CIPRA 2023

Congresso Internacional de Corrosão, Integridade, Pintura e Revestimentos Anticorrosivos

CTQFF.ORG
CENTRO DE TREINAMENTO E QUALIFICAÇÃO FERNANDO FRAGATA

How to properly assess protective coating's performance – The importance of intact coating evaluation complementing traditional methods in ISO 12944-9

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What is performance?

Definition of "performance": "the action or process of performing a task or function"

How we define and measure performance influences the outcome

Proving coating performance

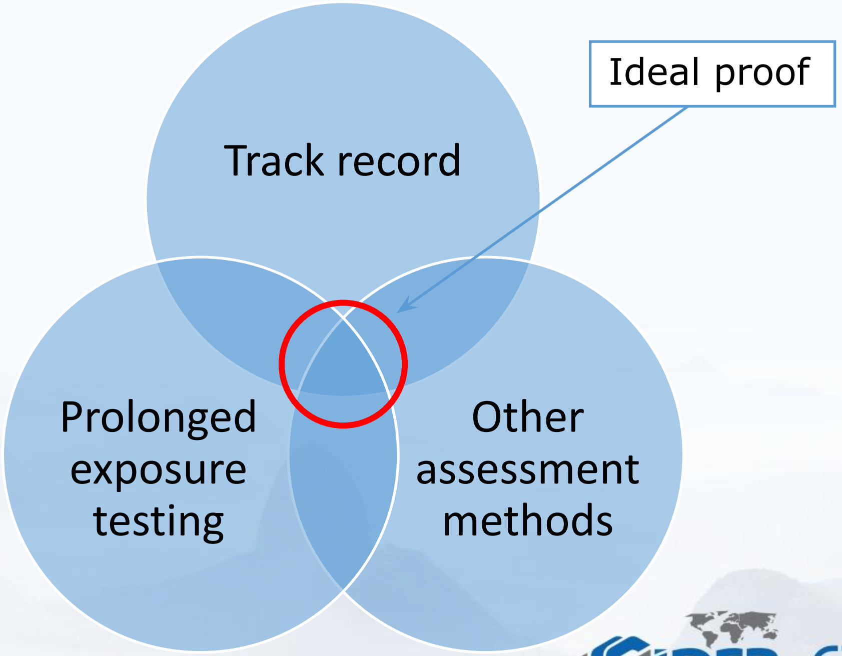
Approvals/certificates do not distinguish the cream of the crop!

- NORSOK M-501
- ISO 12944-6
- ISO 12944-9
- IMO PSPC-WBT - MSC.215(82)
- IMO PSPC-COT – MSC.288(87)

Differentiated approach

↓

Improved assessment methods



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Proving coating performance

Accelerated laboratory testing

- Well established methods
- Separates the good and the bad!
- Do not necessarily mimic field conditions well
- Poor differentiation?

Field testing

- Real performance under controlled and comparable conditions
- Often takes too long >5 years
- Differences between sites – tempered C5 vs. tropical C5

Proven track record

- Performance that actually matters
- Takes too long >10 years
- Not necessarily easy to document
- Significant differences between sites

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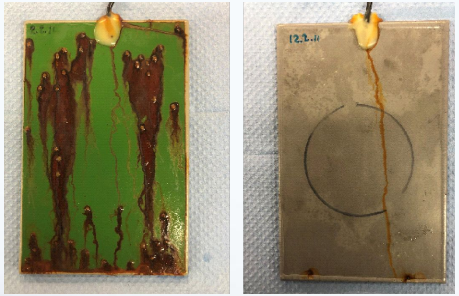
Performance indicators for corrosion protective coatings

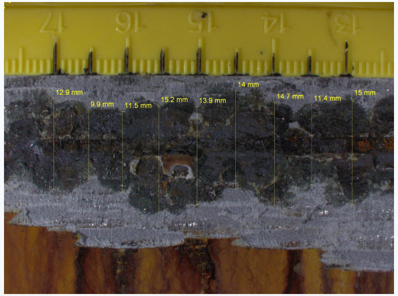
1. Visual assessment

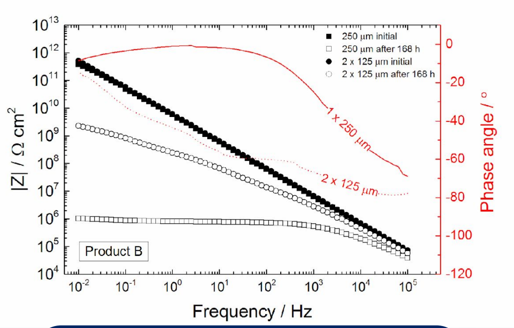
2. Corrosion creep

3. Pull-off adhesion

4. EIS measurements







3000h salt spray (ISO 9227)

4200h cyclic ageing (ISO 12944-9 Annex B)

720h water condensation (ISO 6270-1)

Electrochemical impedance spectroscopy (EIS) (ISO 16773-2)

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Coating systems investigated

Single coat	Two coats
1 x 250 µm Product A	2 x 125 µm Product A
1 x 250 µm Product B	2 x 125 µm Product B
1 x 250 µm Product C	2 x 125 µm Product C
1 x 250 µm Product D	2 x 125 µm Product D

Price ↓

Quality ↓

Objectives:

