An effective answer to the tank system corrosion problem

Cathodic protection is installed on existing steel underground storage tanks and piping that contain product to meet Federal and State corrosion protection requirements. However, corrosion protection compliance is not complete once these cathodic protection systems are installed. They must be inspected and surveyed for proper operation. Tanknology's Gilbert Schutza discusses cathodic protection methods, regulations, and ways UST owners are meeting monitoring criteria associated with their systems.

Cathodic protection

Corrosion technician finalizes installation of cathodic protection system remote monitoring unit

Environmental Protection Agency (EPA) final tank regulations require that all buried metallic tanks and buried metallic piping that routinely contain product have corrosion protection. Corrosion of underground storage tanks (USTs) and piping once was the principal cause of leaking underground storage tanks in the United States.

In most cases, corrosion protection of steel USTs will include the application of cathodic protection (CP). Dielectric coatings with cathodic protection for new steel tanks and installation of cathodic protection on existing steel tanks have been cost-effective methods for corrosion control and leak prevention. The EPA regulations require that cathodic protection systems "be operated and maintained to continuously provide corrosion protection to the metal components of that portion of the tank and piping that routinely contain regulated substances and are in contact with the electrolyte (ground)."

The key to effective cathodic protection systems is to insure that they are installed and maintained properly. Maintenance includes monitoring and testing based on EPA and state regulations and the type of CP system involved.

Cathodic protection basics

Cathodic protection causes external buried steel surfaces on tanks and piping to collect current, thereby reversing the flow of natural corrosion current on unprotected steel. This collection of current on the tanks makes the tanks the cathode of the electrochemical corrosion cell (i.e., the cathodic protection system). Corrosion does not cease to exist but is simply transferred from the tank to an external anode in the corrosion cell. With cathodic protection, corrosion always takes place at the anode (where current leaves the metal surface and enters the soil). Corrosion will not take place at the cathode (where current is received by the metallic surface from the electrolyte).

Therefore, an entire buried external metallic surface can be forced to become cathodic and it will not corrode because it becomes cathodically protected. Cathodic protection is defined as “the reduction of corrosion rate by shifting the corrosion potential of the electrode toward a less-oxidizing potential by applying an external electromotive force.” The anodes around the tanks are the external forces that corrode by forcing current to the ground and onto the tanks (cathode).

It is necessary to conduct periodic inspections of the cathodic protection systems. Current must be provided continually to the tank system. Should the CP system be interrupted, the tanks will begin to corrode again.

To reduce the amount of current needed to stop corrosion, cathodic protection is frequently used in conjunction with protective coatings. These high performance coatings (paint) keep most of the metal surface from coming in contact with the soil/water environment. The cathodic protection then provides current only to those steel surfaces which become exposed to the electrolyte due to coating failure or damage. These coating failures are typically called holidays.

There are two types of cathodic protection systems for UST facilities: sacrificial (galvanic) anodes and impressed current systems. Both types do exactly the same thing—deliver current to the steel tanks and piping that are in contact with the soil and/or water.

Advantages	Disadvantages
• No external power supply required. • Installation is realtively easy. • Installation costs are lower. • Maintenance costs are lower. • Interference problems are rare. • Effective for protecting small electrically isolated structures.	• Driving voltage and current output are low. • Not practical for use in soils with very high or low resistivity. • Not effective on large uncoated steel structures. • Anode life may be short when protecting large surface areas of buried steel. • Not practical for most UST facilities. • Requires tanks and piping to be electrically isolated from assocaited conduit and othe underground metallic structures.

Advantages and disadvantages of galvanic systems

Galvanic systems

Galvanic/sacrificial anode systems produce the protective current by an electrochemical reaction similar to an everyday flashlight battery. A metal that is less noble, or more active, than the metal to be protected is selected for the sacrificial anode. The anode is electrically connected to the tank/pipe to be protected and buried in the soil. A galvanic cell develops and the more active metal (anode) corrodes (is sacrificed) while the metal tank/pipe (cathode) is protected. The protective current enters the structures, and opposes, overcomes and prevents the flow of any corrosion current that existed on the underground tank/pipe.

