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OFFSHORE CATHODIC PROTECTION 101: WHAT IS IT AND HOW DOES IT WORK?

Dick Baxter & Jim Britton

www.cathodicprotection101.com

How Does Steel Corrode in Seawater?

To understand cathodic protection one must first understand the corrosion mechanism.
For corrosion to occur, three conditions must be present.

1. Two dissimilar metals
2. An electrolyte (water with any type of salt or salts dissolved in it)
3. A metal (conducting) path between the dissimilar metals

The two dissimilar metals may be totally different alloys, such as steel and aluminum, but are more usually microscopic or macroscopic metallurgical differences on the surface of a single piece of steel.

If the above conditions exist, at the more active metal surface (in this case we will consider freely corroding steel which is non uniform), the following reaction takes place at the more active sites:

$2Fe => 2Fe^{++} + 4e^-$ (2 Iron ions plus 4 free electrons)

The free electrons travel through the metal path to the less active sites where the following reaction takes place:

$O_2 + 4e^- + 2\ H_20 => 4\ OH^-$

(Oxygen gas converted to oxygen ion - by combining with the four free electrons - which combines with water to form hydroxyl ions)

Re-combinations of these ions at the active surface produce the following reaction, which yields the iron corrosion product ferrous hydroxide.

$2Fe + O_2 + 2H_2O => 2Fe\ (OH)_2$

(Iron combining with oxygen and water to form ferrous hydroxide)

This reaction is more commonly explained as current flow through the water from the anode (more active site) to the cathode (less active site).

How Does Cathodic Protection Stop Corrosion?

Cathodic protection prevents corrosion by converting all of the anodic (active) sites on the metal surface to cathodic (passive) sites by supplying electrical current (or free electrons) from an alternate source.

Usually this takes the form of galvanic anodes which are more active than steel. This practice is also referred to as a sacrificial system, since the galvanic anodes sacrifice themselves to protect the structural steel or pipeline from corrosion.

In the case of aluminum anodes, the reaction at the aluminum surface is:

$4Al \Rightarrow 4AL^{+++} + 12\ e^-$ (4 Aluminum ions plus 12 free electrons)

and at the steel surface,

$3O_2 + 12e^- + 6H_20 \Rightarrow 12OH^-$

(Oxygen gas converted to oxygen ions which combine with water to form hydroxyl ions)

As long as the current (free electrons) is arriving at the cathode (steel) faster than oxygen is arriving, no corrosion occurs.

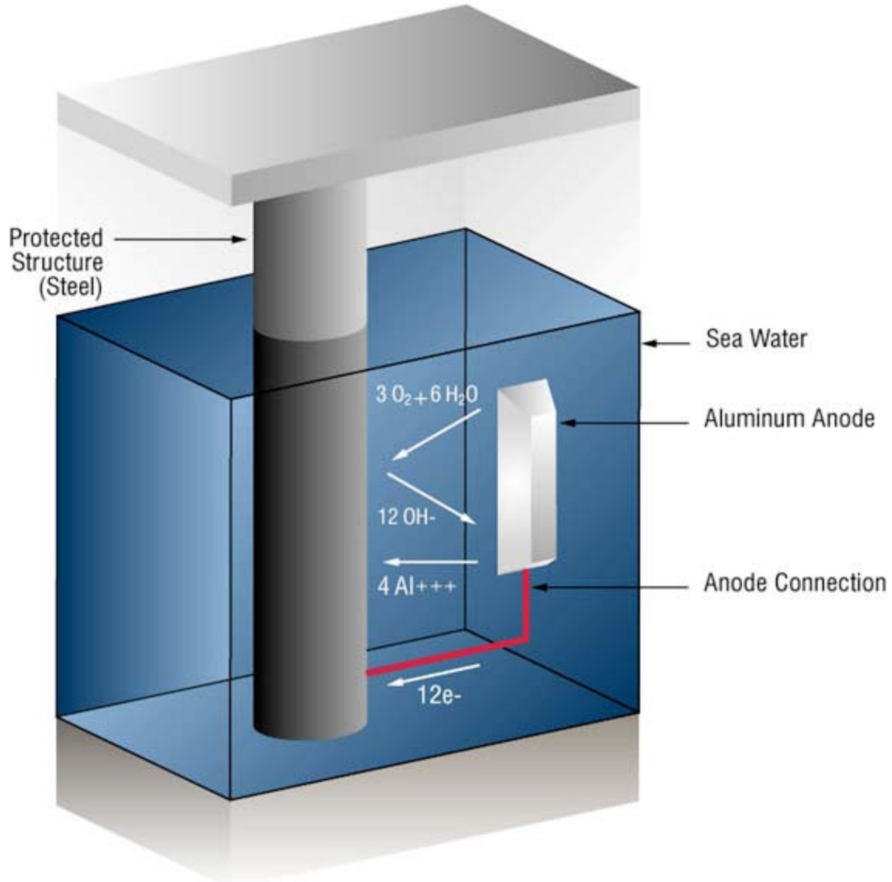

Figure 1: Sacrificial Anode CP System in Seawater

Deepwater Corrosion Services Inc.
10851 Train Court, Houston, TX 77041 USA
Telephone +1 (713) 983-7117 **Email** sales@stoprust.com
www.stoprust.com

