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CORROSION OF PIPELINES

Аннотация*: в данной статье говорится о том, что общим определением коррозии является деградация материала через взаимодействия с окружающей средой. Авторы работы рассматривают коррозию трубопроводов. Материалы исследования могут быть полезны специалистам в технической области.*

Ключевые слова*: коррозия, покрытие, ток, катод, скорость, напряжение, тесты, управление, использование, электричество, анод.*

Abstract*: one general definition of corrosion is the degradation of a material through environmental interaction. The authors consider the corrosion of pipelines. Material EC-sequence may be useful to those skilled in the technical field.*

Keywords*: corrosion, coating, current, cathodic, rate, areas, voltage, important, tests, control, use, electrical, effective, anode, may, application, means, reduce.*

What is corrosion?

One general definition of corrosion is the degradation of a material through environmental interaction. This definition encompasses all materials, both naturally occurring and man-made and includes plastics, ceramics, and metals. A significant amount of energy is put into a metal when it is extracted from its ores, placing it in a high-energy state. These ores are typically oxides of the metal such as hematite (Fe_2O_3)

for steel or bauxite (Al_2O_3¢H_2O) for aluminum. One principle of thermodynamics is that a material always seeks the lowest energy state. In other words, most metals are thermodynamically unstable and will tend to seek a lower energy state, which is an oxide or some other compound. The process by which metals convert to the lower-energy oxides is called corrosion.

How do we detect corrosion?

The electrochemical nature of the corrosion process provides opportunities to detect and mitigate corrosion of underground structures. We can monitor the voltages and the currents associated with the corrosion process.

When a piece of metal is placed in an electrolyte, such as soil, a voltage will develop across the metal-electrolyte interface because of the electrochemical nature of the corrosion process. We cannot measure this voltage directly but, using a voltmeter, we can measure a voltage between two different metals that are placed in the soil. We also can measure the voltage difference between a metal and a reference electrode, commonly called a half-cell electrode. This voltage is referred to as a corrosion potential, an open circuit potential, or a native potential for that metal in the environment in which the measurement is being obtained. For soil environments, the most common reference electrode used is the copper-copper sulfate reference electrode (CSE). Potential measurements can be used to estimate the relative resistance of different metals to corrosion in a given environment. Noble metals, such as gold and platinum, have more positive potentials and are more resistant to corrosion than are the more common engineering metals such as steel and aluminum. A galvanic series is a list of metals and alloys arranged according to their relative corrosion potentials in a given environment. The potentials measured for the different metals in a galvanic series vary somewhat, depending on the nature of the environment, but the relative position of the metals is similar for natural environments such as soil and seawater.

How do we mitigate corrosion?

The principal methods for mitigating corrosion on underground pipelines are coatings and cathodic protection (CP). Coatings normally are intended to form a continuous film of an electrically insulating material over the metallic surface to be protected. The function of such a coating is to isolate the metal from direct contact with the surrounding electrolyte (preventing the electrolyte from contacting the metal) and to interpose such a high electrical resistance that the electrochemical reactions cannot readily occur. In reality, all coatings, regardless of overall quality, contain holes, referred to as holidays, that are formed during application, or during transport or installation of mill-coated pipe. Holidays in coatings also develop in service as a result of degradation of the coating, soil stresses, or movement of the pipe in the ground. Degradation of the coating in service also can lead to disbanding from the pipe surface, further exposing metal to the underground environment. A high corrosion rate at a holiday or within a disbonded region can result in a leak or rupture, even where the coating effectively protects a high percentage of the pipe surface. Thus, coatings are rarely used on underground pipelines in the absence of CP. The primary function of a coating on a cathodically protected pipe is to reduce the surface area of exposed metal on the pipeline, thereby reducing the current necessary to cathodically protect the metal.

One definition of CP is a technique to reduce the corrosion rate of a metal surface by making it the cathode of an electrochemical cell. This is accomplished by shifting the potential of the metal in the negative direction by the use of an external power source (referred to as impressed current CP) or by utilizing a sacrificial anode. In the case of an impressed current system, a current is impressed on the structure by means of a power supply, referred to as a rectifier, and an anode buried in the ground. In the case of a sacrificial anode system, the galvanic relationship between a sacrificial anode material, such as zinc or magnesium, and the pipe steel is used to supply the required CP current.

Effectiveness of coatings as a means of corrosion control.

