In many locations cathodic protection is mandated, and in the absence of legislation it is still often dictated by good engineering practices

Protecting storage tank bottoms

Controlling corrosion risk is critical to maintaining the integrity of aboveground storage tanks (ASTs) and maximising their service life.

Cathodic protection (CP) is typically applied to all ASTs built on a ring wall foundation to protect the external tank bottom in contact with the soil/sand foundation. It is not as relevant for smaller tanks built on concrete slab foundations.

Galvanic versus impressed current

Historically, various configurations of galvanic anodes, including discreet anodes and ribbon type anodes, have been used to protect AST bottoms. Experience has shown that these systems do not provide the uniform current distribution necessary over the entire CP system design life and result in premature failure as the galvanic anodes consume. ASTs require significant current, which generally precludes the use of galvanic anodes. Almost all AST CP systems today are designed with impressed current systems to provide the current required over a long period of time.

Design information

The following information is required to develop a CP design for ASTs:

Tank diameter
This is necessary to calculate the surface area to be protected.

Tank bottom coating
Typically tank bottoms are bare plate steel, but in some cases the plate steel may be coated on the bottom, which reduces the current required for cathodic protection. CP is still recommended for tanks with coated bottoms.

Installation of concentric Matcor SPL-FBR anode rings

Current density required
Typical design current density requirements of 1 mA/ft2 (10 mA/m^2) are sufficient to achieve NACE criteria for cathodic protection (see discussion on operating temperature).

Depth of anode
The separation distance between the anode and the tank bottom affects current spread and anode spacing.

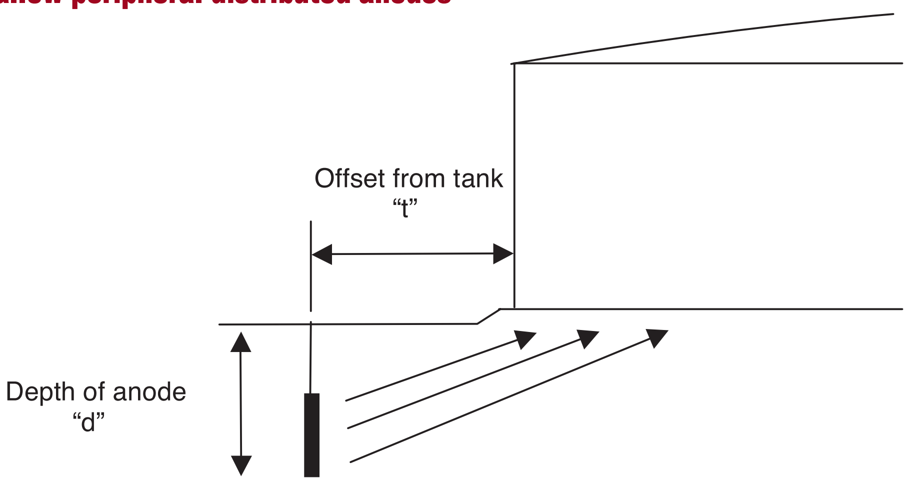
Sand/soil resistivity
This information is necessary to estimate overall system resistance necessary to properly size the rectifier voltage. In many cases, it may make sense to install the anode system and test the actual circuit resistance using a portable rectifier or car battery before committing to a specific rectifier size.

Tank operating temperature
Corrosion rates increase significantly with elevated temperature, necessitating more current. Typically the following temperature correction formula is used for CP designs for heated tank bottoms: for every 10°C above 30°C the current requirement increases 25%.

Area classification
Rectifiers and junction boxes must be designed with suitable enclosures for the area classification where they will be installed. Often, these can be located in non-classified areas with minimal additional cost of cable while saving significantly on the cost of the enclosures and classified components.

Secondary containment liners
If polyethylene or other such plastic liners are to be placed underneath the tank, these liners act as a barrier to the flow of current and the anodes

Shallow peripheral distributed anodes



must be placed between the liner and the tank bottom. If Claymax or other conductive type liners are to be used, the anodes do not have to be placed between the liner and the tank bottom.

Design life
Typical design life for new construction ASTs is 25 to 30 years. It is important to note that the actual operating life of ASTs often exceeds this value and depending on the design of the tank, its location, and the selection of a containment liner. Replacement of the CP system may be difficult to impossible so some consideration should be given to the economic value of extending the design life. For a typical concentric ring MMO/Ti linear anode configuration, the incremental anode cost to go from 30-year design life to 50-year design life is approximately 25% additional anode cost, with no increase in installation costs, making this a very attractive alternative.

