

Effect of RH Cycling on Scribe Creep of Coated Steel Panels

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MECHANICAL ENGINEERING

The effect of cyclic RH on corrosion is well established



- For aluminum alloys, cycles with RH values between 55% and 75% RH, exfoliation behavior, intergranular corrosion, and rapid fracture are observed.
- For steel alloys, more cycles and higher corrosion rates of the substrate lead to increased scribe creep
- For mixed metal couples (galvanized steel, aluminum/steel, etc), cyclic RH leads coupling and decoupling of galvanic interactions

Objective

- Further explore the effect of RH cycle on scribe creep
 - Different cycle parameters
 - At different times of exposure



Experimental

Test Specimens

- Steel panels with either
 - Coating “A”
 - Coating “B”
- Panels
 - 4” x 6”
 - 4.5” scribe length
 - 0.5 mm scribe width

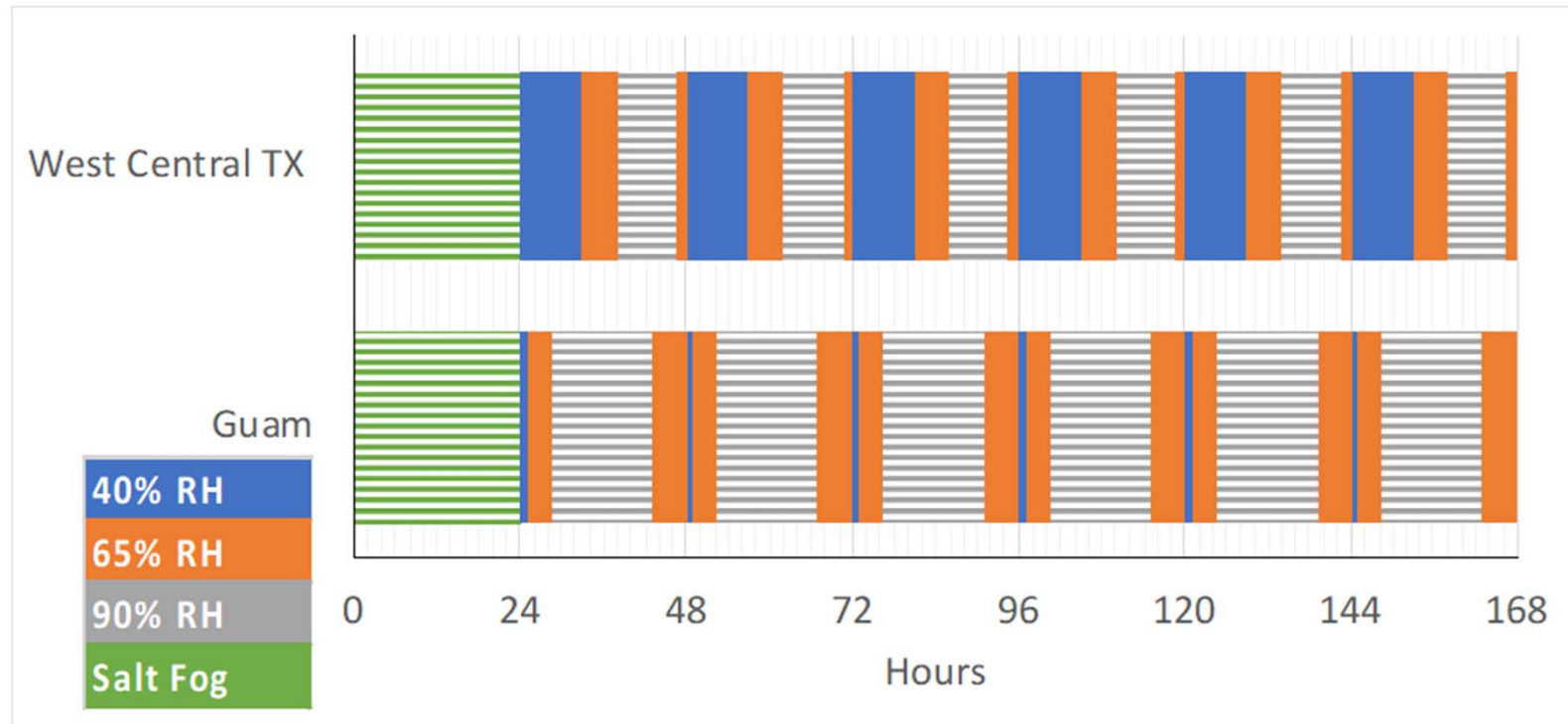


Coating “A”

