Enhanced Corrosion Inhibition in Powder Coatings

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AGENDA

Enhanced Corrosion Inhibition in Powder Coatings

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2 Powder Coating Background
3 Corrosion Background
4 Test Design
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The Drive to Sustainability

The Impact of Corrosion

Cost of corrosion

- $2.5 Trillion USD globally and increasing

Environmental Impact

- Metal production accounts for 10% of global GHG emissions

Impact on Human Health and Community

- Use of hazardous corrosion inhibitors: lead, chromium, zinc
- Safety concerns caused by failing infrastructure

*Source: 1. NACE International IMPACT Report, 2013 2. IRP, Global Resources Outlook 2019: Natural Resources for the Future We Want, A Report of the International Resources Panel, 2019

The Drive to Sustainability

ICL’s Mission to Reduce the Affects of Corrosion

- Our vision to create positive impact on our world, in collaboration with others, drives us forward as we aim to offer additional innovative solutions to vital challenges in our focus area of protective metal coatings.
  - Analyze and understand carbon footprint of our products.
  - Implement circular economy in production of ICL products.
  - Address GHG (greenhouse gas) emission levels through responsible consumption of raw materials and finished goods.
  - Offer heavy-metal free corrosion inhibitors to replace traditional chemistries and maintain coating performance while creating a more sustainable product.

Powder Coating History

A period of rapid advancement and adoption

1950's
German scientist granted patent for first powder process.

1960's
Extrusion and electrostatic spray application.

1970's
Regulations pushed adoption in many segments.

End of 20th century
Period of high growth and displacement of liquid coatings.

2000-2020
Increased competition, consolidation & cost competitive products.

Present & Future
Optimization and expansion into emerging markets.

Powder Coating Advantages

Intentional Growth Avenues

Sustainability

No VOC

Minimal waste; overspray can be collected & recycled.

