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Excavation, Removal and Evaluation of Coupons Exposed to AC Interference While Connected to an Operating Product Transmission Pipeline

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ABSTRACT

This paper presents the results of an investigation that included the excavation and analysis of six (6) coupons test stations exposed to changing levels of induced AC interference from adjacent HVAC transmission lines. The coupon test stations were installed on a liquid product pipeline. The locations were selected based on AC interference historical records and accessibility. The coupon excavation and removal procedures were performed in a manner that allowed the soil near the coupons to be observed intact and separated from the surrounding backfill. The coupon conditions were photographed and documented upon excavation, prior to cleaning and after all deposits and corrosion products were removed. The maximum pit depth, diameter reduction and morphology all were documented and compared to the AC interference history (A/m^2 levels and time of exposure). Notable findings include that all the examined CP coupons showed some AC assisted corrosion damage. In some cases, this damage was severe even with a high level of cathodic protection. The field testing and laboratory analysis showed that the CP current collecting on the bonded coupon caused significant changes in the chemistry in the adjacent soil compared to the nearby backfill.

Key words: liquid product pipeline, induced AC interference, soil chemistry, AC assisted corrosion damage

INTRODUCTION

Approximately 52 coupon stations with remote monitoring units (RMU) were installed to record the AC voltages and current densities on a 16 inch (410 mm) diameter externally coated, steel liquid product pipeline exposed to induced AC interference. The pipeline is 126 miles (203 km) long and is collocated with existing HVAC lines with a rated operating AC voltage ranging from 69kV to 500kV for a significant portion of the pipeline right-of-way (ROW). The pipeline was installed in the late 1980s with an extruded polyethylene external coating. A few short sections were recoated/replaced with FBE or mastic.

This investigation included the excavation and analysis of six (6) coupon test stations. These locations were selected based on the AC interference historical records and accessibility. These test stations were installed as shown in Figure 1. This standard assembly includes two ½ inch (1.27 cm) diameter x 1 inch (2.54 cm) long carbon steel coupons (one for bonding to the pipeline i CP coupon and one not connected i Native Coupon). The CP coupon is connected through a switch in the test station head circuit board to allow instant-off potentials (DC) and the direct measurement of current (AC and DC). The coupons were installed in the spring of 2014 and the CP coupons connected to the pipeline that fall. The RMU data collection began in the fall of 2015.

