



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUL 18 1986

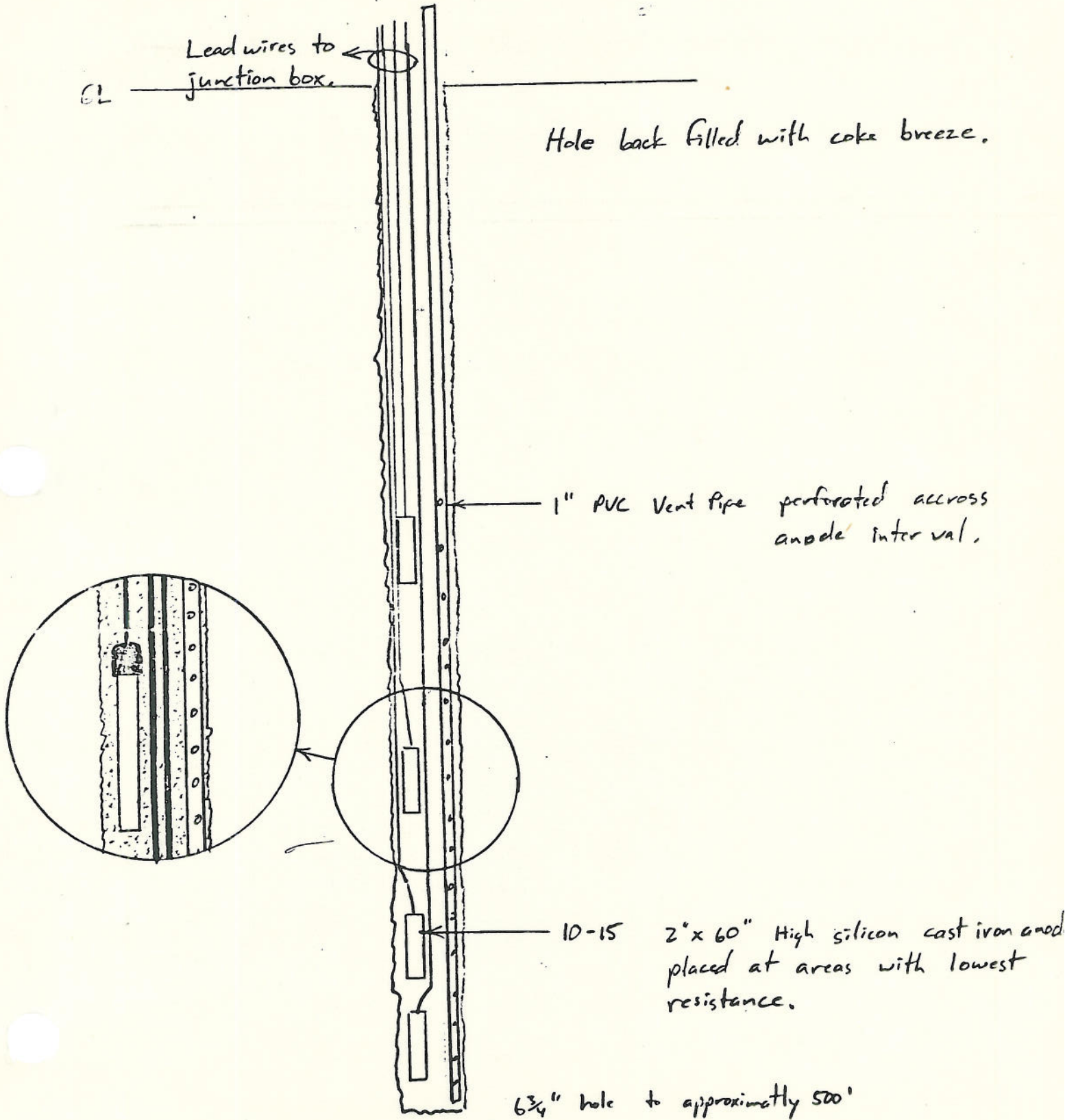
OFFICE OF
WATER

MEMORANDUM

SUBJECT: Cathodic Protection "Wells"
FROM: Thomas E. Belk, Chief *Thomas E. Belk*
Underground Injection Control Branch (WH-550)
TO: Patrick A. Crotty, Acting Chief
Drinking Water Branch (8WM-DW)

I am responding to your memo of June 30, 1986. We have reviewed the new information on the Cathodic Protection Systems, and we agree that such practices may pose a threat to Underground Sources of Drinking Water. However, we continue to be convinced that they are not covered by the Underground Injection Control program. It may be that the State has jurisdiction to protect USDW's from such practices. We applaud your concern for the protection of Underground Sources of Drinking Water. Please let us know if any agency has jurisdiction and if we can be of any assistance in bringing this concern to their attention.

