Corrosion: 2. Measurement of Corrosion Rates

Weight loss measurements

The simplest way of measuring the corrosion rate of a metal is to expose the sample to the test medium (e.g. sea water) and measure the loss of weight of the material as a function of time. Although these tests are simple, there is no simple way to extrapolate the results to predict the lifetime of the system under investigation.

Electrochemical Tests

As mentioned in the previous application notes, most corrosion phenomena are of electrochemical nature and consist of reactions on the surface of the corroding metal. Therefore electrochemical tests methods can be used to characterise corrosion mechanisms and predict corrosion rates.

Calculation of corrosion rates

The corrosion rate depends on the kinetics of both anodic (oxidation) and cathodic (reduction) reactions. According to Faraday's law, there is a linear relationship between the metal dissolution rate or corrosion rate, R_M, and the corrosion current i_{corr}:

$$R_M = \frac{M}{nF\rho} i_{corr}$$

In this equation *M* is the atomic weight of the metal, ρ is the density, *n* is the charge number which indicates the number of electrons exchanged in the dissolution reaction, and *F* is the Faraday constant, *F* = 96,485 C/mol. The ratio *M/n* is also sometime referred to as equivalent weight.

Calculation of corrosion currents

Calculation of corrosion rates requires the calculation of corrosion currents. When reaction mechanisms for the corrosion reaction are known, the corrosion currents can be calculated using Tafel Slope Analysis.

The relationship between current density and potential of anodic and cathodic electrode reactions under charge transfer control is given by the Butler-Volmer equation.

$$i = i_{corr}(\exp(2.303\frac{\eta}{b_a}) + \exp(-2.303\frac{\eta}{b_c}))$$

$$\eta = E - E_{corr}$$

In the above equation *E* is the applied potential and *i* the measured current density. The overpotential, η, is defined as the difference between applied potential and the corrosion potential E_{corr}. The corrosion potential, E_{corr} is the open circuit potential of a corroding metal. The corrosion current, i_{corr}, and the Tafel constants b_a, and b_c can be measured from the experimental data.

For large anodic overpotentials (η / b_a >>1) the Butler Volmer equation simplifies to the Tafel equation for the anodic reaction.

$$\eta = \log i_{corr} + b_a \log i$$

Analogously, for large cathodic overpotentials (η / b_c << -1) the Tafel equation for the cathodic reaction is given by

$$\eta = = \log i_{corr} - b_c \log |i|$$

The Tafel equations predict a straight line for the variation of the logarithm of current density with potential. Therefore, currents are often shown in semilogarithmic plots known as Tafel plots. This type of analysis is referred to as Tafel Slope Analysis.

Calculation of corrosion currents in GPES

The GPES software provides a convenient interface for making Tafel plots, calculating Tafel slopes and corrosion rates. In Figure 1 the current potential curve for an iron screw immersed in seawater is shown. Selection of the Tafel slope analysis tab in the Analysis section of the Data Presentation window results in an Automatic Tafel plot as shown in Figure 2. Users can also specify the equivalent weight, density of the electrode material and the surface area of the electrode as shown in Figure 3.

The user, with the help of markers, needs to specify the anodic and cathodic Tafel region. Once the regions are selected the GPES software automatically calculates the Tafel slopes and the corrosion currents. The Tafel slopes are then automatically plotted on the Tafel Plot as shown in Figure 4 and the results are tabulated as shown in Figure 5.

In choosing the regions for Tafel slope analysis, care must be taken. A correct estimate of the Tafel slopes is possible only if the linear Tafel region (region between markers in Figure 3) covers at least 1 decade in current. In certain cases (*e.g.,* passivation of iron shown in Figure 6) the Tafel slope analysis is not possible.

Figure 1: Current potential curve for iron screw immersed in seawater.

