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THE IDEAL OR UNIFIED CORROSION EQUATION–by Hycent Agala

C.R (in mpy)= $0.128 I_{corr} Ae^{-E/RT} \cdot tw$

During nine months research spent in investigating Corrosion occurrence offshore as part of the work involved in studying for an M.Sc from Edinburgh Napier University, it occurred to me that a single unified equation describing corrosion rates could be synthesized from two established equations.

The Aim was to predict corrosion mathematically in nature using data from accelerated corrosion tests. Some of the offshore corrosion evidence types considered were: Uniform corrosion, Crevices, Pitting, Galvanic reactions, Stress and Intergranular Corrosion. The Natural testing comprised: In-service Monitoring, simulated Testing in Laboratories. Accelerated Testing involved: Salt spray, Relative Humidity, Electrochemical impedance tests and High temperature tests. The derivation of the unified equation shown above is now outlined.

The ideal or unified corrosion equation is a theoretical equation formulated from two standard, proven and tested scientific equations used for the prediction of atmospheric corrosion from accelerated testing.

These two established equations are noted to be ONLY applicable with their corresponding experiments. The applied equations are:

i- Arrhenius **Equation**, $Corr/t_w = Ae^{-E/RT}$ which can be applied as a correlation developed for the prediction of atmospheric corrosion rates of steel using atmospheric corrosion factors (I.e. Cl^- deposition fluxes, time of wetness and temperatures.) in a salt spray chamber at a constant temperature/ humidity (RH=60%). [1]

ii–The Stern–Geary Equation, $$\text{C.R. (in mpy)} = \frac{0.128\, I_{corr}(EW)}{\rho}$$

This is applicable in order to determine the rate of corrosion within a short period of time so as to relate it to the natural (i.e. atmospheric) in an electrochemical process with respect to determining the corrosion/(open circuit) potentials, E_{corr}, polarisation Resistance, R_p and the corrosion current, I_{corr}. by depositing a thin film on carbon or stainless steel [2].

WHY THESE EQUATIONS?

From research I found out that, amongst most of the relevant predictive mathematical equations used for the prediction of atmospheric corrosion from accelerated testing, these are the most consistent, with highest frequency of use,

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most predictive, tested and proven by experiment, and most closely related unlike others.

WHAT ARE THE EQUATIONS- THEIR MEANINGS:

It should be noted that, the proof of these equations are not herein shown but are rather given as a useful tool for engineering applications. So, if interested in the proof from the first principle, you can obtain or check up from the references given(best still consult me). This work reveals the importance of the equations, their similarities and applicability. It was their similarities that gave birth to the new equation- making them to be one-**UNIFIED!**

The Arrhenius equation

(I) $Corr/\ t_w = Ae^{-E/RT}$ 1

where Corr = thickness loss(µm) =Equivalent weight(g) per iron density(g/cm3)

t_w = time of wetness (in years)

E = activation energy of corrosion with chlorine

A = frequency factor of corrosion rate constant

R = universal gas constant (8.31g/mol)

T = Absolute temperature (K)

ARRHENIUS PREDICTIVE EQUATION MADE EASY:

Step1- To solve for E & A as the only unknown values (the rest are constants or measurable) in equation 1 above from lab test, Use given or obtained values to plot graph of In (Corr/t_w) Vs 1/T,

where, slope = E^o/RT(get E^o). **which is the active energy of corrosion without Cl^-**

Intercept= In A (solve for A)- natural logarithm

Step2-Use E_o to get E by equating: $E=E_o+a_1[Cl^-] +a_2[Cl]^{-2}$

where E is the active energy of corrosion with Cl^-

Step3- Substitute E into Arrhenius' equation $C_{orr}/\ t_w = Ae^{-E/RT}$ with t_w determined to get C_{orr}, which is thickness loss.

"The Corrosion thickness obtained helps us determine the amount of materials left with respect to the original at that given time of exposure to the atmosphere (t_w). With that verified, PREDICTION IS SURE".

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(ii) ***Stern-Geary equation:***

$$\text{C.R. (in mpy)} = \frac{0.128\, I_{corr}(EW)}{\rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 2$$

where EW= equivalent weight of corroding species, g

ρ = density of corroding species, g/cm^3

I_{corr} = *corrosion* current density (μA/cm^2)

RELATIONSHIP AND THEIR SIMILARITIES

Now comparing equations (1) and (2) we can see that from equation 1: Corr/ t_w= $Ae^{-E/RT}$

As already defined in (1) **Corr = EW**

$$\text{Corr} = \frac{EW}{\rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ a$$

where iron density is 7.86g/cm3 and by considering a unit mass of weight, EW equation (a) becomes

$$\frac{1}{7.86} = 0.1272$$ **(see eqn 2 to know how value was obtained!)**

Substituting therefore (a) into (1) gives:

$$EW/\rho.t_w = Ae^{-E/RT} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3$$

Re-arranging (3) becomes: $EW/\rho = Ae^{-E/RT}.t_w \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3a$

Re-arranging (2) now becomes:

$$EW/\rho = \frac{\text{C.R. (in mpy)}}{0.128\, I_{corr}} \quad \ldots\ldots\ldots\ldots\ldots\ 4$$

Now equating (3a) and 4 gives;

$$Ae^{-E/RT}.t_w = \frac{\text{C.R. (in mpy)}}{0.128\, I_{corr}} \quad \ldots\ldots\ldots\ 5$$

Solving therefore for C.R(Corrosion Rate) in (5) yields:

$$\text{C.R (in mpy)} = 0.128\, I_{corr}\, Ae^{-E/RT}.t_w \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 6$$

Equation (6) is what I called, "The Unified or Ideal Corrosion Equation"

Why Unified Equation?

This is because it is a combination of the two most relevant, related, widely used and predictive corrosion equations.

Why Ideal?

As we can see by comparing equation (6) to (1) and (2), it is obvious that(6) is most complete, thorough and contain all the relevant corrosion factors necessary for effective and most reliable prediction.

Also to state that, though equations (1) and (2) produces similar answer there is (but) yet negligible differences between them whereas, the Ideal equation produces their average result which is always mostly the correct answer.

Even when (1) and (2) are confirmed correct, they are but ONLY useful and remembered when applied specifically with their related experiment whereas the IDEAL EQUATION has helped to introduce them both always in UNITY-UNIFIED!

The Author proposes that, to ensure validity,immediate Salt spray & Electrochemical test be carried out to verify applicability of the new equation.

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