Basic Considerations When Designing Sacrificial Anode Systems

The electrical current, which an anode discharges is controlled by **Ohm's law**; that is:

$I = E / R$

Where:
I= Current flow in amps
E= Difference in potential between the anode and cathode in volts
R= Total circuit resistance in ohms

Initially current will be high because the difference in potential between the anode and cathode are high, but as the potential difference decreases due to the effect of the current flow onto the cathode, current gradually decreases due to the polarization of the cathode.

The circuit resistance includes both the water path and the metal path, including any cable in the circuit. The dominant value here is the resistance of the anode to the seawater.

For most applications the metal resistance is so small compared to the water resistance that it can be ignored. (Not true for sleds, or long pipelines protected from both ends).

In general, long thin anodes have lower resistance than short fat anodes. They will discharge more current, but will not last as long.

Therefore a cathodic protection designer must size the anodes so that they have the right shape and surface area to discharge enough current to protect the structure and enough weight to last the desired lifetime when discharging this current.

As a general rule of thumb:

Length of the anode determines how much current the anode can produce, and consequently how many square feet of steel can be protected.

Cross Section (Weight) determines how long the anode can sustain this level of protection.

Impressed Current Cathodic Protection Systems

Due to the high currents involved in many seawater systems it is not uncommon to use impressed current systems. Impressed current systems use anodes of a type that are not easily dissolved into metallic ions, but rather sustain an alternative reaction, oxidization of the dissolved chloride ions.

$$2Cl^- \Rightarrow Cl_2 + 2e^-$$

Power is supplied by an external DC power unit.

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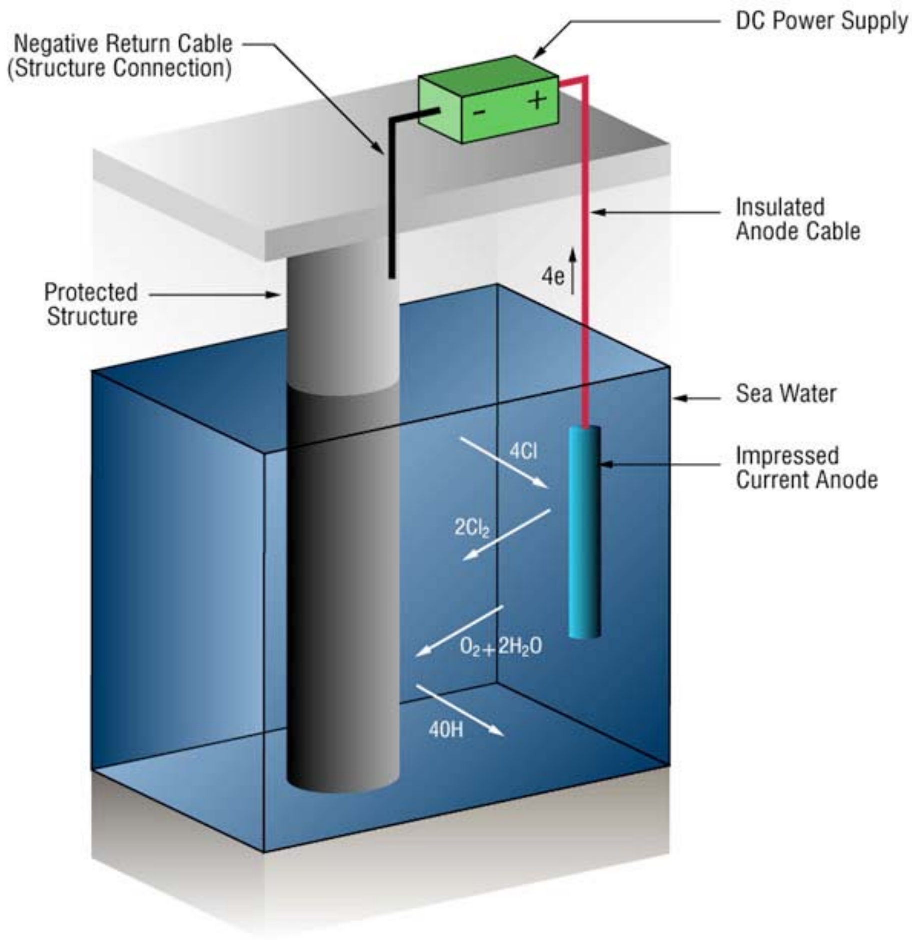

Figure 2: Impressed Current Cathodic Protection System

How do we know when we have enough Cathodic Protection?