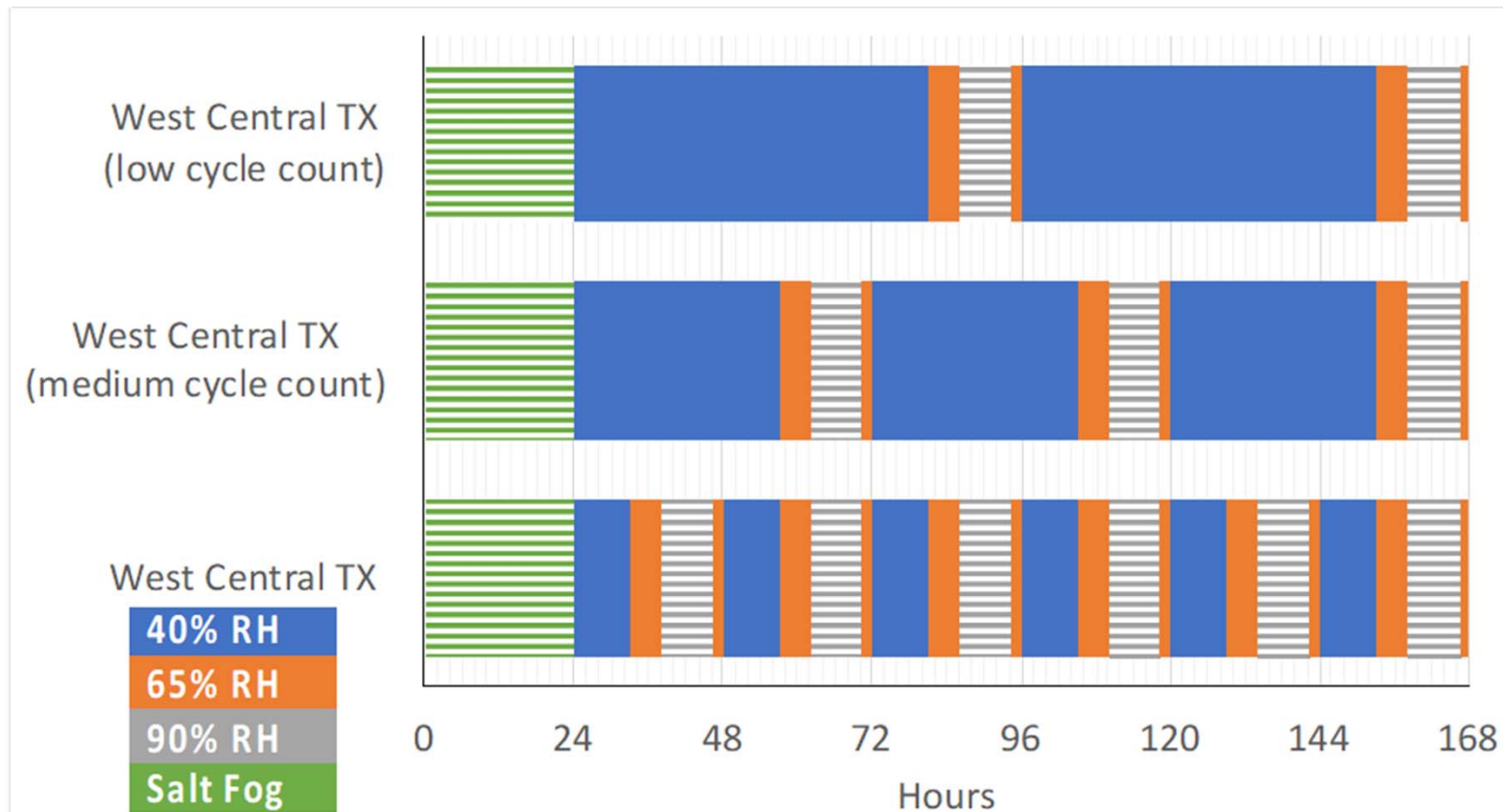


Coating “B”

Exposure cycles used. Fog was 10x dilution of simulated sea water at pH = 3.

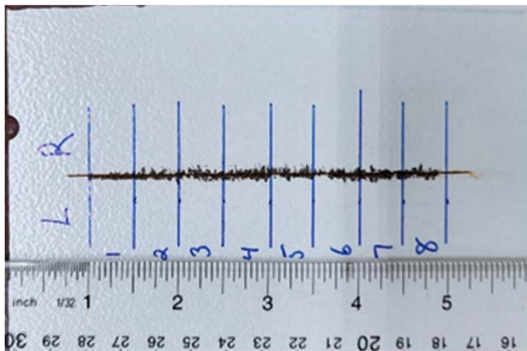


Exposure cycles used. Fog was 10x dilution of simulated sea water at pH = 3.

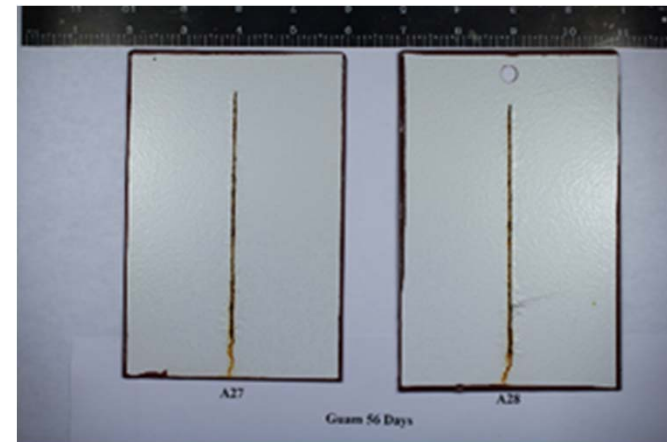


Scribe Creep measurements

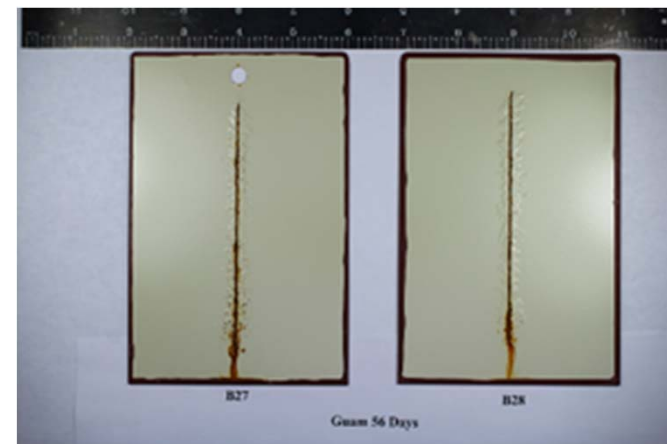
- Used knife to lift coating away in order to see creep
- Defined creep length
 - Divided panel into sections
 - Measured creep length in each section
 - Averaged over panels and replicates



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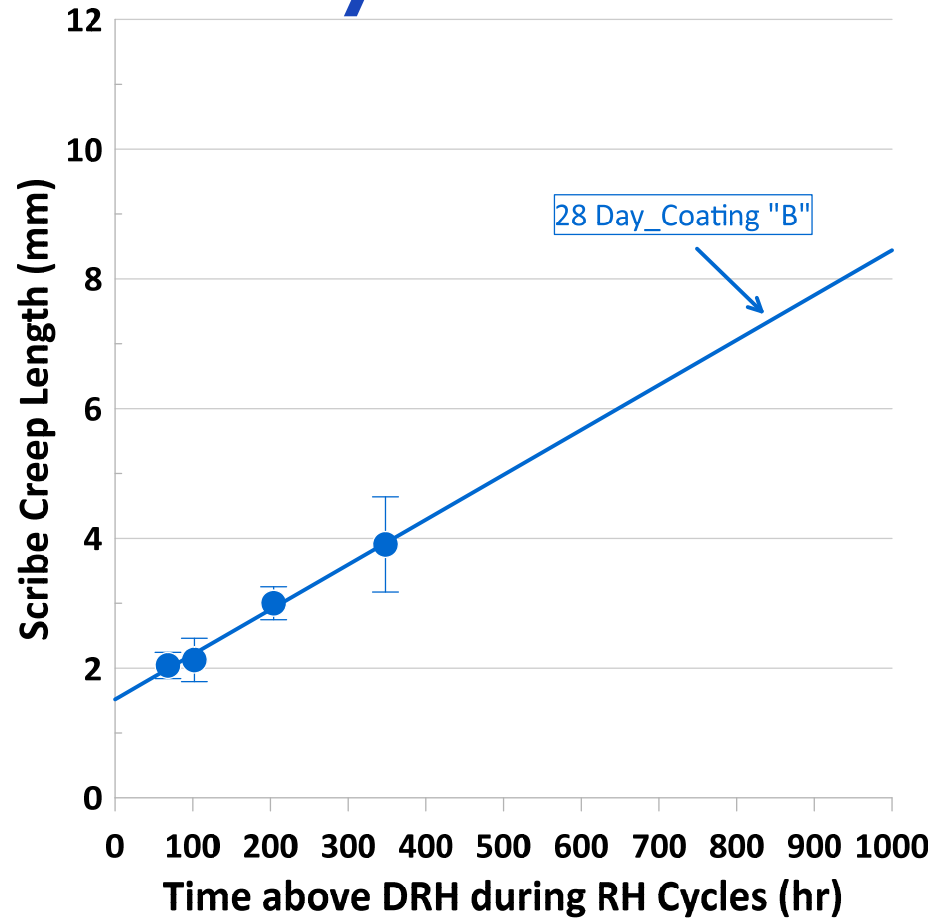
Coating "A"
Guam
diluted



