

Reassessment of CP Effectiveness in a Multifaceted Electrolyte

Paul Murray, C.E.T.
Enbridge Employee Services Canada Inc.
10175 101 Street NW
Edmonton, Alberta, T5J 0H3
Canada

Wolfgang Fieltsch, P.Eng.
Stantec
300W-65 Cochrane Drive
Markham, Ontario, L3R 0B8
Canada

Stephen Gibson, P.Eng.
Corrpro Canada Inc.
10848 214 Street NW
Edmonton, Alberta, T5S 2A7
Canada

Samay-Sanat Sahoo, P.Eng.
Stantec
300W-65 Cochrane Drive
Markham, Ontario, L3R 0B8
Canada

Lyndon Crone, E.I.T.
Corrpro Canada Inc.
10848 214 Street NW
Edmonton, Alberta, T5S 2A7
Canada

ABSTRACT

A 2018 case study (C2018-10909) required a rapid quantitative assessment of the external corrosion rate (CR) that buried station piping was subject to when equipped with an underperforming Cathodic Protection (CP) system in a high electrolyte resistivity environment. Originally installed multi-function instrumented probes provided initial operating data indicating acceptable CRs despite sub-criterion and speculative CP data. Operating this monitoring system in a multifaceted electrolyte, with confounding electrolyte variables, warranted further investigation when intriguing data was recorded.

This follow-up case study presents findings post installation and operation of a revised soil side electrical resistance (ER) probe and coupon monitoring system following originally installed 100 μ m probe failures. Utilizing monitoring hardware from multiple manufacturers and datasets beyond CP helped to shed light on the real driver of the original accelerated probe failures. Soil composition at pipe burial depth, installation practices, ER probe data, and CP data all combined to facilitate assessment of the corrosion mechanism through a wider lens.

Key words: corrosion rate, cathodic protection coupon, electrical resistance probe, cathodic protection, soil composition

INTRODUCTION

Operating a Cathodic Protection (CP) system at a remote pump station in a high soil resistivity environment (soil resistivity up to 50,000 ohm-cm) came with its initial challenges. Post original CP system installation it was evident that, at the time, non-traditional monitoring provisions were required to evaluate the CP system performance, and the overall corrosion prevention system effectiveness. Upon installation of the non-traditional monitoring provisions, intriguing data in the form of an elevated Corrosion Rate (CR) were observed over a longer-term period as the system reported data.

Background

The original installed CP system, designed to electrically isolate unintended below grade metallic infrastructure from the below grade product carrying piping, was impacted from piping installation deficiencies rendering the original CP design objective unachievable.¹ Inconclusive CP data was obtained from CP monitoring devices, which included test stations equipped with CP coupons, installed during pump station construction. A prompt project decision was made to install soil side Electrical Resistance (ER) probes to quantify the corrosion rates observed on probe element surfaces. Detailed in previous paper (C2018-10909), the ER probes initially operated as envisioned, and depicted acceptable corrosion rates given the inconclusive CP data and high electrolyte resistivity.

Subsequently, there was a prolonged CP system outage, which resulted in the failure of most of these original 100 μm ER probes, due to corrosion. As a result, new 1000 μm ER probes were installed to ensure that the system could continue to be monitored. An additional shorter outage occurred with these ER probes, facilitating comparison between the originally installed 100 μm ER probes and new revised 1000 μm ER probes. Both sets of data have been evaluated in this case study.

Original Corrosion Monitoring Provisions

The information obtained from the five originally installed multifunction ER probes with 100 μm thick elements, indicated corrosion rates of less than 3 μm per year over a period of time. A corrosion rate of this magnitude, considering special conditions coupled with relevant considerations, was an acceptable benchmark for effective external corrosion.² Although speculative CP data was obtained at the early construction/commissioning stage, the underlying corrosion threat appeared to be mitigated as a result of an acceptable corrosion rate. It is important to note that the original five ER probes installed utilized a 100 μm thick carbon steel strip, with a coupon defect area of 1 cm^2 , and had a detection time of 0.5 hours to detect a measurable corrosion rate by the manufacturer. The decision to select a thin probe element thickness (i.e. 100 μm) was based on the early construction/commissioning project time constraints but lacked vision of long-term operational robustness.