CP configurations for new construction ASTs

Shallow distributed anodes around tank periphery
One common design approach to AST bottom CP is to install a shallow distributed point anode system around the periphery of the tank. These are typically augured in to depths of five to 10 feet. This design approach only works when there is no electrically isolating secondary containment liner under the tank.

For these designs, the critical issue is assuring that sufficient current reaches the centre of the tank. Above ground storage tank bottoms are large bare surfaces requiring a lot of current. To assure that current distributes properly, the anode depth and distance from the tank are critical. Shallow peripheral anodes are not able to throw current to the centre of all but the smallest of ASTs.

This approach is generally not recommended for ASTs with tank diameters exceeding 20 ft (6m) due to the quantity of anodes required and the risk of poor current distribution to the centre of the tank.

Deep well anode systems
This approach is based on using one or more deep well anode systems located well below the tank bottom to provide current uniformly to the tank bottom. This approach has some limitations in heavily congested plant or terminal environments where current can flow to other buried structures. When multiple deep wells are employed to protect more than one tank in a cluster, care must be taken to assure proper current distribution.

As with any deep well, there are concerns with drilling (typically 150+ feet to bottom of hole) including access issues for a drill rig, environmental concerns, permitting and handling of drilling spoils. Even with a deep well approach, when dealing with new construction, reference electrodes should be installed under each tank.

Many operators prefer a close coupled dedicated CP system for each tank rather than the blanket coverage afforded by a deep well system.

Should the design for the new construction tank use a containment liner that shields current (i.e. polyethylene liner), the deep well anode system cannot be used.

Distributed anodes below tank bottom
While not as common today, many older designs used individual anodes laid horizontally along the tank bottom and connected parallel to header cables exiting the ring wall. The economics of this design, both in terms of installation costs and material costs, are not favourable and this design has been dropped in favour of either a grid system or linear anodes in a parallel concentric ring arrangement.

MMO ribbon matrix system
This configuration involves laying out parallel titanium conductor bars and then running mixed metal oxide (MMO) ribbon anode perpendicular to the conductor bars. The MMO

Completed installation of anode rings prior to backfilling

Horizontal directional drilling under an existing AST to install a leak detection tube and reference electrode assembly rings prior to backfilling

ribbon anode is field spot welded to the titanium conductor bar to provide both mechanical and electrical connections. Wherever the titanium conductor bars cross, they too must be field welded together. Power feeds (preassembled cables with a flat plate to connect to the conductor bar) are secured to the titanium bar in multiple locations and routed to the ring wall penetration.

This system is a labour and QA/QC intensive installation process requiring significant field welding and on-site testing to assure electrical continuity. The attachment of the power feeds to the titanium grid is critical to the system reliability. From a design perspective, the spacing of the anodes and conductor bars must be sufficient to assure even current distribution. In competitive situations, the temptation is to increase the spacing to reduce the materials costs.

Concentric ring systems

Unlike the ribbon matrix system, the concentric ring linear anode system for AST tanks can be factory assembled to eliminate the need for any field fabrication, which greatly simplifies installation and reduces QA/QC issues, eliminating field welds and power feed connections that are relied upon with the matrix system to assure electrical continuity and system integrity.

The principal advantage of the linear system is that everything under the tank is factory assembled and tested prior to installation and the only installation effort is to lay the anode assemblies in accordance with the design drawings and installation instructions. This provides for an exceptionally simple installation while assuring the highest system reliability; installation costs are minimal.

There are two primary configurations for linear anodes under tank bottoms. The parallel linear anode arrangement has multiple parallel anode segments, which are fed from each end of the anode. The anode connections are field spliced to loop cables, which terminate at two anode junction boxes.

