Impactful Corrosion Solutions for Metal Protective Coatings

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AGENDA

Impactful Corrosion Solutions for Metal Protective Coatings

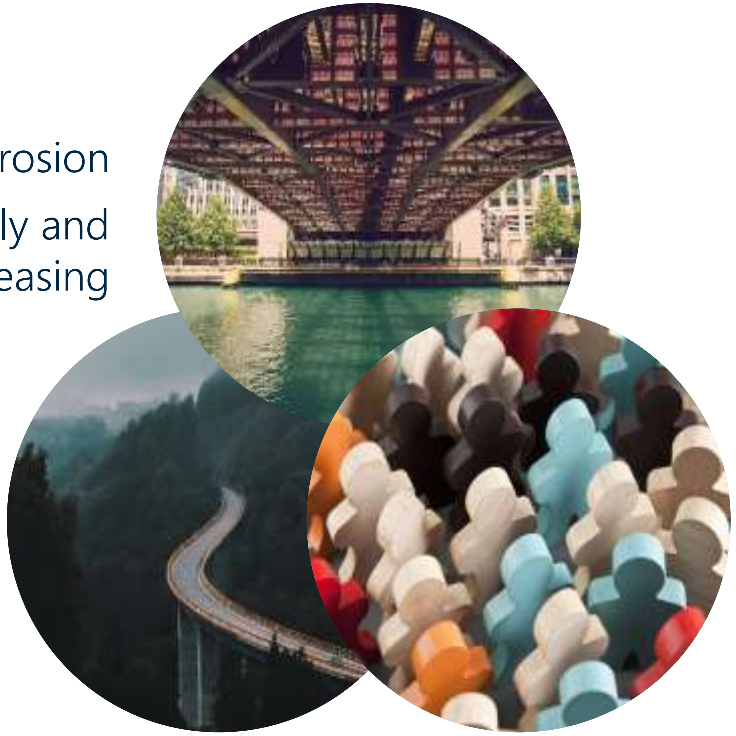
Source: https://sdgs.un.org/goals

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

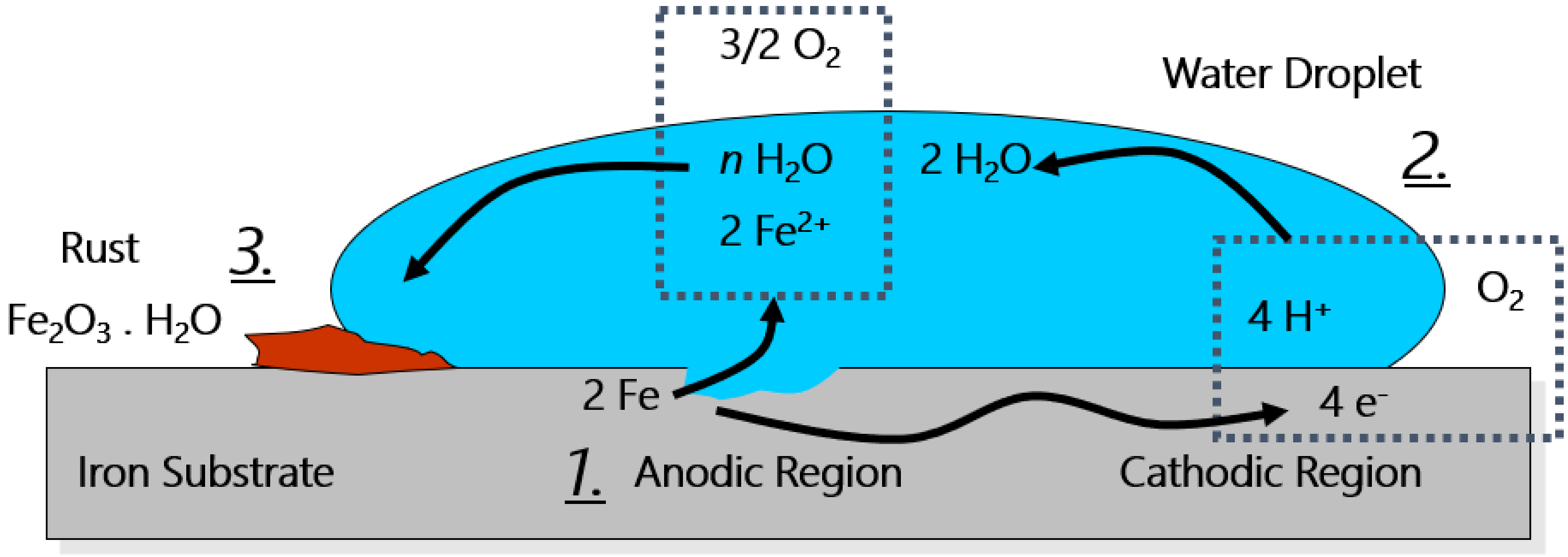
The Drive to Sustainability

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.

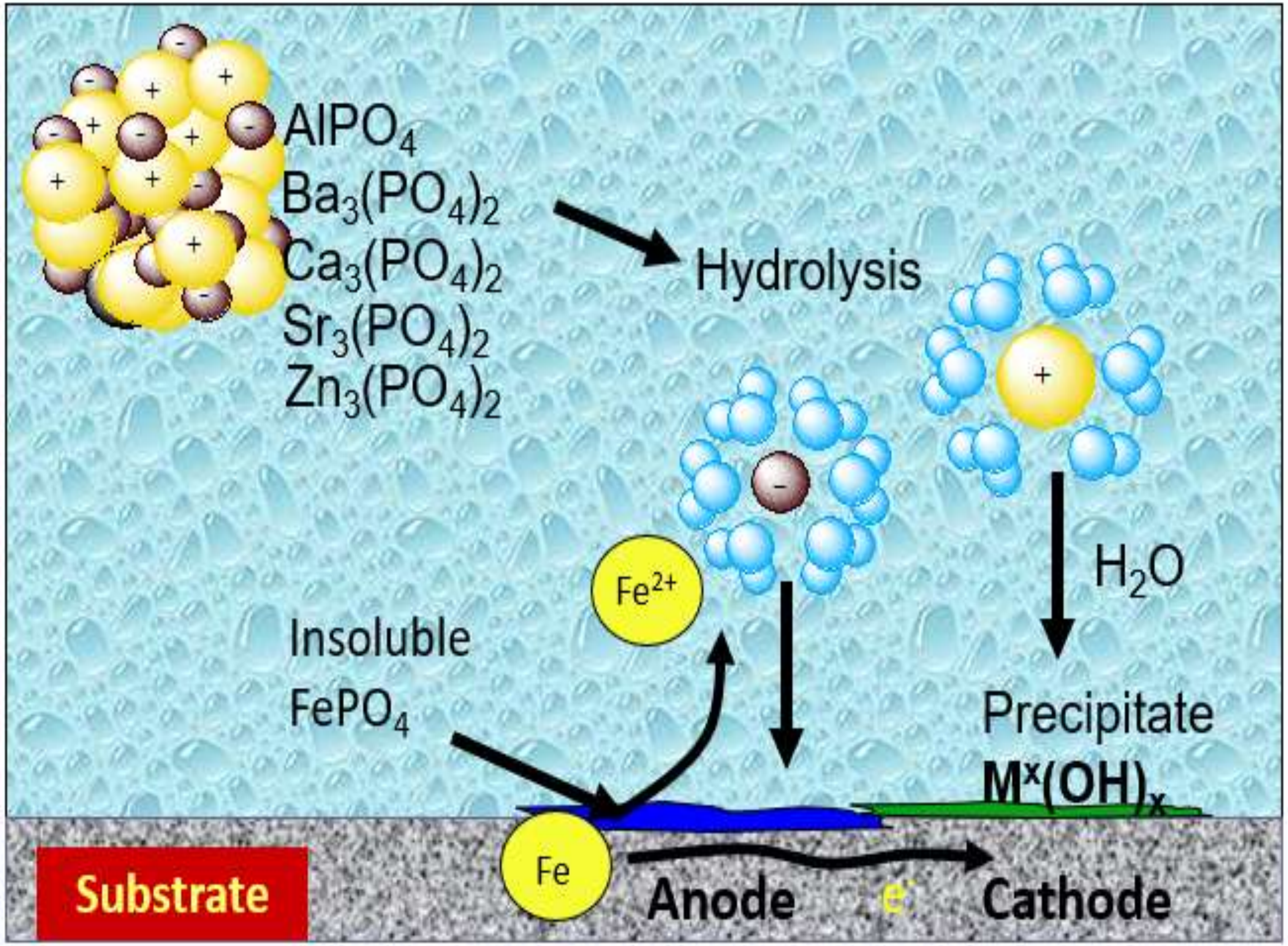
Corrosion Formation & Inhibition

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 Phosphates – Passivation Mechanism



