# Corrosion Control using Cathodic Protection for Prefabricated Buried Steel Pump Stations[1]

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*Abstract*

Municipal water and sewer utilities can face significant economic and safety consequences from external corrosion of buried prefabricated steel pump stations. Avoiding corrosion failure is paramount since these structures contain sophisticated electronic controls or protect important access points for future pump maintenance. The author's empirical field data shows that cathodic protection (CP) systems using sacrificial anodes on pump stations rarely have a service life that exceeds five to seven years. Since sacrificial anode CP systems have been shown to have a limited service life, a municipal utility that wants long-term corrosion protection should consider a properly-designed, installed, and maintained rectified-anode CP system. A recent study by the U.S. Federal Highway Administration and NACE International concluded that external corrosion of buried utility structures can be effectively mitigated by the application of coatings and cathodic protection (1).

*Introduction*

For the discussion that follows, a prefabricated buried steel pump station (pump station) could be one of two types:

- A water booster pump enclosure that has its pumps located at a relatively shallow depth of approximately 10 to 15 feet below grade. Typical shapes are circular for single pump units and oval for multi-pump installations. A single incoming water pipe enters the pump station, runs through one or more booster pumps, and a single pipeline runs out of the pump chamber into a water main.
- Dry-pit flooded-suction sewage pump stations have ejector pumps that can be located as much as 30 to 35 feet below grade. Typically shaped as a vertical cylinder set alongside a cast-in-place sewage wet well. Multiple suction pipes run from the wet well into the pump chamber. A single ejector line runs out of the pump chamber into a sewage main.

Regardless of the fluid being pumped (potable water or sewage), a pump station as shown in Figure 1 relies on a carbon steel pump chamber to house the pumps and contain their associated piping in a safe and controlled environment. Dehumidification, sump drains, and air-circulation blowers work to reduce accumulated moisture within the pump station. Preventing corrosion in the pump chamber is paramount since the structure contains sophisticated electronic controls that are necessary to operate the pump station with minimal direct human intervention as well as to provide an access point for pump maintenance.

*Corrosion Control using Coatings*

Considering that typical installation costs for a new pump station can range from $300K to $500K, external corrosion of buried prefabricated steel pump stations can present significant economic and safety concerns to municipal water and sewer utilities. If left unprotected in aggressive soils, a pump station can experience external corrosion failures in less than 10 years. This rapid failure rate is often exacerbated by corrosion concentrated at small defects in the pump chamber's external coating. Steel corrosion can manifest by separation of the bottom floor plate from the pump chamber shell or by corrosion pitting and subsequent perforation of the shell walls as shown in Figure 2.

To increase the effective service life of a pump station, manufacturers typically apply a bonded urethane or epoxy coating to the exterior surfaces of the pump chamber. High-quality coatings will limit water and oxygen access to the metal surface; unfortunately, no coating is perfect, and installation defects and third-party damage can contribute to corrosion failures.

*Corrosion Control using Cathodic Protection*

Corrosion is defined as the electrochemical degradation of a metal resulting from its reaction with its environment. Cathodic protection is a system for reducing corrosion of a metal structure by turning the entire structure into the cathode of a galvanic or electrolytic corrosion cell. Direct electrical current, either generated by the galvanic cell or fed into the electrolytic cell from an external source, flows into the protected structure, overcoming any currents that might be created by naturally occurring corrosion cells in which the structure would be the anode (2).

Design standards for critical military installations require CP installation for critical buried infrastructure (3). It is also a regulatory requirement that buried pipelines that convey both hazardous liquids or gases in the United States must be installed with CP (4,5). Although there are many variations of cathodic protection, there are essentially two basic methods, i.e., sacrificial (galvanic-anode) CP and impressed current (rectified-anode) CP.

*Cathodic Protection using Sacrificial Anodes*

Design engineers commonly address external corrosion control posed by aggressive soils through specific requirements in their bid specifications. Common requirements could include the following language or something similar to "the station shall be provided with a minimum of four magnesium anodes. The CP test box shall be mounted on the electrical rack."

Such a specification could be improved by providing details as to the anode alloy, burial installation details, and how the Owner will verify the anodes are effective at the test box. For buried prefabricated steel pump stations, a typical anode alloy is magnesium, or in very low resistivity soils, zinc. The installation depth of each anode can range from just below the soil surface, to halfway between grade and the bottom depth of the pump station, to unspecified.

