Application Note AN-COR-003

Corrosion part 3 – measurement of polarization resistance

In the previous application note, the procedure for estimating corrosion rates was outlined. The calculations were valid under the assumption that the corrosion reactions were under charge transfer control and that the mechanisms of the reactions were known. In real life, often, corrosion is a result of several reactions and it is not possible to determine a priori the reaction mechanism. In such cases, the polarization resistance can be used to determine the resistance of the metal under investigation against corrosion.

POLARIZATION RESISTANCE

An electrode is polarized when its potential is forced away from its value at open circuit or corrosion potential. Polarization of an electrode causes current to flow due to electrochemical reactions at the electrode surface. The polarization resistance R_p is defined by the Equation 1:

$$R_p = \left(\frac{\Delta E}{\Delta i}\right)_{\Delta E \to 0} \qquad (1)$$

Where E (V) is the variation of the applied potential around the corrosion potential and i (A) is the resulting polarization current.
The polarization resistance, R_p (Ω), behaves like a resistor and can be calculated by taking the inverse of the slope of the current potential curve at corrosion potential (OCP).

During the polarization of an electrode, the magnitude of the current is controlled by reaction kinetics and diffusion of reactants both towards and away from the electrode.
The Butler-Volmer relates the current i with the overpotential η, Equation 2:

$$i = i_{corr}\left(e^{2.303\frac{\eta}{b_a}} - e^{2.303\frac{\eta}{b_c}}\right) \qquad (2)$$

The overpotential $\eta\,(V) = E - E_{corr}$ is defined as the difference between applied potential E and the corrosion potential E_{corr}. The corrosion potential E_{corr} is the open circuit potential of a corroding metal. The corrosion current i_{corr1} and the Tafel constants b_a and b_c can be measured from the experimental data.

For small overpotentials η, i.e. for potentials close to corrosion potential, the above equation can be reduced to:

$$i_{corr} = \frac{1}{R_p}\left[\frac{b_a b_c}{2.303(b_a + b_c)}\right] \quad 3$$

Or, when the expression is rearranged:

$$R_p = \frac{1}{2.303}\frac{b_a b_c}{b_a + b_c}\left(\frac{1}{i_{corr}}\right) \quad 4$$

If the Tafel slopes are known, the corrosion currents can be calculated from the polarization resistance using the above equations. If the Tafel slopes are not known (e.g., when corrosion mechanism is not known), R_p can still be used as a quantitative parameter to compare the corrosion resistance of metals under various conditions. A specimen with low R_p will corrode more easily than a specimen with a low R_p.

MEASUREMENT OF RP USING ELECTROCHEMICAL METHODS

Linear Sweep Voltammetry (LSV)

In **Figure 1**, the results of a LSV experiment performed on an iron screw immersed in seawater are shown. The slope of the curve at $E_{corr} = -0.319$ V can be calculated by performing a linear regression tangent to the data from -10 mV vs. E_{corr} and +10 mV vs. $E_{corr.}$