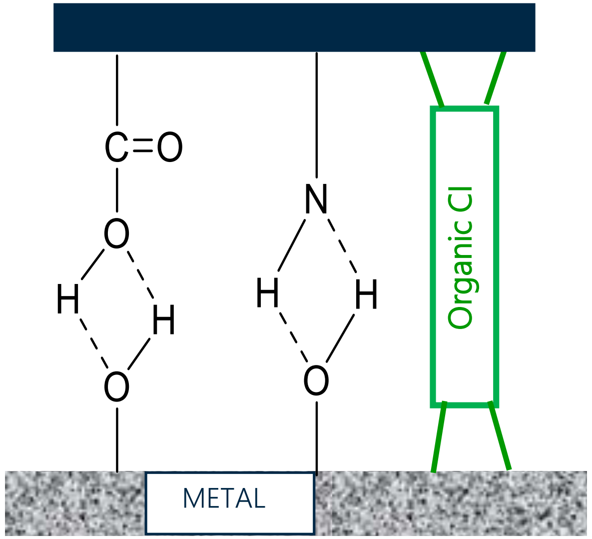
Phosphate	Ksp
Li3PO4	$2.4x10^{-4}$
CaHPO4	$1.0x10^{-7}$
MgNH4PO4	$2.5x10^{-13}$
AlPO4	$1.3x10^{-20}$
FePO4	$1.3x10^{-22}$
Mg3PO4	$6.3x10^{-24}$
Ba3(PO4)2	$1.3x10^{-29}$
Ca3(PO4)2	$2.0x10^{-29}$
Sr3(PO4)2	$1.0x10^{-31}$
Zn3(PO4)2	$9.0x10^{-33}$
CePO4	$2.9x10^{-34}$

Organic Inhibitor – Adhesion Promoter

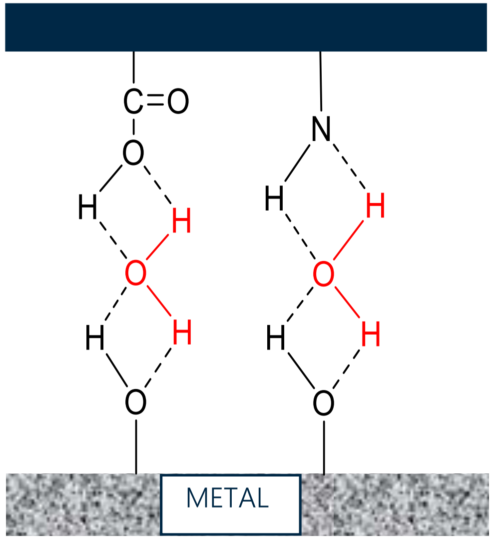
Water and corrosion products can cause:

Adhesion Loss, Delamination, Blistering

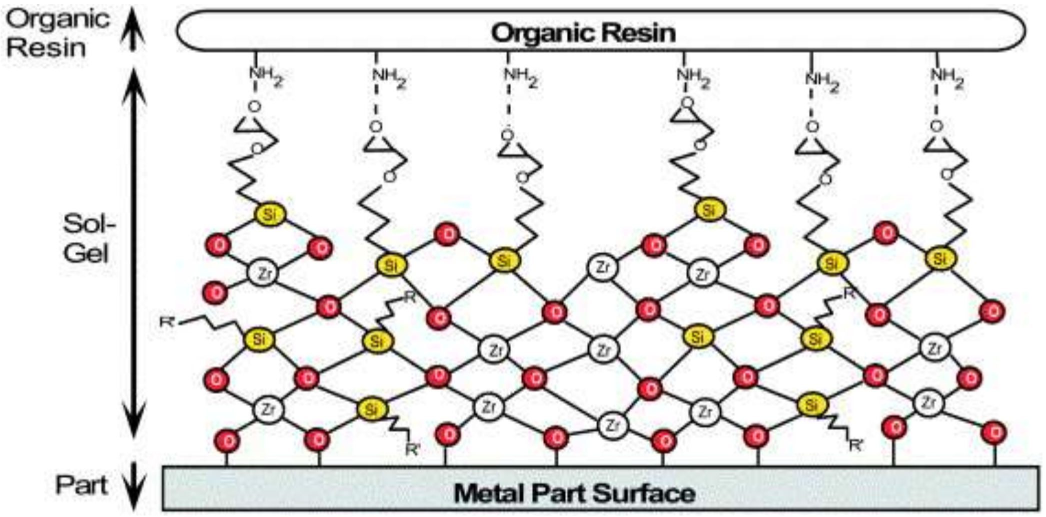
(Cathodic Reactions)



ABSENCE OF WATER



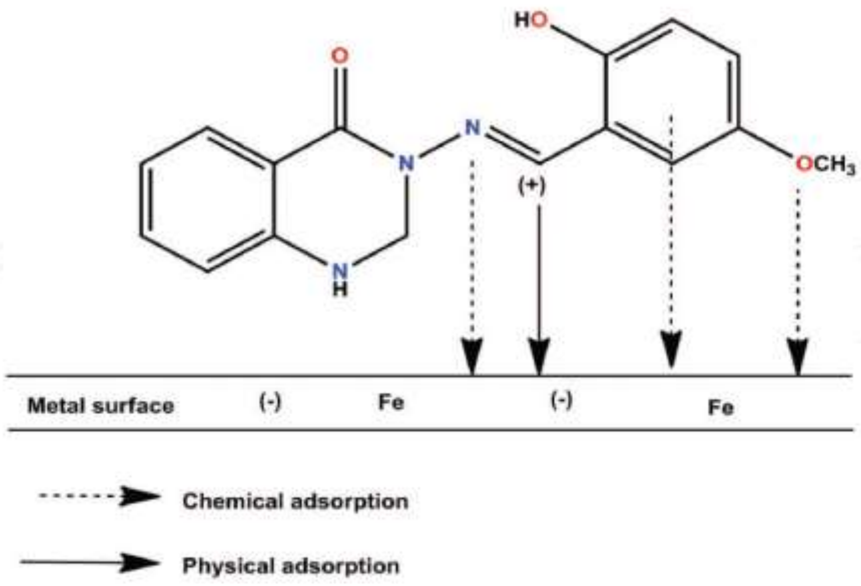
SMALL QUANTITIES OF WATER



Coatings adhere by mechanical AND polar interactions (e.g. hydrogen bonding).
These can be displaced by water.

Organic Inhibitor – Adhesion Promoter

- Act as cathodic or anodic inhibitors
- Heteroatoms and π–electron moieties
  - Corrosion inhibition efficiency: P>S>N>O
- Adsorb on surfaces (physisorption or chemisorption)
  - Physisorption (electrostatic interaction b/n charged meta surface and charged inhibitor)
  - Chemisorption (transfer or share of unbounded electrons b/n molecule and metal surface)
- Can enhance adhesion
- No gloss detriment
- Effective at wide range of temperatures
- Good solubility in water
- Can be low cost
- Relatively low toxicity



