Mixed metal oxide (MMO) anodes find extensive use in impressed current cathodic protection installations. Part 1 of this article (May 2007 MP) covered the electrochemistry, manufacture, and operation of these anodes. Part 2 presents three case histories showing application of MMO anodes.
anode lead wires. Halar™ lead wire insulation is preferable to either high molecular weight polyethylene or Kynar™ when the anodic reaction is chlorine evolution. Lead wires from individual anodes were extended, without splices, from each anode to a junction box for both surface and deep anodes.

There were four anode configurations selected for CP of the well casings. Two were deep anodes for one- or two-well clusters (Figures 1 and 2), and two were surface anode beds for one- or two-well clusters. In the case of deep anodes, the depth to the top of the active anode column varied by location to account for variations in subsurface geology and depth to water. Surface anode configurations were used only in stable soils with low resistivities (sabkha areas). The anodes in both the deep and surface anode beds were backfilled with calcined petroleum coke.

Both 20- to 25-A and 40- to 50-A deep and surface anode configurations were developed. Using a very conservative anode rating of 50% of the manufacturers’ published data, the capacity of each anode is 170 A/y. For 10 electrode anode beds rated at 20 A, and 20 anode beds rated at 40 A, the theoretical design life of the anode system is 85 years. For 25- and 50-A capacity systems with transformer-rectifiers, the design life of the anode system is 68 years.

The advantages of these groundbed designs were evident during construction and commissioning:

- The anodes are lightweight, reducing packaging and shipping costs.
- The anode connections are low resistance and well sealed against moisture penetration.
- The anodes are easy to handle because of the size, shape, and weight.
- The anode bed hole diameter can be minimized and still allow for sufficient calcined coke to surround the anode.
- The anodes can be operated at high CDs during initial polarization without compromising long-term anode performance.
- The extended life of the anode columns was achieved at minimal incremental cost.

**MMO Ribbon for External Side of Tank Bottoms**

A low-profile CP system for tank bottom protection above a secondary containment liner or in the space between an old bottom and a new bottom retrofit was developed, using a grid pattern of ribbon anodes. The first system with this configuration was designed and installed in 1987 for a 105-m (345-ft) diameter tank in a U.S. Gulf Coast refinery. It consisted of coated ribbon anodes placed on 1.5-m (5-ft) centers with conductor bars every 7.6 m (25 ft). At every point of intersection, the anode ribbon was resistance-welded to the conductor bar (Figure 3). The ribbon was 6-mm (0.025-in.) thick by 6.4-mm (0.25-in.) wide, and the conductor bar was 1-mm (0.04-in.) thick by 13-mm (0.50-in.) wide. Eight power feeds and six reference cells were installed as part of the system (Figure 4). The tank is used for storage of surface water run-off from heavy rains and is therefore operated at ambient temperature. For this application, the anode grid was designed for a 50-year life at a current capacity of 1.1 µA/cm² (1 mA/ft²). The protection criterion selected was 100 mV polarization decay due to the changing conditions under an aboveground tank from condensation, water accumulation, temperature variations, and varying oxygen levels created as the tank is filled and emptied, causing the bottom to flex. These factors can impact the free corrosion potential.

It took 60 days for polarization at a CD of 0.4 µA/cm² (0.36 mA/ft²). CP with the MMO-coated titanium ribbon in the grid configuration provides many advantages:

- Low profile, allowing use between the tank bottom and any secondary containment liner or existing tank bottom in the case of a double bottom tank.
- Easy to handle and install.
- Even current distribution over the entire tank bottom.
Redundant resistance welds for electrical continuity across the grid.
- No requirement for calcined petroleum coke backfill, saving time during installation and eliminating the possibility of the coke creating a system short.
- No field splices.
- Low direct current (DC) circuit resistance, resulting in low power requirements.
- Redundant, shop-assembled power feeds.
- No electrical isolation required.
- Extended anode life of more than 50 years.
- No interference with adjacent structures.
- Environmentally friendly, avoiding the need for drilling into subsurface strata.

