Cathodic Protection Applications for Aboveground Wastewater Storage and Treatment Tanks

Jeffrey A. Schramus
Cathodic Protective Systems Co., 3005 South 76th Ave., Bridgeview, IL 60455

Large tanks containing up to three million gallons (11,360 m³) of process waste water from agricultural chemical production facilities have been internally protected. Some tanks contain process waste water with organic solvents. Others are used to store waste water prior to treatment. Proper design and operation of cathodic protection is critically dependent on the condition of the tank’s internal coating and the characteristics (pH and conductivity) and degree of organic contaminants in the waste water.

The U.S. Environmental Protection Agency (EPA) has issued regulations under the Resource Conservation and Recovery Act (RCRA). Any RCRA treatment, storage, and disposal facility that may have, has had, or is having a release of any chemical listed by RCRA must be cleaned up according to the EPA standards.

As a result of the regulations, many companies are now minimizing their potential liability and meeting the requirements for surface water treatment and pretreatment to eliminate their obligations under RCRA. Surface impoundments and lagoons are being eliminated, and aboveground wastewater treatment and storage tanks are taking their place. Corrosion control for these facilities is now an important consideration for environmental control and compliance. If a corrosion failure occurs, a company could face significant liability. An example of two projects that use cathodic protection (CP) for corrosion control at agricultural chemical wastewater treatment and storage facilities are discussed.

Tank Structure
Design Considerations

Case 1

The first case is a group of three agricultural wastewater treatment tanks. Data for these tanks’ capacities and their dimensions are shown in Table 1.1. Although these tanks are similar in their configuration, the smaller of these tanks (No. 3) will be the focus of this case example.

Design criteria required that a CP system be installed to protect the submerged interior of the vessel. The tank is currently an open-top structure, but a roof may be installed at some future date. Therefore, any components of the CP system that would be routinely inspected or tested would have to be installed on the exterior of the tank.

Because the vessel was newly constructed, a high-quality tank lining was installed. However, the CP system would be required to compensate for lining degradation over the tank’s intended design life. In addition, the waste water would be contaminated with organic compounds requiring specific CP system components with high resistance to organic solvents. Finally, due to varying volumes of process waste water within the vessel, a potential-controlled rectifier was to be installed that could automatically adjust the CP system’s output to maintain a constant tank-in-water potential under varying wastewater levels. The rectifier would comply with National Electric Code Article 500 for classified hazardous locations.

The tank contains an impressed current CP system with the following major components (Table 1.2 and Figures 1.1 through 1.8):
- Pad-mounted, oil-immersed, automatic potential-controlled rectifier with a maximum output of 90 A at 35 V;
- Nine tubular mixed metal oxide-ceramic titanium anode strings suspended from stainless steel cables.

MPA August 1990
that are anchored to the inside walls of the tank.

- Three permanent dual copper/copper-sulfate and zinc reference electrodes suspended within the tank.

The tank also contains a supplemental sacrificial anode CP system. Sacrificial zinc ribbon anodes have been attached to stainless steel mounting plates welded to the tank bottom. The zinc anodes were designed to provide supplemental CP to the tank bottom during periods of low water within the tank (a delay will automatically de-energize the AC service to the impressed current rectifier during periods of low water). Twelve anode ribbons are located within the tank and have been spliced to a common header cable for connection to the tank at a junction box mounted at the rectifier.

Case 2

The second case consists of two similar underground wastewater treatment tanks. Data for the tanks’ capacities and their dimensions are shown in Table 2.1.

The CP system installed within these vessels is a rehabilitation of a previous corrosion control system that was installed after the tanks’ construction in the mid 1970s. Similar design constraints were present for these tanks as were posed for Case 1. Specifically, the system had to be routinely tested and inspected from the exterior of the tank. However, as the tanks were not newly constructed, the CP systems had to be retrofitted to existing structures that would not be lowered. Because the previous platinum/nickel wire anode system had failed, an alternate anode material was selected. High dissolved oxygen concentrations and the extreme turbulence of the waste water inside the bare steel tank interior dictated a durable anode material. Testing of a mixed oxide anode indicated that a nodular porosity was possible; therefore, a high silicon, chromium cast iron anode was chosen. An automatic potential-controlled rectifier was also selected to maintain a constant tank-to-water potential level.