Verification of a sacrificial anode CP system's effectiveness is inferred by viewing the CP test box (i.e. an ammeter as shown in Figure 3) and seeing a meter needle deflection greater than zero milliamperes (mA) when the "TEST" switch is engaged. However, other than the ammeter reading equal to zero (indicating a "dead" anode), the ammeter reading is meaningless to the Owner as there are no guidelines given as to how much DC current any individual anode should produce nor what reading would be considered "NORMAL. "

Empirical field data shows that CP systems using sacrificial anodes on pump stations rarely have a service life that exceeds five to seven years (6). Because the pump station's electrical equipment is grounded under such a scenario, the resistance-to-earth of the combined anode-pump station circuit is just a few ohms. Consequently, the sacrificial anodes (having a fixed driving voltage) will be quickly consumed when trying to provide DC current to the pump station and every other buried structure that is interconnected with the same low-resistance ground.

*Cathodic Protection using Rectified Anodes*

If conditions require investment beyond the typical use of "anode bags" (Figure 4), it is recommended to include a bid specification that requires the CP system to automatically supply a constant amount of DC current regardless of wet or dry soil conditions. Such situations likely require a CP system that uses multiple canistered anodes placed around the periphery of the pump station (Figure 5) and installed in vertically-drilled boreholes reaching down to the bottom of the pump chamber. The anodes come preassembled with an insulated lead cable that is direct buried. Once entering the pump chamber, the cables typically run in a conduit to the CP rectifier, which is a device that steps down an input AC voltage (via a transformer) and converts it to output DC voltage (via diodes). The minimum service life of a rectified anode is typically at least 20 years, which is significantly longer than that typical of a sacrificial anode for this type of structure.

The CP system's automatic rectifier (Figure 6) is equipped with the following features:

- Termination points for each individual anode to measure separate DC current outputs.
- A separate termination for a buried reference electrode to validate the structure-to-soil potential of the station per NACE International Standard Practices (7).
- Individual voltage and amperage meters to verify the rectifier's DC outputs.

There is no routine maintenance other than periodic verification of the rectifier's AC power source. Since many municipal utilities have stringent safety protocols for personnel access into pump chambers, a utility's SCADA system can be connected to the rectifier to remotely monitor its operation.

*Comparison of Sacrificial- versus Rectified-Anode CP Systems*

Typically, sacrificial anode CP systems are used to deliver small amounts of DC current to an electrically-isolated structure such as a well-coated natural gas service pipe. Conversely, rectified-anode CP systems are used to supply large amounts of DC current on structures that are either poorly-coated or not electrically-isolated, such as buried piping at a power plant.

To illustrate by comparison the difference in the magnitude of DC current provided by sacrificial anodes versus rectified anodes on a pump station, consider the following example:

- The typical DC current output from a single sacrificial magnesium anode (typically a 17-pound ingot) installed in clay-loam soils is usually between 50 and 100 milliamperes.
- Empirical field data shows that, on average, most buried pump stations will require between 4 and 7 DC amperes (equivalent to between 4000 and 7000 milliamperes) to meet the minimum requirements for corrosion control established by NACE International® (7).
- Thus, and in general, assuming a conservative output of 100 DC mA per anode, it would take from 40 to 70 anodes to meet the same performance capability of a rectified-anode CP system. By this simple example, the practical limitations of having to install so many sacrificial anodes should be obvious.

*The Benefits of a Rectified-Anode CP system*

In the end, sacrificial anodes installed on a buried steel pump station are merely a short-term corrosion-reduction strategy. A rectified-anode CP system that can overcome aggressive soil conditions, coating degradation, and interconnections with foreign grounds will add years of additional service life to the pump station. Industry experience (8) and the professional literature (9) have shown a benefit-to-cost ratio of between 7:1 and 10:1 by applying CP as a corrosion mitigation practice in municipal water utilities. Considering both the direct (operating losses from non-operation) and also the indirect (societal) costs of pump station corrosion failures, similar benefits will apply to rectified-anode CP systems installed on buried steel pump stations.

