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Sacrificial Cathodic Protection of a Concrete Overpass Using Metallized Zinc

R. Brousseau, B. Baldock, G. Pye, and Ping Gu
Institute for Research in Construction, National Research Council of Canada, Bldg. M-20, Montreal Rd., Ottawa, Ontario K1A 0R6 Canada

Removing salt-contaminated concrete, patching, and applying waterproofing membranes are treatments used to rehabilitate corrosion-damaged infrastructure. There are concerns about the effectiveness of only using such an approach to mitigate reinforcement corrosion when the concrete is salt-contaminated. Sacrificial cathodic protection (CP) using metallized zinc coatings is regarded as a possible rehabilitation alternative.

Seven reinforced concrete columns of a bridge in Montreal were flame sprayed with zinc. The zinc anode delivered adequate levels of cathodic protection (CP) for more than 14 months. However, the metallized zinc slowly decreased its current delivery over time.

In the past two decades, significant advances have been made in the development of impressed current CP systems to mitigate steel reinforcement corrosion. Little has been done to evaluate the feasibility of applying CP by sacrificial anodes in Canada. This is likely related to the concern that sacrificial anodes, because of their low driving voltage, might not have the ability to deliver adequate current to cathodically polarize the embedded reinforcing steel. Conversely, sacrificial CP systems might be more desirable for prestressed concrete structures where overprotection may lead to hydrogen embrittlement of the high-strength steel. Another attractive feature of sacrificial anode systems is they do not require maintenance, rectifiers, or monitoring.

In a sacrificial CP system, an electronegative metal, such as zinc, is electrically coupled with the reinforcing steel. A flow of the protective current is induced by the electromotive force that arises. Some studies have suggested possible merits of sacrificial CP systems.[1-4] Others found their future questionable, given their low driving voltage and the high resistivity environment provided by most concretes.[5] Whiting and Stark evaluated the performance of two types of sacrificial anode systems on a reinforced concrete bridge deck.[2] The first consisted of commercially available zinc ribbon anodes placed in slots cut into the deck at regular intervals with porous Portland cement as backfill. The second consisted of perforated zinc anode sheets bedded on a lift of similar porous mortar.

The results of this study indicated that a sacrificial anode CP system, based either on closely spaced ribbon anodes or on perforated zinc sheets, has potential for supplying CP to the top mat of reinforcing steel in a reinforced concrete bridge deck, particularly in a warm and humid environment.[2] In dry or cold periods, current dropped significantly, and was lower and less uniform. The lack of adequate polarization under these conditions was confirmed by the Ontario Ministry of Transportation using the zinc ribbon.[6]

The Illinois Department of Transportation also conducted research with zinc ribbon and concluded that, after three years, the zinc anodes were capable of protecting only a 3 in. (7.62 cm) wide strip each side of the anodes.[3]

The Florida Department of Transportation is testing the performance of sacrificial CP on several reinforced concrete piers and columns on marine bridges.[4] Various configurations of sacrificial zinc mesh anodes, used in conjunction with a submerged bulk zinc anode, have successfully been used to provide CP in the tidal zone of reinforced concrete piers.[7] Their research has shown that

metallized zinc coatings delivered appreciable cathodic polarization levels to the reinforcing steel for several months when there is frequent wetting of the concrete.[8]

In view of what has been observed in Florida with metallized zinc CP, comparable research for northern conditions was undertaken. The data suggests a promising future for metallized zinc CP on concrete exposed to deicing salts.

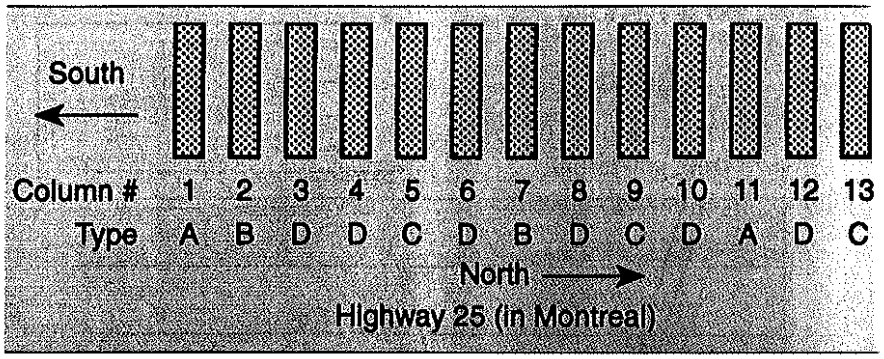

FIGURE 1
Schematic diagram of the 13 columns of the Yves Prevost overpass used in the test program.

