Polarization Resistance and Electrochemical Impedance Testing of Alloy 22

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Projects

- Polarization Resistance and Electrochemical Impedance (EIS) Testing of Alloy 22

Polarization Resistance & EIS for Alloy 22

Objectives:

- Assess the applicability of the Polarization Resistance method and the Electrochemical Impedance method for corrosion rate measurements of passive alloys
- Determine Uniform Corrosion Rate of Alloy 22

Polarization Resistance Tests for Alloy 22

Specimen: C-22 (Heat: 2277-8-3175) Polished to a 600 grit finish

8 cm^2 surface area

Equipment: Standard Electrochemical Test Cell with condenser, counter electrode, reference electrode, thermometer, thermocouple, housed in a Faraday cage

Solartron 1260 &1287

CorrWare Software

zPlot & zView Software

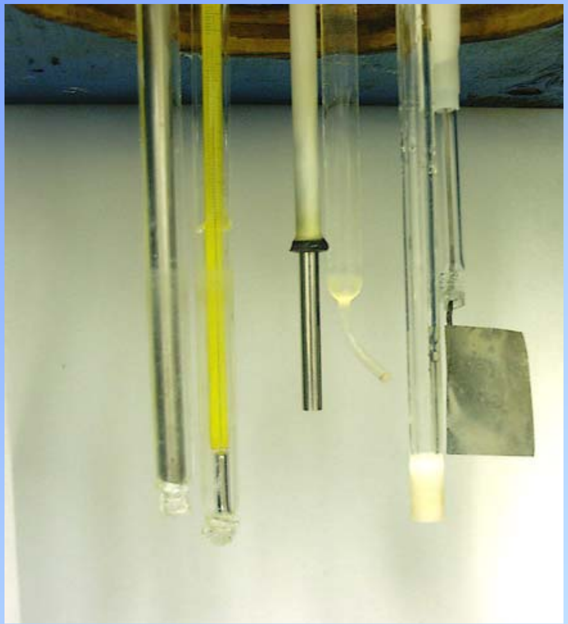
Polarization Resistance Tests for Alloy 22

Experiment:

Scan: -15mV to +60mV vs. Open Circuit Potential

Scan Rates: 1, 0.1, 0.01, 0.005, & 0.001 mV/s

Test Cell:



Polarization Resistance Tests for Alloy 22

Method I:

$$R_p = \left[\frac{\delta E}{\delta i}\right]_{E_{corr}} = \frac{1}{2.303\left(\frac{1}{\beta_a} + \frac{1}{\beta_c}\right) i_{corr}}$$

β_a = infinite

$$i_{corr} = \frac{\beta_c}{2.303\, R_p}$$

β_c = 0.030 to 0.120 V

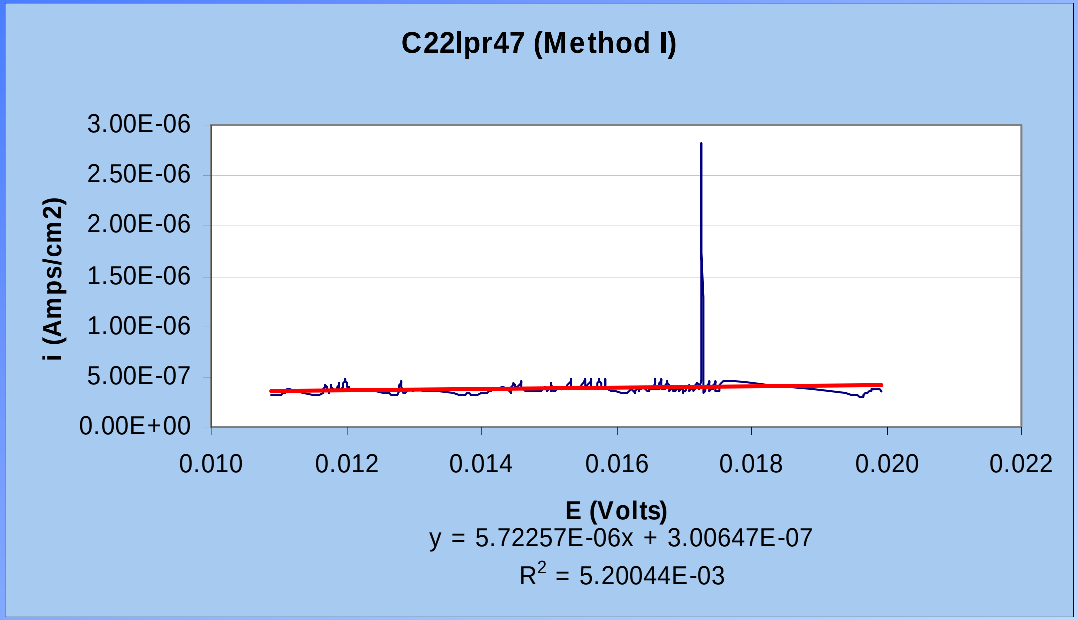
$$\text{Corrosion Rate (C.R.)} = \frac{0.00327 \times i_{corr} \times \text{E.W.}}{\rho}$$

