

February 1, 1971

DESIGN NOTE NO. 12*

Subject: Control of Underground Corrosion

Buried metal pipes and other underground metal objects are subject to very rapid corrosion under certain conditions, conditions which occur commonly enough to demand careful attention. A considerable number of steel irrigation pipes and galvanized steel pipe spillway conduits installed with SCS assistance have failed by corrosion after only a few years' service.

The purpose of this design note is to provide interim guidance in carrying out the requirements of Engineering Standard 432-F and Engineering Memorandum-27 pertaining to corrosion control. A technical release on the general topic of underground corrosion will be issued later if it proves to be needed.

Engineering Standard 432-F applies to steel irrigation pipelines. Engineering Memorandum-27 covers the use of galvanized steel and welded steel pipe in earth dams. The discussion that follows is directed toward these kinds of pipe installations. However, most of it is equally applicable to any underground or partly underground steel structure.

Aluminum alloy pipes and structures are not specifically included. They are subject to similar corrosion processes, and the same principles apply to their protection, but the properties of aluminum differ from those of steel in several important ways:

- (1) A natural oxide forms immediately upon exposure of any aluminum surface to the atmosphere, which provides substantial protection against corrosion in most environments.
- (2) The exclusion of oxygen from portions of the surface, as by chunks of stiff clay in the backfill around a pipe, for example, promotes rapid corrosion at points where the oxide film is broken by preventing re-formation of the natural oxide.
- (3) Alkaline soils and waters are especially corrosive to aluminum, while they tend to inhibit corrosion of steel.

*By A. S. Payne, Assistant Chief, Design Branch

- (4) The natural potential of aluminum is so close to that of zinc that zinc anodes cannot be relied upon for cathodic protection. Magnesium anodes can be used, however.
- (5) The corrosion of aluminum is hastened rather than inhibited by cathodic protection if too much current is applied.

NATURE OF CORROSION

Underground corrosion is an electrochemical process similar to the action in a dry cell battery. It can take place only when four essential elements are present: (1) an anode, (2) a cathode, (3) an electrolyte, and (4) an electrical conductor connecting the cathode to the anode. An electrolyte can be any liquid, paste, or gas which can conduct electricity by the migration of ions. In the case of underground corrosion, the electrolyte is the soil. Moisture and dissolved salts have to be present in the soil to provide the ions.

These four elements provide a complete electrical circuit. An electromotive force (emf) also is necessary. It may be the result of galvanic action within the cell or of stray electric current from some external source. Current flows through the electrolyte from the anode to the cathode, and through the conductor from the cathode to the anode.¹

In a common dry cell, the zinc case is the anode, the carbon rod is the cathode, and the paste with which the battery is filled is the electrolyte. Current flows, and corrosion of the zinc case takes place, when a conductor is connected from the cathode to the anode. In underground corrosion, of a pipe for example, the soil is the electrolyte and the pipe itself usually is the conductor. One part of the pipe's surface may be the anode and another part the cathode.

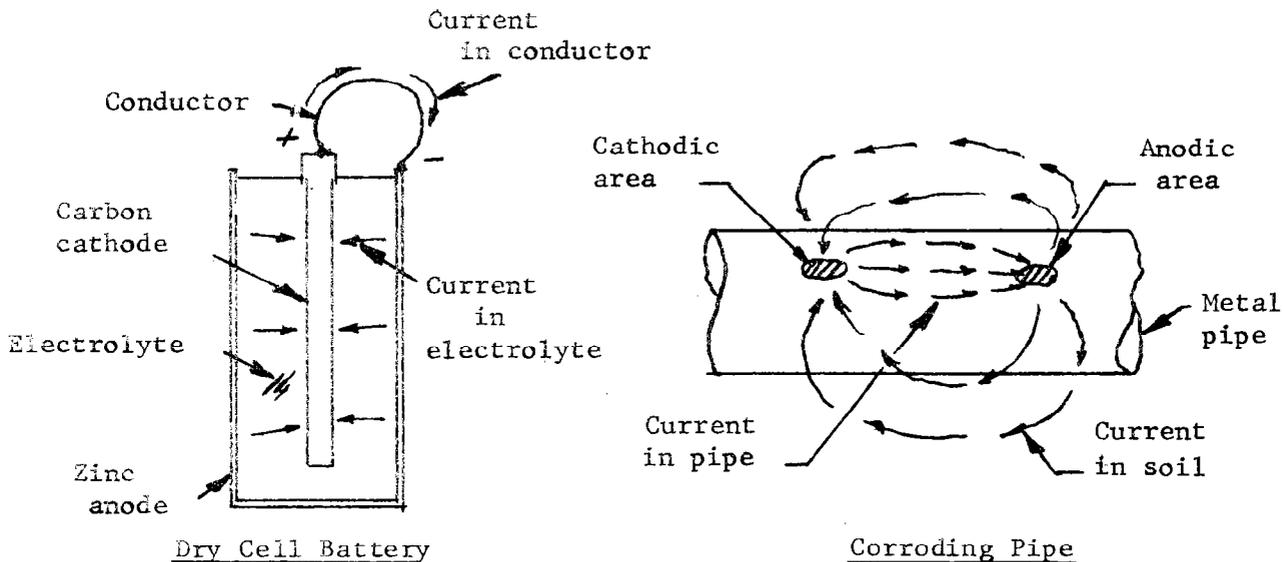


Fig. 1 - Corrosion Cells

¹The direction of current flow, as used throughout this discussion, is the conventional direction, opposite to the direction of electron flow.

The complete system (anode, cathode, electrolyte, and conductor) is called an electrolytic or galvanic cell or corrosion cell. The anode and cathode may include major areas of the pipe, or they may be minute, as at pinholes in a protective coating. Rusting of iron under a drop of water illustrates the action of a complete corrosion cell within the drop. By definition, in any electrolytic cell, current flows from the anode to the electrolyte and to the cathode from the electrolyte. Corrosion takes place where current leaves the metal and enters the electrolyte, hence at the anode.

