Using Squidstats To Perform Corrosion Testing On A Metal Coupon

Written by Sujan Shrestha, PhD | sujan@admiralinstruments.com

Any Squidstat potentiostat can be a very useful tool for quality control testing and to evaluate new material formulations for corrosion protection

Potentiostats can be used to test corrosion of a coupon sample in several ways. To begin, it's important to understand how a potentiostat is different from other devices that can supply and measure current or voltage. The major difference is the circuit that is specially designed to operate what electrochemists call a "three-electrode cell" (see Figure 1). As the name suggests, a three-electrode cell has three electrodes: 1) a working electrode (WE), 2) a reference electrode (RE), and 3) a counter electrode (CE). A potentiostat/galvanostat controls the voltage/current of the WE with respect to the voltage/current measured at the RE and is designed to ensure this control is as precise as possible. No current flows between a WE and a RE. Rather, the current always flows between the WE and the CE. The counter electrode is there to balance the current flow through the working electrode. The CE can be thought of as referee of a game. The CE, like a referee, is not tasked with making any decisions that directly affect the result of a game. Instead, they are there to simply ensure that the game is being played according to the conditions agreed to in advance. This type of circuit allows one to control potential of the working electrode no matter what the flow of current may be.

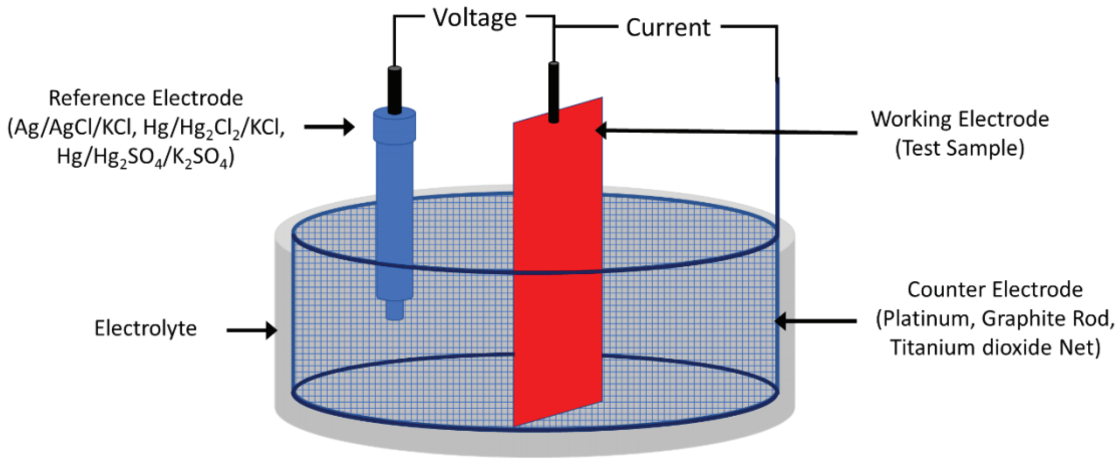

***Figure 1**. A typical three-electrode setup consisting of a working electrode (WE), reference electrode (RE) and a counter electrode (CE). The voltage of the WE is controlled with respect to the RE, while the current is measured between the WE and the CE.*

In a normal two electrode setup, if an oxidation reaction is occurring at one electrode, a reduction reaction must be occurring at the other electrode to complete the current loop. So, an electrode influences the current and voltage of the other electrode and vice versa. However, this is not the case with a three-electrode cell and a potentiostat. The electrochemical phenomena happening at the WE are solely dependent on the WE and its surrounding environment, which is defined as the electrolyte. It does not matter what is happening at the other electrode. This is very difficult to achieve with any other type of instrument such as a power supply with a multimeter, or a source-measurement unit (SMU). Only a potentiostat is designed to easily carry out this type of measurement.

