Cathodic Protection Systems For Crude Oil Producing

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INTRODUCTION

Cathodic protection has been used to protect metal from the ravages of corrosion for over 100 years. In fact, the first technical paper published on the subject was written by Sir Humphrey Davy in 1842. It was entitled "On the Corrosion of Copper Sheeting by Sea Water and on Methods of Preventing This Effect; and on Their Application to Ships of War and Other Ships." However, the use of cathodic protection in crude oil producing is relatively new.

FUNDAMENTALS

When metals are processed from their ores, they are raised to a much higher level of chemical energy. Thereafter they will always have a tendency to release this energy through the process of corrosion. Metals revert back to the lower energy level through either direct chemical attack or electrolytic attack. In crude oil producing the type of corrosion usually encountered is electrolytic rather than direct chemical attack.

Basically, electrolytic corrosion is caused by an electric current leaving the surface of a metal. The amount of corrosion is directly proportional to the magnitude of the current; so when the current is reduced or stopped, corrosion is reduced or stopped. Cathodic protection is merely the application of an electric current which suppresses or opposes the corroding current. If a cathodic protection system is designed properly, it will balance out or "buck out" the corroding current.

Some of the terms used to describe cathodic protection are:

1. Anode: A metal rod or block from which the protective current flows. It is corroded or "sacrificed" for the metal being protected.
2. Cathode: The metal which receives the protective current or which is being protected.
3. Electrolyte: A substance capable of conducting an electric current and in which the anode and cathode are immersed. Usually it is soil or salt water.
4. Rectifier: An electrical device which changes alternating current into direct current.

Theoretically, cathodic protection can be used to protect a metal from any environment, providing the environment is a fairly good electrolyte. Of course, only the metal surface actually in contact with the electrolyte is able to be protected.

CATHODIC PROTECTION EQUIPMENT

Cathodic protection systems require various types of equipment depending on the equipment to be protected. There are two types of cathodic protection systems — sacrificial anode and impressed current. The term "sacrificial anode" is somewhat misleading since the anodes in both systems are "sacrificial." It is used to describe a system which supplies its own protective current. An impressed current system is one which requires DC current from another source. The equipment required by these systems will be discussed under four headings: anodes, rectifiers, control devices and accessories.

Anodes

Just as there are two types of cathodic protection systems, there are two types of anodes — sacrificial anodes and impressed current anodes. Sacrificial anodes are made of magnesium or zinc. These metals are more active than iron as can be seen on the electromotive series chart. When either of these metals is connected to iron, and both are placed in an electrolyte, current will flow. This is similar to the operation of a car battery.

Impressed current anodes are those which require DC current from an external source. The source could be commercial AC power rectified to low voltage DC power or a DC generator. Impressed current anodes are made of scrap iron, high silicon cast iron, or carbon graphite. Listed below are some of the characteristics of each anode material.

1. Magnesium: Does not require electric power, has low driving voltage, has a relatively short life.
2. Zinc: Same as magnesium except it has an even lower driving voltage, but has a longer life.
3. Scrap Iron: Very cheap, short life, requires large anode bed, requires impressed current.
4. High Silicon Cast Iron: Has a relatively long life, subject to oil fouling, requires impressed current, is very brittle.
5. Carbon Graphite: Has a relatively long life, requires impressed current, is very brittle, subject to oil fouling.

Rectifiers

A rectifier is a device to convert alternating current into direct current. A rectifier has two main components — a transformer and a rectifier. The transformer changes the 110, 220, or 440 volt AC power to the voltage desired. The rectifier element then changes AC into DC. The four types of rectifiers used today are copper oxide, silicon, selenium, and germanium. Listed below are the characteristics of each.

1. Copper Oxide: Used for low voltage (6 volts or less), low efficiency, long life, resistant to power surges, suitable for intermittant service.
2. Silicon: Relatively new, small in size, very long life, good efficiency, not resistant to power surge, suitable for intermittant service.
3. Selenium: Most commonly used, good efficiency, fair life, resistant to power surges, not suitable for intermittant service.
4. Germanium: Relatively new, very long life, good efficiency, suitable for intermittant service, not resistant to power surges.

Rectifiers come with various types of enclosures. This would depend on the type of cooling used and the environment encountered (corrosive, rain, sun, dust, explosive). They are described as air cooled (semi-enclosed and totally enclosed) or oil immersed.

Rectifiers offer several advantages over the sacrificial anode system. They can provide the large amounts of current necessary for protecting long pipelines or well casings. They provide for good control as the current can be checked and adjusted easily. Their main disadvantages are high initial cost and required power availability.

Control Devices

Any cathodic protection system will require devices for controlling current output. In the case of sacrificial anode systems, it will consist of resistance wire, a calibrated shunt and a millivolt meter. When a new sacrificial anode is placed in service it will put out more current than is needed. To conserve anode energy, the resistance wire is placed in the circuit so that the current can be cut back to the desired level.

