Cathodic Protection of Above Ground Storage Tank Bottoms

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ABSTRACT

The corrosion of steel containment vessels in contact with soil and water is a natural phenomenon that must be arrested to provide for public safety and environmental protection. Cathodic protection is a proven technology for controlling corrosion on the bottoms of above ground storage tanks. This paper addresses various options for cathodic protection of the external (groundside) surfaces of tank bottoms which are in contact with sand pads or native soil. Advanced application techniques are described for both existing tanks and new construction with secondary containment.

BACKGROUND

Cathodic protection is a proven method of controlling corrosion of buried, partially buried and submerged metallic structures. A properly designed, installed and operated cathodic protection system will eliminate the corroding areas by passing direct current to the metal surface. The direct current is discharged from electrodes installed in the electrolyte adjacent to or near the structure being protected. In this manner, corrosion is arrested when the direct current is of sufficient magnitude and is properly distributed over the entire surface to be protected.

There are two basic types of cathodic protection systems which can be used to arrest corrosion. One type of cathodic protection system is referred to as a galvanic or sacrificial anode system. The galvanic anode system is based upon the natural potential difference which exists between the structure being protected and the auxiliary electrode (anode) which is installed in the electrolyte. As a result of the potential difference, a battery effect is created and electrical current flows from the anode through the electrolyte to the structure. Materials which are commonly used for galvanic anode systems are magnesium, zinc and aluminum.

Another method of cathodic protection uses anodes in conjunction with an external D.C. power source. This type of cathodic protection system is known as an impressed current system. The anodes are installed in the soil or water and are connected to the positive terminal of a D.C. power source such as a rectifier. The structure to be protected is connected to the negative terminal of the power source and electrical current is forced to flow from the positive terminal to the anodes through the electrolyte to the structure. This type of cathodic protection system uses long life anode materials such as high silicon chromium cast iron, graphite, and mixed metal oxide coated titanium.

There are numerous publications that discuss the principles of corrosion and the application of cathodic protection to prevent corrosion of steel in contact with earthen environments.[1,2] Cathodic protection is not a new corrosion control technology. The first documented application dates back to the early 19th century.

Each of us has a cathodic protection system in our homes. The zinc or magnesium rod installed in domestic hot water heaters is a cathodic protection anode which provides protective current to the submerged steel surfaces. The number and/or dimensions of the anode has a direct bearing on the length of the manufacturer's warranty,-i.e. the longer the anode life, the longer the warranty.

Cathodic protection is an established technology for economically preventing leaks. It is required by the EPA for protecting underground steel tanks3, and by the DOT for protecting underground **pipelines.**[4] In addition, API has recently published Recommended Practice (API RP 651) for "Cathodic Protection of Above-Ground Petroleum Storage Tanks."

EXISTING TANKS

Cathodic protection for corrosion control of existing tank bottoms has been applied using a variety of approaches with varying degrees of success. The use of sacrificial anodes is typically limited to those applications where the tanks are of small diameter and where they are electrically isolated from other underground metallic structures. Impressed current systems have been used where more protective current is required and where a longer system life is desired.

