Making Sure Cathodic Protection Works

by Jeffrey A. Schramuk and Keith Switzer

In 1982, a $3 billion expansion and renovation of Chicago’s O’Hare Airport began. Construction crews soon found that much of the original drainage and wastewater pipe laid in the 1950s had corroded so badly that some literally no longer existed. As the nationwide infrastructure repair and rehabilitation work gets underway, an appalling number of badly corroded water and wastewater pipelines, like those at O’Hare, are being uncovered.

Thinking ahead and faced with the high cost of failure and replacement of water/wastewater system components, industry managers are increasing the emphasis on prevention. A relatively small short-term investment in corrosion protection, for example, nearly always pays for itself in terms of reduced maintenance costs and increased longevity.

Cathodic protection (CP) systems remain the most effective method for preventing corrosion. Consulting engineers are recommending that new and replacement pipes should be installed with CP systems. To ensure permanent electrical integrity, they are taking a closer look at the methods used to make all conductor-to-pipe and related connections.

Properly installed exothermically welded bonds, which are permanent, corrosion-resistant electrical connections, are becoming increasingly common. There are several methods for producing exothermic bonds, but for corrosion prevention duty, it is important to use bonds designed specifically for CP.

What Causes Corrosion?

Corrosion is the destructive attack of a metal (or sometimes other materials) by a chemical or electrochemical reaction with another material in its environment.

The most familiar example can be found in a common dry-cell, or flashlight, battery. It consists of a zinc case, which serves as the anode, and a carbon rod, which serves as the cathode, both in an electrolyte. When an external wire, or circuit, connects anode and cathode, the electrical action that lights the flashlight bulb causes zinc ions to flow through the electrolyte and be exchanged for hydrogen ions that collect on the cathode, causing the zinc anode to corrode.

In underground installations, galvanic reactions usually involve two dissimilar metals, such as two sections of pipe, surrounded by an electrolyte. This can be soil or condensation on the surface of the pipe.

Galvanic reactions can also occur, however, when the same metal is placed in two different electrolytes, for instance when a metal pipe runs through two different kinds of soil (e.g. clay and loam), or is laid on undisturbed soil at the bottom of a trench and then backfilled.

Other conditions that can set up a corrosion reaction in water/wastewater piping systems include:

- joining two different metals, such as a brass fitting to a steel pipe, or copper water service to a steel main (Figure 1)
- connecting old and new steel pipe together (although corrosion usually is not severe unless the new section is small in comparison to the older pipe)
- cinders in backfill that touch a pipe and become a cathode, corroding the pipe or anode
- pipe with some mill scale removed, such as during handling, so that the bare spot becomes an anode to the surrounding area’s cathode

Stray dc electrical current also can be a major contributor to corrosion. Any nearby source of dc power—such as electrified rail transit lines (Figure 2) or electroplating facilities—can exacerbate the situation and needs to be considered in any new pipeline project.

Even concrete pipeline is not immune to corrosion, because it is conductive and contains metallic traces. Especially vulnerable are concrete water and wastewater system pipes with prestressed wire reinforcement. If the prestressing wire, which surrounds the steel and concrete core and gives the pipe its strength, is allowed to corrode, failure can occur with catastrophic results. And because this kind of pipe sometimes is mistakenly thought to be immune to corrosion, it is often installed without any provisions for corrosion protection.

Cathodic Protection Stops Corrosion

Engineers involved with pipeline design, construction and operation have understood for decades that corrosion can be inhibited or stopped entirely if current flow can be reversed to prevent ions being removed from the pipe, prestressing wire, rebar, or other critical material. Two methods for providing this cathodic protection use galvanic and impressed current respectively.

The galvanic method employs a sacrificial anode that has a higher potential on the Galvanic Series of metals than that of the metal being protected. Steel, for instance, which normally would be considered anodic (likely to corrode), is less anodic than magnesium, zinc and aluminum.

If a mass of any of these is located next to steel, the current is reversed and the steel will not corrode.

Because the protection they provide requires these sacrificial anodes to corrode, they should be large enough to provide protection for a minimum of 20 years so as to preclude frequent replacement.

The impressed current system approach uses an external power source with a rectifier to drive a low-voltage dc current through an electrolyte (soil or water) to the pipe’s surface. If this current is of a magnitude greater than and flows in a direction opposite to the natural galvanic cell current, the pipe becomes cathodic and is protected effectively from corrosion. An anode is still required, but it can be made of an inexpensive material, such as scrap iron or graphite.

