

Metallurgy for Industries

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A Monthly News Letter

May, 2017

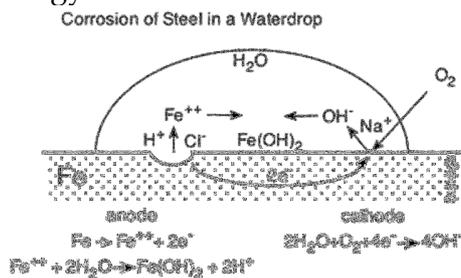
Volume 48

Fundamentals of electrochemical testing

An introduction

Corrosion is an electrochemical process:

When a metal corrodes, metal atoms at the surface loose electrons and migrate to the solution in the form of metal ions. Thus, oxidation of metal atoms is called Anodic process. The electrons released by this process travel to a nearby site on the metal surface and take part in a reduction process, which is known as cathodic reaction. Following diagram illustrates the process morphology.

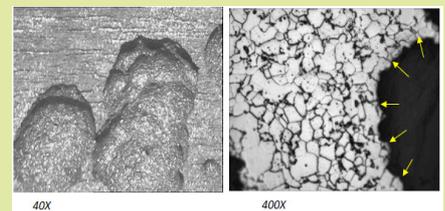


The flow of electrons is current, which is termed as corrosion current. Corrosion current is directly proportional to metal ions formed i.e. corrosion rate of the metal. The corrosion current flows from cathodic to anodic site, which are adjacent to each other. Also, the cathodic and anodic sites are frequently changed at random. Hence, it is not possible to directly measure this current. However, there are other techniques for measurement of corrosion current.

1. Tafel Extrapolation Technique
2. Linear Polarization Technique

In order to understand these techniques, it is necessary to know polarization. In a freely corroding metal, when electrons are released by the metal atoms, these electrons must react with other species nearby where the electrode potentials of cathodic and anodic reactions oscillate and attain one value. This is known as Corrosion Potential or Open Circuit Potential. The current potential curve on semi-log scale is show below.

Microstructure of the Month



Magnification: 40X and 400X

MOC: SA 210 Gr. A1

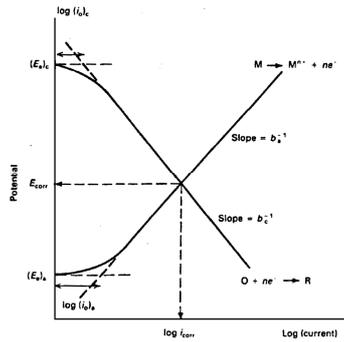
Component: Re-boiler tubes

Observation: Stereo microscope image indicates groove formation on ID surface. Erosion marks are seen on ID surface as well as on the surface of the grooves.

Optical microscope image shows corrosion damage by way of groove formation from ID side.

Cause: Premature tube failure in re-boiler tube heat exchanger is on account of cavitation erosion corrosion damage where the tubes are facing shell inlet steam directly.

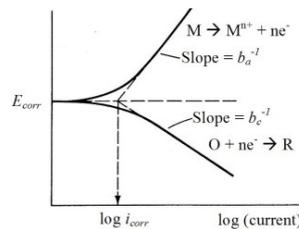
Useful hints: A suitable impingement plate may have to be provided to prevent direct impact of steam on the tube skin at the shell inlet (N3) in consultation with the design expert. A process design expert may be consulted to avoid the direct transfer of the heat of the steam at the inlet. A design modification may be done to avoid bubble formation due to heating at entry level.



The straight lines in the polarization curves are Tafel lines. The slope of Anodic Tafel lines is known as β_a and Cathodic Tafel slope is β_c . β_a and β_c depend only on metal and solution characteristics, and are independent of other parameters related to measurement.

Tafel Extrapolation Technique:

When a corroding metal is connected to another electrode with known electrode potential, the potential difference between them can be used to calculate open circuit potential. Using external power source, if the potential of corroding sample is altered to become more anodic or more cathodic, then the current potential relationship in semi-log scale is observed as follows:



Corrosion rate can be calculated from the equation:

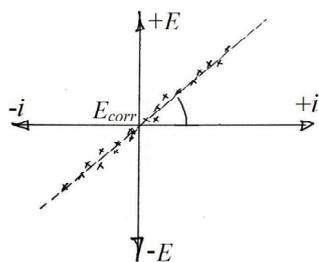
$$i_{corr} = \frac{\Delta i_{appl}}{2.3 \Delta \phi} \left(\frac{\beta_c \beta_a}{\beta_c + \beta_a} \right)$$

Corrosion rate in mils per year (mpy) = $0.129 \times I_{corr} \times EW / D$

Where I_{corr} = Corrosion current in Amp/cm², EW = Equivalent Weight and D = Density

Linear Polarization Technique:

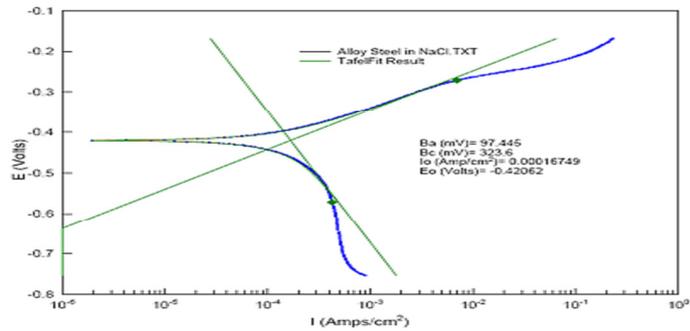
When applied external DC power is within 10 mV- more noble or more active than the corrosion potential, it is observed that the applied current density is linear function of the electrode potential. This is illustrated in Figure



$\frac{\Delta E}{\Delta i}$ = polarization resistance R_p

$$I_{corr} = \frac{\beta_a \beta_c}{2.3 R_p (\beta_a + \beta_c)}$$

Latest Instruments are designed to precisely measure current and potential values at a pre-defined interval for generating polarization curves, and also can calculate corrosion rate.



Electrochemical testing is widely used in industries for following applications.

1. Corrosion rate measurement
2. Evaluation of galvanic corrosion
3. Tendency for pitting or crevice corrosion
4. Critical pitting temperature.

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