Yves Prevost Overpass

Initial results measured on the overpass Yves Prevost, on Highway 25 in Montreal, are presented. Depending on the season, traffic routinely sprays a mixture of salt, melting snow, and rain on the support columns investigated. Seven of the 13 columns in the south bound direction were zinc metallized (Figure 1). The growth of the delaminations on the control and metallized columns will be monitored over several years, to help determine the life-cycle cost effectiveness of this approach. For now, all that can be presented is the current delivered by the zinc anode, and the resulting cathodic polarization at the rebar.

The zinc coating was flame sprayed onto the concrete to a thickness 0.3 to 0.4 mm. Four small patches (60 x 60 cm) of the zinc coating were electrically isolated to allow anode current density measurements. The patches for columns 2 and 7 were installed according to the schematic of Figure 2. A zinc patch was electrically isolated at the base of the pier, one on either side, and one in the back. The current flowing between the metallized zinc and the rebar was measured using a zero resistance ammeter .

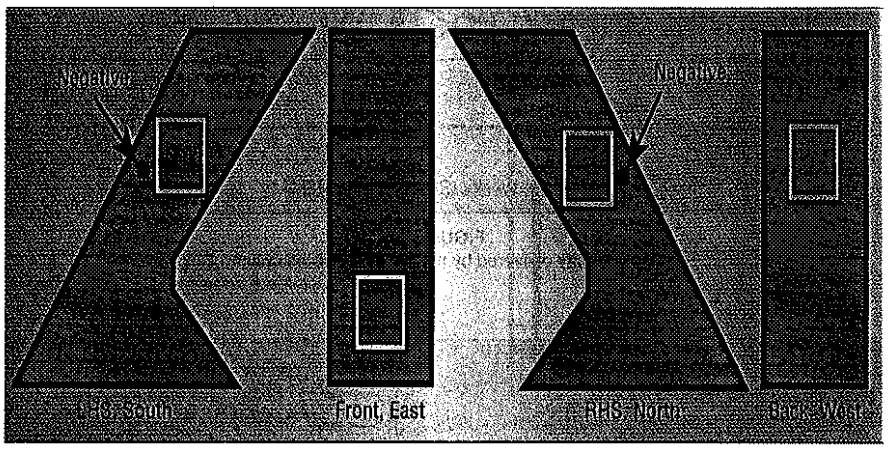

FIGURE 2
Schematic diagram showing the location of the 60 by 60 cm zinc patches on columns 2 and 7.

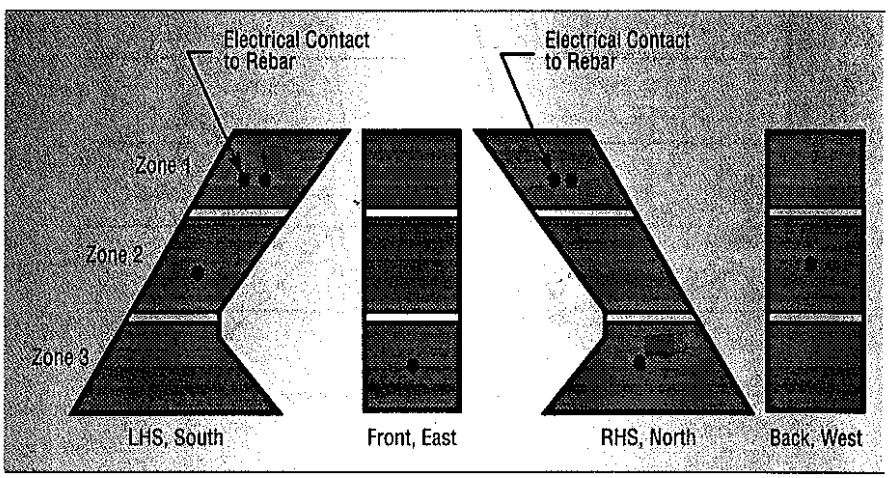

FIGURE 3
Schematic diagram of test column 1, monitored in the four-hour depolarization measurement.