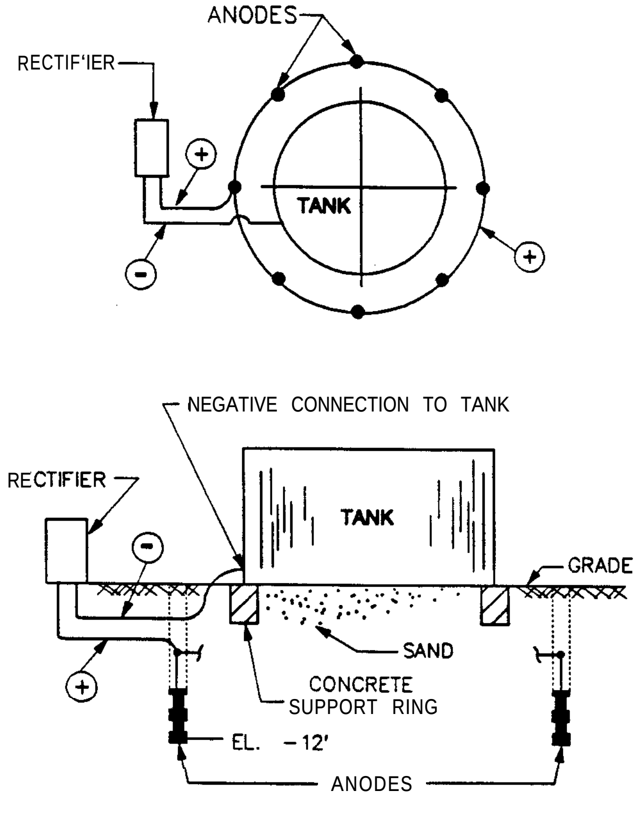

Figure 1

Distributed Anode System

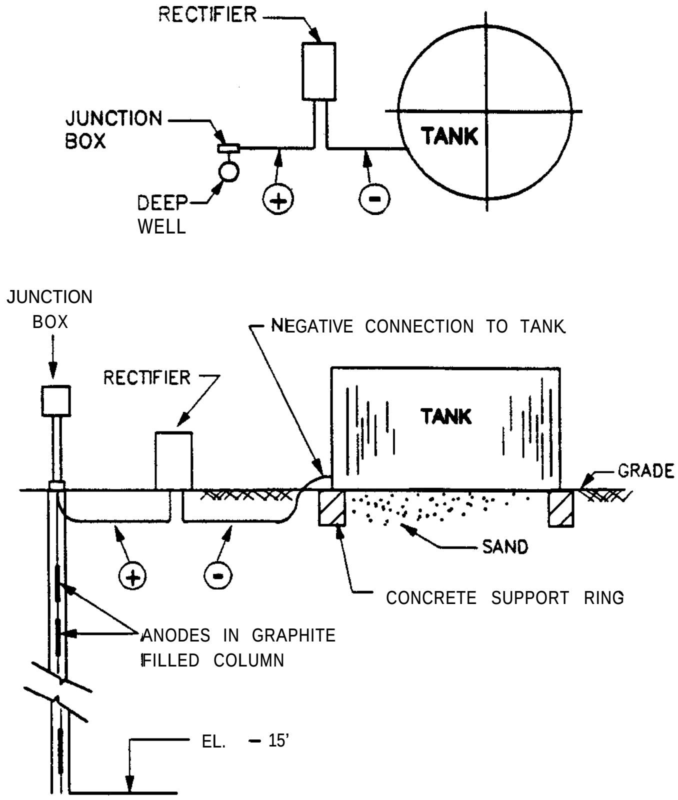

figure 2

Deep Anode System

Several different types of anode installations to distribute the protective current to the tank bottom are possible:

- Horizontal or vertical anodes distributed around the periphery of the storage tank (Figure 1).
- Deep anode systems in long, vertical columns (Figure 2).
- Angle drilled anode systems extending the anodes under the tank bottom (Figure 3).

The standard method for determining the effectiveness of cathodic protection is the tank-to-soil potential measurement. These measurements are performed using a high impedance voltmeter and a stable, reproducible reference electrode contacting the soil.

The natural potential of a carbon steel tank in contact with the soil is usually on the order of -0.540 volts when measured with respect to a copper/copper sulfate electrode (CSE). Values which are more positive are typically indicative of steel structures which have

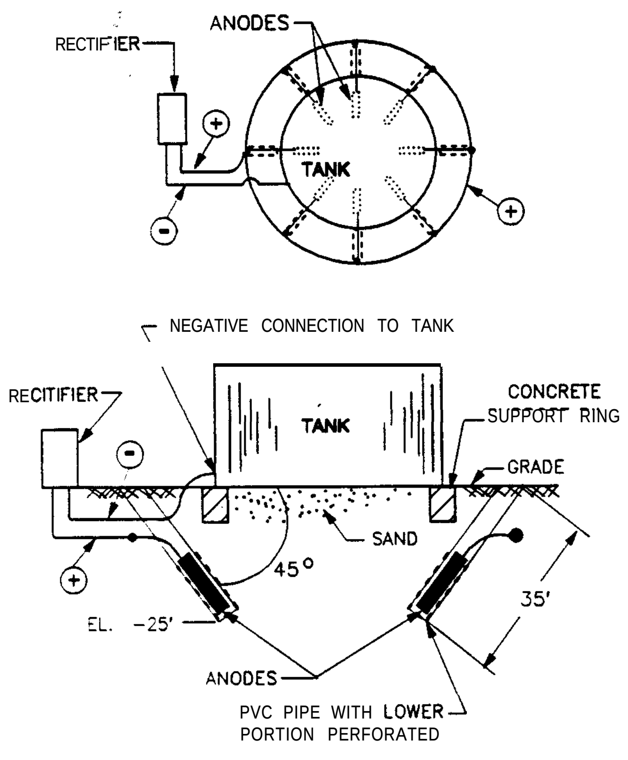

Figure 3

Angle Drilled Anode System

undergone corrosion, while values more negative are indicative of new, well coated structures or a structure which is under the influence of cathodic protection.