Application

Spray applied

Single, thick coat can be achieved

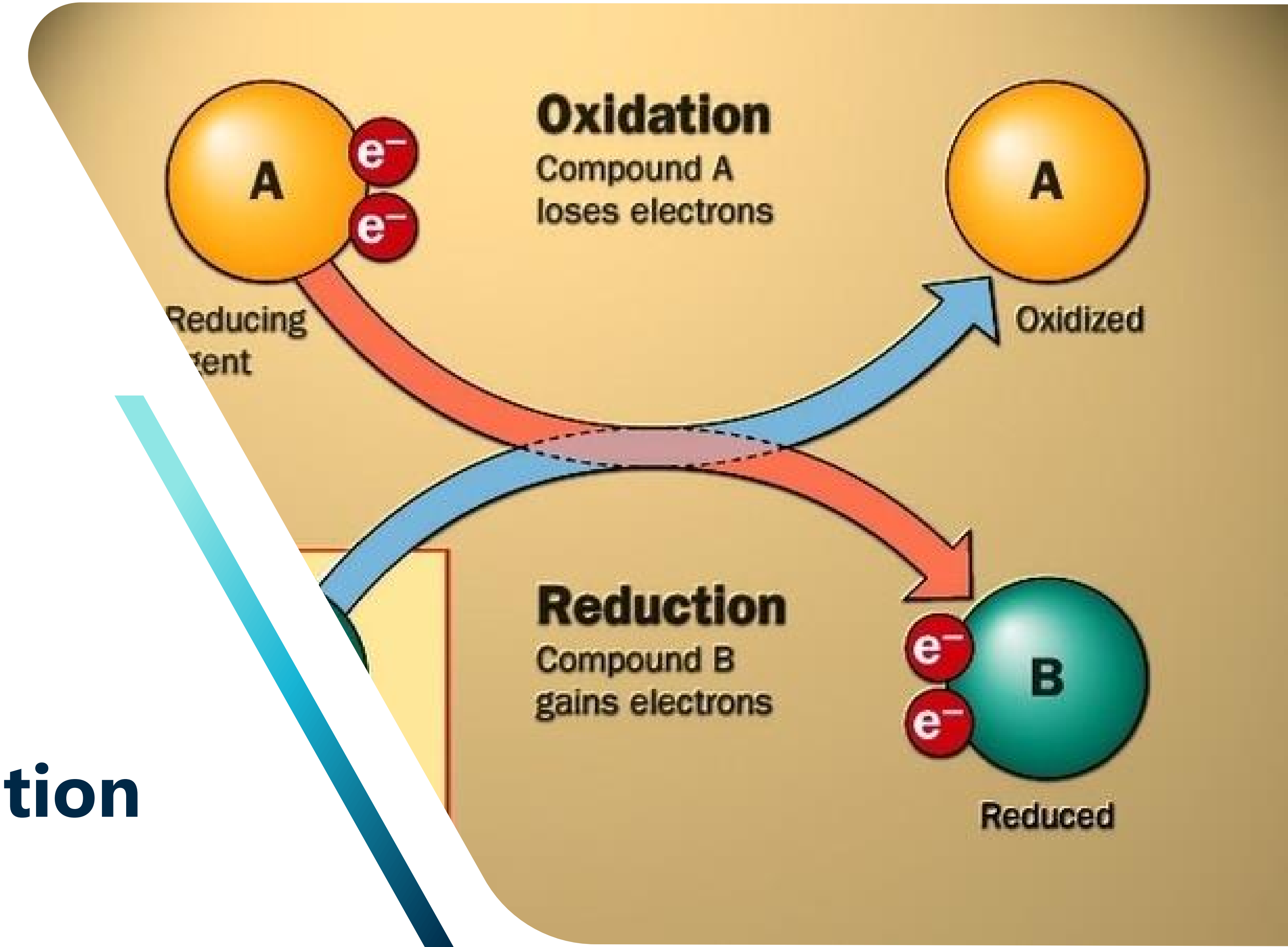
Performance

Economical high performance

Simple formulation

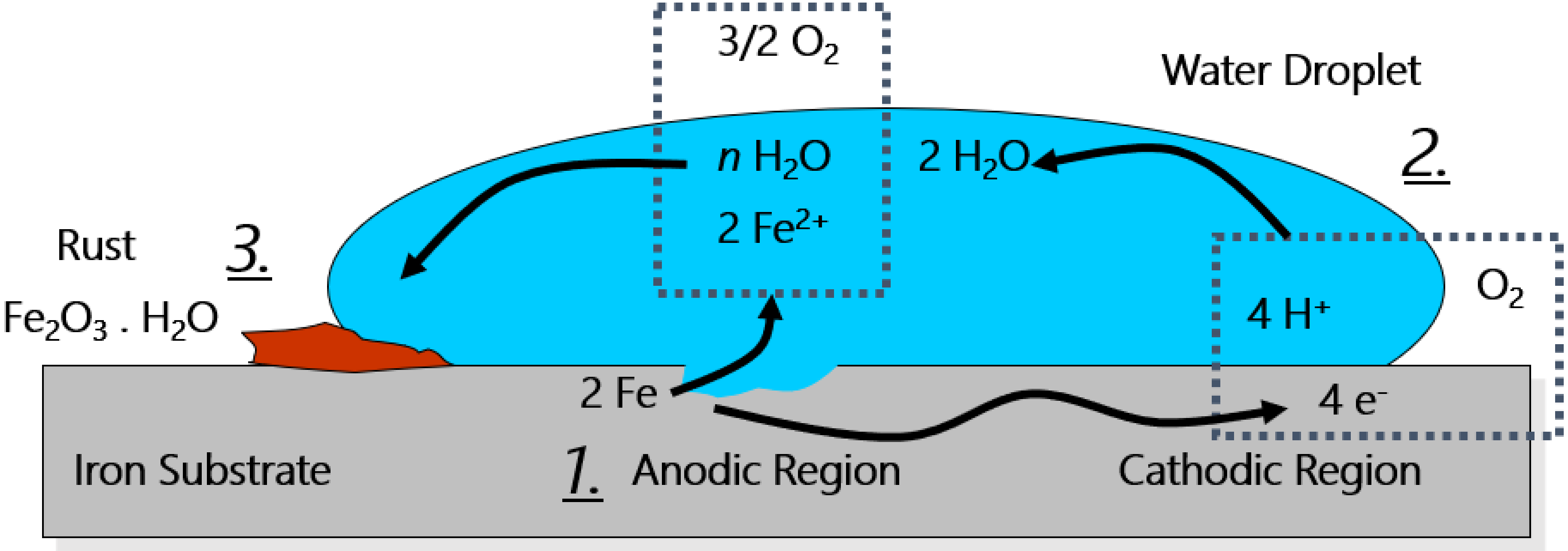
Limitations

- Factory application
- High temperature cure (limited substrates)
- Intensive processing (high energy demand)