CAUSES OF CORROSION

When the four essentials of a corrosion cell (anode, cathode, electrolyte, and conductor) are present, as they usually are when a metal object is buried in the ground, the rate at which corrosion takes place in each cell depends upon the amount of electric current flowing, which in turn depends upon the emf and the electrical resistance:

$$\text{Current (amps)} = \frac{\text{emf (volts)}}{\text{Resistance (ohms)}}$$

Thus, rapid corrosion is promoted by a high emf and low cell resistance. Since the electrolyte, which is the soil, is part of the cell circuit, soil with a high resistance retards corrosion. Likewise, pipe coatings having high electrical resistance inhibit current flow from the metal to the soil and so resist corrosion.

The conditions that can generate the emf necessary to make a corrosion cell operate are so numerous that some of them are nearly always present. Following is a partial list.

Properties of the metal object itself

- Dissimilar metals connected together
- Flaws and inclusions in the metal
- Forming strains, and variations in internal stress
- New metal connected to old metal
- Scratches, abrasions, pipe threads, etc., exposing clean metal
- Mill scale

Properties of the soil or other environment

- Variations in soil moisture
- Variations in aeration of the soil
- Variations in kind of soil
- Variations in acidity or other chemical properties
- Part of the metal submerged and part exposed to atmosphere
- Part of the metal encased in concrete and part in soil or water

External influences

- Induced current from nearby electrical equipment
- Stray currents in the soil from grounded electrical equipment

Probably the most generally recognized of these is the combination of dissimilar metals. For example, it is well known that steel will corrode very rapidly when coupled to brass or copper in a corrosive environment, i.e., in an electrolyte.

GALVANIC SERIES

When a metal is immersed in an electrolyte it develops an electrical potential (emf) with respect to the electrolyte. The magnitude of this potential is different for different metals. The "electromotive force series" is an arrangement of metals and their characteristic potentials arranged in order of increasing (positively) potential. The potentials usually shown are as measured with reference to a standard hydrogen reference electrode, in an electrolyte consisting of a solution of the metal's own salts. In other electrolytes the potentials are different, but the relative positions of the metals in the series usually are the same. Table I lists certain common metals and their potentials in the electromotive force series. Table II is a "practical galvanic series" of metals and their typical potentials in neutral soils and water when measured with respect to a standard copper-copper sulfate reference electrode.

Table I

Electromotive Force Series¹

<u>Metal</u>	<u>Emf - Volts²</u>
Magnesium	-2.37
Aluminum	-1.66
Zinc	-0.76
Iron	-0.44
Tin	-0.14
Lead	-0.13
Hydrogen	0.00
Copper	+0.34 to +0.52
Silver	+0.80
Platinum	+1.20
Gold	+1.50 to +1.68

Table II

Galvanic Series for Metals in Soil³

<u>Metal</u>	<u>Emf - Volts⁴</u>
Commercially pure magnesium	-1.75
Magnesium alloy (6% Al, 3% Zn, 0.15% Mn)	-1.6
Zinc	-1.1
Aluminum alloy (5% zinc)	-1.05
Commercially pure aluminum	-0.8
Mild steel (clean and shiny)	-0.5 to -0.8
Mild steel (rusted)	-0.2 to -0.5
Mild steel in concrete	-0.2
Copper, brass, bronze	-0.2
Mill scale on steel	-0.2
Carbon, graphite, coke	+0.3

¹From "Handbook of Chemistry and Physics"

²Potential of metal in solution of its own salts, measured with respect to hydrogen reference electrode.

³From Peabody, "Control of Pipeline Corrosion"

⁴Typical potential in neutral soils and water, measured with respect to copper-copper sulfate reference electrode.

In general, when any two metals are buried in the ground, or immersed in any other electrolyte, and are connected electrically (by an electrical conductor), a galvanic cell is established in which the metal higher in the series is the anode and the metal lower in the series is the cathode.

PROTECTION AGAINST CORROSION

Coatings

Coatings which will not conduct electricity or transmit moisture are effective in limiting underground corrosion. However, practically all coatings have some minor flaws ("holidays") through which moisture and electric current can pass. Corrosion tends to concentrate at the flaws because they are the only points at which current can flow from the metal. A coated pipe thus may be perforated by corrosion in less time than an uncoated pipe in the same environment.

Electrical Insulation

Corrosion caused by dissimilar metals can be prevented by electrically insulating one metal from the other; for example, by using insulating couplings to connect copper pipe and fittings to steel pipe. Insulation also may be applicable in controlling stray current corrosion.

Cathodic Protection

Cathodic protection of a buried pipe consists of lowering the electrical potential of the pipe, relative to the adjacent soil, to the extent that current can flow only from the soil to the pipe. The whole pipe becomes a cathode and does not corrode. A cathodic protection installation is a corrosion cell in which the pipe is the cathode and a separate, "sacrificial" anode is provided. The anode usually consists of a bar, rod, or wire of metal or carbon whose only function is to be an anode. It is expected to corrode and, if left in service long enough, to be essentially consumed.

Cathodic protection is provided either by galvanic action or by impressed current. In a galvanic cell, dissimilar metals are used for the anode and cathode. When a steel pipe is to be protected, the anode usually is zinc or magnesium. In an impressed current cell, the emf is supplied from an outside source of d.c. power or, more often, commercial a.c. power passed through a rectifier. The anode can be any electrical conductor and usually is of a durable metal, such as a corrosion resistant cast iron, or of carbon.

