

Corrosion current measurement for an iron electrode in an acid solution

I – Introduction

The corrosion current is a typical corrosion value which can be related, for example, to the corrosion rate. The information obtained from both values is necessary when studying the corrosion state of a given system. The aim of this tutorial is to show to the user how to determine the corrosion current using simple graphic tools on EC-Lab linked to the Tafel equation: **Tafel fit** and **R_p fit**.

II - Experimental conditions

- Working electrode: RDE (Rotating Disk Electrode) of iron, working area: 0.0314 cm², electrode rotation speed: $\Omega = 800$ rpm (rotations per minute).
- Counter electrode: Platinum wire
- Reference electrode: Saturated Calomel Electrode (SCE)
- Solution: HCl (0.1 M)

III - Protocol description

The current was measured through a LSV (Linear Sweep Voltammetry) response with a low scan rate (10 mV/s). The potential was scanned from -0.6 to 0 V/SCE.

The protocol used under EC-Lab was Linear Polarization (Fig. 1). The parameters settings were the following:

In the “Parameters Settings” tab,

- **1st block:** default settings
- **2nd block:**
 - Scan E_{WE} with **dE/dt = 50 mV/s** from E_I = **-0.6 V** vs. <None> to E_L = **0 V** vs. <None>
 - Record <I> over the last **100 %** of the step duration, average **N = 50** voltage steps
 - with I Range = **Auto** and Bandwidth = **5 – medium**

Note: In the “Advanced Settings” tab, E_{WE} max and E_{WE} min were respectively set to +1 and -1 V. This increases the potential control resolution (span) by diminishing the minimum potential step height from 300 to 50 μ V (cf. Technical Note #8 – Adjustment of the potential control resolution).

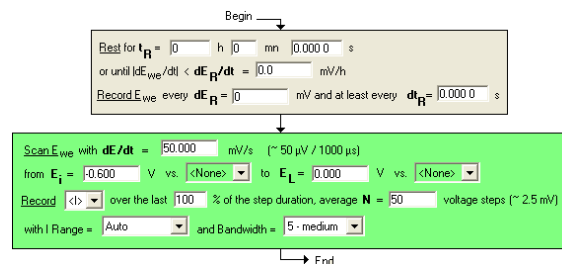


Figure 1 – LP “Parameters Settings” window.

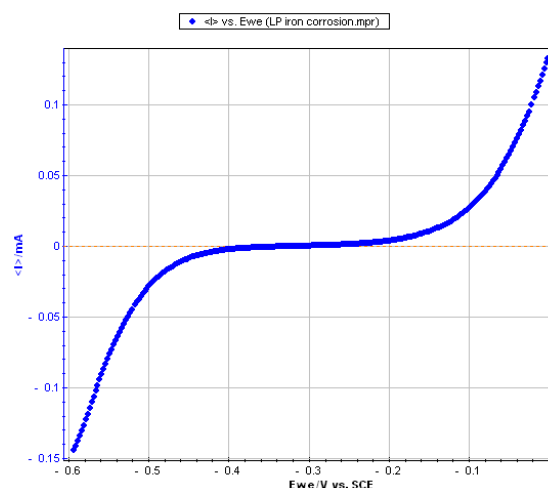


Figure 2 – Steady-state curve I vs. E_{WE}.

Note: It is possible to load the different LP_iron_corrosion files with EC-Lab software in the following folder: C:\EcLab\data\samples.

IV – Stern Method (Tafel fit)

The Stern relation can be written as followed:

$$I = I_{corr} \left(\exp \left(\ln 10 \frac{E - E_{corr}}{\beta_a} \right) - \exp \left(\ln 10 \frac{E - E_{corr}}{\beta_c} \right) \right)$$

From the graph displaying **log |I| vs. E_{WE}**, it is possible to determine the values of I_{corr} , E_{corr} , β_a and β_c by a simple analysis.

The **Tafel fit**, which is a Graph Analysis tool from EC-Lab (cf. Quickstart – Analysis Graph Tools), can determine automatically these values (Fig. 3).

