Pump ED 101

Corrosion – A Natural Process

Joe Evans, Ph.D http://www.pumped101.com

About 900 years before Newton formulated his universal gravitational theory the Greek philosopher, Aristotle, espoused something very different. He believed that all things had a natural place in the universe and therefore, any object that fell to the earth did so because it had a "need" to return to its natural place. He further theorized that heavier objects would fall faster than lighter ones because they had an even greater need to return. We know now that his theory was a bit off the mark but, had he adapted it to corrosion it could have described the process quite well.

Corrosion, like biological and organic decomposition, is a naturally occurring process. The question is not if it will occur - - it is how quickly. Steel, for example, is a man made material that is manufactured from iron ore (mostly iron oxides). Because energy is added during the manufacturing process the end product is unstable and, given the opportunity, it will return to its natural state. Now, whether it truly "needs" to resume its original identity is a question I shall leave to the psychologists.

Corrosion is an electrochemical process that requires that five conditions be present if it is to occur. There must be:

1) A supply of oxygen
2) An anode (where corrosion occurs)
3) A cathode
4) An electrolyte that permits the flow of ions and electric current
5) A conductive path for the return flow of current

The anode and cathode are electrically distinct areas that exhibit properties similar to the poles of a battery. They may be different structures (i.e. two different pieces of metal) or they may be two different locations within the same structure. The anode is the location or structure that suffers metal loss during corrosion. An electrolyte can be almost any material that contains moisture. Air, water, soil, and concrete are but a few common examples. Its purpose is to provide a path for the flow of metal ions between the anode and cathode. It also provides a conduit for the electrical current that is generated by ion flow. The greater an electrolyte's conductivity, the better its electrolytic capability. Salt water, for example, provides a much better path for ion and current flow than does fresh water and therefore hastens the corrosion process. In a similar fashion, the metal itself provides a return path for the flow of current from the cathode back to the anode.

Corrosion chemists refer to the different environments where these conditions can occur as "corrosion cells". Three types of corrosion cells are common in pumping applications.

1) Dissimilar metal cells - Commonly referred to as galvanic corrosion, these cells occur when two different metals contact one another in a common electrolyte.
2) Dissimilar electrolyte cells - This type of corrosion occurs when a single structure passes through an electrolyte of varying properties.
3) Differential aeration cells - These cells occur commonly in soils where a single structure passes through areas of differing oxygen concentration.

Corrosion, if left unchecked, can be an extremely efficient and swift process. For example, a current of a single ampere flowing from a steel pipeline into the soil can consume twenty pounds of pipe in just a year's time. Fortunately, it can be prevented if any one of the required conditions can be eliminated.

Probably the most common method of eliminating one of the required conditions is to coat the surface of a metal. A good coat of paint or epoxy can electrically isolate the surface of a metal structure from a potential electrolyte and therefore prevent it from corroding. Some of the epoxy coatings available today can make cast and ductile iron pumps quite corrosion resistant, even in salt water applications. In fact the product of corrosion itself can, in some cases, provide a protective coating. The iron oxide (rust) formed as iron or steel corrodes is not a very good conductor. But, unfortunately, it does not adhere very well and tends to flake away thus exposing the surface to additional degradation. Aluminum oxide, on the other hand, is an extremely hard and durable substance and often does a good job of protecting aluminum surfaces from further corrosion.

Another method of corrosion prevention that has been used for well over one hundred years is passive cathodic protection. I said earlier that it is the anode that suffers metal loss during corrosion. If we transform a structure that is normally an anode into a cathode and let some other structure become the anode, we can protect the original structure. Cathodic protection does this by adding a sacrificial metal that gives up electrons more easily than the metal to be protected and thus becomes the anode. This allows the original structure to undergo a major life change (to that of a cathode). The process is termed passive because current flow between the anode and cathode occurs naturally and is due to "galvanic" action. It is an example of a dissimilar metal corrosion cell and illustrates how we can use a normal corrosion process to selectively protect a structure that would otherwise undergo corrosion.

One of the most common forms of passive cathodic protection is the galvanized coating of zinc we find on sheet metal and steel piping. Since zinc is the less "noble" (looser electrons) metal, it becomes the anode and is sacrificed in order to preserve the primary metal. In submersible pump installations we can often attach a sacrificial anode directly to the pump body and achieve the same results as coating its entire internal and external surfaces. In either case the anode, depending upon its rate of decomposition, must be renewed periodically.

Another common type of cathodic protection is "impressed current" cathodic protection. Instead of relying on a natural flow of current between the sacrificial anode and cathode, an external direct current is applied to both. The impressed current makes the anode, regardless of its nobility, more positive than the structure that is to be protected. An advantage of this method is that almost any conductive material may be used as an impressed current anode. In fact, materials with very low consumption rates are the most desirable since they require less frequent replacement.

Another form of impressed current cathodic protection is known as "capacitive discharge oxidation interference" (CDOI). This system uses a capacitor bank to affect a bulk transfer of electrons through an electrolyte. Its claim to fame is that it can increase the effectiveness of cathodic protection in instances where very small amounts of electrolyte are present.

In pumping applications, dissimilar electrolyte and differential aeration corrosion are found typically in connecting piping that is buried or in contact with an aqueous solution. In both cases a single structure (a length of pipe) contains both anodic and cathodic areas. In a differential aeration cell differing concentrations of oxygen in the soil (the electrolyte) will determine which area is which. The section of pipe in soil with a good supply of oxygen (well aerated) will become the cathode and the poorly aerated section the anode.

In the case of a dissimilar electrolyte cell, variations in resistivity within the electrolyte can occur due to differences in chemical composition. The area of the pipe in contact with lower resistivity will become the anodic area. Corrosion protection for these systems is usually accomplished via coating, impressed current cathodic protection, or a combination of the two.

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pumps & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.pumped101.com. If there are topics that you would like to see discussed in future columns, drop him an email.