Because the circuit potential can be controlled at near equilibrium, the anode usually is consumed at a slow rate. For these reasons, an impressed current system is sometimes preferred for water distribution system piping.

Galvanic systems are used in...
more than half of all CP situations. They are less expensive initially and, assuming the sacrificial anodes are large enough to provide a reasonable (20 years) span of protection, they require less maintenance than an impressed-current system.

Many new water piping systems, particularly those that have been coated with bitumastic or coal tar, are protected with sacrificial anodes. In fact, galvanic CP systems provide adequate protection in any application with low current requirements. Impressed current systems are more likely to be used on very long or very large pipelines, or whenever high-resistivity soil or some other factor demands high current levels.

Making Connections

To ensure proper protection, all pipe sections and other metallic structures nearby must be bonded together. The current must have a continuous, low-resistance metallic pathway to prevent leakage from the structure through the surrounding electrolyte. Electrical connections are extremely important.

Even when a pipeline is not going to be cathodically protected immediately after installation, low-resistance continuity bonds between pipe sections are a necessity for two reasons. First, when the pipeline is electrically continuous, a reliable survey of electrical potential along its length will warn of developing corrosion and pinpoint the location. Second, if corrosion problems are discovered, they can be arrested by creating a cathodic protection system using the electrical connections in place. This logic is so compelling that pipe manufacturer frequently provide bonding tabs to facilitate cathodic connections.

Connections in a system are different from conventional grounding or power connections. Grounding connections, for instance, normally do not carry current until a fault occurs, at which time they must carry huge surges, often large enough to melt the conductor. They must be able to withstand high current and the electromechanical forces.

Normal power circuits and their connections carry 110 volt or higher potentials that easily counteract small amounts of inefficiency associated with corrosion or other problems sometimes found with mechanical (pressure-type) junctions. Connections used in a cathodic system, on the other hand, are subject to low currents, at low voltages. Small, even localized, resistances can render the system inefficient or ineffective.

In the first year of the O'Hare project, for instance, cathodic connections were made using bronze ground clamps. These mechanical bonds were expensive and not always effective because they sometimes loosened to break the circuit. Because cathodic protection connections must be as efficient as possible and capable of maintaining their integrity over an extended lifetime, the specifications written for the O'Hare project called for exothermically welded connections.

The Cadweld exothermic welding process is considered to be the accepted method of attaching CP leads to cast or ductile iron pipe, steel pipe, tanks, and other structures. Unlike mechanical connections, which can corrode to produce a less effective current path, this exothermic process results in a fusion weld of the conductor to the surface of the material to be protected. The resulting connection
- has current carrying capacity equal to that of the conductor;
- is permanent and cannot loosen or corrode—with no increase, therefore, in resistance.
- requires only lightweight inexpensive equipment for installation, and no special skills or outside power source
- can be visually checked for quality.

This type of connection uses different alloys for welding the various metals found in cathodic protection systems. A semipermanent graphite mold holds the conductors to be welded. Weld metal, for instance a mixture of copper oxide and aluminum, is dumped into the top of the mold. The mold is covered and the weld metal ignited. The exothermic reaction produces molten copper which forms a permanent, high conductivity connection.

The Verdict

The initial cost of a pipeline protected by a cathodic protection system is higher than that of an unprotected installation and an impressed-current system usually costs more than a sacrificial-anode system. But a well-designed and maintained CP system can extend the lifespan of pipes and other structures by a factor of ten or more. When lifespan costs of a protected pipeline are compared to the repair and replacement costs for unprotected pipe, a cathodic protection system usually is justified.

Equally persuasive are the arguments in favor of making exothermically welded bonds rather than mechanical connections. Experience has demonstrated that a CP system requires a continuous, high integrity, low impedance electrical path, and mechanical connections will not always provide that. Only welded bonds are permanent. Experiences encountered by many installers have helped Cadweld perfect tools and materials that make exothermic welding suitable for water storage and distribution system applications. There is an exothermic bond for virtually any cathodic protection situation.

For more information on this subject, circle 882 on the reader service card.

About the Authors:
Jeffrey A. Schramuk is regional manager for Cathodic Protection Services and Keith Switzer is an applications engineer with ERICO, Inc.