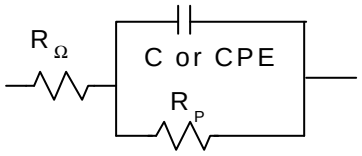
Corrosion: 4. Equivalent circuit models

In recent years Electrochemical Impedance Spectroscopy or EIS has been successfully applied to the study of corrosion systems. EIS has been used effectively to measure the polarization resistance for corrosion systems and for the determination of corrosion mechanisms for systems where DC electrochemical methods have failed.

EIS has been applied, among others, to uniform corrosion, pitting corrosion, corrosion in concrete, and corrosion underneath coatings. In this application note some of the equivalent circuit models that are used to model corrosion systems are described.

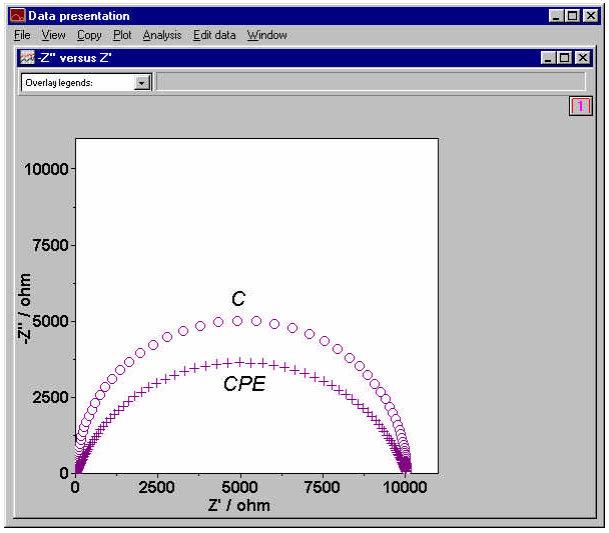
Uniform Corrosion

The most common equivalent circuit used to model corrosion of bare metal in aqueous electrolyte is the Randles circuit. The model can be used to estimate the polarization resistance R_P from the impedance data.

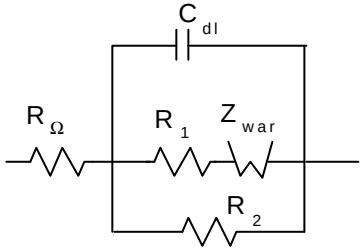


where.

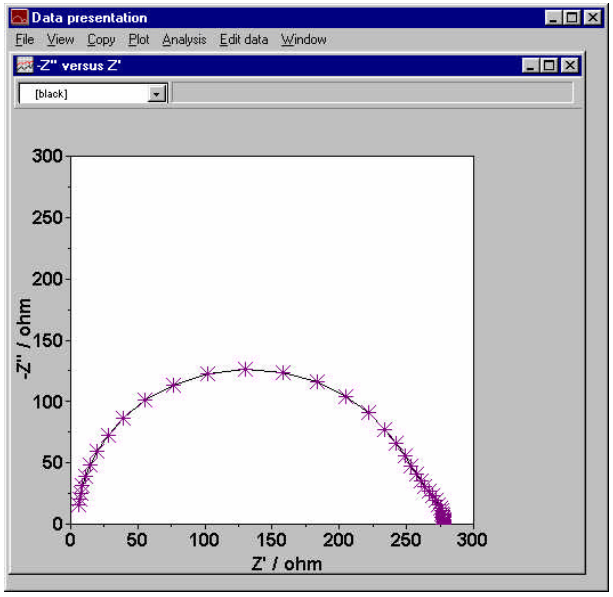
R_W	Electrolyte resistance
R_P	Polarization resistance
C or CPE	Double layer capacitance



For corrosion of low carbon steel in NaCl solution, the following equivalent circuit has been proposed.