We know whether or not we have enough current by measuring the potential of the steel against a standard reference electrode, usually silver silver/chloride (Ag/AgCl sw.), but sometimes zinc (Zn sw.).

Current flow onto any metal shifts its normal potential in the negative direction.

History has shown that if steel receives enough current to shift the potential to (-) 0.800 V vs. silver/silver chloride, the corrosion is essentially stopped.

Due to the nature of the films formed, the minimum (-0.800 V) potential is rarely the optimum potential, and designers try to achieve a potential between (-) 0.950 V and (-) 1.000 V vs. Ag/AgCl sw.

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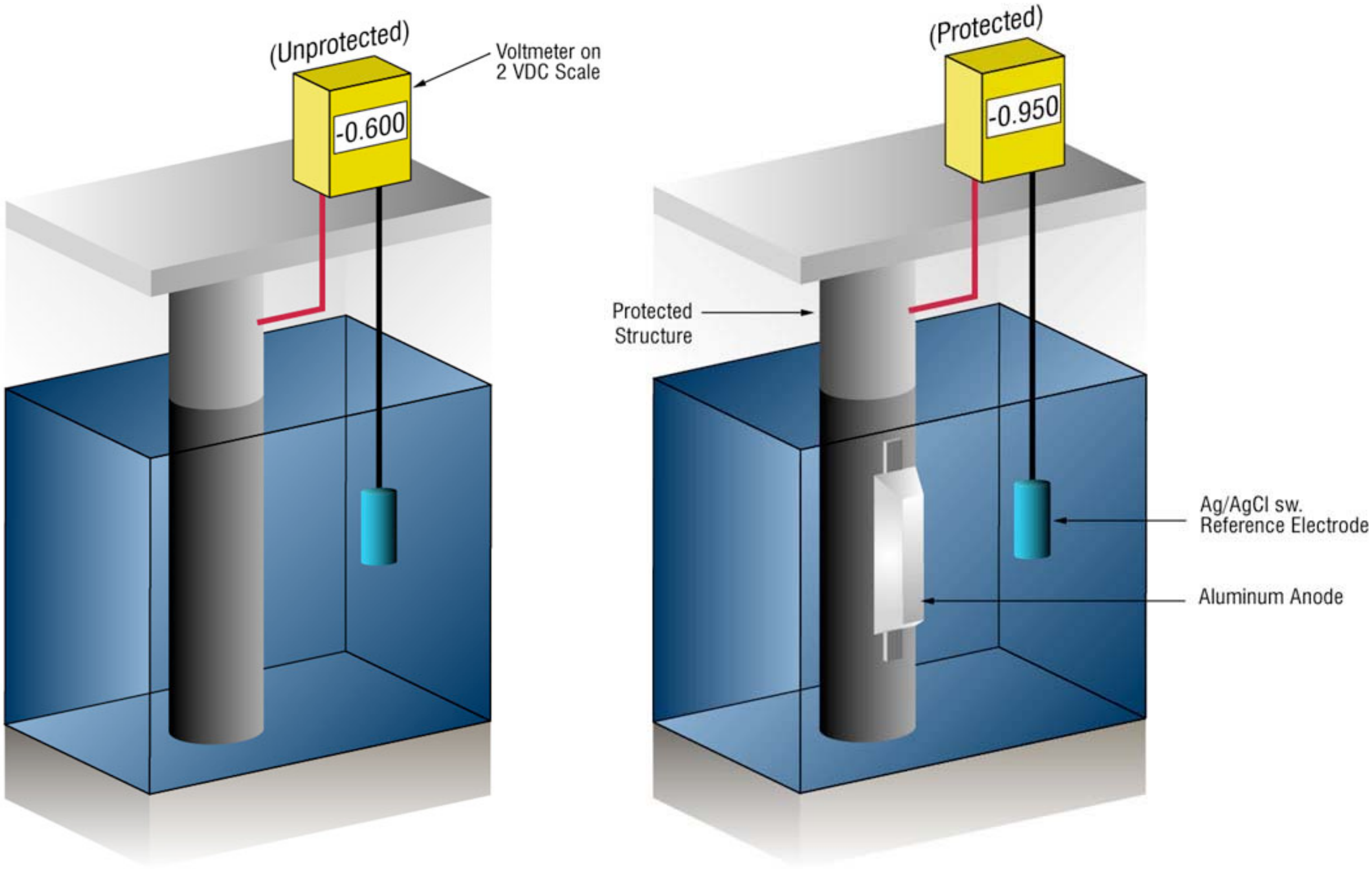

Figure 3: Cathodic Protection Potential Measurement (Unprotected Left – Protected Right)

For more information about cathodic protection offshore, please visit our **Anti-Corrosion Technical Library** online.

If you have any questions about this paper, or you would like to make an addition, please **contact us**.

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