

Note: These questions will be discussed during the tutorial sessions on March 18th.

Question 1:

A brine solution is used as a cooling medium in a steel heat exchanger. The brine is circulated within the heat exchanger and contains some dissolved oxygen. Suggest four methods for reducing corrosion of the steel by the brine. Explain the rationale for each suggestion.

Solution:

The most common and practical method is using cathodic protection. Other possible methods that may be used to reduce corrosion of the heat exchanger by the brine solution are as follows:

- (1) Reduce the temperature of the brine; normally, the rate of a corrosion reaction increases with increasing temperature.
- (2) Change the composition of the brine; the corrosion rate is often quite dependent on the composition of the corrosion environment.
- (3) Remove as much dissolved oxygen as possible. Under some circumstances, the dissolved oxygen may form bubbles, which can lead to erosion-corrosion damage.
- (4) Minimize the number of bends and/or changes in pipe contours in order to minimize erosion-corrosion.
- (5) Add inhibitors.
- (6) Avoid connections between different metal alloys

Question 2:

A thick steel sheet of area 400 cm² is exposed to air near the ocean. After a one-year period it was found to experience a weight loss of 375 g due to corrosion. What rate of corrosion, in mm/yr, does this correspond?

Solution:

This problem asks for us to calculate the CPR in both mpy and mm/yr for a thick steel sheet of area 400 cm² which experiences a weight loss of 375 g after one year. Employment of Equation 17.23 leads to

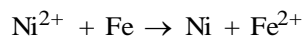
$$\begin{aligned}\text{CPR}(\text{mm/yr}) &= KW\rho At \\ &= (87.6)(375\text{g})(103\text{mg/g})(7.9\text{g/cm}^3)(400\text{cm}^2)(24\text{h/day})(365\text{day/yr})(1\text{yr}) \\ &= 1.2 \text{ mm/yr}\end{aligned}$$

Question 3:

An electrochemical cell is constructed such that on one side a pure nickel electrode is in contact with a solution containing Ni²⁺ ions at a concentration of 3×10^{-3} M. The other cell half consists of a pure Fe electrode that is immersed in a solution of Fe²⁺ ions having a concentration of 0.1 M. At what temperature will the potential between the two electrodes be +0.140 V?

Solution:

On the basis of their relative positions in the standard emf series (Table 17.1), assume that Fe is oxidized and Ni is reduced. Thus, the electrochemical reaction that occurs within this cell is just



Thus, Equation 17.20 is written in the form

$$\Delta V = (V_{\text{Ni}}^{\circ} - V_{\text{Fe}}^{\circ}) - \frac{RT}{nF} \ln \frac{[\text{Fe}^{2+}]}{[\text{Ni}^{2+}]}$$

Solving this expression for T gives

$$T = -\frac{nF}{R} \left[\frac{\Delta V - (V_{\text{Ni}}^{\circ} - V_{\text{Fe}}^{\circ})}{\ln \frac{[\text{Fe}^{2+}]}{[\text{Ni}^{2+}]}} \right]$$

The standard potentials from Table 17.1 are $V_{\text{Fe}}^{\circ} = -0.440$ V and $V_{\text{Ni}}^{\circ} = -0.250$ V. Therefore,

$$T = -\frac{(2)(96,500 \text{ C/mol})}{8.31 \text{ J/mol-K}} \left[\frac{0.140\text{V} - \{-0.250\text{V} - (-0.440\text{V})\}}{\ln\left(\frac{0.1\text{M}}{3 \times 10^{-3}\text{M}}\right)} \right]$$

$$= 331 \text{ K} = 58^\circ\text{C}$$

Question 4:

Identify the type of corrosion in the following cases:

- a) General rusting of steel and iron when the entire surface is exposed to air;
- b) Domestic water heater where copper and steel tubing are joined;
- c) Corrosion in firearms, in the bore of the barrel when corrosive ammunition is used and the barrel is not cleaned soon afterward;
- d) Flanges, Washers, O-rings on metal plates immersed in seawater;
- e) Weld decay in stainless steel;
- f) Stainless steel parts in a combustion engine operated at temperatures between 500 and 800°C for long time;
- g) Elbow fitting in a steam condensate line;

Solution:

- a) Rusting of steel Corrosion type: Uniform Attack
- b) Domestic water heater where copper and steel tubing are joined; Corrosion type: Galvanic corrosion where steel will corrode in the vicinity of the junction
- c) Corrosion in firearms, in the bore of the barrel when corrosive ammunition is used and the barrel is not cleaned soon afterward; Corrosion type: Pitting corrosion
- d) Flanges, Washers, O-rings on metal plates immersed in seawater; Corrosion type: Crevice corrosion
- e) Weld decay in stainless steel; Corrosion type: Selective leaching

- f) Stainless steel parts in a combustion engine operated at temperatures between 500 and 800oC for long time; Corrosion type: Intergranular corrosion
- g) Elbow fitting in a steam condensate line; Corrosion type: Erosion corrosion

Question 5:

How can fatigue wear be reduced?

Solution:

- (a) reducing the load and sliding distance and increasing the hardness
- (b) improving the quality of the contacting materials, such as eliminating inclusions, impurities, and voids;
- (c) improving the surface finish and integrity during the manufacturing process;
- (d) surface working, such as shot peening or other treatments;
- (e) reducing contact stresses; and
- (f) reducing the number of total cycles.

Question 6:

- (a) Why is the abrasive wear resistance of a material a function of its hardness?
- (b) Why is it difficult to use friction sawing on nonferrous metals? Explain.

Solution:

- (a) Higher hardness indicates greater resistance to penetration, hence less penetration of the abrasive particles or hard protrusions into surfaces, and the grooves produced are not as deep. Thus, abrasive wear is a function of hardness
- (b) Nonferrous metals have a tendency to adhere to the blade, caused by adhesion at the high temperatures and attributable to the softness of these materials. Note also that these materials typically have high thermal conductivity, so if the metal has melted, it will quickly solidify and make the operation more difficult.