The calibrated shunt is also placed in the circuit so current measurements can be made with the millivolt meter instead of breaking the circuit to install an ammeter. The shunt is called a Holloway shunt. It is calibrated to a 0.01 Ohm resistance. To calculate the protective current in amperes, divide the millivolt reading across the shunt by ten. There are some inexpensive volt meters calibrated to read directly in amps when used with the 0.01 Ohm shunt.

Impressed current systems are usually controlled by rheostats; however, in a very corrosive environment, resistance wire may be used. Most rectifiers will have a builtin ammeter for checking the current output.

Another way to check the protective current is to measure the potential between the electrolyte and the metal. Using established criteria, it would be possible to tell if the metal was being protected. In enclosed systems, it is usually not practical to measure potential; however, potential measurements are used considerably for buried structures.

In the latter case, it is usually called a "pipe-to-soil measurement." This measurement is made with a potentiometer, or a high resistance volt meter, and a copper-copper sulfate reference electrode. When making these measurements, it is very important to have good contact with both the equipment surface and the soil.

Accessories

Accessories include cable, insulators, connectors, couplings, power poles and other miscellaneous equipment necessary to get the system into operation.

In selecting cable, there are two important things to remember. First, it must be large enough to carry the system's maximum current without offering too much resistance. And second, it must be covered with a good electrical insulating material able to resist the environment. The most suitable cathodic protective cable is insulated with a two layer coat. The inner layer is made of polyethelene. The outer layer is polyvinylchloride. The polyethelene is used for its electrical resistance while the polyvinylchloride provides protection from mechanical damage and chemical attack.

Electrical splicing and splicing insulation are two common weak points in a protective system. A poor connection can cause too much resistance in the circuit. A poorly insulated connection will leak off current, possibly causing the system to be under protected. The current leak will also corrode the connection. There are two very satisfactory methods for connecting wires.

In the first method, the wires are joined by a split bolt or other type of compression device. The joint is then covered with an insulating putty. Then, it is wrapped about three times with an electrical tape. The second method uses a plastic mould. The wires are placed in the mould and an epoxy resin is poured in. When the plastic hardens, it holds the wires in place and insulates the joint.

Some other accessories include insulators (to electrically isolate a piece of equipment), devices for suspending anodes, test stations, lightning arrestors, etc.

APPLICATION

This section will deal with the design and installation of systems in several environments. The two environments most important to us in crude oil producing are soil and salt water. In soil the primary consideration will be flowlines and well casings. Tanks, gunbarrels, water treating vessels, and emulsion treaters will be discussed under water handling vessels.

Well Casings

The protection of well casings is one of the most difficult cathodic protection design problems. First of all, it is almost impossible to detect where and when severe external casing corrosion will occur. Second, it is fairly difficult to determine the amount of current required for protection. Third, equipment and other well casings in the area will affect and will be affected by the system. And fourth, cathodic protection of well casing is fairly expensive.

The first step in design of the system is to determine the current required for protection. There are several methods used to do this. At the present time the most popular method seems to be the combination of surface potential break surveys and downhole potential surveys. However, several other methods are becoming popular — especially for deep wells. All of the methods require elaborate equipment and special techniques.

Ground-bed or anode-bed selection is the second step. To operate most efficiently, we must find the least resistant soil in the area. This is particularly important in west Texas since most of our soil has a high resistivity or resistance to current flow. A soil resistivity survey will be needed.

As a general rule, the soil in an old mud pit is the least resistant soil that can be found around a well. In some cases, one mud pit will be used for two or three ground beds. When the anode bed has been selected the anodes are placed either in a vertical hole or in a horizontal ditch. A granulated backfill is tamped around the anodes. This backfill increases the surface area of the groundbed and extends anode life.

A third step in designing a cathodic protection system is to decide between sacrificial anodes or impressed current. With well casings, there is no decision to make. An impressed current system will be needed because of the high current requirements.

A final step in the design is the selection of the cable size and the electrical connection to be used. In an impressed current system, there are two main cables. One cable connects the anodes with the positive terminal of the rectifier or generator. The other cable connects the negative terminal of the power source and the structure to be protected.

There are several precautions to be observed when installing an impressed current system. When electrical cables are laid in a ditch they should be laid in a curved or "snaked" position. This reduces the possibility of damage to the cable by earth stresses. It is important that all rocks or sharp objects be removed from the ditch so the insulation will not be punctured. If the insulation is punctured, or if one of the joints is poorly insulated, current will leak off causing corrosion of the cable and a loss in protection.

Before putting the rectifier system into operation it is imperative that a check be made to see that the anode cable is connected to the positive terminal of the power source. If the cables were reversed, the system would accelerate corrosion instead of offering protection.

Flowlines

Because the climate is dry, the soil is sandy, and lines are often not buried, flowline corrosion in west Texas is not as common as in some areas. Nevertheless, the combination of caliche beds and sand can cause severe corrosion. The first step is to determine if the protection should be applied to the whole line or just the "hot spots." This can be done using a pipe-to-soil survey and/or a soil resistivity survey. If the pipeline has been coated and wrapped, cathodic protection will usually be applied to the whole line on the theory that no coating is perfect. For bare lines, "hot spot" protection is usually the most economical approach.

