CASE HISTORY

Cathodic Protection for a New Ductile Iron Water Transmission Main

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In recent years, the corrosion of ductile cast iron pipe (DIP) has gained wider publicity in the water utility industry. The water industry, corrosion engineers, and pipe manufacturers often disagree about the most appropriate corrosion control measures for DIP. This article presents a case history of the application of cathodic protection (CP) to improve the performance of a poly-wrapped DIP water transmission main. The annual cost of the CP is only 0.325% of the total construction cost of the main. The CP can extend the life of the main at a much lower cost than pipe repairs, main replacement, or service disruption.

In recent years, the corrosion of ductile cast iron pipe (DIP) used to construct water transmission and distribution systems has gained wider publicity in the water utility industry.[1] The water industry, corrosion engineers, and pipe manufacturers often disagree, however, when discussing the most appropriate corrosion control measures for this pipe material.[2-5]

A recent study by the U.S. Federal Highway Administration and NACE International concluded that the external corrosion of water mains can be effectively mitigated by the application of coatings and cathodic protection (CP).[6] When confronted with aggressive soil environments for new ductile iron water mains, many civil engineers will specify that the pipe be encased with loose polyethylene (PE) wrapping (poly wrap) according to ANSI/AWWA standards.[7] The Ductile Iron Pipe Research Association (DIPRA) will no longer honor a warranty for DIP with any exterior dielectric coating other than poly wrap.[8]

Many corrosion engineers consider poly wrap to be an ineffective means of corrosion protection on DIP.[9-11] Therefore, this article presents a case history showing how applying CP can improve the effectiveness of PE encasement and extend the service life of a new DIP water transmission main.

Background

In 2002, the Des Moines, Iowa, Water Works (DMWW) planned to expand its water distribution system by constructing a new transmission main called the East Feeder Main (EFM). The EFM would provide the primary water supply to a new 540 MW combined-cycle power plant owned by the MidAmerican Energy Co. and known as the Greater Des Moines Energy Center. The transmission main would also serve a proposed agricultural-industrial park located in the southeast part of the city of Des Moines. The EFM would have a capacity of 6,500 gpm to meet domestic and industrial flow demands while providing fire flow capacity in excess of 3,000 gpm.

The general site for the EFM project was within the Des Moines River valley. The Des Moines River served as a major outwash stream for the large volumes of water that flowed from the ice margins of the numerous glaciers that advanced into and retreated from central Iowa between 9,500 and 20,000 years ago. These outwash streams carried and deposited large amounts of sand and gravel into the river valley. This material was encountered throughout the entire project and was used as the bedding and backfill material for the transmission main.

Corrosion Control Requirements for Several Pipe Options

The route that was selected for the EFM project required ~9,300 ft (2,835 m) of 30-in. (762-mm) transmission main and 4,500 ft (1,327 m) of 24-in. (607-mm) transmission main. To estimate the CP requirements for the proposed transmission main, predesign drawings that described the proposed water main's overall routing plan and profile were reviewed. Since DMWW intended to allow all contractors to bid factory-coated steel pipe (AWWA C200), prestressed concrete cylinder pipe (AWWA C301), and poly-wrapped (8-mil [203 μm] thickness) Pressure Class 200 DIP (AWWA C151), the three pipe material options were evaluated for their corrosion control requirements. DMWW specified the following requirements for corrosion control in the bid solicitation:

- Steel pipe—bond pipe joints and install sacrificial anodes/test stations.
- Prestressed concrete cylinder pipe—bond pipe joints and install monitoring test stations.
- Ductile iron pipe—bond pipe joints and install sacrificial anodes/test stations.

Prior to bidding, DMWW estimated the corrosion control material costs for each pipe option. Since DMWW would furnish these materials directly to the job site, the contractors' bids would include only the installation of the corrosion protection systems. Once DMWW received the contractors' bid prices to furnish and install the water main, the corrosion protection prices were added to contractors' pipe bids, and total installation prices were calculated for each pipe option for each bidder. Ultimately, the low bidder for the work was awarded a contract that used poly-wrapped DIP for the water-main construction.

FIGURE 1

Damaged PE wrapping.

FIGURE 2

Connecting cable bonds using exothermic welding.

FIGURE 3

Flange isolation at tie-in to existing water main.

FIGURE 4

Electrical isolation in casing sleeve at road crossing.

Cathodic Protection Design

In-situ soil resistivity data were obtained from the ground surface to depths of 5, 10, 15, and 20 ft (0.3, 3.05, 4.6, and 6.1 m) at 1,000-ft (305-m) intervals along the proposed route of the main. The average soil resistivity data between the surface and 10 ft (3.05 m) (approximate pipeline depth) is 5,100 Ω-cm to the north and west away from the Des Moines River. The average soil resistivity data is considerably lower at ~2,100 Ω-cm (more conductive) near the river; this is likely a direct result of the river bottom deposits and agricultural fields that are present in this area.