The tanks contain an impressed current CP system with the following major components (Table 2.2, Figures 2.1 through 2.3):

- Pad-mounted, air-cooled, automatic potential-controlled rectifier with a maximum output of 150 A at 28 V
- Twenty high silicon, chromium cast iron anodes suspended from stainless steel cables that are anchored to the inside walls of the tank and
- Three permanent dual copper/copper-sulfate and zinc reference electrodes suspended within the tank.

Other Considerations

Since each of these tanks is nearly 30 ft (9.1 m) in height, the installation of these systems required a crane and an equipment basket to lower both the men and equipment into the vessels. Scaffolding was installed in the wastewater tank; however, the presence of the air intake headers precluded scaffolding in the aerated tank.

The presence of significant amounts of organic vapors from the agricultural waste water as well as the concentrations of organic solvents in these tanks necessitated that polyvinyl chloride-based materials not be used. All reference electrodes were specially fabricated from polypropylene tubing as were the support ropes that were used to hang the components from the stainless steel suspension cables. Polyethylene sheathing was also used on the mixed metal oxide anode cables to minimize possible degradation of the ethylene-propylene-chlorosulfonated polyethylene wire insulation. Type 316 SS (UNS S31600) hardware was used to secure the suspension cables to the inside of the tank walls.

Results

Case 1

Following the conditioning of the tank, the rectifier was energized and the unit's automatic potential controller was adjusted to achieve a maximum tank-to-water potential of +1250 mV to a copper/copper-sulfate electrode (CS). The reference electrode installed within the sump pit of the tank was selected to automatically signal the rectifier's control unit, because this location was considered to represent the most conservative point within the vessel.
TABLE 1.2

Aboveground Wastewater Treatment Tank

<table>
<thead>
<tr>
<th>Area of Tank</th>
<th>Design Summary</th>
<th>mA/m²</th>
<th>mA/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank bottom</td>
<td>10</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>0 to 2 ft (0.6 to 0.6 m)</td>
<td>10</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>2 to 6 ft (0.61 to 1.8 m)</td>
<td>8</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>6 to 10 ft (1.81 to 3.1 m)</td>
<td>6</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>10 to 21 ft (3.11 to 6.4 m)</td>
<td>6</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous internal equipment</td>
<td>10</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

- Velocity of electrolyte: 
  - Top: 10 ft/min (30.5 m/min)
  - Bottom: 1 ft/min (0.3 m/min)
- Internal lining: 
  - Stainless steel, 45 mm glass, 10 mm glass resin
- Liner effluent: 
  - 90% capacity, 20% at 20 year life
- Total current x % bare area at 20 years = 50 DCA

Supplemental sacrificial anode:
- Zinc rod (ASTM B48-86)
- Ribbon box: 6 8 ft (1.6 x 2.2 cm)
- No. ribs in parallel: 12
- Total amount of zinc: 1000 lb (363 m)

<table>
<thead>
<tr>
<th>Wastewater Composition</th>
<th>Normal Conc. (ppm)</th>
<th>Major Spill Conc. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austere</td>
<td>10 to 200</td>
<td>20</td>
</tr>
<tr>
<td>Toluene</td>
<td>10 to 200</td>
<td>20</td>
</tr>
<tr>
<td>Cresol</td>
<td>10 to 200</td>
<td>70</td>
</tr>
<tr>
<td>Methylbutylketone</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dinitrobutylide</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Isopropyl</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Alkyl phenol</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dichloroethane</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

Other Information
- T.D.S.: 3000 ppm
- Chloride (ppm): 400 ppm
- Fluoride (ppm): 15 ppm
- Hardness (ppm): 250 ppm
- Temperature: 2°C to 4°C (36°F to 39°F)

A potential profile was obtained at approximately 90-degree intervals around the tank and at 3 ft (0.9 m) depths down the tank walls. Consideration of IR drop error in the potential measurements was made by locating the reference electrode within 6 in. of the tank walls (no instant-off potentials were possible due to the zinc anode material installed on the tank bottom). The data indicated that the ~500 mV CSE NA+/H₂O criterion could be met at all measurement locations within the tank. De-energizing the rectifier during periods of low water level indicated that the zinc anode ribbon would maintain a potential of approximately ~500 mV CSE to each of the three permanently installed reference electrodes.

