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CORROSION 99

CORROSION MEASURING TECHNIQUES CONFIRM EFFECTIVENESS OF PULSE CATHODIC PROTECTION FOR BURIED STEEL PIPELINE

Ted M. Doniguian
Farwest Corrosion Control Company
17311 South Main Street
Gardena, Ca 90248

Ronald C. Robinson
Kinder Morgan Energy Partners
2319 S. Riverside Avenue
Bloomington, CA 92316

ABSTRACT

Safe pipeline transportation and storage of liquid petroleum products necessitate the use of several methods of corrosion control, including protective coatings, cathodic protection and corrosion monitoring. When a polarization potential survey was performed on a recently acquired 35-mile long pipeline, the survey indicated areas of marginal protection. The results of the survey necessitated a more comprehensive investigation to establish remedial measures, including supplemental protection. Accordingly, the effectiveness of installing a high voltage, pulse rectifier, at the pumping station end of the buried steel pipeline, to improve protection distribution at the remote reaches, was confirmed.

Keywords: corrosive soils, cathodic protection, pulse cathodic protection, pipeline transportation, liquid petroleum products.

INTRODUCTION

During a recent acquisition of a 35-mile long, 6 inch, jet fuel pipeline located in Central California, an initial polarization potential survey was conducted. The survey on the buried steel pipeline indicated wide ranges of protection levels from excessive near the pump station, located at the Northern reaches of the pipeline, to marginal at the Southern reaches. It was suspected that the marginal levels of protection were due to the non-uniform distribution of protection from the rectifier and semi-deep anode bed located at the pump station.

Shortly after the pipeline was acquired in April 1996, an additional deep well anode bed, several test stations, and a pulse rectifier were installed to improve protection. Polarization and electrical probe measurements at remote test stations were utilized to confirm that the addition of pulse CP to the existing conventional CP system, improved protection levels at 29 and 35 miles from the pump station.

PUMP STATION AND PIPELINE PROTECTION

The pump station and the distribution pipeline were constructed in 1991. They supply jet fuel via a high pressure buried 6 inch steel line to a Naval Air Base located 35-miles southwest of Fresno, California. The pipeline is fabricated from API-5L Grade X-46 high strength steel which includes a nominal 40-mil thick extruded polyethylene coating, plus primer. The pipeline traverses rural agricultural areas that are heavily irrigated, resulting in alternate wetting and drying soil exposure. Soil corrosivity is accentuated by fertilization and buildup of salinity, resulting in severely corrosive conditions. Further, the line traverses several canal, river, and slough crossings that necessitated installation of block valves in vaults that are often flooded with aggressive ground water.

Initially, the pump station equipment, storage tanks, block valves, and the pipeline were being partially protected using a conventional cathodic protection (CP) rectifier and a semi-deep anode bed. The CP rectifier was adjusted to approximately 22 amperes of dc current output. Shortly after the line was acquired, magnesium anodes were installed at the valves to provide supplemental protection during flooding. After several months of exposure, the valves were relocated to higher ground for better accessibility.

SOIL CORROSIVITY TESTS

Chemical, electrical and corrosion rate tests verified that the soil conditions are more corrosive at the remote end of the pipeline than at the pump station, where the original protection system is located. Results of laboratory tests for soil samples at three mile posts (MP) along the pipeline from the pump station (MP 0.08), slough (MP 28.84) and the military base (MP 34.91), are shown in Table 1. The soil conductivity and chemical content are several magnitudes higher at the remote end of the pipeline compared to the pump station end. The soil at the remote end also displays low soil resistivities and high concentrations of corrosive chloride ions. The remote end of the pipeline also contains corrosive sulfates and nitrates that are often associated with agricultural fertilizers.

When the block valves were relocated at the above three locations, corrosion monitoring stations were also installed. The stations included electrical resistance (E/R) probes to measure steel corrosion rates and polarization potentials. A pulse rectifier and a new anode bed were also added at the pumping station facility, where electrical power and security is provided. An investigation was initiated to evaluate high voltage pulse CP protection (1), (2), (3) in conjunction with conventional CP. Figure 1 depicts the pulse and conventional CP rectifiers mounted side by side at the pump station.