Continued monitoring of the 100 μm probes produced intriguing data, which is summarized in Figure 1. Four of the ER probes in Figure 1 depict insignificant corrosion with the CP system fully operational. One of the probes (ER-02-OLD) failed during a period of time with the application of CP. The data was erratic and inconsistent, and was attributed to faulty equipment.

During a CP system outage, Figure 1 depicts when three of the remaining original ER probes exhibited high corrosion rates, and eventually failed (i.e. ER-01-OLD, ER-03-OLD, ER-04-OLD). In all cases, there was an incubation period before the corrosion began to accelerate, which varied from two to five days for probes ER-03-OLD and ER-01-OLD, to 50 days for probe ER-04-OLD. Once initiated, an average CR between 0.7 and 1.4 mm per year was observed, resulting in the failure of all three probes within 27 to 62 days of the CP system outage. No corrosion occurred on probe ER-05-OLD during the outage, and the measured CP current density remained close to zero with the CP system both On and Off, indicating that the probe may not be fully continuous with the structure.

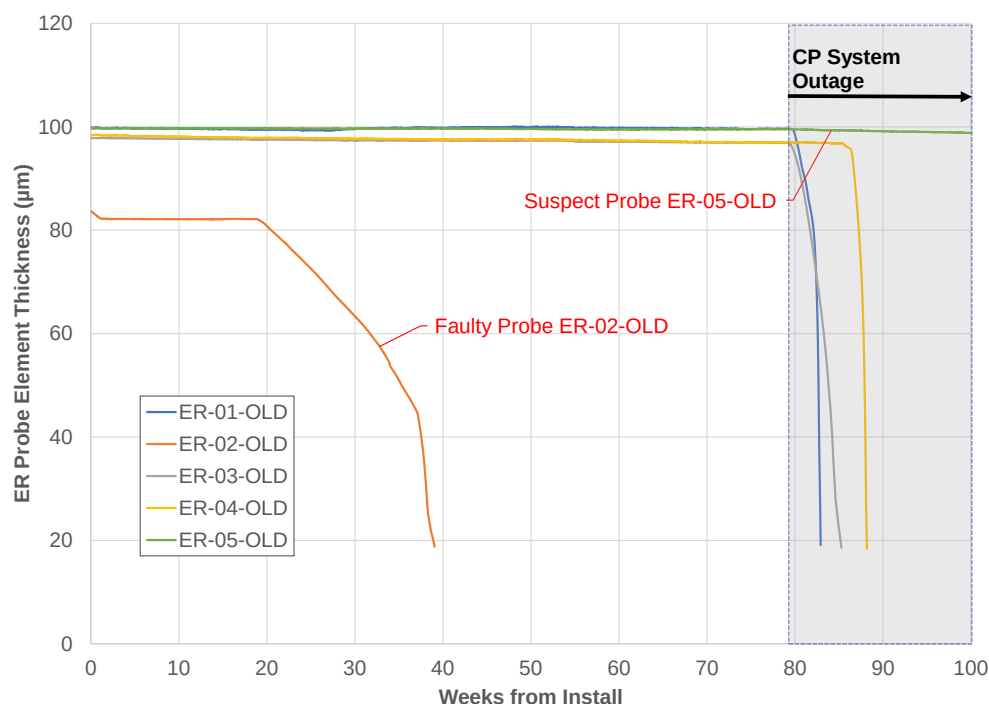


Figure 1: Summary of 100 µm ER Probe Data

As shown in Figure 2 for ER-01-OLD, the start of corrosion was accompanied by a significant shift in current density (iDC) in the positive direction (indicating current discharge), with current densities as high as 2 A/m² recorded on Probe ER-01-OLD.

