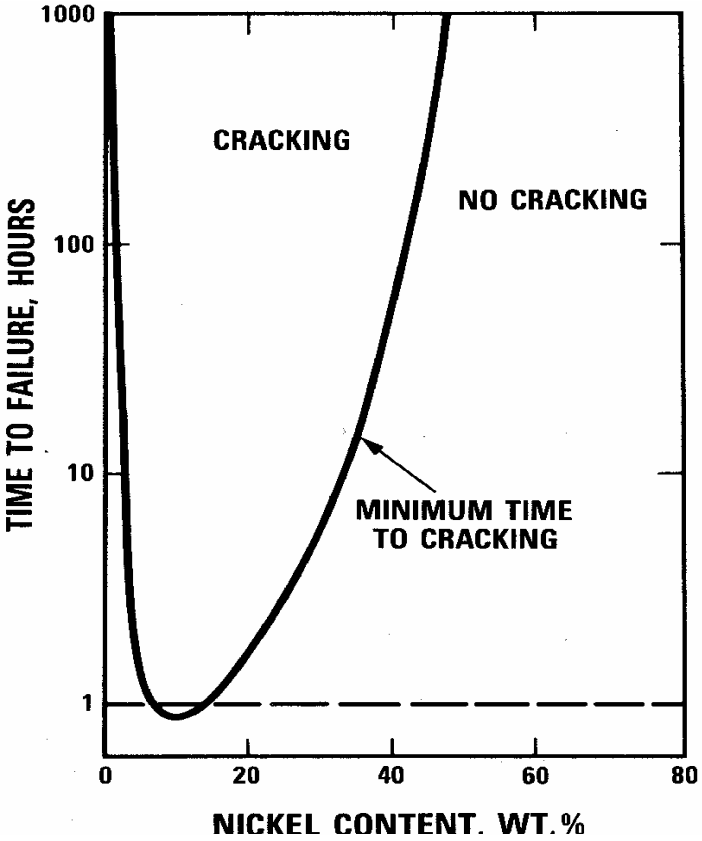
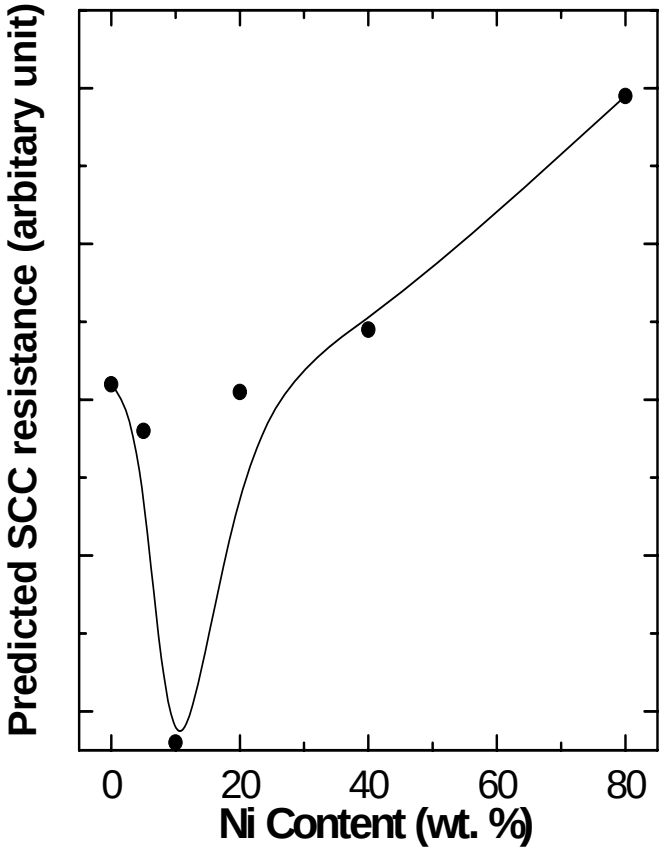
14.5 Stress Corrosion Cracking of Stainless Steels

Austenitic stainless steels ; explained by the film rupture and slip dissolution model.

