GCLs USED IN SECONDARY CONTAINMENT

Secondary containment systems are required for many aboveground storage tanks. Secondary containment typically consists of a low permeability liner installed directly beneath the tank and in the bermed area surrounding the tank. Geosynthetic clay liners (described in this paper as "bentonite geocomposite liners") are commonly used as secondary containment liners. Sodium bentonite, when hydrated, is known for its excellent permeability characteristics and ability to form a barrier to petroleum hydrocarbons (TR-103). It is also electrically conductive (fully hydrated bentonite yields an expected electrical resistivity of 250 ohm-cm), allowing GCLs to be used in conjunction with cathodic protection (CP) of the primary tank bottom.

To evaluate GCL performance in this type of application, CP systems were installed on 14 aboveground storage tanks with conductive bentonite liners for secondary containment. Initial testing was performed on nine of the 14 tanks. In general, groundbed resistances with the under-tank systems were relatively low, ranging from 0.3 to 1 ohm. No significant or unusual effect of the GCL was observed in any of the installations. Significant potential shifts were measured for all the tanks tested, indicating that cathodic protection was achieved by the applied current through the bentonite liner. Thus, hydrated GCLs appear to be compatible with traditional CP methods and materials.

GCLs normally hydrate over time by slowly pulling soil moisture up from the subgrade (TR-222). To ensure full GCL hydration upon installation, it may be necessary to initially hydrate the GCL. This initial hydration can be achieved by either "flooding" the cover soil with enough water to hydrate the GCL, or preparing a subgrade at or above optimum moisture content. A minimum GCL moisture content of 100 percent is recommended (Daniel, 1993).

Once hydrated, the GCL can retain water for a significant period of time, depending upon the temperature, overburden type and thickness. A laboratory study performed on a hydrated GCL covered with 8 inches of sand found that the GCL retained a moisture content over 200 percent for 90 days (TR-106). It should be noted however, that this laboratory testing did not take into account evaporation due to wind nor did it simulate transpiration from plants. Wind and plant uptake could result in lower moisture contents and desiccation of the GCL. To assist in long-term moisture retention, water can be manually applied to the overlying soil every few months as part of a maintenance program. The amount of water and frequency of watering will vary depending on site-specific conditions (climate, evapotranspiration rate, and the field capacity of the cover soil). This maintenance watering can be conducted using portable sprinklers, or by flooding the in-situ leak detection system that is sometimes required as part of the tank containment.

If long-term maintenance watering is not feasible, CETCO suggests that a membrane-laminated GCL (such as Bentomat CL) be used in secondary containment applications. Placing the GCL with the membrane-side up will deter bentonite desiccation, thus providing additional assurance that the secondary containment liner will maintain a low permeability. However, since plastic membranes are nonconductive, they can pose problems with the cathodic protection of steel tank bottom. Design engineers can address this issue by specifying a standard geotextile-encased GCL directly beneath the tank bottom (as to not interfere with the cathodic protection) and a membrane-laminated GCL in the bermed area surrounding the tank (to deter bentonite desiccation and ion exchange). However, the engineer must be aware of the trade-off associated with this approach (improved cathodic protection vs. increased potential for bentonite desiccation beneath the tank bottom).

Compatibility of Cathodic Protection Systems with Bentonite Containment Barriers

Terry F. May
Mesa Corrosion Control Inc., P.O. Box 52608, Tulsa, OK 74152

Secondary containment barriers for aboveground storage tanks are commonly used for new tank construction. One type of barrier is the dielectric plastic liner. Another type, which uses conductive material, allows the use of traditional methods and materials for applying cathodic protection (CP) and has retrofit capabilities. Initial performance results of several tank applications have indicated that external CP systems can be successfully used with conductive barriers.

The use of nonconductive plastic liners for secondary containment has created unique problems in the application of cathodic protection (CP) to the primary tank bottom. The dielectric liners electrically insulate the steel tank bottom from surrounding soil, preventing the use of traditional CP systems.

Typically, the dielectric liners are installed from 6 to 12 in. (15 to 30 cm) under the steel bottom. The area between the liner and the tank bottom is filled with a high-resistivity dry sand. Although the sand will hopefully create an environment with a low corrosion rate, environmental and safety considerations dictate the installation of a CP system in the annular space between the liner and the tank. These systems are relatively expensive and their long-term reliability is uncertain. If the CP system fails for any reason, there are no practical methods for retrofitting a new system for the primary large tank bottom.

