CORROSION ENGINEERING

Corrosion by soils can be easily halted

Cathodic protection techniques provide a direct means of stopping metal loss due to stray earth currents. The method ensures long life and reduced maintenance for buried equipment

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Concerned with the production of a corrosion-resistant steel for use in soils, steel pipe manufacturers before the turn of the century were so preoccupied with the technical niceties of cast iron versus wrought iron that they completely overlooked the influence of environment on the buried piping.

It was left for Whitney, in his monumental treatise on the Corrosion of Iron, to point out that the culprit in this world-wide corrosion problem was the environment, and that small changes in the composition of steel piping would have little effect upon the severity of corrosion. He also pointed up the essentially electrochemical character of this corrosion, and can certainly be considered the father of the modern corrosion mitigative practices.

In tests undertaken by research groups in the petroleum industry and by similar groups at the U.S. Bureau of Standards, certain factors were recognized as influencing the corrosiveness of soils. Corrosivity is not an easy term to define, but we can make some arbitrary classifications of soils which, under stipulated conditions, can be termed corrosive or non-corrosive. The first division would be according to pH.

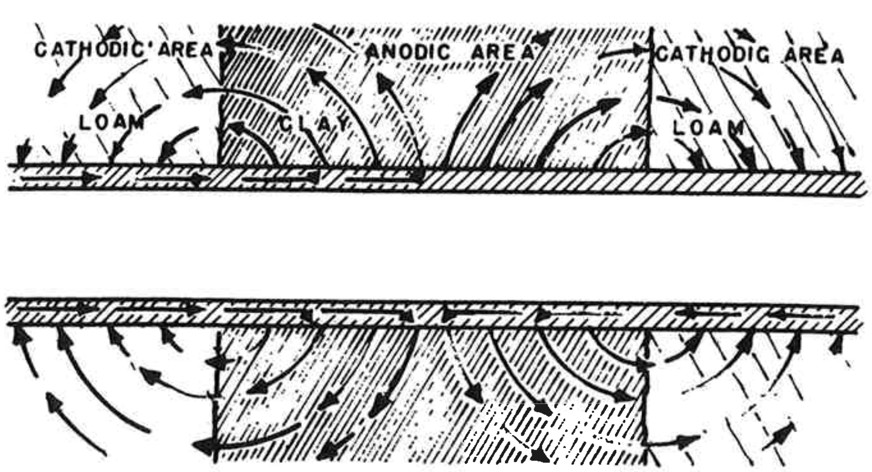
It would seem that in acid soils the acidity would be a good index of corrosiveness, whereas in non-acid soils the conductivity of the soil would constitute a fairly good measure of corrosive character. Corrosion engineers generally agree that soils can be classed in the five following resistivity classifications, with regard to corrosivity:

- Soils with resistivities of 0 to 900 ohm-cm, are apt to produce very severe corrosion.
- Resistivities of 901 to 2300 ohm-cm. are classed as severely corrosive.
- Resistivities of 2301 to 5000 ohm-cm. are classed as moderately corrosive.
- Resistivities of 5001 to 10,000 ohm-cm. are classed as mildly corrosive.
- Resistivities of 10,000 plus ohm-cm. are classed as very mildly corrosive.