In accordance with NACE RP0290-90, the polarization shift of the steel vs embedded graphite reference electrodes also was monitored for a four-hour period following the interruption of current from the zinc to the rebar. To measure such potential shifts, 12 reference electrodes were permanently embedded in the concrete of two metallized columns. To interrupt the flow of current externally, the zinc coating on these columns was divided in three zones electrically isolated from the reinforcing steel. A schematic drawing of column 1 is presented in Figure 3.

Results and Discussion

The zinc was metallized on the concrete columns in October 1993. The monitoring of the current and polarization was initiated in May 1994. Prior to then, no current flow was allowed on the columns since no

metallized zinc coatings delivered appreciable cathodic polarization levels to the reinforcing steel for several months when there is frequent wetting of the concrete.[8]

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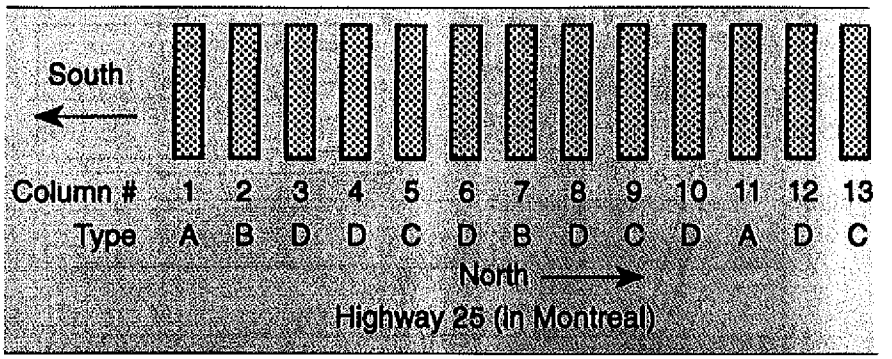

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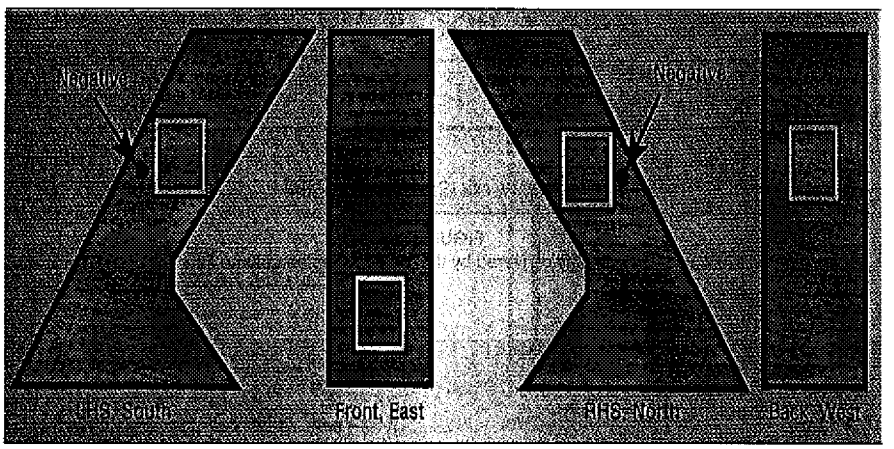