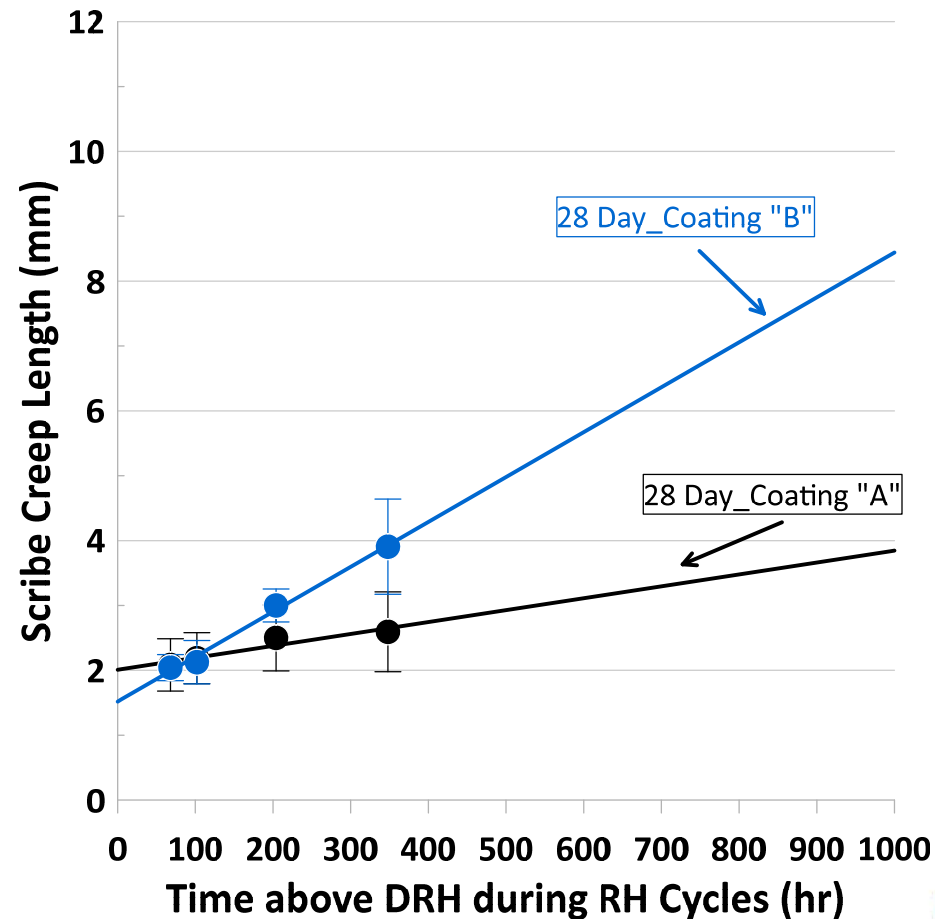
Coating "B"
Guam
diluted

Results

Scribe creep rate is linear with $t_{RH > DRH}$ regardless of cycle or periodicity.

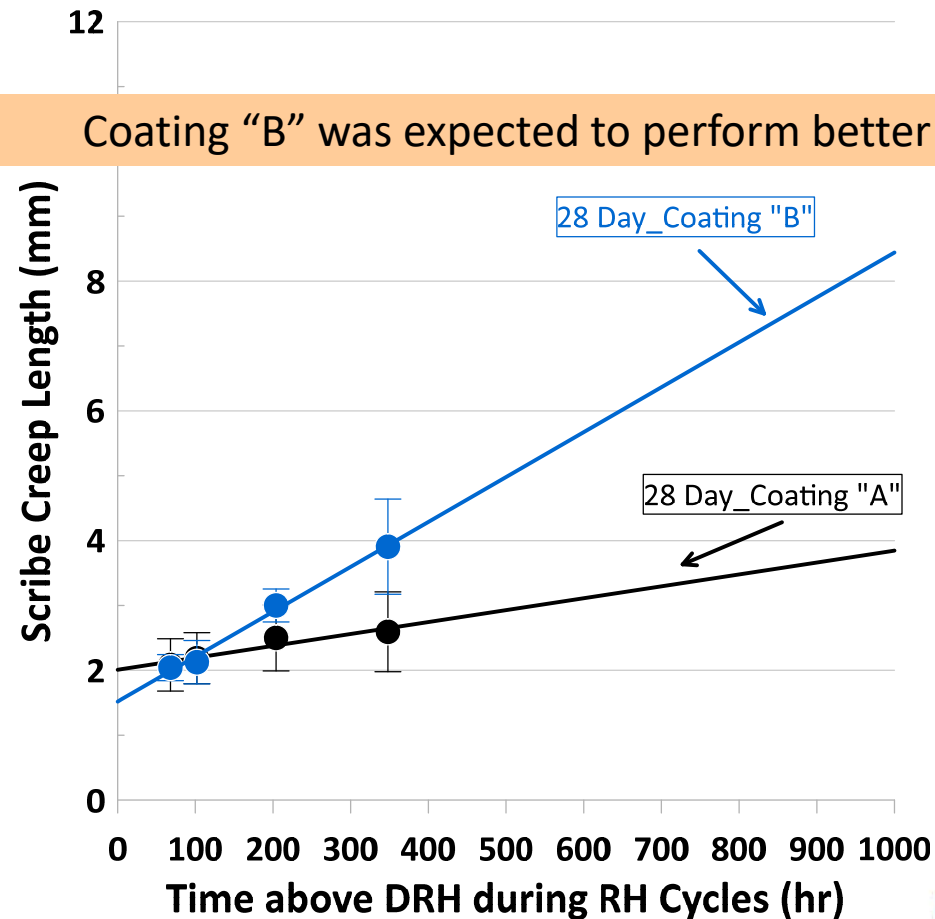


After a 28 day exposure, coating “A” outperforms coating “B”