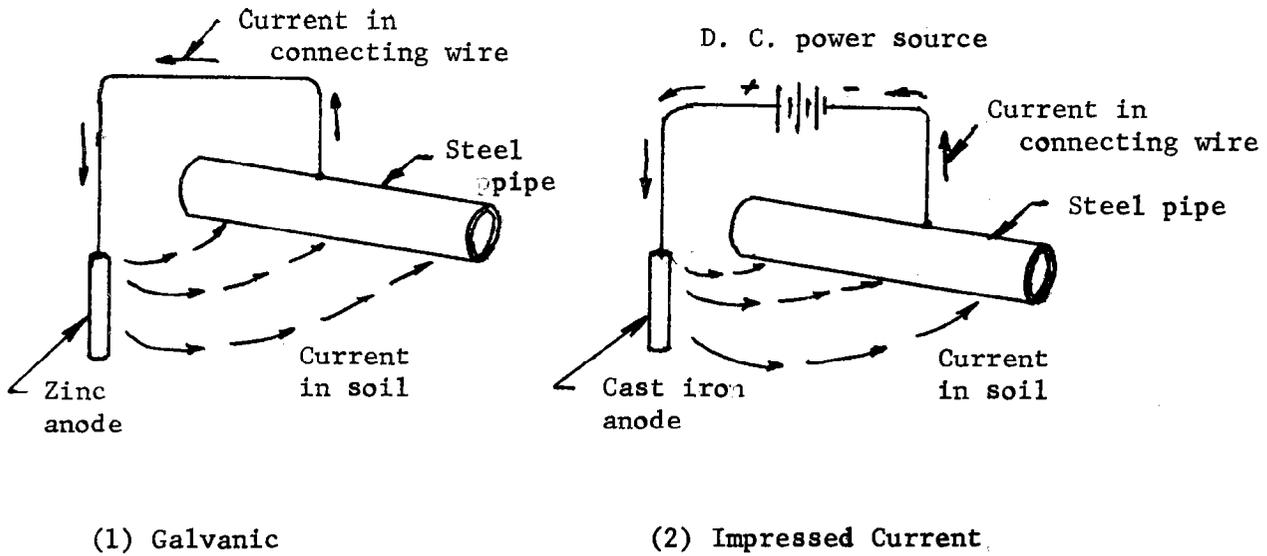


Fig. 2 - Cathodic Protection

TESTS FOR CORROSION CONTROL

Soil Resistivity

One of the most influential factors affecting the rate of corrosion and the design of cathodic protection is the resistivity of the soil. Resistivity is a unit measure of the electrical resistance of the soil. It is defined as the resistance of a unit cube, usually a one centimeter cube, to the passage of electric current and is expressed in resistance-length units, usually ohm-centimeters (ohm-cm). The resistance (R) of a given block of soil is equal to the resistivity (ρ) multiplied by the length (ℓ) in the direction of current flow, divided by the cross section area (a) perpendicular to the direction of current flow.

$$R \text{ (ohms)} = \frac{\rho \text{ (ohm-cm)} \times \ell \text{ (cm)}}{a \text{ (cm}^2\text{)}}$$

Soil resistivity has a major effect on the rate at which current passes from a metal surface into the soil, or from the soil into the metal, under a given emf and on the current a given anode can supply in a cathodic protection installation.

In general, resistivity decreases with increasing moisture in the soil and with increasing total salts. For practical purposes it is nearly constant for moisture contents from field capacity to saturation. The conductivity of a saturation extract of soil is used in Soil Survey measurements of total salts. This measure does not correlate well with resistivity, but does give some indication of the corrosivity of the soil. It has the advantage that it is available for many soils already tested.

Soil resistivity should be measured before a metal pipe is installed and in many cases after it is installed, also, especially if the soil moisture is different after the pipe is installed.

Laboratory Tests. The Soil Mechanics Laboratory in Lincoln, the Engineering Materials Laboratories in Portland and Fort Worth, and the Soil Survey Laboratories in Lincoln and Riverside all are equipped to make resistivity measurements. They use the Bureau of Soils resistivity cup or similar devices. Two or three pounds of soil should be sent to the laboratory for each test. A device similar in principle to the resistivity cup but larger is the "soil box." Its volume is about 35 cubic inches, while that of B of S cup is 50 ml.

Since the resistivity of most soils decreases with increasing moisture content, resistivity tests should be made with the samples at a moisture content representing the wettest condition likely to prevail for any significant time in the vicinity of the pipe after it is installed. For metal pipes in earth dams, the soil should be tested in a saturated condition. The resistivity also is affected by salts in the ground water. This should be considered in testing soils which may become saturated with water having a higher salt content than the natural ground water.

Field Tests: Single Probe. The resistivity of small volumes of soil in place at or near the surface, or in a pipe trench or exploration pit, can be measured with any of various models of single-probe instruments. These measure the resistance between 2 electrodes in a probe rod which is inserted into the soil to be tested. The equipment is portable and tests can be made quickly. The soil may not be at the moisture content it will have after the pipe is installed, however, in which case the readings will not indicate the resistivity to be expected when the pipe is in service. A nearly-saturated condition for the test can be achieved by boring a hole to the depth at which the measurement is to be made, pouring water into it, and allowing the water to soak into the soil before making the test.

In SCS experience to date, single-probe resistivity instruments have not given consistent results. This probably is because of their sensitivity to local variations in the soil. It is likely that the local resistivity is altered somewhat by compression of the soil when the probe is inserted.

Field Tests: Wenner 4-Pin Method. The average resistivity of a large volume of soil in place can be measured quickly and easily, if the equipment is available, by the 4-pin method. Four electrodes are stuck into the ground equally spaced in a straight line. Electric current is applied to the end electrodes and the resulting change in voltage between the two intermediate electrodes is measured. From the measured current and voltage, the resistivity can be calculated. The measurement is considered to represent the soil in the vicinity of the pins to a depth equal to the pin spacing. Changes in resistivity with depth can be detected by making a series of measurements with the pins at different spacings, e.g., 5, 10, 15, and 20 feet.

When resistivity is measured by this method in the vicinity of a pipeline already in place, the electrodes are placed in a line transverse to the pipeline. Otherwise, the pipe would carry part of the electric current and the reading would not be correct.