Heavy-Metal Free Corrosion Inhibitors

The Sustainable Future

Organic

OFS

- Organofunctional silane
- Liquid

AAC

- Acid-Amine Complex
- Solid or neutralized liquid version

Inorganic

CAP 1

- Calcium phosphate
- Low solubility
- GRAS material

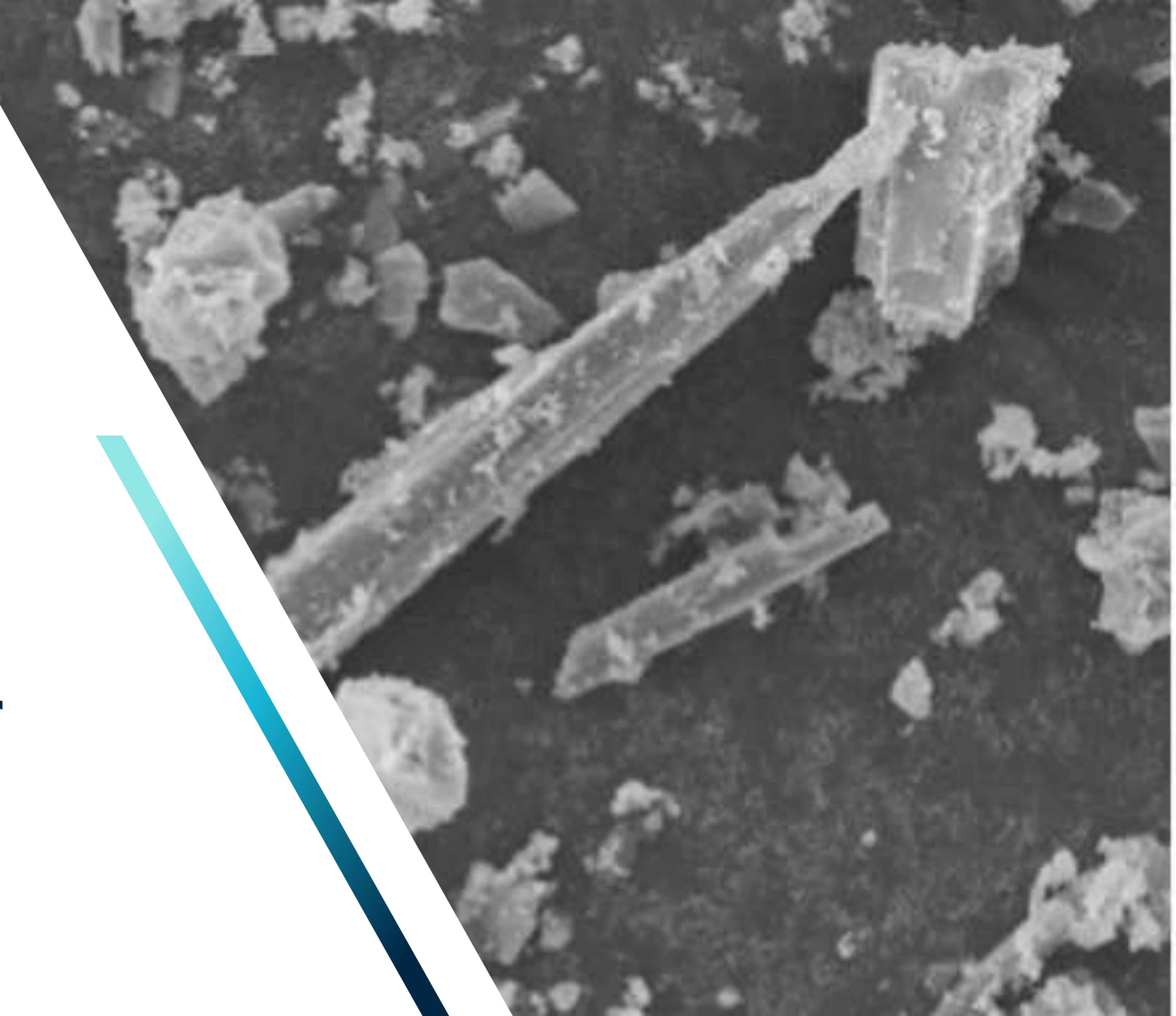
SRP

- Strontium phosphosilicate
- Low solubility

CAP 2

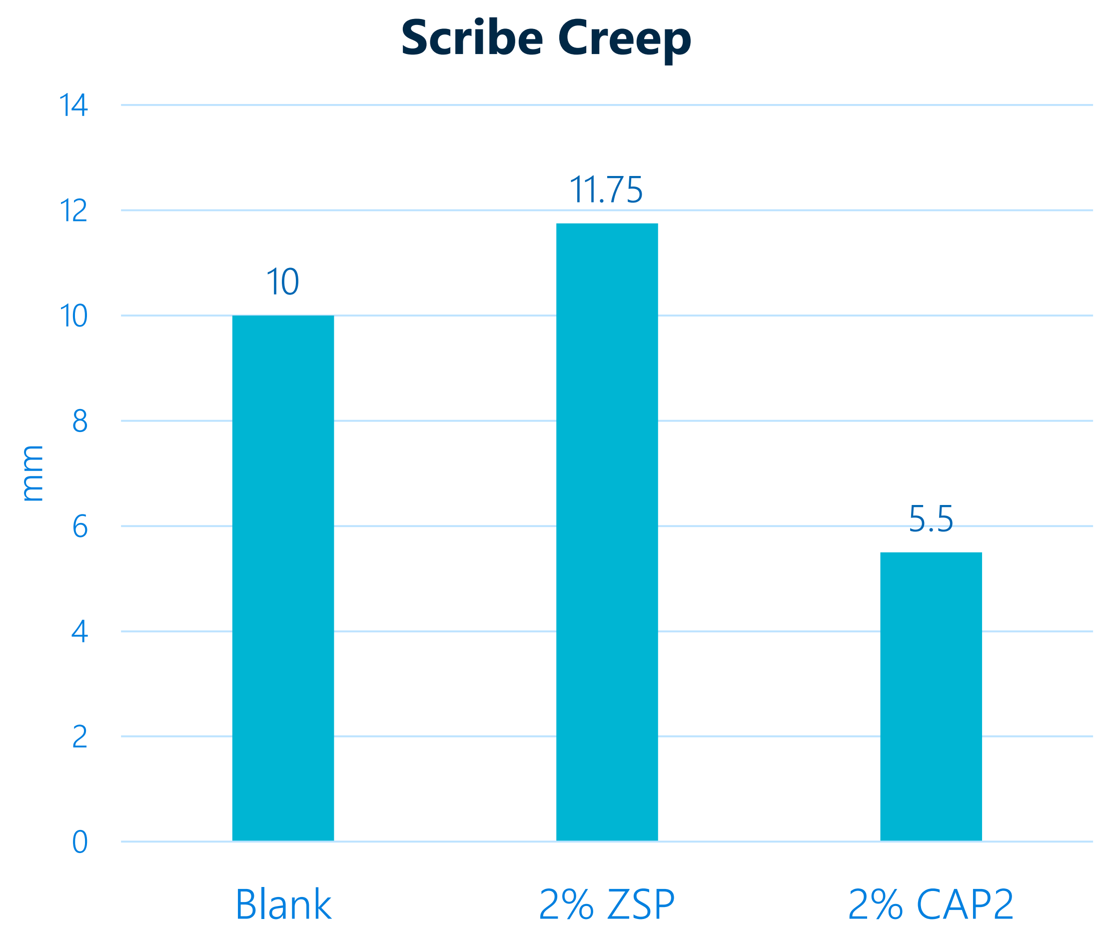
- Calcium phosphate +
- Ion exchange mechanism
- Moderate solubility

Inorganic Corrosion Inhibitor Case Studies

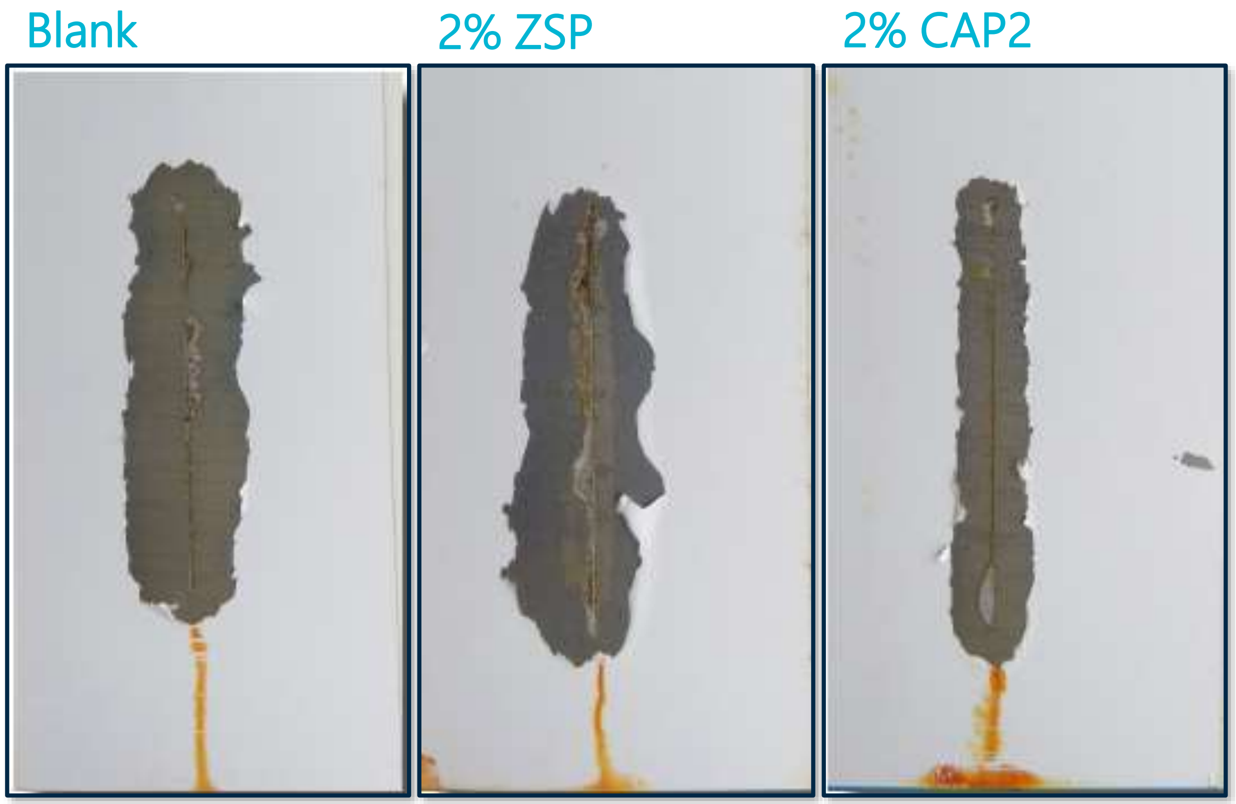


Calcium versus Zinc Containing CI

Water-based Light Industrial PU DTM



ASTM B117 @ 144 hours; 2 mils DFT over B1000



Key:

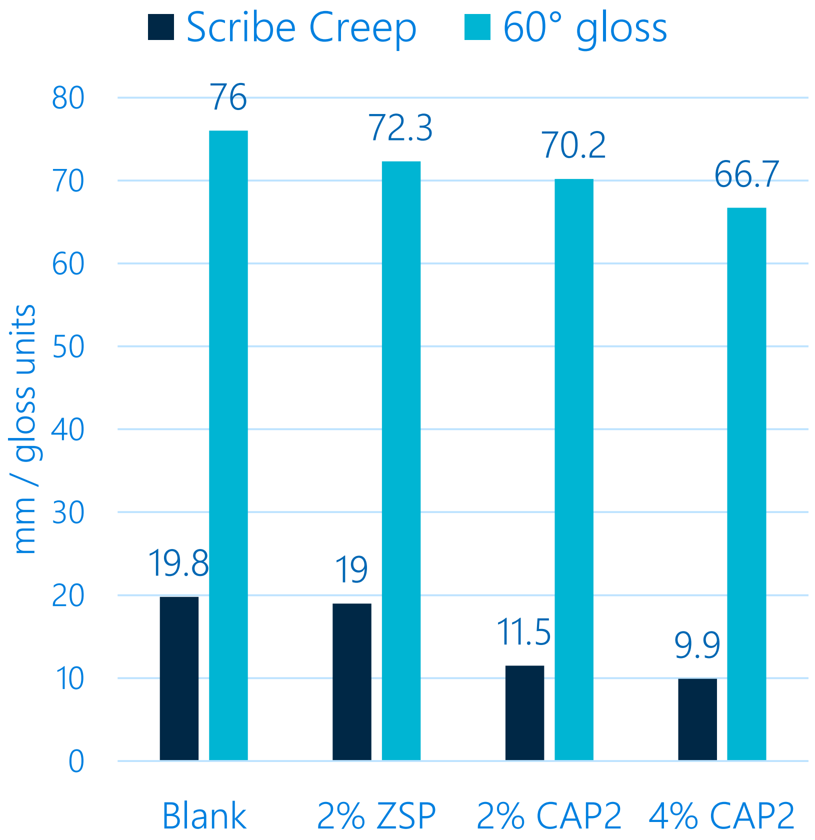
ZSP: Zinc strontium phosphosilicate

CAP2: Calcium phosphate +

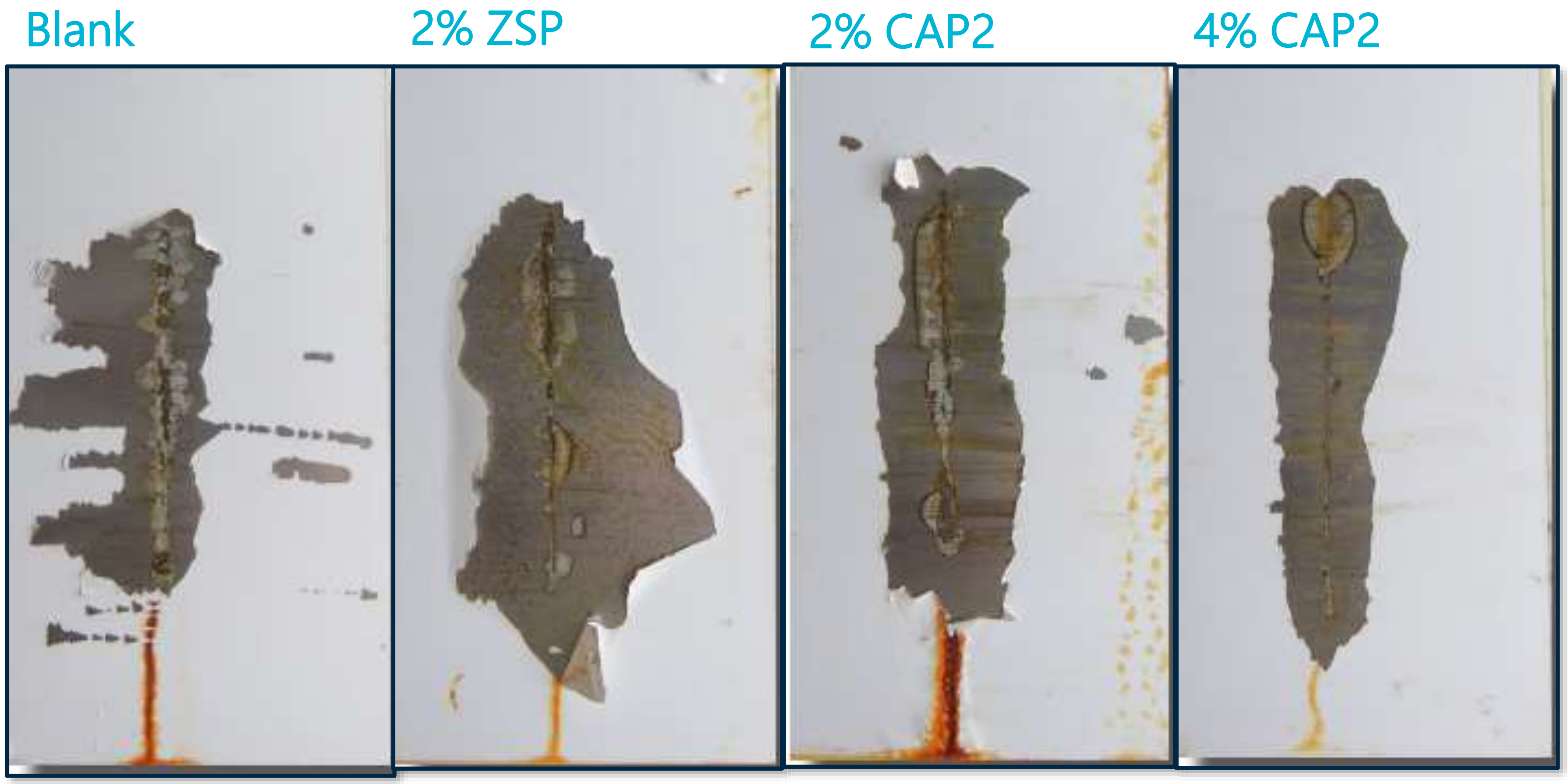
Calcium versus Zinc Containing CI

Water-based Light Industrial PU DTM

Panel Data



ASTM B117 @ 144 hours, 2 mils DFT over CRS



Key:
ZSP: Zinc strontium phosphosilicate
CAP2: Calcium phosphate +

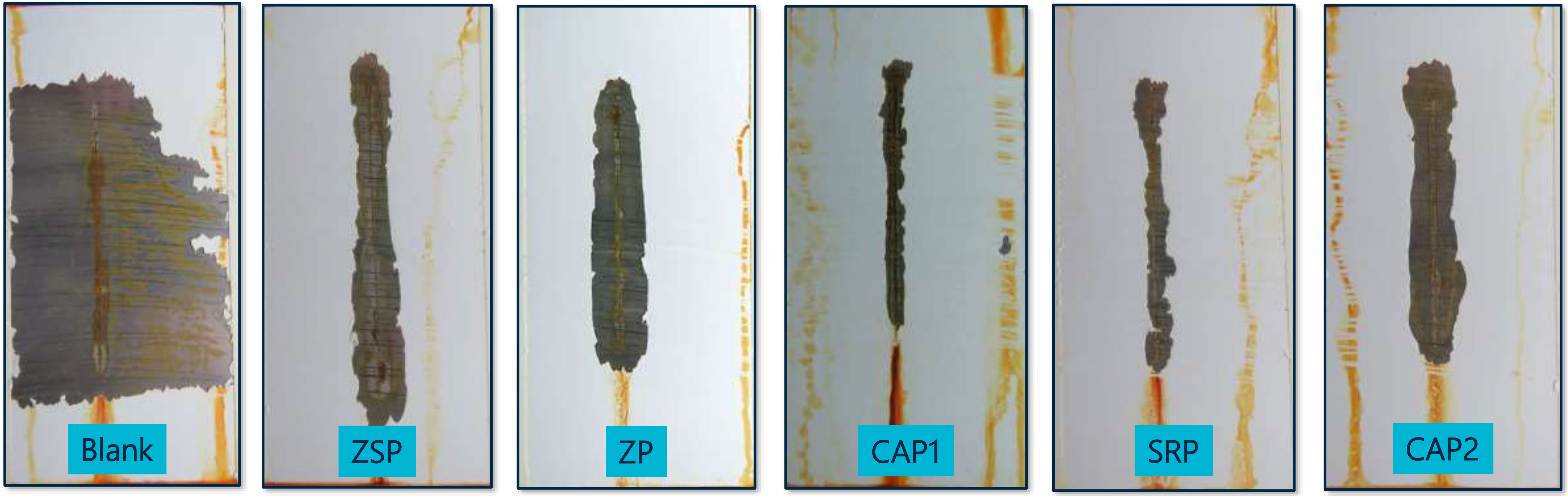
Heavy Metal Free versus Zinc

Water-based Light Industrial DTM Epoxy

ASTM B117 @ 168 hours; 4 mils over CRS

5% loading level

Sample ID	Scribe Creep (mm)
Blank	26.4
ZSP	6
ZP	6.9
CAP1	2.9
SRP	3.9
CAP2	6.4



Key:

ZSP: Zinc strontium phosphosilicate

ZP: Zinc phosphate

CAP1: Calcium phosphate

SRP: Strontium phosphosilicate

CAP2: Calcium phosphate + ion exchange

ICL

Organic Corrosion Inhibitor Case Study

WB 2K Epoxy Primer Case Study

Organic Corrosion Inhibitor Screening

Formula Specs:
- PVC: 30%
- Weight solids: 61.5%
- Amine:Epoxy ratio: 0.6:1
- VOC: <100 g/L

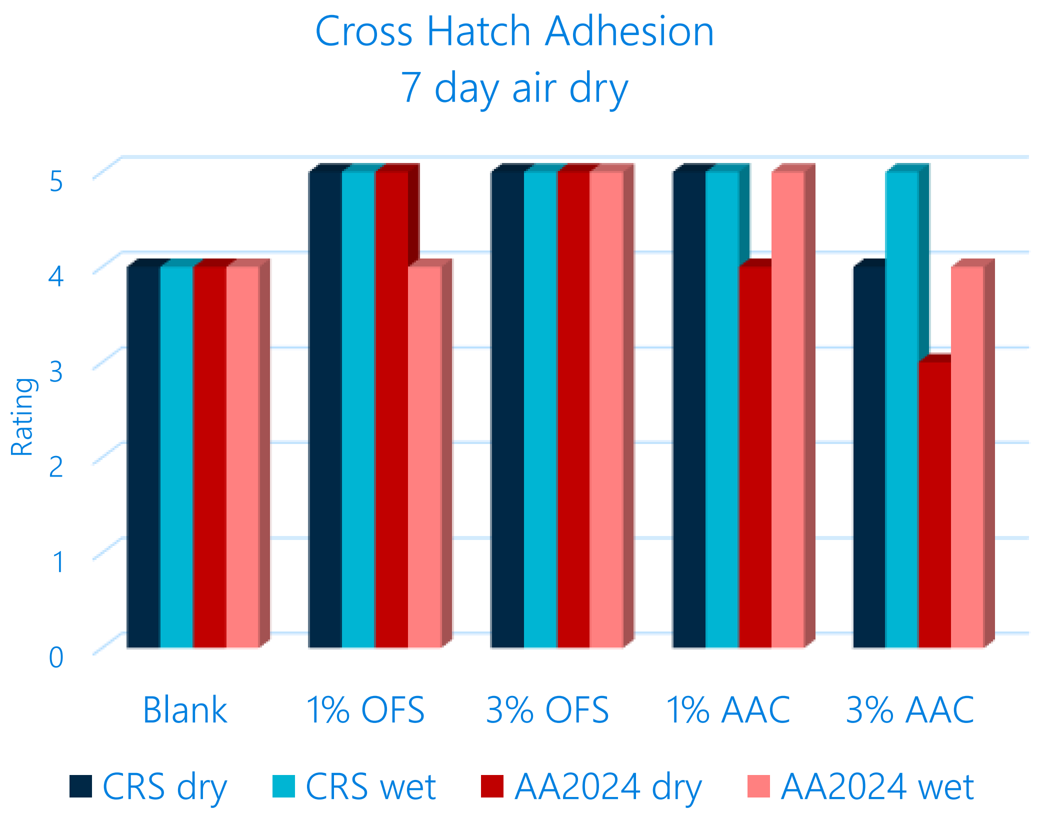
Parameters:
- HMF inorganic CI control
  - SRP at 8%
  - Flash rust inhibitor control
  - Sodium nitrite solution at 0.2%
- Evaluate organic inhibitor chemistries
  - **Organofunctional silane (OFS)**
  - **Acid Amine Complex (AAC)**
    - 1% & 3% tfw
  - Order of addition varies

