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

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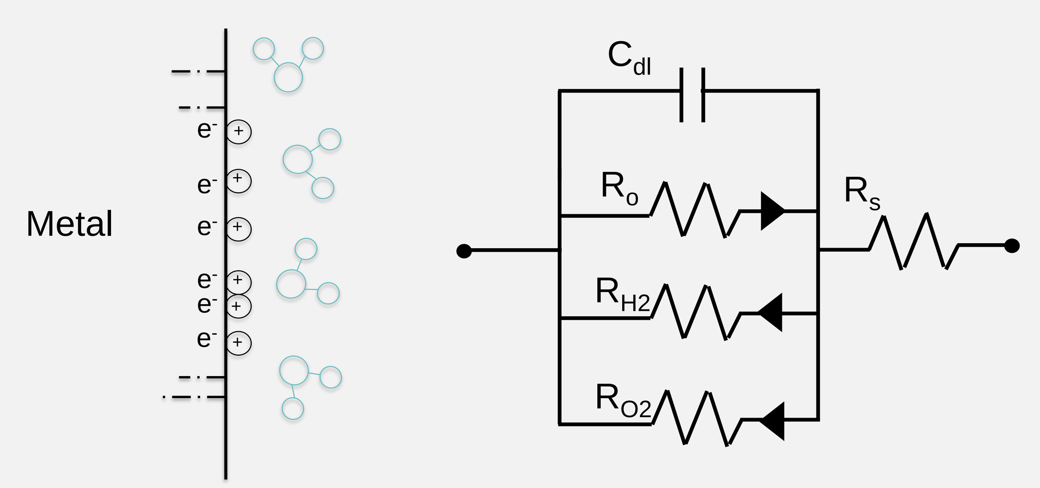
Problem & Objectives

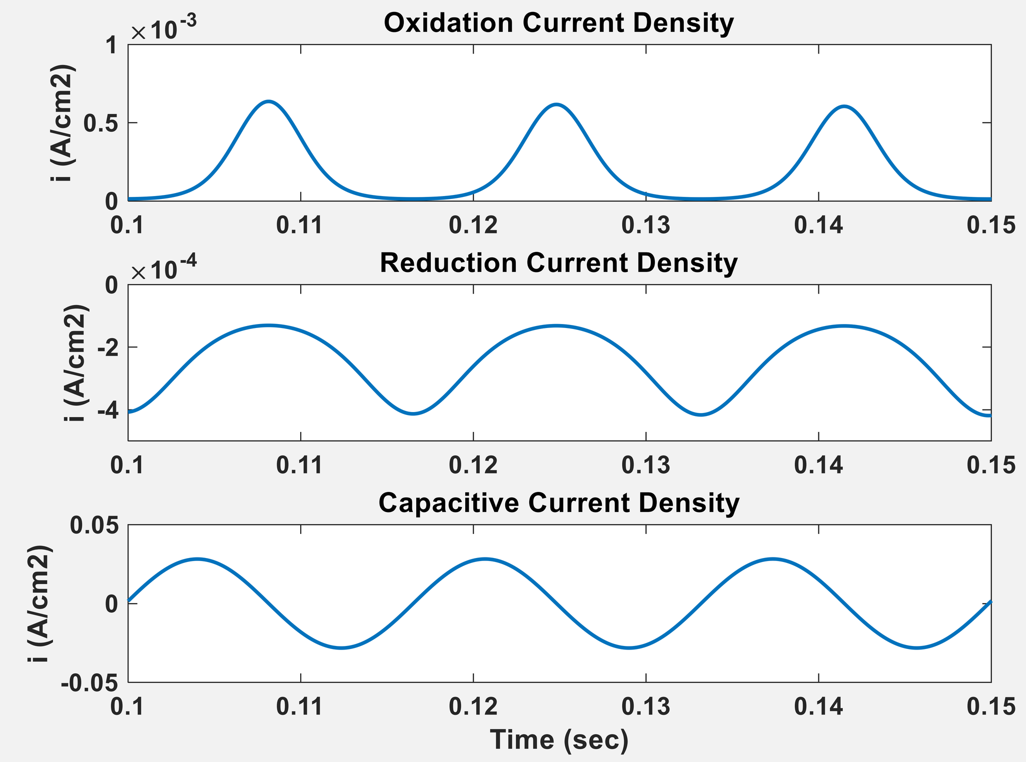
Problem:

- Electromagnetic Interference on pipelines due to overhead high-voltage power lines can lead to large alternating pipe-to-ground potentials.
- It has been recognized that these large AC voltages can lead to greater than anticipated corrosion rates, although the requisite conditions for elevated corrosion risk are uncertain.