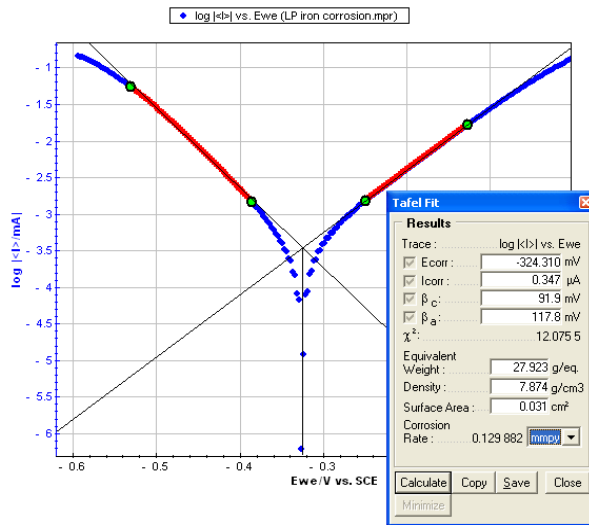


Figure 3 – Tafel Fit Analysis.

Note: The corrosion rate can be determined if the user enters the values of the equivalent weight (atomic weight divided by the number of electrons involved in the reaction), the material density and the active surface area.

V – Stern and Geary method (R_p fit)

The expression of the polarization resistance can be defined as:

$$R_p = \frac{1}{dI/dE} \quad \text{where}$$

$$I = I_{corr} \left(\exp \left(\ln 10 \frac{E - E_{corr}}{\beta_a} \right) - \exp \left(\ln 10 \frac{E - E_{corr}}{\beta_c} \right) \right)$$

which means that for $E = E_{corr}$,

$$R_{p,E_{corr}} = \frac{\beta_a \beta_c}{I_{corr} (\beta_a + \beta_c) \ln 10}$$

and knowing the values of $R_{p,E_{corr}}$, β_a and β_c , we can figure out the value of I_{corr} with the following relationship:

$$I_{corr} = \frac{\beta_a \beta_c}{R_{p,E_{corr}} (\beta_a + \beta_c) \ln 10}$$

The value of $R_{p,E_{corr}}$ can be simply determined by displaying the graph giving E_{WE} vs. I around the corrosion potential and calculating the slope of the curve.

The **R_p fit**, which is a graph analysis tool from EC-Lab (cf. Quickstart – Analysis Graph Tools), can automatically calculate the value of R_p . It is also possible to determine the corrosion current I_{corr} if the values of the Tafel coefficients β_a and β_c are known. The user will just have to type these values in the R_p fit analysis window before the fit (Fig. 4).

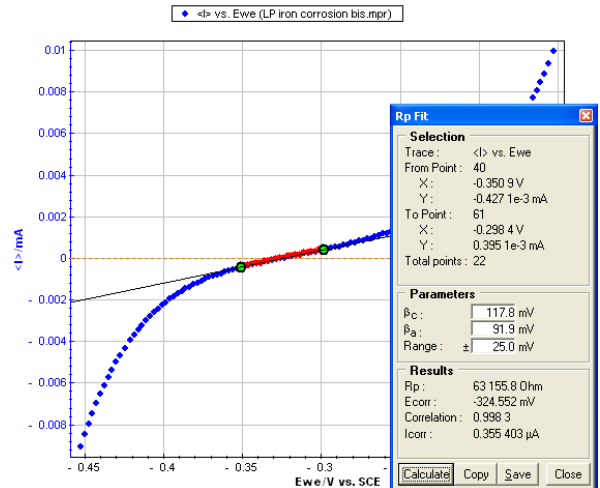


Figure 4 – R_p fit analysis.

VI – Conclusion

The values of the Tafel coefficients β_a and β_c found with the Tafel fit were used to find the corrosion current with the R_p fit and the results found with both methods are very close:

- for Tafel fit, $I_{corr} = 0.347 \mu\text{A}$
- for R_p fit, $I_{corr} = 0.355 \mu\text{A}$

These graphic tools seem therefore quite efficient. The Tafel fit can also be used to determine the corrosion rate. The value found for this experiment is:

$$\text{Corrosion rate} = 0.130 \text{ mmpy.}$$

References

Traité des Matériaux, 12, Corrosion et Chimie de Surfaces des Métaux, D. Landolt, ed., Presses Polytechniques et Universitaires Romandes, 2003.

Cinétique électrochimique, J.P. Diard, B. Le Gorrec, C. Montella, ed., Hermann, 1996, p. 204.