Cathodic Protection and bed Schematic





UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII

ONE DENVER PLACE — 999 18TH STREET — SUITE 1300
DENVER, COLORADO 80202-2413

JUN 30 1986

Ref: 8WM-DW

MEMORANDUM

TO: Thomas Belk, Chief
Ground Water Protection Branch (WH-550)

FROM: *Mike Strickly*
Patrick A. Crotty, Acting Chief
Drinking Water Branch (8WM-DW)

SUBJECT: Cathodic Protection Wells

My staff recently obtained information from Northwest Pipeline Company pertaining to cathodic device protection wells, which are used in connection with gas production wells in southwest Colorado. This type of well is used to protect the steel long string casings of production wells from galvanic corrosion caused by a difference in electrical potential.

The cathodic protection system in Colorado involves drilling uncased wells to 500 feet, installing ten high-silicon cast iron anodes which are connected to an electric junction box, installing a perforated 1" PVC pipe to vent gases, and backfill the well with coke breeze slurry. The purpose of the coke is to provide a low resistance electrical contact with the soil. The A-C, provided by an external electrical source, is converted to D-C by a selenium rectifier. The current is introduced into an area of least resistance through the anode. The current flows toward the steel casing, which is acting as a cathode. Corrosion will occur at the cast iron anodes, and no corrosion will occur at the steel casing (cathode). Additional background information for cathodic protection is found in the attachment entitled "Cathodic Protection Fundamentals".

The concerns relating to cathodic protection system are as follows:

1. The number of these wells, for just the limited area of southwest Colorado, may number in the thousands.
2. The wells are not sealed off at the surface to prevent surface inflow.
3. Although the well is backfilled with coke breeze, there is the tendency of granular (1/4" and smaller particles) coke to have seepage pathways. This would not provide the filtering claimed by the operator.

(copy to Graham)
AC-7/3

4. There are drinking water formations in the area that may be contaminated by surface inflow. The residents in the immediate vicinity of the cathodic wells obtain their drinking water at the 200 foot level. One domestic well is located within 200 feet of a cathodic protection well.
5. Well construction (see attached diagram) does not indicate the use of cement to seal off the zone where drinking water is located.
6. In this particular area there is concern for cross contamination of lesser quality water with drinking water. The operator, however, does seal off those zones that are under artesian pressure. Area residents are concerned about the potential for cross contamination of their drinking water.

In view of the construction methods employed, it appears that the type of well should be classified as a Class V well. We are requesting your review and assessment of the cathodic device well. Should you concur with the Class V classification, it is recommended that other Regions be alerted to this type of well and begin owner notification, inventory and assessment of this type of Class V well.

Attachments

JOSEPH A. LEHMANN
Executive Vice President

Cathodic Protection Fundamentals★

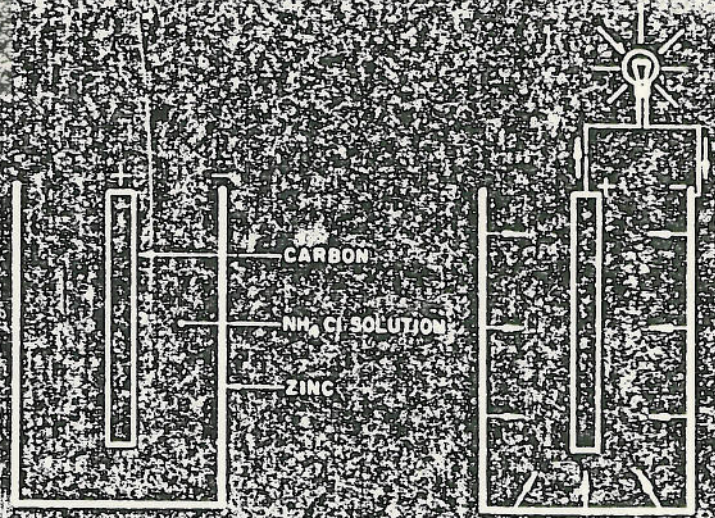


Figure 1—A simple demonstration of the corrosion process is seen in the operation of a dry cell battery. Corrosion occurs when current flows from the zinc casing (anode) through the electrolyte (ammonium

chloride solution) to the carbon rod (cathode). Corrosion appears at the zinc casing where current enters the electrolyte. No corrosion occurs at the cathode.