Case 2
After the tank anodes had been installed, the vessel was recommissioned. The rectifier was then reenergized and the unit’s automatic potential controller was adjusted to achieve a maximum tank-to-water potential of ~100 mV CSE to the permanently installed CSE within the tank. Initial negative potential shifts between 100 and 200 mV were recorded for each of the reference electrodes inside the tank. Although the NACE -850 mV CSE criterion was not initially being met at all measurement points, the selection of this criterion may be overly conservative. The large amount of bare steel to protect under such extremely turbulent condition within the vessel will not permit initial polarization. Nevertheless, the ~850 mV criterion has been met for the adjacent aeration tank under similar anodic current outputs after at least three months of continued operation. It would be expected that the 100 mV polarization decay criterion would be a more appropriate criterion to use for cathodically protected structure operating under such severe conditions.

Summary
Aboveground chemical wastewater storage and treatment tanks can be satisfactorily cathodically protected if the following factors are considered in the design of corrosion control systems.
The selection of an anode material must consider the wastewater's pH, conductivity, dissolved oxygen content, velocity, and degree of organic contaminants that can be expected in the process wastewater.

- Cathodes must be protected from attack by organic compounds in the waste water.
- Automatic potential-controlled rectifiers provide flexibility in maintaining a proper tank-to-water potential without repeated manual adjustments due to changes in the volume of the tank's contents.
- Permanent installation of reference electrodes allow for repetition of data points for future monitoring and adjustments to the systems.
- The evaluation of the CP system's effectiveness must use a criterion that considers the coating effectiveness of the structure.

References:
FIGURE 1.6
Anode suspension cable connection.

FIGURE 1.7
Gas-cell reference electrode for severe service immersion.

FIGURE 1.8
Zinc anode ribbon mounting.

Figure 2.1
Plan of aboveground vertical tank.

Figure 2.2
Hull section of aboveground vertical tank.
TABLE 2.1

Aboveground Aeration Tanks

| Capacity (gal) | 1.6 x 10^4 | 1.5 x 10^4 |
| Diameter (ft)  | 5.7 x 10^3 | 5.7 x 10^3 |
| Length (ft)    | 106      | 106      |
| Height (ft)    | 31.92    | 32.62    |
| Height (m)     | 9.7       | 9.96     |
| Capacity (m^3) | 6.16      | 6.06     |
| Capacity (gal) | 25       | 25       |
| Load (tons)    | 150      | 150      |
| Tank type      | Carbon    | Carbon    |
| Number anodes | 20       | 20       |
| Anode type     | -liner   | -liner   |
| Ring (ft)      | 5 @ 0.05  | 5 @ 0.05  |
| -liner ring    | 5       | 5 @ 0.05 |
| -middle ring   | 5 @ 0.30 | 5 @ 0.30 |
| -middle ring   | 5 @ 0.30 | 5 @ 0.30 |
| -middle ring   | 10 @ 0.40| 10 @ 0.40|
| -middle ring   | 10 @ 1.22| 10 @ 1.22|
| Anode size (cm)| 2 x 60  | 2 x 60   |
| Anode type     | Zn/CuO/CuO  | Zn/CuO/CuO |
| Monitoring type| 3        | 3        |

TABLE 2.2

Aboveground Aeration Tank

Design Summary

Tank Design: 10 m^3/4 (9.33 m^3/ltr)
Tank size: 2 NFMP (0.76 m^3/ltr)
Internal lining: none
Lining effectiveness: essentially bare steel
Velocity of electrolyte: 0.01 m/s (1.12 to 2.4 m/s)
Total current required: 145 SSA

NACE COURSE ANNOUNCEMENT

LONDON November 1992

NACE International Corrosion Inspector Training and Certification Program

Session II - Intermediate Corrosion Inspection: November 1-6, 1992

Session III - Advanced Corrosion Inspection: November 8-12, 1992

Other Information

Hospital: 1000-1500 ppm
pH: 5.2 to 7.4 (normally controlled)

For more information, contact:
NACE UK Representative
Phone: +44 (0) 683 418299
Fax: +44 (0) 683 418928

NACE COURSE ANNOUNCEMENT

LONDON November 1992

NACE International Corrosion Inspector Training and Certification Program

Session II - Intermediate Corrosion Inspection: November 1-6, 1992

Session III - Advanced Corrosion Inspection: November 8-12, 1992

Other Information

Hospital: 1000-1500 ppm
pH: 5.2 to 7.4 (normally controlled)

For more information, contact:
NACE UK Representative
Phone: +44 (0) 683 418299
Fax: +44 (0) 683 418928