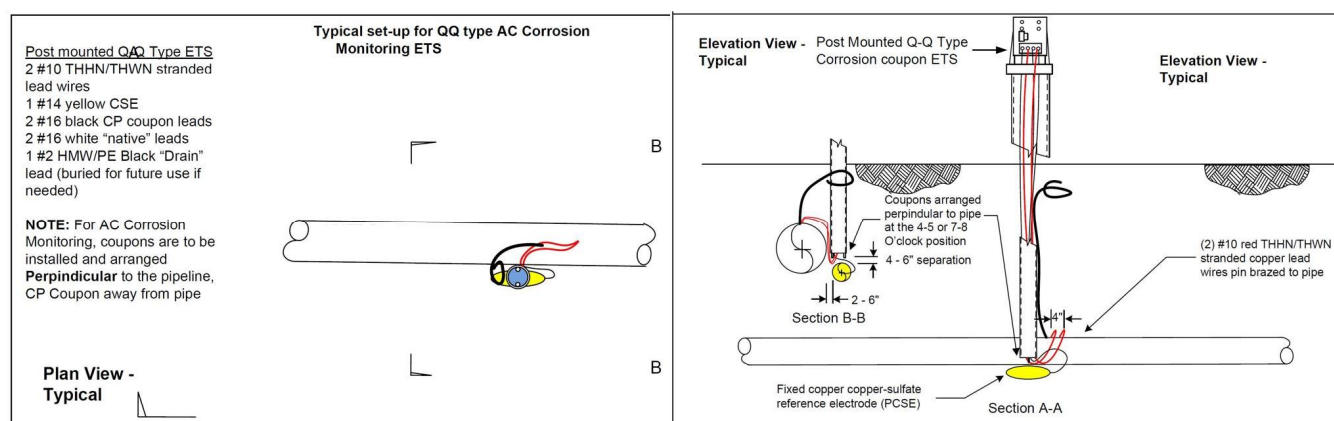


Figure 1: Typical Coupon Test Station Installation Detail

EXCAVATION PROCEDURE

The coupon excavation and removal procedure was performed in a manner that allowed the soil near the coupons to be observed intact and separated from the surrounding backfill. This was done so that any soil characteristic changes from the current collecting on or discharging from the CP coupon could be documented. It also assured any deposits on the coupons or adjacent corrosion products could be preserved and collected. The soil was first removed with a backhoe down to the level of the bottom coupon tube to within 12 inches (300 mm) from the side of the coupon tube. The coupons were then exposed by manually, carefully removing the soil to expose the coupons. Any difference in appearance between the soil at the coupons was documented and photographed. Care was taken to keep this soil separate from the surrounding backfill when the soil samples were collected. Figure 2 is a drawing showing this excavation procedure.

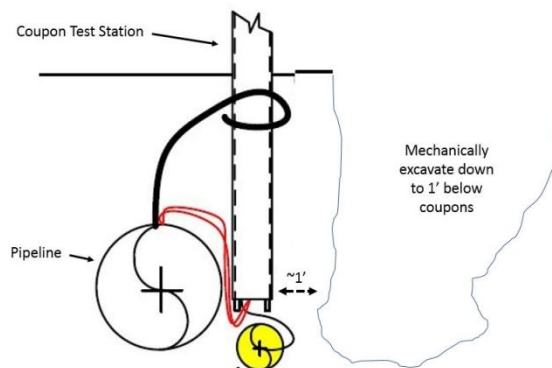


Figure 2: Coupon Excavation Procedure

RESULTS

Coupons at MP 54.447

These coupons were installed on April 24, 2014 and the CP coupon connected to the pipeline on October 28, 2014 (after aging for 187 days i 6.15 months). They were removed on September 27, 2018 for examination and analysis after approximately 53 months of exposure to soil backfill. The bonded (CP) coupon was exposed to varying levels of AC interference for a period close to 47 months

A remote monitoring system was installed and activated at this location in December, 2015. This system recorded the AC volts and CP coupon AC current density at 1-hour intervals. Annual inspections in 2015, 2016 and 2017 included direct measurement of this interference data. The annual survey data indicated much lower levels of AC interference (maximum of 53.82 A/m²) and average of 25.59 A/m²) than the RMU data shown in Figure 3. There was a significant increase in AC interference in late December 2016. The effect of mitigation installed in April 2018 can also be seen.