*References*


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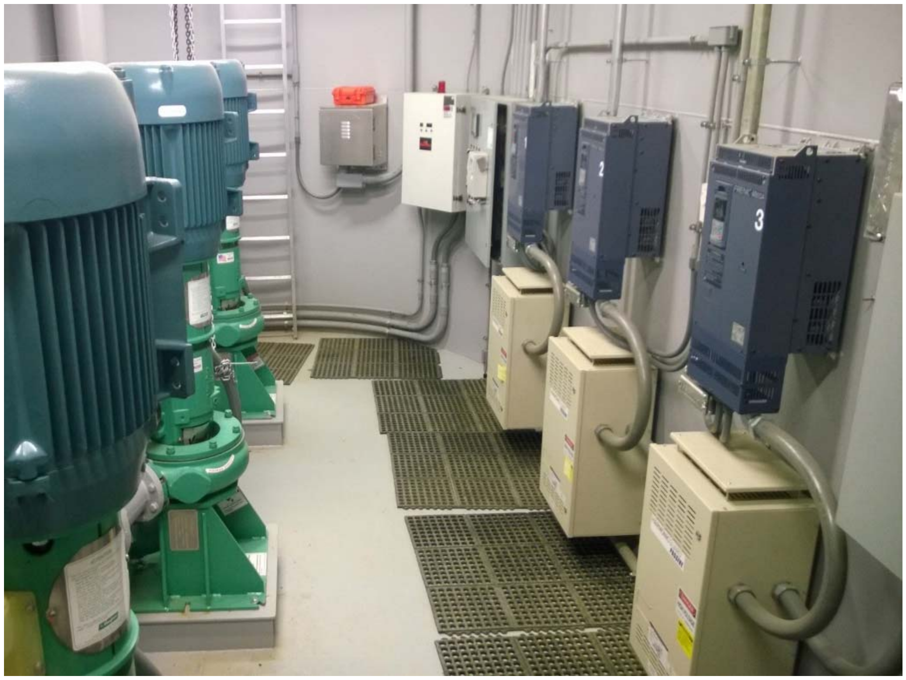