Another type of secondary containment barrier is available that allows the use of traditional CP methods and materials. This type of barrier consists of a flexible, high-strength sodium bentonite geocomposite mat. These electrically conductive bentonite barriers are easily installed.

Compatibility issues of CP and conductive barriers only will be discussed. The performance and capabilities of these barriers in terms of permeability and containment is not directly addressed.

Traditional Tank Bottom CP

The use of CP for protection of aboveground storage tank bottoms has been well documented since the 1940s.[1-5] Traditional design and installation methods used for pipeline applications have been adapted in numerous configurations for tank bottom application. Both sacrificial and impressed current systems have been used. The effectiveness of the various system designs is primarily determined by local conditions such as the tank base material, drainage, soil resistivity, soil moisture, subsurface geology, electrical connection to other facilities, etc.

Common configurations for tank bottom protection include:

- anodes installed either vertically or horizontally around the perimeter of the storage tank;
- anodes installed in deep beds near the storage tank;
- anodes installed in angle-drilled holes with anode placement under the tank; and
- anodes installed either vertically or horizontally under the tank bottom.

Secondary Containment

Concerns for environmental contamination and recent regulatory changes have led to the use of secondary containment systems for aboveground storage tanks. Secondary containment typically consists of an impermeable liner installed under the tank bottom. The liner can be placed over an old bottom or on a padded fill. They are normally constructed of a dielectric material such as high-density polyethylene.

API Recommended Practice 651[1] describes the advantages and disadvantages of secondary containment

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liners. Ideally, installation of a nonconductive liner with a dry, high-resistivity sand fill placed between the liner and the tank bottom will provide an environment than eliminates or minimizes bottom corrosion. Unfortunately, it is doubtful that the sand-filled annulus can be maintained moisture free for the life of the tank.[5,7] Moisture intrusion into the sand will result in a significantly increased corrosion current activity in those areas.

The use of dielectric plastic liners precludes the use of traditional CP methods. The existence of a high dielectric barrier dictates that anodes must be placed in the annular space between the liner and the tank bottom in order to be effective. Sacrificial ribbon anodes were initially installed for these situations. The choice between zinc or magnesium and the spacing requirements has created some controversy in the industry. There is a great deal of conflicting information regarding the effectiveness of these systems.[8,9]

The increasing use of nonconductive liners has led to the development of distributed impressed current systems such as mixed metal oxide (MMO) anodes installed in the space between the tank bottom and the liner.[6,8] Although these systems will provide very effective protection, there is no long-term history of these materials in this type of application.

Whether using a sacrificial anode system or an impressed current system, there are some definite concerns with the use of dielectric containment barriers. Their use virtually eliminates any retrofit capability of CP. The CP system must be designed for the expected life of the tank.

Geocomposite Bentonite Liners

API 651 lists three methods for providing secondary containment:

- use of impervious clay pad in tank dike,
- dual bottom tank design, and
- impervious nonmetallic membrane.

The use of compacted clay to create an impervious layer with hydraulic conductivities to 1×10^{-7} cm/s has a long history in industry. Clay liners are the most common barrier materials used for cover systems of waste disposal areas.[10] The best known clay material is a Western or Wyoming (sodium) bentonite clay. The primary advantage to the use of clay to provide secondary containment is its low electrical conductivity. Electrical resistivities of 250 ohm-cm are to be expected with fully hydrated bentonite. Industry experience is that a bentonite layer under a tank bottom will not significantly affect the operation of a conventional CP system.[1]

Industry experience is that a bentonite layer under a tank bottom will not significantly affect the operation of a conventional CP system.

Geocomposite liners (GCL) made from bentonite clays have been developed specifically for use in secondary containment applications. The geocomposite liner is made with a high swelling sodium bentonite clay. The liner consists of approximately one pound of granular bentonite per square foot sandwiched between two geotextiles. The composite liner provides a uniform layer of clay in a flexible, carpet form. The manufactured material has a thickness of approximately 1/4 in. (0.6 cm).