Component	Quantity		% Weight
PART A:			
GRIND:			
Epoxy resin	306.4	Lb	26.6
Solvent	7.1	Lb	0.6
Solvent	12.5	Lb	1.1
Water	94.5	Lb	8.2
Defoamer	2.0	Lb	0.2
Wetting agent	10.2	Lb	0.9
Titanium dioxide	122.6	Lb	10.6
Barium sulfate	68.5	Lb	5.9
Wollastonite	102.1	Lb	8.9
Strontium phosphosilicate	96.7	Lb	8.4
Mica	3.0	Lb	0.3
High speed disperse to 5+ NS Hegman grind.			
Epoxy resin	125.6	Lb	10.9
Organic corrosion inhibitor	**34.5**	**Lb**	**3.0**
Surfactant	4.4	Lb	0.4
SUBTOTAL:	990.0	Lb	85.9
PART B:			
Amine curing agent	110.5	Lb	9.6
Sodium nitrite solution	2.0	Lb	0.2
Water	50.0	Lb	4.3
	100.0	Gal	100.0

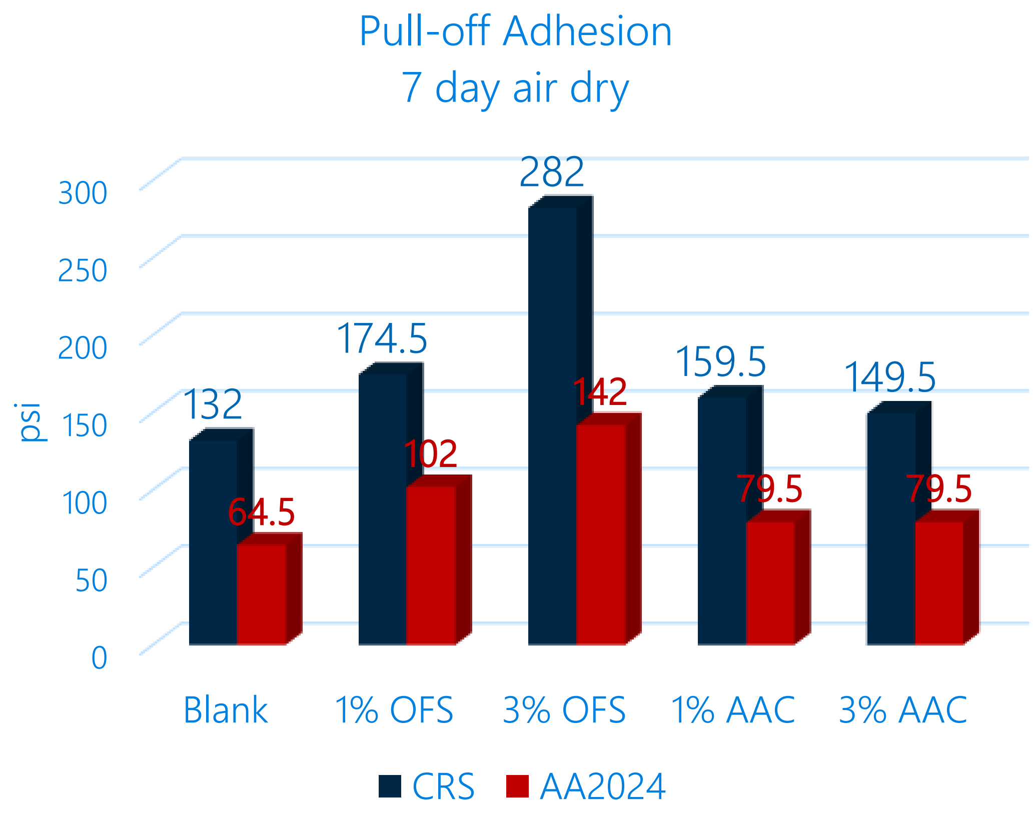
WB 2K Epoxy Primer Case Study

Organic CI screening

ASTM D-3359



ASTM D-4541



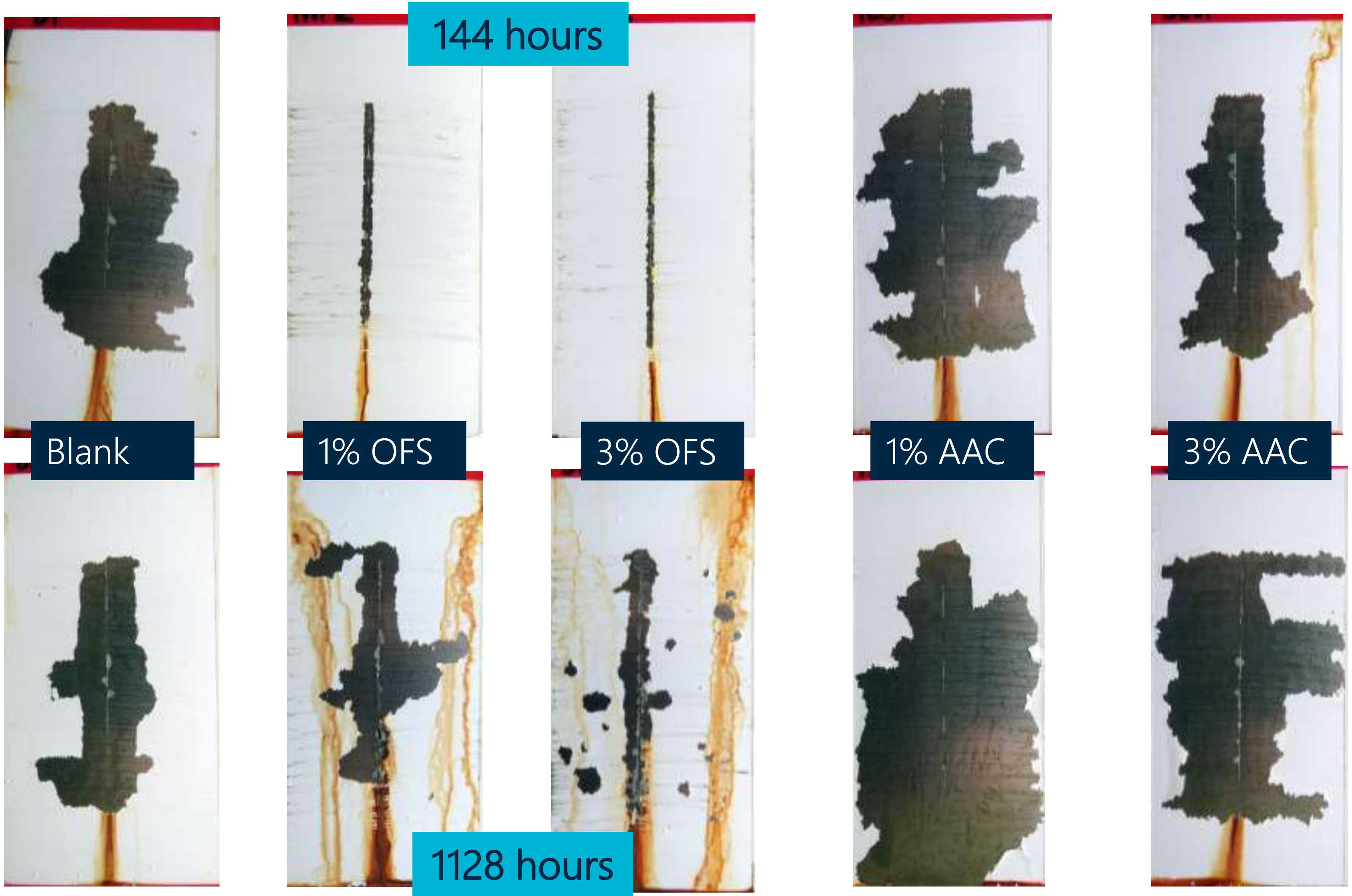
Key:

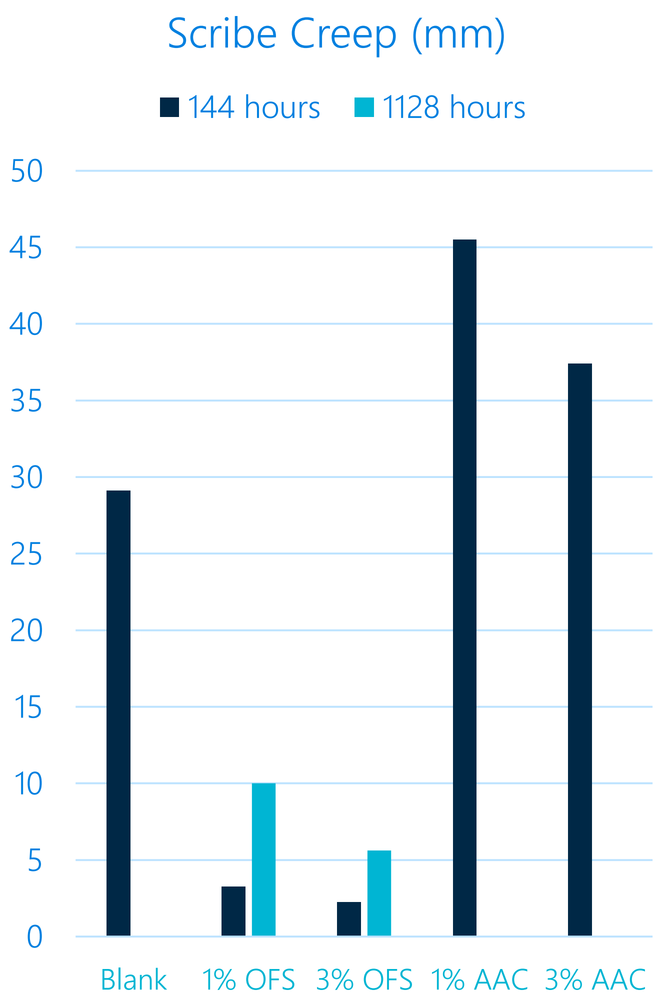
OFS: Organofunctional silane

AAC: Acid amine complex

WB 2K Epoxy Primer Case Study

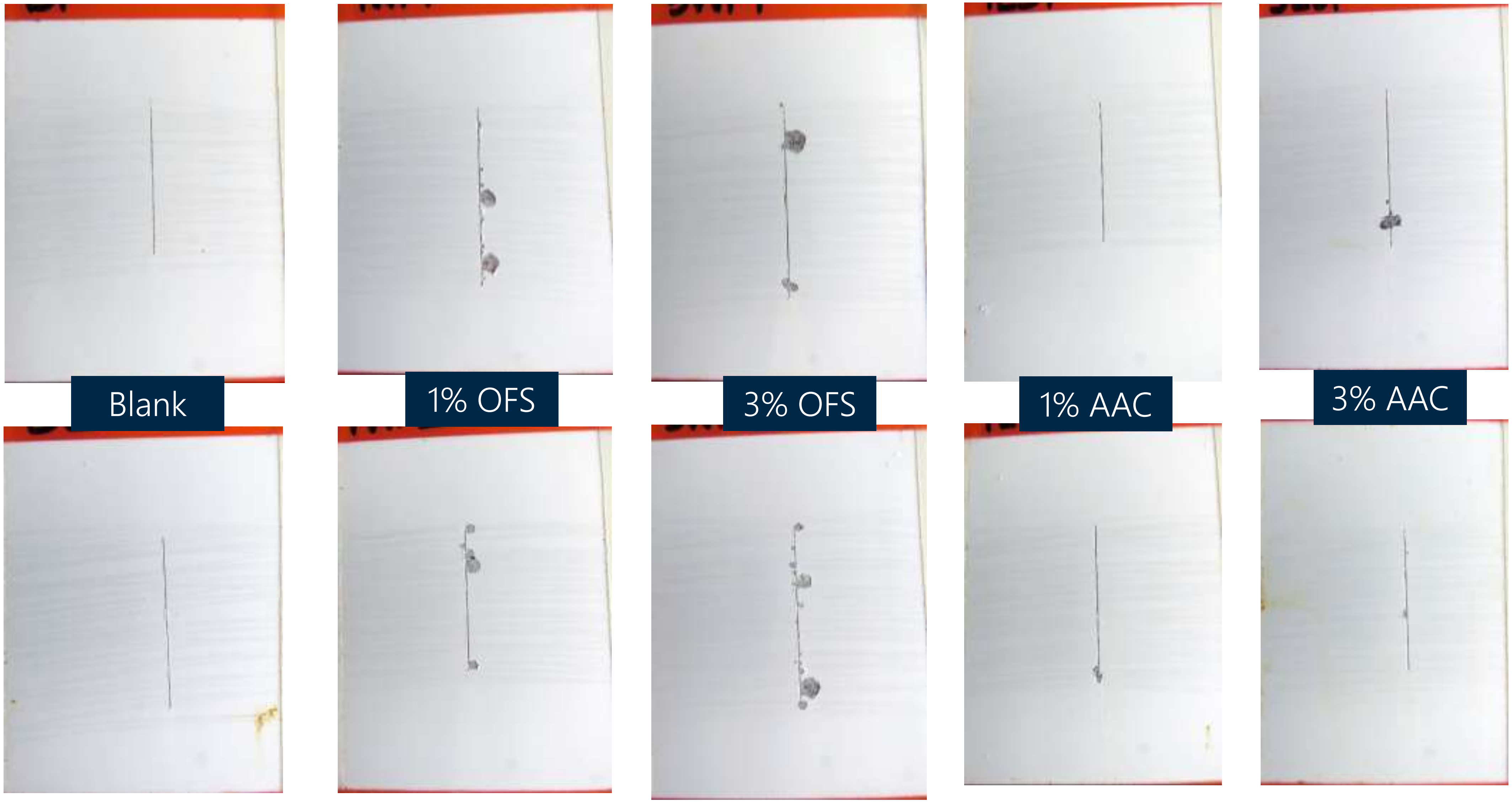
ASTM B-117 ~ 144 hours ~ Cold Rolled Steel ~ 56 µm DFT





WB 2K Epoxy Primer Case Study

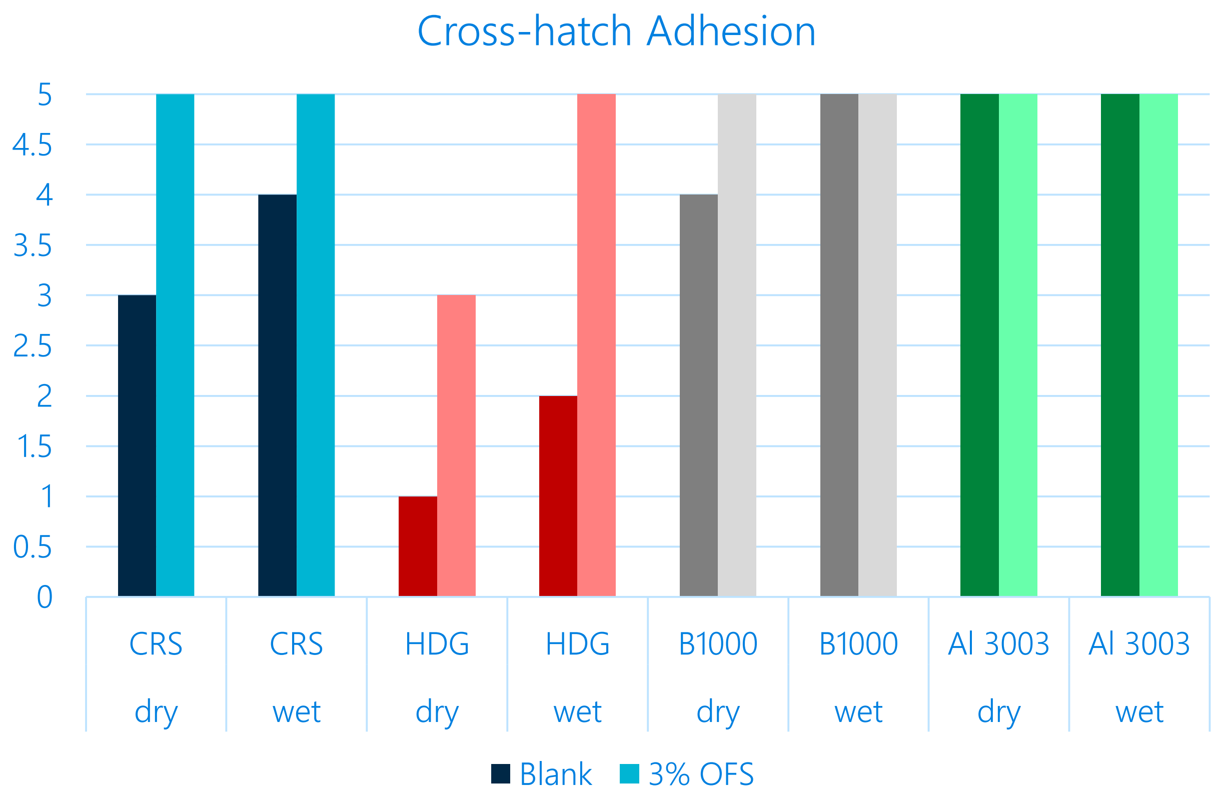
ASTM B-117 ~ 4424 hours ~ ACT Al 2024 T3 Alclad Alodined ~ 56 µm DFT ~ SCRAPED