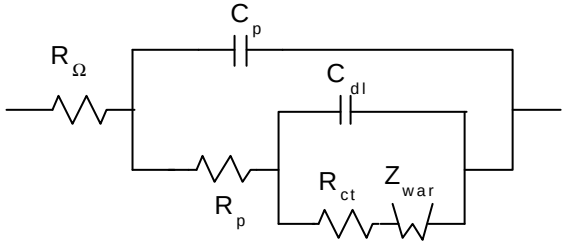


R_W	Electrolyte resistance
R_1	Charge transfer resistance of the anodic reaction
R_2	Charge transfer resistance of the cathodic reaction
C_{dl}	Double layer capacitance
Z_{war}	Warburg impedance



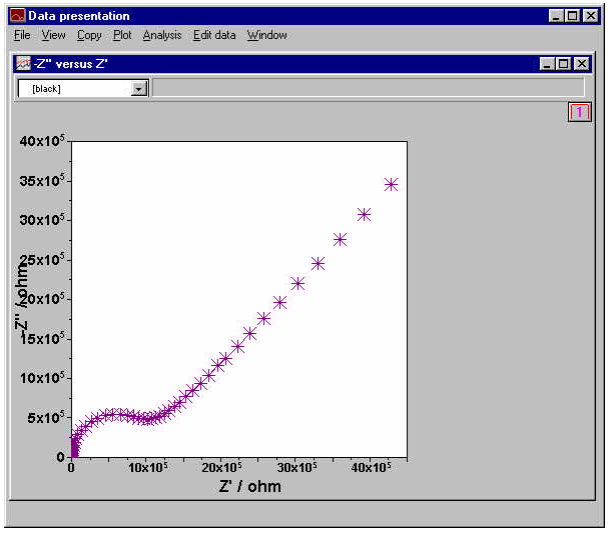
Coatings

Impedance spectroscopy has been used extensively to characterize the corrosion protection of metals by coatings. The following equivalent circuit is often used to model a coating.

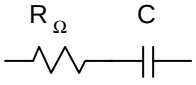


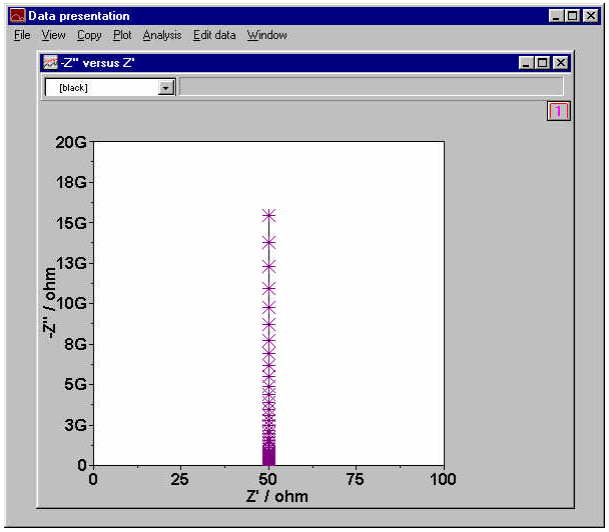
where,

R_w Electrolyte resistance
R_p Paint resistance, measure of paint porosity
C_p Paint capacitance, measure of water uptake by the paint
R_{ct} Charge transfer resistance, measure of the protection of the substrate
C_{dl} Double layer capacity, measure of the delamination of the paint
Z_{war} Warburg impedance, measure of the diffusion resistance.



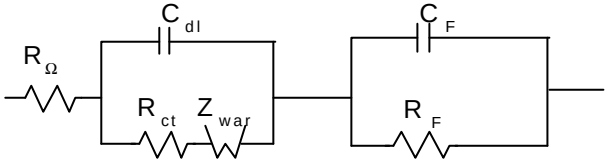
When the coating is intact, in the previous circuit, R_P the paint resistance goes to infinity and the circuit reduces to the following equivalent circuit model,





Corrosion in concrete

The following equivalent circuit has been proposed the corrosion of steel in concrete.



where,

R_w Electrolyte resistance
R_F Resistance at the concrete/steel interface
C_F Concrete capacitance
R_{ct} Charge transfer resistance of the corrosion reaction
C_{dl} Double layer capacity
Z_{war} Warburg impedance, measure of the diffusion of oxygen to steel.