Cathodic Protection

An Online Continuing Education Course for Engineers

Course Number: MA-4003

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CATHODIC PROTECTION

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Introduction

Cathodic protection is a technique to control the corrosion of a metal surface by making it work as a cathode of an electrochemical cell. Corrosion is an electrochemical process in which a current leaves a structure at the anode site, passes through an electrolyte, and re-enters the structure at the cathode site.

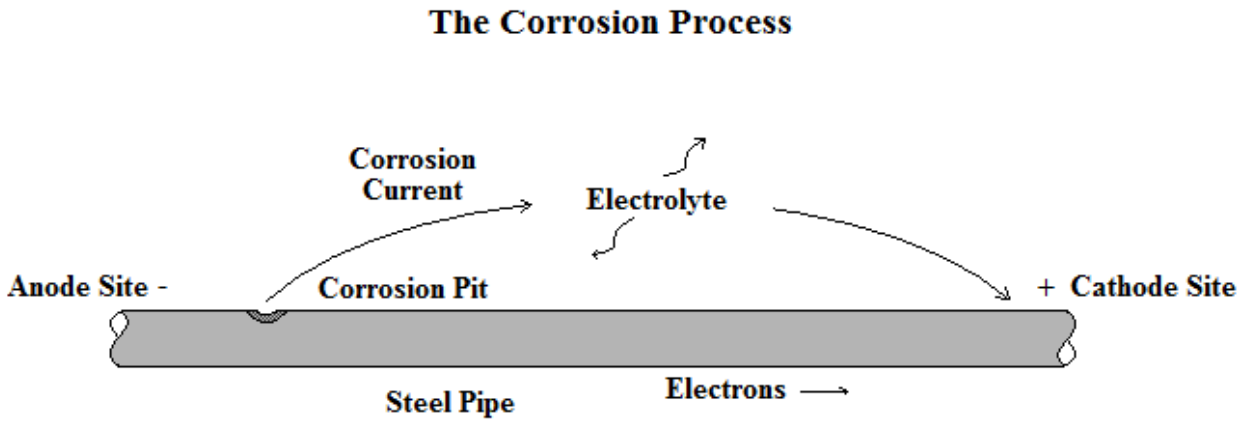

Figure 1

Definitions

Anode - electrode at which oxidation of its surface or some component of the solution is occurring.

Cathode - electrode at which reduction of its surface or some component of the solution is occurring.

Electrolyte - chemical substance or mixture, usually liquid, containing ions that migrate in an electric field such as soil or seawater.

For example, see Figure 1 where one small section of a pipeline is anodic because it is in a soil with low resistivity compared to the rest of the pipeline. Current leaves the pipeline at that anode site, passes through the soil, and re-enters the pipeline at a cathode site. Current flows because of a potential difference between the anode and cathode. That is, the anode potential is more negative than the cathode potential, and this difference is the driving force for the corrosion. The total system—anode, cathode, electrolyte, and metallic connection between anode and cathode —is termed a *corrosion cell.*

Cathodic protection (CP) is a method to reduce corrosion by minimizing the difference in potential between anode and cathode. This is achieved by applying a current to the structure to be protected (such as a pipeline) from some outside source. When enough current is applied, the whole structure will be at one potential; thus, anode and cathode sites will not exist. A cathodic protection system prevents corrosion by converting all of the anodic sites on the metal surface to cathodic sites by supplying electrical current from an alternate source. Usually the alternate source is a galvanic anode, which are more active than steel.

Cathodic protection systems are most commonly used to protect steel, water or fuel pipelines and storage tanks, steel pier piles, ships, offshore oil platforms and onshore oil well casings. External surfaces of buried metallic structures, surfaces of metal waterfront structures, such as sheet pilings or bearing piles, and the internal surfaces of tanks containing electrolytes, such as water, are applications where cathodic protection is usually technically feasible and cathodic protection is used in protecting such structures.

When construction of a new buried or submerged system is being planned, the corrosivity of the environment should be considered as one of the factors in the design of the system. If experience with similar systems in the vicinity of the construction site has shown that the site conditions are aggressive based on leak and failure records, cathodic protection should be considered as a means of controlling corrosion on the new system. Cathodic protection is one of the few methods of corrosion control that can be effectively used to control corrosion of existing buried of submerged metal surfaces. Thus, if leak records on an existing system show that corrosion is occurring, cathodic protection can be applied to stop the corrosion damage from increasing. Cathodic protection can, however, only stop further corrosion from occurring and cannot restore the material already lost due to corrosion.

In some cases, cathodic protection is required by policy or regulation. Regulations by the Department of Transportation have established standards for transporting certain liquids and compressed gas by pipelines in order to establish minimum levels of safety. The regulations require that these pipelines be protected by cathodic protection combined with other means of corrosion control, such as protective coatings and electrical insulation. The regulations provide excellent guidelines for the application of cathodic protection to buried and submerged pipelines. In addition to regulations, primarily due to the safety and environmental consequences of system failure, there are an increasing number of federal, state and local governmental regulations regarding the storage and transportation of certain materials that require corrosion control. Many of these regulations either specify cathodic protection as a primary means of corrosion control or allow its use as an alternative method of controlling corrosion.

Galvanizing generally refers to hot-dip galvanizing which is a way of coating steel with a layer of metallic zinc. Galvanized coatings are quite durable in most environments because they combine the barrier properties of a coating with some of the benefits of cathodic protection. If the zinc coating is scratched or otherwise locally damaged and steel is exposed, the surrounding areas of zinc coating form a galvanic cell with the exposed steel and protect it from corrosion. This is a form of localized cathodic protection - the zinc acts as a sacrificial anode.

This course is a brief introduction to cathodic protection. It explains the basics using a couple of very simple examples. Anyone interested in designing an actual cathodic protection system should consult with a corrosion specialist. NACE International is an association of corrosion engineering professionals with design experience in all types of cathodic protection systems. NACE is on the web at www.NACE.org. NACE also provides industry standards for the application of corrosion protection systems.

In the next section we review the basics of how cathodic protection systems operate. Subsequent sections will cover the actual design of a simple galvanic and impressed current system.

I. Types of Cathodic Protection

There are two main types of cathodic protection systems: galvanic and impressed current. Both types use anodes from which current flows into the electrolyte, a continuous electrolyte from the anode to the protected structure, and an external metallic wire connection. These items are essential for all cathodic protection systems.

Galvanic system

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Figure 2

Today, galvanic or sacrificial anodes are made in various shapes using alloys of zinc, magnesium and aluminum. The electrochemical potential, current capacity and consumption rate of these alloys are superior for corrosion protection than iron.