Understanding and Mitigating the Threat of AC Induced Corrosion on Buried Pipelines

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Main Objective

- AC interference occurs by way of conduction or induction when pipelines share right of way with interference sources fed by high voltage lines.
- Impressed AC voltages at CP potentials can lead to greater than anticipated corrosion rates. There is a lack of consensus on AC mitigation criteria due to an incomplete mechanistic understanding.
- This work investigates the mechanism of AC induced corrosion and proposes a new comprehensive theoretical model based on the combined capacitive and faradaic components of AC current for X65 pipeline steel in soil environments.
- The model of AC induced corrosion will be validated through experiments in CP test fields and pipeline right-of-ways.
- The effects of scale build-up and soil properties including conductivity, pH mineral content and spread resistance will be investigated especially in regard to their effect on interfacial capacitance at coating holidays.

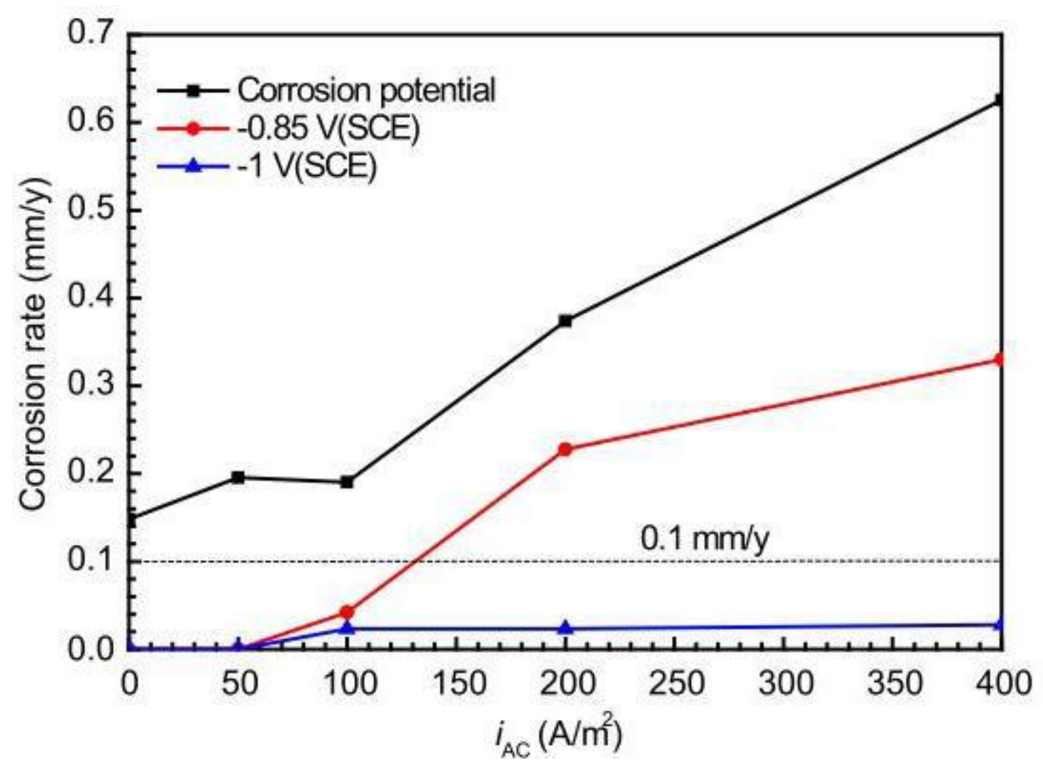

Figure 1: Corrosion rates at different CP potentials by weight loss analysis in simulated soil solution with and without AC.[2]

Results To Date

Validation of Model Predictions and Experimental Electrochemical Results:

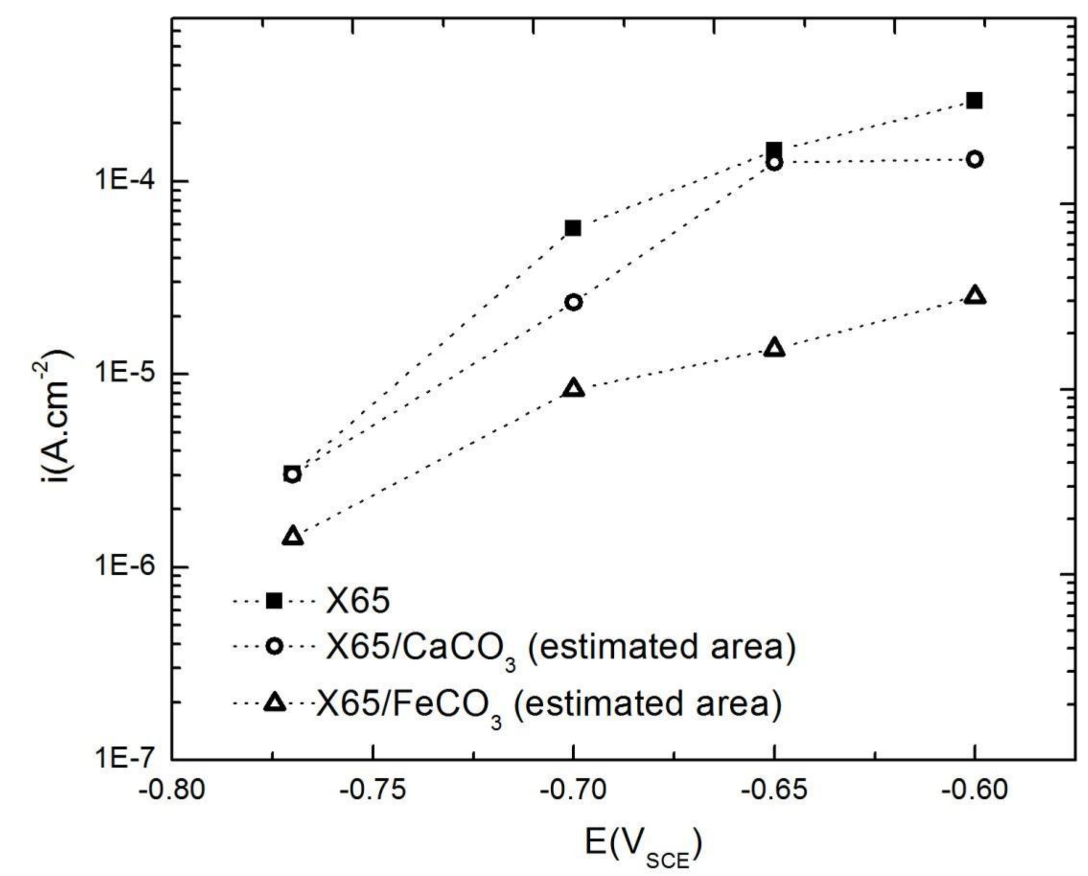

Figure 6: Investigation of the effect of scale formation on AC corrosion rates at CP potentials in NS4 solutions.

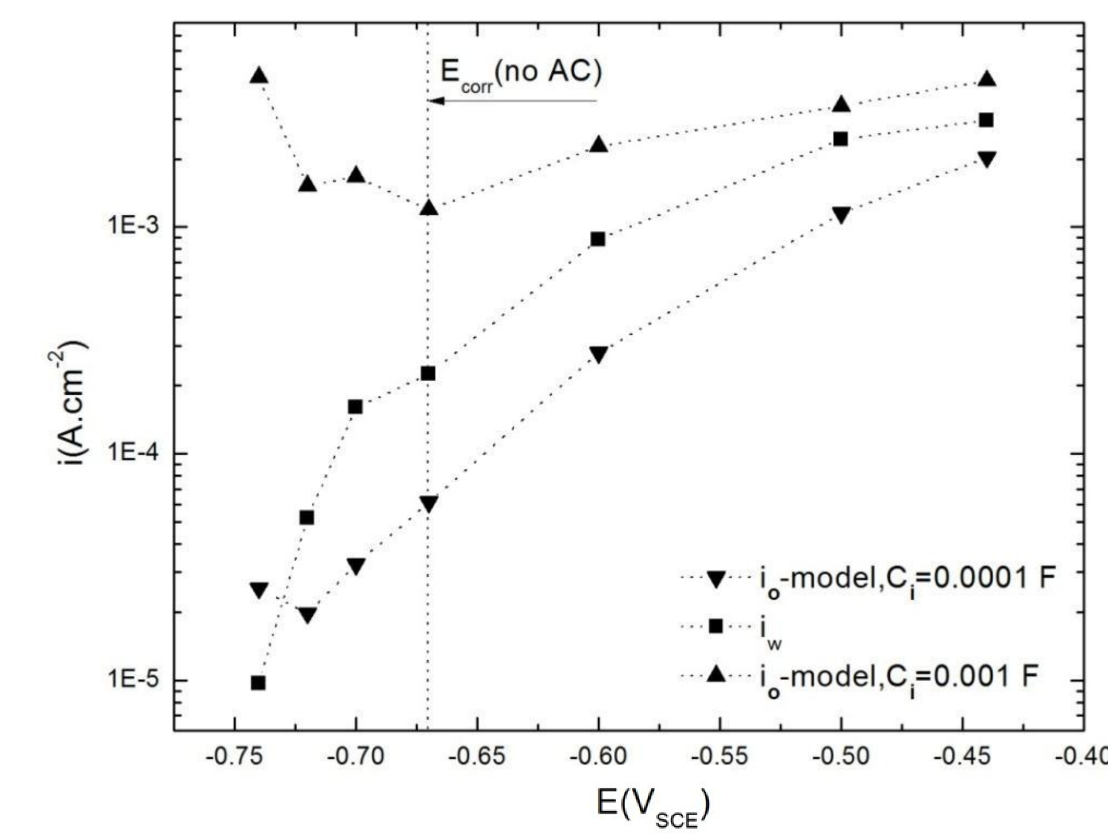

Figure 7: Comparison of experimental mass loss data at 60Hz AC and model predictions at two different capacitance values.