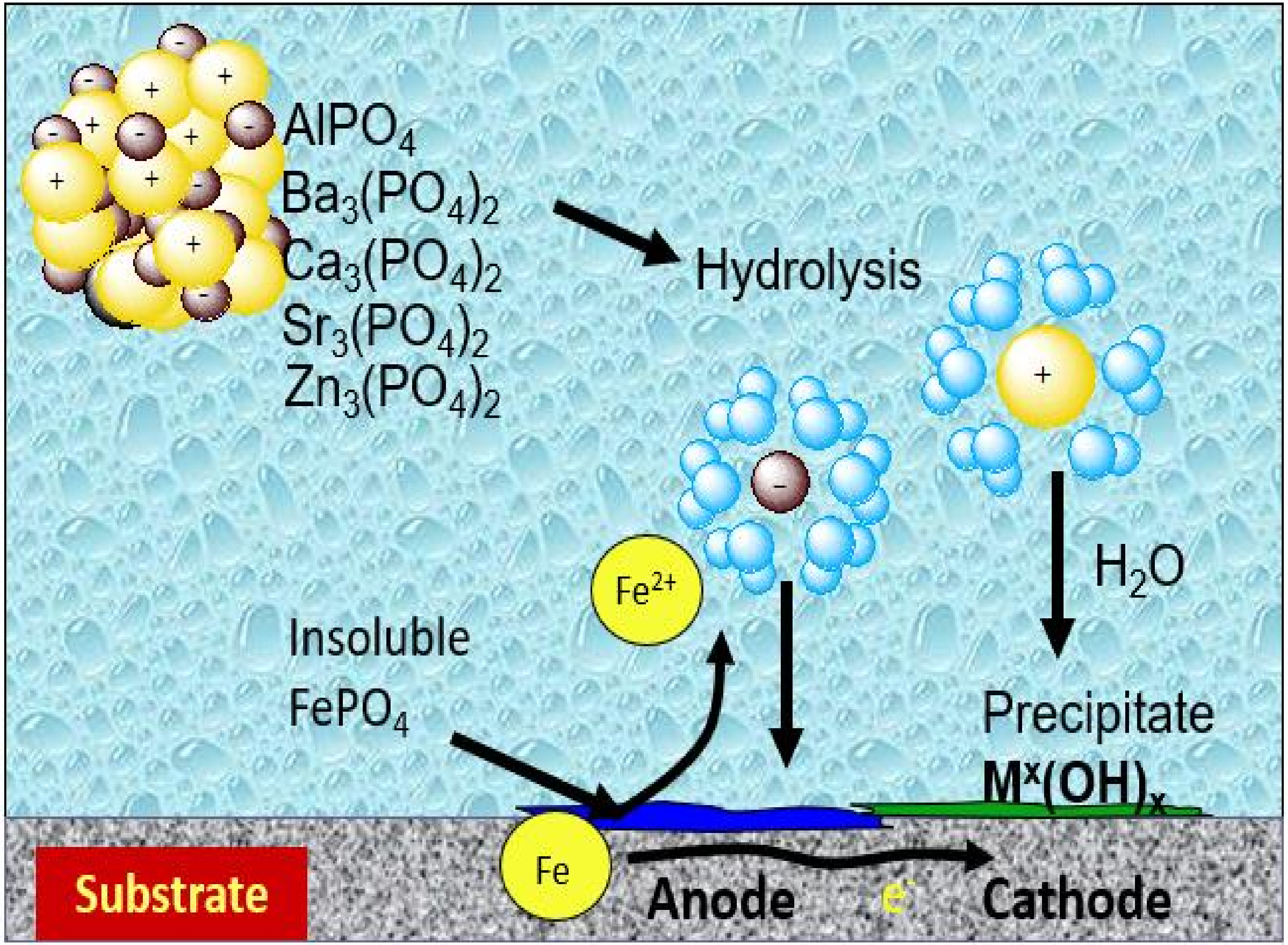
Corrosion Formation & Inhibition

Uniform Corrosion Cell Diagram



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

Mixed Metal Cation Inorganics – Passivation Mechanism



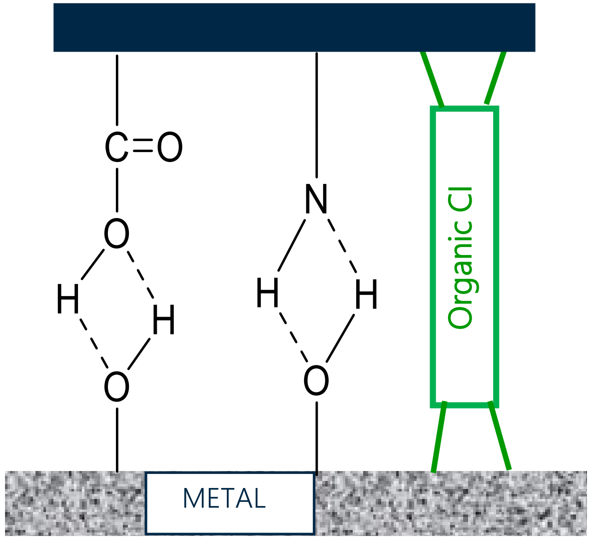
Phosphate	Ksp
Li3PO4	2.4×10^{-4}
CaHPO4	1.0×10^{-7}
MgNH4PO4	2.5×10^{-13}
AlPO4	1.3×10^{-20}
FePO4	1.3×10^{-22}
Mg3PO4	6.3×10^{-24}
Ba3(PO4)2	1.3×10^{-29}
Ca3(PO4)2	2.0×10^{-29}
Sr3(PO4)2	1.0×10^{-31}
Zn3(PO4)2	9.0×10^{-33}
CePO4	2.9×10^{-34}

Organic Inhibitor – Adhesion Promoter

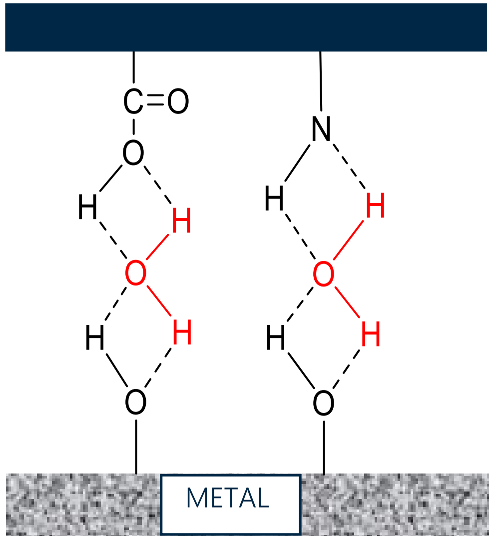
Water and corrosion products can cause:

Adhesion Loss, Delamination, Blistering

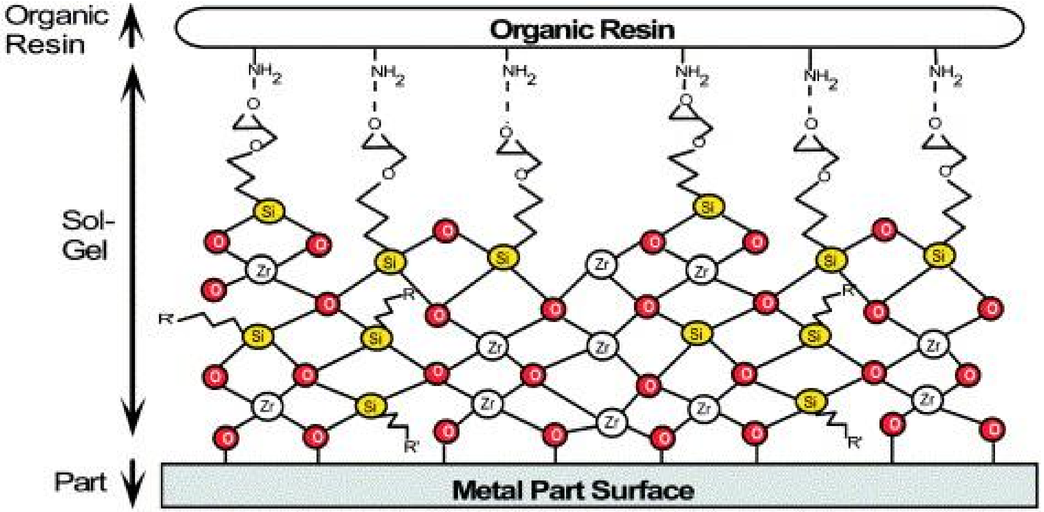
(Cathodic Reactions)



ABSENCE OF WATER



SMALL QUANTITIES OF WATER



Coatings adhere by mechanical AND polar interactions (e.g. hydrogen bonding).

These can be displaced by water.

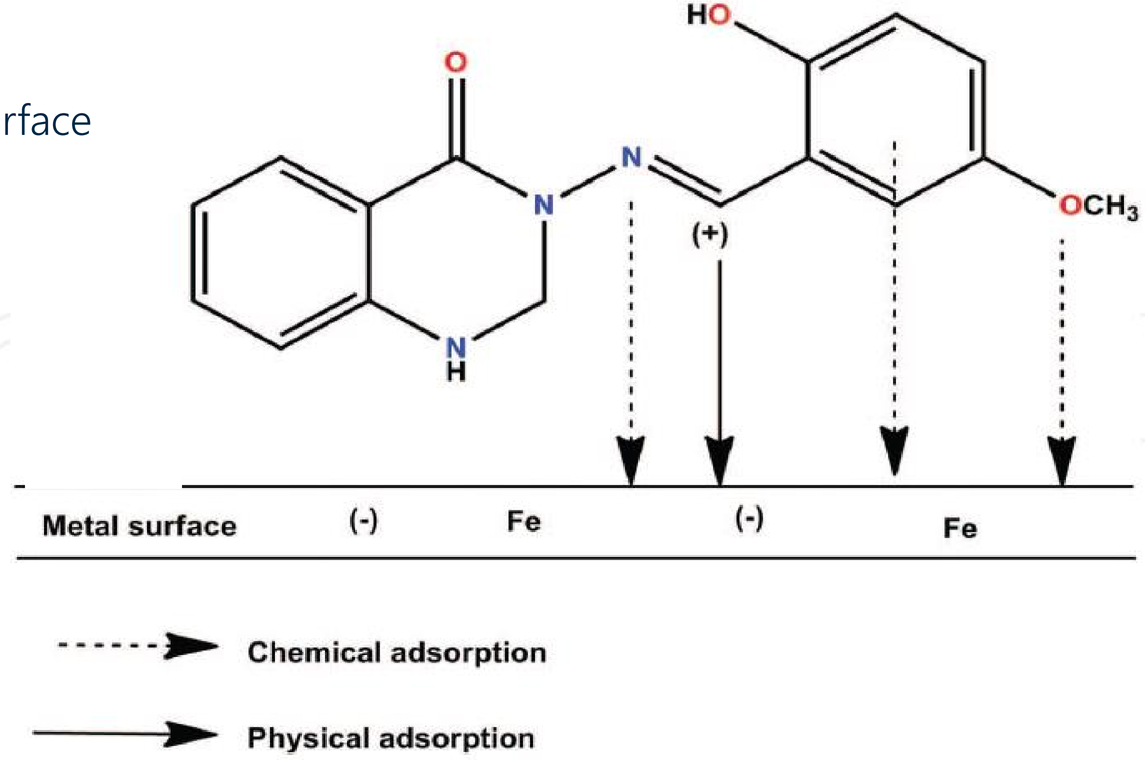
Why Use Organic Corrosion Inhibitors?

- Act as cathodic or anodic inhibitors.