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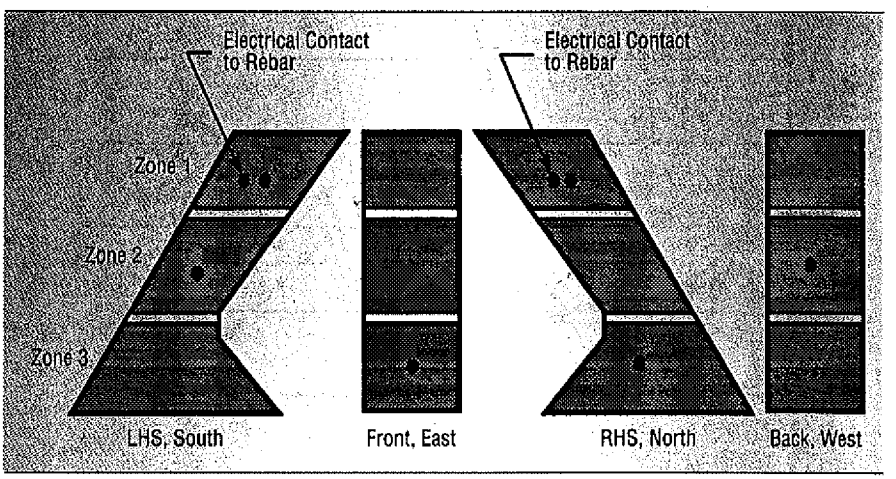

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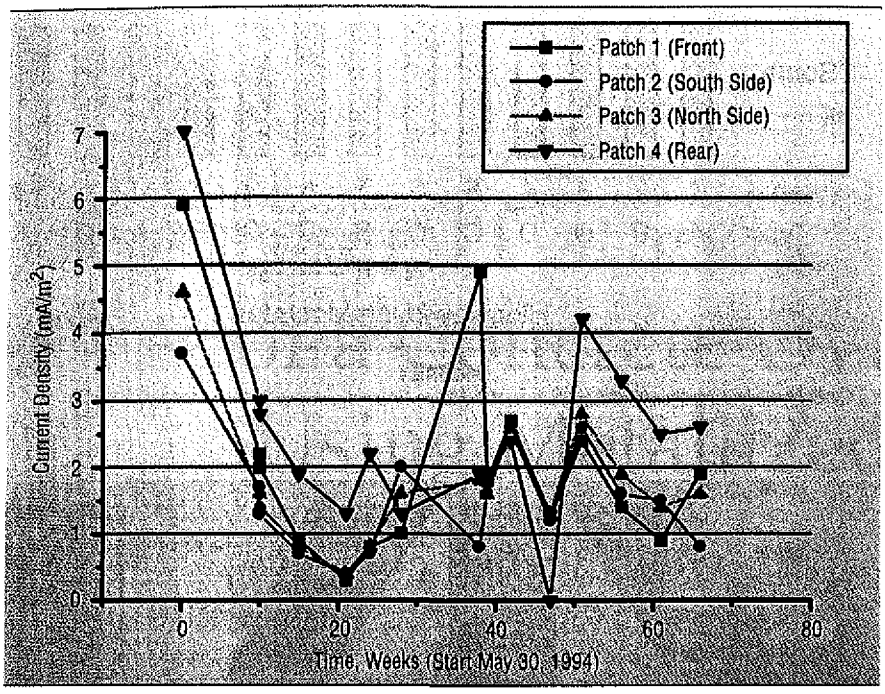

FIGURE 4
Current density delivered by the zinc patches on column 2.