When protecting underground storage tanks, the anode material can be magnesium or zinc. The number, size, type and location of anodes should be determined by a detailed survey of the UST facility. Many facts about the UST facility must be considered before deciding to use sacrificial cathodic protection systems. Such factors as electrical isolation/continuity of the tank system, soil resistivity, response of buried structures to current applied and external coatings must be considered. Galvanic systems have a lower capacity to protect tanks and are normally used on new, well coated and electrically isolated tanks.

In general, galvanic sacrificial anodes are used when:

- Current requirements are low.
- Soil resistivity is low (seldom used when resistivities are higher than 10,000 ohm-cm).
- Interference problems with other metallic underground structures are common.
- Electrical power is not available.
- Tanks and piping are coated and electrically isolated.

In most instances, the magnesium or zinc anode is directly connected to the tank or piping to be protected. These special anodes require no external power source. Magnesium and zinc anodes are surrounded by a special backfill (gypsum/bentonite). This backfill is required to insure a consistent, moist, low resistivity environment, which increases efficiency and prolongs anode life.

There are some distinct advantages and disadvantages to the galvanic sacrificial cathodic protection system, as shown above.

The sti-P3® system

The most common form of sacrificial anode systems are those designed as part of a new steel tank. The Steel Tank Institute P3 tank (sti-P3®) is a sacrificial anode system. P3 stands for “protected three ways.” Its corrosion protection design consists of a dielectric coating, insulating flanges and zinc or magnesium sacrificial anodes.

The sti-P3® system is designed to protect the outside of the tanks only. The risers/piping are electrically isolated from the tank and are not included. The sti-P3® tank incorporates a good exterior coating and factory-installed anodes. The anodes are provided to protect the surface areas on the tank where coating holidays exist and exposure to corrosion occurs. The surface areas are very small and do not require a large number of anodes for protection.

When foreign structures are electrically shorted to the tanks (e.g., piping) the protective effect is depleted and the anodes for the tanks are consumed. Therefore, it is very important to maintain effective electrical isolation of the sti-P3® tank. Additionally, sacrificial anodes have a specified design life. That is, since the anodes corrode, or are sacrificed, they will deteriorate and cease to provide corrosion protection. Thus, cathodic protection surveys are required every three years by EPA, state agencies and nationally recognized practices for sti-P3® tanks.

Remote monitoring by paging technology eliminates the need for multiple phone lines at UST facilities

Impressed current systems

The use and design of impressed current systems are more flexible than galvanic anode systems. The impressed current cathodic protection systems work by the same principle as galvanic systems. However, impressed current systems use an external power source to energize the anodes at a much higher voltage.

The external power source is called a cathodic protection rectifier. It converts the alternating current (AC) to direct current (DC), which is impressed into the electrolyte from the anodes to the tanks (cathode). The protective current is impressed to the exterior metal surfaces of the tanks/piping from the electrolyte and overcomes and prevents the flow of any corrosion current from the tank/piping metallic surface. The cathodic protection rectifier can be made with automated control to deliver constant current to the UST facility. Moreover, some rectifiers are also made with alarm lights to indicate proper operation. Other commonly used rectifiers have more basic voltage taps for current output adjustment and one or two meters for monitoring.

Many different types and sizes of impressed current anodes are available for use with impressed current systems. They include:

• Graphite
• High silicon cast iron
• Platinized niobium
• Titanium or tantalum
• Mixed metal oxide

Each anode has special design, installation and operating characteristics. Most anodes are pre-packaged or backfilled in the field with highly conductive coke breeze—a coal by-product that conducts current. The specialized backfill provides uniform low electrical resistance to increase anode life and efficiency. Anodes are normally installed in augured holes (4-inches to 6-inches in diameter) to tank bottom depth and are geometrically spaced around the UST facility in order to more evenly distribute the protective current to the tank system. Above are some advantages and disadvantages of impressed current systems.

Many facts about the site must be considered prior to installing impressed current systems. They include, but are not limited to:

• UST physical condition and geometry
• Soil resistivity
• Presence of other underground metallic structures
• Electrical isolation/continuity of the UST facility
• Tank/piping coating efficiency
• Current requirements

• Available power sources

Advantages	Disadvantages
• Available of large driving potential.	• May cause interferences problems on foreign underground metallic structures.
• High-current output capable of protecting other underground structures with a low operating cost.	• Current may be switched off and protection temporarily eleminated.
• Flexible output current.	Must be regularly monitored and maintained.
• Applicable to any soil resistivity.	• Maintenance and operating costs are relatively high.
• Can protect large bare-steel structures.	
• Can have alarms that indicate proper operations.	