▶ ***Effects of Ni on stress corrosion susceptibility of Fe-20Cr-xNi (x = 0~80 wt %) SSs.***





14.6 Stress Corrosion Cracking Control

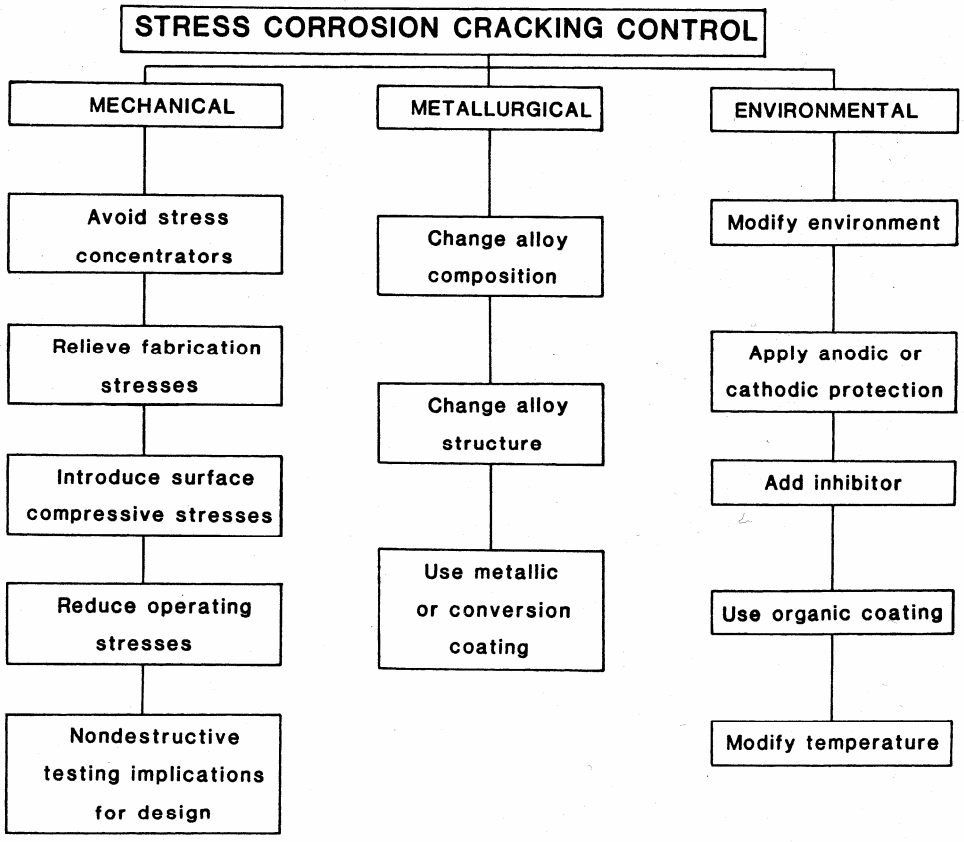


FIGURE 9. Approaches to SCC control.

case 1. Non-aggressive anion on SCC of stainless steel in hot chloride solution.

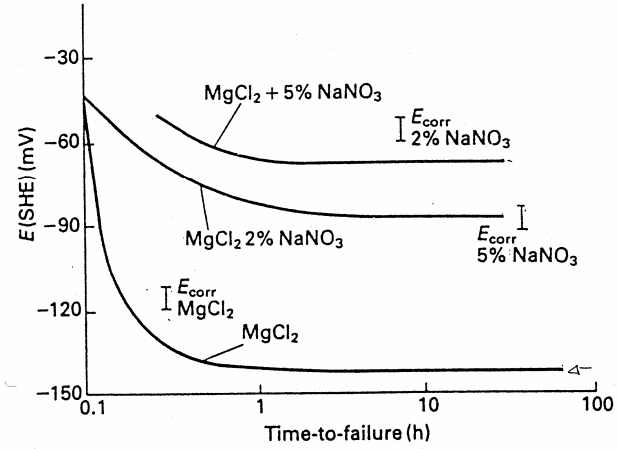


FIG. 100. The time to failure of an austenitic stainless steel in $MgCl_2$ solution at 130°C[180] to which additions of $NaNO_3$ have been made. Additions narrow the range of potential over which failure occurs and with 5% addition E_{corr} lies outside the cracking range of potential.

case 2 : How to control the IGSCC of sensitized 304 SS in high temperature water env. (275 to 330 °C)

A. The principal phenomenological features of IGSCC of sensitized 304 SS.

1) IGSCC is a high temperature phenomenon in that it has not been detected in high purity water at temp. below 100 °C.