1. Can we differentiate products wrt performance (same product series)?

2. Difference in performance between 1 and 2 coats?

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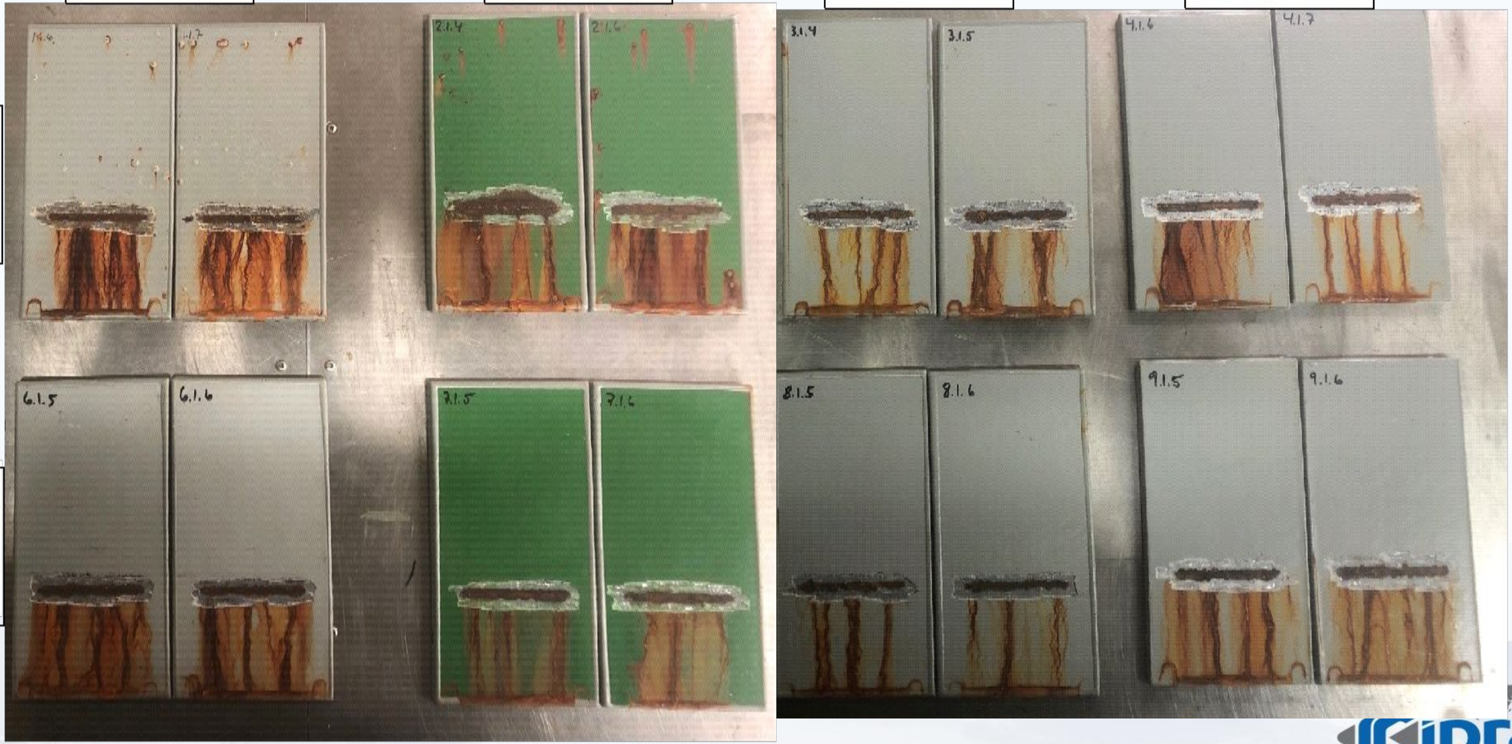
Visual assessment after 1440h salt spray (ISO 9227)