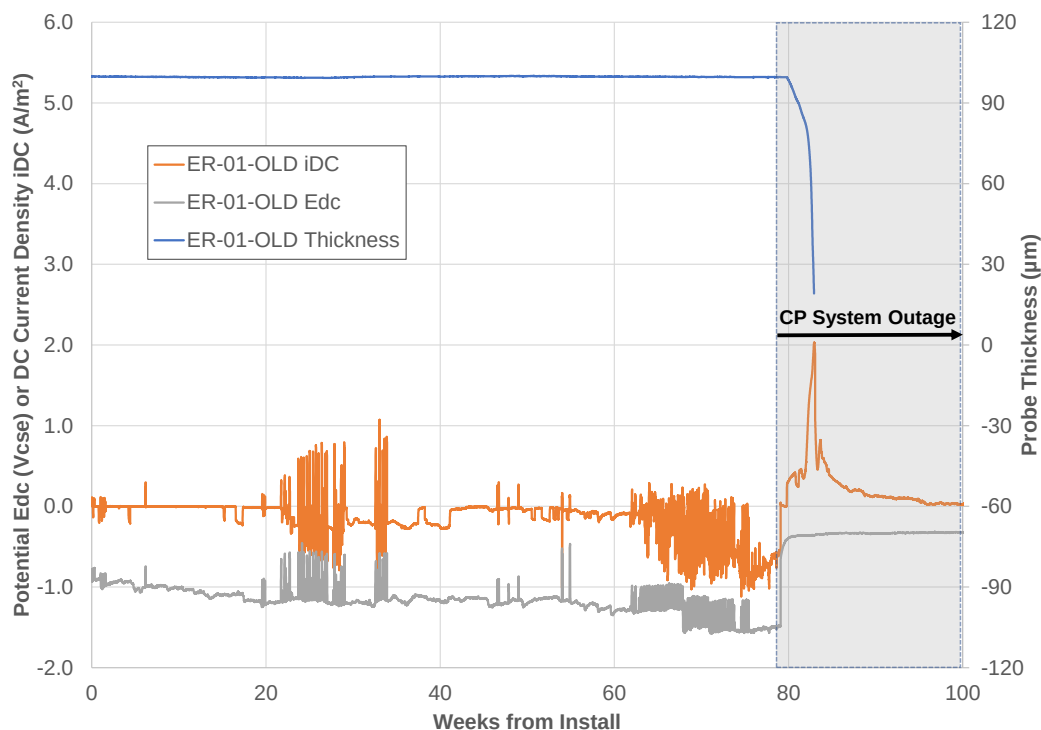


Figure 2: Summary of ER-01-OLD Probe Data (Location 01)

Though corrosion can be expected during a disruption in CP current application, the rates experienced by the originally installed ER probes were definitely not anticipated, particularly when considering the

high resistivity soil environment. A summary of the data for the originally installed ER probes is provided in Table 1.

Table 1
Summary of 100 μ m ER Probe Data During Outage

Probe	EDC ON (mV)	EDC OFF Max (mV)	Incubation (Days)	Max iDC (A/m ²)	Days to Failure	Avg. CR (μ m/yr)	Comments
ER-01-OLD	-1511	-370	5.3	2.03	27	821	
ER-02-OLD	-807 to -601	Failed	N/A	-0.01	Failed*	129*	*Suspect - failed on prior to outage
ER-03-OLD	-1144	-486	2	0.40	43	697	
ER-04-OLD	-780	-280	50	0.94	62	1365	
ER-05-OLD	-1311	-321	N/A	0.01	N/A	2	Suspect – CR and iDC close to 0

Elevated corrosion rates were not expected, but one must consider that buried station piping and ER probes are electrically continuous with the station. The station's infrastructure includes buried copper grounding, reinforced concrete, and bare steel piles. This would result in the piping and ER probes being anodic to the other structures in the galvanic corrosion cell, and thereby preferentially corrode during an outage after a period of depolarization. Moisture in the soil, which varies seasonally is also expected to be a major factor in the corrosion rates during any outages.

PROJECT OVERVIEW

Geospatial Overview

Given the multiple datasets required for analysis (e.g. corrosion rates, coupon-to-electrolyte potentials, coupon currents, soil composition) a Geographic Information System (GIS) environment was utilized for comparison and analysis of data with spatial and attribute qualities represented in a digital format.⁴ Figure 3 provides an overview of particular feature classes, commonly referred to as a layers, that developed an important visual used to understand the reported attribute data in proximity to other buried electrically continuous metallic infrastructure (steel piles, coated piping, copper ground rods).

