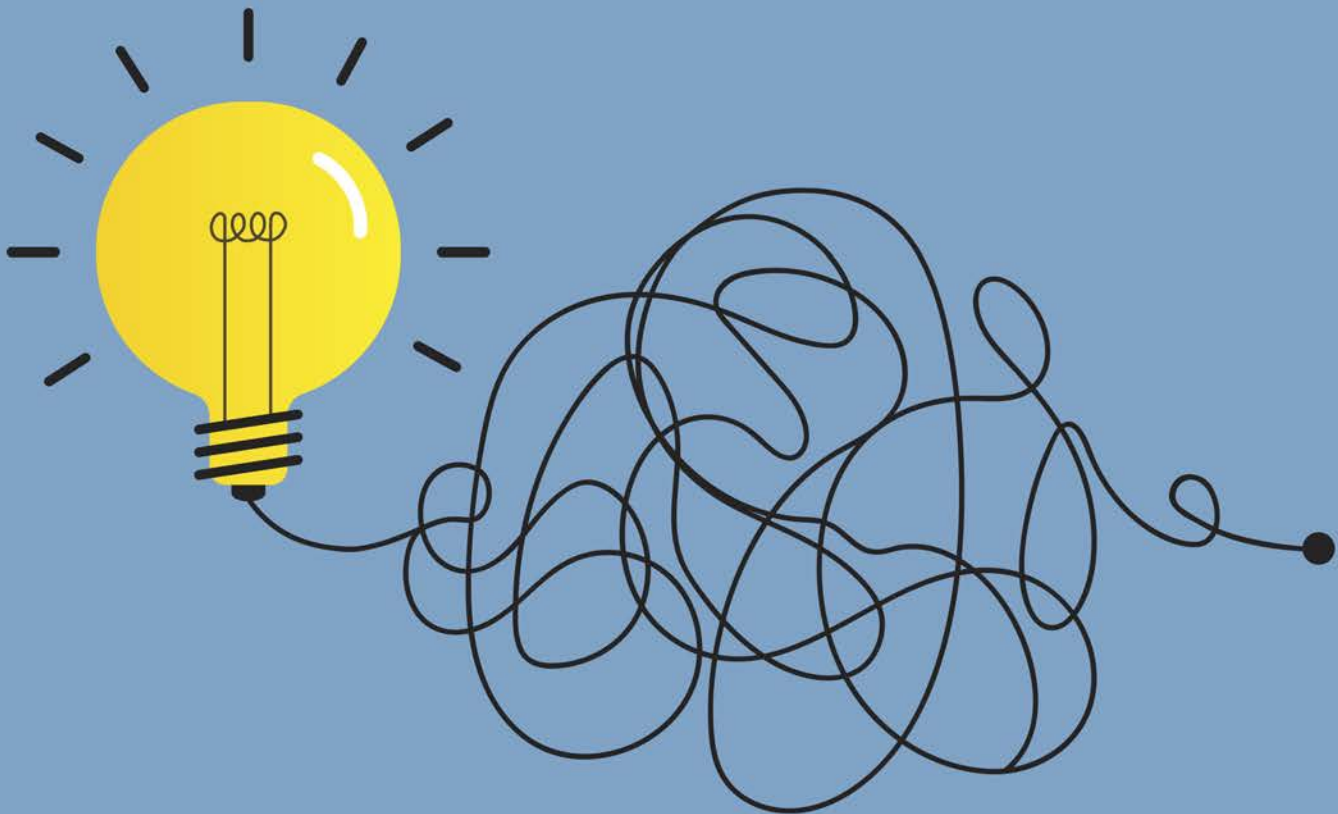
Understanding cathodic protection systems



Ted Huck, MATCOR Inc., USA, explains how to assess the performance of cathodic protection systems.

Cathodic protection (CP) to protect the underside of a tank is considered good engineering practice for large-diameter aboveground storage tanks (ASTs) resting on grade or supported on a prepared sand foundation with a concrete ring wall. Typically installed during the initial tank construction, CP systems are generally designed to last for a minimum lifespan of 20 years, with newer construction tanks utilising longer life mixed metal oxide (MMO) type anodes that can easily last for more than 50 years. These systems, when properly designed, installed, and operated can provide a long service life before needing to be replaced. This article will focus on the simple question: "How do I know if the system is working?"

Figure 1. Anode junction box for tank CP system. A typical junction box with shunts to allow for measuring curent flow to the individual anode rings.

Figure 2. Typical air cooled rectifier – impressed current CP system DC power supply.

What type of CP system do I have?