HIGH COSTS of materials and labor demand that engineers use every means at their disposal to prevent material waste: Corrosion of metals is probably the greatest waste incurred by modern civilization. Loss of an automobile muffler, the replacement of a hot water tank, the collapse of a bridge, a gas explosion, or a water main "break" are just some of the corrosion problems man has encountered. No one seems to be immune from its ravages.

Just what is corrosion? Some have called it rust, oxidation, deterioration, chemical attack, and electrolysis. The easiest way to understand the corrosion reaction is to examine a simple application of the corrosion principle—the dry cell battery (galvanic cell), as diagrammed in Figure 1.

Basically, a battery consists of three essential parts: an anode, a cathode, and an electrolyte. The container, usually a zinc casing, is the anode (negative terminal). The cathode (positive terminal) is the center carbon rod. The electrolyte is the compound consisting of ammonium chloride, moisture, and a depolarizing agent such as

manganese dioxide which are encased around the carbon. When a light bulb is connected between the positive and negative terminals, an electrical current will flow conventionally from plus to minus because of electrochemical reaction occurring simultaneously at both electrodes. Within the battery (internal circuit) the current will flow from the zinc through the electrolyte to the carbon rod. Corrosion will occur at the anode where the current leaves the metallic surface and enters the electrolyte. No corrosion will occur at the cathode (carbon) where current is collected from the electrolyte.

After the continued use of a dry cell, the container becomes corroded and the electrolyte leaks out. The current flow is caused, essentially, by the difference in electrical potential between the two dissimilar metals. Zinc is more electro-negative (less noble) than carbon; therefore, it is anodic to the carbon. Similarly, current can be generated by electrically coupling any two

★Revision of the paper "Fundamentals of Cathodic Protection" presented at North Central Region Conference, National Association of Corrosion Engineers, October 1-3, 1963, Kansas City, Mo.

SUMMARY

Discusses fundamentals of cathodic protection using simple dry cell battery as illustration. Explains application of cathodic protection and suggests methods for maximum efficiency. Describes galvanic and impressed current systems. Emphasis is placed on cathodically protecting pipelines. Discusses current variables for maximum protection.

