Cathodic Protection Problems for Gas Pipelines South of Isfahan, Iran

A. AGHAJANI AND M. SHIRANI, *Subsea R&D Center, Isfahan University of Technology, Isfahan, Iran*
A. SAATCHI, *Department of Materials Engineering, Isfahan University of Technology, Isfahan, Iran*

Isfahan is one of the largest cities in Iran. In the southern portion of the city, there were some problems with the cathodic protection (CP) of coated gas pipelines buried in soil. The CP levels decreased as the distance from the CP stations increased. Adding new CP stations, repairing anode beds, and applying more CP current produced no significant improvement. During investigations, it was found that the CP designers had not considered factors such as soil resistivity, electrical isolation, and proximity of foreign structures. The design considered only groundbed resistance, and the result was poor distribution of protective current.

The Zayanderood River divides Isfahan, Iran into north and south portions. The northern portions and both sides of the river are relatively flat plains, but the area toward the south is mainly mountainous. There was no problem with cathodic protection (CP) for the buried gas pipelines in the area north of the river, but pipe-to-soil potentials indicated ineffective CP at many locations south of the city. Pipelines in some southern areas were under–protected, while piping near groundbeds had very large negative CP potentials.

Table 1 shows "on" and "off" drain potentials at CP groundbeds. These estimated groundbed resistances to earth were between 1.2 to 2.46 Ω, which would be considered suitably low. Because the potentials between the pipe and anodes with the rectifiers turned off were not considered, these resistances are approximate; however, these values are adequate for determining the suitability of the installations.

According to Table 1, the groundbed resistances for different CP stations were low enough to provide adequate CP current. However, at distances as small as ~400 m from the groundbeds, CP potentials were not sufficient to indicate effective protection. Table 2 shows CP "on" potentials within a radius of ~400 m from the groundbed of CP station No. 1, which provided a –2.05 V "on" potential vs. a copper/copper sulfate ($Cu/CuSO_4$) reference electrode (CSE) at the groundbed location. Only a short distance from the groundbed, however, potentials were –0.84 to –0.68 V. The rapid decay in CP potentials stabilized as the distance from the groundbed exceeded 400 m.

Figure 1 shows a profile of CP "on" potentials vs. distance from the groundbed of CP station No. 2. At distances ≳400 m from the groundbed, the CP potential was ~ –0.7 V vs. CSE, with no significant local potential change. This suggested that the gas pipeline had a good-quality coating. Excavations at selected locations confirmed the coating condition was generally good with good adhesion to the metal substrate.

CP station No. 2 was switched off and the CP potentials were measured. The CP

TABLE 1. TYPICAL CONDITION OF SOME CP STATIONS IN THE SOUTHERN REGION OF ISFAHAN					
CP Station (No.)	Rectifier Output "On" Potential (V)	Rectifier Output Current (A)	Drain "On" Potential vs. $Cu/CuSO_4$ (V)	Drain "Off" Potential vs. $Cu/CuSO_4$ (V)	Approximate Anode Bed Resistance (Ω)
1	8	4	–2.05	–1.02	2
2	18.5	7.8	–2.05	–1.00	2.46
3	14	9	–1.45	–0.80	1.55
4	3	2.5	–1.45	–0.83	1.2

TABLE 2. CP "ON" POTENTIAL VS. CSE IN DIFFERENT LOCATIONS WITHIN A RADIUS OF ~400 m FROM THE GROUNDBED OF CP STATION NO. 1

Location	"On" Potential (V)
1	–0.84
2	–0.72
3	–0.87
4	–0.85
5	–0.95
6	–0.73
7	–0.75
8	–0.70
9	–0.68
10	–0.76

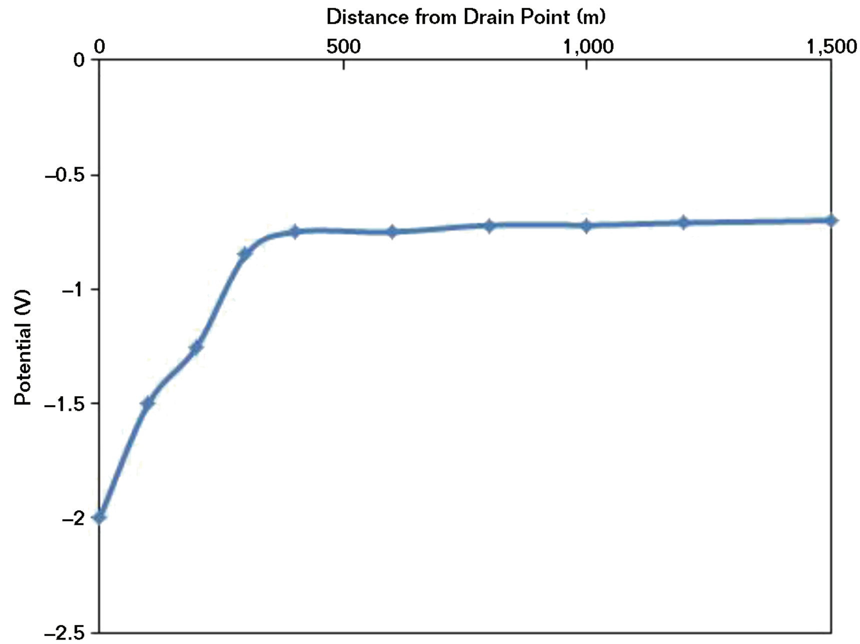

FIGURE 1 A severe drop in potential is seen at a short distance from the drain point of CP station No. 2 (potentials measured vs. CSE).

potentials closest to the groundbed changed considerably, but there was little change in CP potentials at farther distances. Those values were similar to the free potentials of the gas pipelines. On average, "off" potentials were ~ –0.67 V vs. CSE, therefore the gas pipelines in the vicinity of CP station No. 2 appeared to receive CP current from neighboring CP stations. When maps of the buried gas pipelines were reviewed, it was found that isolation devices were not used to electrically separate the gas pipelines in different soil resistivity conditions that existed north and south of the river (Figure 2). Soils north and south of the river are mainly clay and mountainous, respectively.

