

## **CORROSION AND CATHODIC PROTECTION IN UNDERGROUND PIPING SYSTEMS**

### **INTRODUCTION**

As restrained pipeline systems become increasingly popular, more questions concerning corrosion of restrained joints are being asked. This paper is an attempt to address some of these questions, provide a basic understanding of galvanic corrosion, and suggest methods for controlling corrosion.

### **THE GALVANIC CELL**

The major corrosion concern in the water works industry is "galvanic" corrosion. Galvanic corrosion takes place due to current flow in a "galvanic cell" which is defined as (1) two dissimilar metals, an anode and a cathode, (2) in electrical contact with each other and (3) a common electrolyte. A galvanic cell is produced when the pipeline components come in contact with the soil. In such a cell, one of the metals, the anode, corrodes away and the other metal, the cathode, is protected. The rate of the corrosion is dependent on the current and the current density, which are functions of galvanic potential difference.

However, most useful metals are alloys created by combining elements with different galvanic potentials. Alloys alone meet the first two requirements for a galvanic cell; which is why a single metal will corrode when exposed to an electrolyte. Therefore, most corrosion control methods attempt to separate the metal from an electrolyte or to control the corrosion current. This paper will deal mainly with controlling the corrosion current.

### **MATERIAL CHOICE**

The simplest method for controlling the corrosion current is the selection of the structural materials. In the water works industry, the selection of the pipeline and appurtenance materials is very important in preventing a corrosion related failure.

The rate of corrosion and the current density, the amount of current per unit area, are proportional. Therefore if the current density in the corroding metal, the anode, is reduced, the rate of corrosion will be reduced. The current density can be reduced in two ways: reduce the current flow or increase the area of the anode with respect to the cathode.

Reducing the current density may be accomplished by reducing the corrosion current. In cathodic protection systems, a minimum amount of current must be maintained. However, in unprotected or coated systems, the current produced should be kept to a minimum. This is accomplished by the difference in potential of the metal components. For example, EBAA Iron's set screws, MEGALUG® wedges, and glands are all made of ductile iron. Because EBAA's products are made completely of the same metal as the pipe and the fittings, the effects of corrosion are greatly reduced. Choosing materials which are close to each other in a galvanic series will reduce the difference in potential. A galvanic series is defined by the National Association of Corrosion Engineer's as: "A list of metals arranged according to their relative corrosion potentials in some specific environment; sea water is often used."

Another way to reduce the current density is to increase the area of the anode with respect to the cathode. For this reason, T-bolts in a pipeline should be slightly cathodic to the rest of the system. If T-bolts were anodic to the pipeline system, they would corrode at a very rapid rate since the area of the anode, the bolts, would be very small in comparison to the cathode, the pipeline. By the same principle, the sacrificial anodes should be sufficiently large.

The practice of using Cor-Ten bolts with follower glands for mechanical joints is an example of slightly cathodic bolts being used. Cor-Ten bolts are slightly cathodic to ductile iron in most cases. This choice reduces the current density in the anode both possible ways. Since in most cases Cor-ten is only slightly cathodic, the potential difference is small which keeps the amount of produced current small. Also by making the bolts cathodic, the pipe and the gland are anodic. Since the pipe and the gland have a much larger area than the bolts, the current density in the anode is small compared to the cathode.

Sometimes, stainless steel T-bolts are used in pipeline joints. This would seem to be a practical solution to corrosion and in fact, the bolts do not corrode in most environments. However, in studies by the Cast-Iron Pipe Research Association in which stainless steel bolts were used, the areas of contact between the bolts and the glands were severely corroded. This was due to the great difference in galvanic potential between stainless steel and iron.

## SACRIFICIAL ANODES

In a corrosion cell, current flows from the anode through the electrolyte to the cathode. Cathodic protection methods attempt to control the direction of the corrosion current. One such method is the use of a sacrificial anode. A sacrificial anode is an anode electrically connected to the system to be protected. The sacrificial anode will corrode and therefore, the cathodic system will be protected. The basic idea is to force certain parts to be cathodic or anodic with respect to the other in order to control the current direction. If a sacrificial anode is chosen that is anodic to every metal in the pipeline system, the anode will corrode while the pipeline is protected.

A prime example of a sacrificial system is the use of magnesium anodes in connection with the pipeline system. The magnesium is buried in the ground within the same electrolyte as the pipeline. The pipeline and the anode are electrically connected, and as the magnesium corrodes, the pipeline is protected.

The magnesium should be alloyed to prevent passive layering. A passive layer is an oxide film that forms naturally on the surface of most metals. This passive layer becomes a protective coating on an anode and prevents further corrosion. If the sacrificial anode does not corrode, the protection current is not produced. If this happens, the pipeline will begin to corrode.

## IMPRESSED CURRENT SYSTEMS

Another form of cathodic protection is an impressed current system. In this system, an external source, not the galvanic reaction, forces the direction of the current. The positive terminal from a power source is connected to the anode and the negative terminal is connected to the cathode. The pipeline is connected to the negative terminal and consequently becomes cathodic. It is very important that the positive terminal be connected to the ground bed anodes, the material to be corroded. If the positive terminal is connected to the pipeline, the pipeline will become anodic and corrode. Several different current sources are available for use in impressed current systems. Batteries, DC engine-generators, and thermo-electric generators all provide direct current. Alternating current sources such as a power line may be used if a rectifier is used to convert the current to direct current. Alternating current will not provide any protection since the pipeline would be anodic or cathodic depending on the direction of the current.

The biggest advantage in cathodic protection systems is its effectiveness. However, in order to provide

effective corrosion protection, the system must be carefully maintained. It is important that the current and the anodes are continually monitored for both the impressed current and the sacrificial anode systems. Cost is another factor one must consider when using a cathodic protection system. In both the aforementioned methods, the anodes will require replacement at some period of time. The current must be maintained in an impressed current system. The equipment needed to maintain these methods must be considered. Also, the soil must be tested in order to determine the amount of current needed to provide optimum corrosion protection.

## OTHER CONSIDERATIONS

Several factors should be carefully considered during the design of a corrosion control system. One such consideration is the environment. For a pipeline, the environment would consist of the soil and anything in the soil such as other pipelines, buried cable, minerals, and water. Be aware of other current sources. A stray current source can affect the amount of protection a corrosion control system can provide. In an unprotected system, stray currents can increase the rate of corrosion. Economic and life requirements are two more things to be considered. Usually, pipelines are designed to last many years, so enough corrosion protection should be provided to insure the pipe and its components will last. Also, keep in mind the pipeline material to be used, including special coatings or polyethylene wrap. The effects of polyethylene wrap and coatings are discussed in Connections™ bulletin GI-3. Whichever method you choose, the corrosion protection system should be economically justified.

## SUMMARY

Galvanic corrosion continues to be a major concern in the water works field. Therefore material choice, such as EBAA Iron's all ductile iron joint restraint, becomes important. Also since the environment changes from job to job, a corrosion control system must be designed for each individual situation. Each corrosion control method should be considered carefully based on the soil type and other important factors.

## REFERENCE LIST

AWWA Manual M27; External Corrosion- Introduction to Chemistry and Control, 1st. ed., American Water Works Association, Denver, CO, 1987.

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NACE, NACE Basic Corrosion Course, 11th Printing, National Association of Corrosion Engineers, Houston, TX, 1980.

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