2) A critical potential (E_{cc} = -0.23 V_{SCE}) exist below which cracking does occur. The critical potential shifts sharply in the negative direction with increasing temperature for any given degree of sensitization and with degree of sensitization at any given temp.

3) The same critical potential (corrosion potential) is observed regardless whether the potential is established chemically (by controlling the oxygen concentration) or electrochemically (by using a potentiostat).

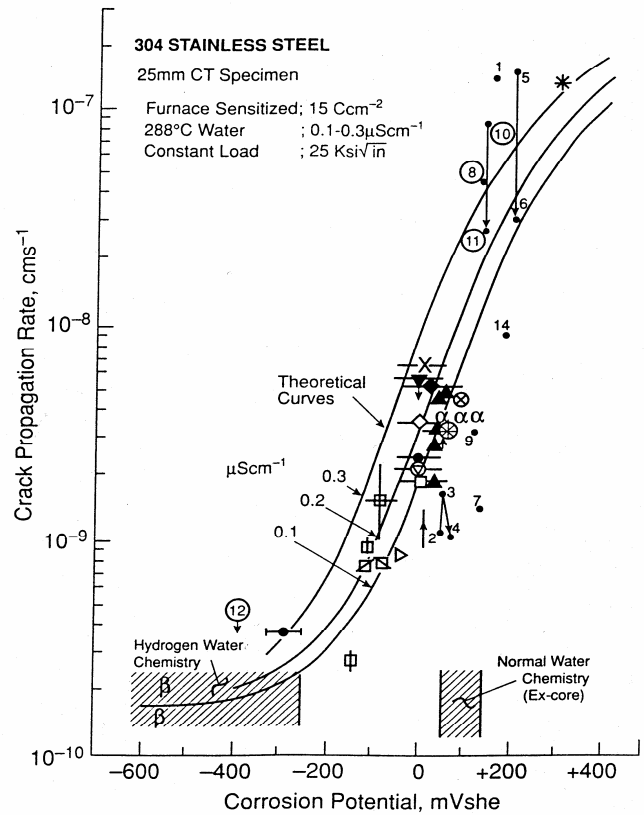


FIGURE 14 Observed and predicted relationships between the crack propagation rate and corrosion potential for sensitized type 304 stainless steel in water under constant load. Water conductivity in range 0.1 to 0.3 μS/cm. (From Ref. 1.)

4) IGSCC crack velocity is strongly dependent on the concentration of impurities in the aqueous environment and hence on the conductivity.
5) The pH of the environment has an important effect on the susceptibility of 304SS to IGSCC in high temp. aqueous systems. Slightly acidified environments (0.005 M H_2S_4 + 0.005 M Na_2SO_4) give rise to IGSCC at potentials more negative than the critical potential observed in neutral solutions at the same temp., suggesting that hydrogen cracking may occur in acidic solutions.
6) The same critical potential is observed under constant extension rate loading, static loading, and fatigue loading for similarly sensitized steel under identical environmental conditions.
7) IGSCC is caused by electrodissolution of Cr-depleted grain boundaries in the steel matrix.

B. Hydrogen water chemistry treatment in BWR(boiling water reator)

- $[O_2]$ in BWR : 150~350 ppb as a result of radiolytic decomposition of water.
- E_{corr} (0.10 V_{SCE})of 304 SS > E_{cc} (-0.23 V_{SCE}) : → IGSCC

Injection of 1.5 ppm H_2 into the circulation water reduces the $[O_2]$ to 10 – 20 ppb

↓

$E_{corr} < E_{cc}$ (0.23 V_{SCE})

↓

Suppress IGSCC of sensitized 304 SS

15.Corrosion Controls

15.1. Material selection
15.2. Coatings

15.3. Cathodic protection

Cathodic protection is achieved by supplying electrons to the metal structure to be protected and widely used in :

1) long pipe lines,
2) gas and oil transmission lines,
3) ships,
4) chemical processing equipments.

Cathodic protection can be done either by appropriate galvanic coupling (to Zn, Al, Mg and their alloys)or by an external power supply.