This is the first question that needs to be asked. In an ideal world, you would have a detailed design package and as-built drawings along with an initial system commissioning report from the original tank construction along with any annual test data that has been maintained since the tank was built. For older tanks, it is quite possible that none of these records exist. Almost all tank bottom CP systems are impressed current type systems – meaning they have a power supply, commonly referred to as a rectifier, that drives current from the anodes to the tank. These are relatively easy to identify because of this. In the very rare event that there is no power supply driving current to the tank CP system, it is possible that you have a galvanic anode-based system – but again these are quite rare for storage tanks of any reasonable size.

Another important question to ask is whether you have a close-coupled dedicated CP system with anodes located directly under the tank foundation. Alternatively, if you do not have a close-coupled dedicated CP system, the other two common configurations are distributed perimeter type anodes and remote deep anodes. It is important to understand how the anodes are configured when discussing a tank CP system's performance.

Most tanks have some form of secondary containment liner, although there are many older tanks that do not utilise any liners. The type of liner in place is another important consideration when assessing your tank bottom CP system. The early tank liners were all non-conductive plastic sheet lining materials that block the flow of current. The only viable CP system for these types of tanks are the dedicated close-coupled systems where the anodes are installed under the tank and above the liner. Over the past decade, there has been an increased use of geotextile clay type liners (GCL). These are conductive and allow the anodes to be placed outside the containment liner and still be able to flow current to the tank bottom.

Finally, when assessing what type of CP system you have it is important to understand what testing provisions exist. This is critical because testing options for AST CP systems are limited to the testing provisions designed with the CP system and the condition of those testing provisions. The most common testing provision is to install reference electrodes at strategic locations directly below the tank bottom during the foundation work prior to the tank being erected. These reference electrodes provide a means of collecting data at fixed points under the tank. Another common testing provision is the installation of potential profile monitoring tubes under the tank. These profile tubes have become very common on new construction tanks, but tanks more than 10 – 15 years old likely did not have these installed. Assuming a conductive GCL type liner construction (or no liner), profile tubes can often be installed using HDD technology any time after the original installation. Some tank operators are starting to incorporate the use of ER probes for measuring instantaneous corrosion rates to see if that information is useful in evaluating and predicting corrosion rates.

How do I know if the CP system is working?

CP is the application of DC current flowing from an anode source, through an electrolyte (typically sand for a tank bottom application) to the tank bottom structure being protected. The simplest way of determining if the system is working is to check the output of the system rectifier or power supply. Is current being discharged from the power supply to the anodes? This is usually a simple matter of visually checking the DC amp meter display on the rectifier itself. If the rectifier has a DC output amp meter and the amp meter is registering DC current flow, that is a clear indication that the CP system is operating. That does not necessarily confirm that enough current is flowing to the tank bottom, but it is confirmation that the CP system is operating and discharging some amount of current.

When DC current is discharged off the anode and flows to the cathode (the structure being protected), the flow of electrons causes the structure to be shifted to a more negative electrical potential – it accumulates a negative charge which is referred to as polarisation. This polarisation starts when the CP system is first energised, and this polarisation increases until it reaches a new equilibrium point, at which stage it is fully polarised. For tank structures it might take months to fully polarise, however, within a few days the structure will typically be sufficiently polarised to begin testing. Likewise, when the flow of current stops, the structure will immediately begin to depolarise. Depolarisation has a different rate than polarisation, but it still may take a week or more to fully depolarise a structure.

Selecting the appropriate CP criterion

A quick grammatical note – criterion is a singular standard or rule by which something is judged. Criteria is the plural of criterion and represents multiple possible standards by which something is judged. In this case we are interested in judging whether the CP system is providing sufficient CP current to stop the corrosion reaction at the tank bottom. It is not possible to completely stop the corrosion reaction; however, if the CP system is operating properly and meeting the appropriate criterion, the corrosion reaction is reduced to such a low rate that for all practical purposes it is considered to have been stopped entirely.

For CP, there are two basic criteria that can be applied. The first is the 100 mV shift potential criterion and the second is the -850 mV OFF criterion. There is also a -850mV ON criterion; however, this criterion is really a slightly reworded version of -850 mV Off criterion and is very difficult to properly apply in the field and as such it is rarely used for tank bottom applications. The 100 mV shift criterion simply requires that there is a 100 mV difference between the polarised off potential and the native or depolarised tank potential. This is a relative criterion in that it requires taking readings of the polarised tank bottom and comparison to a second data set representing the potential without polarisation. The second criterion is an absolute criterion – the off potential readings taken must hit a specific value to meet the criterion.

With both criteria, the term 'off potential' is used – what does that mean? Quite simply, this is the potential that is read with all of the system current turned off. When current is flowing through the system, it creates 'noise' or a 'measurement error' commonly referred to as IR drop. The true reading of the level of polarisation occurs the instant that this noise is turned off, but before the polarisation starts to decay. This is easily achieved by installing an interrupter device that turns the power supply on and off, allowing for readings to be taken with the system on and with the system off. The on readings include the noise of IR drops, while the off readings provide a truer picture of the polarisation of the structure itself without the interference of the noise.