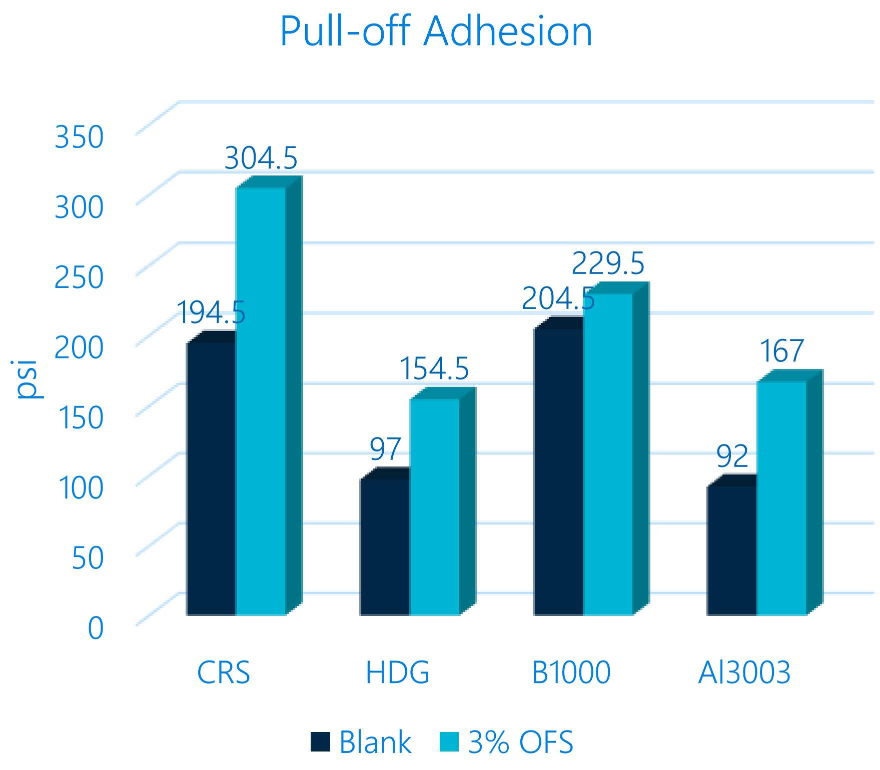
WB 2K Epoxy Primer – Substrate focus

3% OFS over multiple substrates

ASTM D-3359

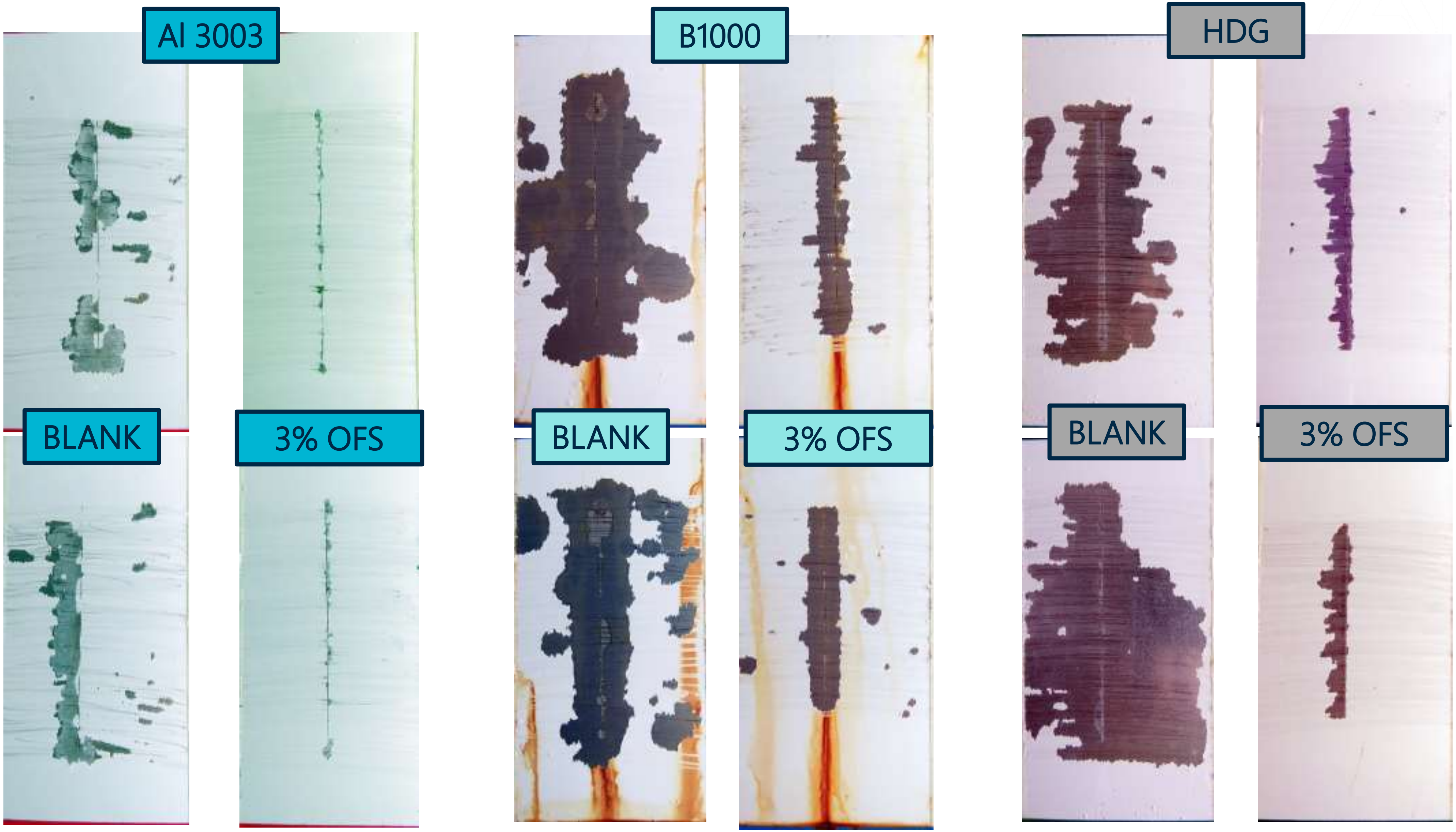


ASTM D-4541



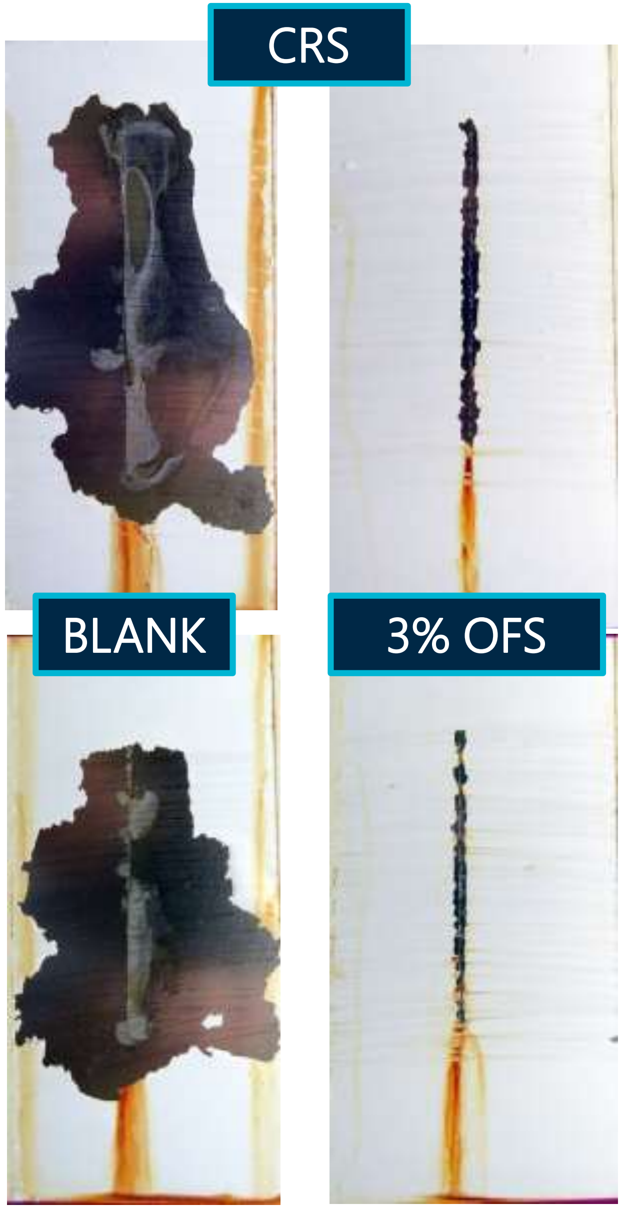
WB 2K Epoxy Primer – Substrate Focus

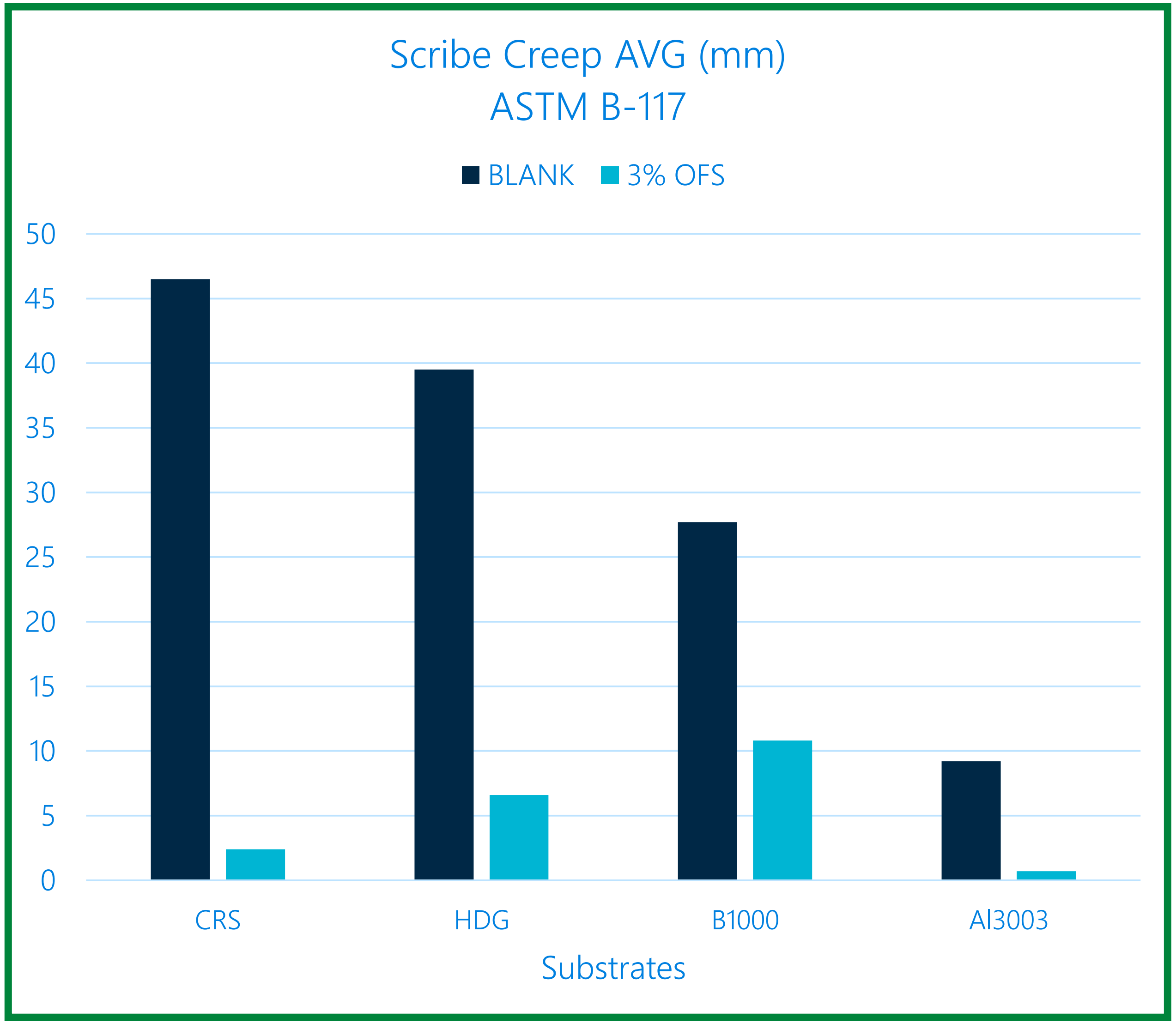
ASTM B-117 ~ 264 hours ~ Cold Rolled Steel ~ 2.4 mil DFT



WB 2K Epoxy Primer – Substrate Focus

ASTM B-117 ~ 144 hours ~ Cold Rolled Steel ~ 2.4 mil DFT





Coating Optimization

Creating Coatings Solutions

Factors to Consider

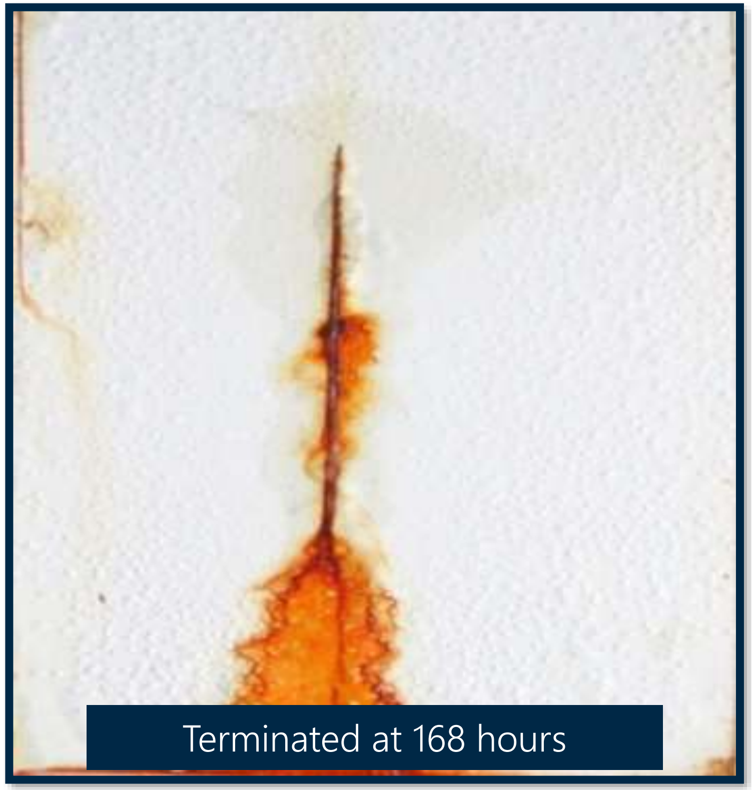
- Combine inhibitors – synergy of multiple mechanisms.
  - Inorganic/Flash Rust
  - Inorganic/Inorganic
  - Inorganic/Organic
- Optimize ratio of inorganic inhibitors.
  - Synergize short term and long-term corrosion inhibitors based on their solubility.
- Inhibitor concentration
  - Volume vs weight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

Combining HMF Corrosion Inhibitors

DTM WB Epoxy, ASTM B117 @ 336 hrs,

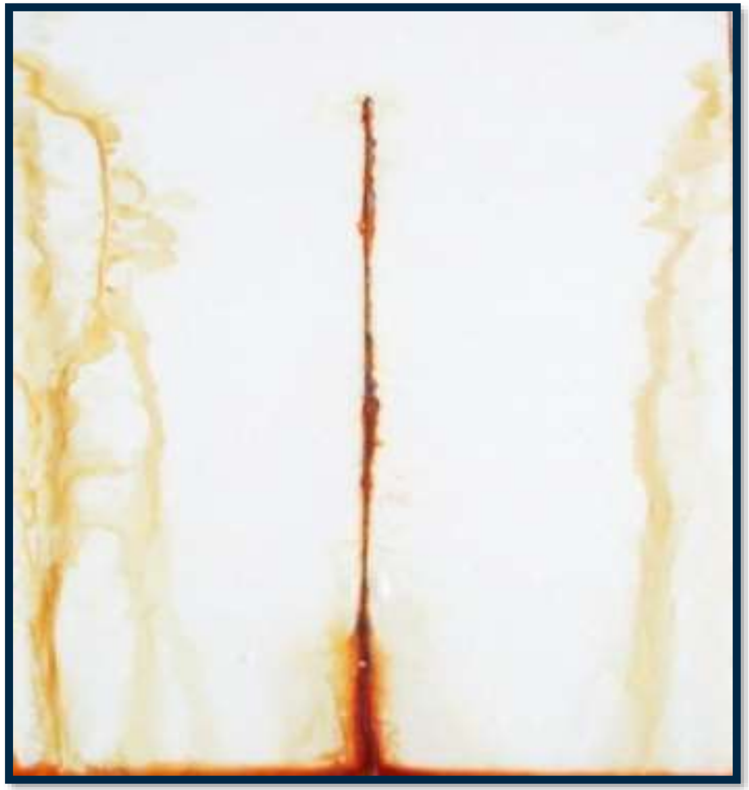
2 mils DFT over CRS

Blank Control



3% SRP

3% SRP
***plus* 3% AAC**



Field Blistering:	8D	2F	8F