Sodium bentonite is well known for its excellent permeability characteristics. It has the property of swelling to 10 to 15 times its dry volume when fully hydrated. When confined by backfill, swelled bentonite thickness is controlled to two or three times its dry volume. If confined by backfill, a low permeable barrier is formed. Bentonite is a stable material and will provide an inert barrier to hydrocarbons.

The ability to function as an effective containment barrier is a function of the moisture content of the bentonite. Following initial installation, the bentonite GCL is hydrated with a water flood. Bentonite also acts as a drying agent to the surrounding environment. In tank bottom applications, the concrete ringwall and the bentonite liner would serve to contain moisture after initial hydration. Once the tank is built, it is doubtful that the moisture levels would ever significantly decrease. However, GCL manufacturers recommend external hydration every six months in locations where soil moisture is low.

The bentonite material will crack as moisture evaporates. The water retention characteristics are significantly improved when bentonite is subjected to loading and is covered with a backfill material. Laboratory tests have been performed under controlled conditions of temperature and humidity with and without a sand overburden. The tests indicate a fully hydrated GCL with an 8-in. (21-cm) sand overburden will retain a moisture content of well over 200 percent for 90 days without additional moisture.[11]

Geocomposite liners are installed in much the same method as nonconductive plastic membranes. The material is unrolled in a carpet-like form and placed on a compacted, prepared base. The seams are overlapped approximately 6 in. (15 cm). Seams, tears, and punctures are self-sealing because of the moisture-absorbing expanding properties of the bentonite. After laying the liner, an overburden is installed. Typically, it consists of 6 to 12 in. of a well-draining sand. Following placement of the overburden, the bentonite is hydrated by a water flood. After hydration, the bentonite will swell through the geotextile fabric and seal itself at seams and tears (Figure 1).

The primary concern in the use of GCL's is its ability to retain its low permeability characteristics under normal conditions of moisture. In addition, will the GCL materials perform any differently than a pure bentonite clay layer in terms of its electrical conductivity? Do the geotextile fabrics used in its construction constitute any significant electrical barrier to external CP current?

CP and GCL Liner Installation

CP systems have been installed on 14 new aboveground storage tanks that use conductive bentonite liners for secondary containment. The tanks range in diameter from 28 to 210 ft (8.5 to 64 m). These tanks are located in Michigan, Missouri, Oklahoma, and Texas.

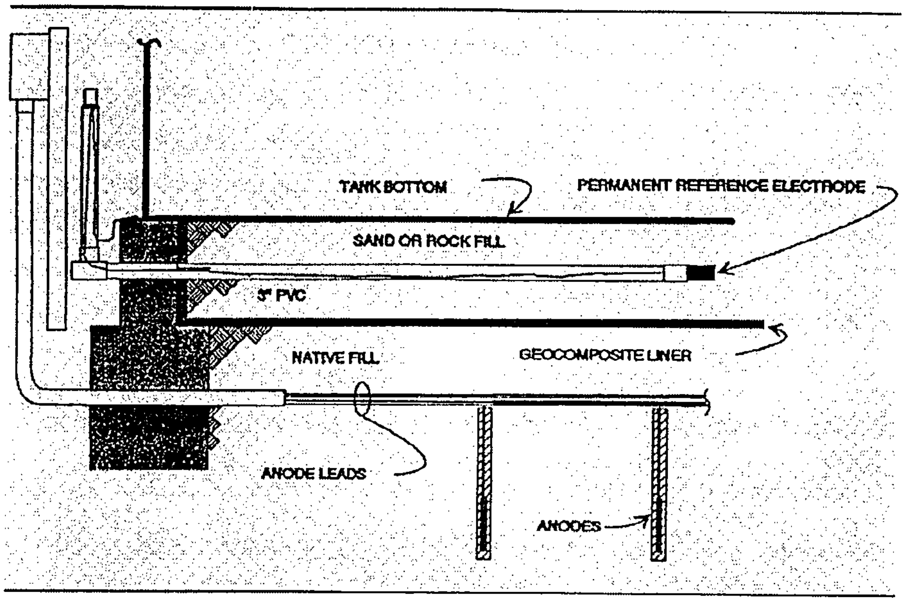

FIGURE 1
Geocomposite liner installation.

