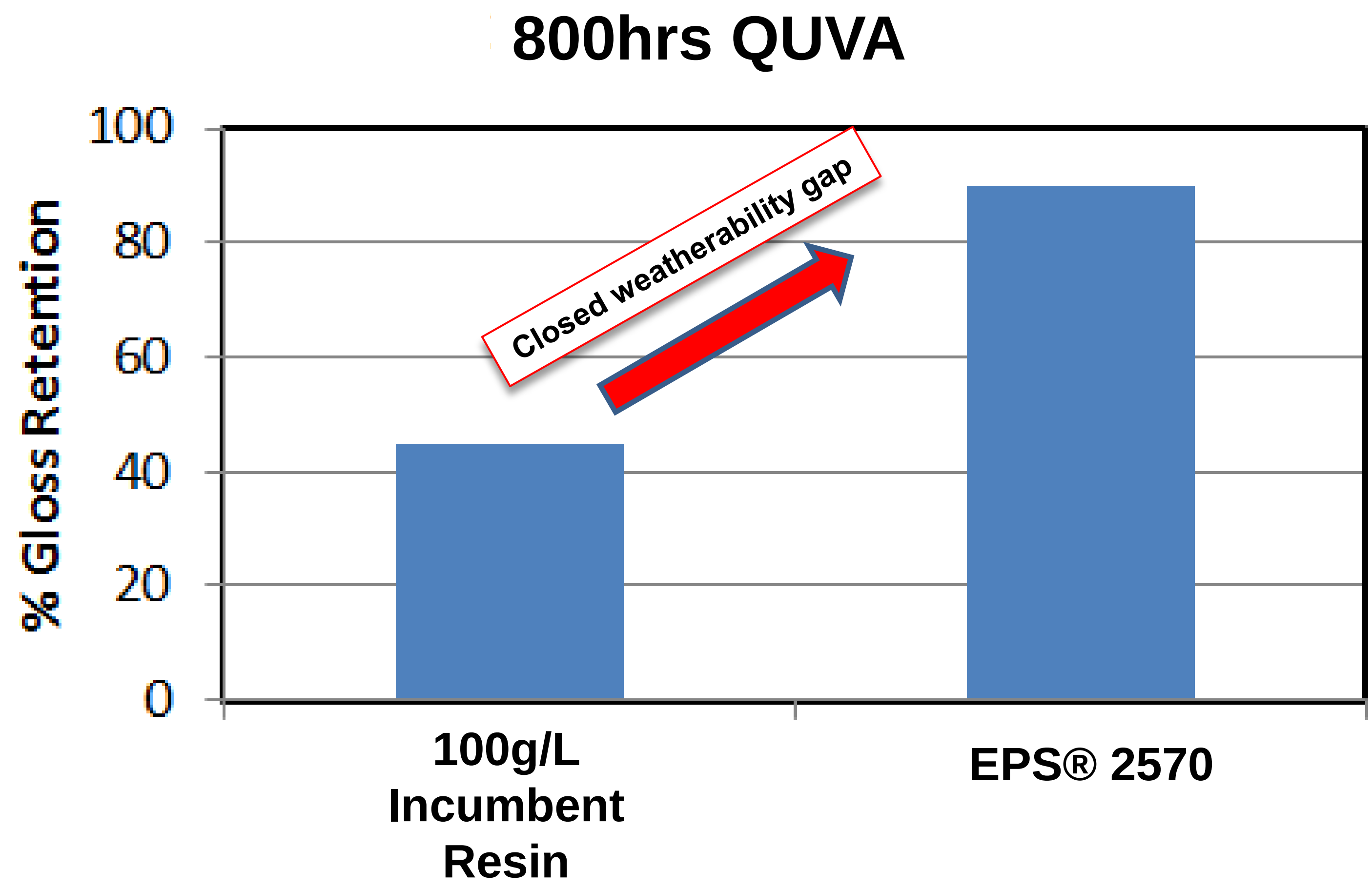
Commercial Paints – Corrosion Resistance