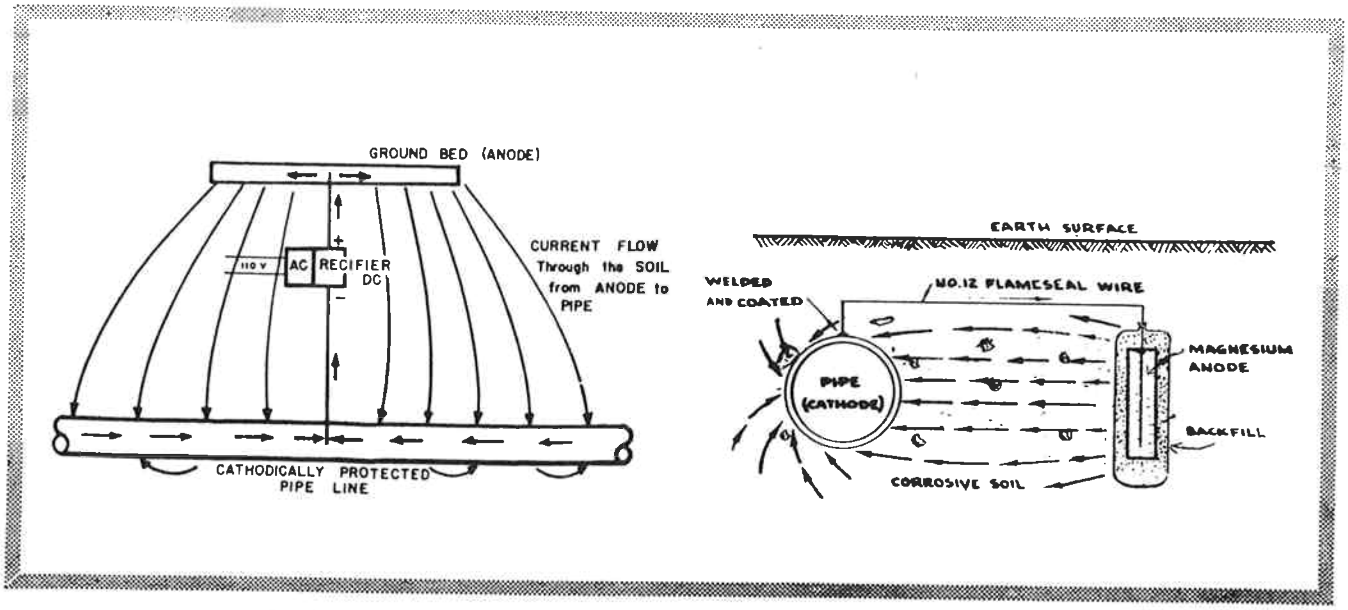
Readings change

However, when there is a marked change in resistivity readings, corrosion is likely to occur; e.g., when the resistivity is running consistently at 10,000 ohm-cm. in one area and in an adjacent area it drops suddenly to 4,000 ohm-cm., corrosion is likely to occur in the 4,000 ohm-cm. area; or when the resistivity is running at 20,000 ohm-cm. and it drops to 10,-

Here's how soil differences cause corrosion



ELECTROLYTIC action occurs between moist soils and metal of pipe. This causes metal to dissolve in anodic areas



CATHODIC PROTECTION can be applied to a buried metal system in two ways: by providing a direct current from a rectifier to balance stray earth currents (left); or by using a sacrificial magnesium anode which corrodes instead of the protected system

000 ohm-cm., corrosion will occur in the 10,000 ohm-cm. soil, but at a less rapid rate than in the preceding example.

Since the pipeline operator must bury his piping with a view toward initial economies in materials and labour, large digressions from straight line routes to achieve better soil conditions, are seldom feasible. It has been the usual practice to use high-resistivity sand as a backfill material, the pipe being laid on sand padding and backfilled with sand for several feet above the pipe.

This has the advantage of providing a relatively uniform environment for the pipe, and certainly would assist in the reduction of the localized corrosion attack except in the case where the pipe dips below the water table along its route. The sand, being permeable, presents no barrier to the intrusion of the ground water to the pipe surface. The ground water usually contains the dissolved salts and other conducting materials present in the adjacent soil, and could contribute directly to corrosive attack due to an abrupt change of resistivity, as described above. Coating the pipe with an impervious coating, would seem to be a reasonable insurance against this type of attack. However, it was found, from practice during the 1920's and 1930's, that coated pipes usually suffered pitting attack at imperfections in the coatings. These pits would perforate the pipe at a much greater rate than would occur if the pipe were laid bare.

Fortunately, in the early 1930's, operators again experimented with cathodic protection, an old principle with a new application; the principle being originally discovered by Sir Humphrey Davy in 1824. Whereas its practice has been developed almost entirely in the past twenty years by the oil and gas pipeline industry, here it was purely a matter of economics and of necessity. No other group had such a large proportion of its assets in the form of buried steel. As a result of this work, cathodic protection today is the standard specification for every major steel pipeline on this continent.

Impressive economies

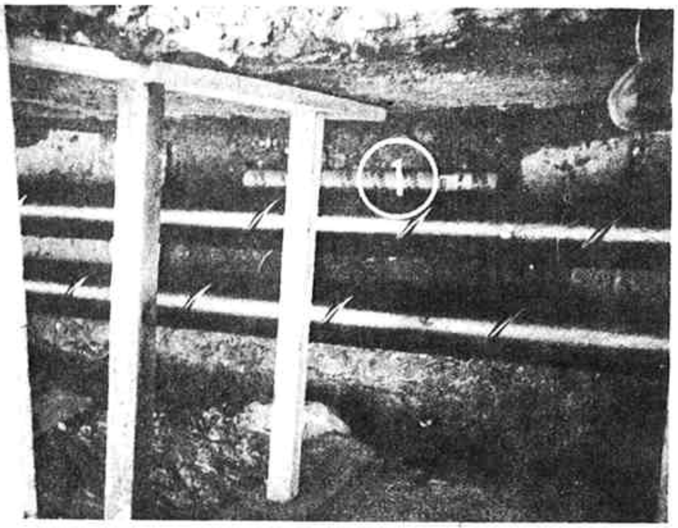
Following in the wake of the pipeliners, many other industries began to follow their example, and, as cathodic protection effected impressive economies in other fields, its use spread. Today, this method is used to maintain buried tanks of many kinds, large oil-storage tank bottoms, lead sheath telephone, telegraph and power cables, ships' hulls and cargo tanks. As a result of work conducted by the Naval Research establishment in Halifax, N.S., every ship in the Royal Canadian Navy is now cathodically protected from corrosion of its plates by sea water.

Sheet-steel piling and marine installations, may be similarly preserved. Many types of process machinery are under cathodic protection, and, in recent years, domestic hot water tanks, equipped with magnesium anodes, have greatly reduced one aspect of corrosion which affects us all.