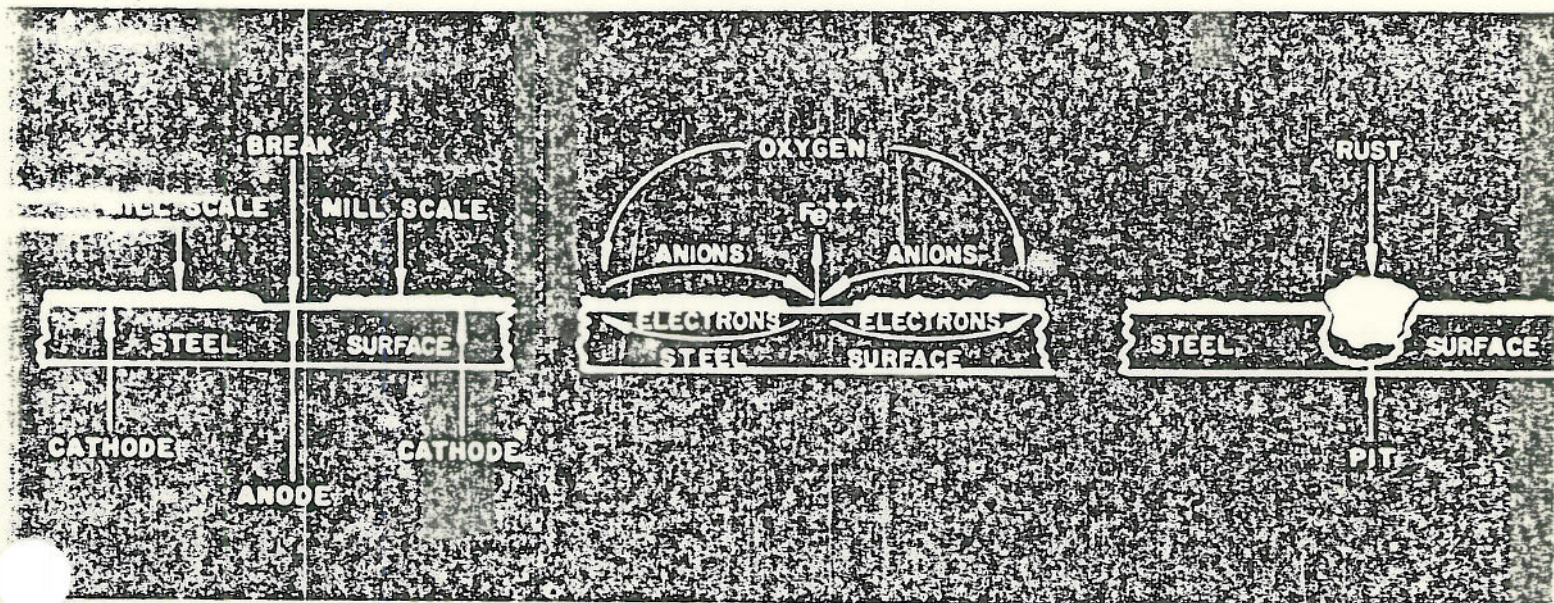


Figure 2—Cause, effect, and result of the corrosion process on a metallic sample exposed to conditions favoring galvanic attack (oxygen, dissimilar metals, and moist atmosphere).

dissimilar metals within an electrolyte. In fact, differences in electrical potential resulting in galvanic (corrosion) cells can occur on metallic surfaces simply because of environmental or physical variations (Figure 2). In addition to corrosion from the inter-connection of dissimilar metals, galvanic cells are created because of variations in ion concentration, oxygen differential, variances in stress, cold worked metal in contact with the same metal annealed, and heterogeneous soil conditions.

Regardless of the conditions causing a corrosion cell, the basic requirements are always the same: an anode coupled to a cathode in an electrolyte. Considering these basic requirements, the following methods of corrosion control are suggested:

1. Electrical insulation of the anode from the cathode.
2. Electrical insulation of both anode and cathode (or either) from the electrolyte.

3. Treatment of the electrolyte so that it will have a high electrical resistance, retarding the flow of corrosion current.

4. Use of nonmetallic materials.

5. Making entire metallic surface (anode-cathode) cathodic to an external anode. This is called "cathodic protection" (Figure 3).

Frequently, corrosion engineers use a combination of two or more of these corrosion control methods when eliminating or retarding corrosion activity. Examples of such applications, as related to pipelines, might be as follows:

1. Electrically insulating anodic area from cathodic area. When new steel pipe is connected to old rusty pipe, generally, the new pipe is anodic to the old pipe. By installing an insulating flange at the junction between the new and old pipe, the long line galvanic cell is "broken up"—the anode (new pipe) is electrically separated from the cathode (old pipe).

Similarly, when a pipeline transverses moist clay areas adjacent to dry loam, steel surfaces