2-2.5mil DFT, CRS

Paint G
<100hrs

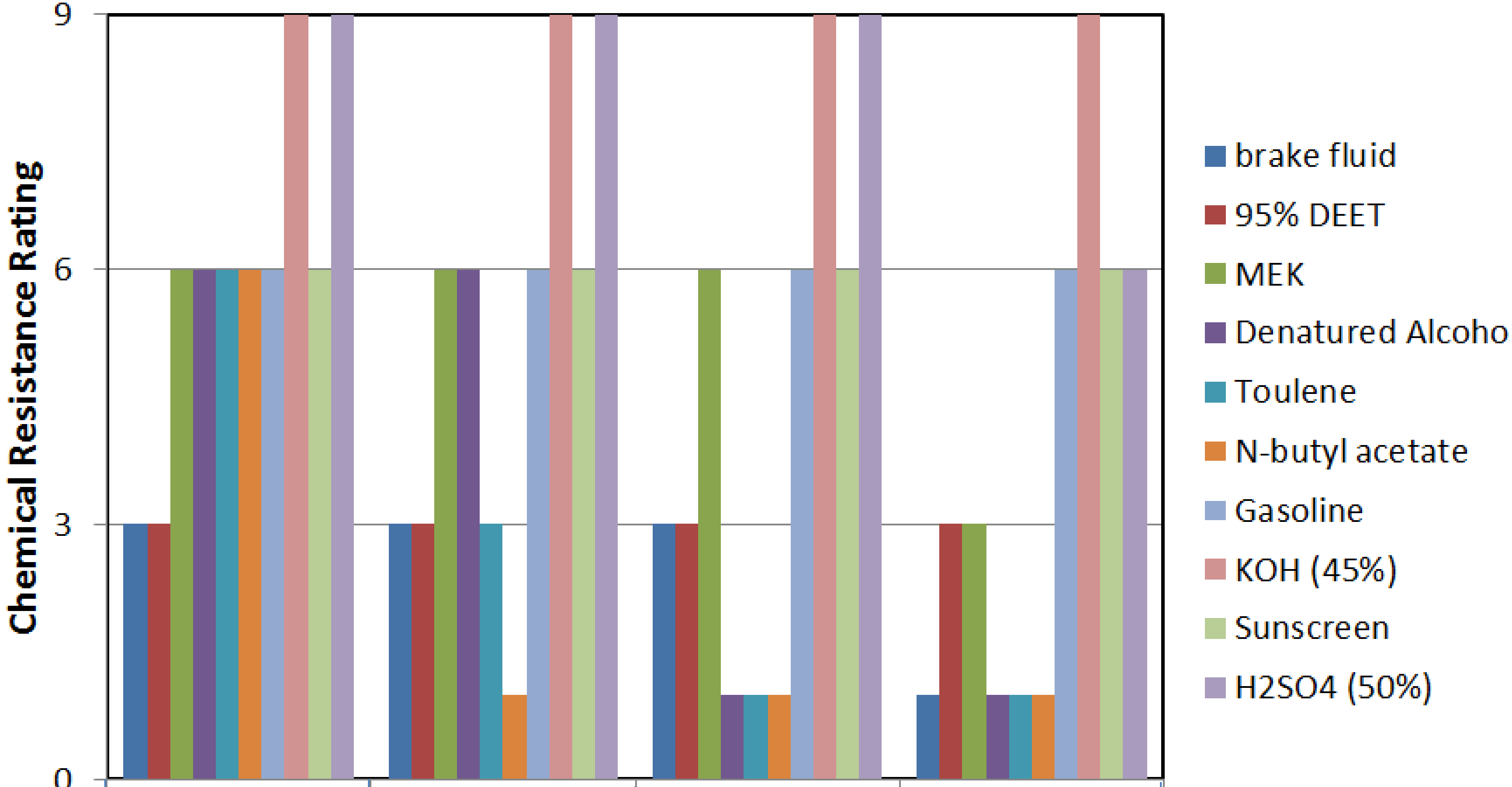
Paint H
<100hrs

Weatherability



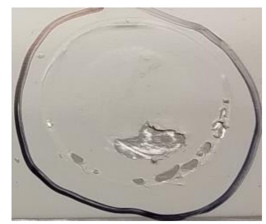
Chemical Resistance

9=no change to gloss
6=reduction in gloss
3=film softening
1=delamination

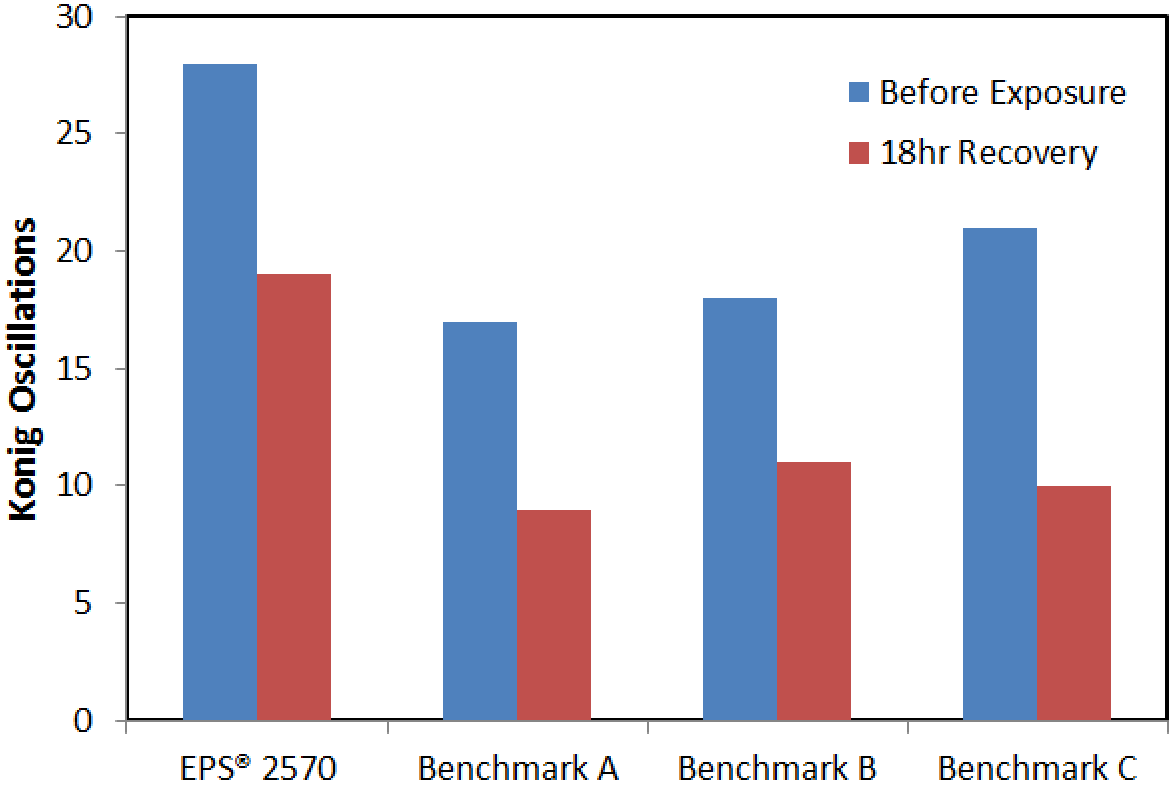


	EPS®2570	Benchmark A	Benchmark B	Benchmark C
Rating Totals	**60**	**52**	**45**	**37**

Chemical Resistance Pictures

	EPS® 2570	Benchmark A	Benchmark B	Benchmark C
Sunscreen				
Denatured Alcohol				
Toluene				
n-Butyl Acetate				

Lotion Exposure



- Films exposed 4hrs
- All polymers softened by lotion
- EPS® 2570 maintains hardness advantage on recovery

Summary

- Market survey of incumbent <100g/L technologies showed a significant performance gap in a balance of hardness/block/corrosion resistance
- Low VOC trends place significant difficulties on resin selection and design
- EPS sought to develop the best overall balanced polymer in the <100g/L DTM category
- A next generation development based on current state of the art polymer understanding fills that performance gap
- Balancing adhesion and corrosion requires special consideration in waterborne styrenated acrylic systems
- Ongoing work to fully understand formulation space/performance of the new polymer

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- Iain Harvey – Project/Process Director

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Questions?

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