



Corrosion



Type of Corrosion

- Uniform
- Galvanic
- Pitting and Crevice Corrosion
- Stress Corrosion Cracking
- Erosion
- Microbiologically Induced Corrosion

Uniform Corrosion

- Can be a good or a bad thing
- Corrosion occurs evenly over the surface
- Oxide layers can be very tough
 - Magnetite
 - Fe_3O_4



Effect of pH

- Magnetite (for example)
 - Low pH no oxides form
 - High pH porous $\text{Fe}(\text{OH})_3 \cdot x\text{H}_2\text{O}$ forms
 - pH 10-12 ideal range for carbon steel
- Different metals require different conditions for uniform corrosion
- pH is controlled to control uniform corrosion



Galvanic Corrosion

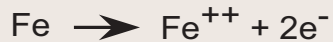
- Chemical reactions
- Electrons removed from one reactant travel through an external circuit
- On material tends to disappear



Galvanic Cell

Reactions

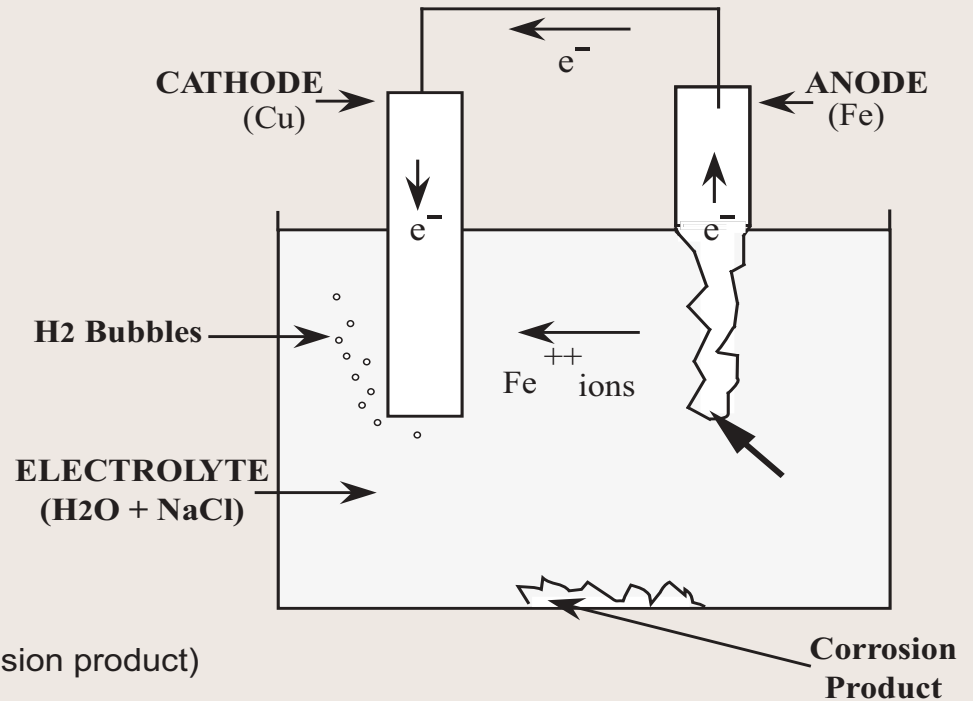
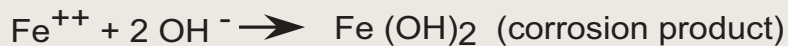
At the Anode:



At the Cathode:

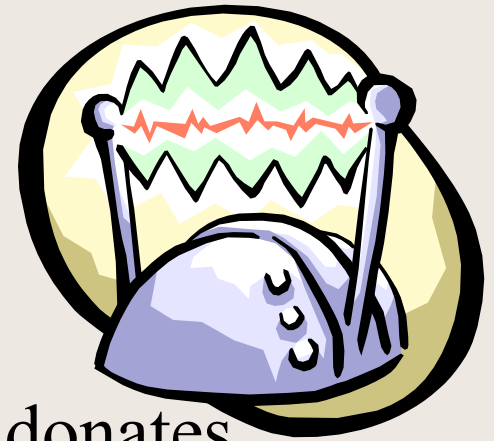


In the Electrolyte:



Cathodic Protection

- Each metal has a different potential to donate electrons
- Anode always corrodes
- To protect a metal
 - Select a metal that more easily donates electrons
 - Build a cell with metal to be protected as cathode