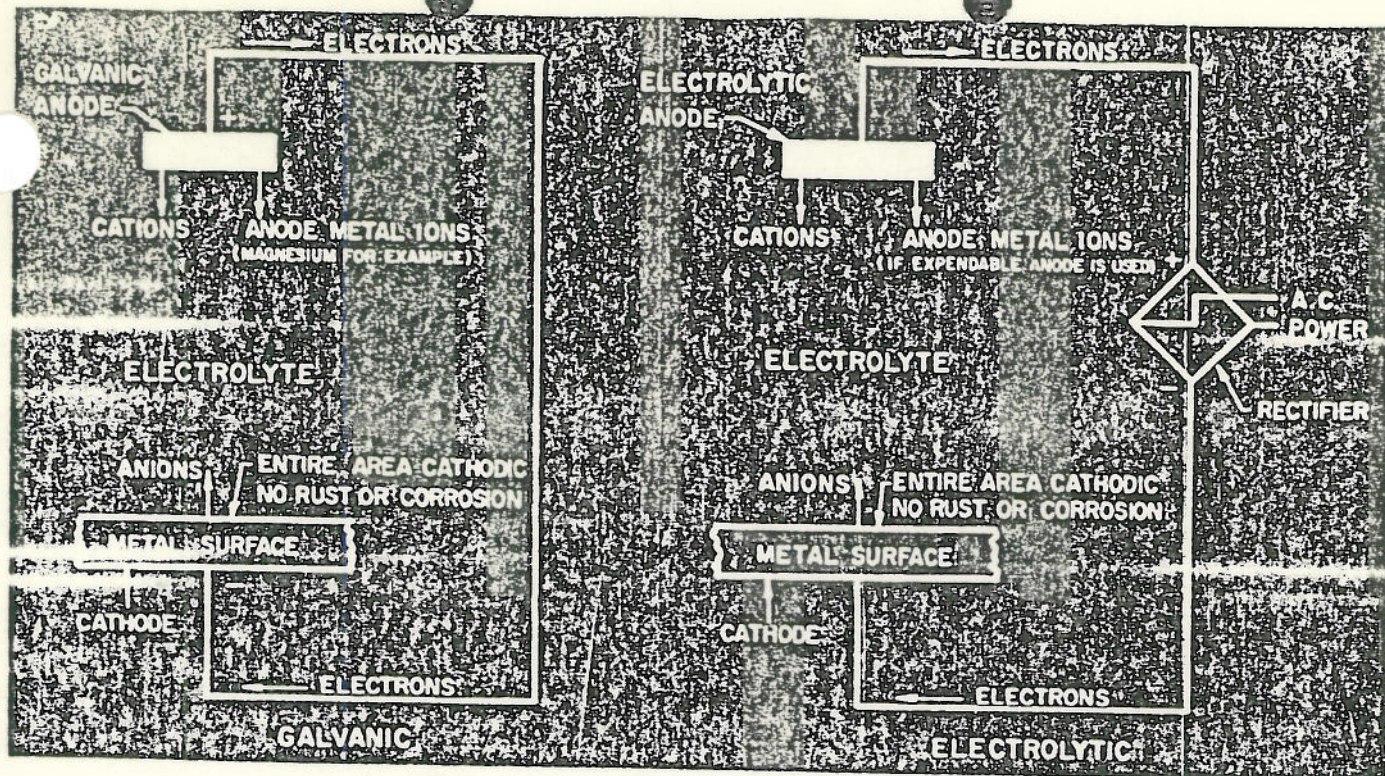


Figure 3—Two types of cathodic protection are the galvanic (sacrificial) system at left and the impressed current system at right. In the galvanic system, a less noble metal (anode) is installed to absorb negatively charged anions. In the impressed current system, an external energy source is used to introduce current into the electrolyte, rendering the pipe cathodic.

the wet area become anodic to steel surfaces in the dry area. For this reason, corrosion engineers frequently install insulating flanges (or other insulating type fittings) in the pipeline on each side of a swamp to insulate the known anodic area from the cathodic sections.

Insulating fittings also are used to electrically separate dissimilar metals. Insulating couplings are used on gas service lines to insure electrical separation from copper water services (which normally would be connected electrically to the gas line by means of the customer's water heater).

2. Electrically insulating anode or cathode from the electrolyte. This is probably the most common practice used in combatting corrosion. If a structure can be insulated from the electrolyte (soil or water), the metallic surfaces are not affected by the environment; therefore corrosion is eliminated.

In recent years, many types of coatings have been developed for this purpose. These range from heavy asphalt, coal tar mastics, and enamels to thin plastic films. If a coating is to be effective, it should have such properties as high dielectric strength, excellent bonding characteristics, low water absorption properties, and good physical strength. High dielectric strength is required to effectively insulate the pipeline from the surround-

ing soil. Strong bonding properties are necessary to insure continuous and permanent contact between the steel and the coating itself. If the coating separates from the steel pipe, water can seep in between the coating and the pipe, permitting corrosion beneath the protective coating.

Low water absorption characteristics are necessary to maintain the dielectric strength and physical properties of the coating. This is particularly important when considering the combined use of coatings with cathodic protection. Physical strength is necessary to avoid damage to the coating in shipping, installation, and penetration caused by rock in the pipe trench.

Coatings also must be able to withstand physical damage resulting from soil stress, which can rip the coating from the pipe, especially in certain types of clays that are subject to expansion and contraction because of alternate wetting and drying cycles. Other considerations such as insolubility and inertness are important with regard to pipeline coatings.