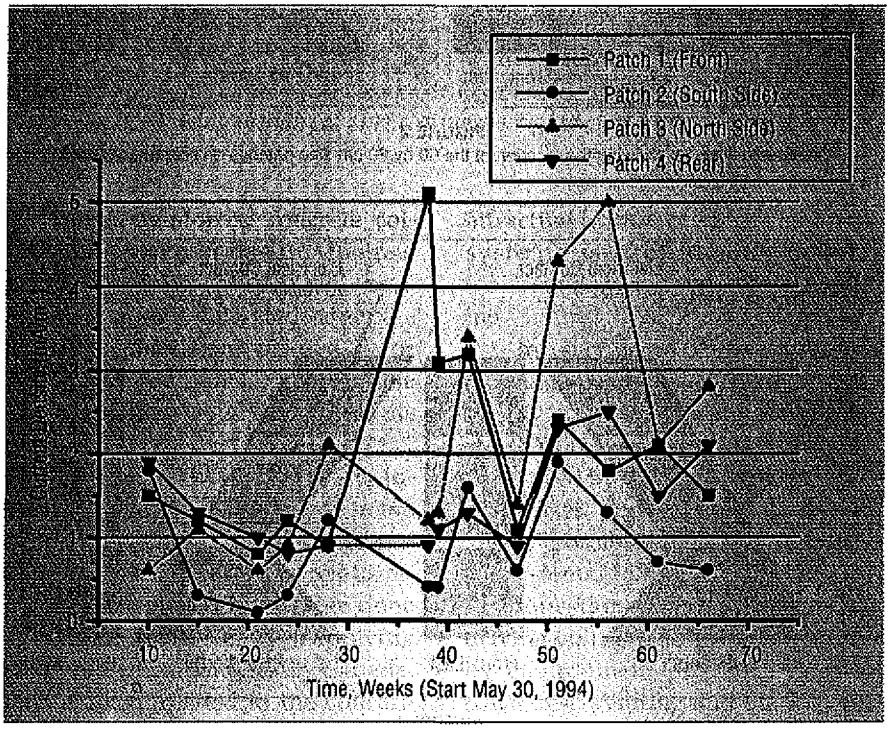

FIGURE 5
Current density delivered by the zinc patches on column 7.

external connections were made between the test patches/zones and the rebar.

The current density at the four patches on columns 2 and 7 are presented in Figures 4 and 5. Adequate galvanic current densities are initially obtained. At first, the current density delivered decreased as the dry summer of 1994 progressed. Currents increased later during the late fall and the unusually mild 1994/1995 winter. A possible explanation for recovery in current density is the metallized zinc coating was reactivated by the melting snow and salt splashed by passing vehicles. The frequent fall rains also could have resulted in a higher concrete moisture content. This would have reduced the overall circuit resistance that must be overcome if galvanic current is to flow to the reinforcement. The current densities measured at the three short-free zones of column 1 show a similar trend (Figure 6).

The four-hour steel reinforcement polarization shifts measured initially exceeded the 100 mV criteria (Figure 7). Between week 10 and 25, it did not exceed it. A recovery of the steel polarization shifts was observed similar to current when winter 1994/1995 arrived. Over the past few months, these values have slowly decreased, similar to the anode current densities. Current requirements for corrosion protection of the steel reinforcement are anticipated to decrease with longer periods of cathodic polarization. This is because the CP process is known to repel the chloride ions away from the negatively polarized reinforcing steel. CP also converts the dissolved oxygen, usually required for corrosion, into hydroxyl ions. This favors steel repassivation and further mitigates corrosion.

Conclusions

The performance of metallized zinc as a sacrificial anode for the CP of reinforced concrete in Canada shows some promise, based on the relatively short-term experimental data acquired in the field. Long-term performance must be established before it is recommended as a cost-effective rehabilitation of reinforced concrete. For drier environments, where the amount of reinforcing steel and resistivity of the concrete is relatively high, there is concern that pure zinc might not provide adequate levels of CP required. More electronegative metallized coatings should be developed for sacrificial CP to be used in such unfavorable conditions.