If there are two criteria, which of these is appropriate for tank bottom applications? In most cases, the appropriate one is the 100 mV shift criterion. There are some notable exceptions, the most important of which is the temperature of the tank bottom being protected. Testing has shown that for tanks storing product at elevated temperatures with tank bottom metal temperatures over 30˚C, 100 mV shift is not sufficient and 200 mV shift or more would be appropriate. But for most tanks, the 100 mV shift is the appropriate option to be selected.

Some specifications will require the tank CP system to meet the -850 mV OFF criterion. This is typically a more difficult requirement to achieve and, in some cases, tanks that have more than enough CP to meet the 100 mV shift criterion will not be able to achieve -850 mV OFF. In most cases, achieving -850 mV will require more current than is necessary, wasting power and reducing the useable life of the anode system.

Figure 3. Typical anode installation: concentric ring impressed current CP anodes being installed.

What if my tank is not reaching either criterion?

For most tank CP applications, if the CP system is properly designed and installed, the tank should be able to meet the selected criterion given sufficient time to fully polarise. It is not uncommon for the tank to be 90 – 95% of criterion at all viable test points after only a couple of days of operation, but meeting full criterion might require several additional weeks of polarisation. But there are the occasional tanks that, even with a fully functional CP system that is discharging what should be sufficient current to fully polarise the tank bottom to meet criterion, fall short at one or more test locations.

There are a few things that should be considered, in the event that the system is not fully polarising at one or more test point locations. These considerations are outlined below:

If you are using the -850 mV OFF criterion and you cannot meet that criterion at every test point, consider changing your criterion to the 100 mV shift requirement. This may require taking an additional set of data to provide the depolarised potential reference point but achieving -850 mV OFF for some tanks can be quite difficult. Looking at polarisation shifts might be the more appropriate criterion.

Are the potential readings being taken with the appropriate equipment? The typical voltmeter used by most CP technicians is a handheld digital multimeter. This type of meter typically has a fixed input impedance of 10 Mega Ohm. This may not be adequate for some tanks which characteristically may have very high resistance sand pads. Using a standard digital handheld multimeter could result in readings that are erroneous by as much as 300 mV. The use of a high input or variable input impedance meter or a selectable impedance adapter can allow for an error-free reading. This could be the difference between meeting and not meeting criterion.

Current losses to other structures may be 'stealing' current intended to protect the tank bottom. Using appropriate equipment, an experienced technician can evaluate whether significant amounts of current are being lost to other structures and thus impacting the system's meeting criterion.

Poor performance can be caused by the testing provisions being inadequate, shielded, or damaged. Under tank fixed reference electrodes that provide readings that do not make sense could be damaged or shielded. These reference electrodes are often shipped in a plastic bag – it is imperative that this plastic bag be removed prior to installation. Jobsite trash or debris laying over the top of a potential profile tube could result in erroneously low readings along part of the profile tube. Profile tubes with blocked micro slots are also prone to providing poor or inaccurate readings.

Poor quality or dissimilar sand being used on the foundations can lead to significant performance issues. It is important that tank foundations utilise very similar sand that comes from a single source and with similar moisture content. If dissimilar sands are used or some areas are backfilled with a native soil to make up for an insufficient quantity of the specified sand, the CP system may not be able to fully polarise some areas of the tank with the dissimilar base materials.

Another cause of CP systems not meeting criterion is the 'oxygen as a polariser' diagnosis. This has to do with the use of bare mixed metal oxide (MMO) anodes in sand. Typically, this is common with the Grid™ type arrangement where anode ribbon is placed in one direction and titanium conductor bars are run at 90° angles and welded at every point of intersection. These systems have a decent track record, but in some rare cases they are found to not be able to reach a sufficient polarisation level – and adding more current does not seem to help. The primary electro-chemical reaction for bare MMO in sand creates oxygen. Unfortunately, oxygen is a strong natural depolariser and if the oxygen is concentrating at points under the tank bottom at the metal surface, it could be negating the impact of the CP. In these cases, if you increase the amount of CP current being generated to meet your polarisation criterion that also results in more depolarising oxygen being generated.

Summary

Assessing the performance of your tank bottom CP system is generally a rather simple exercise provided sufficient time is allowed for the tank to polarise and in some cases depolarise, and the appropriate criterion is used. If the tank CP system is operating as intended and can discharge sufficient current, then it should be able to meet one of the accepted criterions. For those rare tanks that have a seemingly properly operating CP system and are still not meeting criterion, then further investigation is certainly warranted. Enlisting the services of someone experienced in diagnosing tank CP systems is often necessary in these cases.