# CAAP Quarterly Report

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Prepared for: *U.S. DOT Pipeline and Hazardous Materials Safety Administration*

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Project Title: Probabilistic Performance Evaluation of Cathodically Protected Pipeline Considering AC Corrosion

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## Business and Activity Section

### (a) Contract Activity

The subcontract for Marquette University is requested due to Dr. Qindan Huang's move from University of Akron to Marquette University during this quarterly period.

No materials were purchased during this quarterly period.

### (b) Status Update of Past Quarter Activities

The kick-off meeting of this project was performed on Nov. 16, 2020 with project managers, PIs, and graduate students.

### (c) Cost Share Activity

No cost share is used during this quarterly period.

### (d) Technical Approach

The goal of this proposed study is to probabilistically evaluate the performance of cathodically protected pipelines under AC-induced (alternating current, AC) corrosion. This study will utilize the experimental testing and numerical analysis to examine AC-induced corrosion, which will be used for identifying key influencing factors and understanding the AC corrosion mechanism. Meanwhile, the monitored defect profile will be used for the probabilistic defect time-evolution model development, which is crucial for the reliability evaluation of pipeline performance. Knowing how the influencing factors and different cathodic protection (CP) design impact the pipeline performance, optimal CP design can be determined. Specific technical objectives are proposed as follows:

- Determine critical influencing factors on AC corrosion;

- Better understand AC corrosion mechanisms with systematical consideration of different combinations of influencing factors;
- Probabilistically model time evolution of AC corrosion profile;
- Assess pipeline performance under CP and AC corrosion based on the probability of failure;
- Optimize CP design under different combinations of influencing factors;
- Investigate the impact of various physical quantities and uncertainty sources on pipeline reliability.

To achieve the proposed research objectives, four tasks are developed.

- Task 1. Identify key influencing factors in AC corrosion (Drs. Huang & Zhou)
- Task 2. Generate realistic AC corrosion profile (Dr. Zhou)

  Task 2a. Corrosion profile configuration in AC corrosion

  Task 2b. Systemically investigation on AC corrosion with CP
- Task 3. Numerical simulation of AC corrosion behavior and CP system (Dr. Wang)
- Task 4. Probabilistic prediction model of AC-induced corrosion and reliability assessment (Dr. Huang)

## 1. Task 1: Identify key influencing factors in AC corrosion

### 1.1 Background and Objectives in the 1st Quarter

AC interference can affect adversely the effectiveness of CP on pipelines by shifting the applied CP potential from the design value. Parameters that influences AC corrosion have been studied including the real level of polarization of steel pipeline by the CP, the level of AC current density, the surface of the exposed cathode at coating defects, and the electrolyte (soil composition, resistivity) (Collet et al., 2001). The shift of the CP potential depends on the applied CP level, AC current density, AC voltage, the presence of DC interference, and other factors such as the diffusion of generated ferrous ions, the deposit of corrosion products on the steel surface, and the combined effect of DC and CP on cathodic reduction reaction (Kuang & Cheng, 2016).

The first objective of this task in the 1st quarter is to identify key influencing factors in AC corrosion that contribute to the CP potential shift through a comprehensive literature review. The second objective is to understand different testing methods for studying AC corrosion in the literatures.

### 1.2 Research Progress in the 1st Quarter

The literature review focuses on these four questions: 1) What are the influencing factors in AC corrosion that contribute to the CP potential shift? 2) How these factors shift the CP potential? 3) What are the testing methods involved in AC corrosion? 4) How to measure the true potential of the pipeline in the presence of AC current/voltage?

The influencing factors we studied from literatures in this quarter include AC density, CP potential, CP current density, the ratio between AC and DC density (Du et al., 2017; Wang et al., 2018; Ormellese et al., 2010; Xu et al., 2013; Brenna et al., 2020). Generally, the CP potential is shifted either positively or negatively by AC density. There is a limitation of AC density for effective CP. The influence of CP potential is complicated because it also relates to the AC current density. Same to CP current density, its influence on CP potential shift is associated with AC current density. Therefore, it is not a simple relationship to describe the influence of each of the factors since they also have a synergic effect. More literatures will be

reviewed in order to better demonstrate the influence of the key factors and their correlations.

Testing methods we studied from literatures in this quarter include the potential measurement under different AC density, mass loss measurement for the corrosion rate, and electrochemical measurement for the corrosion rate.

### 1.3 Conclusions

Some influencing factors are identified in AC corrosion that contribute to the CP potential shift. They are AC density, CP potential, and CP current density. Testing methods in AC corrosion study include electrochemical measurement for potential, corrosion rate, and mass loss measurement.

### 1.4 Future work (next quarter)

More literatures will be reviewed to better demonstrate the influence of the key factors and their correlations. The testing methods and experimental setups for AC study will also be reviewed. Besides that, the threshold values in cathodic protection standard will be studied to understand the effectiveness quantification of the cathodic protection.

## 2. Task 2: Generate realistic AC corrosion profile

This task will start on the 3rd quarter of this project.

## 3. Task 3: Numerical simulation of AC corrosion behavior and CP system

This task will start on the 5th quarter of this project.

## 4. Task 4: Probabilistic prediction model of AC-induced corrosion and reliability assessment

This task will start on the 7th quarter of this project.

## References


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Ormellese, M., Lazzari, L., Brenna A., & Trombetta, A. (2010). Proposal of CP criterion in the presence of AC-interference. *NACE CORROSION* (10032), 1-17.

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