A tank is considered to be effectively protected when a potential measurement at least as negative as -0.850 volts CSE is obtained (one of several accepted criteria)[5]. For a true representation of electrical potential measurements, the reference electrode is to be placed as close as possible to the tank bottom.

The problem associated with monitoring cathodic protection systems on tank bottoms is the inability to place a portable reference electrode in close proximity to the underside. Most of the testing in the past has relied upon readings which have been taken at the perimeter of the tank. The placement of the reference electrode at the tank rim may yield erroneous results because of potential gradients created in the soil as a result of the current discharge from the anode. This is particularly true when using distributed anodes installed along the periphery of the tank.

In certain cases, it has been determined that potential measurements at the perimeter satisfy one of several criteria, but as the reference cell is advanced towards the center of the tank, the potentials become more positive to the point where little if any potential shift is measured, thus indicating a lack of effective corrosion protection at the center. For 120 foot diameter tanks protected by distributed or deep anode systems, it is not unusual for the potential at the center of the tank to be on the order of 300 millivolts less negative than at the tank rim. However, the angle drilled application technique overcomes this problem by evenly distributing the current along the tank bottom.

Experience with various application techniques for cathodic protection of existing tank bottoms has established that:

- Tank-to-soil potential measurements obtained at the perimeter of the tank do not indicate actual cathodic protection levels at the center, particularly on larger diameter tanks.

- Potential measurements at the center of the tank and at other areas under the tank are necessary if tank bottom cathodic protection levels are to be accurately evaluated. This can be accomplished by boring perforated pipe under the tank for reference cell access (Figure 4).

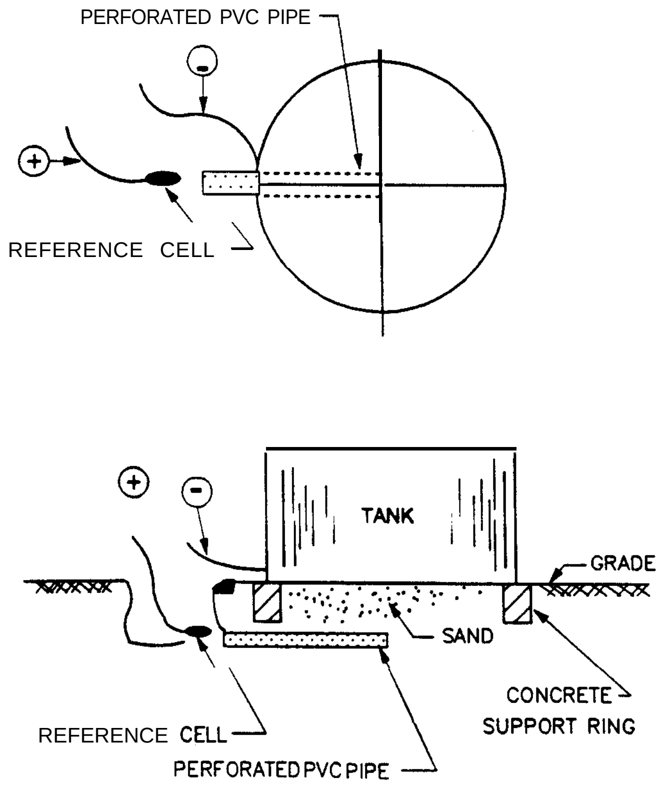

Figure4

Monitoring System for Existing Tank

* When testing, the liquid level in the tank must be sufficiently high to create intimate contact between the tank bottom and the pad. Empty tanks usually result in erroneous test results.

* Certain types of cathodic protection designs may not be effective in providing adequate cathodic protection to the tank bottoms in certain areas.

* An improved design for existing tanks uses slant or angle drilling techniques to locate anodes under the tank bottom (Figure 3). This distributes the current to the center and overcomes the tendency for most of the current from distributed or deep anodes to flow to the tank perimeter.

NEW CONSTRUCTION

For new construction without secondary containment, conventional cathode protection anodes can be distributed under the tank bottom (Figure 5) to optimize the distribution of cathodic protection current. At the same time, permanent reference cells can also be placed at the center of the tank (Figure 6) to provide for accurate system adjustment and monitoring.