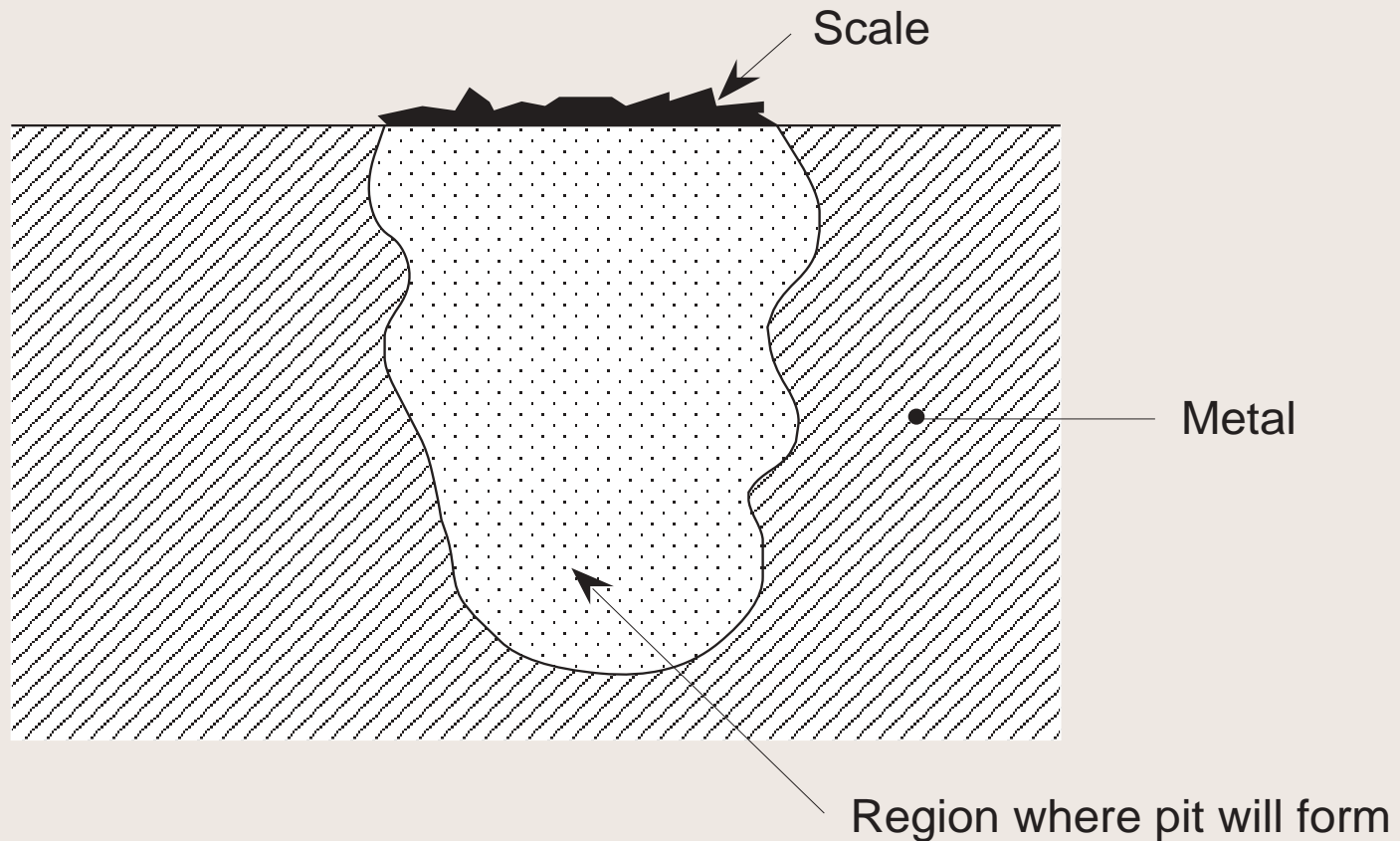


Factors Affecting Galvanic Corrosion

- Oxygen concentration of the electrolyte
- Temperature
- Conductivity of the electrolyte
- Cathode/anode surface area

Pitting and Crevice Corrosion

Electrolyte (H_2O plus dissolved oxygen)



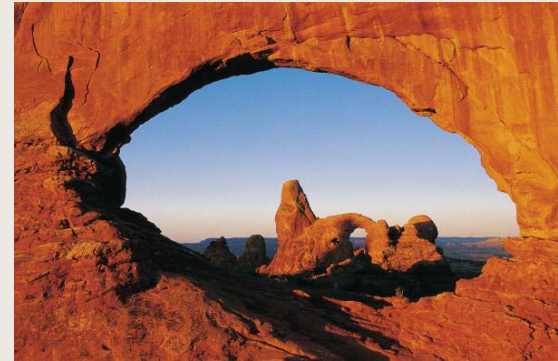
Stress Corrosion Cracking

- Three conditions required for most common kind
 - Metal under tensile stress
 - Dissolved Oxygen
 - Chloride Ion
- Brittle cracks form at the sites of stress
- Failure can be fast
- Failure can occur at stress loads far below yield strength



Erosion Corrosion

- Flow removes protective layer
- New protective layer forms using up metal
- Promoted by
 - High flow
 - Turbulent conditions
 - Particulates in fluid
- Concern with feeders in HTS



Example of Erosion Corrosion



Microbiologically Induced Corrosion

- Bacteria in water
 - Can be in presence of oxygen or not
 - Bacteria form a nodule
- Similar to pitting corrosion.

