Cathodic protection eliminates soil corrosion on steel water pipes

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Soil bears the greatest responsibility for underground corrosion losses, and the differences in corrosion losses of different types of ferrous materials when in contact with the soil are very small indeed.

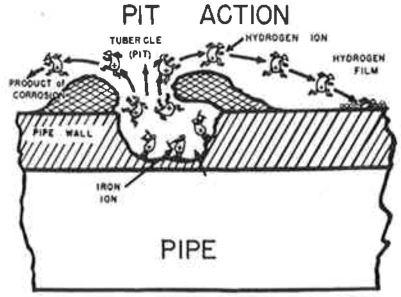
Past histories of pipe performance usually relates to differences of soil composition, moisture content, and pipe thickness, rather than to the material of the pipe itself. An extensive study of underground corrosion undertaken by the National Bureau of Standards of the U. S.* has reached these conclusions after extensive investigations and burial programs.

The responsibility of the soil as the principle cause of corrosive attack was not recognized until the turn of the century, when Whitney published a paper explaining the electrochemical corrosion of iron. Since that time, pipe coatings have come into general use in an effort to insulate the pipe material from its environment. It was found that perfect coating systems existed in theory only, and that all installed pipe coatings had various coating imperfections which were either there initially or developed after burial. These imperfections were referred to in the pipeline industry as coating "holidays". It was found that coating, although it prevented the bulk of the loss of steel from the pipeline, seemed to increase the rate of penetration of the pipe at the "holidays" in the coating.

This experience led several pipeline operators to investigate a process known as cathodic protection which, although it was used successfully as early as 1824 by Sir Humphrey Davy, had fallen into disuse. During the 1930's many miles of pipe were placed under this form of electrical protection, and at the present time, no operator of extensive underground steel piping systems would be without it.

The corrosion reaction can be looked at from many points of view, each of which contains a facet of the complete process, which is electrochemical in nature. On the surface of a piece of immersed steel there are areas which for various reasons tend to corrode more readily than others. These areas that tend to corrode are called anodes, and from these surfaces streams of positively charged iron atoms (ions) flow into the solution, leaving electrons behind in the parent metal.

PIT ACTION

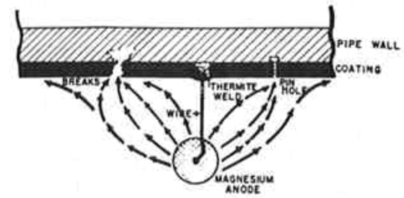


This process continues until the parent metal becomes so flooded with electrons that the positively charged iron atoms can no longer leave the surface because of the attraction of these negative charges.

Another process now takes place, which is equally important to the overall corrosion process. This takes place at those areas that have a lesser tendency to corrode and are denoted as cathodes. Here the electron population attracts hydrogen ions which are present in the soil water and which are capable of picking up the electrons from the surface of the metal to form at first atomic, and finally molecular hydrogen (gas). This cathodic process removes electrons from the metal and therefore allows the anodic process to proceed. The cathodic surfaces become coated with a film of hydrogen which prevents hydrogen ions from reaching the surface, and slows down the corrosion process due to what is known as cathodic polarization.

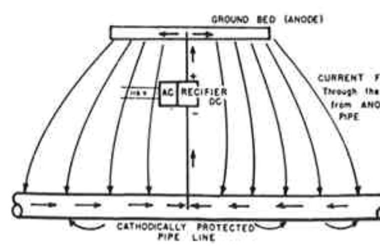
The soil contains many chemicals which are able to combine with the hydrogen of the polarizing film, the most important of which is oxygen, which is usually present in soil waters. Those soils where oxygen is not present usually contain anaerobic bacteria, and some species of these bacteria are capable of removing the hydrogen film at the cathodes. In general, the rate of corrosion at the anodes is governed by the rate of removal of the hydrogen film at the cathodes.

PIPE PROTECTION
with COATING and ANODES



With this basic knowledge of the corrosion process, we can now discuss the operation of cathodic protection. If the steel can be flooded with sufficient electrons by the operation of some external process, then the cathodic process no longer governs the rate of corrosion at the anodes. In fact, the anodic areas themselves would cease to corrode, since the electron population in the metal adjacent to these areas would exert sufficient attraction upon the iron ions in solution to prevent them from leaving the vicinity of the metal surface. Essentially, the entire pipe

CATHODIC PROTECTION
RECTIFIER



would become a cathode and the cathodic process involving the deposition of hydrogen on the surface of the metal would take place over the entire structure. The number of electrons that would have to be supplied from the external source would depend upon the number of depolarizing agents present in the soil, and also upon the area of the bare metal exposed to the environment.

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It can be seen that a well coated pipe would require very small currents for this type of protection, whereas a bare line would require much larger currents. Also pipes laid in soil containing many depolarizing substances would require larger values of protective current than those laid in soil free of these substances.

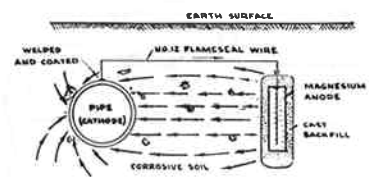
It should be made clear that both the science and economics of pipe protection dictate that coating and cathodic protection must go hand in hand, and that the least installed cost of external pipe protection will involve a judicious balance between these two preventive techniques. For instance, it could not be justified economically, in most cases, to double coat and wrap steel pipe when one considers the small savings in cathodic protection costs that would accrue. By the same token, a great deal of money should not be set aside for coating inspection until some knowledge is gained of the total cost of cathodic protection.

Pipe coatings should not exceed 5% to 6% of the installed cost of the pipe, whereas cathodic protection is usually under ½% of the installed cost of the pipe.

The application of cathodic protection requires a considerable amount of experience since piping systems are usually complex, and in many cases, are laid adjacent to other people's structures. Moreover, these systems often include new and old sections, with coatings that range in quality from nearly bare to excellent. Also, the soils themselves have infinite variety, and changes in soil conditions can be very frequent, especially in urban filled areas.

The corrosion engineer is able to determine whether or not a pipe surface is cathodic by taking potential measurements along the surface of the ground. He can determine the current requirements of a piping system by making some assumptions with regard to the coating quality, and apply his protective current by rule of thumb procedures, or he can perform a current requirements test on the pipe itself, and from this test determine quite accurately the required current for protection.

CATHODIC PROTECTION
MAGNESIUM ANODE



This current can be produced by rectifiers or from sacrificial anodes placed in the soil and attached to the pipe along its route. The sacrificial anode is usually made of magnesium, this metal being chosen because of its greater tendency to corrode. When the magnesium is attached to the steel pipe, it forms a battery with an open circuit driving potential of approximately one volt. Since it corrodes preferentially, it supplies the electrons required to flood the pipe, and thereby protects it. In some cases the sacrificial anode cannot be used, especially in those locations where the soil is a relatively poor electrical conductor. In these cases it is usual to establish a connection to the ground using rods of graphite or Duriron, which are resistant to anodic corrosion and collect electrons from the soil connection, which are pumped onto the pipe through an AC-DC rectifier. These two methods of achieving cathodic protection result in an identical situation on the pipe itself.

The application of modern coatings and cathodic protection to the outside of steel piping, and the internal lining of this pipe with concrete, result in a low cost corrosion-proof water pipe, which can be maintained in this condition with a minimum of supervision and expense.

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