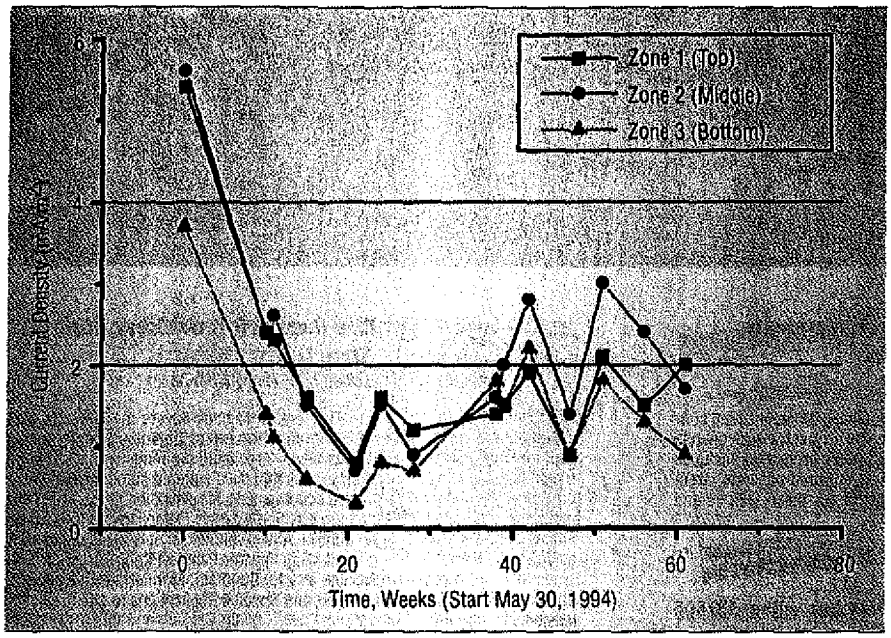

FIGURE 6
Current density delivered by the three zones of the zinc anode on column 1.

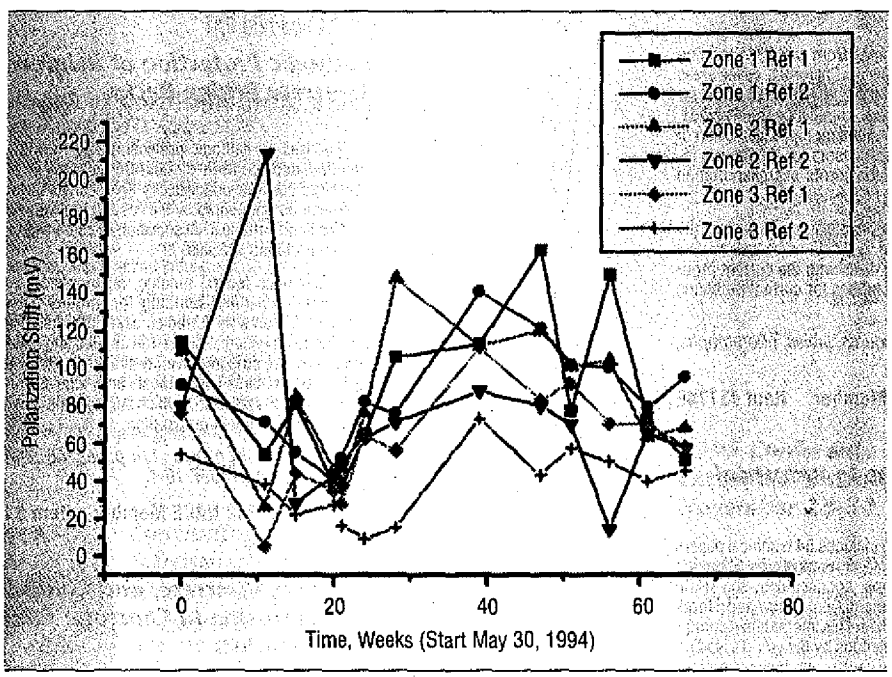

FIGURE 7
Steel polarization shifts measured on column 1 after galvanic current flow from the metallized zinc was interrupted for four hours.

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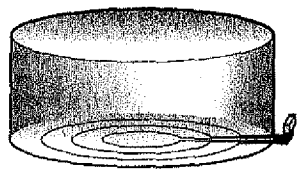
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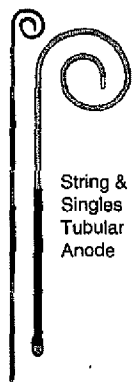
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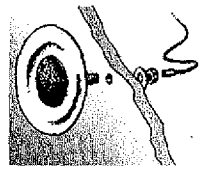
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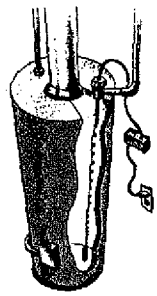
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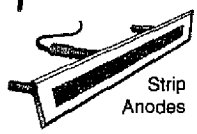
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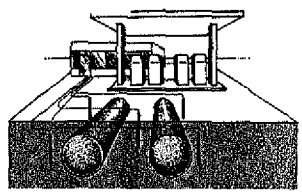
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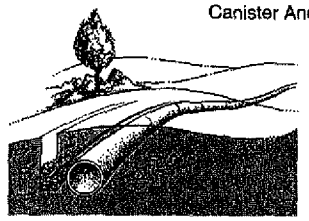
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