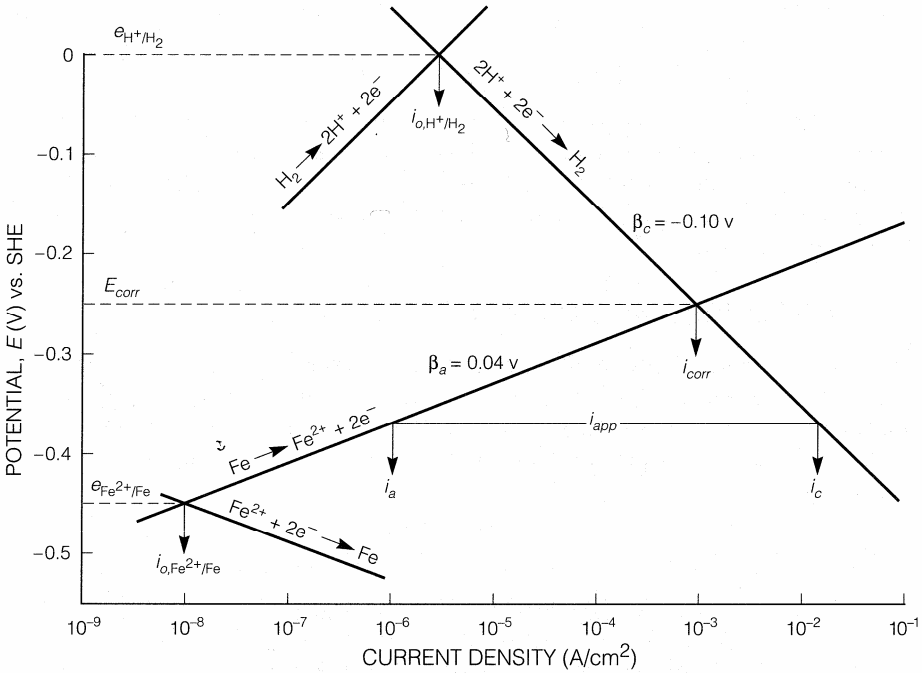


FIGURE 13.4 Cathodic protection with an impressed current density, i_{app}, for steel in an acid solution.

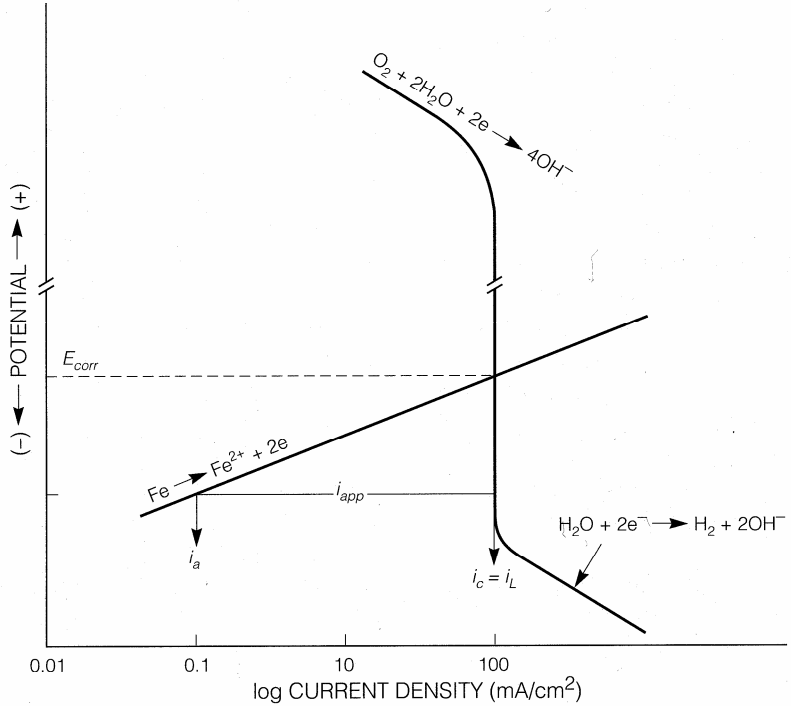
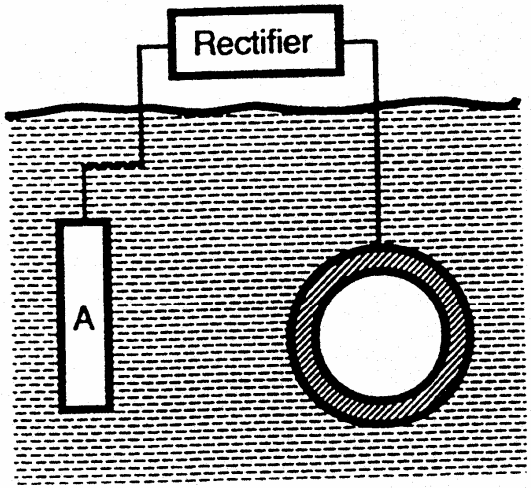
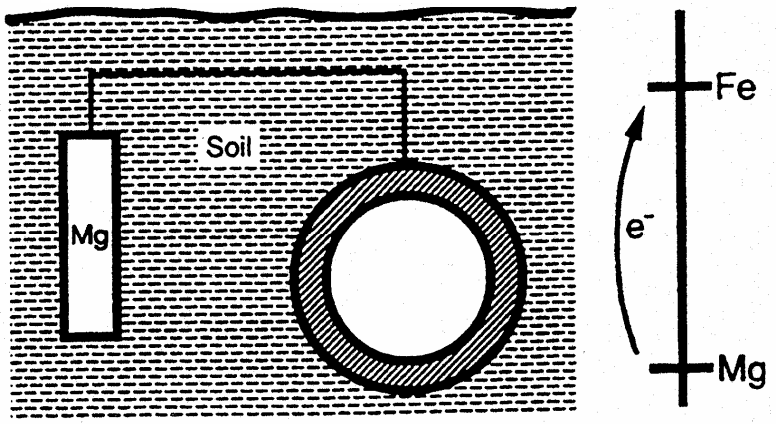