First attempts to control pipeline corrosion relied on the use of coating materials and the reasoning that if the pipeline metal could be isolated from contact with the surrounding earth, no corrosion could occur. This concept is entirely reasonable and logical. Further-more, a coating would be completely effective as a means of stopping corrosion if the coating material: Is an effective electrical insulator; Can be applied with no breaks whatsoever and will remain so during the backfilling process, and Constitutes an initially perfect film that will remain so with time.

While this is possible with some of the advanced multi-layer systems, it may not be practical from an initial cost analysis. Although coatings by themselves may not be the one perfect answer to corrosion control, they are extremely effective when properly used. Most operators plan coatings and cathodic protection (CP) for all their pipelines as a matter of course. A properly selected and applied coating will provide all the protection necessary on most of the pipeline surface to which it is applied. On a typical well-coated pipeline this should be better than 99% and, along with the CP, should give total protection.

Good practice in modern pipeline corrosion control work comprises the use of good coatings in combination with CP as the main lines of defense. Supplementary tactics, such as the use of insulated couplings and local environmental control may be used to reinforce these basic control methods. In selecting a coating system for a given pipeline project, one of the most important characteristics to design for is stability. By this we mean a coating combination that will have a high electrical resistance after the pipeline has been installed and the backfill stabilized and will lose the least electrical resistance over time. Those characteristics are important in any event but particularly so where CP is used to supplement the coating. When used with an unstable coating, a CP system that is fully adequate during the early life of a pipeline may no longer provide full protection as the coating deteriorates (as indicated by a reduction in the effective electrical resistance of the coating), which will require additional current. This means that continued expenditures will be necessary for additional CP installations. The overall economics of the coating- plus-CP concept are adversely affected by poor coating performance. In a review of 50 years of literature on pipeline coatings, the following concepts emerged:

1. Selection of the best coating and proper application are very important.
2. CP must supplement the coating for 100% protection.
3. In-the-ground tests are more reliable than laboratory tests.
4. Results of adhesion tests do not correlate with those of cathodic disbondment tests.
5. Cathodic disbondment tests are the best tests to measure coating performance.
6. The current required for CP is the best measure of coating performance.
7. Optimum coating thickness is important.
8. Soil stress is one of the main problems.
9. Resistance to cathodic disbondment and soil stress are very important requirements of a pipe coating. For a pipe coating to be effective, it should meet these criteria: adhesion, adequate thickness, low moisture absorption/transfer, chemical resistance (especially alkalis from CP), and flexibility.
10. Selection of the best appropriate system is important, but proper application is the most important consideration.

Basic theory of cathodic protection.

CP is a technique to reduce the corrosion rate of a metal surface by making it the cathode of an electrochemical cell. Various conditions that cause pipeline corrosion previously are. In each case, anodic areas and cathodic areas are present on the pipe surface. At the anodic areas, current flows from the pipeline steel into the surrounding electrolyte (soil or water) and the pipeline corrodes. At the cathodic areas, current flows from the electrolyte onto the pipe surface and the rate of corrosion is reduced. In light of the above, it becomes obvious that the rate of corrosion could be reduced if every bit of exposed metal on the surface of a pipeline could be made to collect current. This is exactly what CP does. Direct current is forced onto all surfaces of the pipeline. This direct current shifts the potential of the pipeline in the active (negative) direction, resulting in a reduction in the corrosion rate of the metal. When the amount of current flowing is adjusted properly, it will overpower the corrosion current discharging from the anodic areas on the pipeline, and there will be a net current flow onto the pipe surface at these points. The entire surface then will be a cathode and the corrosion rate will be reduced. A major activity of a CP engineer is to determine the actual level of CP required to reduce the corrosion rate to an acceptable level. Monitoring, in conjunction with the application of CP criteria, are used for this determination. Current is forced to flow onto the pipe at areas that were previously discharging current, the driving voltage of the CP system must be greater than the driving voltage of the corrosion cells that are being overcome. The original cathodic areas on the pipe collect current from the anodic areas. Under CP, these same cathodic areas (which were corroding at a negligible rate in the first place) collect more current from the CP system. For the CP system to work, current must be discharged from an earth connection (ground bed). The sole purpose of this ground bed is to discharge current. In the process of discharging current, the anodes in the ground bed are consumed by corrosion. It is desirable to use materials for the ground bed that are consumed at a much lower rate (pounds/per ampere/per year) than are the usual pipeline metals. This will ensure a reasonably long life for the anodes.

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