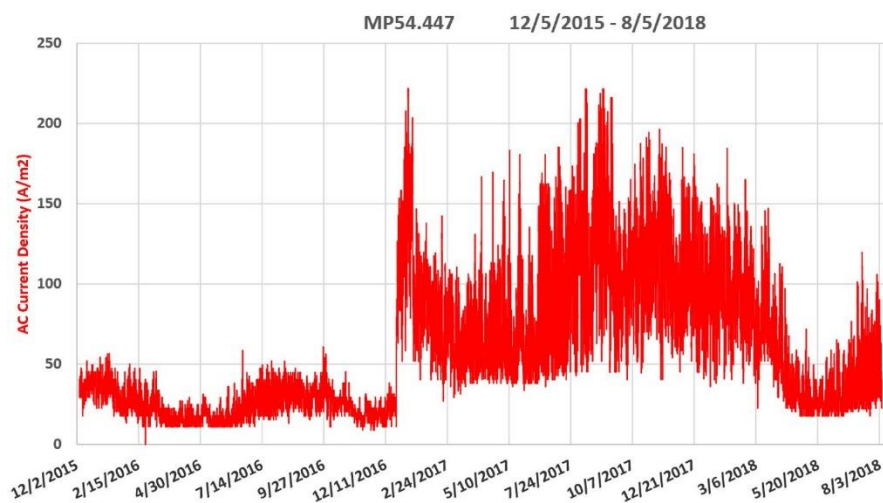


Figure 3: Recorded Coupon AC Current Density at MP 54.447

There was no continuously recorded AC current density data between the time the CP coupon was connected and the RMU activated. The interference levels recorded prior to the large increase in December 2016 was used to estimate the levels during this time. The interference level in the 50 days between the last RMU data and date of removal was estimated based on the last several months of recorded data. This was used to calculate the estimated life time AC interference exposure. The time the coupon was exposed to over 100 A/m², between 100 and 50 A/m², between 50 and 30 A/m² and below A/m² was calculated (Table 1). The recorded RMU data did not include the CP coupon DC

current density or DC polarized (off) potential. However, these were measured just prior to excavation i DC current density 6.2 A/m², polarized potential -1077 mV and AC current density 71 m². The native coupon resistance to the pipe was 380 ohms and the CP coupon 57 ohms.

Table 1: Estimated AC Interference Exposure of CP Coupon at MP 54.447

CP Coupon at MP 54.447			
		6.15	Months exposure free corroion
Estimated 10/14 to 12/15	0%	0.0	> 100 A/m2
RMU 12/15 to 8/18	19.1%	6.13	> 100 A/m2
Estimated 8/5 to 9/27/2018	1%	0.02	> 100 A/m2
		6.15	Months Total exposure > 100 A/m2
Estimated 10/14 to 12/15	0%	0.0	100 to 50 A/m2
RMU 12/15 to 8/18	26.3%	8.42	100 to 50 A/m2
Estimated 8/5 to 9/27/2018	50%	0.86	100 to 50 A/m2
		9.28	Months Total exposure 100 to 50 A/m2
Estimated 10/14 to 12/15	25.0%	3.3	50 to 30 A/m2
RMU 12/15 to 8/18	19.5%	6.23	50 to 30 A/m2
Estimated 8/5 to 9/27/2018	30%	0.51	50 to 30 A/m2
		10.05	Months Total exposure 50 to 30 A/m2
Estimated 10/14 to 12/15	75%	9.9	< 30 A/m2
RMU 12/15 to 8/18	35.11%	11.25	< 30 A/m2
Estimated 8/5 to 9/27/2018	20%	0.34	< 30 A/m2
		21.51	Months Total exposure < 30 A/m2

Figure 4 includes photographs of the soil at the bottom of the coupon test station tube as it was being excavated and the coupons immediately after removal. The soil in a 5 inch (125 mm) diameter ball around the base of the coupon test station was of a noticeably lighter color than the surrounding backfill. Soil box field testing at the excavation indicated the backfill had a resistivity of 2,300 ohm-cm and a pH of 7.5. The lighter color soil at the coupon level was 850 ohm-cm and a pH of 10-11. The CP coupon did not have the typical calcareous build up characteristic of highly polarized steel or a large, black mound of corrosion product typically found in cases of AC corrosion. The CP coupon did have a thin, hard black film on the surface. Both coupons showed signs of corrosion product (red color) leaching into the adjacent soil. Samples of the soil at the coupons and the backfill approximately 12 inches (300 mm) above the coupons were collected for laboratory analysis. The laboratory analysis results are shown on Table 4.