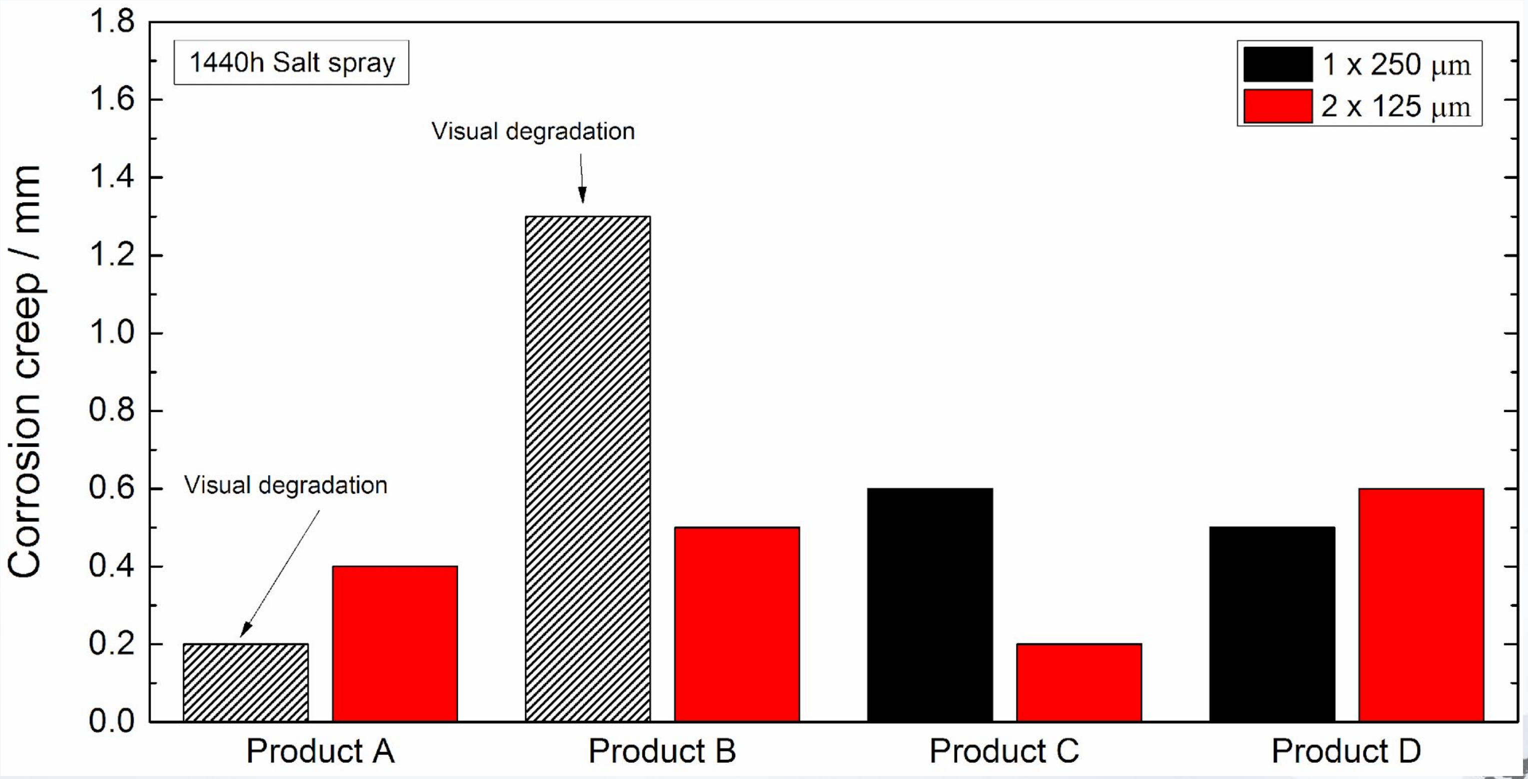
+Price → +Price → +Price →



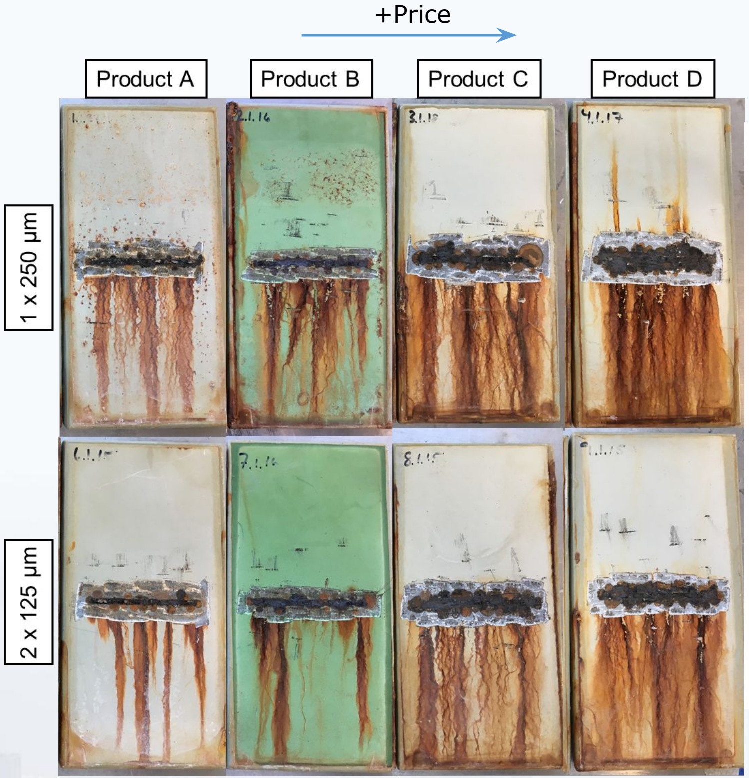
Blistering and rusting – 1 x 250 µm Product A and Product B

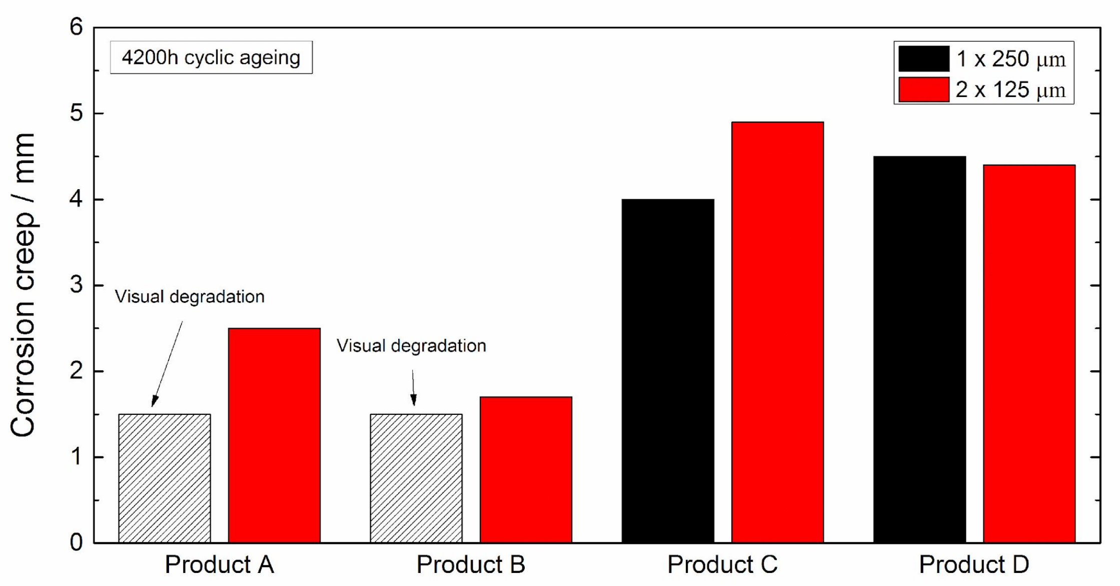
Remaining six systems are indistinguishable

Corrosion creep after 1440h salt spray (ISO 9227)