Unfortunately it is impossible to achieve perfect coating of a pipeline and, under some circumstances, small pinholes called holidays in the coating intensify the corrosion problem. Penetration occurs more rapidly than it would on a bare line.

3. Treatment of the electrolyte. This method of corrosion control has not been widely used on pipelines. Because of engineering and economic considerations, treatment of the environment has largely been confined to the use of selected sand backfill around a newly installed pipe (usually coated). In some instances, alkalis (lime) have been added to the backfill to create a more favorable environment. This treatment usually is used in conjunction with cathodic protection resulting in protective calcareous deposits at coating failure locations.

4. Use of nonmetallic materials. When corrosion conditions are particularly severe and pressure and soil stress conditions are not too great, the use of plastic pipe (polyethylene or polyvinyl chloride) has been successful. Manufacture of plastic pipe during the past ten years has undergone tremendous technological changes, and there is no doubt that these materials will improve, resulting in even greater use for corrosion control.

5. Cathodic protection. It is important to remember that corrosion always takes place at the anode (where current leaves the metal surface and enters the electrolyte) and that no corrosion or a protective effect is experienced at the cathode (where current is received by the metallic surface from the electrolyte). Therefore, if

an entire metallic surface can be "forced" to become cathodic, it will not corrode—it will be cathodically protected. There are two basic methods of applying cathodic protection to a metallic structure in contact with an electrolyte. These are galvanic cathodic protection and impressed current cathodic protection (Figure 4).

The two types of systems are similar because they both deliver electric (d-c) current to the structure being protected.

Galvanic Cathodic Protection Systems

Galvanic systems produce the required protective current by an electrochemical reaction (the same as a flashlight battery). A metal less noble than the metal to be protected is selected for the sacrificial anode. When protecting steel, cast iron, or copper, the anode material can be magnesium, zinc, or aluminum. The number, size, type, and location of anodes is determined by a detailed survey of the structure to be protected. Such factors as coating resistance, soil resistivity, and interference effects must be considered. In general, galvanic anodes are used when:

1. Current requirements are relatively low.
2. Soil resistivity is low (seldom used in electrolytes having a resistivity of 10,000 to 15,000 ohm-centimeter or above) and voltage requirements not high.
3. Electric power is not available.
4. Interference problems are prevalent.
5. Short life protective systems (low capital investment) are required.

In most applications the anode is a cylinder or rod connected electrically by a wire to the structure to be protected. Sometimes a calibrated resistor is installed in the anode lead wire to control current output. Under the same conditions, cylinder type anodes have a longer life but lower current output than rod type anodes. Galvanic anode systems are seldom designed for a life of more than 20 years.

Magnesium and zinc anodes in soil usually are surrounded by a special backfill (gypsum-bentonite-sodium sulfate). This backfill is required to insure a homogeneous, moist, low resistivity environment which increases efficiency and extends anode life.

Impressed Current Systems

The use and design of impressed current systems are more flexible than galvanic anode systems. Design requirements are determined by a sur-

vey of the structure to be protected.

Basically, the principle is the same for both systems except impressed current systems energize anodes by use of an external energy source. Generally, a rectifier is used to convert available a-c to d-c. The direct current is then introduced into the electrolyte by an anode (or anode bed) especially designed to have a long life under relatively high current, high voltage conditions.

Many different types and sizes of anodes are available for use in impressed current systems. These are graphite, high silicon cast iron, lead-silver alloy, platinum, and even scrap steel rails. Each anode has special design, installation, and operating characteristics.

Impressed current systems are advantageous when:

1. Current requirements are high.
2. Electrolyte resistivity is high, requiring higher voltage than is available from galvanic anodes.
3. Long life protective systems are required.
4. Fluctuation in current requirements is encountered (systems can be controlled and adjusted automatically).
5. Electric power is readily available.

When impressed currents are used, it is important to consider interference effects on neighboring structures.

Protection of pipe usually involves installation of a transformer rectifier control unit and several anodes (graphite or silicon cast iron rods) wired in parallel. The positive terminal of the rectifier is connected to the anode bed, and the negative terminal is connected to the structure to be protected. In addition, the power unit is usually equipped with indicating ammeter, voltmeter, and overload circuit breaker. Current output of the unit is adjusted by the taps on the secondary winding of the transformer which vary the a-c voltage to the rectifier stacks.