The 4-pin method is commonly used in resistivity surveys for pipelines. It is especially adapted to quickly surveying a large area and determining in general what corrosion protection will be needed. The results are limited, of course, to resistivity at the moisture content prevailing at the time of the survey.

Soil pH

Acid soils and waters generally hasten the corrosion of steel, and alkaline soils and waters tend to inhibit corrosion of steel. Alkaline conditions increase the rate of corrosion of aluminum alloys. The pH of the soil and water to which a metal pipe will be exposed should be tested before the pipe is installed.

Laboratory Tests. The Soil Mechanics Laboratory, Engineering Materials Laboratories, and Soil Survey Laboratories all can test soil pH. Samples for pH tests should be held at their natural moisture content during handling and shipping to the laboratory because irreversible chemical changes that affect the pH take place in some soils if they are allowed to dry.

Field Tests. Portable "pH meters" are available by which soil pH can be measured electrically. Some SCS soil survey personnel are equipped with such instruments.

Pipe-to-Soil Potential

The "pipe-to-soil potential" is the potential difference between the pipe and a standard reference electrode in electrical contact with the soil. A copper-copper sulfate electrode is usually used as the reference electrode. The electrode is placed in the soil near to the pipe, often directly over it, to read the potential relative to "close" earth. The pipe-to-soil potential specified in Engineering Standard 432-F should be measured with the electrode near to the pipe. Some tests require potentials to a "remote" electrode 100 feet or more away from the pipe.

Pipe-to-soil potentials are read in various ways, with and without applied current from an outside source, to determine where pipes are corroding, to estimate the rate of corrosion, to estimate the amount of current required for cathodic protection, to test cathodic protection after it is installed, to determine pipe-to-soil resistance, and for various other purposes.

A copper-copper sulfate electrode and a high-resistance voltmeter are necessary for the measurement of pipe-to-soil potentials. Some of the tests also require equipment for applying an alternating or interrupted direct current to the pipe and for measuring the current. Performance and correct interpretation of these tests require some training and experience. A number of consulting firms specialize in corrosion control survey and design work. It may be advisable to contract for their services if SCS personnel with the necessary training are not available.

CATHODIC PROTECTION

Anodes

Zinc or magnesium anodes generally may be used for protection of steel pipe. Zinc anodes usually are desirable in soil of especially low resistivity because of their longer life. However, zinc anodes should not be used in alkaline soil. Magnesium anodes should be used for galvanized pipe.

Required Pipe-to-Soil Potential

The open-circuit potential of mild steel in neutral soil, referred to a copper-copper sulfate electrode, is -0.2 to -0.8 volt (see page 4). That of zinc (or a new galvanized pipe) is -1.1 volts. For complete cathodic protection of a pipe, the current from the anodes must be sufficient to increase the difference in potential between the pipe and the adjacent soil to more than the maximum open-circuit difference.

The criterion in Engineering Standard 432-F for cathodic protection of steel irrigation pipe is that the pipe-to-soil potential, with protection installed, must be not less than 0.85 volt (negative), referred to a copper-copper sulfate electrode. To protect the zinc coating on a galvanized pipe in neutral or nearly neutral soil, a pipe-to-soil potential of at least 1.15 (negative) should be maintained.

Required Current

The required cathodic protection current can be measured by applying test currents and measuring the pipe-to-soil potentials or can be estimated as described in Engineering Standard 432-F. The values of C in the formula for required current given in Engineering Standard 432-F ($C = 32$ for Class A coatings and $C = 60$ for Class B coatings) are conservative for dielectric coatings in good condition. However, coatings which are not durable may lose their insulating quality, and considerably higher current may be required than these values would indicate. The C value for bare pipe would be something like 1000. Fortunately, in neutral soils the current requirement tends to decrease with time, a factor tending to counterbalance the effect of a moderate amount of deterioration of the coating.

Zinc coating does not provide electrical insulation. Hence, the C value for a galvanized pipe without an additional, dielectric coating is equivalent to that for bare pipe. For bituminous coated galvanized CMP, SCS engineers in Nebraska use a C of 120.

Anode Current

The number and size of anodes needed to generate the required current depend upon several things, including the pipe-to-soil potential with the anodes installed, the resistance of the pipe coating, the resistivity of the soil, the resistivity of the backfill around the anode, and the resistance of the wire connecting the anode to the pipe.

The formula for anode current output, $I_m = k/R$, in Engineering Standard 432-F may be used with the values of k in Table I, below, for estimating anode requirements. However, the current an anode will supply in a given installation depends upon all of the variables noted in the preceding paragraph. Because the values of many of the variables are not known precisely, the values of k and I_m are necessarily imprecise, and the actual anode current and pipe-to-soil potential must be measured after the anodes are installed to be sure they are doing the job.

The values of k in Table I have been computed with assumed typical or "average" values of the variables as noted in the table. They should be good for preliminary estimates in most cases. More refined calculations of anode current can be made in any specific instance by computing the net driving potential and the total resistance in the pipe-anode circuit. (See Peabody, "Control of Pipeline Corrosion," Chapter 8 and Chapter 10.)

Table I
Values of k for Zinc and Magnesium Anodes¹
Commercial Sizes and Shapes, Packaged

<u>Zinc Anodes</u>		<u>Magnesium Anodes*</u>			
<u>Steel Pipe</u>		<u>Steel Pipe</u>		<u>Galvanized Pipe</u>	
<u>Size</u>	<u>k</u>	<u>Size</u>	<u>k</u>	<u>Size</u>	<u>k</u>
5#	16,000	5#	37,000	5#	18,000
30#	33,000	12#	49,000	12#	24,000
50#	33,000	17#	56,000	17#	28,000
60#	33,000	32#	60,000	32#	30,000
150#	33,000	60#	80,000	60#	40,000

$$I = \frac{k}{R}$$

where I is anode current in milliamps and R is soil resistivity in ohm-cm in the vicinity of the anode

*"Standard" magnesium alloy (6% aluminum, 3% zinc)

¹See note, next page.

