A Sacrificial Anode Retrofit Program for Existing Cast Iron Distribution Water Mains

Jeff Schramuk, *NACE Cathodic Protection Specialist*
Danny J. Klopfer, *Des Moines Water Works*

Water utilities face significant costs from the deterioration of their water distribution systems. For more than a decade, Canadian water utilities have been using an innovative installation technique for retrofitting cathodic protection anodes to existing water mains. In 2003, a similar sacrificial anode retrofit program was undertaken in a U.S. city to reduce its main breaks and extend the life of its system. The results of a 2003-2004 pilot program show that a 20-year life extension can be achieved at less than 10% of the replacement cost of the piping.

In 2001, the U.S. Department of Transportation's Federal Highway Administration (FHWA) and NACE International released a report[1] of a study that investigated the annual costs of corrosion in the U.S. The report indicated that the annual direct cost of corrosion for drinking water systems is roughly $23 billion. The figure includes the costs for replacing aging water piping and lost water from leakage, as well as corrosion control measures. The FHWA report concludes that external corrosion of water mains can be effectively mitigated by the application of coatings and cathodic protection (CP).

More recently, the American Society of Civil Engineers (ASCE) released its annual assessment[2] on the state of the nation's infrastructure for year 2005. The report states that the U.S. faces a serious shortfall of $11 billion per year to replace aging water infrastructure. Federal funding will provide <10% of the total national requirement for fiscal year 2005, however, with no increases in funding planned for fiscal year 2006.

Water utilities face a significant economic burden created by the deterioration of their water distribution systems.[3-6] The failure to manage the consequences of an aging water infrastructure causes product and economic losses as well as increased public health risks. With the economics clearly defined and the technological means in place to mitigate the problem, this article presents an example of how applying CP can extend the life of an existing water distribution main system at a significantly lower cost than pipe replacement.

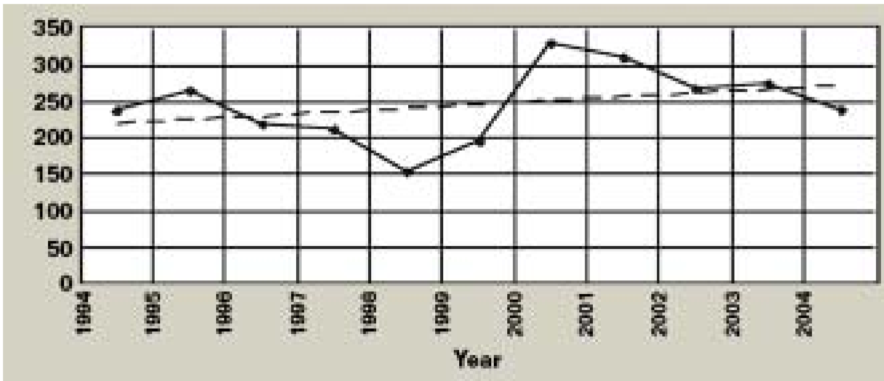
Background

The Des Moines (Iowa) Water Works (DMWW) currently is responsible for maintaining 1,013 miles (1,630 km) of water distribution piping. Current water main break rates are now at ~27 breaks per 100 miles (161 km) of pipe. The trend in main breaks from 1988 to the present time has shown a steady increase in failure rates (Figure 1). Most of the water main breaks in the distribution system are either directly or indirectly related to corrosion, excluding third-party excavation damage to the pipe.

While several Canadian water utilities have been using an innovative installation technique over the past decade for retrofitting CP anodes to existing water mains,[7-9] the technical literature does not show any recent installations in the U.S.

Based on the Canadian work, the DMWW implemented a pilot study to see if an in situ sacrificial anode retrofit program (ARP) could reduce their main breaks and extend the life of their system. In June 2003, several areas within the city were selected for the initial ARP. These areas generally had the highest annual main break rate per mile of pipe. The water main data were reviewed, evaluated for constructability, and prioritized for the pilot study.

FIGURE 1



Total main breaks per year.

FIGURE 2

Steel stud arc welded to the top of the pipe.