Written by Sujan Shrestha, PhD | sujan@admiralinstruments.com

This setup can be modified in many ways depending on what the user wants to measure. If a user wants to measure the effectiveness of cathodic protection on a steel pipe submerged in seawater, a WE can be constructed by connecting a steel pipe to the metal that acts as cathodic protection (see Figure 2). The counter electrode can be a graphite or titanium dioxide net. The reference electrode can be either a silver/silver chloride or a calomel reference electrode. The electrolyte will be seawater.

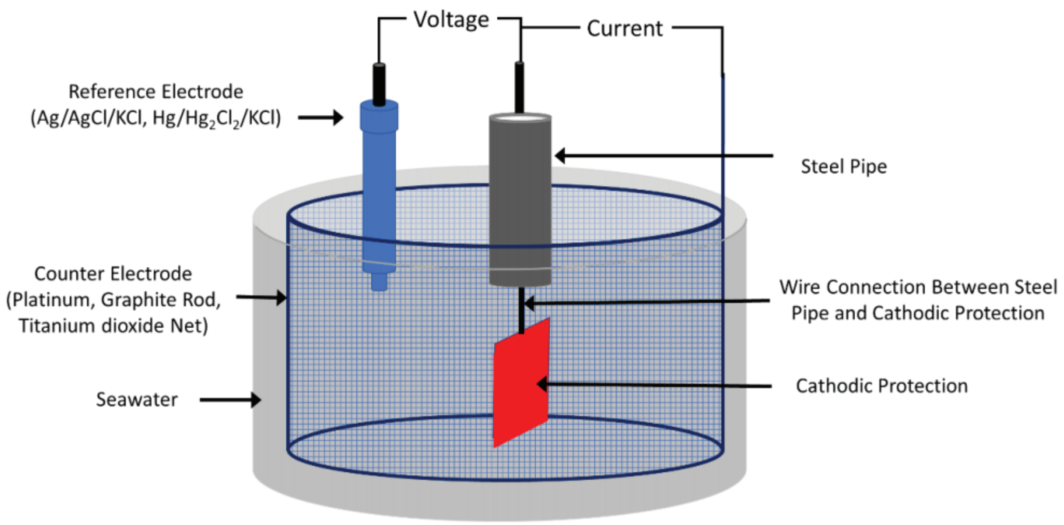

***Figure 2**. A proposed setup for measuring effectiveness of cathodic protection on a steel pipe in seawater. The working electrode is cathodic protection connected to a steel pipe, A silver/silver chloride or a calomel reference electrode can be used. For the counter electrode, a titanium dioxide net or graphite rods can be used.*

After setting up the electrodes and the seawater as the electrolyte, many techniques are available to measure the corrosion rate of the cathodically-protected steel pipe. Some tests, for example potentiodynamic polarization, cyclic polarization, electrochemical impedance spectroscopy, and electrochemical noise techniques, take only a few hours to complete. Others can take several days to complete, for example NACE standard TM0190 to measure "anode efficiency" for magnesium or aluminum alloys. Whatever the test method of choice might be, it can be performed by a potentiostat.

Besides carrying out routine tests for materials standardization recommended by NACE/ASTM, which might require simply applying current over time, a potentiostat can be used to carry out more sophisticated tests requiring complicated types of voltage and current modulation. For research and development, it can help to understand the underlying science behind a corrosion mechanism or protection against it. A user can also develop custom tests to screen and select promising materials. So, even just a single potentiostat like the $1,900 Squidstat Solo is a useful tool for many corrosion-related measurements on sample coupons.

One thing to know when designing an electrochemical experiment with a potentiostat is to ensure the current and voltage range called for in the experiment is within the potentiostat's capabilities. Most potentiostats operate within a few amperes and volts. For example, the $4,900 Squidstat Plus has a current range of 1 A, voltage range of 10 V, and a maximum EIS frequency of 1 MHz. So, the size of the working electrode or test samples may need to be adjusted so the potentiostat does not surpass its current and voltage limit.