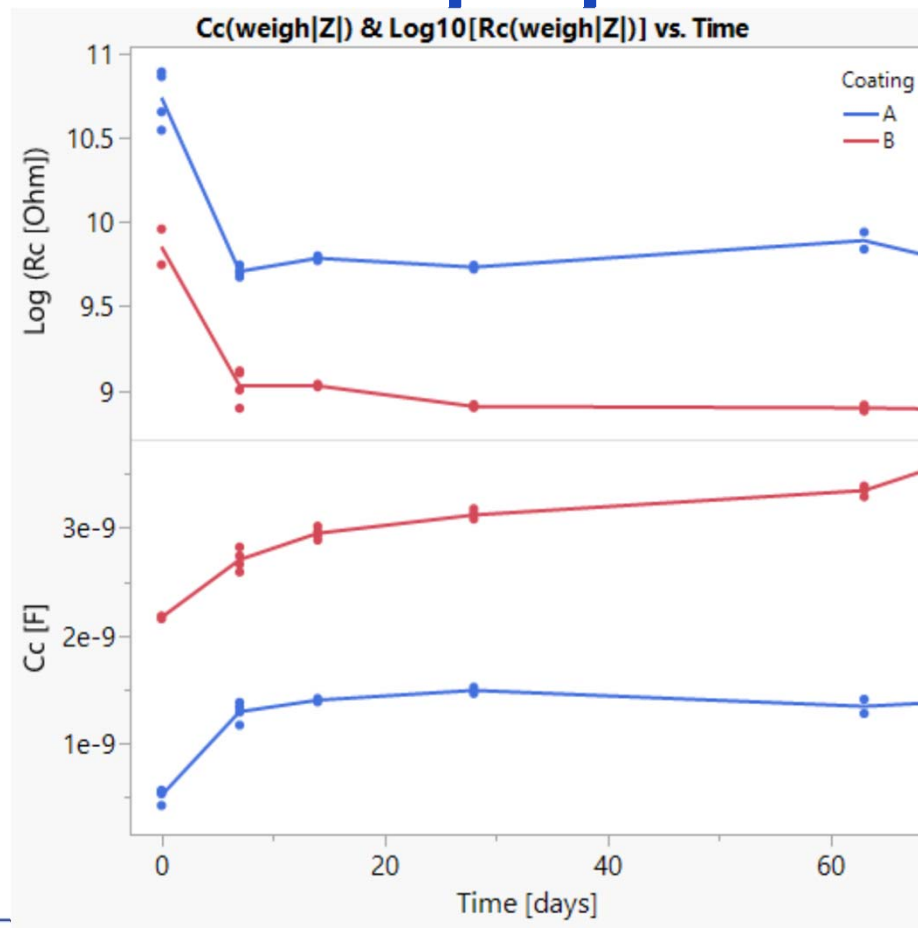


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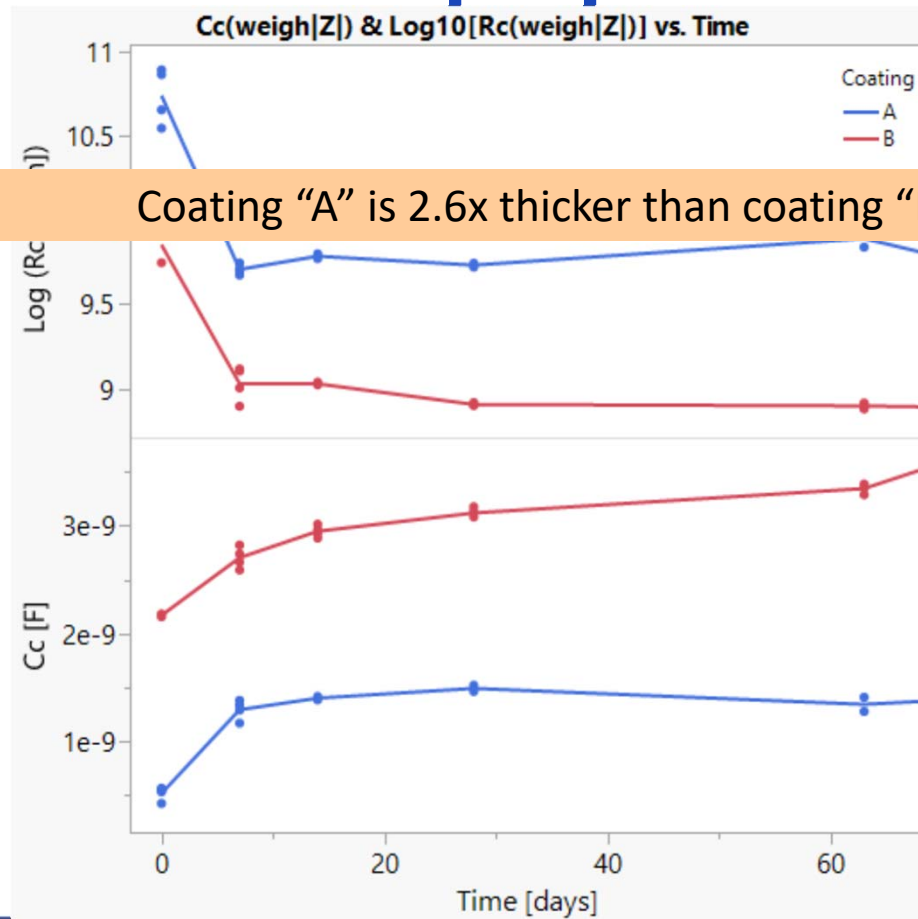
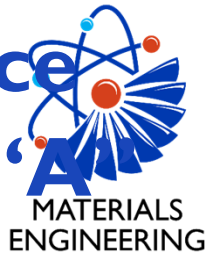
Coating “B” was expected to perform better!