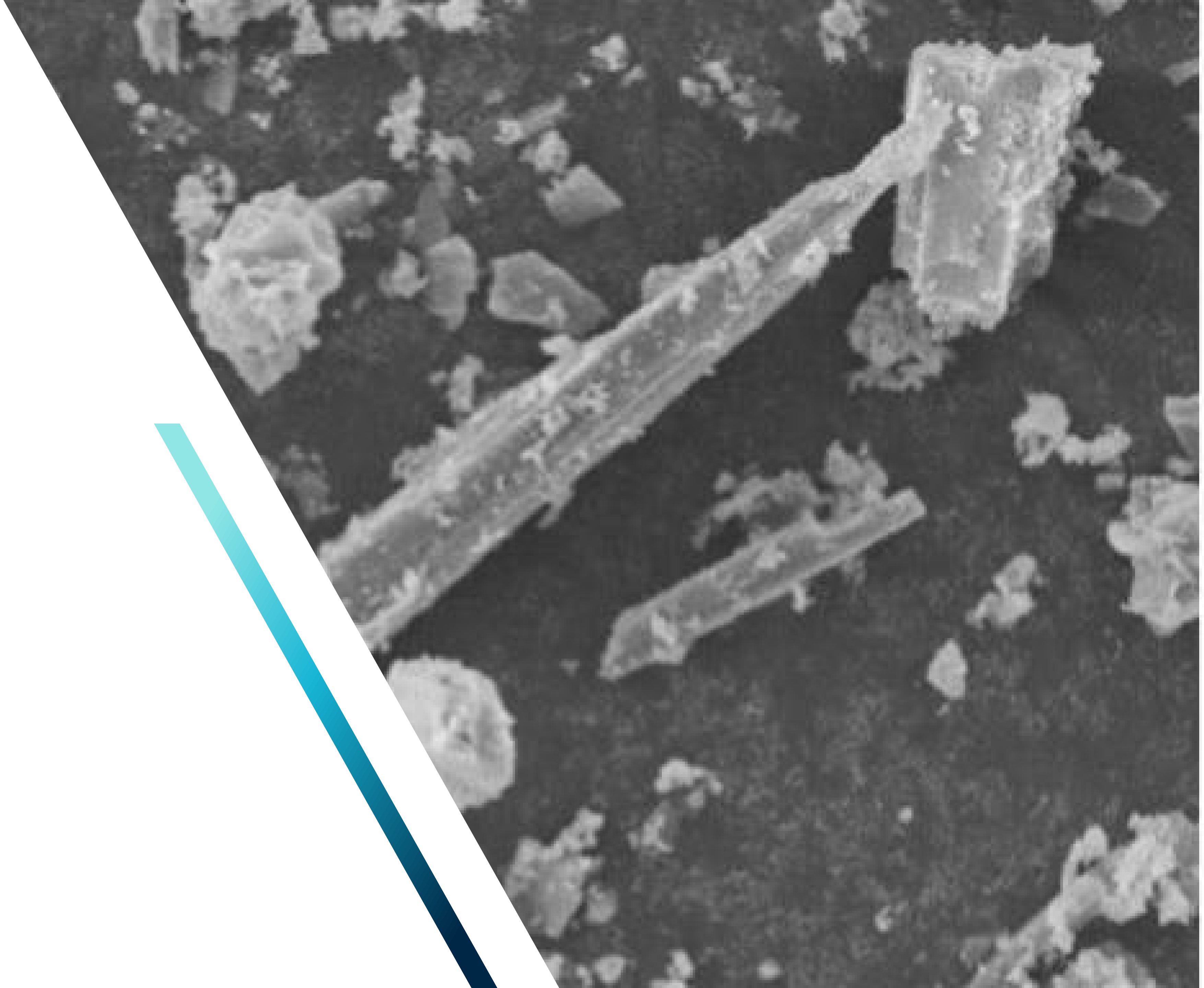
- Adsorb on surfaces:
  - Physisorption
    - Electrostatic interaction between charged metal surface and charged inhibitor.
  - Chemisorption
    - Transfer or share of unbounded electrons between molecule and metal surface.

- Results in enhanced adhesion.

- No negative impact on gloss.
- Provides unique mechanism to inorganic CIs.



Polyester/TGIC Corrosion Case Study



Corrosion Inhibitor Chemistries

DA

- Organic di-acid
- Metal affinity adhesive groups
- Hydrophobic

ZN1

- Strontium zinc phosphosilicate
- Low solubility
- Heavy-metal containing

CA1

- Calcium phosphate +
- Ion exchange mechanism
- Moderate solubility
- Heavy-metal free