FIGURE 13.5 Cathodic protection by impressed current density, i_{app}, for steel in neutral aerated water.

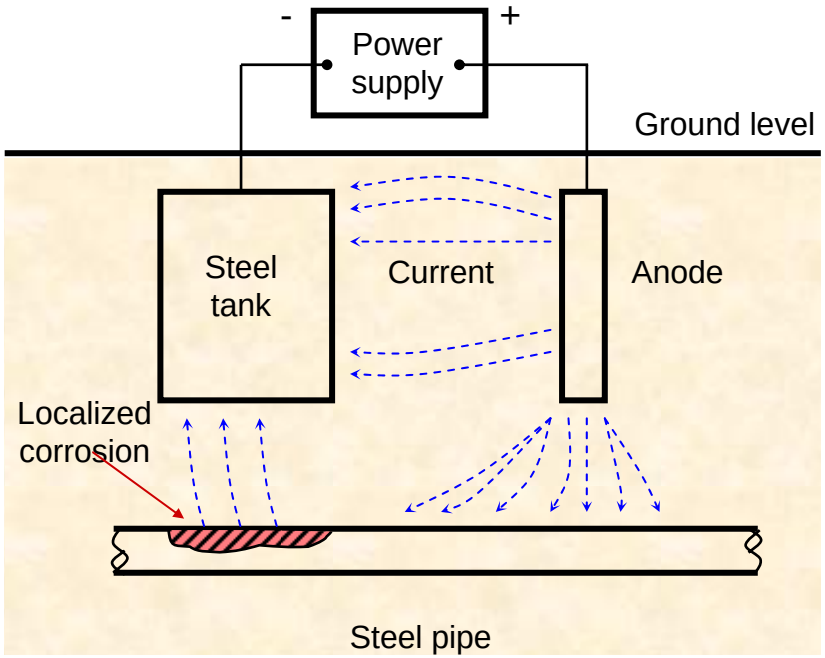


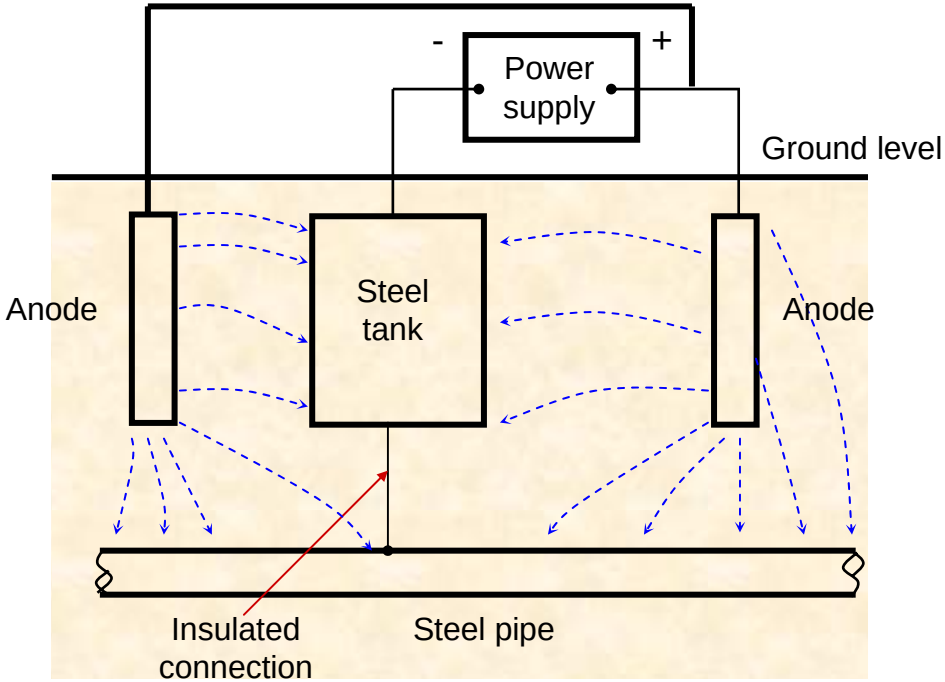
Cathodic protection by impressed current.



Cathodic protection sacrificial anode.

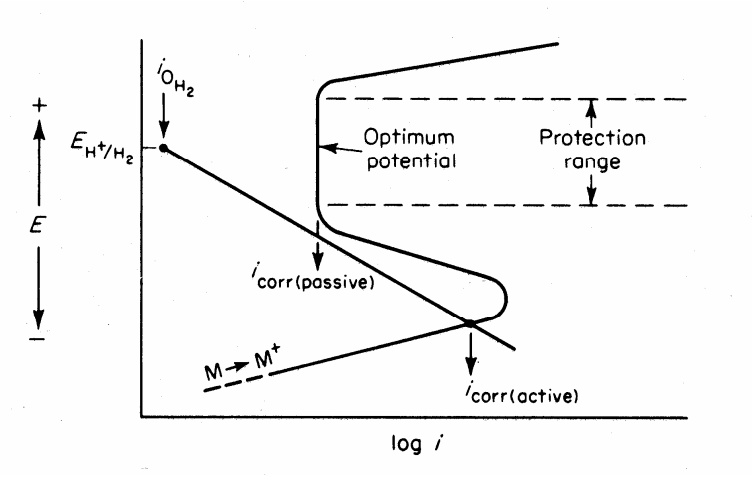