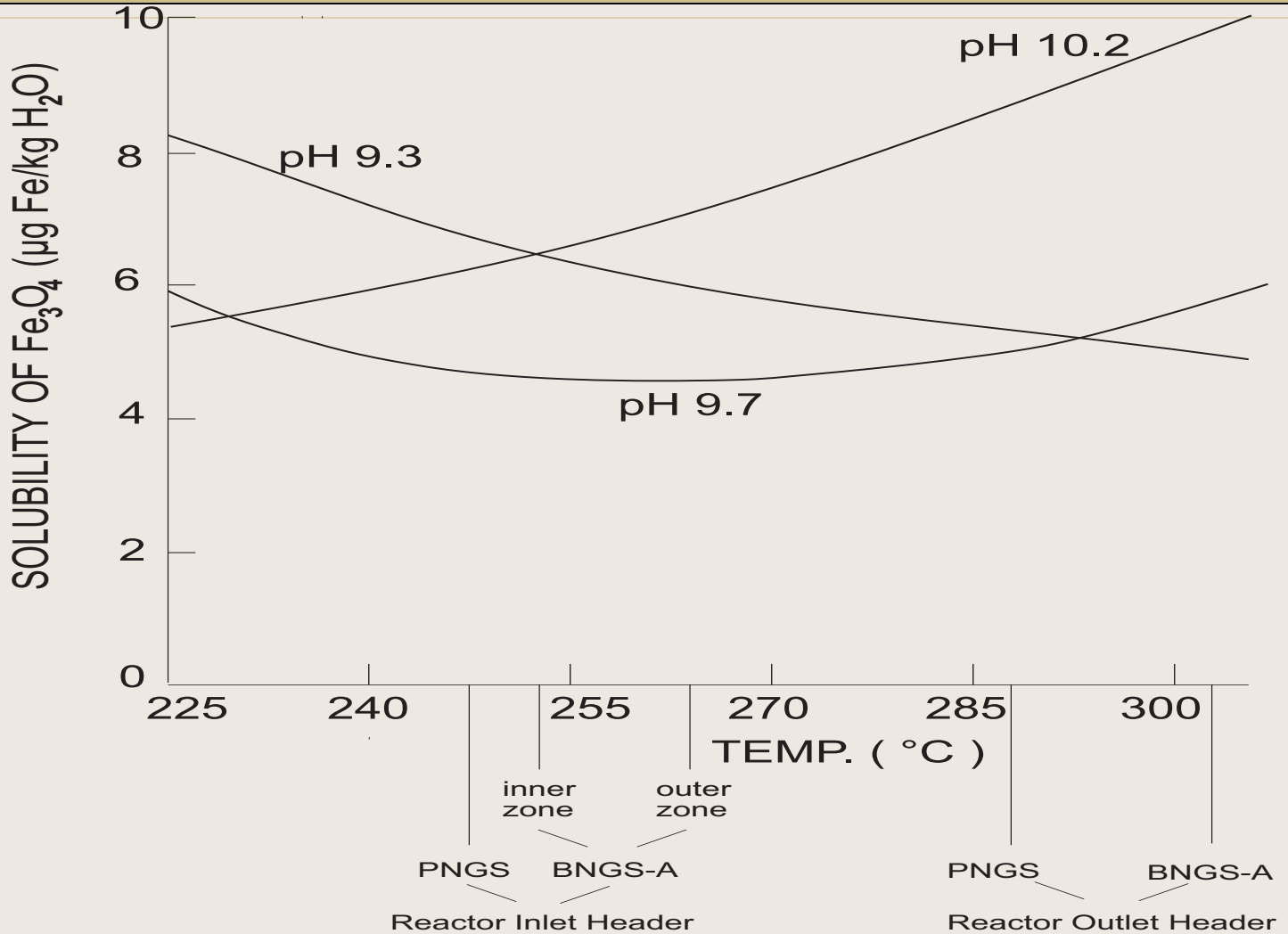


General Corrosion Control

- Eliminate oxygen
- Eliminate chloride ion
- Maintain pH levels
- Prevent stagnation
- Chlorinate



HTS pH Control



pH Control

- Add LiOH for low pH
- Ion exchange columns for high pH
- Lithium tends to collect in the pressurizer
 - pH goes up if water goes to main system
 - Called lithium hide out
 - Possible pH excursions during cool down



Dissolved Oxygen HTS

- Oxygen is corrosive
 - More so in hot water
- Attacks zirconium, iron, their protective oxide coatings
- Continuous source through radiolysis of D_2O
- Controlled by adding excess D_2 or H_2
- Explosion Hazard