Advantages and disadvantages of impressed current systems

Mandated experience

Federal and state regulatory agencies require UST corrosion protection systems to be designed, installed, commissioned and periodically repaired by a corrosion expert. A corrosion expert is defined as a person who, by reason of thorough knowledge of the physical sciences and the principles of engineering and mathematics acquired by a professional education and related practical experience, is qualified to engage in the practice of corrosion control on buried or submerged metal piping systems and metal tanks. Such a person must be accredited or certified as being qualified by the National Association of Corrosion Engineers (NACE International) or be a registered professional engineer who has certification or licensing that included education and experience in corrosion control of buried or submerged metal piping systems and metal tanks.

The right connections

Impressed current protection of USTs involves the installation of a rectifier control unit and several anodes wired to the rectifier. The positive terminal of the rectifier is connected to the anodes. The positive lead is positive with respect to the ground and the tank. If the positive (anode) wire is nicked and not completely insulated from the electrolyte, then the wire discharges current (acts as an anode). As a result, the wire and the cathodic protection system will fail. All anode wires should be inspected prior to backfilling. The negative terminal of the rectifier must be attached to the structure to be protected. The tanks are connected to the negative lead. The connection on the tanks is called bonding, and the preferred method of bonding is by cadweld or thermite weld. However, good mechanical connections can be used. These connections should be coated to prevent oxidation. This should be done to keep a low resistant connection.

Impressed current systems need to be designed to minimize interference effects on neighboring buried metal structures (e.g., water, natural gas and sewer pipes, as well as communication and power cables). If a sufficient number and length of anodes are employed, the required DC voltage is reduced and current distribution on the UST facility is improved. A standard notification letter should be sent to owners and operators of nearby sub-surface structures (i.e., local utilities and municipalities). The letter should describe the CP system and invite interested parties to conduct tests to determine if newly installed impressed current systems are a source for stray current corrosion on their structures. This practice allows interference to be cleared without complications or litigation.

Corrosion technician reads individual anode output at the junction box to evaluate operation of the cathodic protection system

Cathodic protection testing

In determining the type of cathodic protection system, the most important considerations are of soil resistivity and current requirements. How much current is required to protect the UST facility? At what point is protection achieved?

It has been determined that corrosion of steel or iron is stopped when its “potential” relative to a copper-copper sulfate reference electrode is 0.850 volts or more negative with the reference cell placed as close as possible to the electrolyte/structure interface. This potential measurement is most important in determining corrosion control of the UST facility. The measurement is actually a voltage drop at the interface of the metal and the electrolyte.

When using the 0.850 volts or more negative reading for corrosion protection measurement, you must consider voltage drops other than the structure/electrolyte boundary to correctly interpret this higher (more negative) reading. For that reason, the reference cell is adjacent to the tank or piping in the electrolyte. Site soil resistivity, which effects voltage drops, should be considered when evaluating this reading.

Another method which considers voltage drops is the measurement taken the instant the rectifier is turned off. This is called the “instant off reading.” If this reading is above 0.850 volts or more negative, the system is providing cathodic protection to the structure. If the reading is less than 0.850 volts negative, it does not necessarily mean that the system is not providing cathodic protection. If, after turning off the rectifier for an extended period of time, the potential measurement decays by more than 0.100 volts from the instant off potential, the cathodic protection system is still providing adequate protection. This decay is called the polarization decay. Refer to the National Association of Corrosion Engineers Recommended Practice for Cathodic Protection and Cathodic Protection Testing of UST Facilities (NACE RP 0285-95).

Both ends and the middle

Potential readings should be obtained in several areas around the tank and piping system to insure proper protection. It is important to take readings at both ends and the middle of the tank because it is possible that CP can be achieved at one end and not the other. The same is true for metallic piping. Readings should be taken at both ends and the middle of the piping run to insure proper protection levels because each reference cell reading is an indication of the protection level in that area.

