An announcement that a rectifier is going to be installed in an urban area is likely to elicit disparaging remarks. The problem stems from the mindset that rectifiers are a cross-country pipeline phenomenon consisting of units located many miles apart and connected to groundbeds producing fairly high current outputs.

The direct application of the transmission system in a city could indeed be disastrous. Introducing a large amount of current into the earth from a few widely scattered groundbeds could cause a great deal of interference. But if properly engineered, impressed current cathodic protection (ICCP) can be used quite effectively and safely in urban or other congested areas. Three groundbed configurations can be considered: distributed anodes, deep anodes, and small low-output surface beds.

Distributed Anodes

In a distributed anode (parallel) system, the anodes are connected to a header cable and spaced perhaps 50 ft (15 m) apart along a pipeline. Each anode protects only a small amount of piping and the system is not very different from galvanic anodes. In one such installation, a bare 20-in (500-mm) interstation gas main within a large city was protected effectively, with no interference to adjacent buried gas and water piping and telephone cables.

Use of distributed anodes is also a common way to upgrade underground storage tanks. By placing the anodes around the tanks and along the dispenser piping, current is closely coupled to the protected structures and effects on other structures are minimal.

A word of caution, however—be careful with the driving voltage. One such installation was placed in a service station in very high-resistivity soil and energized at 85 V and 3 A. The resultant high-voltage gradient caused serious interference on a nearby gas line. Additional anodes were added to bring the voltage down to ~35 V; the problem was solved, but only at an appreciable added expense to the owner.

Deep Anodes

Deep anode groundbeds, which can be installed on small plots of ground or in an alley or parkway, provide effective protection for coated, isolated pipe in a subdivision or other distribution area. This configuration, which might be used to replace spent galvanic anodes, has been used successfully in several cities without creating interference problems. A variation of this is the semi-deep groundbed, perhaps 35 to 50 ft (10 to 15 m) and generally containing three or four anodes. These installations have been made quite successfully for gas piping in city streets and alleyways, as well as to upgrade underground tanks and piping in service stations.

Low-Output Surface Beds

Frequently it becomes necessary to protect relatively short sections of mains of ~3,000 ft (914 m) under streets or other paving to bring low areas up to protection or to replace dissipated galvanic anodes. This can often be done with a low-output rectifier and a small surface groundbed of one or two anodes. Ground-
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Continued from p. 1

Using Magnetite Anodes in Deep Well Groundbeds

Deepest well anode groundbeds are specially designed and installed as part of an impressed current cathodic protection (ICCP) system to provide a relatively high amount of CP current to structures such as well casings. The selection of appropriate anode material is important to achieve long anode life based on consumption rates.

During the 1980s, one of the largest national oil companies in North Africa had negative experiences with the CP of its well casings due to constant failure of the anode systems after a relatively short operational period (one to five years). The anode systems were installed in areas where the soil and/or water contain a high chloride concentration.

After carefully studying the reasons for the system failures, it was determined that the anodic reaction occurring around the anodes when installed in acidic saline solutions caused chlorine gas production at the anode/electrolyte interface and also a high chlorine gas concentration around the anodes and their components. The presence of chlorine gas is one of the major reasons for an anode groundbed failure.

Laboratory tests in simulated environmental and service conditions showed that magnetite anodes were able to provide a more reliable and longer-lasting anode system than the previously used materials, with a minimum design life of 20-plus years. The known threats to anode groundbed systems, various case studies of large-scale applications, and the requirements for anode systems installed in high-chloride environments, as well as recent developments in improving and optimizing the reliability of the magnetite anode systems, are discussed in CORROSION 2014 paper no. 4470, “Magnetite Anodes for Deep Well Groundbeds,” by T. Krebs. $c

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Summer 2015

Stay Current 3
When a light-rail line was constructed parallel to an existing interstate highway near Portland, Oregon, it crossed five pressurized, large-diameter (60 in [1.5 m]) steel water transmission pipelines that carry drinking water into the city from nearby reservoirs. The transit corridor was considered a high-consequence area because a pipe failure could disrupt both light-rail and highway traffic. To protect the pipes in the transit corridor where they crossed underneath the light-rail tracks, construction of the line included retrofitting the pipelines with a precast concrete box culvert casing and installing an impressed current cathodic protection (ICCP) system.