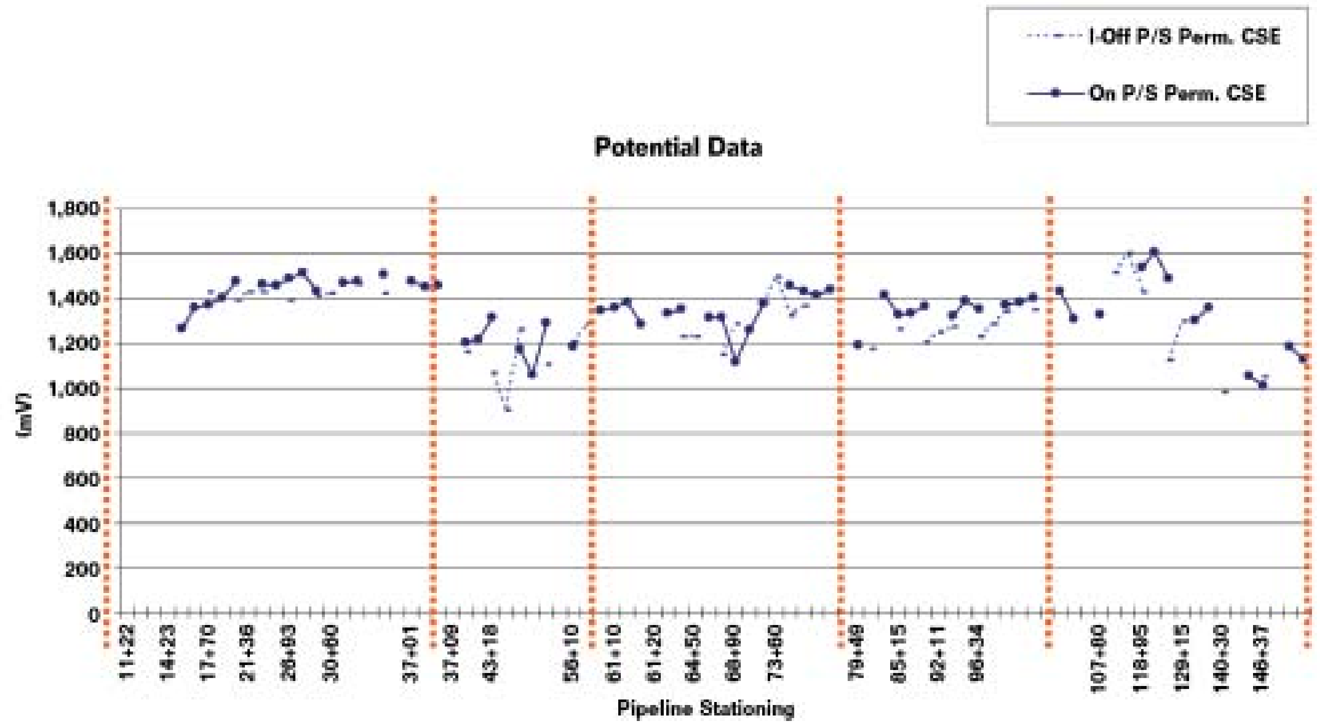
Based upon actual experience, the integrity of field-installed poly wrap is often compromised by the realities of construction techniques used to install DIP (Figure 1). Therefore, a very conservative value of 5% bare was used to estimate the field damage to the poly wrap after the water main was installed.

With the aforementioned considerations, the total number of anodes was calculated using an applied current density (CD) of 2 mA/ft^2 (21.5 mA/m^2) to the pipeline. An average value of 3,000 Ω-cm was used to calculate the expected current output and to deliver a projected 25-year design life from a 48-lb (22-kg) high-potential magnesium anode.

The CP system for the DIP bid option is summarized as follows:

- All mechanical or push-on pipe joints were double bonded with #2 AWG insulated copper cables connected to the pipe by exothermic welds (Figure 2).
- Seven to 10 prepackaged 48-lb (22-kg) high-potential magnesium anodes were installed vertically at 10- to 15-ft (3.05 to 4.6-m) spacing in multiple groups parallel to the pipeline. Each anode group was spaced at ~200-ft (~61-m) centers along the pipeline route with each anode connected to a #8 copper header cable using a mechanical splice and sealed in a rubber-vinyl tape splice.
- The #8 anode header cable runs to a post-mounted test station. Inside the

FIGURE 5



The potential data indicated that the CP system is effective in raising the P/S potentials to –0.850 V.

test station, a 0.01-Ω calibrated shunt resistor is connected in series between the anode header cable and a #8 cable that connects to the water main.

• Two #12 AWG insulated test wires and buried copper/copper sulfate (Cu/$CuSO_4$) reference electrode (CSE) lead wire are run to each test station terminal board for recording the pipe-to-soil (P/S) potential of the water main.