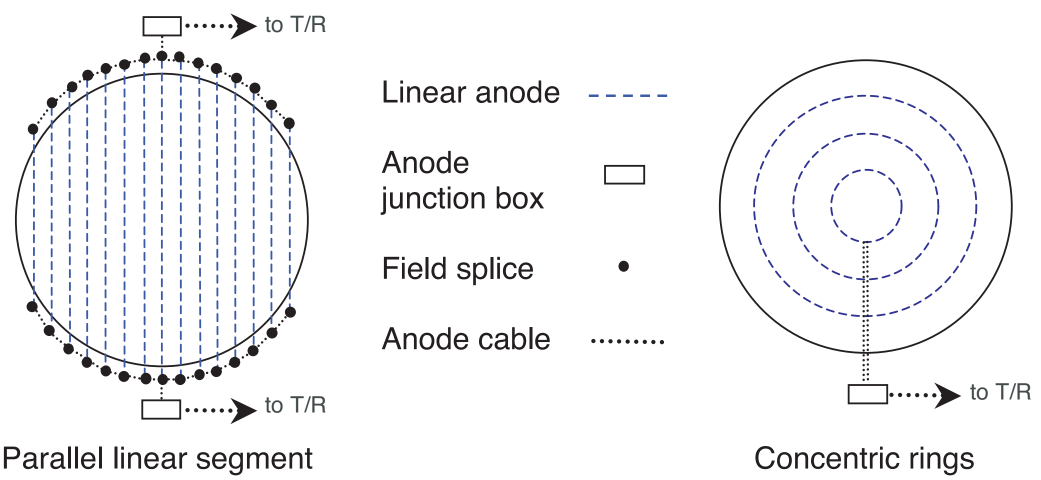
The use of concentric rings offers two key advantages over parallel anode segments. The first advantage is that this configuration does require junction boxes on both sides of the tank, thus eliminating one of the anode junction boxes and reducing the cabling required to run from two anode junction boxes back to the transformer/rectifier unit. The second key advantage to this configuration is that it eliminates the need for two field splices for each anode segment. Each ring can be manufactured with the appropriate length of header cable to run each end directly to the single anode junction box. These field splices are weak links subject to premature failure over the life of the anode system.

As with any system, spacing between anode segments is another key design element. Matcor's experience with ring configurations is extensive and it has determined through numerous installations and its own in-house testing that for tank bottom applications with bare bottom plates and an anode depth of 1 foot, concentric rings with a spacing of 10 feet provide thorough current distribution. When the anodes can be placed deeper than 1 foot, the anode spacing can be extended. Based on the 1 foot depth, typical ambient temperature tanks can be protected for 30+ years with 16 mA/ft linear anode, while a 50+ year design life is typically achieved with a 25 mA/ft rated anode with a modest 25% increase in the anode cost.

Provisions for testing

With any CP system for tank bottoms, it is critical that provisions for testing be installed with the anode system. Once the tank is

Linear anode configurations



erected, making accurate potential measurements at various locations along the tank can only be accomplished if reference electrodes have been installed below the tank. Typically, copper-copper sulfate (Cu-CuSO4) reference electrodes are installed in strategic locations underneath the tank.

These reference electrodes are often mistakenly called permanent reference electrodes; however, they are not permanent as over time the copper-copper sulfate solution becomes contaminated and ceases to provide accurate information. Once a baseline for performance is established over a sufficient operating period, maintaining the appropriate current output to achieve NACE criteria is all that is required.

In some cases, clients may also specify dual reference electrodes such as both zinc and copper-copper sulfate. While the zinc reference electrodes are not as consistent, they provide a much longer operating life and can be calibrated against the copper-copper sulfate electrodes.

In addition to the fixed reference electrodes, it is also common to provide a reference electrode tube/conduit underneath the tank bottom to allow sliding of a calibrated reference electrode through the monitoring tube to take potential readings. These can also function as leak detection tubes.

CP configurations for retrofit applications

Provisions for testing

When installing new tanks, the standard industry practice is to install reference electrodes and leak detection monitoring tubes approximately 4-6 inches from the tank bottom before the final layer of sand cover is placed.

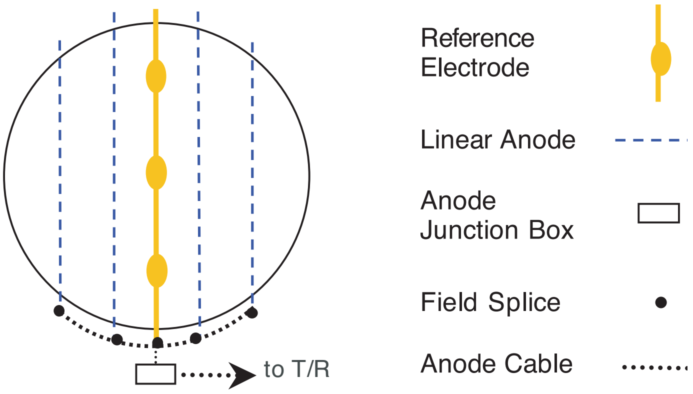
The reference electrodes are necessary so that the CP system can be tested to assure that the entire tank bottom is being properly protected and to adjust the system output for optimum operation.