In the next step of the investigation, soil resistivity was measured at various

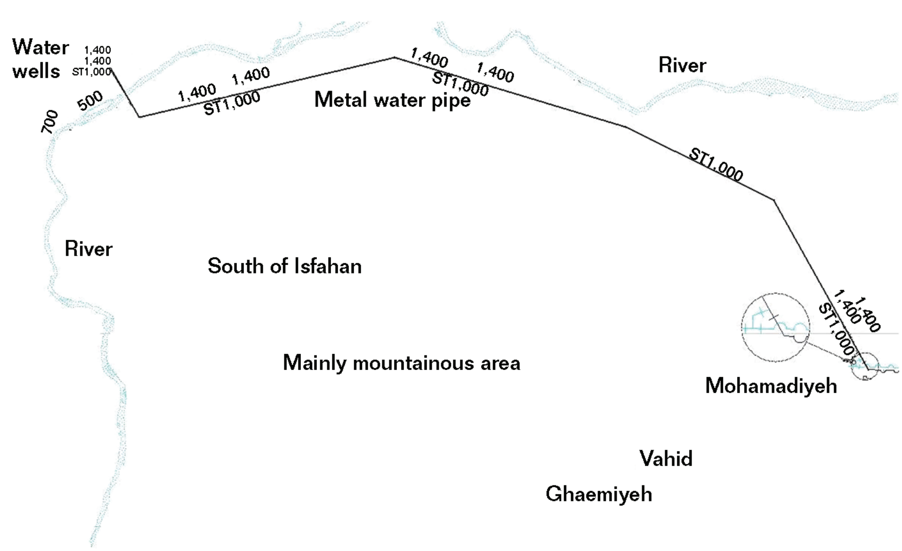

FIGURE 2 A metal water pipeline is located south of Isfahan.

TABLE 3. SOIL RESISTIVITY AT GROUNDBED LOCATIONS FOR CP STATIONS SOUTH OF ISFAHAN

Location CP Station No.	Resistivity (Ω-m)
1	4,872
2	4,873
3	6,020
4	2,424
4	6,028
5	3,390
6	3,026
7	2,826
8	1,193
9	1,168
10	1,800
11	8,289
12	7,913
13	7,913
14	1,959
15	1,695

locations and maps of other foreign metal structures buried in the area were verified. Soil resistivities in the vicinities of CP station groundbeds were measured using the Wenner four-pin method. According to Table 3, soil resistivity values varied considerably.

In addition, as shown in Figure 2, there is one major metal water pipeline south of Isfahan that transfers drinking water. Other water pipelines are made of a special glass fiber and concrete. The metal water pipeline was protected by a coating but did not have a CP system. Nonmetal water pipelines had no influence on CP of the gas pipelines; therefore, they are not shown in Figure 2.

Potentials for the metal water pipeline were measured. In most locations, these were about the same level as the free potential of iron in soil, but several locations were found with potentials more negative or more positive than this free potential, including −1.20, −1.52, −0.12, and +0.14 V vs. CSE.

Discussion

Adding new supplemental CP stations didn't solve the CP potential problem for the gas pipelines. According to the field tests and investigations, factors contributing to this problem included the following:

- Lack of isolation devices
- Foreign metal water pipeline
- Severe differences in soil resistivity

When the soil resistivity varies greatly, the CP design should account for this by sectionalizing the pipeline with isolation devices and/or by appropriate placement of CP stations to provide the necessary current distribution.[1-4] Unfortunately, in the CP design for the gas pipelines of Isfahan, only the reduction of groundbed resistance was considered.

Other important factors, such as soil resistivity and effects of foreign structures, were overlooked. For this reason, the CP stations had low-resistance groundbeds; but protective current had little effect on CP potentials of the portions of pipelines that were located beyond ~400 m from the groundbeds. Consequently, CP current followed paths with low resistivity and did not provide adequate protection outside the immediate vicinity of most groundbeds. Buried foreign metal structures can act as very low resistance paths.[1-2] Therefore, the metal water pipeline south of Isfahan provided another path for conducting CP current to unknown and unintended soil areas with low resistances, thereby contributing to the CP potential problem.

Conclusions

Lack of attention to soil resistivity, foreign structures, and the need for isolation devices in the CP design were primary factors in the CP problems for the gas pipelines south of Isfahan. Therefore, the most practical solution was to redesign the CP system based on the fundamental principles of CP.

References

1 A. Saatchi, A. Aghajani, "Interference Problems in Cathodic Protection of Complex Installation," *MP* 44, 12 (2005): p. 22.

2 A. Aghajani, A. Saatchi, "Correcting Nonuniform CP Potential Distribution and Interference Problems in a Gas Compressor Station," *MP* 53, 4 (2014): p. 24.

3 R. Winston Revie, ed., *Uhlig's Corrosion Handbook,* 3rd ed. (Hoboken, NJ: John Wiley & Sons, Ltd., 2011).

4 J.H. Morgan, *Cathodic Protection: Its Theory and Practice in the Prevention of Corrosion* (New York, NY: Macmillan, 1960).

A. Aghajani bio

A. Saatchi bio

M. Shirani bio