CONVENTIONAL VERSUS PULSE CP

Refined petroleum product facilities often use several corrosion control alternatives, including biased bonding, sacrificial anodes and conventional impressed current systems (4), (6), (7). For this application, the use of impressed current systems was limited to the secured pump station end of the pipeline. Increasing the current output of the conventional CP system, in order to improve the protection on the marginally protected remote reaches of the pipeline, only resulted in excessive protection near the pump station. Pipe to soil potential shifts from the conventional rectifier and the semi deep anode bed were due to IR drop along the pipeline and not to protective polarization potentials. Excessive pipe to soil potentials greater than -3.0 volts to copper, copper sulphate electrodes (CSE) were recorded at several locations including MP 0.52.

The reach of conventional CP down the length of a pipeline is limited to the amount of current being received by the outer surfaces of the pipeline. If the CP current is not adequate, all the corrosion inducing oxygen molecules and hydrogen ions adsorbed on the surface of the steel will not be reduced, and corrosion will continue to occur. Even though they are of very short duration, the very high pulse CP currents are orders of magnitude greater than conventional CP currents. The very high pulse CP currents are able to instantaneously reduce the oxygen molecules and hydrogen ions at greater distances than with conventional CP. A comparison of pulse and conventional output voltage waveforms are depicted in Figures 2 and 3.

POLARIZATION POTENTIAL SURVEYS

After several initial adjustments were made to both the conventional and pulse CP systems, additional potential surveys were performed along the pipeline. The potential profiles for two potential surveys, without and with pulse CP, are depicted in Figure 4. The anomaly in the potential reading, at pipeline mile post 28.84, with only the conventional rectifier operating, was due to the fact that the original magnesium anodes were still connected to the valve. In 1997, the valves were relocated and new magnesium anodes were not as yet connected during the latter survey.

The survey data indicate a significant increase in the protective potentials at the remote end of the pipeline (MP 34.91), when the pipeline is being protected with both the conventional and pulse CP systems, than when protected with only the conventional CP system. The survey data also indicate a significant decrease in the excessive potentials at or near the pump station (MP 0.00 and 0.52).

PROBE CORROSIVITY INVESTIGATION

In addition to the pipeline potential survey profiles depicted in Figure 4, E/R probe investigations were also conducted at valve sites, to confirm the corrosiveness of the soil. The E/R probes were buried at pipe depth and allowed to corrode for a period of time. After 34 days, the carbon steel probes were placed under protection by connecting them to the cathodically protected pipeline.

The E/R probe corrosion readings, as well as polarization potentials of the probes and the pipeline were recorded for a period of 104 days. Profiles of the E/R probe data at MP 28.84 for a period of 62 days, are depicted in Figure 5.

The E/R probe corrosion readings at MP 28.84 began increasing very rapidly after the probe was buried adjacent to the pipeline. The corrosion rate of 65.7 mils/yr, calculated for the period between 28 and 34 days of exposure, confirmed the aggressive nature of the soil. On day 34, the E/R probe was electrically connected to the pipeline. The E/R probe readings ceased increasing, signaling that the E/R probe was being cathodically protected, along with the pipeline. After being connected to the pipeline for only a few hours, the potential reading of the E/R probe was almost identical to the adjacent pipeline reading.

PROBE DEPOLARIZATION INVESTIGATION

A depolarization test was also performed at MP 28.84 to re-confirm the protection levels of the pipeline and the corrosivity of the soil. After day 104, the E/R probe was disconnected from the pipeline and allowed to depolarize for a total of 114 minutes. The E/R probe was then reconnected to the pipeline. A potential profile of the 140 minute depolarization and re-polarization period, is depicted in Figure 6. The rapid depolarization of the E/R probe when the protection was interrupted, confirmed again, the severely corrosive nature of the soil at MP 28.84.

CONCLUSIONS

The case history and the investigations described above, confirm the value of corrosion monitoring and the effectiveness of cathodic protection alternatives for buried steel pipelines. Important considerations in evaluating protection measures are as follows:

* E/R probe polarization, depolarization and corrosion readings can be used to determine the corrosive nature of the soil surrounding buried pipelines. When coupled with potential surveys, they can be used to confirm cathodic protection levels for underground pipelines.

* Since E/R probe corrosion rates tend to stifle when connected to pipeline components under CP protection, the adequacy of CP levels and protection criteria can be assessed with probe corrosion monitoring.

* Pulse cathodic protection can be used in conjunction with conventional CP to improve protection levels for buried pipelines in remote area where conventional systems are limited.