The second step will be to decide between sacrificial anodes or impressed current. If "hot spot" protection is all that is needed, sacrificial anodes will usually suffice. If a long section of line is to be protected, impressed current will probably be needed. As mentioned before, such things as power availability, location, operational cost, and initial cost will affect the choice.

The groundbed and electrical hookup for flowlines is about the same as that discussed under well casings.

Of course, flowlines and well casings are not the only subsurface structures that we protect in crude oil producing. For instance, we can protect the external portion of tanks, emulsion treaters, or any other type of equipment which is exposed to corrosive soil conditions. Often these structures can be protected in conjunction with the flowlines or well casings.

Water Handling Vessels

Under this section we will discuss the protection of vessels which handle water. The design of these systems is much simpler than that of well casings or pipelines. Instead of making detailed surveys, current density is usually used as the criterion. For most water handling equipment in crude oil producing, the current density ranges from 7.5 milliamps per square foot to 10 milliamps per square foot.

Larger current densities are needed where the flow rate is high or the water contains oxygen. Final choice will depend on the severity of the corrosion and the type of vessel to be treated. To determine the amount of current necessary to protect a vessel, or one of its compartments, we calculate the surface area exposed to the electrolyte and multiply by the desired current density. Then, using the control devices, each anode circuit is adjusted to the calculated current.

Emulsion Treaters

The emulsion treater has probably been protected by cathodic protection more than any of the other vessels. Both the sacrificial anode system and the impressed current system are frequently used. Usually the impressed current system is cheaper in the long run if a power source is already available. Emulsion treaters require from two to five anodes for protection, depending on their size and type. An anode is installed in each compartment where salt water will contact the vessel. The burner compartment will usually have two anodes — one on each side of the fire-tube or fire-box.

In placing the anodes in the treater, we assume that the anodes will only protect those surfaces of the metal which it can "see." The anodes are attached to the treater through a nipple which has been welded onto the treater. The anode is slipped through the nipple and held in place by a clamp. Care should be taken not to place the anodes too close to the metal surfaces. If placed too close, the anode may short out and the degree of protection reduced. The anodes have an insulated head. This prevents shorting where the anode is secured to the vessel.

It is important to control the current output when sacrificial anodes are used in lease equipment. Since most lease equipment will not polarize enough to reduce current output, the anode would be used up rapidly. This would cause frequent anode replacements which would be uneconomical.

When using carbon anodes in an emulsion treater, it is important they not become oil wet. This will foul the anode and possibly destroy it completely. To prevent this, it is best to soak the anode in a salt brine before it is used. When installing the anodes, make sure they are being placed in water and not oil.

Gunbarrels

Gunbarrels are frequently put under cathodic protection. Usually, a large sacrificial anode is suspended by an electric cable connected to a deck mount. Water storage tanks can also be protected in the same manner. The control devices used for these systems are the same as for emulsion treaters.

MAINTENANCE

Any type of cathodic protection system should be checked every two or three months. In addition, rectifiers should be checked after every power failure or lightning storm. Tables 1 and 2 list a number of problems encountered in maintaining the systems.

Table 1

Sacrificial Anode System

Symptom	Problem	Solution
1. Low current output	Too much control resistance	Adjust length of resistance wire
	Anode wire loose	Replace or rejoin
	High resistance or loose connection	Clean and tighten connections
	Anode surrounded by thick emulsion	Check vessel operation. Relocate anode.
	Anode fouled by oil	Rejuvenate with applied voltage
	Anodes almost expended	Replace
2. No current output	Anode lead wire broken	Replace or rejoin
	High resistant or loose connection	Clean and tighten connections
	Anode surrounded by oil	Check vessel operation or relocate anode
	Anode expended	Replace

3. High current output	Too little control resistance	Adjust length of resistance wire

Table 2

Impressed Current

Symptom	Problem	Solution
1. Low current output	Too much control resistance	Adjust rheostat or resistance wire
	High resistance or loose connection at rectifier or generator	Clean and tighten
	Anode bed dried out	Water down
	One or more anodes deteriorated or disconnected	Check each anode with pipe-to-soil measurements
	Current leaking from insulation breaks in cable or anode connections	Reinsulate
	Installation of pipe-lines or other structures near the system	Isolate the system with insulators or increase the current output
2. No current output	Rectifier fuse blown	Replace
	Main power off	Check with power company
	Circuit rectifier breaker tripped	Check rectifier for overheating
	High resistant or loose connections at rectifier	Clean and tighten
	Electrical cables broken	Check cable ditch for possible damage. Check continuity with Ohm meter
	Rectifier out of order	Inspect and repair
	Generator out of order	Inspect and repair
3. High current output	Too little control resistance	Adjust rheostat or resistance wire

CONCLUSIONS

As can be seen, cathodic protection can be used to control corrosion of crude oil producing equipment in a variety of applications. Equipment being protected includes well casings, pipelines, gunbarrels, emulsion treaters, storage tanks, filters and other water handling equipment. To be effective and economical, the cathodic protection system must be well designed, properly installed and continually maintained.