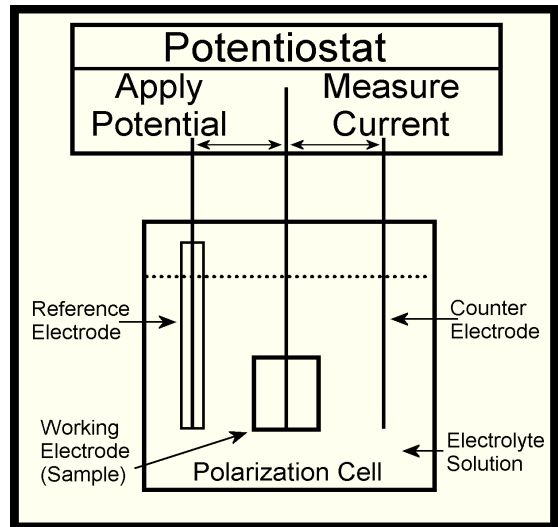# ELECTROCHEMICAL CORROSION TESTING

DESCRIPTION OF METHOD

All corrosion is an electrochemical process of oxidation and reduction reactions. As corrosion occurs, electrons are released by the metal (oxidation) and gained by elements (reduction) in the corroding solution. Because there is a flow of electrons (current) in the corrosion reaction, it can be measured and controlled electronically. Therefore, controlled electrochemical experimental methods can be used to characterize the corrosion properties of metals and metal components in combination with various electrolyte solutions. The corrosion characteristics are unique to each metal/solution system.

In testing practice, a polarization cell is setup consisting of an electrolyte solution, a reference electrode, a counter electrode(s), and the metal sample of interest connected to a specimen holder. (The sample is called the working electrode.) The electrodes are connected to an electronic instrument called a potentiostat. The working, reference, and counting electrodes are placed in the electrolyte solution, generally a solution that most closely resembles the actual application environment of the material being tested. In the solution, an electrochemical potential (voltage) is generated between the various electrodes. The corrosion potential (E_{CORR}) is measured by the potentiostat as an energy difference between the working electrode and the reference electrode.

Electrochemical corrosion experiments measure and/or control the potential and current of the oxidation/reduction reactions. Several types of experiments are possible by manipulating and measuring these two variables.

Most experiments impose a potential on the working electrode and measure the resulting current. A potentiostatic experiment imposes a constant potential on the working electrode for a specific time period. The measured current is plotted verses time.

For potentiodynamic experiments, the applied potential is increased with time while the current is constantly monitored. The current (or current density) is plotted verses the potential. After the potential is scanned to a predetermined current density or potential, the potential scan may be reversed while the current continues to be measured. A potentiodynamic scan like this is referred to as reverse polarization or cyclic polarization.

It is also possible to control the current and measure the resulting potential. Experiments where the current is imposed rather than the potential are referred to as galvanodynamic or galvanostatic. Galvanodynamic methods plot the variation in potential verses the controlled current. Galvanostatic tests maintain a constant current and plot the change in potential verses time.

ANALYTICAL INFORMATION

Potentiodynamic experiments can provide a variety of data related to the pitting, crevice corrosion, and passivation behavior for specific sample/solution combinations. As the potential is increased, pitting corrosion will begin at a certain value known as the breakdown potential (E_B, the lowest potential at which pitting occurs). Since pitting corrosion relates to an increase in the oxidation rate, the E_B is determined by the corresponding increase in measured current. An increase in E_B is associated with higher resistance to pitting corrosion. As the potential is decreased on the reverse scan, there is a decrease in the current. However, hysteresis is observed for the reverse scan and a hysteresis loop is traced. The sample is repassivated at the potential where the reverse scan crosses the forward scan. The repassivation potential, or protection potential (E_P), occurs at a lower potential than the E_B. The difference between E_B and E_P is related to susceptibility to crevice corrosion; the greater the hysteresis in the polarization curve, the greater the crevice corrosion susceptibility.

Representative Potentiodynamic Cyclic Polarization Curves

Electrochemical corrosion experiments may also be used to determine corrosion rates (Tafel Plot), active/passive characteristics for a specific sample/solution system, passivation rates, and anodic and cathodic protection.
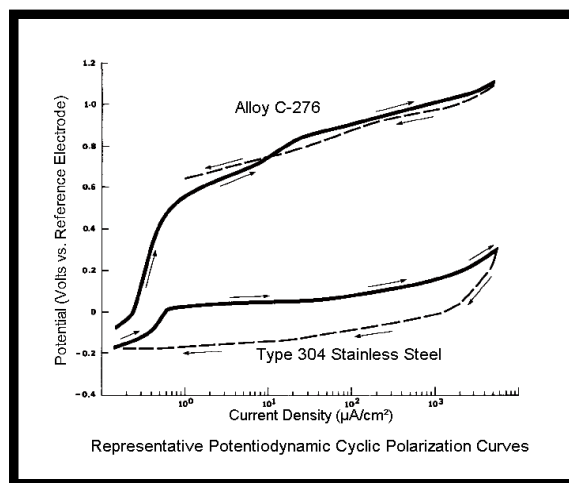
TYPICAL APPLICATIONS

- Analysis of finished medical devices for pitting and crevice corrosion susceptibility
- Comparison of raw materials (screening) for corrosion characteristics
- Evaluating effect of passivation or surface modifications on corrosive behavior
- Evaluate/Compare processing effects on corrosion properties
- Evaluate bimetal combinations for galvanic corrosion behavior

SAMPLE REQUIREMENTS

Samples for electrochemical corrosion testing must electrical conductors and must be small enough to fit in the polarization cell. Components can be tested as a whole or as a smaller section. Metal coupons are specially prepared for some tests.