Model of AC Corrosion[1,2]

- AC on buried steel is made up of both capacitive and faradaic (oxidation and reduction) current contributions.
- A large alternating voltage on a pipeline can lead to increased corrosion through periodic spikes in the oxidation current at the metal interface.





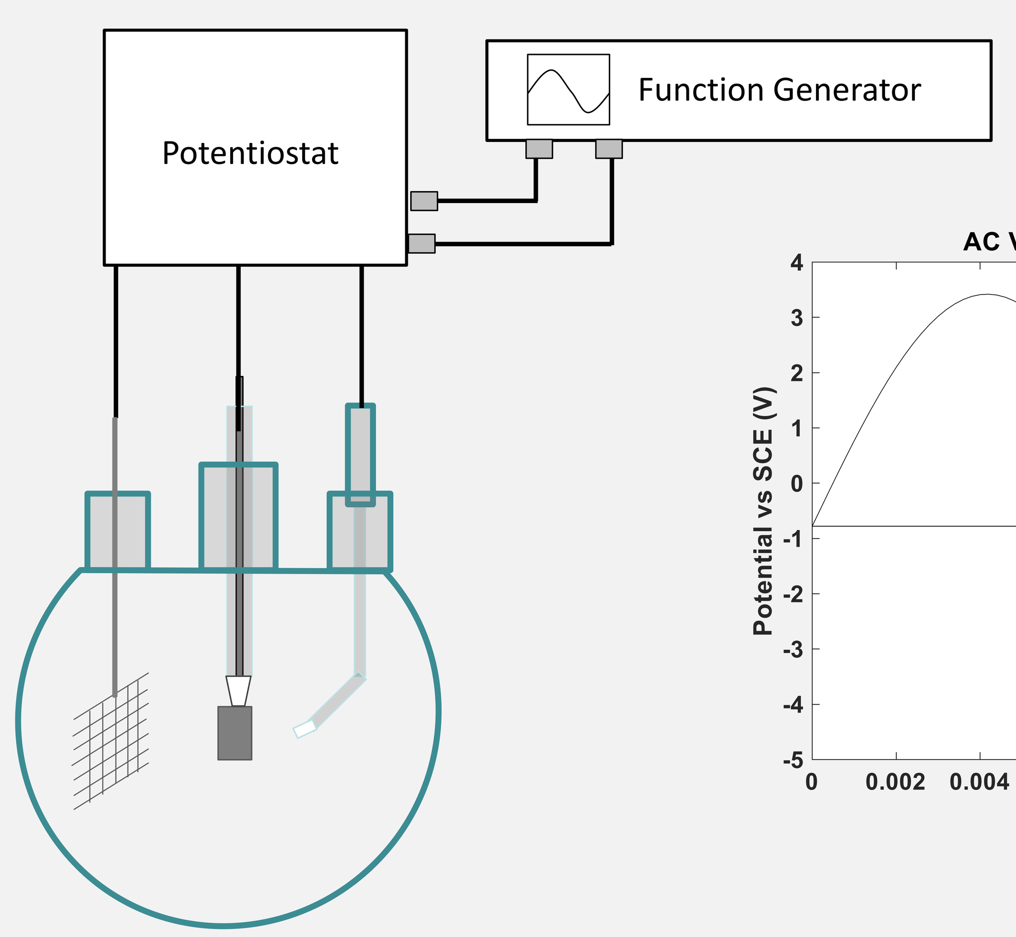
Objectives:

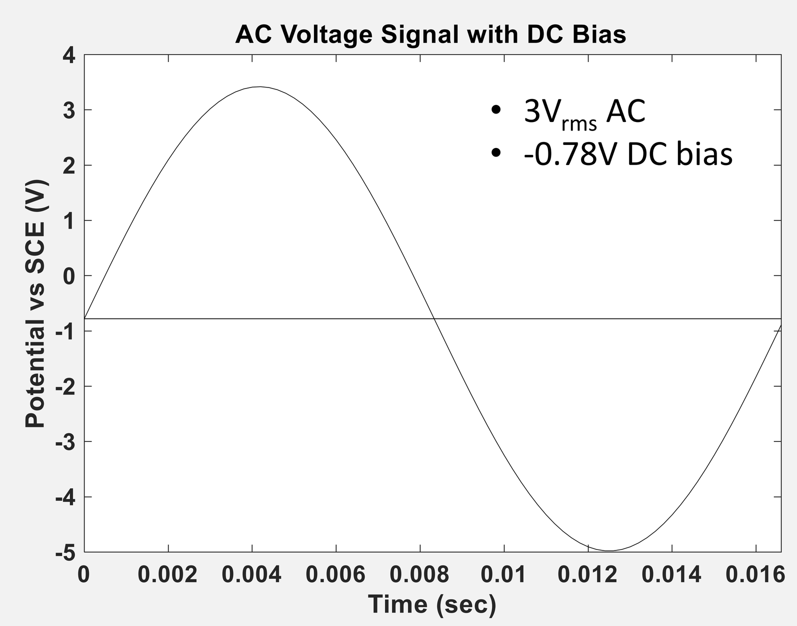
- Determine the combined effects of AC and Cathodic Protection (CP) on the risk of corrosion of in-service pipelines.
- Establish criteria for AC corrosion risk based on physicochemical soil-environment characteristics and their effect on the steel/soil interface.