Potential readings through concrete can be erroneous. This is due to the high electrical resistance of concrete. Potential readings through asphalt cannot be obtained. All readings should be obtained with the reference cell placed in the tank/piping backfill (electrolyte). At UST facilities, it is often difficult to obtain potential readings properly because there is no soil access above the tanks to place the reference cell. This is because containment sumps and concrete tank pads have been installed over the tanks. As a result, pavement inserts (CP Test Stations) are installed over the tanks to enable the reference cell to be placed in the tank electrolyte.

When the proper potential is achieved, the cathode (tank) is polarized to the open circuit potential of the anode and local cathode/anode cells cease to exist on the tank/piping surface.

The current required to achieve cathodic protection is a function of the tank's electrical resistance to the electrolyte. For example, a well coated tank, such as sti-P3®, requires less than three to five microamperes per square foot to achieve cathodic protection. A poorly coated bare steel tank, like many of the older tanks, may require 1.5 to 2.0 milliamperes per square foot to polarize to the 0.850 volts or more negative tank-to-soil potential.

It is important that the CP tester be qualified to evaluate cathodic protection systems. The EPA defines CP tester as "a person who can demonstrate an understanding of the principles and measurements of all common types of cathodic protection systems as applied to buried or submerged metal piping and tank systems. At minimum, such persons must have education and experience in soil resistivity, stray current, structure-to-soil potential, and component electrical isolation measurements of buried metal piping and tank systems." This definition can be found in the Code of Federal Regulations, 40 CFR 280.12. Some states require certification for cathodic protection of USTs from the International Fire Code Institute (IFCI), while others require NACE International, formally known as the National Association of Corrosion Engineers, certification as a CP tester. A few state agencies have their own certification process requiring the passing of a state issued examination.

It is important that the CP tester be able to evaluate the cathodic protection systems properly. NACE International offers several courses for UST owners and CP testers on cathodic protection and cathodic protection design and testing.

Mandated testing

EPA regulations require that all cathodic protection systems for tanks and piping, including flex connectors, must be tested within six months of installation and at least every three years thereafter. This includes both factory and field installed systems. Additionally, impressed current systems must be inspected for proper operation every 60 days. Another requirement is that within six months following the repair of any cathodically protected UST facility, the cathodic protection system must be tested for proper operation. For instance, if the vent piping were replaced or containment sumps were installed on a cathodically protected UST facility, the CP system must be tested for proper operation within six months of that repair.

The basis of these requirements is that cathodic protection systems must be operated and maintained to continuously provide corrosion protection to the metal components of that portion of the tank and piping that routinely contain regulated substances in contact with the ground. Remember, if cathodic protection is interrupted, the tanks and/or piping will begin to corrode. These regulations are to ensure that releases due to corrosion are prevented for as long as the UST system is used to store regulated substances.

Records must be maintained to demonstrate compliance with the regulations. The EPA requires that the results of the last three 60-day rectifier inspections and the last two CP surveys are available at the site or at a readily available alternative site and are provided for inspection to the implementing agency upon request. It is very important that UST owners and operators maintain the reports of the CP installations, CP tests and the rectifier inspections. If records cannot be found to prove proper operation of the CP system, a structural integrity test of the UST facility may be required by the implementing agency. Additionally, fines may be levied and the UST facility may be shut down until regulatory compliance is met. Some fines incurred by UST owners for failing to keep records or to maintain the cathodic protection systems include, but are not limited to:

- No corrosion protection—$300/tank.
- No 60-day rectifier inspections—$150/location.
- No 3-year cathodic protection survey—$300/facility.

Fines can be incurred up to $11,000/day for each site failing to meet environmental compliance. Furthermore, gas sales or gas deliveries may be shut down until compliance is met.

The criteria used to determine that cathodic protection is adequate must be in accordance with a code of practice developed by a nationally recognized association such as NACE RP-O285-95, Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems.

Some states have opted to be more stringent than the Code of Federal Regulations. For instance, some states now require impressed current system testing annually, instead of every three years. Florida, Connecticut, New Hampshire, Maryland and New York require annual surveys on impressed current systems. In addition, soil access stations for testing may be required. In New Hampshire, three tank-to-soil potential requirements are required over each tank. The potential measurements have to be made with the reference cell placed in the electrolyte.

Flexible connectors

EPA regulations require all underground metallic piping that contains product to have cathodic protection. For UST facilities with fiberglass tanks and piping, the metallic flex connectors at the submersible turbine pumps and dispensers must be cathodically protected if they are in contact with the soil or submerged in water. Flex connectors can be contained so they are not in contact with soil.