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TABLE 1

Pipeline Soil Samples
Electical and Chemical Corrosivity Test Results

Sample ID	MP 0.08	MP 28.84	MP 34.91
Resistivity, Ohm-Cm	45,000	200	365
pH	7.7	6.5	6.8
Chloride, Mg/Kg	14	12,053	10,298
Sulfate, Mg/Kg	22	3,417	8,151
Nitrate, Mg/Kg	-	179	155

FIGURE 1 - Pulse (Left) and Conventional Rectifiers

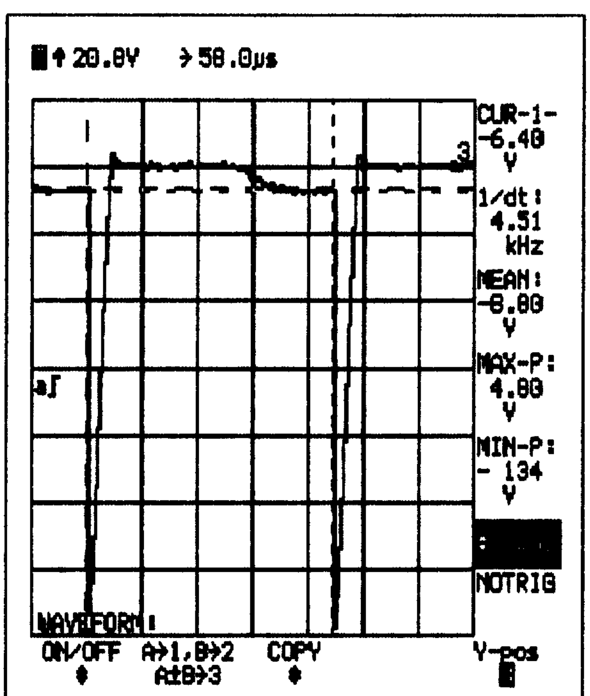

FIGURE 2
Pulse Rectifier
Output Volts

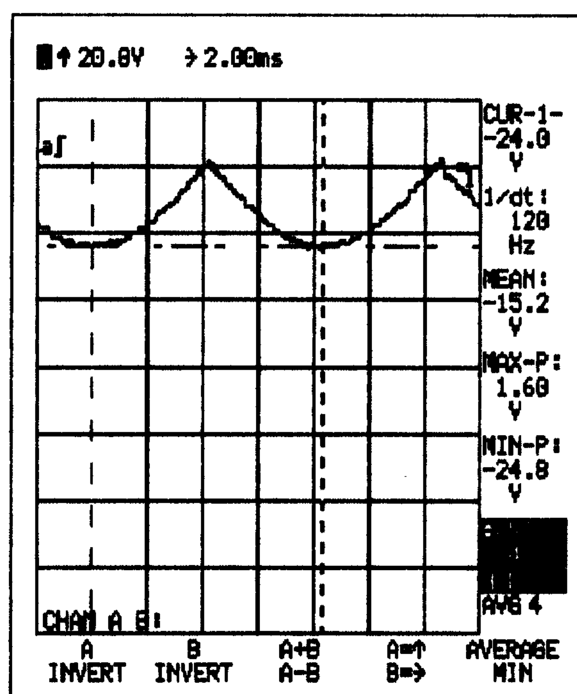

FIGURE 3
Conventional Rectifier
Output Volts