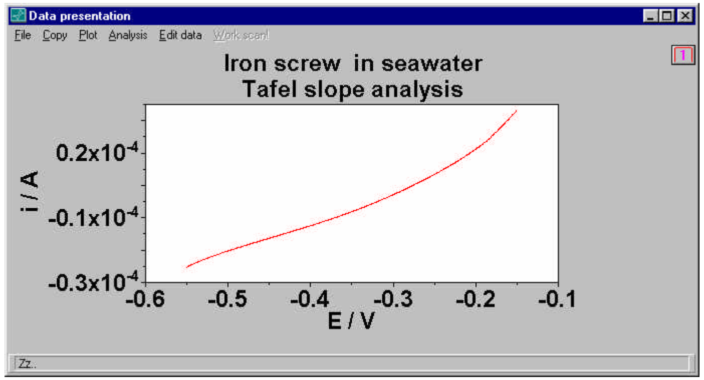

Figure 2: Tafel plot for iron screw immersed in seawater.

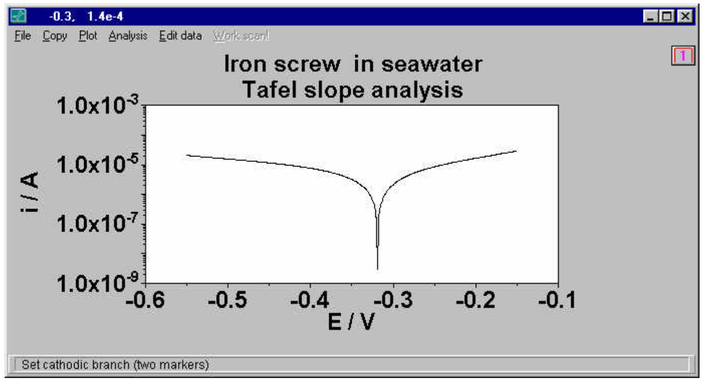

Figure 3: GPES window for specifying the parameters required for Tafel analysis.

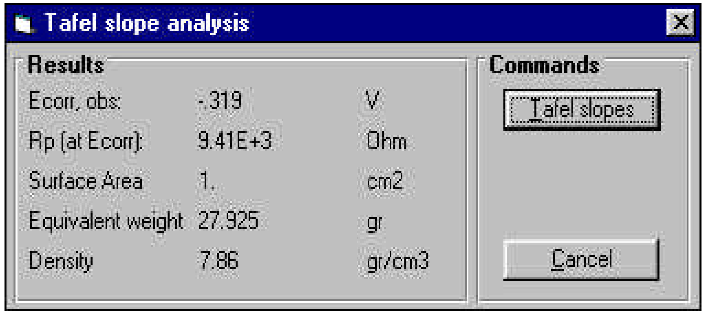

Figure 4: GPES window for the specification of Tafel regions with the help of markers.

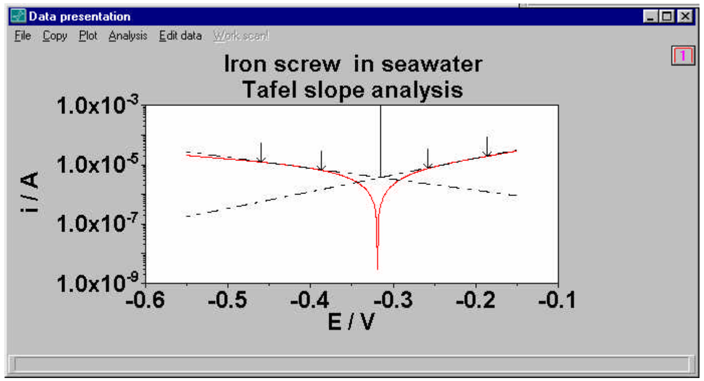

Figure 5: GPES window for showing the results of Tafel analysis.

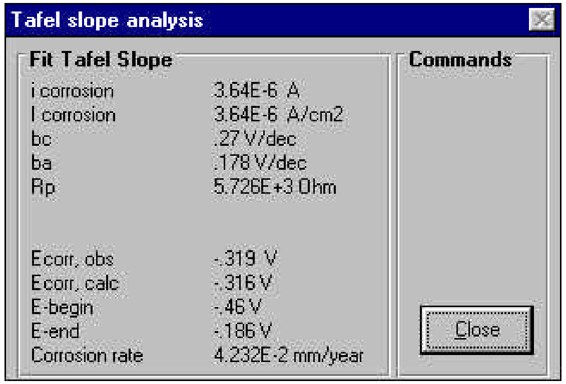

Figure 6: Tafel plot showing passivation of iron in the presence of inhibitor.