EIS values of coating resistance and capacitance indicate better barrier properties for coating “A”

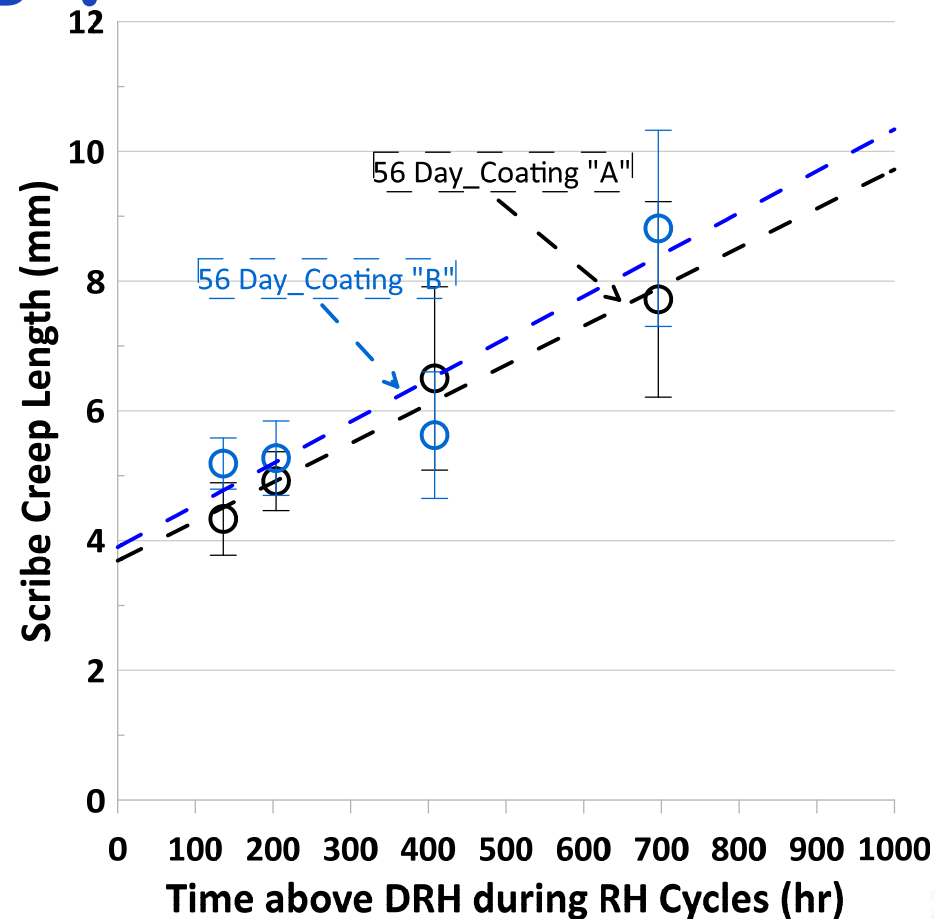


EIS values of coating resistance and capacitance indicate better barrier properties for coating “A”

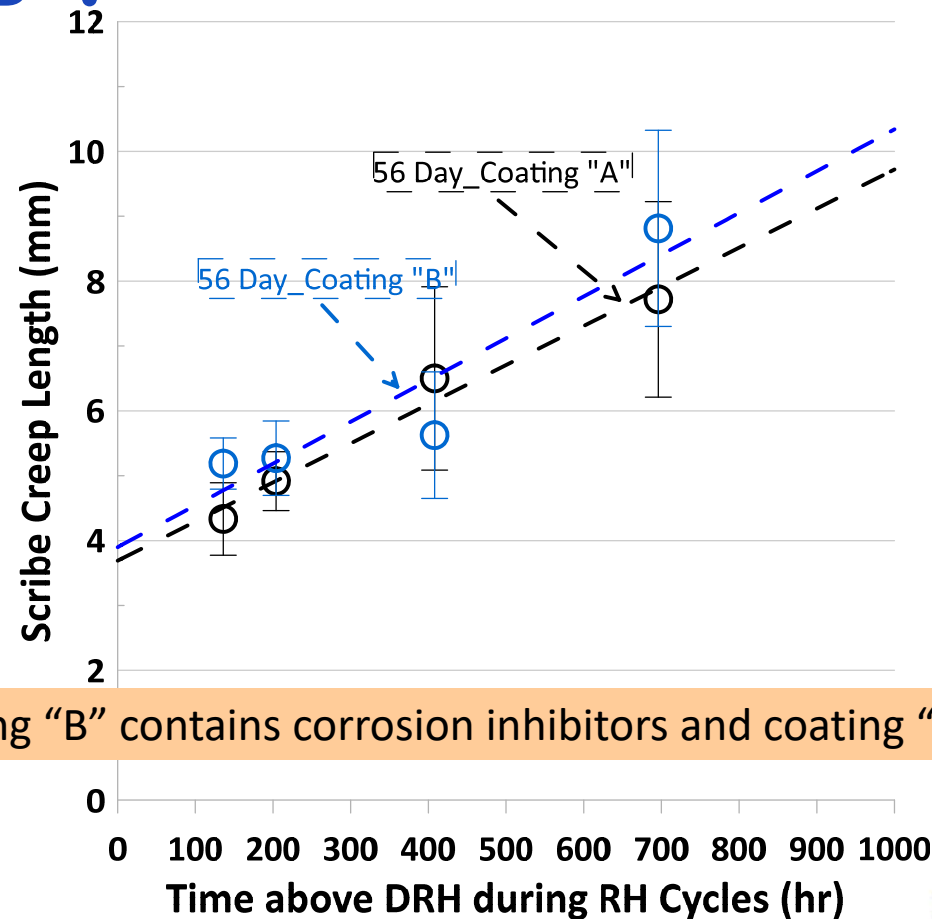


Coating “A” is 2.6x thicker than coating “B”

After 56 days of exposure, coating “A” catches up to coating “B”!