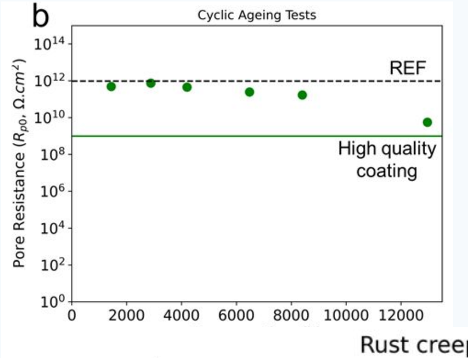
Visual and corrosion creep after 4200h cyclic ageing (ISO 12944-9 Annex B)

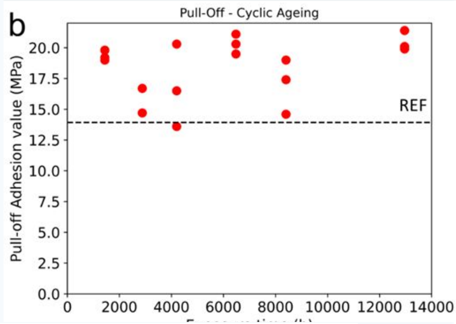


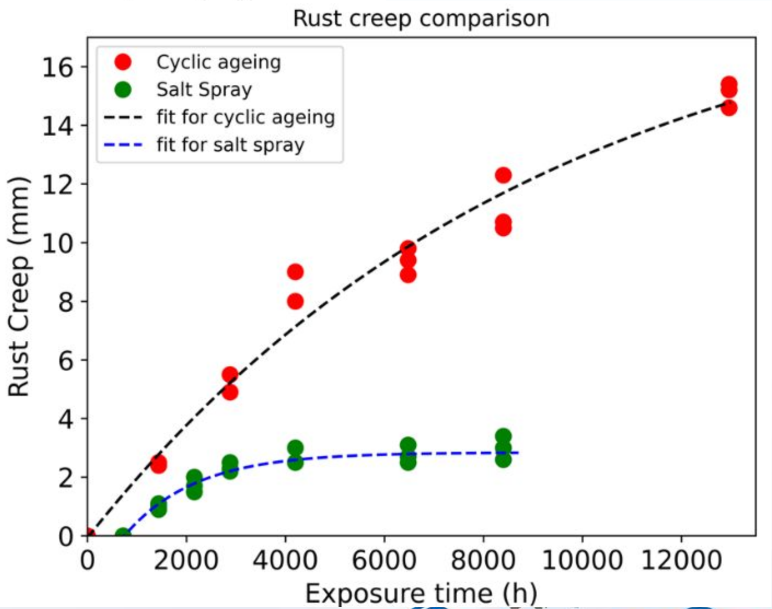


Long term performance = long term testing – right?

- There is a general trend in the industry to move towards longer test exposure durations to account for long term protective performance
- Again, we see very little degradation of the coatings, and again we are left with corrosion creep…
- There is little or no practical use in running long exposures e.g. cyclic ageing







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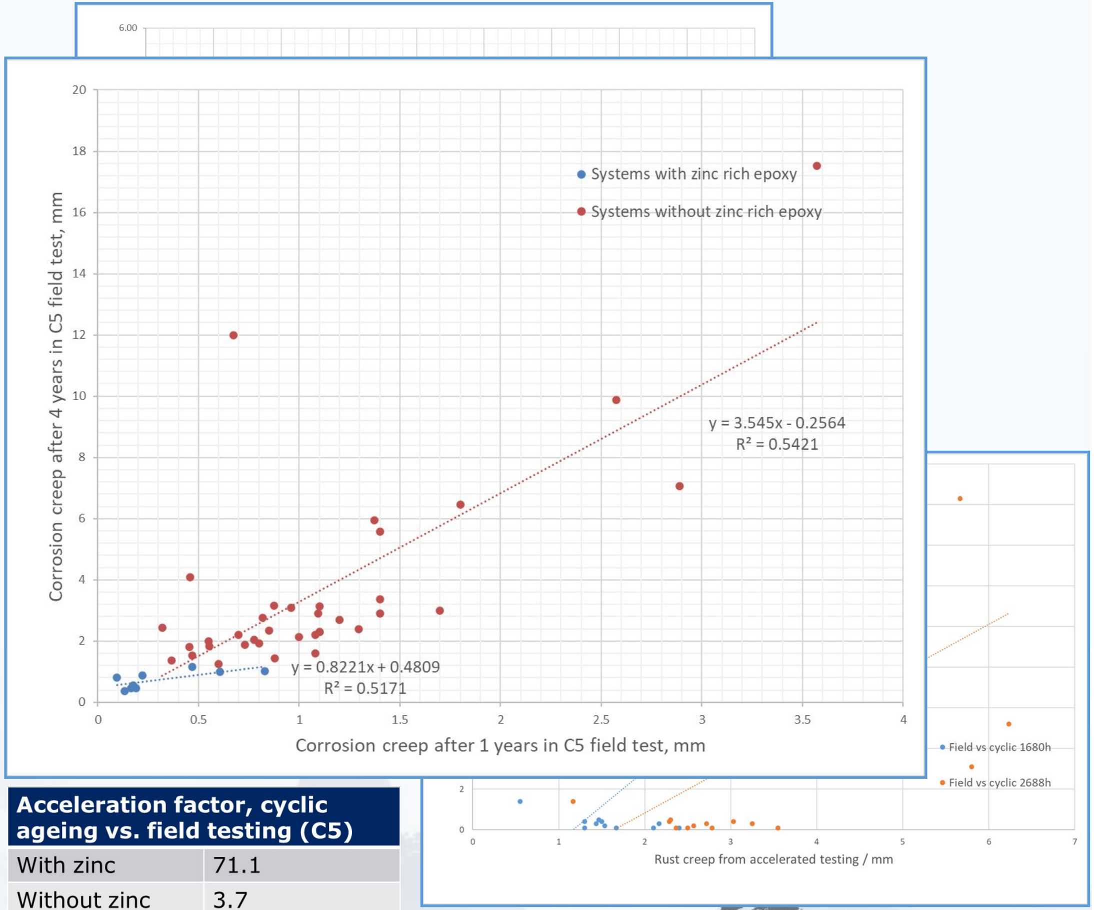
Lab vs. field – are there any correlations?