Cathodic Protection Anode Installation Technique

The anode borehole is initiated by a backhoe-augur that drills through the pavement or surface soils down to ~12 in. (0.3 m) above the pipe. To avoid damage to the buried waterline, the method then utilizes vacuum extraction equipment to remove the remaining soil in the hole down to the top of the buried pipe. Once the top of the pipe is exposed and cleaned, a carbon steel stud is arc-welded to the top of the pipe (Figure 2). The arc welder is run from a portable field generator.

A special insulated extension tool was fabricated to allow the welder to reach to the top of the pipe and contact the pipe surface. The stud is silver-soldered to each anode's #12 AWG lead wire, and the stud fits snugly into a tapered copper sleeve in the end of the extension tool (Figure 3). The extension tool is connected to the welder's trigger handle by high-capacity insulated cables. A steel rebar is used to make the ground connection between the pipe and the welder, also using an insulated cable. When electrical continuity is verified between the stud and the rebar ground, the operator initiates the welder by pushing a button in the trigger handle.

After the stud weld is verified to be secure, the prepackaged sacrificial anode is lowered down into the hole (Figure 4). To achieve the greatest life, a 32-lb (14.55-kg) high-potential magnesium anode was specified for all installations. A 6- to 12-in. (152- to 305-mm) layer of sand/limestone fines is poured into the hole over the weld to ensure that the anode does not rest directly upon the stud. Although the paperboard anode canister is filled with a low-resistance, hygroscopic material, ~5 gal (19 L) of water is poured into the hole to ensure maximum anode current flow to the pipe (Figure 5). Compacted native soil fills the balance of the hole. Pavement restoration or turf replacements complete the installation.

During the anode installations, a #12 AWG test wire was attached at a minimum of two locations on each of the water main segments. The test wire will be used to verify electrical continuity of the main instead of probing the pipe or contacting it through the valve boxes. These test points will also provide contact to the pipe for an over-the-line pipe-to-soil (P/S) potential survey after the anode installations are complete. The test wires are contained in marked cast iron valve boxes to facilitate future accessibility.

This method of applying CP assumes that a degree of electrical continuity exists throughout the piping. Although most mechanically coupled pipe joints will have high resistance (discontinuous) joints after being buried for several years, our testing showed that several sections of water main were indeed electrically continuous over several city blocks. This phenomenon is likely attributed to the interconnections between the uninsulated copper water services and the homeowners' alternating

FIGURE 3

Stud fits in the end of the extension tool.

FIGURE 4

Prepackaged sacrificial anode is lowered down into the hole.

current power system grounds to these water lines. While these interconnections have enhanced the electrical continuity of the piping, they also drain some of the sacrificial anodes' current from the largely bare water mains. Additionally, some older water mains were installed with leaded joints that we would expect to be electrically continuous.

Description of Structures Selected for the Pilot Study

MUSKOGEE—SW 63RD TO SW 59TH

The 8-in. (200-mm) water main was installed in 1949. The pipe is spun cast iron and ~1,267 ft (386 m) in length. The soil was black and silty with traces of clay. Anodes were spaced ~60 ft (18 m) apart. Twenty of 21 anodes were connected to the pipe utilizing the stud-weld technique. To complete the remaining connection, the pipe was excavated and the anode wire was attached directly to the pipe utilizing a prefabricated stainless steel (SS) band clamp. Table 1 summarizes the costs for this installation.

3RD ST.—LAUREL TO UNIVERSITY

The 8-in. water main was installed on 3rd St. in 1963. The pipe is spun cast iron and ~957 ft (292 m) in length. The soil was a sandy clay consistency. The 18 anodes were spaced at an average of 53 ft (16 m) apart. Sixteen of 18 anodes were connected to the pipe utilizing the stud-weld technique. To complete the remaining two connections, the pipe was excavated and the anode wires were attached directly to the pipe utilizing prefabricated SS band clamps. Table 1 summarizes the costs for this installation.

