Assessing the Effectiveness of a Water Utility’s Anode Retrofit Program

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In 2004, a water utility implemented a five-year anode retrofit program to reduce the number of water main breaks and extend the service life of its buried water distribution system. Data from 2004 through 2007 show average main break reductions of 50% in the first year after anode installation and >95% thereafter at <15% of the pipe’s repair or replacement cost.

The American Water Works Association (AWWA) began tracking the critical issues that face the water industry in 2004.1 In 2008, the AWWA reports that aging water infrastructure is the most inadequately addressed issue facing the water industry in the United States,2 ranking second only to source water concerns as both a short-(one to three years) and a long-term (three to five years) concern. As municipal water distribution systems are reaching their life expectancies, the need to rehabilitate or replace water distribution mains is increasing. This article describes the results of four years of retrofitting sacrificial anodes to buried cast iron pipe and is a follow-up to an earlier publication3 that demonstrated how retrofitting cathodic protection (CP) anodes can extend the service life of water distribution systems at a cost that is significantly less than either repairing or replacing the pipe.

Background

Both visual and metallurgical examinations indicate that most of the water main breaks in the Des Moines (Iowa) Water Works (DMWW) distribution system can be either directly or indirectly related to corrosion. With 521 mi (838 km) of its 1,000-mi (1,609-km) water distribution system (excluding a 380-mi [611-km] length of rural water piping) having reached its life expectancy, and another 92 mi (148 km) reaching its life expectancy during the next 10 years, the purveyor must budget aggressively for water main replacements.

Over the last 10 years, there has been a steady increase in cast iron water main failure rates (Figure 1). Through 2003 there were ~275 main breaks per year or ~27 breaks per 100 mi (161 km) of pipe per year. Review of the data through the end of 2007 indicates that this number is ~300 main breaks each year, or ~30 breaks per 100 mi per year. For com-
parison, a “reasonable goal” for water system main breaks in North America is 25 to 30 breaks per 100 mi of main per year.  

The number of system failures has been rising, and so has the cost of main breaks. In 2003, the average direct cost per water main break was ~$3,788. By 2007 the average direct cost had increased to $4,478. With the number and costs of water main breaks increasing, coupled with inadequate funding for asset replacement, the utility implemented a five-year anode retrofit program (ARP) in 2004 to reduce the number of water main breaks and extend the service life of its buried cast iron water distribution system.

Site Selection Process

The sites considered for each year’s anode installations were based upon several criteria, including pipe material, pipe age, number of failures on the pipe, condition of the pipe, the ease of installation of the anodes, soil characteristics, traffic disruption, inconvenience to customers, and excavation and restoration costs. Using an objective ranking model, a short list of water main sections to consider for the installation of anodes is created, based upon the annual CP retrofit budget.

Anode Retrofit Program Installation History

The 2004 pilot project originally began with the installation of anodes for 3,629 ft (1,106 m) of existing cast iron pipe. Approximately 957 ft (292 m) of this pipe was subsequently donated to a local hospital expansion project, leaving 2,672 ft (814 m) for the ARP pilot project. The utility performed the entire installation, including vacuum excavation for each anode, attachment of the anode to the pipe via stud arc-welding or pipe clamps, installation of both anodes and test stations, and backfilling the anodes with soil restoration.

With the success of the pilot project, the footage of pipe protected was increased to 9,935 ft (3,028 m) in 2005. Installations were completed mostly on pipe located in the grassy area behind the street curb, except for one site where holes for 14 anodes were core drilled through pavement. Although a subcontractor vacuum-excavated each anode hole, all other work, including core drilling, anode stud-weld connections, test station installation, backfilling with sand, and restoration, was completed by the utility.

The piping retrofit with sacrificial anodes in years 2006 and 2007 was 14,745 ft (4,494 m) and 9,277 ft (2,828 m) respectively. During this period, both vacuum excavation and pavement core drilling were subcontracted while the utility attached the anodes to the pipe utilizing a pin-brazing technique,
completed test station installations, and made site restorations. Anode holes were now routinely backfilled with a flowable cementitious material in lieu of sand or native soil. With this modification to the anode backfill, the City of Des Moines is encouraged by the success of the ARP in reducing main breaks beneath city pavement infrastructure.