Note: Above k values are based on the following assumptions:

1. Steel pipe: -0.85 volt pipe-to-soil potential.
2. Galvanized pipe: -1.15 volt pipe-to-soil potential.
3. Class B pipe coating, C = 60 (Eng. Standard 432-F).
4. Surface area of pipe exposed to soil - 1250 sq.ft.
5. Anodes are "packaged" or bedded in chemical backfill; e.g., gypsum and bentonite.

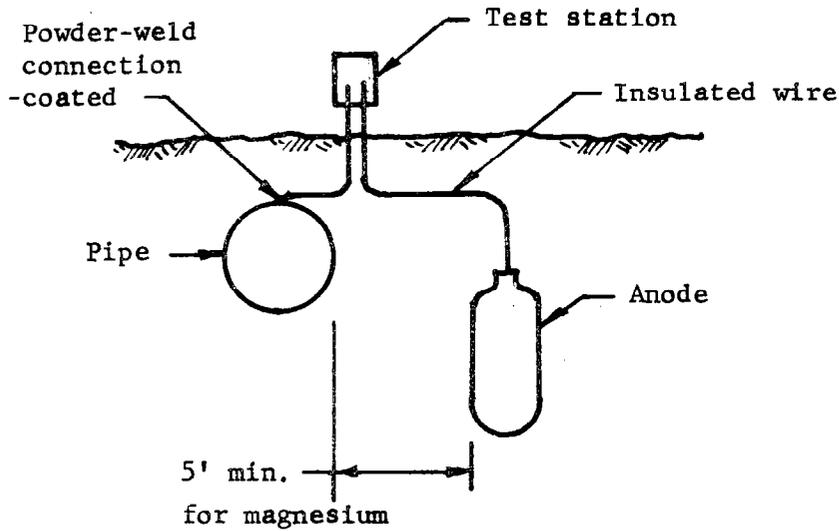
Higher k values are applicable when the pipe to be protected is poorly insulated from the soil. For example, if C is 120 instead of 60, other conditions being the same, the corresponding k is 20 to 40 percent higher than given in the table. For bare pipe, anode k values are roughly twice those in the table.

Anode Life

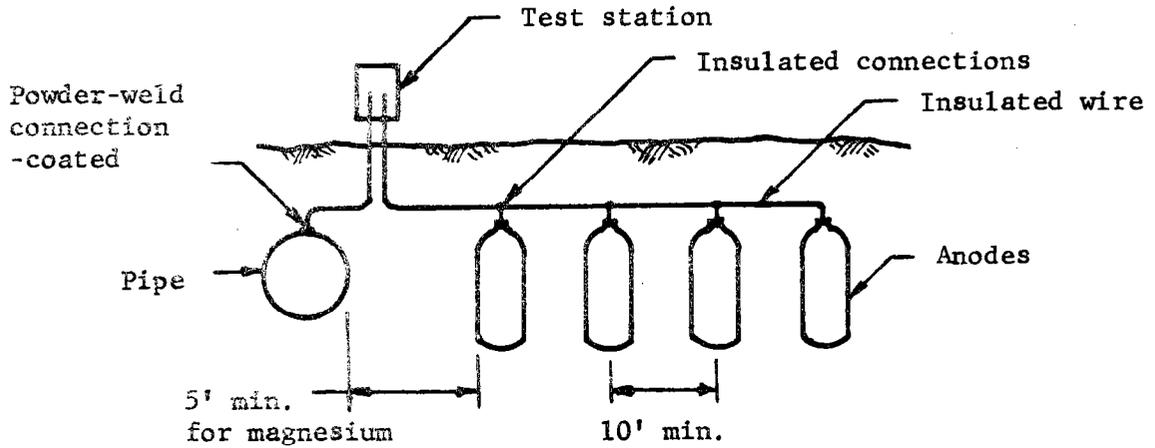
Magnesium anodes are consumed at the rate of about 17 pounds per year per ampere delivered, and zinc anodes at the rate of about 26 pounds per year per ampere. Since anodes can be expected to stop functioning before they are completely consumed, a "utilization factor" of 0.75 to 0.85 usually is applied in calculating anode life. The formulas for anode life in Engineering Standard 432-F include a utilization factor of 0.80.

Anode Installation

Typical single and multiple anode installations are illustrated in Figure 3; and additional details of anode installation are given in the Appendix, which is a copy of Montana job sheet ENG 301 entitled "Installation of Galvanic Anodes for Corrosion Protection of Buried Steel Pipelines."



Single Anode Installation



Multiple Anode Installation

Fig. 3 - Typical Anode Installations

The current that can flow from an anode depends largely upon the resistivity of the material around it. Therefore, it is important that anodes be installed where the soil is moist and be backfilled with the lowest resistivity material obtainable. Generally, "packaged" anodes should be used, in which the magnesium or zinc bars are prepackaged in a uniform chemical backfill of low resistivity. Earth backfill should be firmly compacted around the packaged anode. If packaged anodes are not available, bare anodes can be installed in drilled holes about 8 inches in diameter and backfilled with a mixture of gypsum and bentonite in about equal proportions.

Anodes can be installed vertically or horizontally. This may be governed by soil strata, moisture conditions or other factors. When two or more anodes are used, they should be spaced at least 10 feet apart. Two or more anodes connected to a pipe at one location can be strung out in a line perpendicular or parallel to the pipe centerline and connected to a single header wire. The idea is to obtain uniform distribution along the pipe of the current passing through the soil from the anodes. The closest anodes should be not less than about 5 feet from the pipe. This is more critical for magnesium than for zinc anodes.

Connection between the pipe and the anodes should be made with insulated copper wire, #8 AWG or larger. Copper wire can be fastened to steel or galvanized pipe by brazing or by the powder-weld (thermit) process. Pipe coating damaged in the process should be repaired, and exposed wire and weld metal should be coated. Local corrosion of the pipe adjacent to the copper wire may take place if the whole connection is not thoroughly coated to exclude moisture. Wire splices can be made with split-bolt connectors or by powder-welding or brazing, and must be taped or otherwise insulated.