**MMO Ribbon Mesh for Reinforcing Steel in Concrete**

Reinforced concrete jetties, piers, decks, and piles need to be protected from corrosion. Normally, the pH of Portland cement is 12.4. In this alkaline environment, steel reinforcements corrode very slowly. When exposed to a marine environment, however, chloride ions penetrate the concrete and reduce the pH at the steel surface, leading to high rates of corrosion. The corrosion products occupy approximately twice the volume of the steel; this places the concrete in tension and causes spalling of the concrete. CP provides positive corrosion control. MMO-coated expanded and ribbon mesh titanium anodes are often used for impressed current CP (ICCP) of steel reinforcement.

Many coastal structures along the Gulf of Mexico and Florida coast suffer from premature deterioration of substructure elements. Reinforcing steel or prestressing strands corrode, sometimes at accelerated rates from overdriving of concrete piles during construction. Overdriving causes hairline cracks in the concrete that serve as a direct path for moisture, oxygen, and chlorides to the reinforcing steel.

For many years, the Florida Department of Transportation (FDOT) has combated the deterioration from corrosion on the piles with conventional patching. FDOT has also placed fiberglass jackets around piles and backfilled with grout in an attempt to keep moisture and oxygen out of the pile. These repair procedures were found to have a short life with failures after as little as three years. Further, the pile jackets were only hiding an increasingly dangerous condition as many prestressing strands were found to be completely severed by corrosion.

Through FDOT’s Corrosion Research Lab in Gainesville, Florida, CP was introduced and developed into a standard repair procedure for existing substructures suffering corrosion damage. CP has been used to control corrosion in piles and substructures since 1974. The FDOT standard requires an ICCP sys-
tem utilizing MMO anode mesh attached to the inside of a fiberglass jacket (Figure 5). The jacket is placed around all piles (or other members) and the annular space is filled with grout (Figure 6). This method, using the MMO anode mesh, has a life in excess of 50 years. Further, the system can be safely designed to protect prestressed concrete members.

Expanded mesh and ribbon mesh MMO anodes demonstrate superior performance for CP of reinforcing steel in concrete structures:

- Easy to handle and install.
- Low profile for use with concrete overlays.
- Easily shaped for concrete embeddings.
- Even current distribution.
- Low DC circuit resistance.
- Long life.
- Low life-cycle cost for protection.

Conclusions

MMO-coated titanium anodes can be used for many ICCP applications. Case histories demonstrate that MMO anodes will meet performance objectives.

To ensure performance that satisfies CP system design criteria, it is important that:

- The anode is supplied with the optimum MMO coating for the application.
- The MMO coating is properly applied, with the necessary process control and quality control procedures to ensure optimum performance.
- The electrical connection to the anode is very low resistance and positively sealed from moisture.
- The lead wire insulation is resistant to attack from gases that evolve from the oxidation reactions at the anode surface.

References


This article is based on CORROSION/2007 paper no. 45, presented in Nashville, Tennessee.

DAVID H. KROON is executive vice president and chief engineer of Corrpro Companies, Inc., 7000B Hollister, Houston, TX 77040. He graduated from Yale University with a B.S. in chemistry and is a registered professional engineer in eight states. A NACE member, Kroon has more than 35 years of experience in corrosion prevention, including materials performance, protective coatings, pipeline integrity, CP, and alternating current/DC interference mitigation. Since the early 1980s, he has designed and monitored the performance of MMO-coated titanium anodes for CP.

LYNNE M. ERNES is chief knowledge officer at Industrie de Nora, Via Bistolfi, 35, Milan 20134, Italy. She has a B.S. degree in chemistry from Slippery Rock State University and has worked for ELTECH Systems and De Nora for 29 years. She works in the areas of research and development and business group functions. She worked on the development of the DSA® anode technology and holds 21 patents.

— Next Month in MP —

2007 MP Buyers Guide

♦ The world’s most comprehensive resource for corrosion control products and services

♦ Topical index covering all fields of corrosion work

♦ Listings of hundreds of suppliers, manufacturers, and consultants worldwide

Also in this issue:
Results of the 2007 MP Corrosion Career Survey

Annual listing of universities offering corrosion curricula worldwide