C.R. [=] mm/yr

E.W. = Equivalent Weight = 26.04

$$\rho = \text{Density} = \frac{8.69\text{g}}{\text{cm}^3}$$

Polarization Resistance Tests for Alloy 22



$R_p = 1.7475 \times 10^6\ \Omega\ cm^2$

$i_{corr} = 2.9803 \times 10^{-7}\ A/\ cm^2$

C. R. = 0.00292 mm/yr

Polarization Resistance Tests for Alloy 22

Method II:

$$i_{corr} = m \times E_{corr} + b$$

$$C.R. = \frac{0.00327 \; i_{corr} \; EW}{\rho}$$

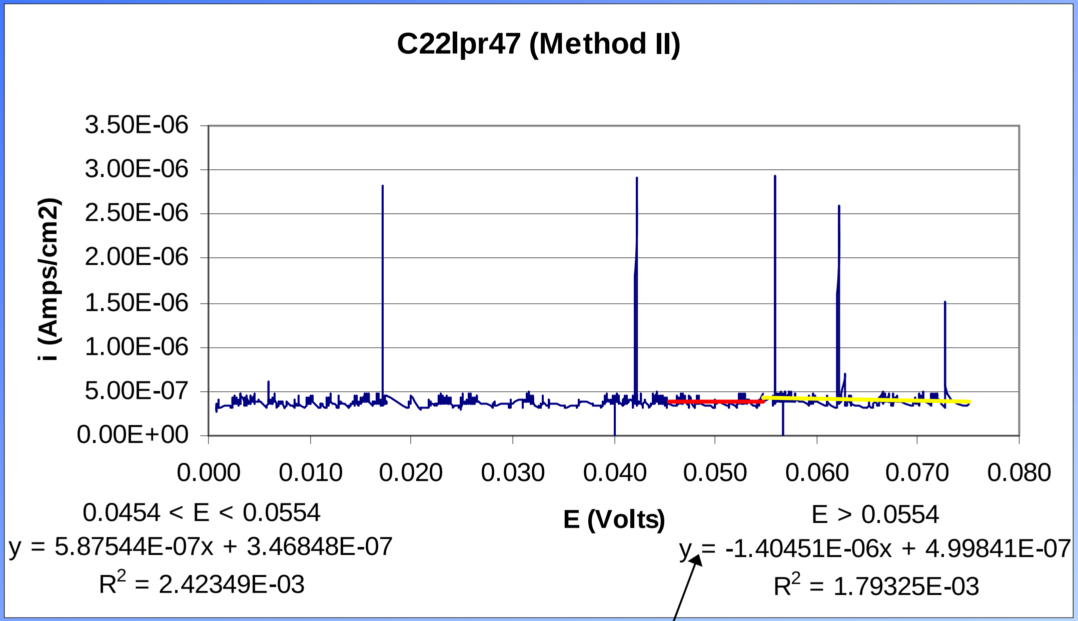
E. W. = Equivalent Weight = 26.04

ρ = Density = 8.69 g / cm^3

A. Data: + 30 mV to +40 mV vs. O.C. Potential

B. Data: + 40 mV to +60 mV vs. O.C. Potential

Polarization Resistance Tests for Alloy 22



A. $i_{corr} = 3.55896 \times 10^{-7}$ A/cm^2