• Stray current corrosion

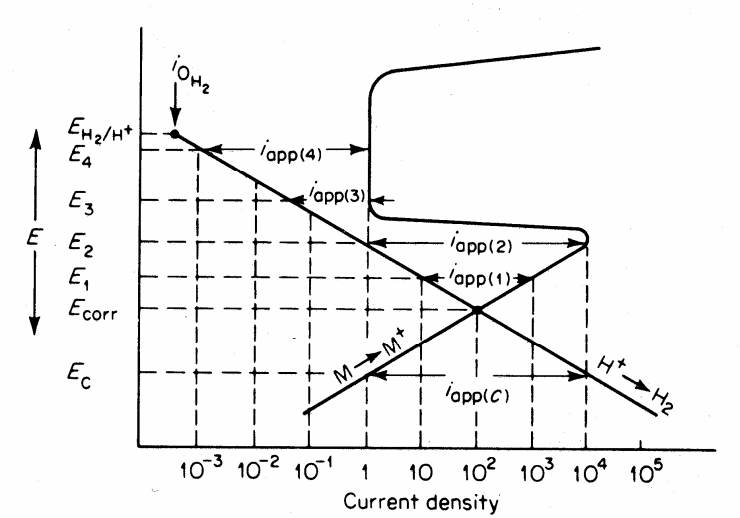




15.4. Anodic protection

If an active-passive alloy is maintained in the passive region with a potentiostat, its corrosion rate will reduced to i_{pass}. This technique is based on the formation of protective film on metals by externally applied anodic currents.