Design and Criteria for Cathodic Protection

In selection of the type cathodic protection system, the most important consideration is that of current requirements. How much d-c is required to protect a given structure? When is protection achieved?

Without going into a great deal of theory regarding electrochemical principles and the solution of metals, it has been determined that corrosion of steel (or iron) is stopped when its potential to a copper-copper sulfate electrode is -0.85 volt or more electronegative with the reference electrode placed close to the electrolyte/structure interface. This potential value is the most significant measurement with respect to corrosion control.

It actually is the measurement of voltage drop at the interface of the metallic surface and the electrolyte, the reference cell being one contact terminal and the structure being protected is the other terminal.

In neutral pH range electrolytes, an iron anode will not have a potential more negative than -0.79 volt to a copper-copper sulfate electrode. Corrosion can be controlled if the entire iron surface is raised to -0.85 volt. In other words, the cathode is polarized to the open circuit potential of the anode, and local cathode/anode cells cease to exist. The value of -0.85 volt is generally accepted to compensate for varying conditions, in particular the physical inability to place the reference cell at the surface of the protected structure. Usually, it is necessary to include more voltage drop than should be allowed (in pipeline work, the cell is generally placed on the earth surface, above the line, three or more feet from the metal's surface).

Current required to raise the structure's potential to protected values is a function of the structure's electrical resistance to the electrolyte. On pipelines, this usually is a combination of coating resistance and soil resistivity (or "contact" resistance). For example, a well coated pipeline in high resistance soil may require as little as five microamperes per square foot to achieve cathodic protection; a bare or poorly coated pipe in low resistivity clay may require 1.5 to 2.0 milliamperes per square foot to be polarized to -0.85 volt or more negative. Furthermore, under conditions where depolarizing agents are prevalent, protective current requirements are relatively much greater. For example, in condenser water boxes where water velocity is high (continuously introducing large amounts of oxygen which depolarize the cathode), current requirements to achieve cathodic protection may be 120 milliamperes or more per square foot.

To determine the specific cathodic protection current requirements for a given structure, it is necessary to simulate a protective system. After a series of soil resistivity tests are made, a suitable site (low soil resistance area) is selected for a temporary test ground bed. The test ground bed usually consists of several steel pins driven into the soil on 15 or 20-foot spacing (or 10 feet of aluminum foil submerged in a conveniently located creek.)

The ground bed usually is energized by a portable d-c generator or six-volt "hot-shot" battery. While the applied test current is interrupted, pipe-to-soil