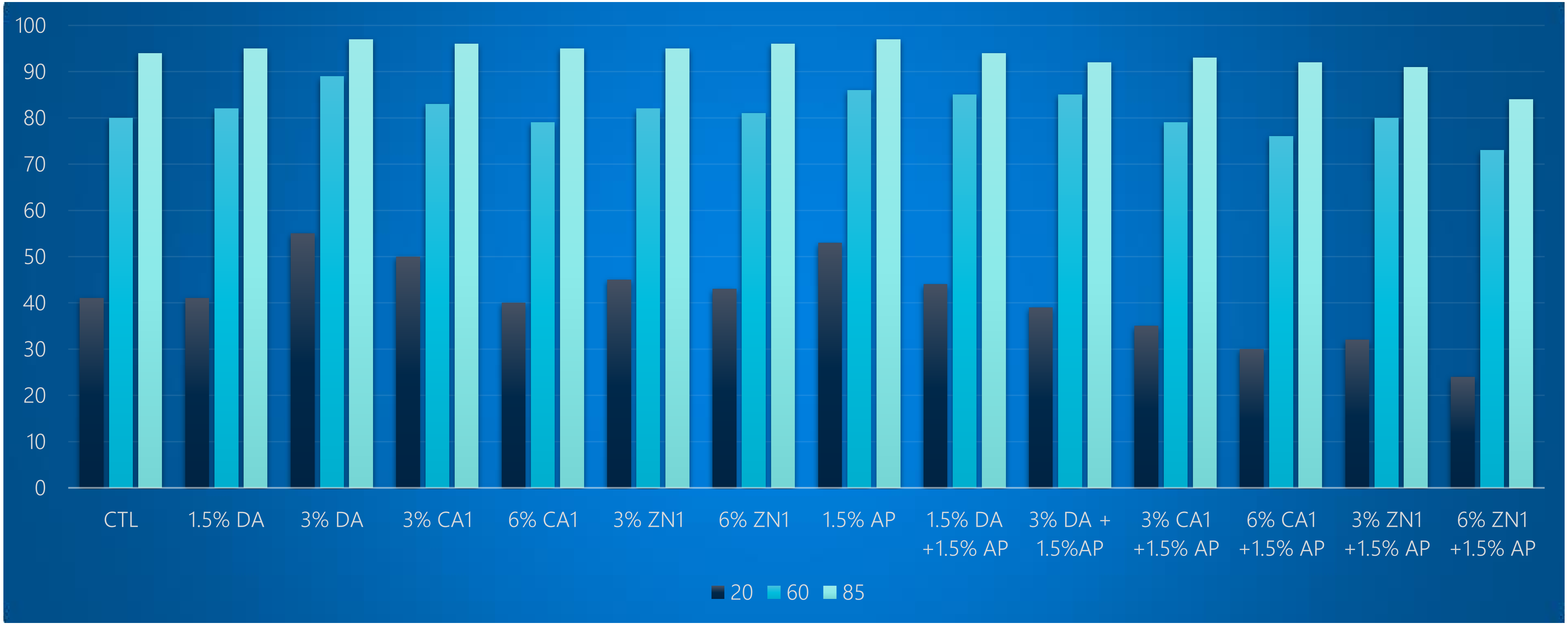
Powder Screening Formula

Corrosion Inhibitor Screening

Component:	DF0075	DF0076	DF0077	DF0078	DF0079	DF0080	DF0081	DF0082	DF0083	DF0084	DF0085	DF0086	DF0087	DF0088
Polyester	65.1	65.1	65.1	65.1	65.1	65.1	65.1	65.1	65.1	65.1	65.1	65.1	65.1	65.1
TGIC	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Flow & Leveling Agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Degassing agent	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Carbon Black	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Titanium Dioxide	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
Calcium carbonate	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Subtotal	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Adhesion promoter								1.5	1.5	1.5	1.5	1.5	1.5	1.5
Organic CI (DA)		1.5	3						1.5	3				
Inorganic CI (CA1)				3	6						3	6		
Inorganic CI (ZN1)						3	6						3	6
TOTAL	100	101.5	103	103	106	103	106	101.5	103	104.5	104.5	107.5	104.5	107.5

Film properties

Gloss



Film properties

	CTL	1.5% DA	3% DA	3% CA1	6% CA2	3% ZN1	6% ZN1	1.5% AP	1.5% DA +1.5% AP	3% DA +1.5% AP	3% CA1 +1.5% AP	6% CA2 +1.5% AP	3% ZN1 +1.5% AP	6% ZN1 +1.5% AP
Mandrel Bend	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟩
MEK Rubs	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟩
Gel time	4:20	-	5:00	-	4:28	-	3:45	-	-	-	-	-	-	-

🟩 PASS
🟥 FAIL

- All samples passed flexibility and film integrity, except high level of di-acid CI.
- Calcium phosphate demonstrates minimal impact on gel time.
- Color data shows not significant impact with additives.

Conical Mandrel Bend to 1/8th inch

50 MEK Double Rubs

Gel Time at 200°C, run in triplicate

ASTM B-117

- CRS
- 900 hours
- 4 mils DFT
- Spatula scraped

BLANK CONTROL

1.5% DA

3% DA

3% CA1

STOPPED at 336 hours

STOPPED at 336 hours

ASTM B-117

- CRS
- 900 hours
- 4 mils DFT
- Spatula scraped

BLANK CONTROL

6% CA1

3% ZN1

6% ZN1

STOPPED at 336 hours

ASTM B-117

- CRS
- 900 hours
- 4 mils DFT
- Spatula scraped

1.5% AP

1.5% AP +1.5% DA

1.5% AP + 3% DA

1.5% AP + 3% CA1

STOPPED at 672 hours

ASTM B-117

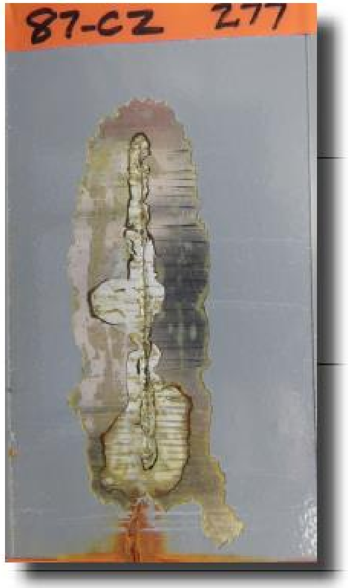
- CRS
- 900 hours
- 4 mils DFT
- Spatula scraped