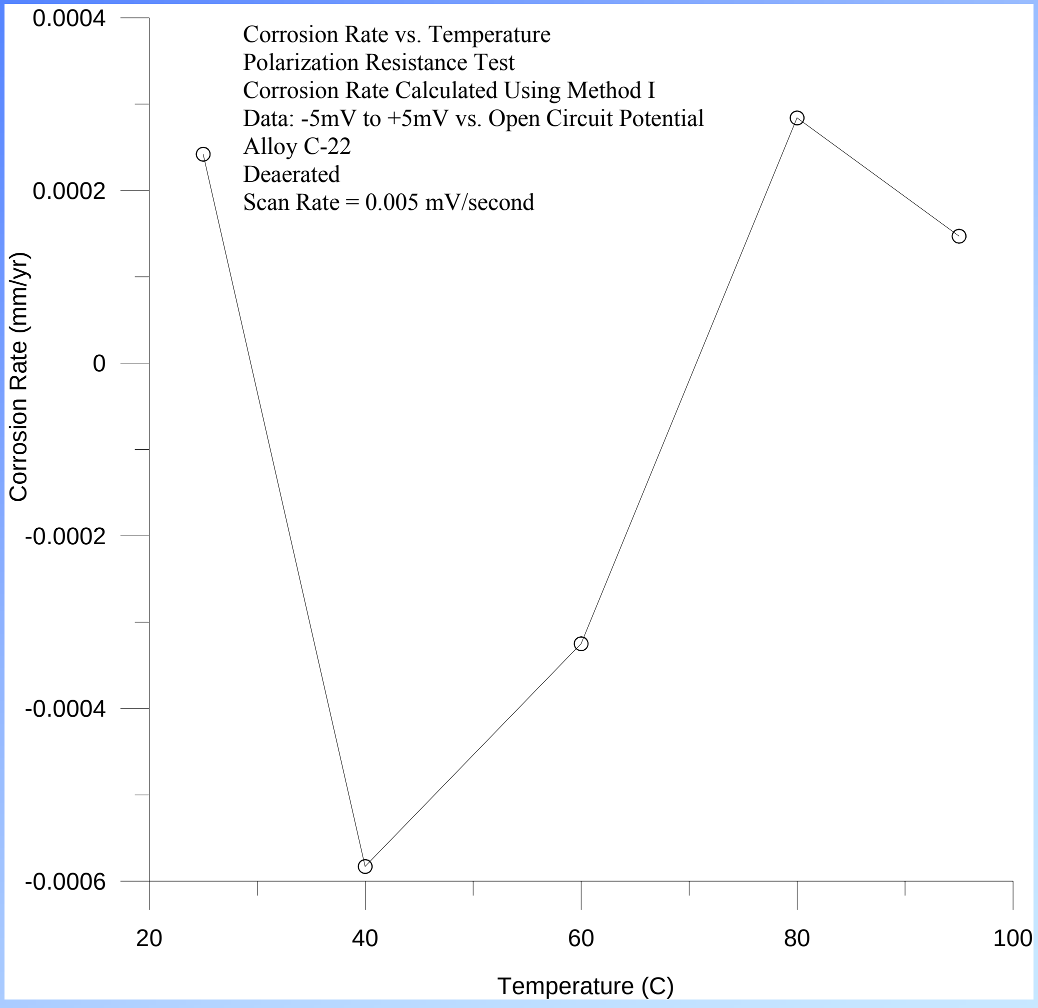
C. R. = 0.00349 mm/yr

B. $i_{corr} = 4.78212 \times 10^{-7}$ A/cm^2

C. R. = 0.00469 mm/yr

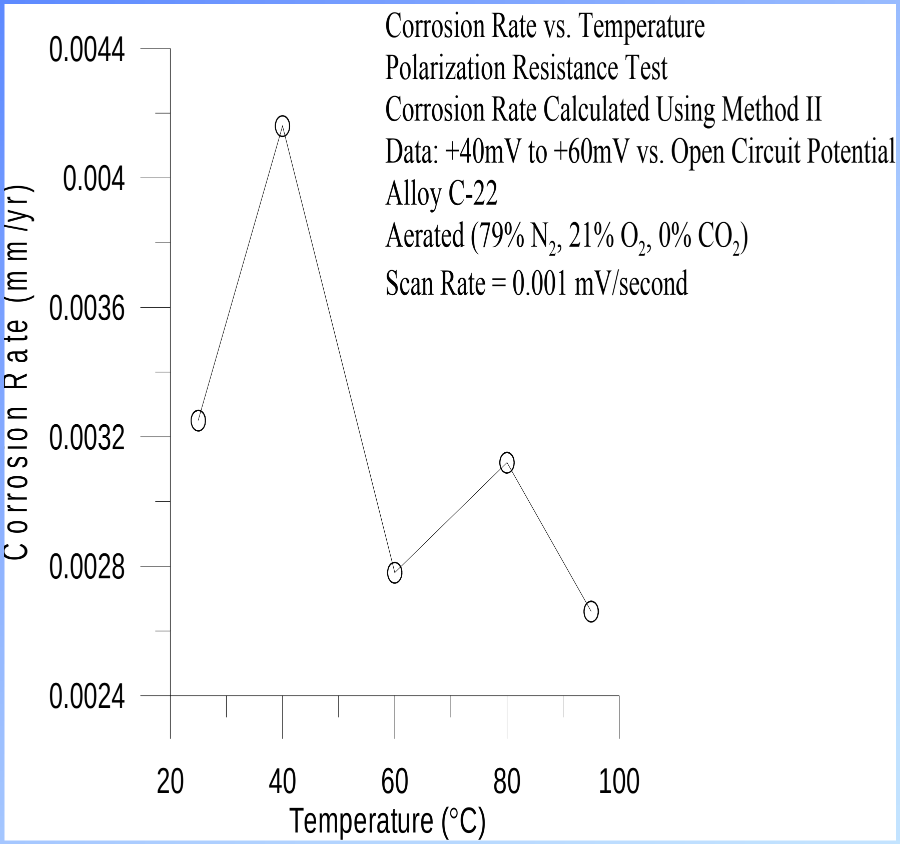
Polarization Resistance Tests for Alloy 22

Method I: Many Negative Corrosion Rates



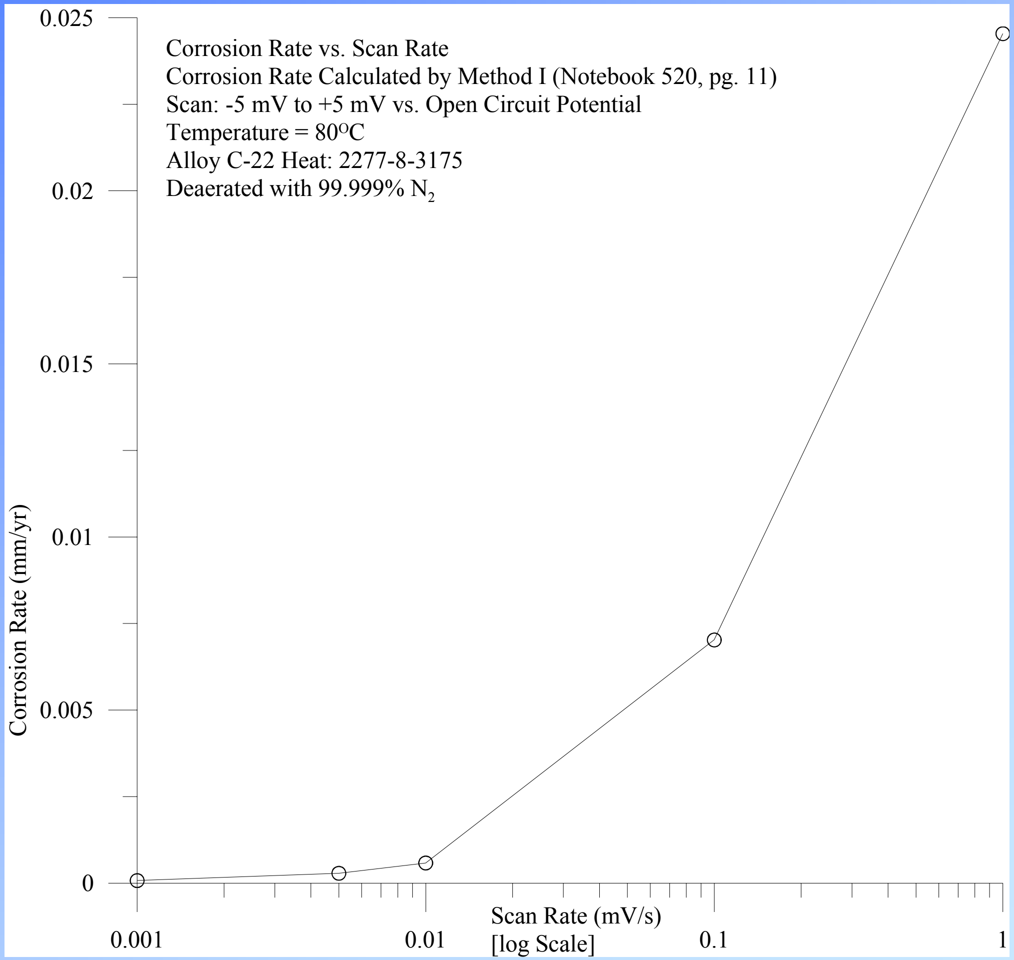
Polarization Resistance Tests for Alloy 22