Bonding

Unless the pipe joints are electrically continuous, such as welded joints, the pipe sections and couplings if any must be electrically bonded together to permit current to flow from the anodes to all parts to be protected. If metal anti-seep collars are used, they also should be bonded to the pipe. Bonding may be accomplished with #6 AWG insulated copper wire brazed or powder-welded to the pipe. Stranded wire may be preferable to solid wire if flexibility is needed. The insulation should have at least a 600-volt rating, and must be tough and waterproof. PVC and polyethylene insulation designed for direct burial are satisfactory. As with other connections to the pipe,

the connections should be coated and pipe coating damaged in the process should be repaired.

Test Stations

Each anode installation, consisting of an anode or group of anodes connected to the pipe at a single point, must be provided with a means of checking the anode current, the pipe-to-soil potential, and the anode-to-soil potential.

A simple way of doing this is to bring the wire from the anodes and the wire from the pipe both into a common junction box above ground at an accessible location near the pipe. This arrangement is illustrated in Figure 4. In operation, the two wires are joined with a split-bolt connector and taped. For testing, the tape is removed and the wires are disconnected. The wires should be cleaned and fastened together securely each time they are reconnected and the whole splice should be thoroughly sealed with rubber or plastic tape. Otherwise, a high resistance can develop in the connection as a result of corrosion of the wires.

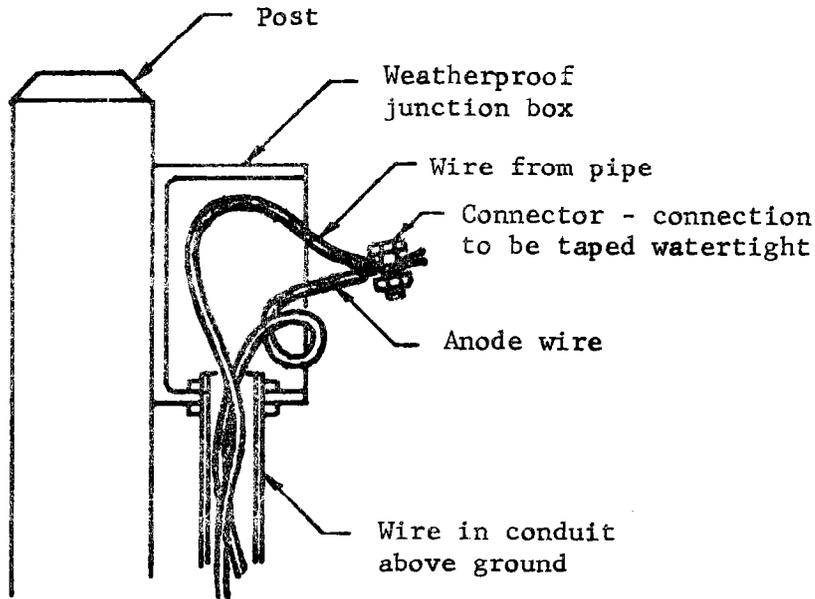


Fig. 4 - Test Station Detail

The cathodic protection current is measured by connecting a milliammeter between the wire from the anodes and the wire from the pipe. Pipe-to-soil potential, with and without the anodes connected, is measured by attaching the test lead from the copper-copper sulfate electrode to the wire from the pipe, with and without the anode wire connected. Anode potential is measured by attaching the test lead to the wire from the anodes.

Figure 2 in the Appendix shows a slightly more elaborate test station using a switch and plug-in receptacle. The anode-to-pipe circuit can be turned on or off by the switch, and the test equipment is designed so that it can be simply plugged into the receptacle for testing.

Adjustment of Current

If the anodes change the pipe-to-soil potential more than necessary for adequate protection, the anode current can be limited by installing a resistor in the circuit. It may be connected between the two wires in the test box described above. The object is to extend the life of the anodes. If the anodes do not change the pipe-to-soil potential enough, it may be necessary to add more anodes.

Maintenance

Cathodic protection installations should be inspected and tested at least once a year. Soil moisture and resistivity change, especially where natural conditions are altered by a dam or other structure; pipe coatings deteriorate; anode and cathode surfaces change chemically; and other changes take place which can influence the behavior of the cathodic protection circuit. The pipe should be inspected for signs of corrosion, also. Anodes should be replaced when they stop providing the necessary protection.

INSTRUMENTS

Some of the instruments that are available are described below with their approximate prices.

For soil resistivity

Soil cup - Beckman Model CEL-M. Available from Beckman, American Instrument, Soiltest and others. @ \$65⁺.
(Used with conductivity bridge.)

Soil box - 1½" x 2½" x 9" plexiglass soil box available from M. C. Miller Co., 288 East Saddle River Road, Upper Saddle River, N. J. @ \$17± . (Used with Vibroground or similar combination instrument, or with milliammeter and high resistance millivoltmeter or potentiometer.)

Conductivity bridge - Beckman Model RC-7. Portable, battery operated. Available from Beckman Instrument Co., Cedar Grove, N. J.; American Instrument Co., 17 Pollock Avenue, Jersey City, N. J. @ \$355± .

Conductivity bridge - Beckman Model RC-19. New light-weight, battery or line operated. Available from Beckman Instrument Co. @ \$595± .

Single-probe instrument - Available from Associated Research, Inc., 3758 West Belmont Avenue, Chicago; Agra Engineering Co., 551 South Quaker Avenue, Tulsa, Oklahoma, and others. @ \$125± . (Used with Vibroground or other bridge.)

Four-pin resistivity instrument - Vibroground Model 293. Battery operated, with steel case, 4 T-shaped ground probes, and test leads. Available from Associated Research, Inc., 3758 West Belmont Avenue, Chicago. @ \$375± .

For soil pH.