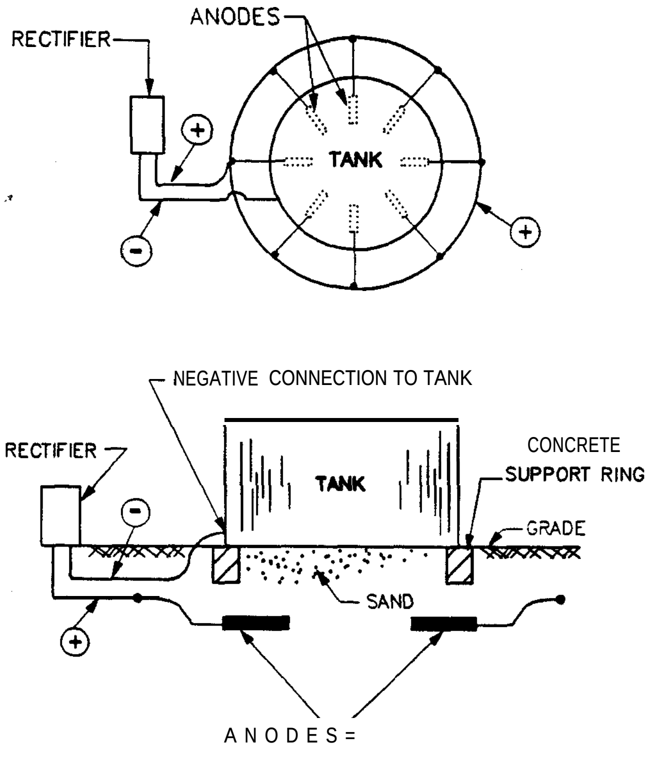

Figure 5

Conventional Anodes Under Tank

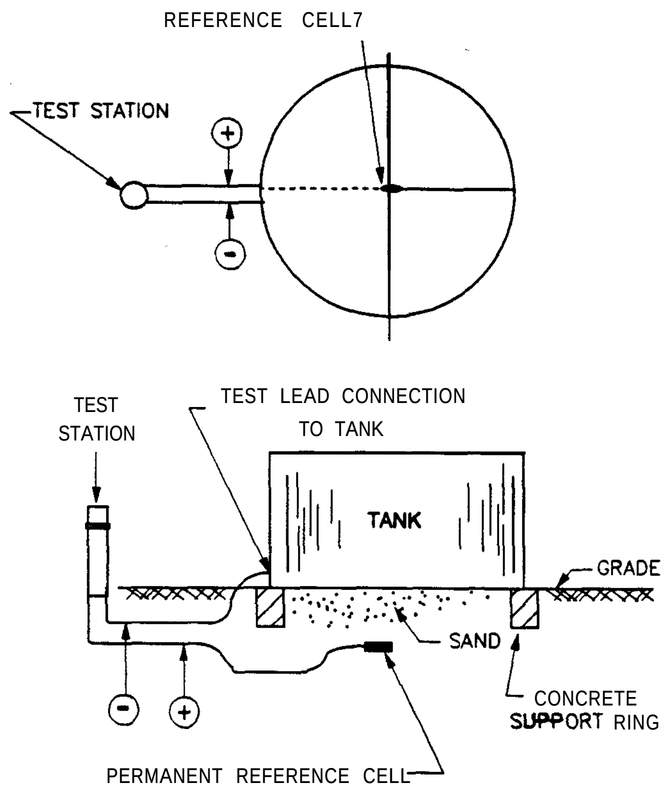

Figure 6

Monitoring System for New Tank

Many new tanks are now constructed with secondary containment liners typically made of 60 mil thick high density polyethylene (HDPE) installed six to twelve inches under the tank. Since HDPE has a high dielectric strength, the liner would prevent protective current from reaching the tank bottom using conventional cathodic protection anode configurations.

Sacrificial anode systems using zinc or magnesium ribbons or rods have been previously used for cathodic protection. These are placed between the liner and the tank bottom but generally suffer from limited system life.

It was desirable to develop a new impressed current cathodic protection technique that would have the current capacity for large diameter tank bottoms and that could be designed for an operating life of up to 50 years. An economical system design was therefore developed using mixed metal oxide coated titanium ribbon. The ribbon is linearly extended in strips above the secondary containment liner. Titanium conductor bars are resistance welded perpendicular to the ribbon to form an anode grid (Figure 7). The grid evenly distributes current to the tank bottom through multiple power feeds. It can be placed as closely as four inches to the tank bottom and still maintain proper protection levels, even with the ribbon spacing extended to six foot centers (Figure 8). Because of the even current distribution provided by this design, current requirements for cathodic protection of the tank bottom are reduced, which in turn reduces the operating costs over the life of the system.