Method II



Polarization Resistance Tests for Alloy 22

Results:

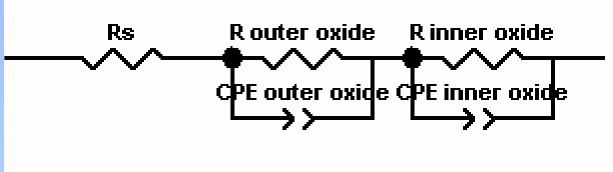


EIS for Alloy 22

Test:

- Initial Frequency: 20000 Hz
- Final Frequency: 0.001 Hz or 0.0001 Hz
- Points per Decade: 10
- Integration Time: 5 Seconds
- Delay: 2 Seconds

Circuit:



EIS for Alloy 22

Formulas:

Resistors:

$$Z = R$$

$$Z' = R = \text{Real Component of Impedance}$$

$$Z'' = 0 = \text{Imaginary Component of Impedance}$$

CPE:

$$Z = \frac{1}{c(\omega \times i)^P}$$

$$c = \text{Capacitance}$$

$$\omega = \text{Frequency}$$

$$i = \sqrt{-1}$$

$$P = \text{CPE characterization term}$$

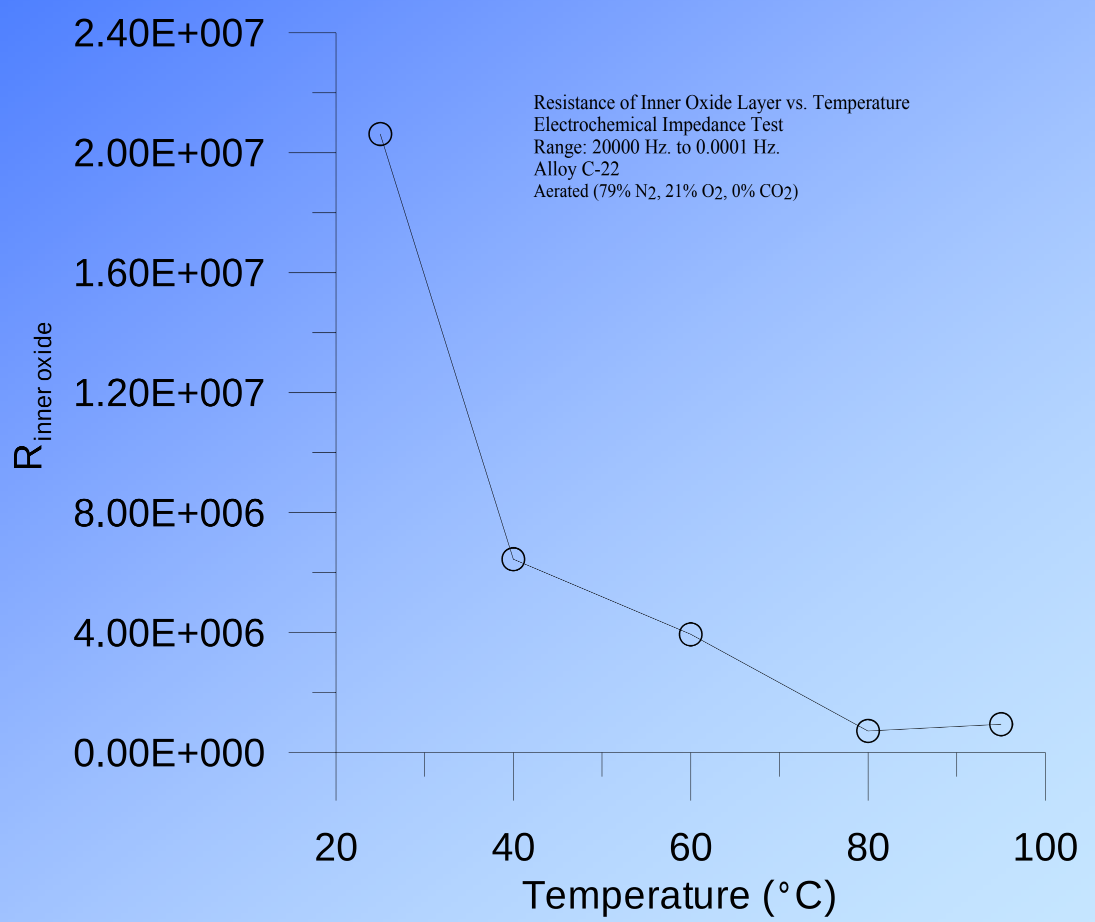
Activation Energy:

$$\frac{d(\ln(\text{Corrosion Rate}[\text{mm}/\text{yr}]))}{d(1/T[\text{K}])} = \frac{-E_a}{R}$$