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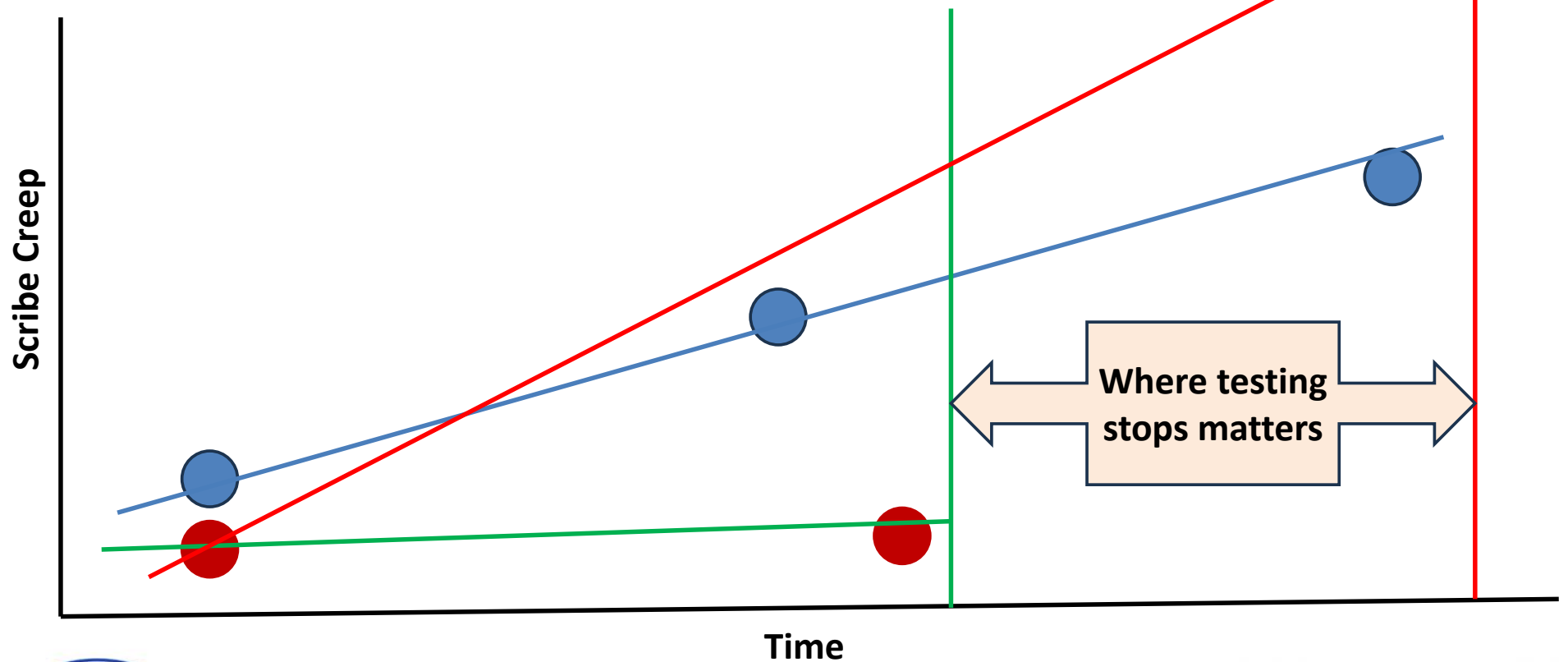
Coating “B” contains corrosion inhibitors and coating “A” does not!

What might be going on?

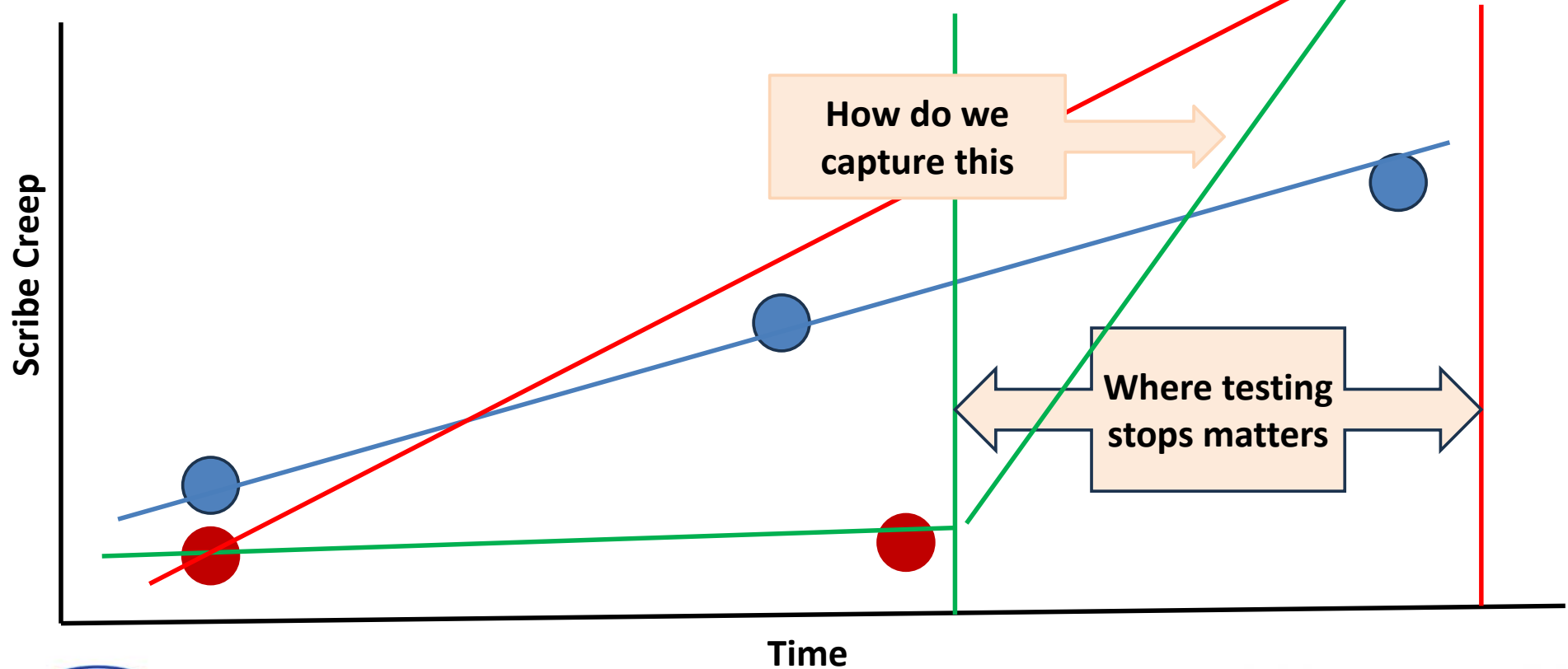
- Scribe creep is a two-step process involving two time constants
 - An initiation or incubation phase
 - A creep growth phase
- The average scribe creep length per time of wetness (μm per hour_{RH>DRH}) ($\mu\text{m}/\text{hour}_{\text{RH>DRH}}$) associated with cyclic RH conditions is shown below