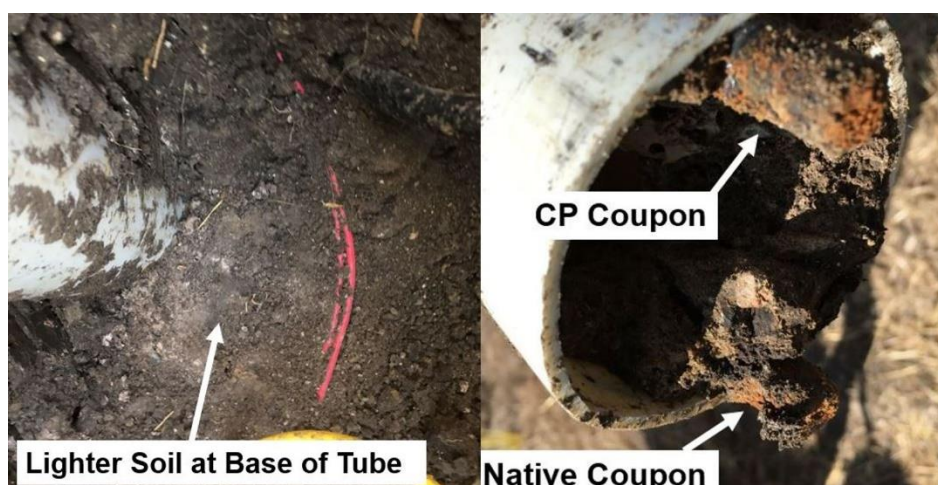


Figure 4: Condition of Soil and Coupons at MP 54.447 Immediately After Excavation

Table 2: Results of Laboratory Testing of Soil Samples Collected at MP 54.447

		MP 54.450 @ backfill	MP 54.450 Inside Under Tube/Coupon
Resistivity		ohm-cm	ohm-cm
	as received	4,400	1360
	saturated	1,080	184
pH		8.0	9.8
		mS/cm	
Electrical Conductivity		0.12	3.66
		mg/kg	mg/kg
calcium	Ca ²⁺	23	72
magnesium	Mg ²⁺	7.9	27
sodium	Na ¹⁺	121	4850
potassium	K ¹⁺	3.9	21
Carbonate	CO ₃ ⁻	0.001	2270
bicarbonate	HCO ₃ ⁻	186	2810
fluoride	F ¹⁻	0.8	11
chloride	Cl ¹⁻	0.001	1.3
sulfate	SO ₄ ²⁻	55	95
phosphate	PO ₄ ³⁻	0.001	0.001
ammonium	NH ₄ ⁺	0.001	24
nitrate	NO ₃ ⁻	21	46

The coupons were cleaned (media blasted) and the apparent corrosion damage was observed. The CP coupon had limited pitting on the sides with a deep pit on the end edge. This deep pit had the morphology typically seen with AC assisted corrosion damage. The native coupon had general corrosion damage over the entire surface. The observed corrosion is consistent with unprotected freely corroding steel for the native coupon and AC assisted corrosion of cathodically protected steel on the CP coupon. Figure 5 includes photographs of the coupons after cleaning. The depth of the pits was measured with a dial indicator gauge and the diameter with a digital caliper. The results of the measurements are summarized in Table 3.

**Figure 5: Photographs of MP 54.447 Coupons After Cleaning****Table 3: Coupon Diameter and Pit Depths Measured on MP 54.447 Coupons**

CP Coupon	Native Coupon
Max Dia = 0.498"	Max Dia = 0.495"
Min Dia = 0.497"	Min Dia = 0.481"
Max Pit Side = 8 mil	Max Pit Side = 21 mil
Max Pit End = 70 mil	Max Pit End = 43 mil

The native coupon showed a significant amount of general corrosion. General corrosion would be expected on the native coupon, as it is not subject to cathodic protection. The maximum pit depth of

the native coupon of 43 mils (0.043 inches -1.1 mm) equates to a corrosion rate of approximately 9.7 mils per year (mpy)(0.25 mm/yr), typical of freely corroding carbon steel in this soil environment and in the absence of CP.