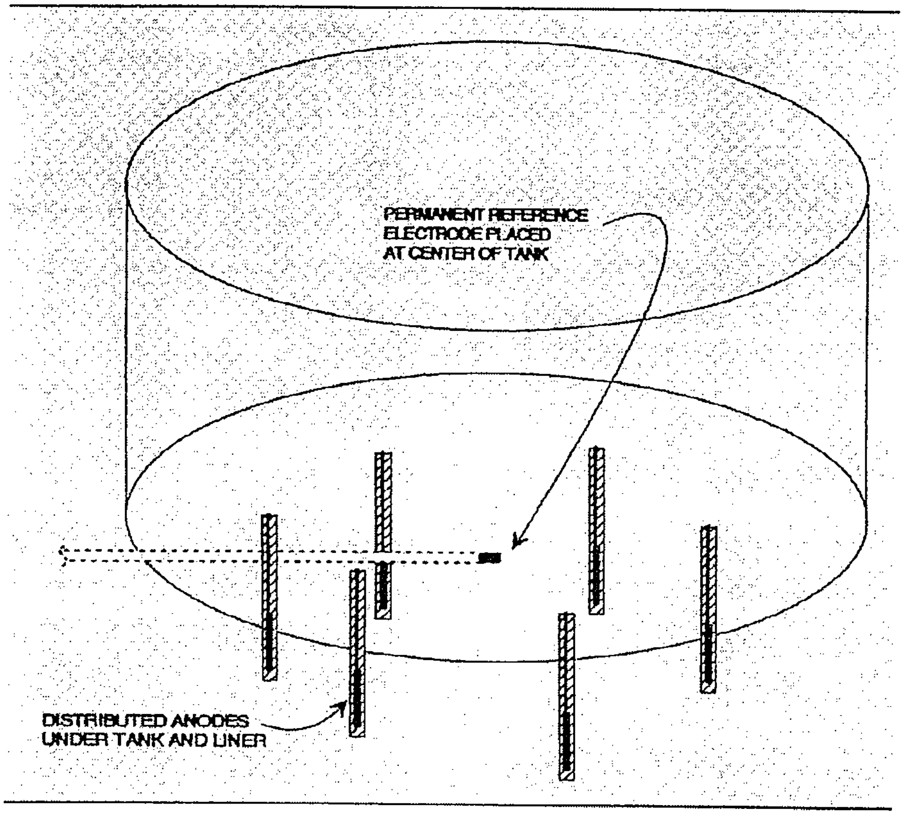

FIGURE 2
Typical anode installation.

Ideally, protective current should be uniformly distributed over the entire bottom. With traditional CP designs, current distribution can be nonuniform depending on soil conditions and groundbed location. A decision was made to install anode groundbeds directly under the new tank prior to installation.

The groundbeds consisted of treated graphite anodes installed in conventional fashion under the new bottom. Typically, the tank ringwalls had already been poured at the time of groundbed installation. Depending on tank diameter, two to 25 anodes were installed. Anodes were installed either vertically or horizontally, depending on subsoil conditions. All anodes were backfilled with carbonaceous coke breeze. Each anode had an individual lead wire that extended underneath the ringwall to a junction box mounted externally on the tank. Following anode installation, the tank base material was then compacted to specification (Figure 2).

The geocomposite liner was then placed over the compacted base to seal the entire area inside the ringwalls. The liner material was installed similar to nonconductive membranes with the exception that no seaming work is required. Eight to 12 in. (20 to 30 cm) of select sand fill was placed over the GCL to provide a high-resistivity, uniform environment to which the tank bottom is exposed. Permanent copper/copper-sulfate electrodes were selectively placed in the sand fill over the liner to enable measurement of tank potentials adjacent to the bottom and verify current flow through the liner material. Most of the tanks were also installed with a perforated PVC pipe to the center of the tank in the sand fill area to allow insertion of an external electrode.

System Testing

Several of these tanks are still under construction, and no performance data is available at this time. However, initial testing has been performed on nine of the 14 tanks. Because of the short test durations, it is doubtful that any significant level of polarization was achieved on the tank bottoms.

Results

In general, groundbed resistances with the under-tank systems were relatively low by normal standards. Resistances ranging from 0.3 to 1 ohm were measured. No significant or unusual effect of the bentonite liner was observed in any of the installations. Significant potential shifts were measured at the permanent reference electrode locations for all of the tanks tested. The magnitude of potential shifts and polarization voltages indicated that protection was being achieved by applied current flow through the bentonite liner.