Pocket pH meter - Beckman. Portable, battery operated, sturdy combination electrode. Available from Beckman or any of their dealers: Chicago Apparatus Co., 1735 North Ashland Avenue, Chicago. @ \$95± .

For pipe-to-soil potential, cathodic protection tests, etc.

Combination current and voltage meter. Available from M. C. Miller, Agra Engineering, and others. @ \$225± .

High resistance voltmeter or potentiometer. Available from M. C. Miller, Agra Engineering, and others. @ \$80-210± .

Portable volt-ohm-milliammeter for pipe continuity checks. Available from Simpson Electric Co. or Triplett Electrical Instrument Co. @ \$70± .

Current interrupter. Available from M. C. Miller, Agra Engineering, and others. @ \$165± .

Copper-copper sulfate electrode. Available from M. C. Miller, Agra Engineering, and others. @ \$15± .

REFERENCES

- Peabody, A. W. "Control of Pipeline Corrosion," National Association of Corrosion Engineers, 192 pp., 1967.
- Romanoff, M. "Underground Corrosion," National Bureau of Standards, 227 pp., 1957.
- Engineering Standard 432-F. Irrigation Pipeline, Steel, SCS National Engineering Handbook, Section 2, 1969.
- Engineering Memorandum-27, Earth Dams, Section E, Principal Spillways, 1969.



MT-JS-ENG 301

INSTALLATION OF GALVANIC ANODES FOR CORROSION PROTECTION OF BURIED STEEL PIPELINES

The proper installation of anodes is the key to the continuing protection from corrosion of a buried steel pipeline. An improperly installed and maintained anode can increase the resistivity of the soil surrounding it and result in an underprotected pipeline thus decreasing the usable life of the line.

Anode Installation

Placement

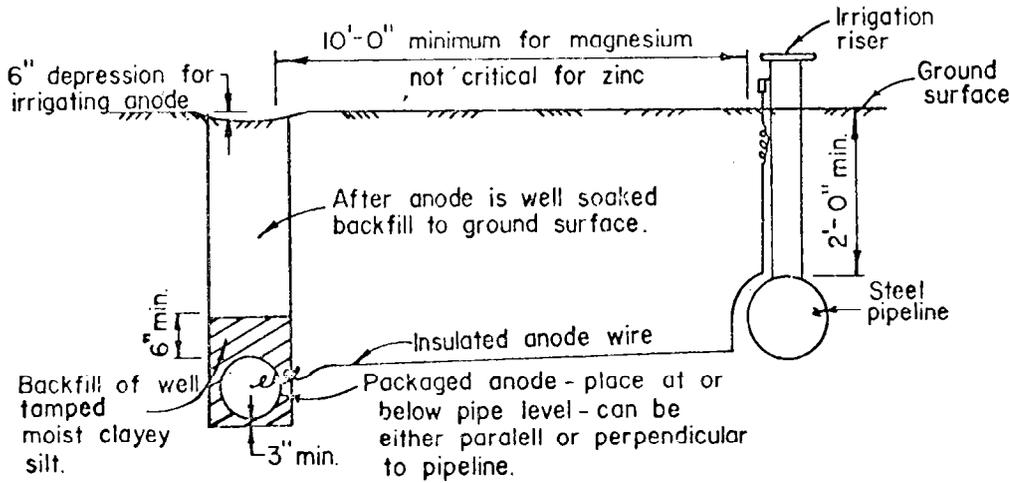
Anodes may be placed either horizontally or vertically in relation to the ground surface and in relation to the pipeline either parallel or perpendicular, see Figure 1. When placed horizontally, they shall be at or below the bottom elevation of the pipeline. Never place anodes in fill material. Vertically placed anodes shall have a minimum distance of 3 feet between the ground surface and the top of the anode.

Location of the anodes in relation to the pipeline is not critical except in the case of magnesium which must be placed a minimum distance of 10 feet from the pipeline.