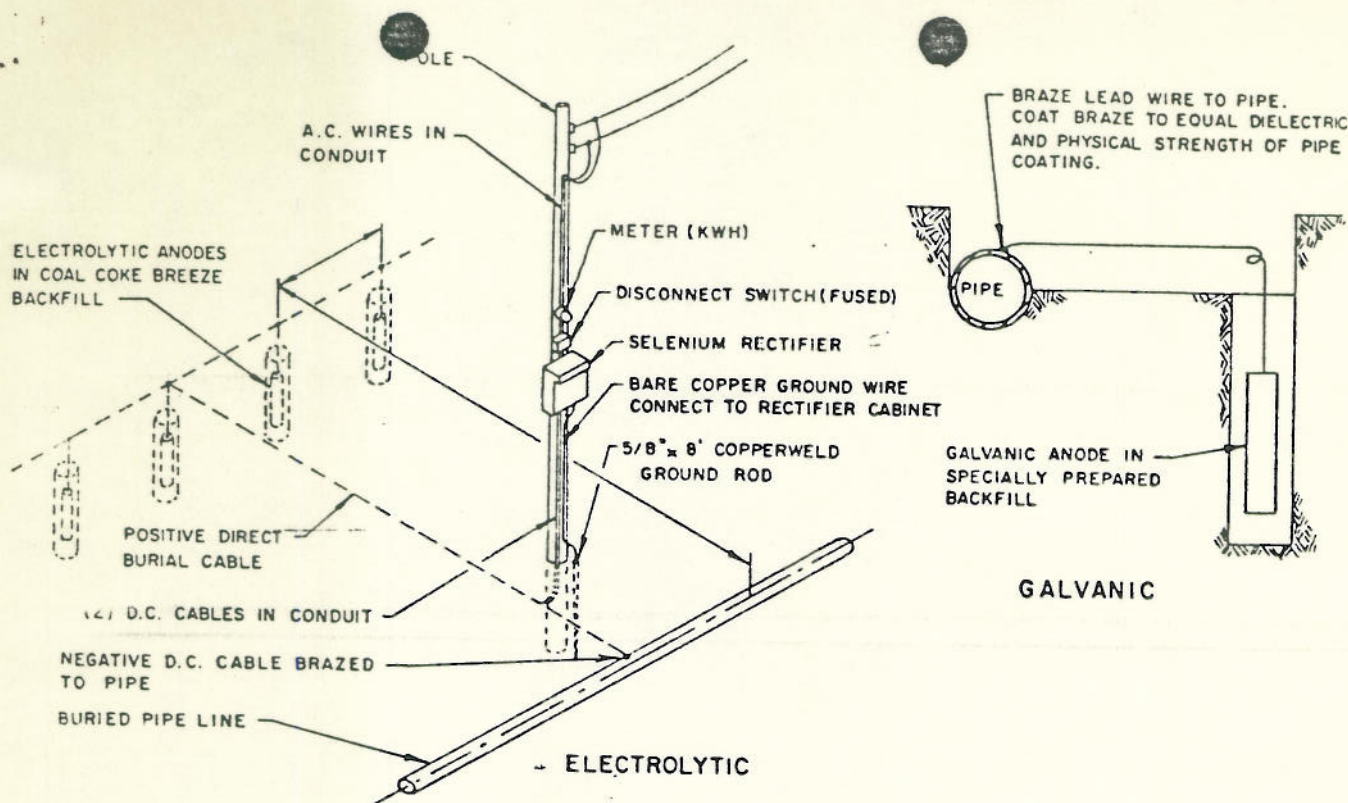


Figure 4—Typical cathodic protection installations. Impressed current (rectifier) system is shown at left and application of a galvanic anode for protection of pipelines at right.

potential measurements are made at several locations along the line to observe the attenuation effect of the current. Under ideal conditions, the applied test current can be adjusted so that minimum protective potentials (-0.85 volt) are observed at critical (or line end) locations. It is advisable to determine extent of interference effects on neighboring structures while conducting current requirement tests so that allowances can be made for clearing such effects when the permanent cathodic protection system is designed.

Once the current requirement is established, the selection of galvanic or impressed current system can be made and the protective system can be designed.

This brief description may lead one to think that testing and design for cathodic protection is an extremely simple matter. This is not the case. Like other engineering applications, there are many techniques and details which create complex problems. Interference on foreign structures is a major concern. Over protection can literally destroy expensive coatings. Electrically isolating the structure to be protected from other metallic structures and insuring electrical continuity of the protected structure are important considerations. A complete understanding of the associated

instrumentation is mandatory, and use of the wrong type meters or misinterpretation of test data can have disastrous results. A complete knowledge of system components (anodes, both galvanic and impressed, rectifiers, backfill materials, and cables) is necessary. Application of cathodic protection is not a simple matter.

During the early history of cathodic protection, systems were crude. Engineers had to use makeshift anodes, rectifier units which were meant to be battery chargers, windmill driven generators, and field test instruments which were designed for laboratory experiments. Today, cathodic protection has come of age, and industry is supplying the corrosion engineer with equipment specifically designed for this work. Recent developments make the use of cathodic protection far more economical than it has ever been—and more effective.

One new "break-through" in this field is the automatic potential control system. This unit makes the use of cathodic protection completely automatic, compensating for any changes which may alter the protective current requirements.

New anode materials now make design more flexible than ever. These include lead-silver alloy anodes, various types of platinum anodes, and new high efficiency aluminum anodes.

CORINTEC  CATHODIC PROTECTION SERVICES, INC.

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CPS has offices in New Orleans and Lafayette, LA/Midland, TX/Liberal, KS/Denver, CO/Tulsa, OK/Farmington, NM/Billings, MT/Corpus Christi, TX. Worldwide affiliates

It has been said that cathodic protection is the most unique form of corrosion control—"fighting corrosion with corrosion." Indeed, the wide spread use of cathodic protection in almost every industry has been effective in preventing waste due to corrosion on a large scale. Certainly this method of combating corrosion, combined with all the advancements in other corrosion control techniques and materials, can help achieve greater savings by preventing waste.