8TH ST.—EUCLID TO BOSTON

The 12-in. water main was installed on 8th St. in 1920. The pipe is pit cast iron and ~1,405 ft (428 m) in length. The soil was black and silty with traces of clay. The 28 anodes were spaced at an average distance of 50 ft (15 m) apart. Seven anodes were connected to the pipe utilizing the stud-weld technique. Thirteen connections were made by excavating the pipe and attaching the anode wires directly to the pipe utilizing prefabricated SS band clamps. The remaining eight anodes were installed by connecting a wire from one anode to another. Table 1 summarizes the costs for this installation.

Results

Data from several Canadian water utilities[10-11] have shown that ~100 mV of current-applied potential shift from the baseline (prior to CP) readings will significantly reduce the rate of corrosion on existing water mains. This practice is consistent with industry experience that the first increment of CP is the most effective in mitigating the corrosion on buried ferrous structures. Information obtained from large-scale installations in Canada indicates that after a relatively short transition period, the main breaks decreased by 90 to 95% for the life of the protection system.[12]

Using a wire reel, current-applied potentials were measured relative to a portable copper/copper sulfate (Cu/$CuSO_4$) electrode placed at regular intervals along the water mains. Anode current outputs and instant-off potential readings (indicating the degree of polarization) could not be measured because the sacrificial anodes could be disconnected from the pipeline. Because of the low soil resistivities, we were able to accommodate the IR contribution in the potential measurements by approximating "remote earth" at the ends of the pipe segments, however.

The potential profiles for Muskogee and 8th St. indicated a shift of more than 100 mV, with the exception of one location on Muskogee, which occurred in an area where the pipe was believed to be electrically discontinuous. No potential measurements were made on Third St. prior to the anode installations; however, the current-applied potentials of 1,000 mV indicate the sacrificial anodes are significantly raising the water main's potentials along this section of the main.

FIGURE 5

Anode is backfilled with limestone fines, native soil, and water.

Economic Analysis—Cathodic Protection vs Main Replacement

CP anodes were installed on ~3,630 ft (1,100 m) of pipe at a cost of $33,500. The replacement cost for this portion of the 8- and 12-in. water mains would have been more than $360,000. Assuming that the life expectancy of a new water main would be 100 years and the life expectancy of the CP system to be 20 years, the savings are $38,500 ($360,000/100 × 20 – $33,500). These calculations, even though oversimplified and conservative, indicate that these methods will permit a 20-year life extension at <10% of the replacement cost of the piping. The ARP is therefore a viable alternative to main replacement and should effectively lower the number of customer outages, while minimizing increases in the distribution system's operating costs.

Economic Analysis—Cathodic Protection vs Repairing Main Breaks

Since the funding for all needed pipe replacement may not be available, a second approach is presented that ignores the fact that the pipe has reached its life expectancy and needs to be replaced. In this case, we compare the cost of installation to the ongoing cost of main break repairs, which would be reduced through CP installation. Main break records indicate that 15 main breaks on these pipes are expected during the next 5 years. Ignoring the fact that without corrosion control, the break rate will increase, 60 main breaks are anticipated on these pipes during the next 20 years.

CP anodes were installed on ~3,630 ft of pipe at a cost of $33,500. We used a conservative CP life estimate of 20 years and also estimated that sacrificial anodes would lower the number of main breaks by 90% (compared to 95% in the Canadian studies). To this we add the cost of the 10% of main corrosion that CP would not stop (10% of $229,200 = $22,900).

TABLE 1

SUMMARY OF INSTALLATION COSTS

Section Name	Cost per Anode	Cost per Foot Pipe
Muskogee	$372.34	$6.17
3rd St.	$488.11	$9.18
8th St.	$602.57	$12.01
Totals	$499.66	$9.22

Adding the annual in-house cathodic anode system testing of ~$500 per year for 20 years gives another $10,000. Adding these costs ($33,500 + $22,900 + $10,000) gives a total of $66,400. We further estimated that there would be three main breaks per year at $3,820 per break for 20 years. This yielded a cost of $3,820 × 3 × 20 years equals $229,200. Thus, using an ARP creates a net savings of ~$160,000 over waiting for the pipe to fail and repairing it as it fails.