1.5% AP

1.5% AP + 6% CA1

1.5% AP + 3% ZN1

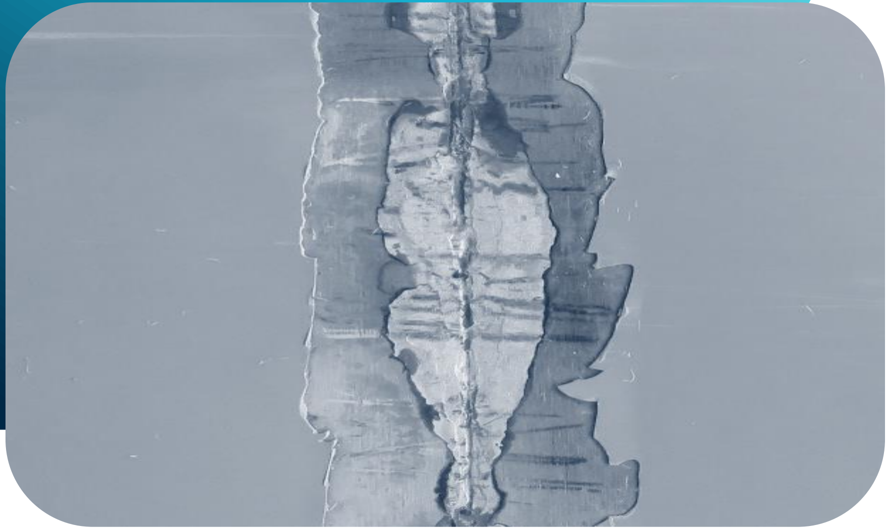
1.5% AP + 6% ZN1

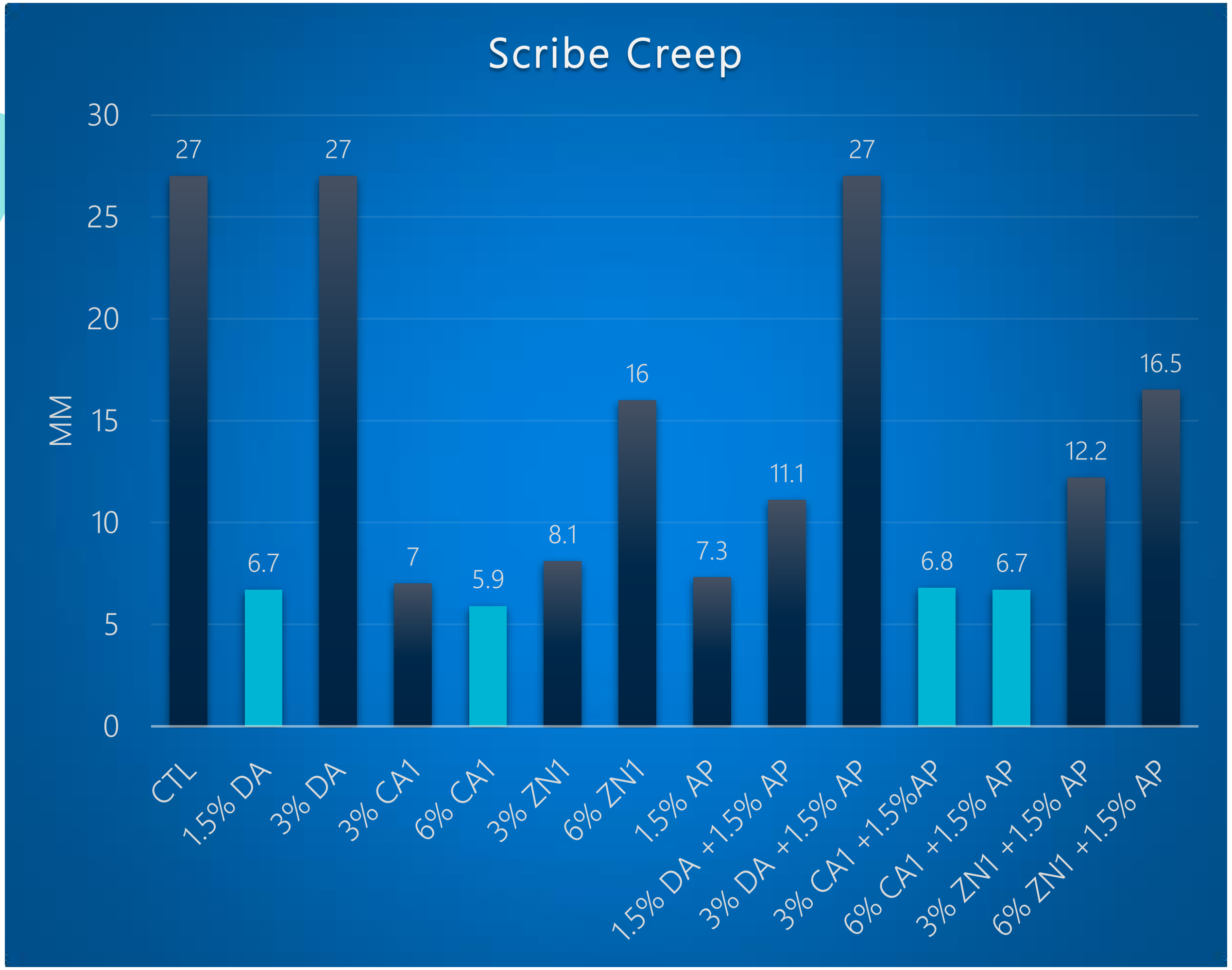


Corrosion Performance

Adhesion at the scribe

- All additives provided improved adhesion and scribe creep performance.
- DA and CA1 provided most improvement.