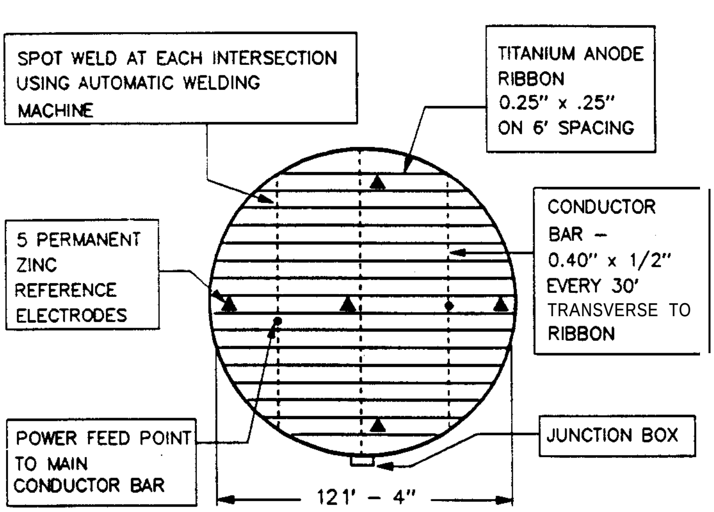

Figure 7

Titanium Anode Grid

Testing of the anode grid systems on a number of tanks has clearly established that:

* Cathodic protection is required for corrosion protection of tank bottoms with secondary containment liners. Even if the liner is perfectly sealed at the ring wall, condensation forms on the tank bottom due to temperature differentials. This results in a corrosive environment.

* The titanium anode grid system provides excellent levels of corrosion protection at reduced operating costs.

* With only factory sealed electrical connections under the tank, the probability of system malfunction due to splice failure is negligible.

* System designs can satisfy design life requirements of up to 50 years.

CONCLUSION

The application of cathodic protection is an economical and effective means of controlling corrosion on tank bottoms. The success of the cathodic protection system is dependent upon proper design, selection of installation type and effective monitoring.

For existing tanks without secondary containment liners, angle drilled impressed current anodes have been proven to be the best approach. Access to the center of

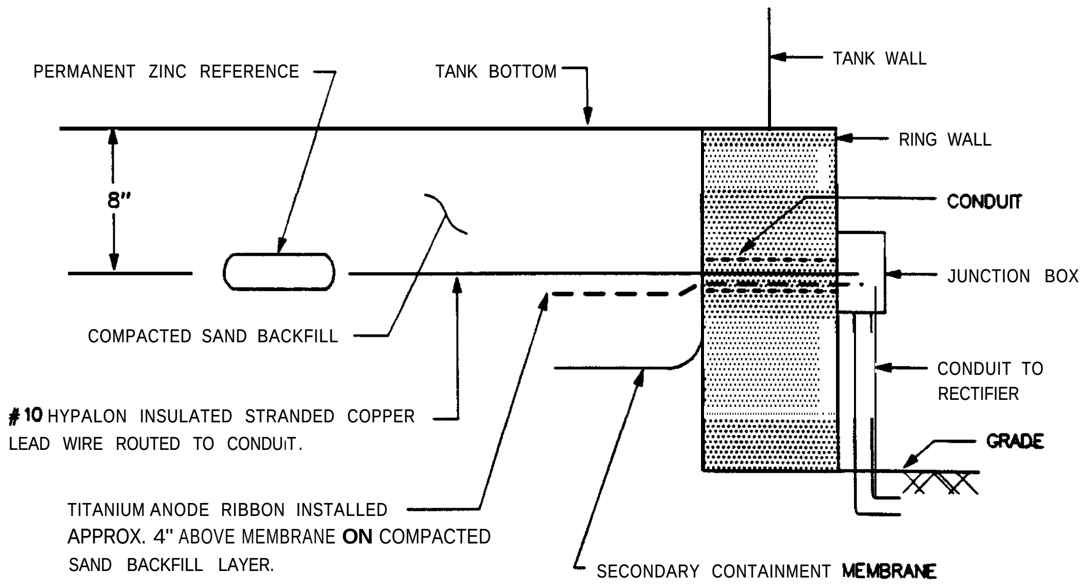

Figure 8

Anode Grid Cross Section

the tank for system testing should be provided by the simultaneous installation of slotted pipe.

For new construction with HDPE secondary containment liners, the preferred application technique uses a titanium anode grid. Accurate cathodic protection monitoring can be achieved by including the installation of one or more permanent reference cells.

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4. Department of Transportation, Title 49, Code of Federal Regulations, Parts 192 and 195, as amended June 30, 1971.
5. National Association of Corrosion Engineers, Recommended Practice RP-01-69, "Control of External Corrosion on Underground or Submerged Metallic Piping Systems," revised 1983.