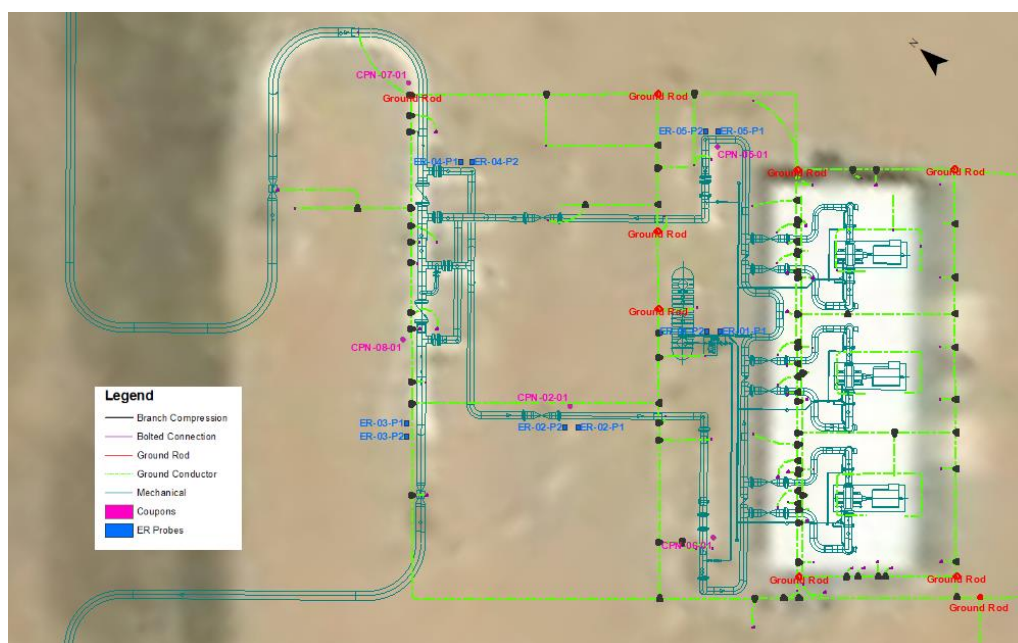


Figure 3: Revised Corrosion Monitoring System Spatial Overview

Methodology for Revised Corrosion Monitoring Provisions

After the failure of the 100 µm thick ER probes, a new set of thicker 1000 µm ER probes were installed. Two new ER probes were paired at each of the same five locations (i.e. total of 10 probes) and installed between 1 meter and 2 meters apart from each other. The new ER probes were installed via hydrovac excavation. Alternative excavation methods were considered but were deemed unfeasible due to frozen ground conditions. The installation guide from the ER probe manufacturer recommends against using hydrovac excavation for the installation of their ER probes due to the potential for introducing contaminants from the water used in the excavation process. To address this concern, the source water for the hydrovac was carefully selected and lab analysis was conducted to document water and soil chemistry. Native fill was used to backfill and surround the probes and then clean sand was used to backfill to grade.

Observed Soil and Water Parameters

Preliminary water analysis was conducted on the water source for the hydrovac prior to starting excavation. The analysis indicated near neutral pH, with very low levels of chlorine, copper, iron, chlorides, sulphates, nitrites, and nitrates. To document potential contaminants in the hydrovac water and soil saturated with hydrovac water, soil and water samples were collected during installation and sent for lab analysis. The lab analysis of these samples did not indicate any additional concerns with backfill soil/water chemistry.

The native soil at probe/pipe level was found to be very sandy, which likely indicates the ability to readily drain water. The resistivities of the native soil samples, saturated with hydrovac water, ranged from 15,000 to 27,000 ohm-cm. Environmental moisture (rain, snow melt, etc.) and accelerated water drainage could result in rapid fluctuations in moisture content in the native soil. Variation in soil moisture content would have a large effect on CP system circuit resistance, likely resulting in the observed fluctuations in CP system performance.

RESULTS AND DISCUSSION

CP System Uptime

The CP system at the pump station could not meet its target output due to large variance in the CP circuit resistance, which resulted in outages. RMU data for the CP source was assessed to determine the total downtime between August 2013 and September 2020. Corrosion was observed on three of five 100 µm ER probes when the CP system was not operational. Furthermore, it was observed that the corrosion was initiated and accelerated after an incubation period, which varied from probe to probe, in all cases.

Probe element thickness loss due to corrosion was calculated during the outage periods. The incubation period for the respective ER probe was subtracted from each of these downtime periods to calculate the actual periods the corrosion would have occurred on the probes. The average corrosion rate measured by the RMU between initiation of accelerated corrosion (after incubation period) and probe failure or end of outage for each probe, was then used to estimate the probe element thickness loss. Table 2 shows the estimated probe element thickness loss based on the 100 µm and 1000 µm ER probes. Note that probes that were suspect or on which corrosion was not initiated during the outage, were not included in this analysis.

Table 2
Estimated Thickness Loss Based on ER Probe Data