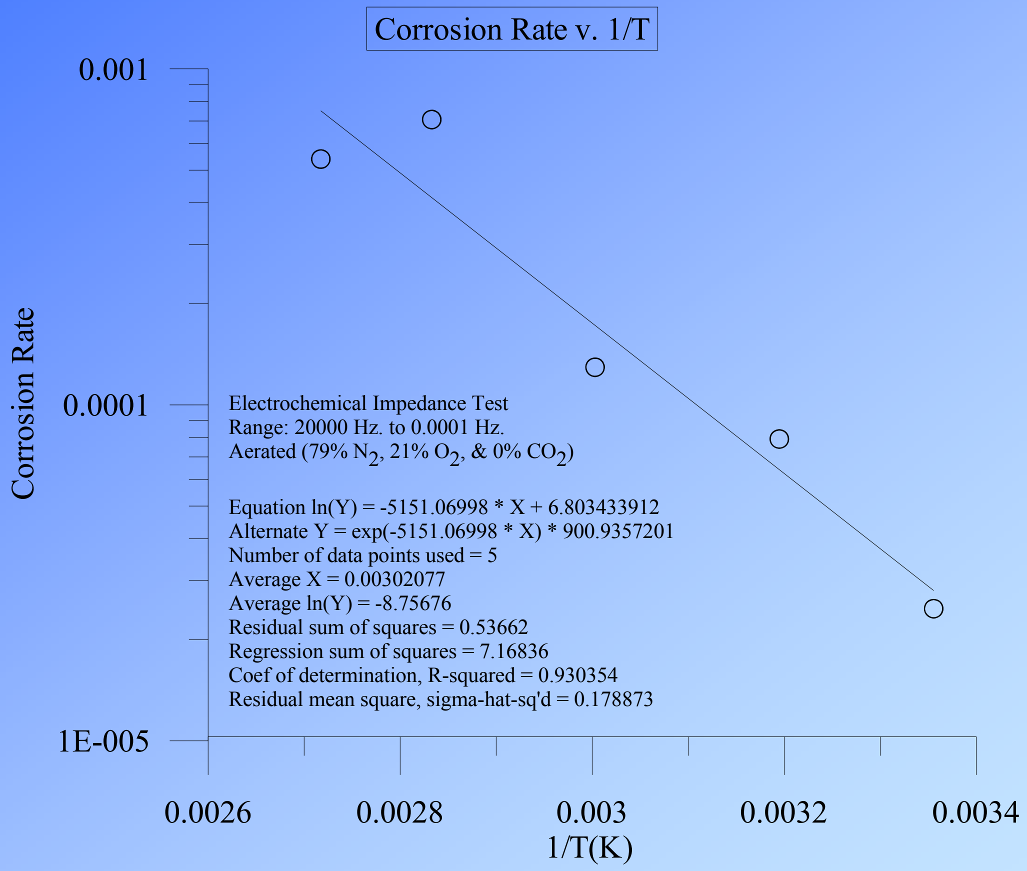
$$E_a = \text{Activation Energy } [=] \text{ kJ}/\text{mol}$$

$$R = \text{Gas Constant} = 8.314 \text{ kJ}/\text{mol} \cdot \text{K}$$

EIS for Alloy 22



EIS for Alloy 22



Calculated Activation Energy: 42.8 kJ/mol

Polarization Resistance & EIS for Alloy 22

- Large uncertainty in calculated corrosion rates from the wide scatter in data points collected
- Scan rate dependent

Polarization Resistance & EIS for Alloy 22

Conclusions: Electrochemical Impedance

- Corrosion rate similar to passive current density method, with less time.
- Analog circuit must have basis in physical properties of the system.

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This paper is an independent product of CNWRA and does not necessarily reflect the views or the regulatory position of the NRC.