• The main is electrically separated via wax-coated buried flange isolation (FI) at all connections to existing watermains (Figure 3). The main is also segmented into five discrete pipeline sections via FI installed on butterfly valves.

• At buried FI and at electrically isolated metallic casing sleeves (Figure 4), two #12 wires run separately into the test station terminal board for recording the P/S potential and electrical isolation of these foreign metallic structures.

Since the construction schedule had a fixed completion date, the contractor was permitted to install the anodes after the water main was in service. Each bidder was permitted to submit unit installation prices for each anode group and a test station. Should the CP system require supplemental anode groups (because of unexpected field damage to the poly wrapping), unit prices were requested from all bidders for additional anode installations.

Results

CP levels were measured at each test station relative to a buried CSE and to a portable CSE placed into the soil above the pipeline. By temporarily disconnecting the anode cable at each test station, local interrupted instant-off potentials were recorded. True polarized potential data could not be measured, since not all sacrificial anodes could be interrupted simultaneously. The data (Figure 5) indicate that the CP system is effective in raising the P/S potentials to –0.850 V. These data represent the potential of the exposed metal surface at the defects in the poly wrap, but do not represent the actual potentials at the pipe surface underneath any gaps that occurred in the poly wrap.

Using the summation of the current outputs from each anode group as an estimate of the actual effectiveness of the loose poly wrap on the pipe, the results are as follows:

• Total anodic current = 6,530 mA

• Total surface area of pipe = 101,400 ft^2 (9,420 m^2)

• Uniformly applied CD = 65 µA/ft^2 (700 µA/m^2)

This empirically calculated CD is consistent with other data collected on poly-wrapped DIP in controlled research studies that have demonstrated a significant reduction in the corrosion rate of the pipe using CP.[12]

Economic Analysis of Applying Cathodic Protection

The initial cost for installing corrosion control measures on a new large-diameter water transmission main is almost always warranted because of the reduction in maintenance costs that can be achieved over the life of the piping system. In this case, a CP system was furnished and installed for the EFM at a cost of ~$125,000. In comparison, the total cost to construct the EFM was $1,543,000. Thus, the total initial cost of the CP system is only about 8% of the total construction cost of the main. When expressed over the 25-year life expectancy of the CP system, however, the annual cost of the CP system drops to only 0.325%. These calculations, even though oversimplified, indicate that the CP system will extend the life of the water transmission main by at least 25 years at a cost that is much lower than pipe repairs, main replacement, or the potentially more significant (but incalculable) indirect costs that could occur as a result of a service disruption to the power plant.

Monitoring and Maintenance Requirements

Since sacrificial anodes are entirely passive, there is no rigorous CP monitoring other than to measure P/S potentials at all test stations on an annual basis. This action will also confirm that the test stations remain intact and all wiring connections remain effective, and will document that all flange isolation continues to function properly. A close-interval potential survey should be conducted over the entire length of the transmission main every 3 years to verify the actual P/S potentials at all points between test stations.

References

1. B.J. Rajani, Y. Kliener, "Protecting Ductile Iron Water Mains: What Protection Method Works Best for What Soil Condition?" J. Am. Water Works Assoc. (2003).

2. R.W. Bonds, A. Horton, G. Oliver, L. Barnard, "Corrosion Control Statistical Analysis of Iron Pipe," MP 44, 1 (2005).

3. B. Spickelmire, "Corrosion Considerations for Ductile Iron Pipes," MP 44, 7 (2002).

4. D.A. Dechant, G. Smith, "Present Levels of Corrosion Protection on Ferrous Water Piping in Municipal Infrastructure: A Manufacturer's Perspective," MP 43, 1 (2004).

5. "Deteriorating Buried Infrastructure, Management Challenges and Strategies" (American Water Works Service Co. Inc., 2002).

6. G.H. Koch, M.P.H. Brongers, N.G. Thompson, Y.P. Virmani, J.H. Payer, "Corrosion Costs and Preventive Strategies in the United States," U.S. Federal Highway Administration Report, FHWA-RD-01-156, March 2002.

7. AWWA, Manual of Water Supply Practices M41, Ductile Iron Pipe and Fittings (Denver, CO: AWWA, 1996).

8. V&A Consulting Engineers, "Assessing DIPRA's New Corrosion Protection Standards," Infrastructure Preservation News (2003).

9. M.J. Szeliga, D. Simpson, "Corrosion of Ductile Iron Pipe: Case Histories," MP 40, 7 (2001).

10. M.J. Szeliga, D. Simpson, "Evaluating Ductile Iron Pipe Corrosion," MP 42, 7 (2003).

11. K.C. Garrity, C. Jenkins, R. Corbett, "Corrosion Control Considerations for a New Water Well Line," CORROSION/89, paper no. 408 (Houston, TX: NACE International, 1989).

12. D.H. Kroon, D. Lindemuth, S. Sampson, T. Vincenzo, "Corrosion Protection of Ductile Iron Pipe," MP 44, 1 (2005).

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