Problem Approach/Scope

- Mass loss was used as a measure of the corrosion rate of steel samples in adjusted NS4 soil-simulant with Ca^+ and Mg^+ removed to avoid the effects of scale development.
  - A sinusoidal potential at 60Hz was input to a potentiostat capable of simultaneously controlling the AC and DC potential on a sample for up to 6 weeks of immersion time.
- This same setup allowed for Electrochemical Impedance Spectroscopy (EIS) to be perfomed on the steel samples from which the interfacial capacitance can be determined and analyzed for its correlation to mass loss results.

Experimental Setup – Laboratory Testing





X65 Steel Composition

Element	at%
C	0.16
Si	0.45
Mn	1.65
P	0.02
S	0.01
V	0.09
Nb	0.05
Ti	0.06
Fe	Balance

NS4 Soil-Simulant

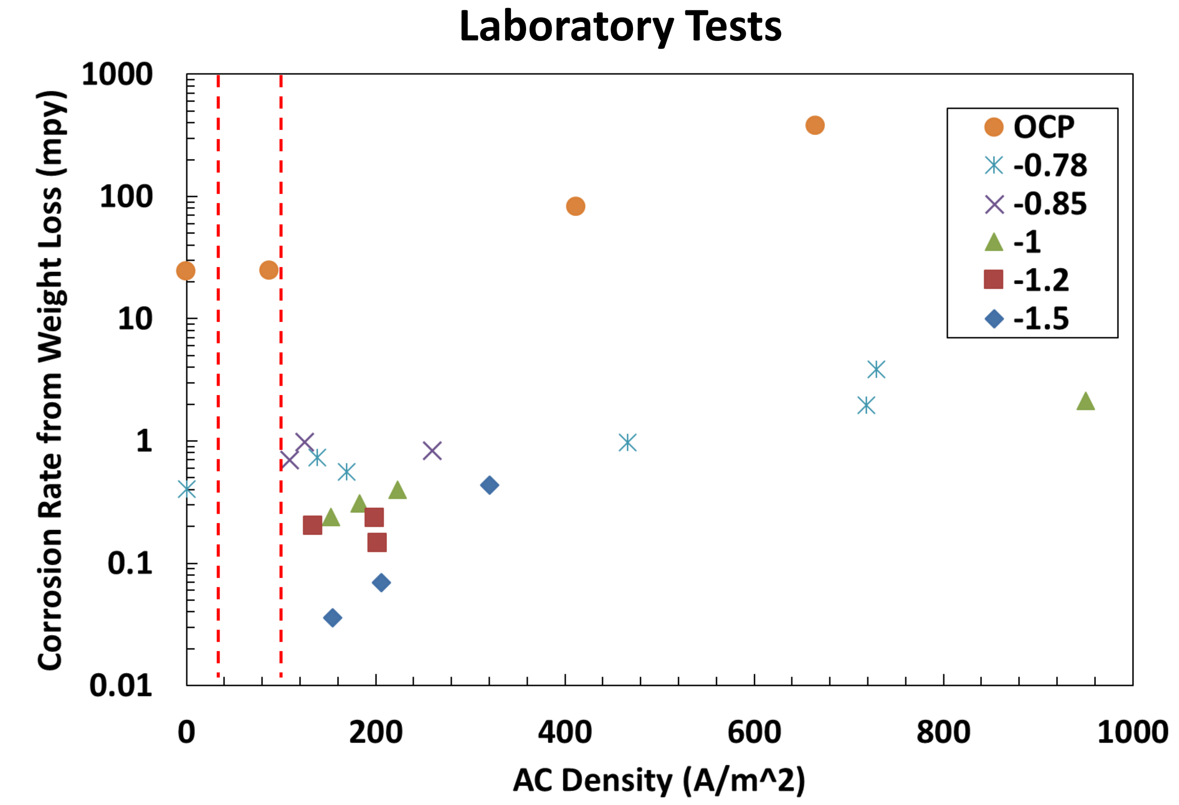
	Concentration (g/L)
KCl	0.3056
$NaHCO_3$	0.483
$NaSO_4$	0.0633