A 110-in. (33.5-m) diameter tank in Texas was discovered to be inadvertently shorted to other facilities before testing was performed. Other tanks at the same location were already protected with an existing CP system. Tank-to-soil potentials around the perimeter and at two permanent electrodes under the new tank indicated that the tank was completely protected even before the undertank groundbed was energized. The existing CP system was effectively protecting the new tank through the bentonite liner.

The most detailed testing was performed at a 150-in. (45.7-m) diameter tank in Oklahoma. This tank had twenty 4 by 80-in. (10 by 2-m) graphite anodes installed under the tank bottom. Two permanent electrodes were placed in the sand layer over the liner. One permanent electrode was located at the center and another approximately midway between the perimeter and the center (Figure 3). Test currents were applied to the tank bottom. Eight perimeter potential measurements were obtained along with the two permanent copper sulfate electrodes. The perimeter measurements were relatively uniform at each test current. The center electrode had the lowest measured potential shift of all locations and the lowest measured polarization voltage. The permanent electrode located midway between perimeter and center had the highest measured potential shift and polarization voltage. This permanent electrode was located close to an anode, resulting in higher current densities in this area.

Conclusions

Although the testing procedure did not result in full tank polarization in all cases, potential shifts above the bentonite liners as a result of applied current are indicative of a conductive path between the anode and the tank bottom.

GCLs are compatible with traditional CP methods and materials.

Use of traditional CP methods with proven materials eliminates concerns regarding the long-term reliability of recently developed anode systems or nonuniform deterioration of sacrificial anode systems.

Use of bentonite barriers provides the capability of retrofit CP application using traditional CP methods and materials.

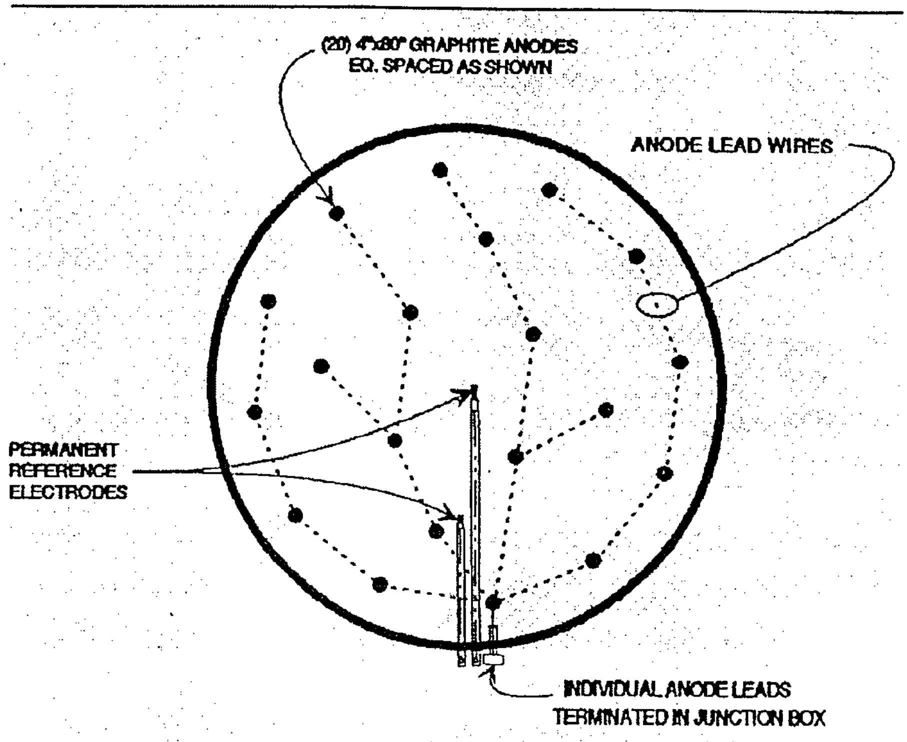

FIGURE 3
Under-tank distributed anode plan.

Since the availability and retention of moisture is critical to the containment performance of the GCL, it may be advantageous to incorporate a moisture-sensing capability to determine when external hydration is required.

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