- Short answer: No!
- Lack of correlation between lab and field has been discussed for more than 60 years
- But, it is not that straight forward
  - There is no correlation when it comes corrosion creep
- Cyclic ageing “punishes” systems with zinc much harder than systems without
- Clear correlation between field and field!



Acceleration factor, cyclic ageing vs. field testing (C5)	
With zinc	71.1
Without zinc	3.7

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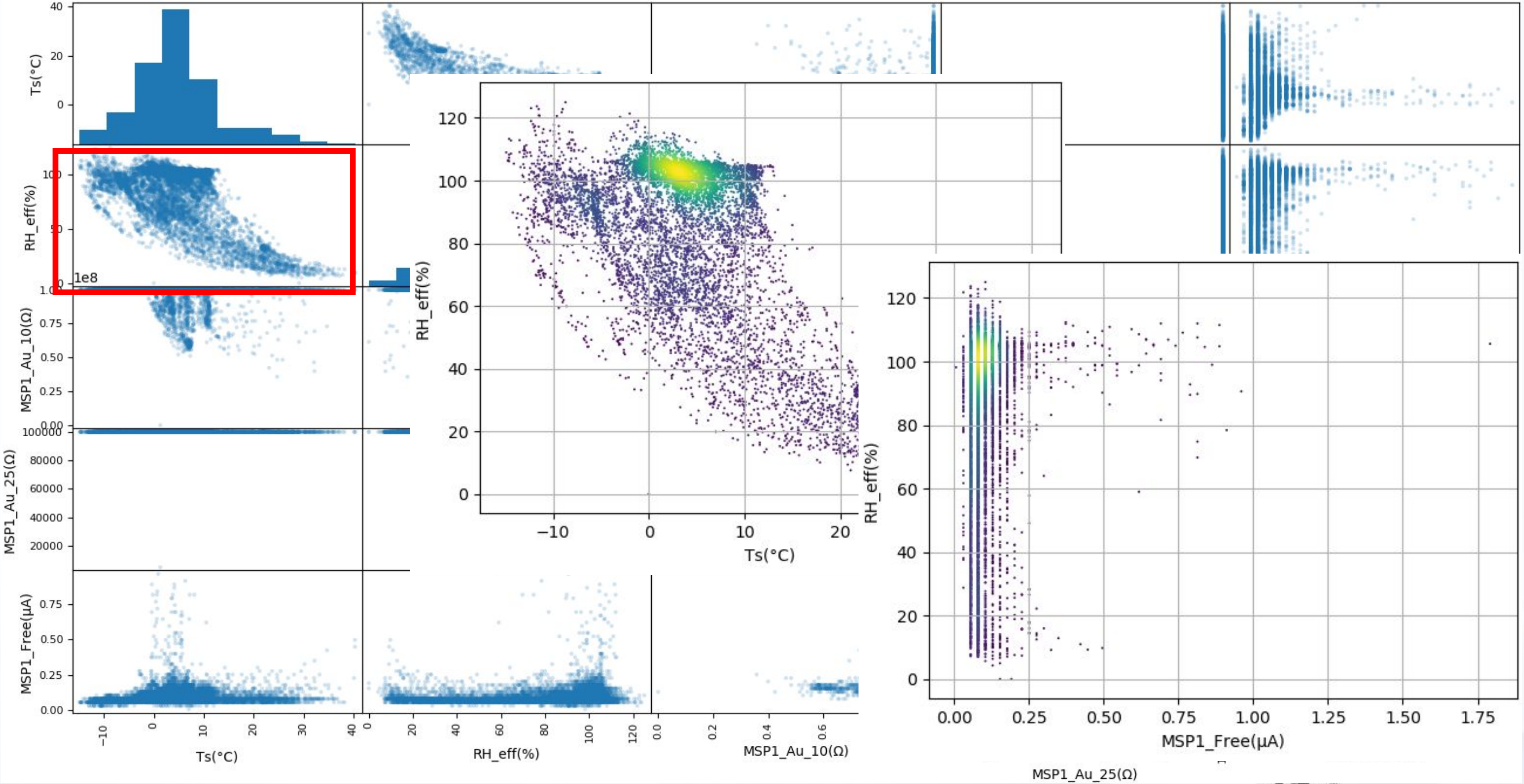
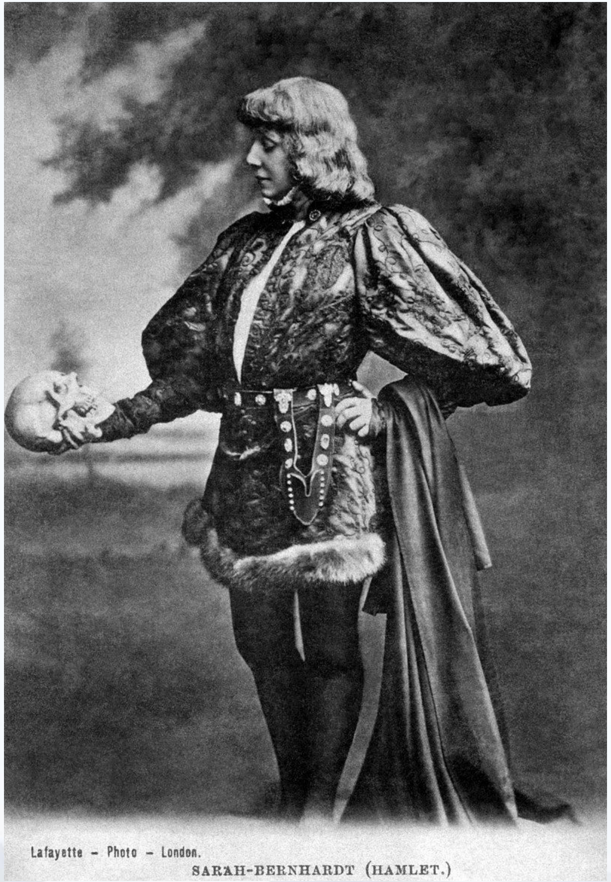