Figure 1 – View within Buried Pump Station Chamber

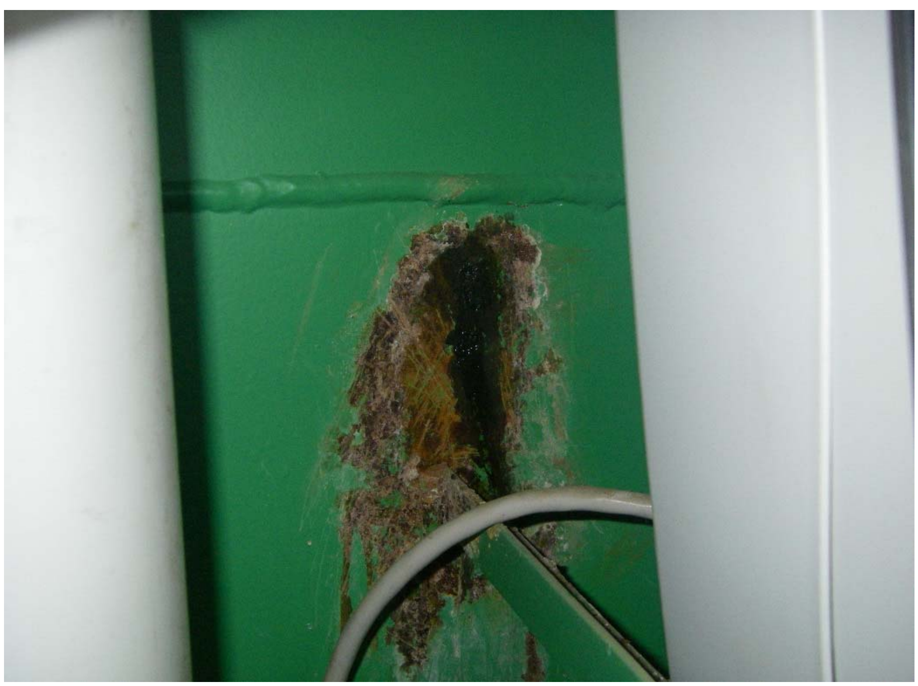

Figure 2 – Corrosion Perforation of Pump Station Wall

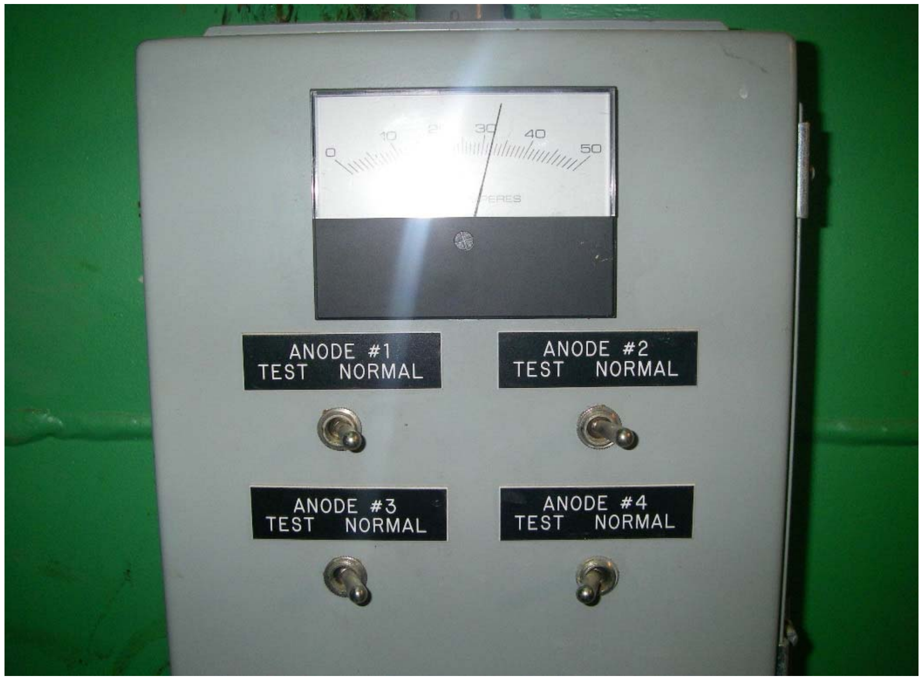


Figure 3 – Test Box for Sacrificial Anodes

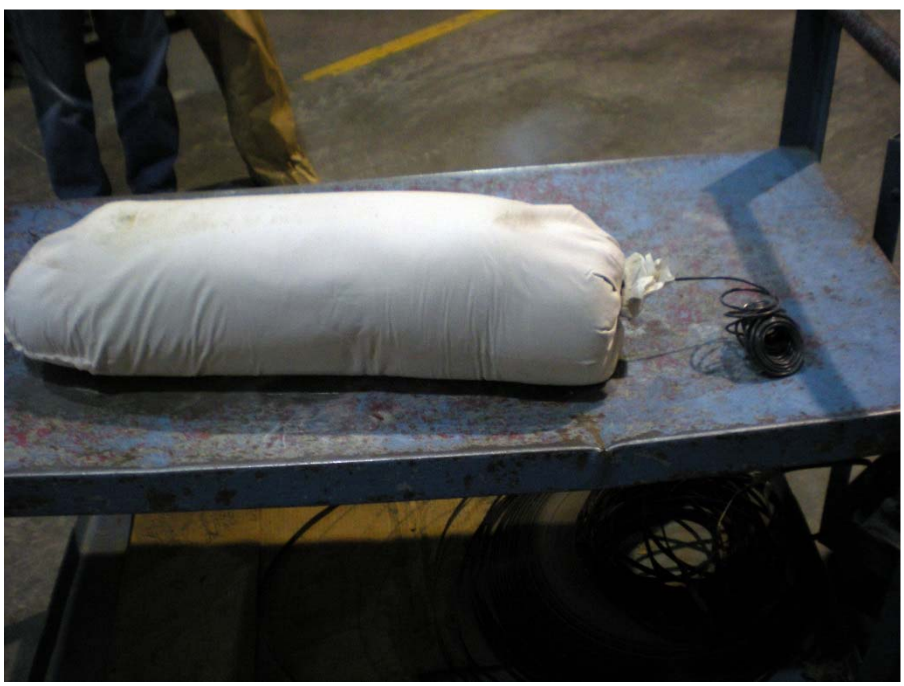