Corrosion is almost always associated with electrolysis. At ordinary temperatures, there is no such thing as direct chemical attack. Metals cannot combine with their environment unless the reaction is accompanied in some way by the passage of an electric current. The reason for this is apparent when it is considered that when metal atoms ionize and dissolve, they leave behind, in the body of the metal, electrons which must be dissipated if the reaction is to continue. The flow of these electrons is the electric current, without which corrosion cannot take place.

On the surface of a corroding pipeline, millions of little electrolytic cells exist. At the places where current goes into the soil from the pipe — which are known as the anodes — metal corrodes at a rate proportional to the strength of the current. At the cathodes, where current goes back into the pipe from the soil, no corrosion takes place, but the function of the cathodes is essential to the reaction. Pits are caused by concentrated corrosion at local anodes. The unaffected areas around the pits, are the cathodes of the cells.

From all this emerges the fact that anodes always corrode and cathodes never do. Metal is only attacked at places where current *leaves* it to go



MAGNESIUM ANODE (circled 1) is installed alongside two coated steam lines to provide long-term cathodic protection

into the ground, and never at areas which receive current.

Cathodic protection

Cathodic protection is merely the science of artificially arranging matters so that current flows to the object to be protected all over its surface in such strength that nowhere on its surface can current leave. In technical terms, the protected structure is made cathodic over its whole area, and local anodes, where corrosion would naturally occur, are nullified by the protective current.

This desirable state of affairs may be arranged by burying a number of graphite rods in the ground and connecting them to the pipe through an A.C.-powered rectifier which supplies D.C. current in such a direction that the graphite is made positive or anodic to the pipe. Current then flows through the ground to all parts of the pipeline. The important thing is that the structure receive current from the soil. Where it originates, cannot affect the degree of protection it affords.

The current to protect buried installations, is often supplied galvanically from magnesium anodes. These are usually cylindrical castings of magnesium alloy buried at intervals along the structure and connected to it by a wire. The magnesium and the steel of a pipeline or tank form a galvanic cell or "battery", and in this case no other power source is required. The magnesium is the anode of the cell and, as such, corrodes sacrificially and is gradually consumed. It is, in fact, the energy of the corrosion of magnesium which provides the power. Magnesium ground anode systems are usually designed to last about 10 years.

The protective current goes only to bare metal surfaces. Since the amount of current required is a function of the bare metal area to be protected, it follows that bare structures require more current than coated ones, because on coated ones the current has only to protect areas revealed by imperfections in the coating.

Current effects

As cathodic protection is applied to a buried structure and current flows to it from the ground, the adjacent soil becomes electrically positive to it. This provides the corrosion engineer with a means of determining how much current the structure will require and how far its effect will spread. Criteria vary, but, it is generally agreed, that if the effect of the current changes the metal-to-soil potential by 0.3 volts, the current is adequate to protect the structure.

In the planning stages of any pipeline project, the design engineer should acquaint himself with the soil characteristics along the pipe route. In general, a soil resistivity survey is usually undertaken by a corrosion engineer, and a resistivity profile drawn denoting those areas where accelerated corrosion could be expected. The corrosion engineer will also examine the soil visually, and, if necessary, chemically, for industrial contaminents — cinder-fill, garbage-fill, etc., which may require coating reinforcement and/or special cathodic protection measures. The likelihood of stray currents from electric railways operating in the area and their effect upon the proposed structure, would also affect the mitigative measures proposed during the planning stages of the pipe. The design engineer then, with the projected life of his piping system in mind, can decide whether to:

- lay the pipe bare and scrap it after some short period of time, i.e., five or six years in heavily-industrialized areas;
- coat and wrap the pipe;
- lay the pipe bare and cathodically protect it; or,
- coat and wrap the pipe, supplying supplementary cathodic protection.

Laying bare pipe

There are some occasions where the laying of bare pipe is economically justifiable, i.e., seasonal irrigation systems, temporary pumping systems, etc. It is also sometimes economically feasible to the third alternative, since the cathodic protection method is capable of protecting bare structures without the assistance of coating. Very short sections of large-diameter pipe, are often more economically protected by cathodic protection alone, but the most common practice is the fourth choice, where the pipe is coated and wrapped with a high-grade coating that resists the mechanical effects of the soil and maintains a high electrical insulation characteristic for a long period of time, and supply supplementary cathodic protection, which seldom costs more than 1% of the installed cost of pipe.

This method eliminates the bulk of the maintenance costs on the pipeline, extending its life indefinitely at a very low annual cost. In the case of obsolescence of a piping system, the pipe is salvagable and re-usable, in most cases.

Cathodic protection will stop corrosion immediately, even though it has been progressing for years. An old leaky line may be rejuvenated and made to give leak-free service for twenty or thirty more years, by applying protective current. Cathodic protection has long since passed the experimental stage; it is sure and effective, tried and tested; it provides today's engineers with a unique tool, a reliable weapon with which to fight the expensive and largely unnecessary ravages of corrosion by soil and water. END