Ts(°C)
RH_eff(%)
MSP1_Au_10(Ω)
MSP1_Au_25(Ω)
MSP1_Free(μA)
1e8
RH_eff(%)
Ts(°C)
RH_eff(%)
MSP1_Free(μA)
MSP1_Au_25(Ω)

“Corrosion or corrosion creep, that is the question!”

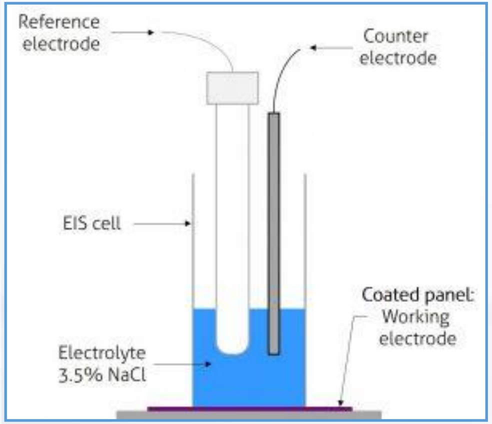
Corrosion creep can be useful to indicate how big of an area you will need to repair if a damage is left to develop for a certain amount of time…

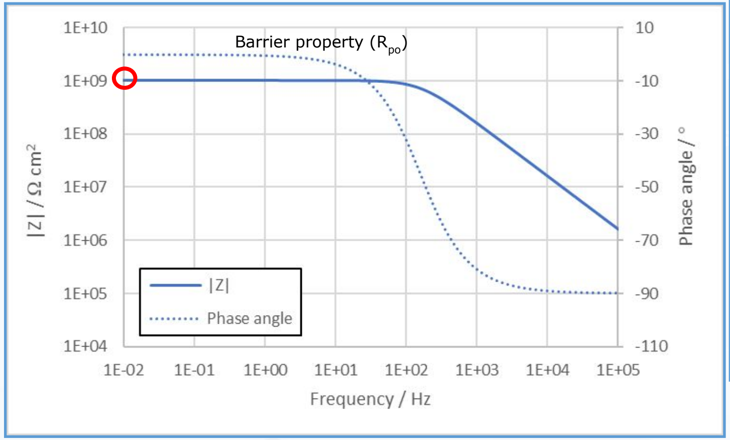
But it is NOT a good performance indicator in terms of how well the overall structure is protected against the environment!

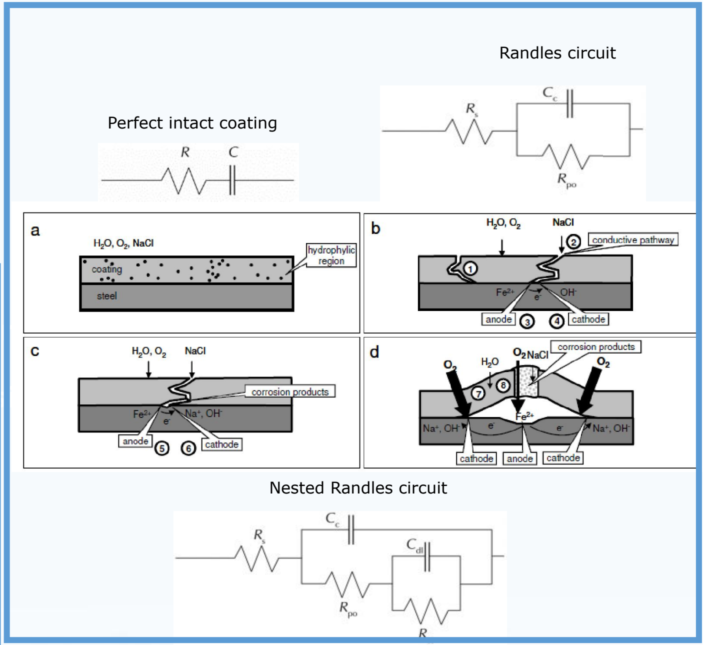
Barrier properties are therefore important also assess



Electrochemical Impedance Spectroscopy (EIS)







EIS provides quantitative data on barrier properties, water uptake, diffusion and corrosion