Results To Date

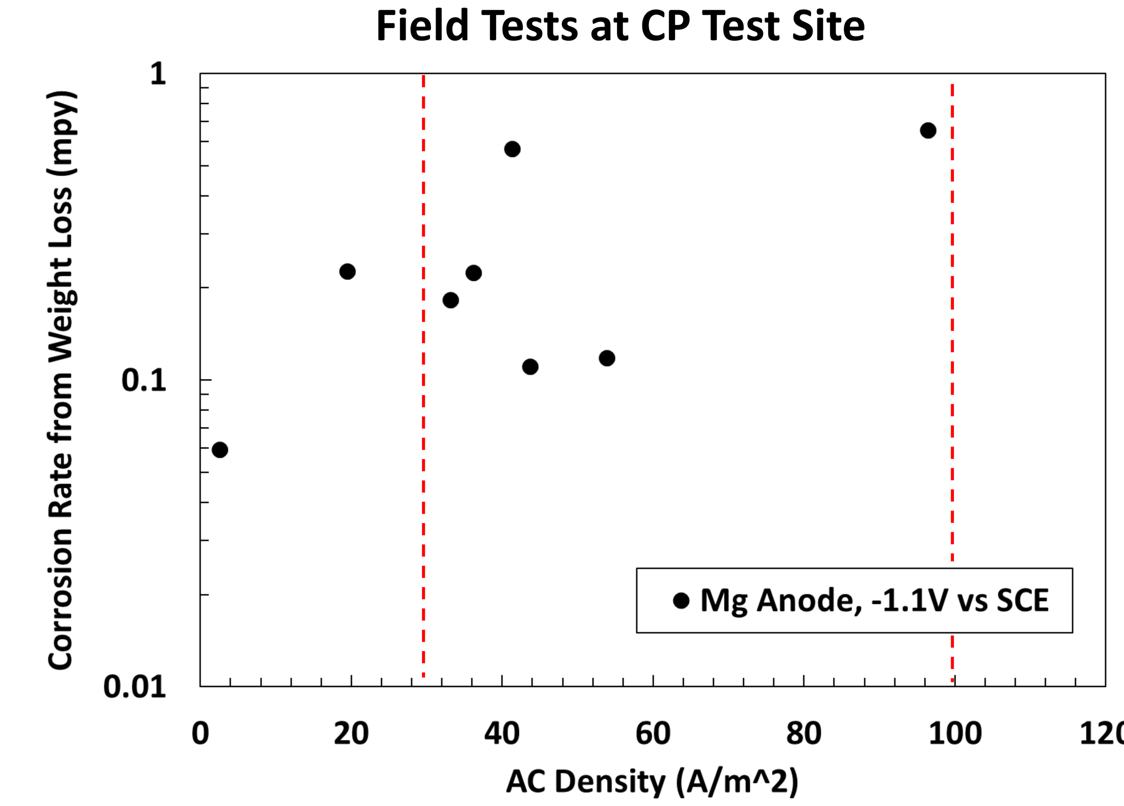
Mass Loss Experiments

NACE State-of-the-Art recommended AC levels for corrosion prevention

Corrosion Risk Levels
- <30 A/m^2 No Corrosion
- 30-100 A/m^2 Corrosion is unpredictable
- >100 A/m^2 Corrosion is likely

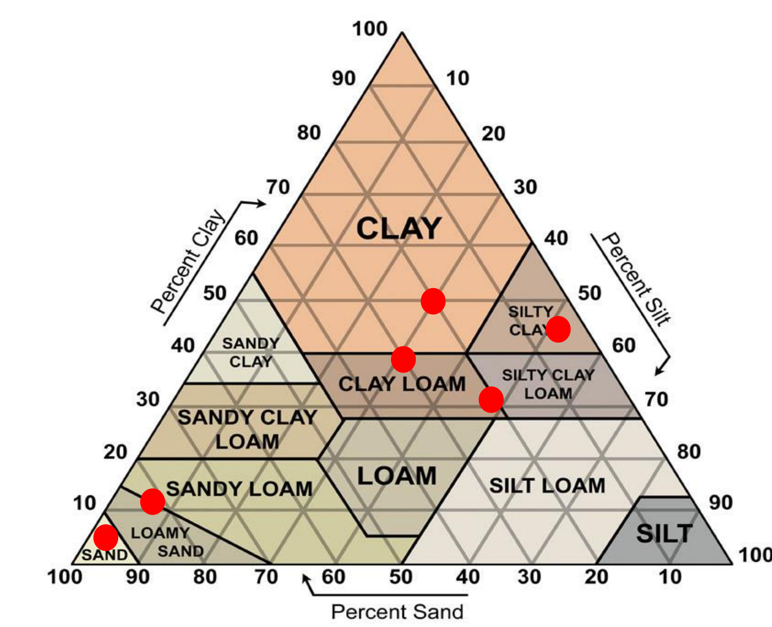


Results from laboratory mass loss experiments on X65 steel samples at various DC potentials exposed to AC voltage for 4-6 weeks. (Voltages vs. SCE)