Cathodic Protection Technical Evaluation of the Anode Retrofit Program

The selection of a CP criterion to significantly reduce corrosion rates for a bare cast iron water main does not require the same conservative NACE International criteria\(^1\) that are applied to coated steel pipelines that convey hazardous gases or liquids. For example, using data furnished from Canadian water utilities,\(^6,7\) studies show that \(\sim 100 \text{ mV}\) of current-applied pipe-to-soil (P/S) potential shift from the baseline readings will significantly reduce the rate of corrosion on existing water mains. Information obtained from large-scale installations in Canada indicates that after a relatively short transition period,\(^8\) main breaks decreased by 90 to 95\% during the life of the CP system. Each year, P/S data are obtained prior to and following the installation of retrofit anodes. In 2008, follow-up P/S data were measured for the 2004 to 2006 ARP installations (Figure 2). In only a few instances have the potential shifts been less than 100 mV.

The current outputs of the 32# magnesium anodes installed during years 2005 to 2007 indicate mean values of 63, 78, and 61 mA for these respective years. Assuming a constant anode current, the estimated average anode life should be at least 25 years. We will continue to use an anode life expectancy of 20 years for evaluation of the ARP installations, however.

Reduced Number of Broken Water Mains

The five-year average for broken water mains on 36,629 ft (11,165 m) of water mains where anodes were retrofitted from 2004 to 2007 was 19.2 main breaks per year (Figure 3). During the first year after installation of retrofit anodes, the number of main breaks decreased to eight—a 58\% reduction. During the second year, no main breaks were observed following the ARP installations.

Economic Evaluation of the Utility’s 2004-2007 Anode Retrofit Program

Table 1 shows a summary of the retrofit anode installations for years 2004 through 2007 and the costs associated with these installations.

Cost Analysis—Cathodic Protection vs. Water Main Replacement

CP anodes were installed on \(\sim 36,629\) ft (11,165 m) of 6-in (150-mm) through 16-in (410-mm) pipe at a total cost of $573,241. This amount includes both the costs for the anode installation as well as periodic maintenance.

The 2007 replacement cost for all the water mains installed with the ARP would have been more than $3,408,590. Assuming that the life expectancy of a new water main would be 100 years and the life expectancy of the CP system would be 20 years, the ARP vs. replacement...
savings are $108,527. This value is calculated as $(3,408,590/100 \times 20) - 573,241.

Cost Analysis—
Cathodic Protection vs. Water Main Repairs

Since capital budgets may not be available to replace all the water mains, an alternative scenario is presented, which ignores that the pipe has reached its life expectancy and needs to be replaced. In this case, it is insightful to compare the cost of the ARP installations to the ongoing cost of main break repairs, which otherwise could be significantly reduced through CP. The total cost to continue repairing these mains over 20 years would have been $1,855,488. Using a conservative estimate that the life of the anodes would be 20 years and the ARP installation would lower the number of main breaks by at least 95%, there would be a net savings of over $1,282,297 by using an ARP vs. waiting for the pipe to fail and repair it as it fails.

Conclusions and Future Plans

The use of CP to extend the life of the utility’s iron water distribution mains has shown at least a 95% reduction in the number of water main breaks at a cost that is <1.5% of main break repair or replacement costs. Field data suggests that at least a 20-year life extension of the water main is a very realistic expectation.

Over the course of the 2004 to 2007 ARP, the stud welding and pin brazing methods were often ineffective in attaching small-gauge copper wire to older pit (sand) cast iron pipe. The 2005 to 2008 ARP installations were therefore limited to only 1.76 million ft (487,680 m) of spin cast iron pipe out of nearly 3.5 million ft (1.07 million m) of gray cast iron pipe. To increase the number of potential ARP candidate sites, a battery-operated exothermic welding tool (Figure 4) has been successfully tested on pit cast iron pipe, which will significantly increase the population of water mains where CP anodes can be installed. As a result, the DMWW has plans to continue its ARP through year 2013.

References

5. NACE International Standard SP0169, “Control of External Corrosion on Underground or Submerged Metallic Piping Systems” (Houston, TX: NACE, 2002).

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