Future Considerations

When considering whether to implement an ARP program, a water utility should base its decision criteria upon the following prioritization factors:

- Number of main breaks per mile of pipe per year

- Cost of main break repairs
- Installation costs
- Soil conditions
- Pipe characteristics
- Condition of pipe
- Future construction activities planned in the same area

In addition to these factors, annual P/S potential maintenance surveys will verify that continued CP is being supplied to the water mains. This will increase the water utility's ability to accurately estimate the life expectancy of its corrosion control anodes.

References

1. G.H. Koch, M.P.H. Brongers, N.G. Thompson, Y.P. Virmani, J.H. Payer, "Corrosion Costs and Preventative Strategies in the United States," Report FHWA-RD-01-156 (Washington, D.C.: FHWA, 2001).

2. "2005 Report Card for America's Infrastructure," American Society of Civil Engineers, March 2005.

3. J.E. Cromwell, H. Reynolds, N. Pearson, M. Grant, "Costs of Infrastructure Failure" (Denver, CO: AwwaRF, 2002).

4. D. Ellison, "Distribution Infrastructure Management: Answers to Common Questions" (Denver, CO: AwwaRF, 2001).

5. K. O'Day, R. Weiss, S. Chiavari, D. Blair, "Water Main Evaluation for Rehabilitation/Replacement" (Denver, CO: AwwaRF and Cincinnati, OH: U.S. EPA, 1986).

6. B. Rajani, J. Makar, S. McDonald, C. Zhan, S. Kuraoka, C. Jen, M. Viens, "Investigation of Gray Cast Iron Water Mains to Develop a Methodology for Estimating Service Life" (Denver, CO: AwwaRF, 2000).

7. D.R. Clemens, "Report: The Status of the Cathodic Protection Program to Prevent Corrosion of Ductile Iron Watermains within the Region of Durham," Durham, Ontario Canada Utilities Commission, January 1998.

8. B.J. Doherty, "Controlling Ductile Iron Water Main Corrosion, A Preventive Maintenance Program," MP 29, 1 (Houston, TX: NACE, 1990).

9. B.M. Green, et al., "In-Situ Cathodic Protection of Existing Ductile Iron Pipes," MP 31, 3 (Houston, TX: NACE, 1992).

10. J.P. Nicolson "Cathodic Protection Program, Water Division, Water Distribution Branch Region's Experience" (Ottawa-Carleton, Ontario: Canada Utilities Commission).