According to NACE International member Stuart Greenberger, senior engineer with the Portland Water Bureau, the main reasons for installing the box culvert casings were to protect the pipes from the increased soil load resulting from grade changes made to accommodate the train tracks, facilitate pipe operation and maintenance without disturbing the tracks, and electrically distance the pipes from close coupling with the light-rail system. “The new threat [to the water pipelines] was stray current corrosion from the light rail,” he says. Typically, cased pipelines comprise a carrier pipe inserted into a larger diameter casing pipe. In this particular instance, Greenberger explains, the five carrier pipelines would need to be drained and have segments removed for a casing pipe to be installed. “It would be an extensive job to get the water out of these pipes, and we didn’t want to take the conduit out of service,” he adds.

A practical and economical solution was to build a box culvert around the ~80-ft (24-m) portion of each pipeline that crossed under the light rail while the pipes remained in service. The box culvert was determined to be less costly than constructing a split casing around the intact pipe. Four of the pipelines, when originally installed, were made of steel with a di-electric coating. The fifth one was bar-wrapped steel cylinder concrete pressure pipe, which is comprised of a welded steel cylinder with steel reinforcing bars wrapped around the cylinder to provide strength. Corrosion protection for the steel components of concrete cylinder pipe is provided by an internal concrete lining and external mortar coating. When the highway was built, the portions of coated steel pipe that crossed under it were replaced with bar-wrapped steel cylinder concrete pressure pipe with poured concrete along the sides. Three of the coated steel pipelines were subsequently fitted with ICCP systems at areas along the route that were considered to be particularly corrosive.

To install the box culverts, small portions of each pipe were excavated at 10-ft (3-m) spans, and concrete support saddles were cast in place around these portions of the pipe while the remaining pipe was left in service. The box culvert was determined to be less costly than constructing a split casing around the intact pipe. Four of the pipelines, when originally installed, were made of steel with a dielectric coating. The fifth one was bar-wrapped steel cylinder concrete pressure pipe, which is comprised of a welded steel cylinder with steel reinforcing bars wrapped around the cylinder to provide strength. Corrosion protection for the steel components of concrete cylinder pipe is provided by an internal concrete lining and external mortar coating. When the highway was built, the portions of coated steel pipe that crossed under it were replaced with bar-wrapped steel cylinder concrete pressure pipe with poured concrete along the sides. Three of the coated steel pipelines were subsequently fitted with ICCP systems at areas along the route that were considered to be particularly corrosive.

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After the pipe was completely excavated, the previously installed concrete around the haunch of the pipe was removed, and a new, continuous concrete foundation footing and floor slab were poured underneath and up the sides of the pipe. Hot-dip galvanized steel pipe saddles with a dielectric coating, designed to hold the pipe in place if the groundwater level should ever rise above the pipe and make it buoyant, were placed over the pipe and fastened to the floor slab with grout-covered bolts. The box culvert and end walls were then put into place and covered with a minimum of 5 ft (1.5 m) of backfill.

For each of the five water transmission pipelines, which are spaced ~1 mile (1.6 km) apart along the transit corridor to provide strength. Corrosion protection for the steel components of concrete cylinder pipe is provided by an internal concrete lining and external mortar coating. When the highway was built, the portions of coated steel pipe that crossed under it were replaced with bar-wrapped steel cylinder concrete pressure pipe with poured concrete along the sides. Three of the coated steel pipelines were subsequently fitted with ICCP systems at areas along the route that were considered to be particularly corrosive.

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corridor, a separate ICCP system was installed. Each CP system has the same design, which includes an automatically controlled rectifier and a permanent copper/copper sulfate (Cu/CuSO\textsubscript{4}) reference electrode (CSE) for rectifier control that is positioned near the pipeline where it crosses under the light-rail tracks. The rectifier uses the CSE to determine the structure-to-electrolyte potential and then continuously adjusts its output to maintain a preset potential for the structure. A CP coupon drop tube test station, installed a few feet away from the CSE (and also near the point where the pipeline and light-rail tracks cross), provides a potential reading that represents the pipe-to-soil (P/S) potential. A 200-ft (61-m) deep continuous column anode bed, built 100 ft (30 m) below grade, contains 10 cast iron anodes in coke breeze. Each anode bed was buried 75 ft (23 m) away from the pipeline and test station, Greenberger says, so electrical current from the anode bed would protect all portions of the pipe crossing underneath the transit corridor.