	28 days	56 days
Coating "A"	1.8	6.0
Coating "B"	6.8	6.4

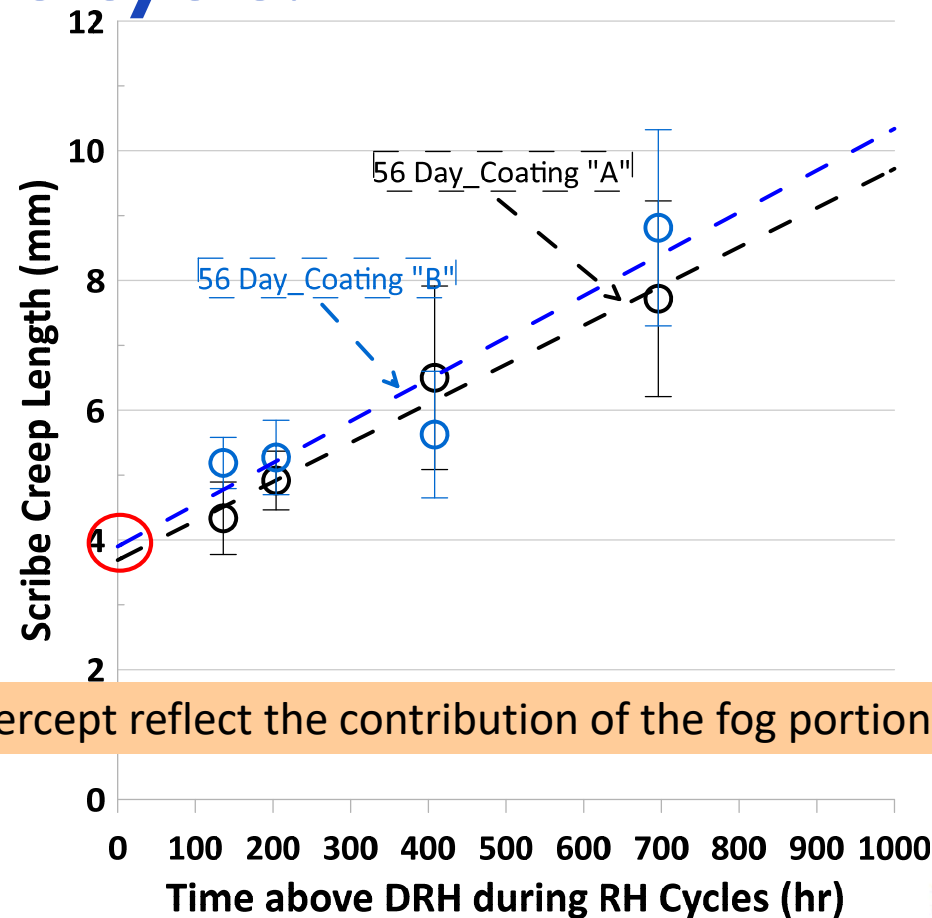
Implications for accelerated corrosion testing and life prediction



Implications for accelerated corrosion testing and life prediction

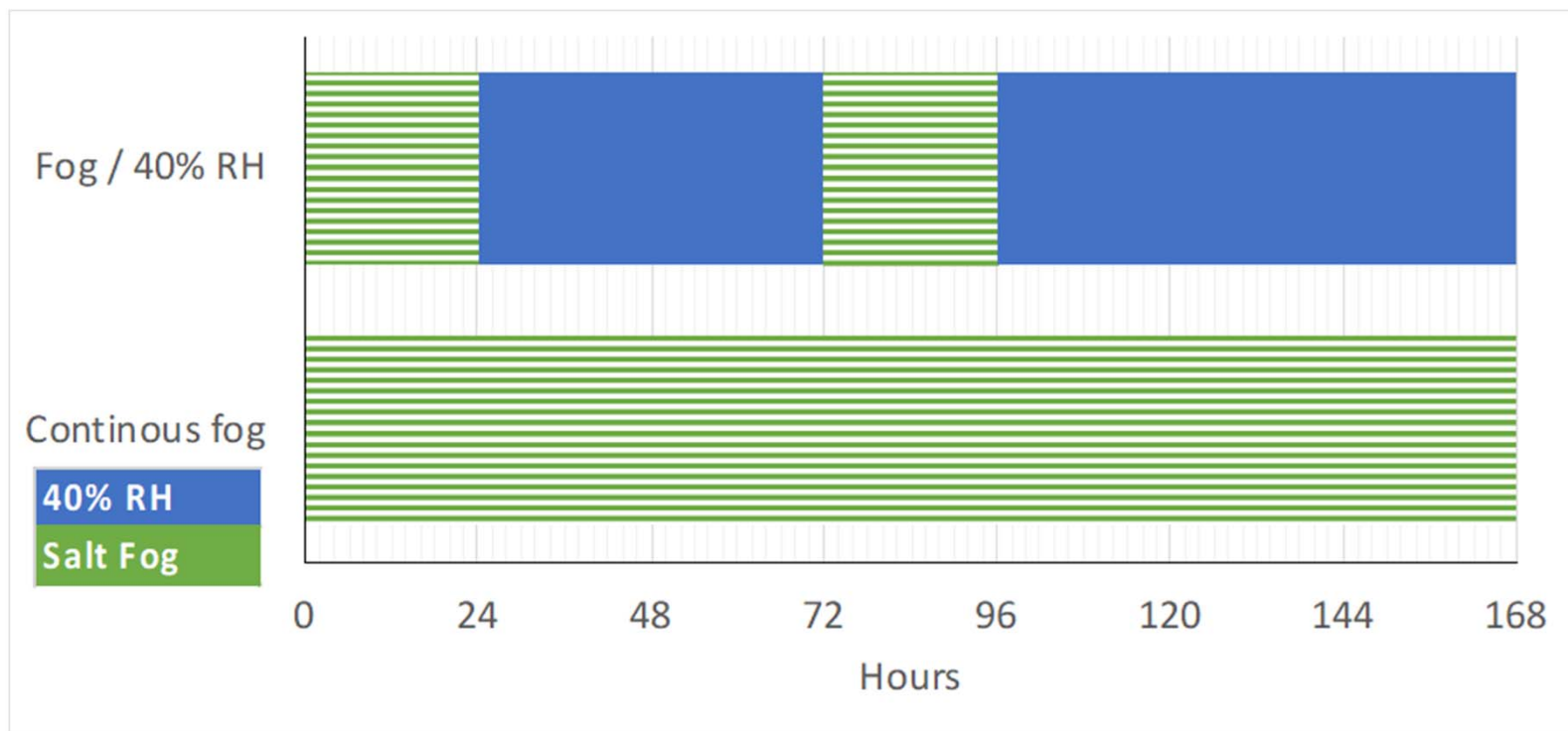


What can we learn about RH cycling vs the fog portion of the cycle?