Improves coating performance assessment

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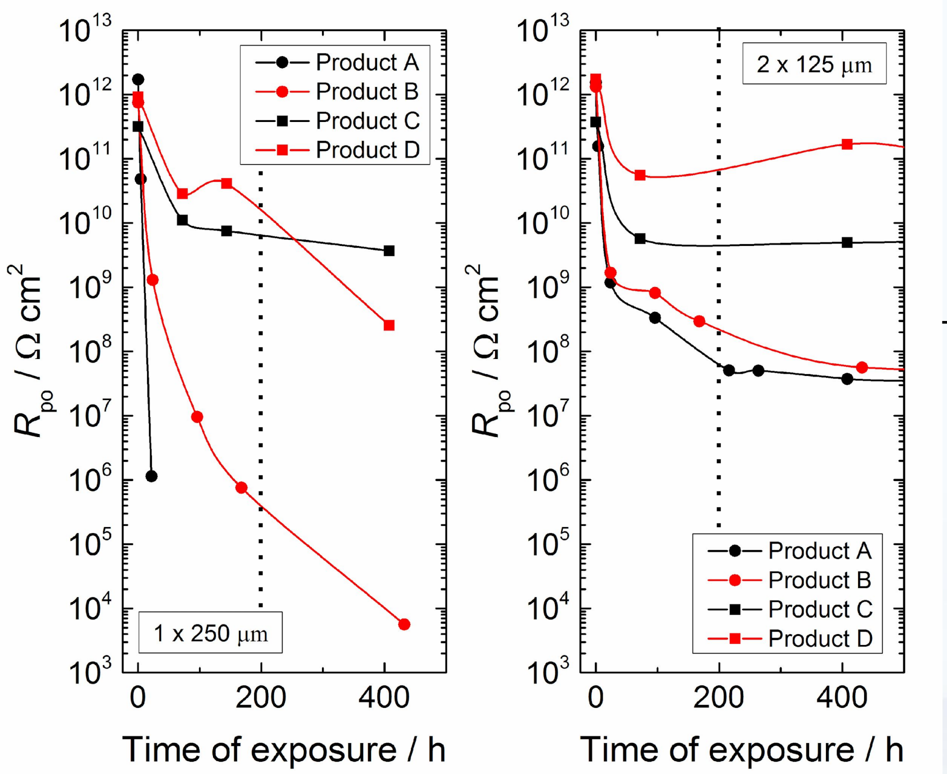
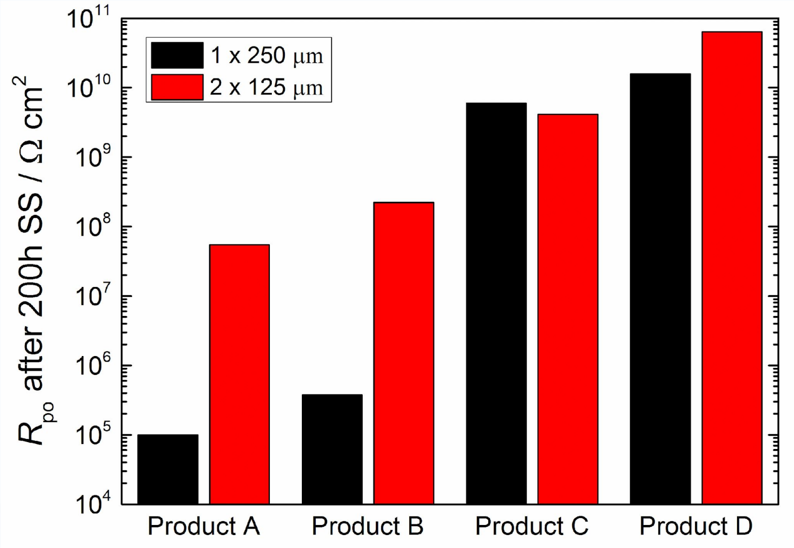
Differentiation of coating performance - EIS

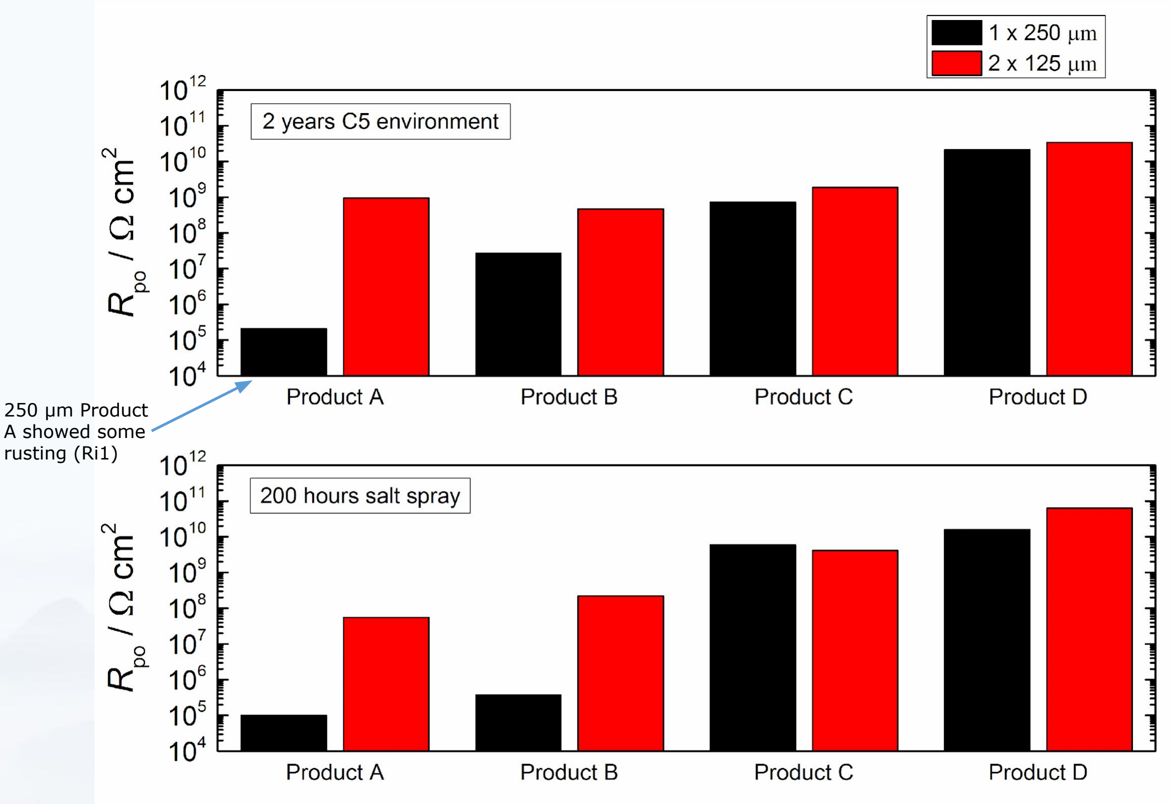




Performance ranked:

Product A → Product B → Product C → Product D

EIS = the bridge between field and lab?