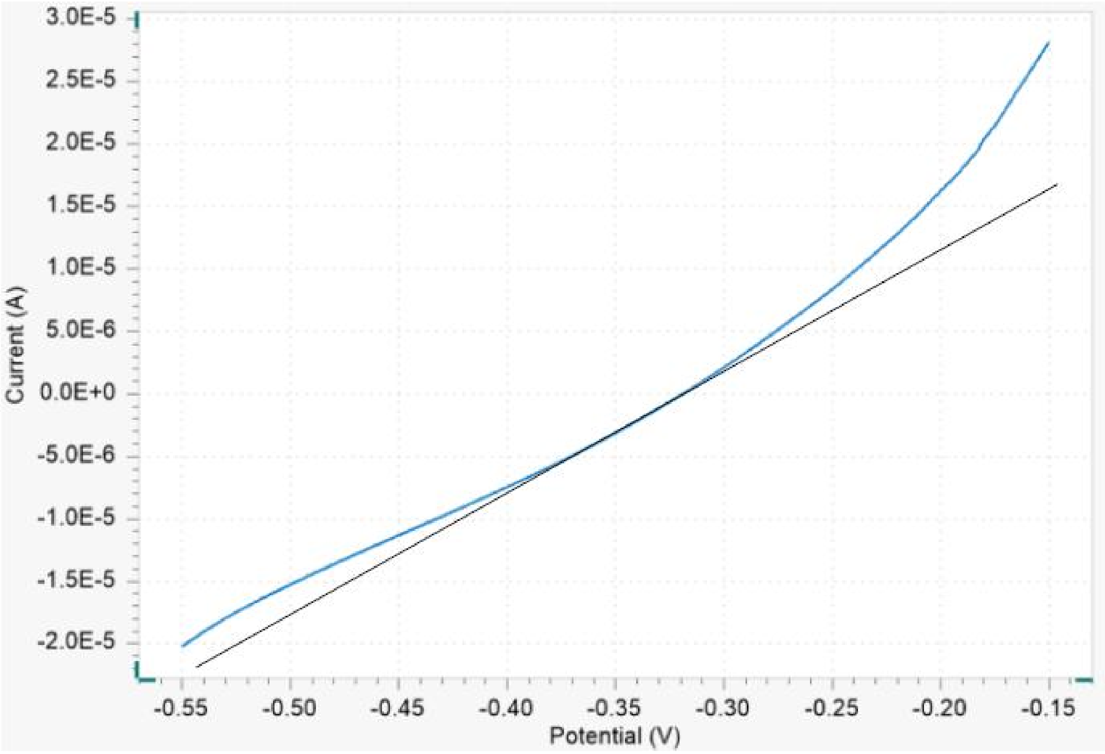

Figure 1. LSV data for the corrosion of an iron screw in seawater

The results of the regression are shown in Figure 2. The polarization resistance R_p is calculated from inverse of the slope (1/slope) and is found to be 9.489 kΩ.

Function description	y = 3.3767E-05 + 0.00010538x
Correlation coefficient	0.99891
a	3.3767E-05
b	0.00010538
1/Slope	9489.3

Figure 2. The calculated regression line equation for the corrosion of an iron screw in seawater

Electrochemical Impedance Spectroscopy

The polarization resistance can also be measured with electrochemical impedance spectroscopy (EIS). For simple systems where the Nyquist plot shows one semicircle, the equivalent circuit shown in **Figure 3** can be used to estimate R_p.

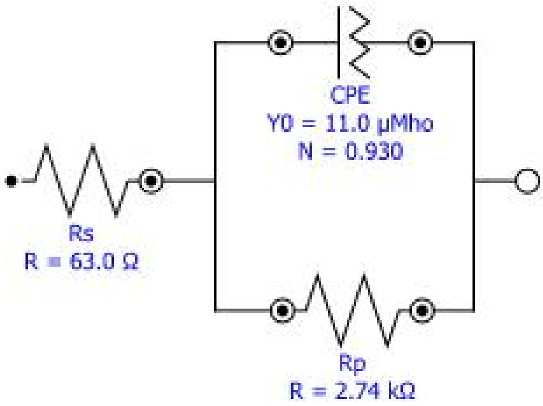

Figure 3. The equivalent circuit used to fit a semicircle in the Nyquist plot.

In **Figure 4**, the Nyquist plot resulting from the corrosion of iron in sulfate solution is shown. The solid line represents the fit of the circuit shown to calculate the polarization resistance R_p.