Cathodic protection for a flex connector typically will consist of a magnesium anode directly connected to and buried below the flex connector. Electrical isolation of the flex connector from the submersible turbine pump and dispensers may be required if the associated metal surface area of the conduit in contact with soil is too large and draws too much current for the anode to protect the flex connector. Larger magnesium anodes may be required in some instances if electrical isolation of the flex connector is not completed.

Some flex connectors are fabricated at assembly with a magnesium anode attached. These should be electrically isolated from the submersible turbine pumps and dispensers. If they are not, additional magnesium anodes may be required for adequate cathodic protection. Flex connector cathodic protection systems must be inspected six months after the installation and every three years, as with all sacrificial cathodic protection systems installed at UST facilities.

Corrosion technician prepares to make tank connection for reading tank-to-soil potential to evaluate cathodic protection system performance

Structural integrity requirements

Existing steel tanks that were ten years old or older were required to pass a structural integrity test before cathodic protection could be installed. Assessment techniques included: tightness testing, internal tank inspection, site corrosion survey or other state approved assessment methods.

Field installed cathodic protection systems, either impressed or sacrificial, are also required to be designed by a corrosion expert.

Many UST owner/operators are meeting the various regulatory requirements by using corrosion consultants and contractors to perform the necessary integrity assessments, system designs, installation work, subsequent surveys and rectifier inspections. The 60-day rectifier inspections are not required to be performed by certified inspectors. Qualified or certified cathodic protection testers must perform the cathodic protection surveys. Installation and repairs should be performed by corrosion experts. The 60-day rectifier inspections can be logged by station personnel or by qualified contractors. The rectifier log sheets and CP survey reports are typically kept at the store or at a readily available compliance office.

System monitoring advances

For owners of large tank populations, computerized systems are used to help keep the required inspections scheduled and up to date. Owners are beginning to use remote monitoring technology for 60-day rectifier inspections. The benefits of remote monitoring include reduction of long term costs, improved monitoring accuracy and ease in meeting the regulatory requirements.

Remote monitoring technology eliminates the need for technicians to travel to stores to collect rectifier output data and allows UST operators to concentrate on their core business. Another benefit is that updates of the rectifier output can be more frequent. Immediate notifications of rectifier output abnormalities through email, fax or pager can help the owner/operators mitigate potential problems and lessen the likelihood of violations and fines.

Rectifier data can be transferred to monitoring stations by phone lines, two-way pagers and cellular phone systems. Remote monitoring systems are simple and only require two channels to monitor voltage and rectifier current output. With permanent reference cells on site, more sophisticated monitoring systems can measure tank-to-soil potentials from off-site locations to insure that the tanks are meeting cathodic protection requirements.

Remote monitoring devices based on two-way paging transmitters are a relatively new. Two-way paging is a very appropriate communications platform since the data transmission (bandwidth) requirements associated with CP systems are relatively low compared to other applications such as automatic tank gauges. Therefore, remote monitoring systems can be deployed at CP locations at much lower costs than purchasing a modem and installing a dedicated telephone line. Since two-way paging systems utilize established networks such as SkyTel and PageNet, coverage ratios are extremely high. In addition, these networks are completely Internet-enabled, so all data is available to the tankowner via a standard web browser.

CP Coupon Test Station

Advances in cathodic protection test station technology are also making testing more reliable. The CP coupon test station is relatively new and can be used for steel underground tank and piping systems. With the CP coupon, the technician can obtain an instant off potential without interrupting the current source.

For sti-P3® tanks, the magnesium anodes are welded to the tank bulkheads and cannot be disconnected from the tank to obtain an instant off potential. With the CP coupon test station, the technician interrupts the connection between the tank and the coupon to obtain the instant off potential and determine the extent of cathodic protection on the structure. Some CP test stations employ a second coupon that is not connected to the tank. This coupon has the native corrosion potential to which the instant off potential can be compared for the polarization decay. The 100-millivolt potential decay is one method that is used by corrosion engineers to prove cathodic protection. These relatively new test stations also allow for measurement of the CP current density and depolarization rates.

Cathodic protection is an effective answer to the tank system corrosion problem. But it requires proper installation, maintenance, testing and upkeep to remain trouble free.

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