- Almost identical trends for salt spray and field exposure when EIS is used!

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Why is there a mismatch in performance?

	Product A	Product B	Product C	Product D
1 x 250 µm	• Blistering and rusting • Very poor barrier property ✗	• Blistering and rusting • Very poor barrier property ✗	• No visible degradation • Excellent barrier property ☑	• No visible degradation • Excellent barrier property ☑
2 x 125 µm	• Low corrosion creep ? • Poor barrier property	• Lowest corrosion creep ? • Poor barrier property	• Modest corrosion creep ? • Excellent barrier property	• Modest corrosion creep ? • Excellent barrier property

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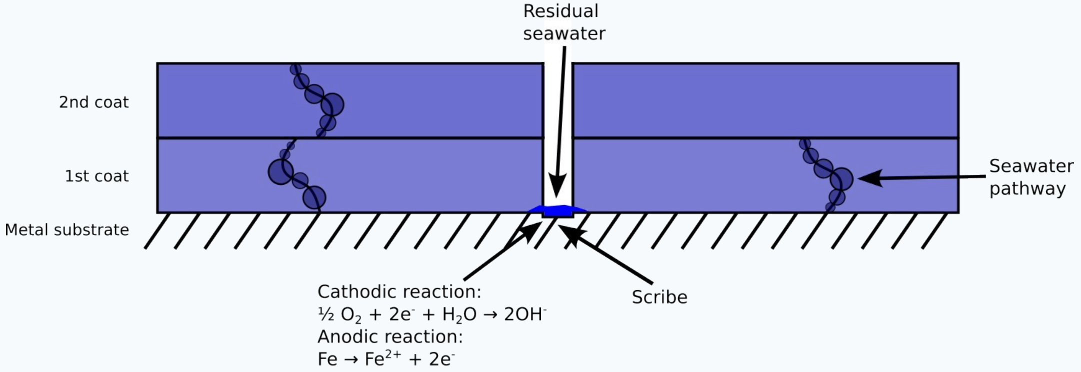
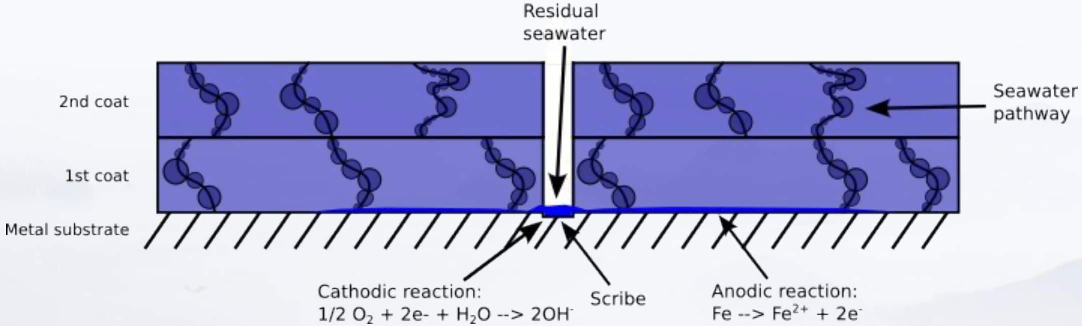
Why is there a mismatch in performance?



High barrier property and low permeability of seawater – Products C and D

Cathodic and anodic reactions only at or near the scribe



Low barrier property and higher seawater permeability – Products A and B

Electrolytic contact underneath coating – anodic and cathodic reactions spatially separated

Gives artificially lower corrosion creep

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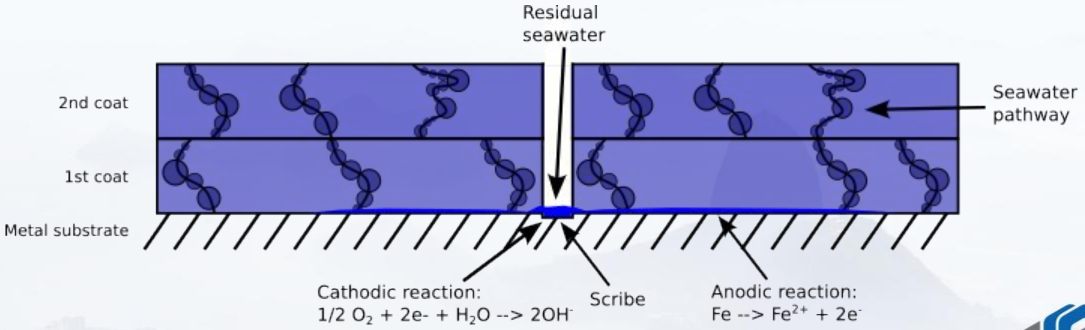
Conclusions

- Coatings are predominantly assessed based on corrosion creep results after accelerated exposure testing
- Corrosion creep as a performance indicator is limiting and can even result in misleading conclusions – with obviously poorer coating systems exhibiting lower corrosion creep
- By combining traditional results with EIS characterizations, an improved overall picture of the corrosion protective performance can be achieved



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