Retrofit projects, however, are not so simple. The challenge with retrofit installations is that it is not possible to test the potential of the tank, except at the periphery, without having some sort of reference electrode directly under the tank. Standard industry practice is to use horizontal directional drilling (HDD) to install leak detection and fixed reference electrode assemblies under the tank. The leak detection and monitoring tubes consist of slotted or drilled/perforated pvc tubes with reference cell assemblies that can be pulled under the tank.

For small diameter tanks (less than 20 foot), testing around the perimeter of the tank is sufficient and it is not necessary to install reference electrodes directly under the tank to assure proper cathodic protection, but Matcor cannot recommend that for larger tanks prone to poor current distribution. If Matcor cannot test the CP system's performance there is no reason to have a system.

It is good engineering practice to install monitoring tubes and reference electrodes under the tank using HDD. This provides the only means of assuring that the CP system is providing thorough coverage across the entire tank profile.

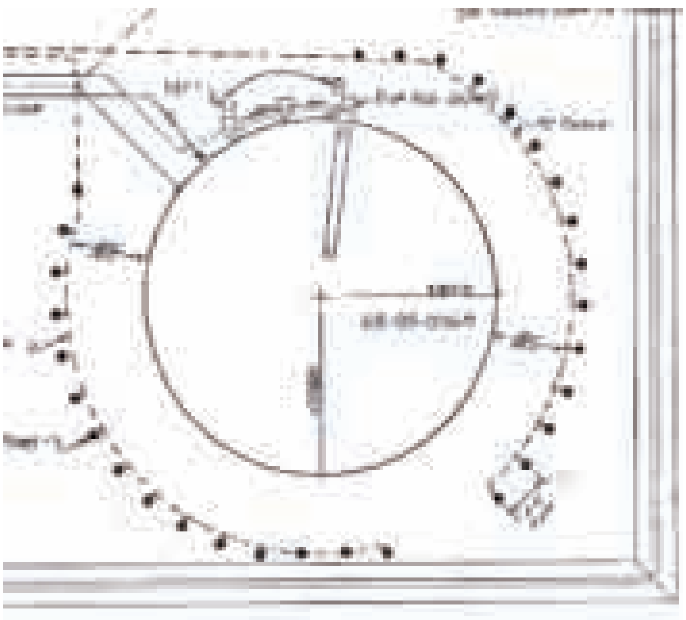
Linear anode and reference electrode design



Linear anodes installed below tank bottom

When installed in conjunction with fixed reference electrodes and leak detection monitoring tubes, linear anodes placed directly beneath the tank bottom provide the highest degree of design certainty. With the anodes directly below the tank bottom, stray current concerns are minimised and thorough current distribution across the entire tank bottom is assured.

Common design from the 1970s



Shallow distributed anodes around tank periphery

One tempting design approach to retrofit AST bottom CP is to install a shallow distributed point anode system around the periphery of the tank. These are typically augured in to depths of 5-10 feet. Unfortunately shallow distributed anodes often fail to provide sufficient current to the centre of the tank.

Above ground storage tank bottoms are large bare surfaces requiring a great deal of current. To assure that current distributes properly, the anode depth and distance from the tank are critical. Shallow peripheral anodes are not able to throw current to the centre of all but the smallest of ASTs.

As with new construction ASTs, it is generally not recommended to install shallow peripherally distributed anodes for ASTs with tank diameters exceeding 20 ft (6m) due to the quantity of anodes required and the risk of poor current distribution to the centre of the tank.

Deep well anode systems

Deep well anodes are often a viable solution for existing ASTs, however care must be taken to assure that current from the deep well anode system is not causing interference with nearby buried structures. It is also very important to note that deep well anode systems will not provide current to tanks protected with containment liners that shield the tank bottom such as plastic sheeting materials.

Maintenance and inspection

Annual testing and inspection of any tank CP system by a qualified NACE CP level 1 or higher technician familiar with testing CP systems for ASTs is advised. As with any impressed current system, monthly rectifier checks should be performed by plant maintenance to assure that the rectifier is on and that the voltage and current outputs remain stable.

For more information:
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