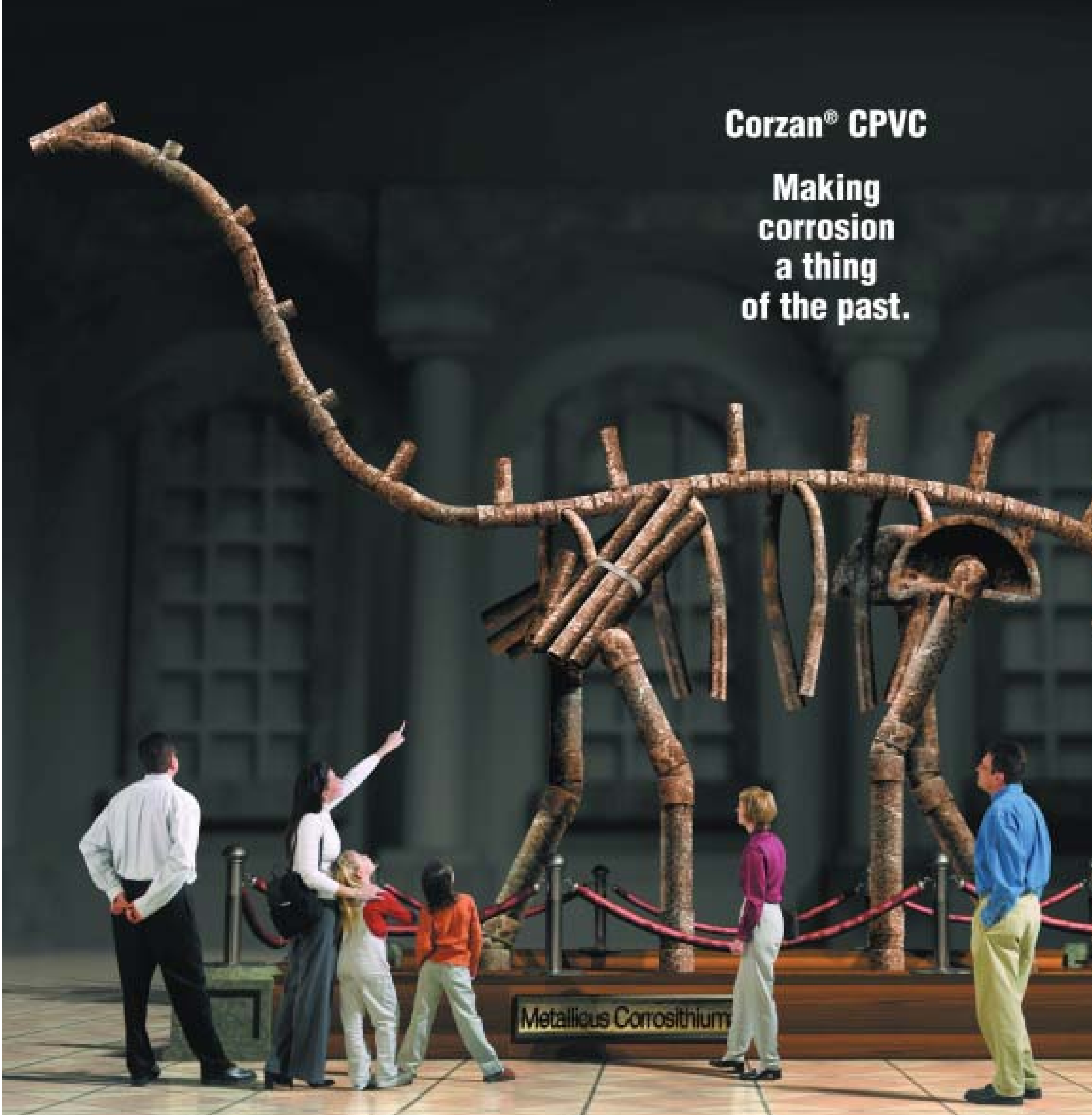
11. D. Raymond, "A Report on the Efficiency of the Cathodic Protection System Installed on the Water Mains in Petersborough" (Petersborough, Ontario: Ontario Utilities Commission, December 1991).

12. Y. Kliener, R. Balvant, "Quantifying the Effectiveness of Cathodic Protection in Water Mains," NACE Northern Area Seminar, held August 2002 (Houston, TX: NACE, 2002).

This article is based on a presentation made at the 96th Annual Conference of the AWWA Illinois Section held March 22-24, 2005, in Springfield, Illinois.

JEFF SCHRAMUK is NACE CP Specialist #7695, 1167 Independence Dr., Bartlett, IL 60103. He has been involved with CP applications for 25 years and currently assists water utility companies in addressing their corrosion problems. A NACE member since 1982, Schramuk also is an active member of AWWA. He has published several technical papers in *MP* and other publications.

DANNY J. KLOPFER is Director of Water Distribution at Des Moines Water Works, 2201 George Flagg Pkwy., Des Moines, IA 50321. He is responsible for the maintenance of more than 1,000 miles (1,609 km) of water distribution piping, installation of service connections, geographic information system and maintenance records, underground location of facilities, and all related pavement repairs. He has a B.S. in civil engineering from the University of Missouri-Rolla, is a registered professional engineer in Iowa and Missouri, and is an active member of AWWA. MP



Just as the dinosaurs were unable to adapt to their changing environments, metal piping systems often can't survive the corrosive demands of industrial use.

Make corrosion a thing of the past by installing pipe and fittings made from high-quality Corzan® CPVC. Backed by more than 40 years of proven CPVC experience in corrosive environments, Corzan™ Industrial Systems signal the end of the metal pipe age and the dawn of a new era of longer service life, lower maintenance costs and reduced downtime.

In today's highly competitive environment, it's a matter of survival of the fittest. Isn't it time you chose the product that has endured the test of time?

For more information on Corzan® CPVC, visit www.corzancpvc.com or call 888-234-2436.

CORZAN™
INDUSTRIAL SYSTEMS