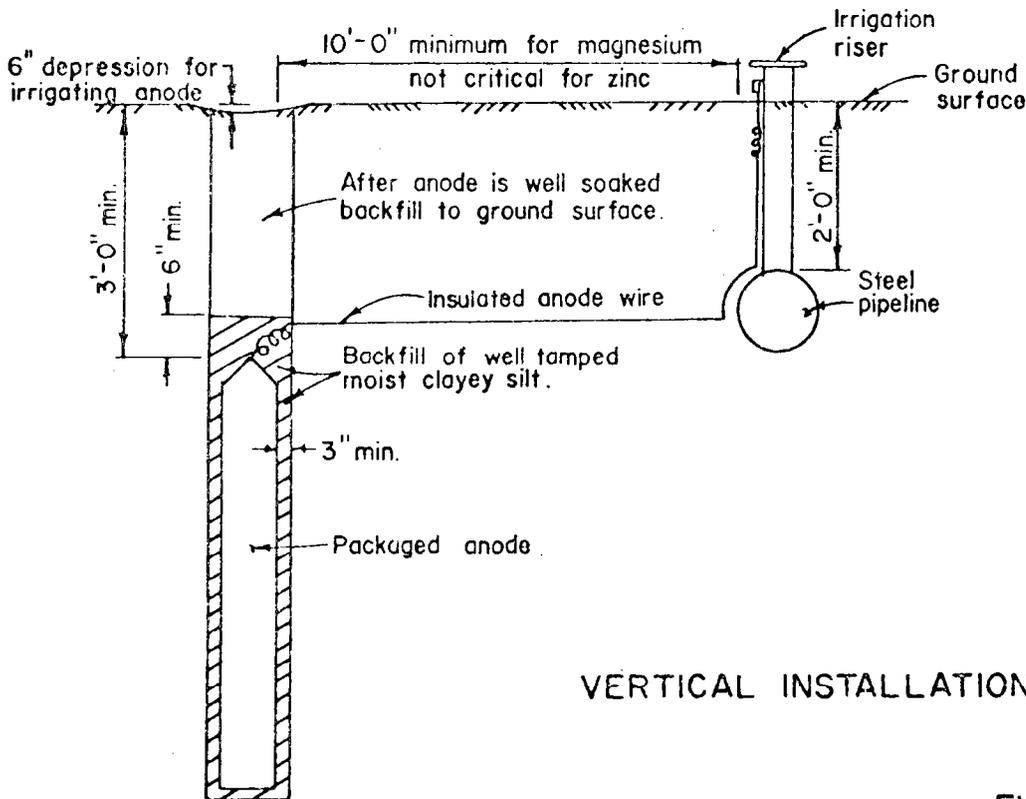
Installation

1. Excavate hole or trench for anode package.
2. Prepare bedding for the anode package in the bottom of the hole or trench with well tamped moist clayey silt.
3. Place anode package in the prepared bed making sure that the anode is centered in the package. Use extreme caution not to get the anode package wet before it is placed and backfilled. Never lift the anode by the lead wire.
4. Complete backfilling around anode with well tamped clayey silt to a point 6 inches above the anode, see Figure 1.
5. Attach anode lead wire to the pipeline by brazing or cadweld making sure that the pipe coating removed is repaired. When the anode is to be attached to a testing station, attach as shown in Figure 2.
6. Irrigate the anode by pouring several barrels of water in the hole or trench and let soak in to insure moistening of the anode packaged backfill.
7. Complete backfill with native soils leaving a 6 inch surface depression as shown in Figure 1.

When anodes are placed in tight native clays, some provision must be made to insure continued irrigation of the anode. This can be accomplished with a sandy gravel "French drain". If the anode is in a vertical hole, the native backfill can be replaced with a sandy gravel backfill. Where the anode is placed in a horizontal position, this procedure cannot be used as a gravel backfill above the anode would reduce the current output 30 to 50 percent. In this case, at one end of the anode backfill a trench with sandy gravel from anode depth to the surface of the ground. The trench length should extend away from the anode 2 to 3 times the depth of the anode.



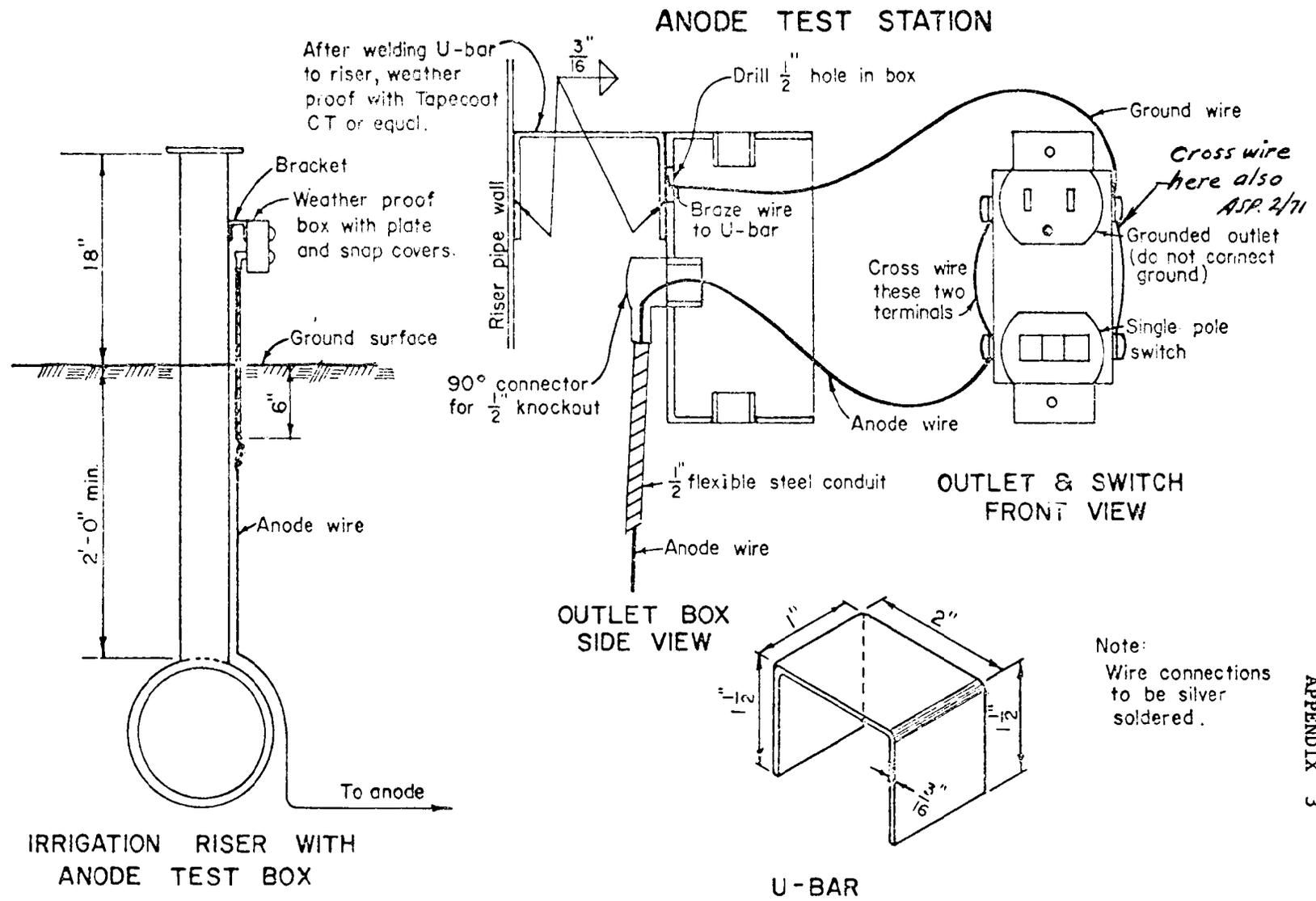
HORIZONTAL INSTALLATION



VERTICAL INSTALLATION

FIG. 1

FIG. 2



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