Project Approach/Scope

- Modeling of the effects of AC voltage was achieved by considering the activation-controlled Tafel parameters of anodic and cathodic reactions as well as diffusion-limited oxygen reduction and hydrogen evolution on the steel surface.
- Validation of model predictions was done through electrochemical tests of API X65 Carbon Steel in 0.01M NaCl solution .
- Samples were prepared with both CaCO3 and FeCO3 scales to determine the effect of scale on RC parameters.

- To accurately model an AC system, an equivalent circuit model and corresponding time-dependent differential equation was proposed.

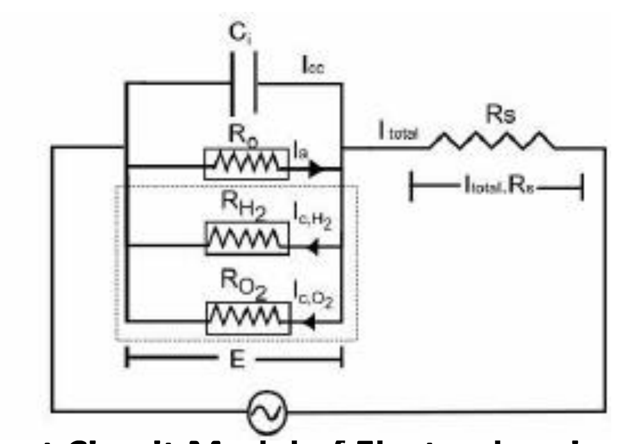

Figure 3: Equivalent Circuit Model of Electrochemical Interface

- The non-linear differential equation for time-dependent potential of this circuit takes the following form:

$$\frac{dE}{dt}+\frac{E}{C_iR_s}+\frac{\xi}{C_i}=\frac{E_{DC}+E_0 sin\omega t}{C_iR_s}$$

where

$$\xi = i_{corr}\left(e^{2.3\frac{(E-E_{corr})}{\beta_a}}-\frac{e^{2.3\frac{(-E+E_{corr})}{\beta_c}}}{1-\frac{i_{corr}}{i_l}+\frac{i_{corr}}{i_l}e^{2.3\frac{(-E+E_{corr})}{\beta_c}}}\right)+i_{0H_2}e^{2.3\frac{(-E-0.244)}{\beta_{H_2}}}$$

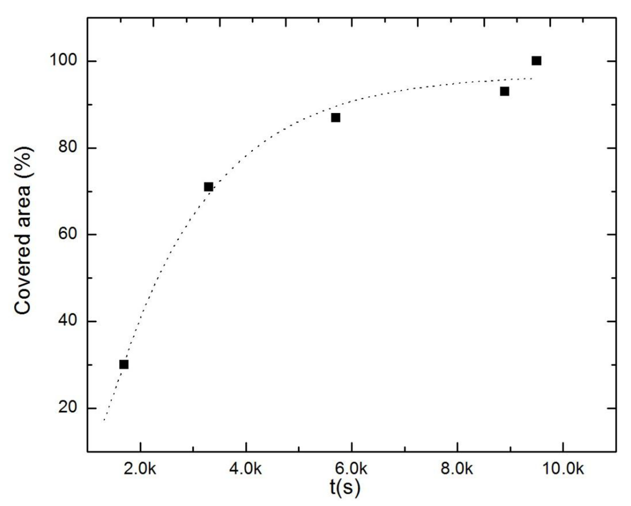

Figure 5: Covered area vs. deposition time for $CaCO_3$ scale.

- Production of $CaCO_3$ and $FeCO_3$ scale was accomplished through carefully controlled deposition on X65 steel.

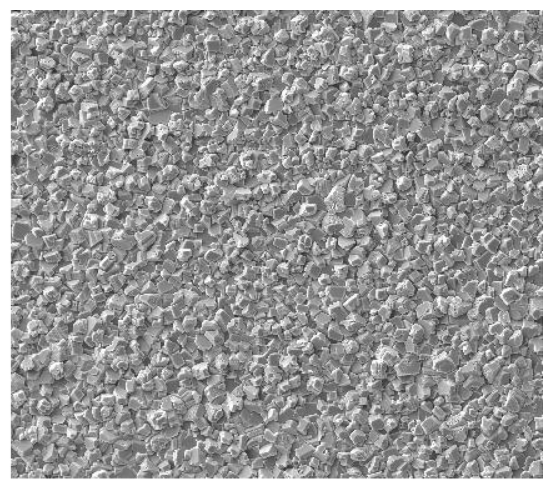

Figure 4: SEM image of $CaCO_3$ scale on X65 at -0.8 V_{SCE}

- Scale formation was observed and analyzed through time and under varying conditions.
- EIS analysis of the resulting scale-covered samples allowed fitting of equivalent circuit component values.