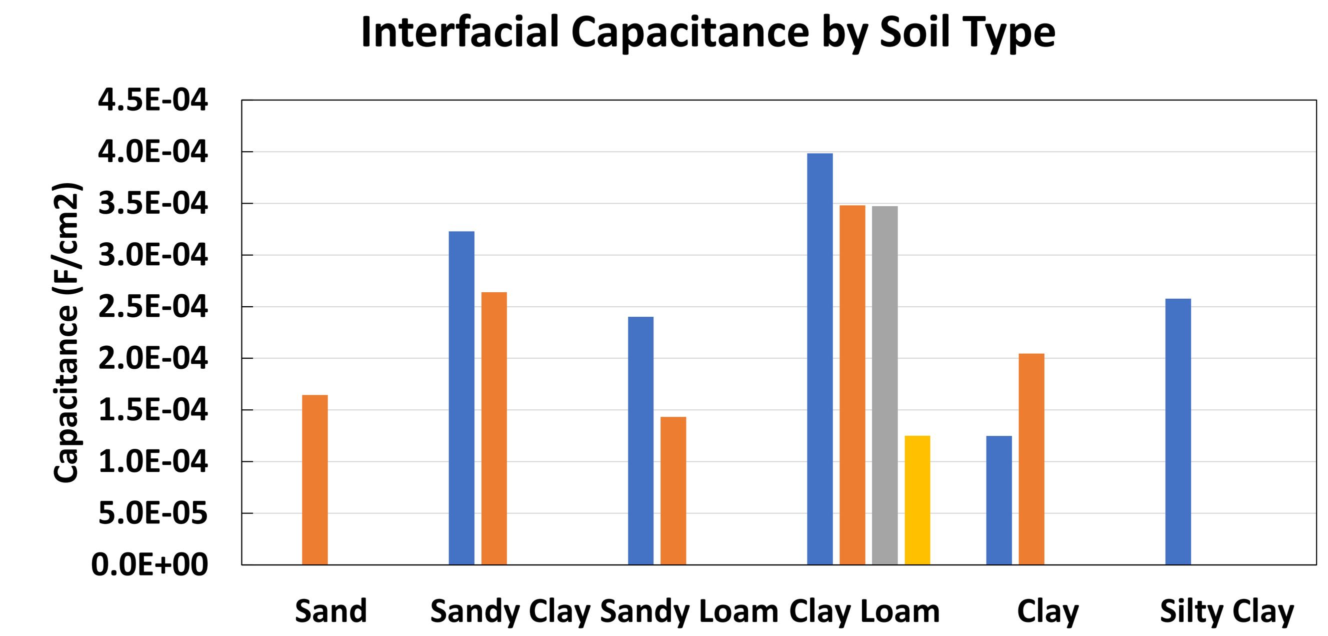


Results from field tests for X65 steel samples bonded to a CP test pipeline protected by a Magnesium anode system for 2-3 months.

Interfacial Capacitance in Soils



USDA soil texture triangle classifying soil types according to percentage of sand, silt, or clay content (<2mm = Sand, <50μm = silt, <2μm = clay). Red dots indicate soil compositions tested.



Interfacial Capacitance values of steel obtained for several tests in various soil types by fitting a parallel CPE circuit to EIS data and converting to capacitance with a formula by Hirschorn[3].

Future Work

- Determine the role soil constituents play on the interfacial capacitance of buried pipeline steel as well as how this parameter affects expected AC corrosion rates.
- Extend the range of AC densities from field testing on mass loss samples to achieve very high AC density

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References

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2. Ghanbari, E., M. Iannuzzi, and R. S. Lillard. "The Mechanism of Alternating Current Corrosion of API Grade X65 Pipeline Steel." *Corrosion* 72.9 (2016): 1196-1210.
3. Hirschorn, Bryan, et al. "Determination of effective capacitance and film thickness from constant-phase-element parameters." *Electrochimica Acta* 55.21 (2010): 6218-6227.