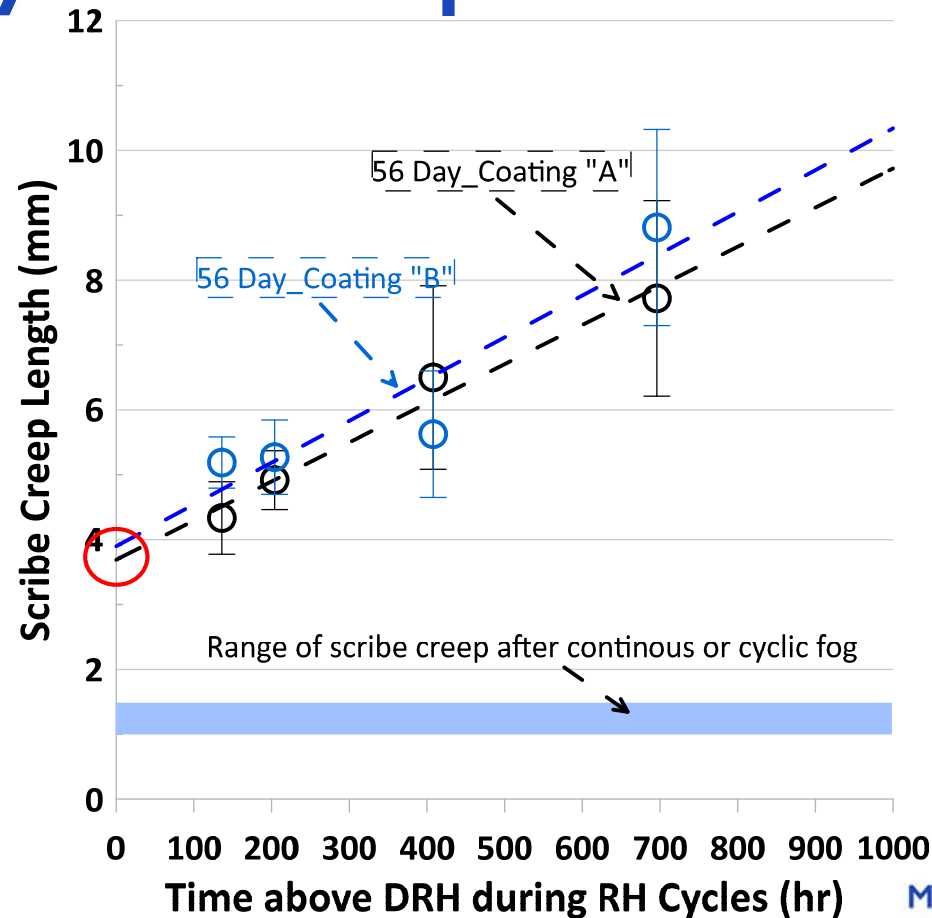


Does the y-intercept reflect the contribution of the fog portion of the test to creep?

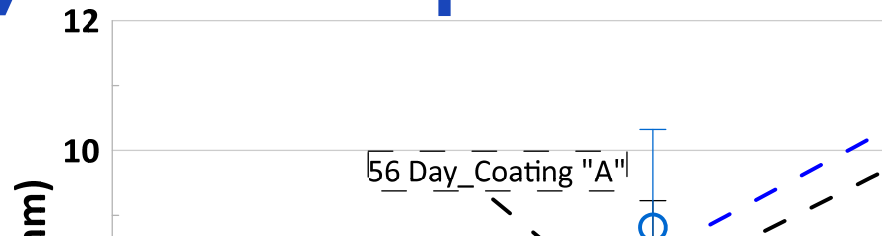
Fog only experiment for a total of 8 equivalent fog days.



8 days of fogging (continuous or intermittent) results in very little creep.

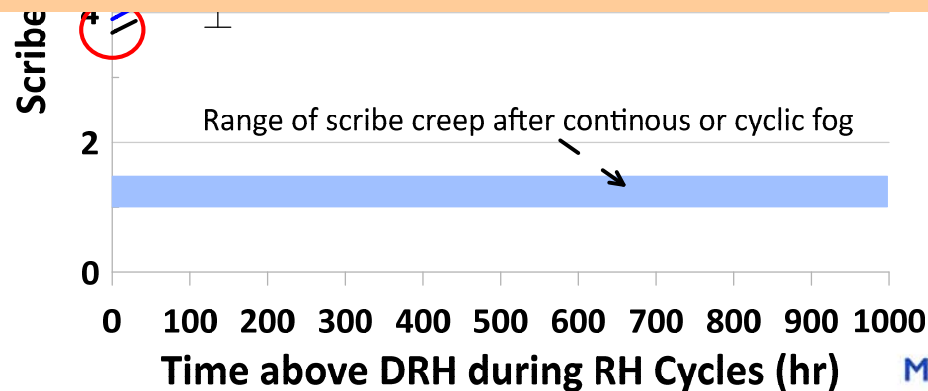


8 days of fogging (continuous or intermittent) results in very little creep.



Potential reasons for the difference in y-intercept and experimental fog creep values

- 1) Mechanical lifting
- 2) Interfacial strain with moisture uptake into the polymer
- 3) Enhanced cathodic reactions during drying
- 4) Hygroscopic corrosion product keeping the creep region active



Hypothesis for scribe creep

- incubation
 - Moisture penetrates the coating polymer
 - Volume swell and a reduction in adhesion forces result in delamination sites
- Growth
 - Moisture has reached the polymer metal interface ahead of the delamination front
 - Corrosion occurs at the delamination sites under high RH and fog conditions
 - During drying, solution saturation occurs and corrosion product form that lift the polymer. These forces may be enhanced by polymer volume swell

Important Takeaway



- Scribe creep is a function of more than one-time dependent mechanisms
- Initial time dependant behavior may be a function of bulk coating properties
- After some initial period, creep growth is a function of
 - Time with RH > 40% RH (i.e. related to corrosion processes)
 - Drying (i.e. related to corrosion product wedging)
 - Coating bonding forces
- To improve life prediction, we will need to better understand the different phases of scribe creep
- Cannot define acceleration factors of corrosion tests assuming a single rate limiting step for life prediction

Thank You