Future Work

Figure 8: Mears Integrity LaGrange, Texas Facility

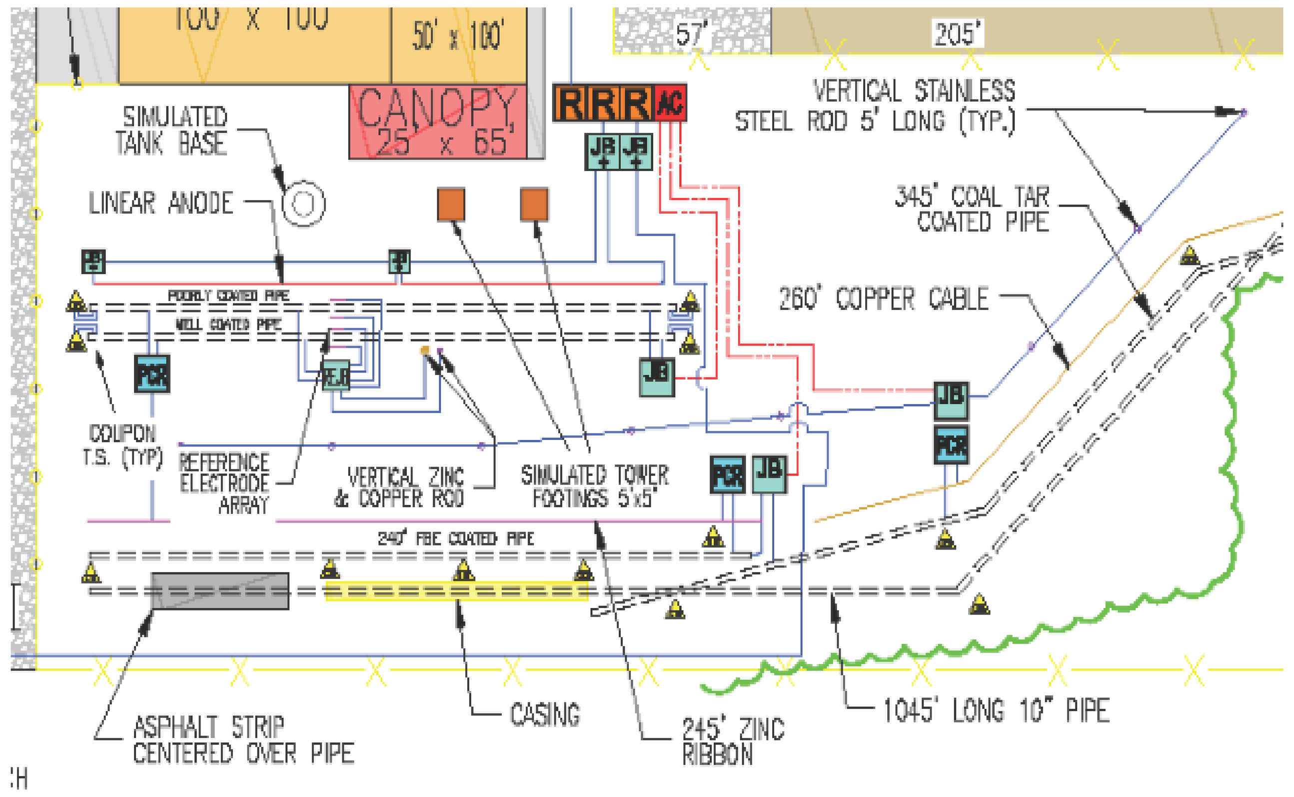

Figure 9: Schematic of LaGrange, Texas Facility

- Tests will be performed at the Mears LaGrange , Texas facility.
- Results from evaluation of test samples connected to an active pipeline in a transmission power line right-of-way will allow collection of real-world data to be used in AC risk analysis.
- Critical Parameters will be benchmarked at CP test facilities that allow control of exposure conditions.
- Surface preparation and scale thickness will be evaluated with comparison of corrosion rate measurements and EIS.

Acknowledgements

- This project is funded by DOT/PHMSA's Competitive Academic Agreement Program #DTPH5615HCAP02

References

1. Ghanbari, Elmira. "Corrosion Behavior Of Buried Pipeline In Presence Of AC Stray Current In Controlled Environment". Ph.D. The University of Akron, 2016. Print.
2. Xu, L.Y., X. Su, and Y.F. Cheng, *Corros. Sci.* 66 (2013): pp. 263-268