Scribe creep is recorded by the AVG of 5 measurements along scraped scribe. Total wide of failure divided in half.

ASTM B-117

- Al 3003
- 3000 hours
- 4 mils DFT

Al 3003			3000 hours		
Sample	Panel #		Scribe Creep ASTM D-1654	Field Corrosion D-610	Field Blistering ASTM D-714
75	A-1	control	10	10	10
75	A-2	control	10	10	10
76	A-1	1.5% DA	10	10	10
76	A-2	1.5% DA	10	10	10
77	A-1	3% DA	10	10	10
77	A-2	3% DA	10	10	10
78	A-1	3% CA1	7	10	10
78	A-2	3% CA1	7	10	10
79	A-1	6% CA1	7	10	10
79	A-2	6% CA1	7	10	10
80	A-1	3% ZN1	5	10	10
80	A-2	3% ZN1	5	10	10
81	A-1	6% ZN1	5	10	10
81	A-2	6% ZN1	5	10	10
82	A-1	1.5% AP	10	10	10
82	A-2	1.5% AP	10	10	10
83	A-1	1.5% DA + 1.5% AP	10	10	10
83	A-2	1.5% DA + 1.5% AP	10	10	10
84	A-1	3% DA + 1.5% AP	10	10	6MD
84	A-2	3% DA + 1.5% AP	9	10	10
85	A-1	3% CA1 + 1.5% AP	10	10	10
85	A-2	3% CA1 + 1.5% AP	10	10	10
86	A-1	6% CA1 + 1.5% AP	10	10	10
86	A-2	6% CA1 + 1.5% AP	9	10	10
87	A-1	3% ZN1 + 1.5% AP	9	10	10
87	A-2	3% ZN1 + 1.5% AP	10	10	10
88	A-1	6% ZN1 + 1.5% AP	10	10	10
88	A-2	6% ZN1 + 1.5% AP	10	10	10

- Control adhesion to bare aluminum was excellent.
- Inorganic corrosion inhibitors showed a negative effect in salt spray.
- Adhesion promoter demonstrated improved adhesion when blended with inorganics.

Powder Coatings Solutions

Factors to Consider

Summary:

- CIs had minimal impact on gloss and color.
- Film integrity can be negatively impacted by higher loading levels.
- Gel time can be impacted by inorganic cation selection.
- CI provides dramatic improvement in adhesion and corrosion resistance over CRS.

- Combine inhibitors – synergy of multiple mechanisms.
  - Inorganic/Flash Rust
  - Inorganic/Inorganic
  - Inorganic/Organic
- Optimize ratio of inorganic inhibitors.
  - Synergize short term and long-term corrosion inhibitors based on their solubility.
- Inhibitor concentration
  - Volume vs weight substitution.
- Substrate focus
  - CI selection can be substrate dependent.

Future Focus

1 Seeking further optimization with current and innovating products.

2 Defining synergistic benefits between products to provide solutions for regulated chemistries.

3 Focus on developing label-free corrosion inhibitors to satisfy the powder and liquid coatings market.

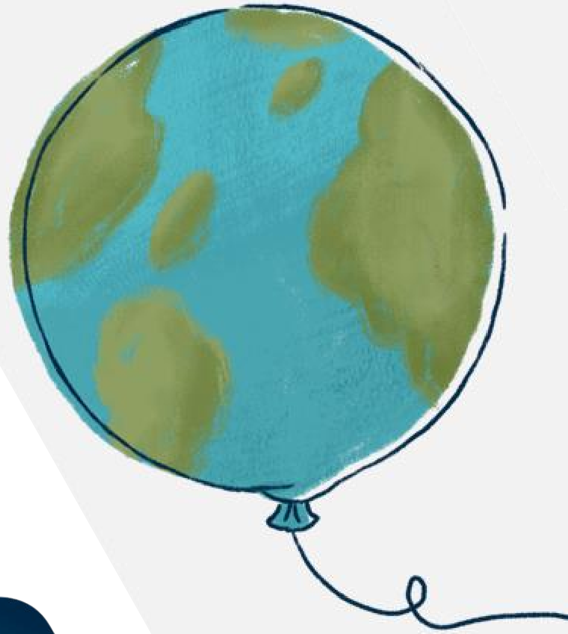
4 Understand novel chemistries like cerium, lithium, and lanthanum for high performance applications.

5 Partner with industry experts to advance the corrosion management initiative.

SUMMARY

Sustainability is Our Strategy for Growth

- Powder coatings have experienced rapid development and growth.
- Many applications benefit from their sustainable advantages.
- High performance can be achieved with simple formulations.
- Optimization of corrosion inhibitor package can find cost/performance benefits.
- Heavy-metal free options provide excellent performance.



Thank You

Enhanced Corrosion Protection in Powder Coatings

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