Conductivity HTS

- Used for troubleshooting
- Not controlled



pH Secondary Side

- pH controlled by adding chemicals
 - Ammonia (from decomposed hydrazine)
 - Morpholine
- Chemicals must be volatile



Dissolved O₂ Secondary Side

- O₂ is corrosive particularly if Cl⁻ is present
- Three levels of removal
 - Air extraction
 - Deaerator
 - Hydrazine addition
- Environmental hazard
 - chemicals discharged in boiler blow off

Conductivity Secondary Side

- Conductivity of boiler water shows the presence of bad boiler things
- Specifically cation conductivity is measured
 - Measures the conductivity of anions Cl^- , SO_4^- , HCO_3^-
 - IX is used to replace cations with H^+
 - Conductivity sensitive to the anions

Moderator Normal

- Stainless steel system
- Requires neutral pH and low conductivity
- Deuterated IX columns remove all impurities
- Conductivity monitored
- pH is used for troubleshooting



Moderator Over Poisoned

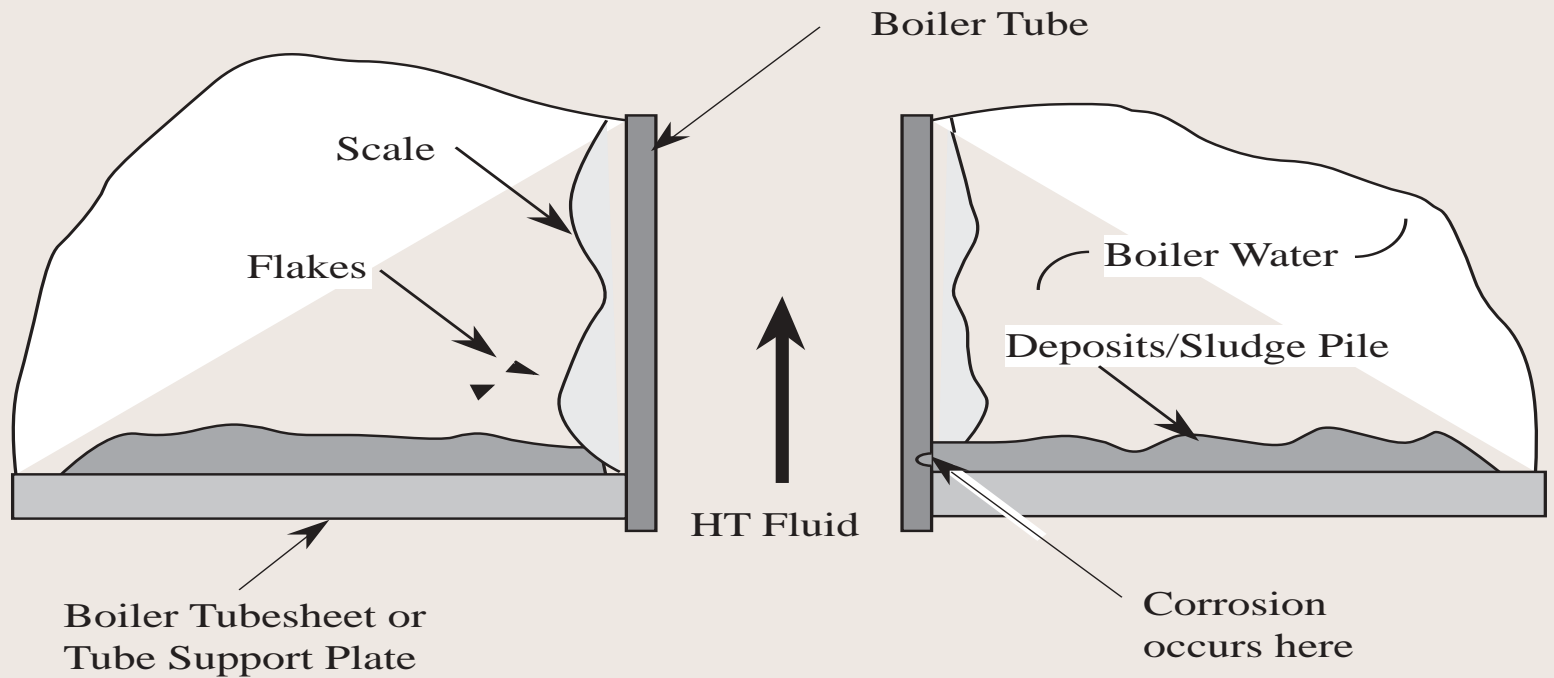
- pH 4-6 to prevent gadolinium nitrate precipitation
- pH is monitored



Moderator Chemistry Control

- Proper use of IX's
- Prevent air in-leakage

Sludge and Scale



For You to Do

- Read the section on corrosion pp. 19-37
- Answer questions p. 38