Normal operation of each ICCP system requires ~1.0 A of rectifier output to maintain pipe potentials of −1.0 V, the “on” potential as measured at the CP coupon drop tube test station when the rectifier is operating and generating current. A nearly constant pipe potential indicates a well-insulated rail system with high track-to-earth resistance. Greenberger notes that rectifier output readings and potential readings indicated normal operation for four of the ICCP systems.

At one crossing, however, the ICCP system was experiencing a problem. When the rectifier was turned on, the current output required to maintain fairly constant pipe potentials varied between 0.0 and 4.0 A. When the rectifier was turned off, the P/S potentials varied from −1.0 to +2.0 V. The potential measurements displayed the characteristic signature of train movement, Greenberger explains, which meant the pipe was being subjected to stray current driven by the track voltage. The varying output from the rectifier indicated a track-to-earth short.

When the light-rail line was constructed, a track switch at a transit station was located directly over the pipe at this particular crossing. To ensure the track switch didn't freeze, a heater was installed on it and electrically grounded above the pipe. The grounding created a 25-\textOmega track-to-earth short and allowed current from the track to enter the ground just above the pipe. “The whole idea is to isolate the rail from the ground because that’s where stray current comes from, and we don’t want current exchange between the rail and pipe,” Greenberger says. “Instead, when they grounded the heater at that location, the rail was no longer isolated. As current was coming off the rail, the rectifier was putting current in the ground to offset the rail current. The amperage from the rectifier varied significantly because it was counteracting the stray current from the rail,” he adds. The rectifier was doing exactly what it was supposed to do, and doing an exceptional job, he notes, commenting that the rectifier was able to keep pace with the stray current signature of the train and hold the pipe potentials relatively constant—within 100 mV.

The stray current, measured by placing a shunt in the track switch heater’s electrical ground circuit, ranged from 0.0 to 300 mA. Greenberger comments that the close proximity of the short to the rectifier’s control reference electrode, coupled with the somewhat remote deep anode bed trying to offset the effect of the local current, caused a relatively small voltage gradient from the stray current to drive a large amount of current output from the rectifier, which can use up the anodes at a faster rate. In this case, he adds, the stray current problem was resolved by installing a polarization cell replacement (PCR) on the grounding for the track switch heater. The PCR blocks direct current (DC) but allows alternating current (AC) grounding, so the track switch heater is AC grounded and the DC stray current is blocked. This allowed the ICCP system to function properly.

To avoid a large current output from an automatically controlled rectifier to counterbalance a small amount of stray current at a closely coupled pipe-to-track crossing, Greenberger suggests operating automatic rectifiers in a current limiting mode, as well as monitoring the system. When a
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The principle of a close-interval potential survey (CIPS or CIS) is to record the pipe-to-soil (P/S) potential profile of a pipeline over its entire length by measuring potentials at intervals that do not significantly exceed the depth of the pipe (often ~1 m).

The negative terminal of a portable recording voltmeter is typically connected to the pipeline at a test point through a spool of thin copper wire. The positive terminal is usually connected to a pair of copper/copper sulfate (Cu/CuSO₄) reference electrode probes that are alternately positioned in the ground over the pipeline at regular intervals in “leap-frog” fashion. This polarity displays the pipeline potentials as positive.

The actual survey typically involves three distinct tasks: 1) locating and marking the pipeline with stakes or flags inserted at regular intervals, based on tape measurements or chaining; 2) data collection, including P/S potentials and notation of physical features along the right-of-way with global positioning system (GPS) coordinates collected separately for these features; and 3) clearing the right-of-way of survey wire and other materials. The field crew must be prepared to identify and repair breaks of the trailing copper wire; areas such as road crossings and stockyards may require the use of heavier, insulated wire that is resistant to breakage.

Because the potential of interest is at the structure-electrolyte boundary, it is important to consider possible voltage (IR) drop errors that result from the flow of current through the earth the stray current. For example, during the construction of box culverts for similar projects, canister anodes were installed for the CP system. Since an automatically controlled pipeline CP system might trace a voltage (IR) gradient in the soil, Greenberger suggests making the control reference electrode integral with a CP coupon test station, including a drop tube, where possible.

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More information on this case study can be found in CORROSION 2014 paper no. 4008, “Corrosion Control System Performance for Large Diameter Water Mains in a Light-Rail and Interstate Highway Corridor,” by S. Greenberger and G. Wallis.