Figure 4 – Prepackaged Sacrificial Anode

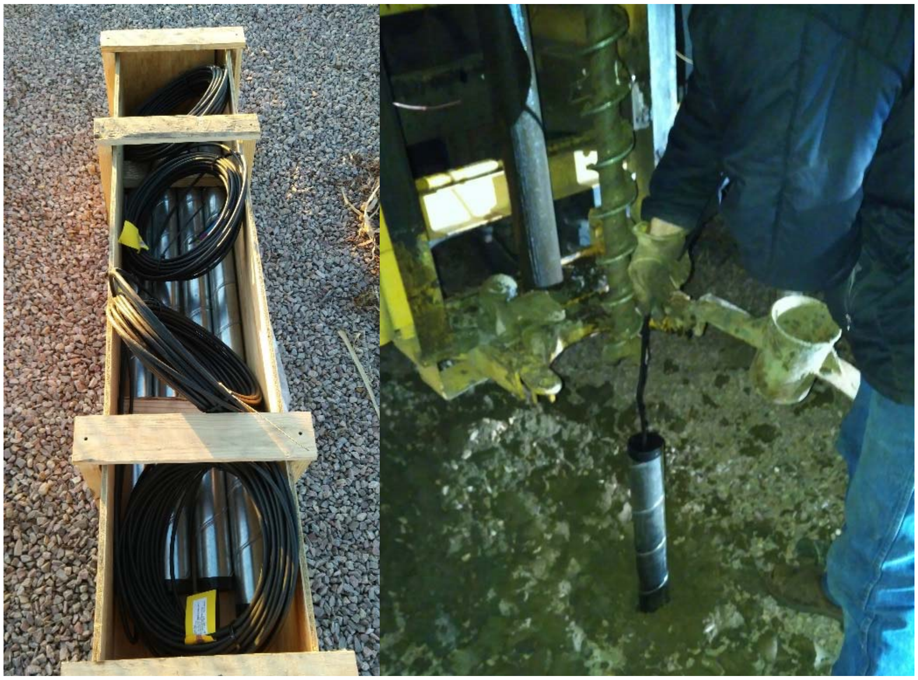

Figure 5 – Left: Crated Canistered Anodes; Right: Anode Being Installed

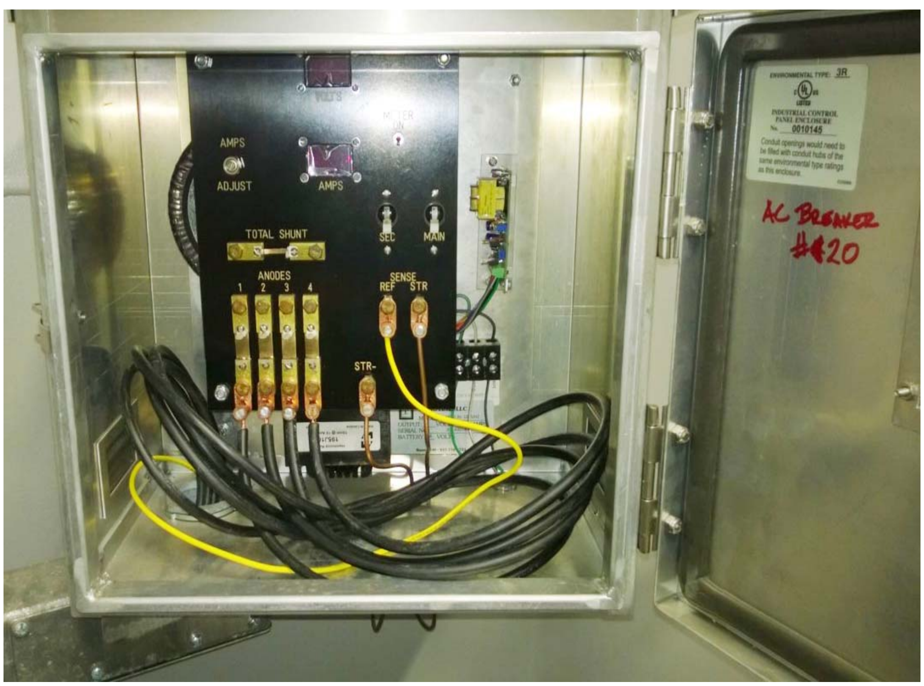


Figure 6 – CP Rectifier with Integral Anode Junction Box