Key:

SRP: Strontium phosphosilicate

AAC: Acid Amine Complex

Future Focus

Sustainability is Our Strategy for Growth

1 Continue to investigate current chemistries for more effective synergies.

2 Understand novel chemistries like cerium, lithium, lanthanum.

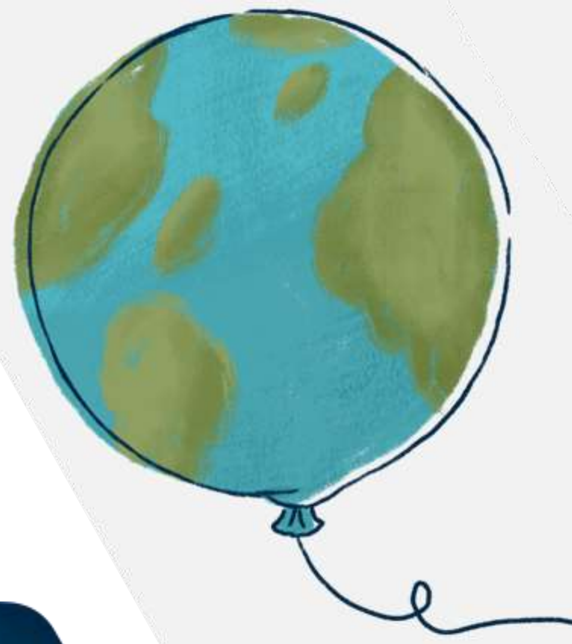
3 Focus on near zero VOC flash rust inhibitors and liquid corrosion inhibitors.

4 Use bio-based rather than petroleum-based solvents as carrier fluids for CI.

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

SUMMARY

Sustainability is Our Strategy for Growth



- Heavy metals continue to have regulatory and consumer scrutiny.
- Current HMF products can match performance of zinc and chromate counterparts.
- Inorganics based on Ca and Sr demonstrate good performance.
- Organic inhibitors provide added benefits beyond heavy metal CI's.
- Combining chemistry types achieves superior corrosion performance.
- Further technology is required for high performance applications.

Thank You

Impactful Corrosion Solutions for Metal Protective Coatings

Visit us at Table 4

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