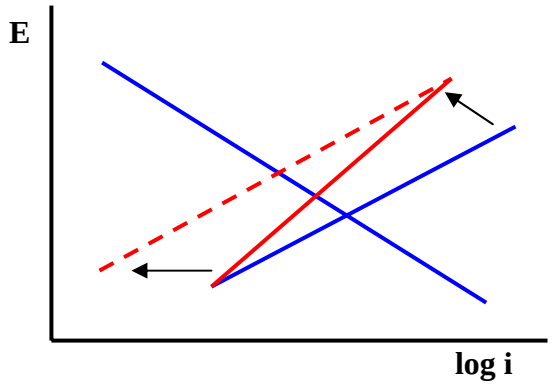




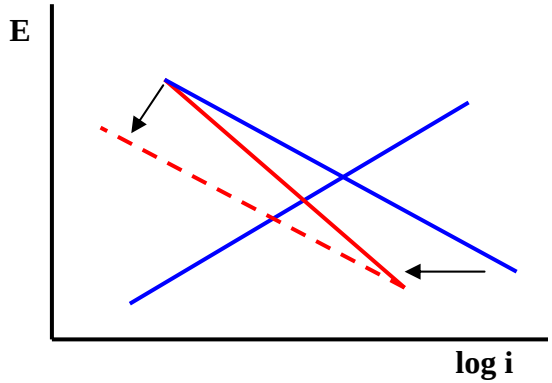
15.5.Inhibitors

An inhibitor is a chemical substance that, when added in small concentration to an environment, effectively decreases the corrosion rate. A minimum conc. of inhibitor must be present to maintain the inhibiting surface film. Thus, good circulation and the absence of any stagnant areas are necessary to maintain the required level of inhibitor concentration.

An addition of inhibitors reduces i_{corr} by increasing the Tafel slope and/or by reducing the exchange current density.



Anodic inhibitor



Cathodic inhibitor

A. Adsorption -type inhibitors

Organic compounds which adsorb on the metal surface and supress metal dissolution and reduction reactions. Typical of this class of inhibitors are the organic amines.

B. Hydrogen evolution poisons

The susbstances such as As, Sb, P, and S retard hydrogen recombination reaction, thereby reducing corrosion rate of a metal in acid solutions.

C. Scavengers

These substances act by removing corrosive species from solution :