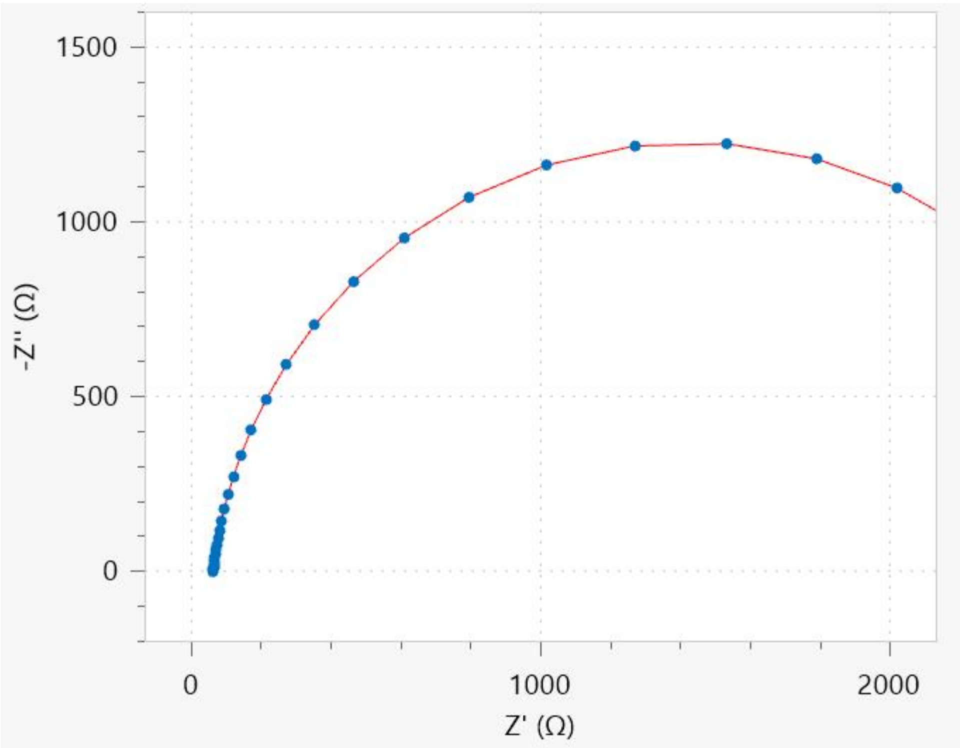

Figure 4. Estimation of Rp for corrosion of iron in seawater using EIS

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CONFIGURATION

Autolab PGSTAT204

PGSTAT204 合了小巧格和模化。器包括基本恒位/恒流,其从 20 V,最大流 400 mA 或 10 A,与 BOOSTER10A 合使用。此恒位可随用附加模行展,例如 FRA32M 化学阻抗(EIS)模。
PGSTAT204 是一款惠的器,可置于室的任何位置。具有模和数字入/出,可控制 Autolab 附件和外部。PGSTAT204 包括内置模分器。与高性能的 NOVA 件用,可用于大多数准化学技。

Autolab PGSTAT302N

高端高流恒位/恒流,具有 30 V 从, 1 MHz,可与我的 FRA32M 模用,化学阻抗而。
PGSTAT302N 是流行的 PGSTAT30 的后款型。最大流 2 A,借助 BOOSTER20A 流范可展至 20 A,当流范 10 nA 流分辨率 30 fA。

1 l

Autolab 1 l 腐池用于根据 ASTM 准行腐量。池具有一个恒温外用于温度控制,和一系列口可用于相、pH 感器、温度、金-哈伯毛管以及气体化。
1 l 的腐池用于量直径 14.7 至 16 mm 厚度 0.5 至 4 mm 的品腐情况。裸露的表面 1 cm2。用天然橡密封。

0.250 L
完整的腐量池,250 mL。

Autolab 400 ml 腐池用于腐量。池具有一个恒温外用于温度控制,和一系列口可用于相、pH 感器、温度、金-哈伯毛管以及气体化。
400 ml 的腐池用于量直径 14 mm 厚度 1 mm 的扁形品浸入解中的腐情况。裸露的表面 0.785 cm2。支架由 Delrin 聚甲脂制成,用 Viton 橡密封。

用于大型扁平品的完整平面品平台。
字:腐池,性化,塔菲,腐速度,扁平品,