Contact Stuart Greenberger, Portland Water Bureau—e-mail: Stu.Greenberger@portlandoregon.gov.
## NACE Cathodic Protection Course Schedule

### July–December 2015

**China**
- **CP Interference**
  - Beijing, China November 9-14, 2015

**Colombia**
- **CP3—Cathodic Protection Technologist**
  - Bogota, Colombia July 6-11, 2015
- **CP4—Cathodic Protection Specialist**
  - Bogota, Colombia September 14-19, 2015

**Egypt**
- **CP4—Cathodic Protection Specialist**
  - Cairo, Egypt August 15-20, 2015

**India**
- **CP1—Cathodic Protection Tester**
  - Mumbai, India August 3-8, 2015
- **CP2—Cathodic Protection Technician**
  - Mumbai, India August 10-15, 2015

**Malaysia**
- **CP1—Cathodic Protection Tester**
  - Kuala Lumpur, Malaysia September 7-12, 2015
- **CP2—Cathodic Protection Technician**
  - Kuala Lumpur, Malaysia September 14-19, 2015

**Saudi Arabia**
- **CP1—Cathodic Protection Tester**
  - Dammam, Saudi Arabia August 22-27, 2015
- **CP2—Cathodic Protection Technician**
  - Dammam, Saudi Arabia August 29-September 3, 2015
  - Dammam, Saudi Arabia December 12-17, 2015

**South Africa**
- **CP1—Cathodic Protection Tester**
  - Midrand, South Africa September 14-19, 2015
- **CP2—Cathodic Protection Technician**
  - Midrand, South Africa September 14-19, 2015
- **CP4—Cathodic Protection Specialist**
  - Midrand, South Africa November 23-28, 2015
- **CP Interference**
  - Midrand, South Africa October 26-31, 2015

**Spain**
- **CP2—Cathodic Protection Technician**
  - Madrid, Spain October 5-10, 2015

**Trinidad & Tobago**
- **CP1—Cathodic Protection Tester**
  - Marabella, Trinidad August 2-7, 2015

**United Arab Emirates**
- **CP1—Cathodic Protection Tester**
  - Dubai, UAE August 8-13, 2015
  - Dubai, UAE August 29-September 3, 2015
- **CP2—Cathodic Protection Technician**
  - Dubai, UAE August 15-20, 2015
  - Dubai, UAE September 5-10, 2015
- **CP3—Cathodic Protection Technologist**
  - Dubai, UAE September 26-October 1, 2015

**United States of America**
- **CP1—Cathodic Protection Tester**
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  - Houston, TX July 19-24, 2015
  - Houston, TX July 26-31, 2015
  - Livermore, CA July 27-August 1, 2015
  - Houston, TX August 2-7, 2015
  - Houston, TX August 9-14, 2015
  - Livermore, CA August 24-29, 2015
  - Houston, TX August 30-September 4, 2015
  - Houston, TX September 13-18, 2015
  - Tulsa, OK September 27-October 2, 2015
  - Rosebush, MI October 4-9, 2015
  - Houston, TX October 4-9, 2015
  - Houston, TX October 25-30, 2015
  - Houston, TX November 1-6, 2015
  - Claysville, PA November 8-13, 2015
  - Houston, TX November 15-20, 2015
  - Houston, TX November 29-December 4, 2015
  - Chicago, IL December 6-11, 2015
  - Plano, TX December 13-18, 2015
  - Houston, TX December 13-18, 2015
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  - Houston, TX July 12-17, 2015
  - Houston, TX July 19-24, 2015
  - Plano, TX July 26-31, 2015
  - Houston, TX August 2-7, 2015
  - Houston, TX August 16-21, 2015
  - Houston, TX August 29-September 4, 2015
  - Houston, TX September 20-25, 2015
  - Houston, TX September 27-October 2, 2015
  - Houston, TX October 11-16, 2015
  - Houston, TX November 8-13, 2015
  - Claysville, PA November 15-20, 2015
  - Houston, TX December 6-11, 2015
- **CP2—Cathodic Protection Technician—Maritime**
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- **CP3—Cathodic Protection Technologist**
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  - Kilgore, TX August 2-7, 2015
  - Anchorage, AK August 23-28, 2015
  - Houston, TX October 4-9, 2015
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  - Houston, TX December 6-11, 2015
- **Coatings in Conjunction with Cathodic Protection**
  - Houston, TX July 26-31, 2015
  - Houston, TX September 13-18, 2015
  - Houston, TX November 15-20, 2015
- **CP Interference**
  - Houston, TX September 13-18, 2015

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