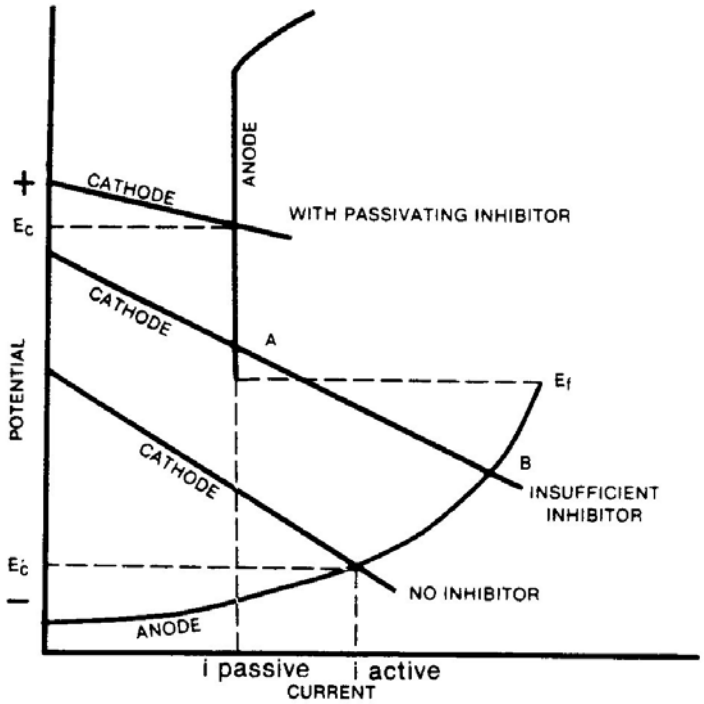
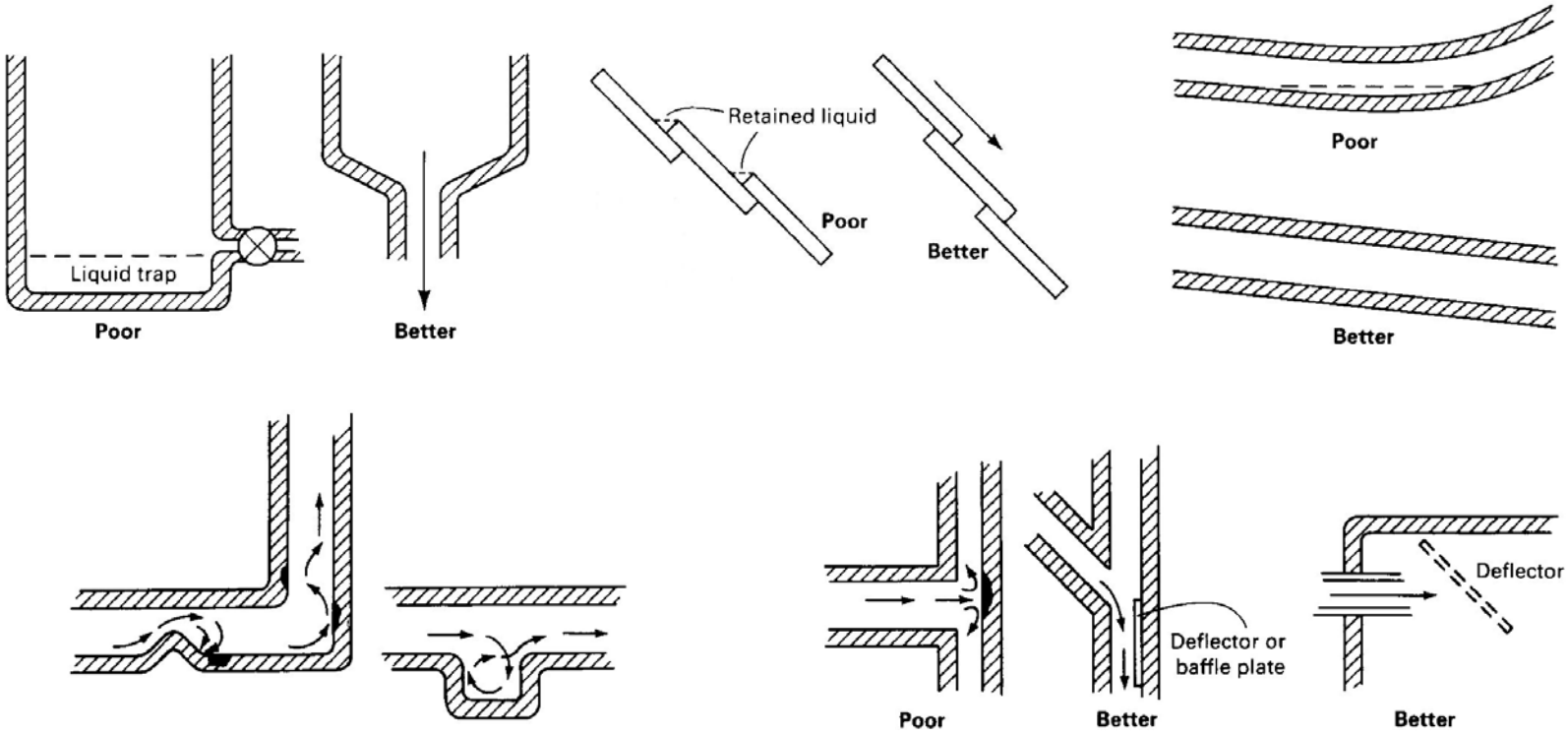
Sodium sulfite : $2Na_2SO_3 + O_2(sol.) \rightarrow 2Na_2SO_4$

Hydrazine : $N_2H_4 + O_2 \rightarrow N_2 + 2H_2O$

D. Oxidizers or passivators

-effective only in metals showing active/passive transition.

: CrO_4^{2-} , NO_2^-, MoO_4^{2-} , WO_4^{2-} , and ferric salt



15.6 Design to minimize corrosion