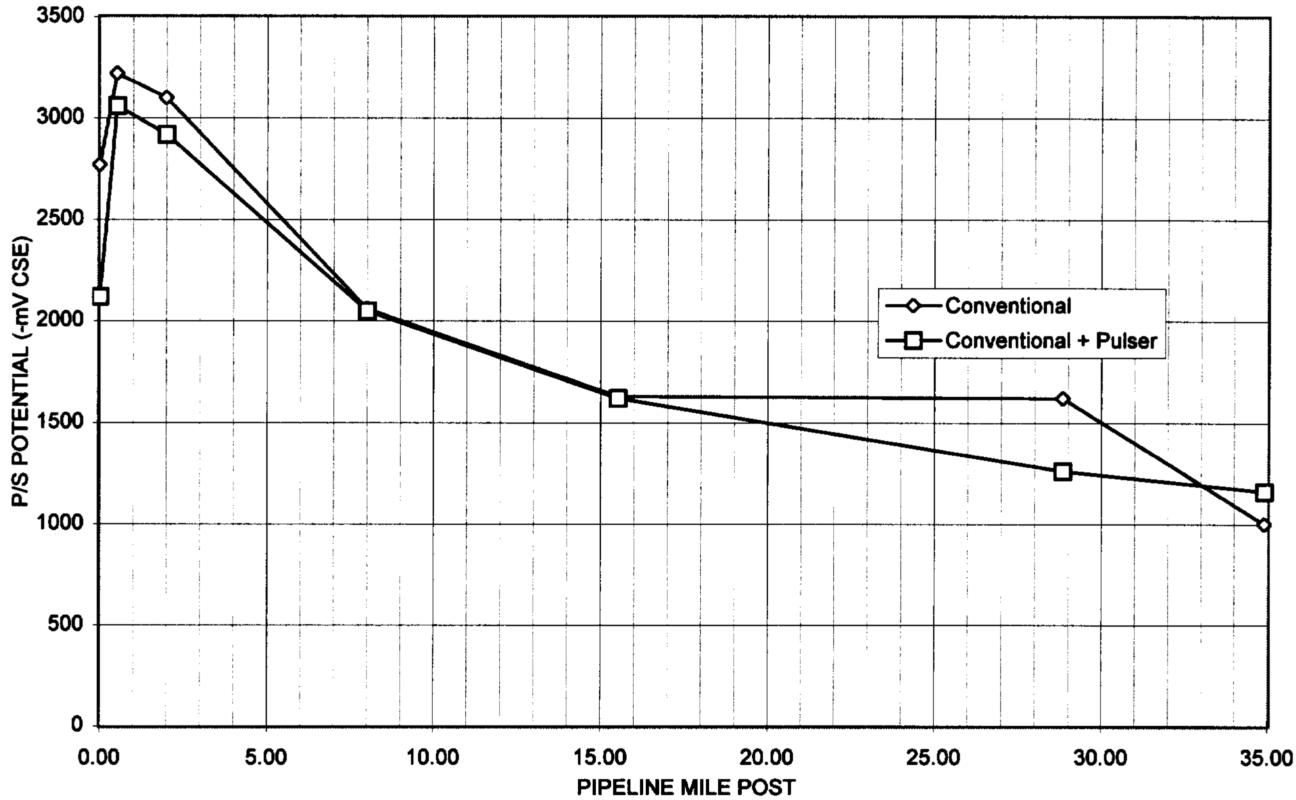

FIGURE 4 - Polarization Potential Survey

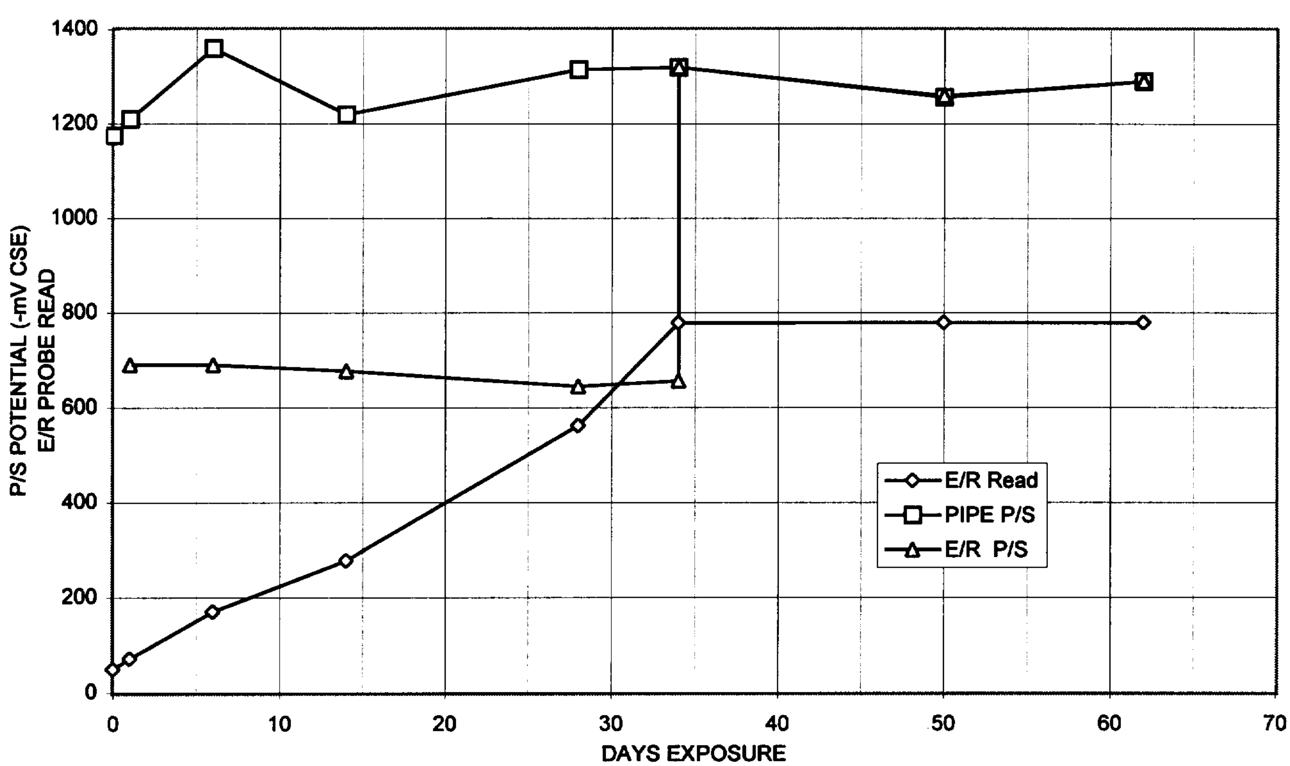

FIGURE 5 - E/R Probe and Pipeline Polarization at Mile Post 28.84

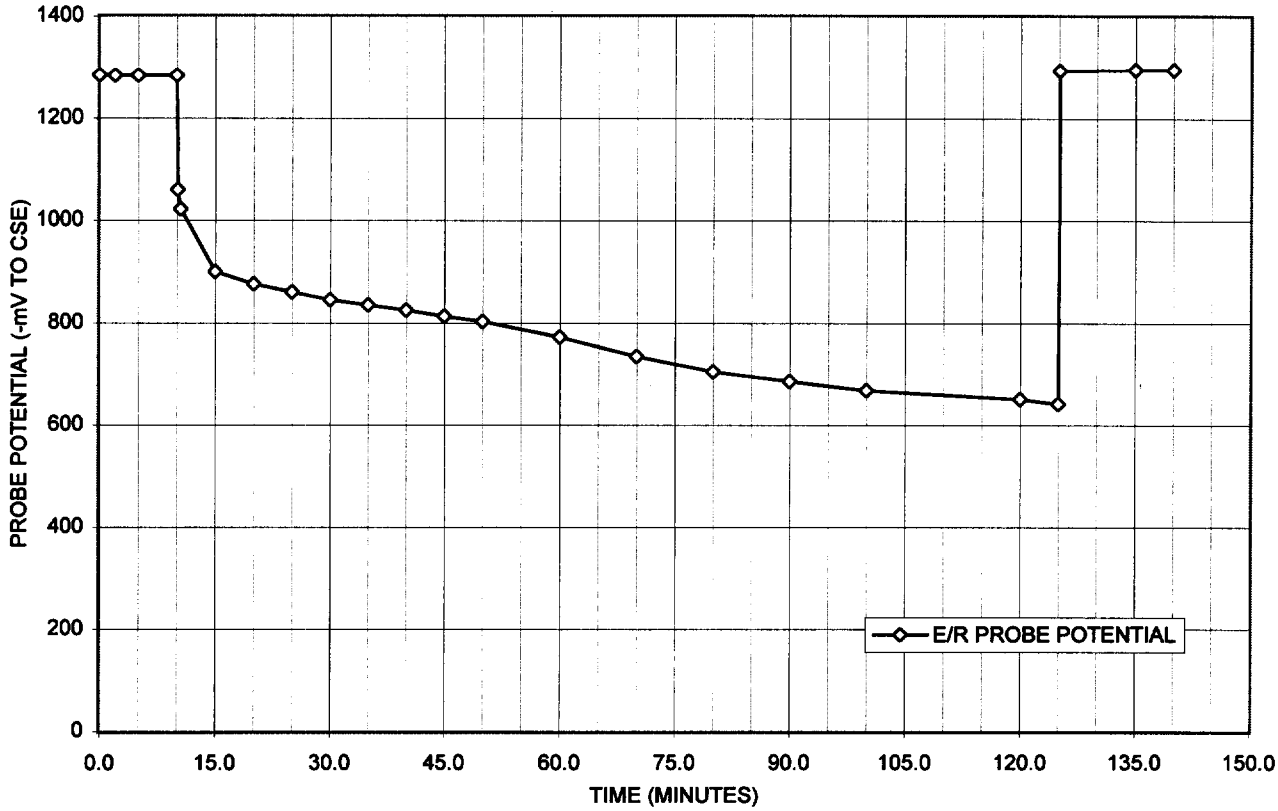

FIGURE 6 - E/R Probe Depolarization at Mile Post 28.84