The maximum depth of corrosion on the CP coupon was 70 mils (0.0708 inches-1.8 mm). It was installed 187 days prior to being connected to the pipeline and receiving cathodic protection and subject to AC interference. If the native coupon corrosion rate of 9.7 mpy is applied to the CP coupon prior to bonding, then approximately 5 mils (0.13 mm) of corrosion damage occurred before being subject to AC interference (assuming adequate CP after it was bonded). If the 65 mils (1.7 mm) of AC corrosion damage only occurred during the 6.15 months the AC current density was above 100 A/m², the average indicated AC corrosion rate would have been 127 mils/year (3.2 mm/yr). If the damage occurred during the entire time the AC current density was above 50 A/m² (15.32 months), the average indicated AC corrosion rate would have been 51 mils/year (1.3 mm/yr).

Coupons at MP 58.974

These coupons were installed on April 28, 2014 and the CP coupon connected to the pipeline on October 27, 2014 (after aging for 182 days ÷ 5.9 months). They were removed on September 27, 2018 for examination and analysis after approximately 53 months of exposure to soil backfill. The bonded (CP) coupon was exposed to varying levels of AC interference for a period of 47 months

A remote monitoring system was installed and activated at this location on December 4, 2015. Annual inspections included direct measurement of this interference data. The annual survey data indicated much lower levels of AC interference (maximum of 40.9 A/m² and average of 25.83 A/m²) than the RMU data shown in figure 6. There was a significant increase in AC interference on January 12th, 2017. The effect of mitigation installed in May 2017 can also be seen. The calculated estimated lifetime exposure to the various levels of AC interference for the coupon at MP 58.974 is shown in Table 4. Just prior to excavation the DC current density was 2.3 A/m², polarized potential was ÷ 1,280 mV and AC current density 85 A/m². The native coupon resistance to the pipe was 61 ohms and the CP coupon 25 ohms.

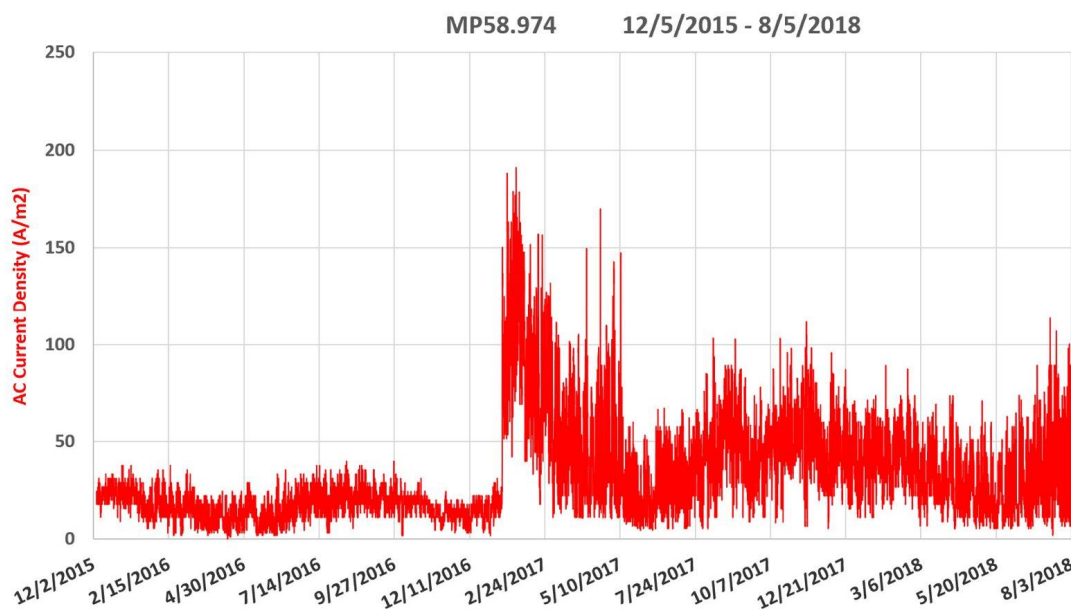


Figure 6: Recorded Coupon AC Current Density at MP 58.974