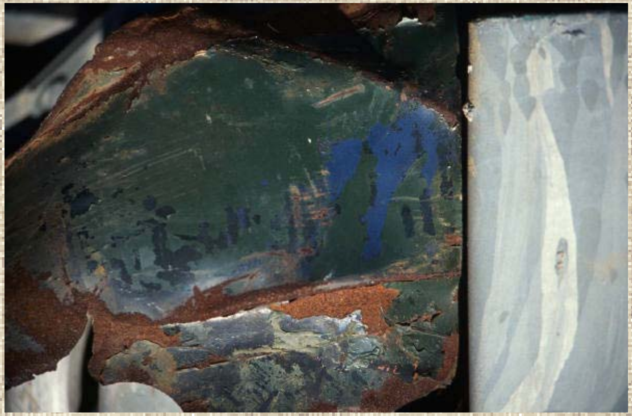
Corrosion



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 $Fe(OH)_3.xH_2O$ 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:

$Fe \rightarrow Fe^{++} + 2e^{-}$

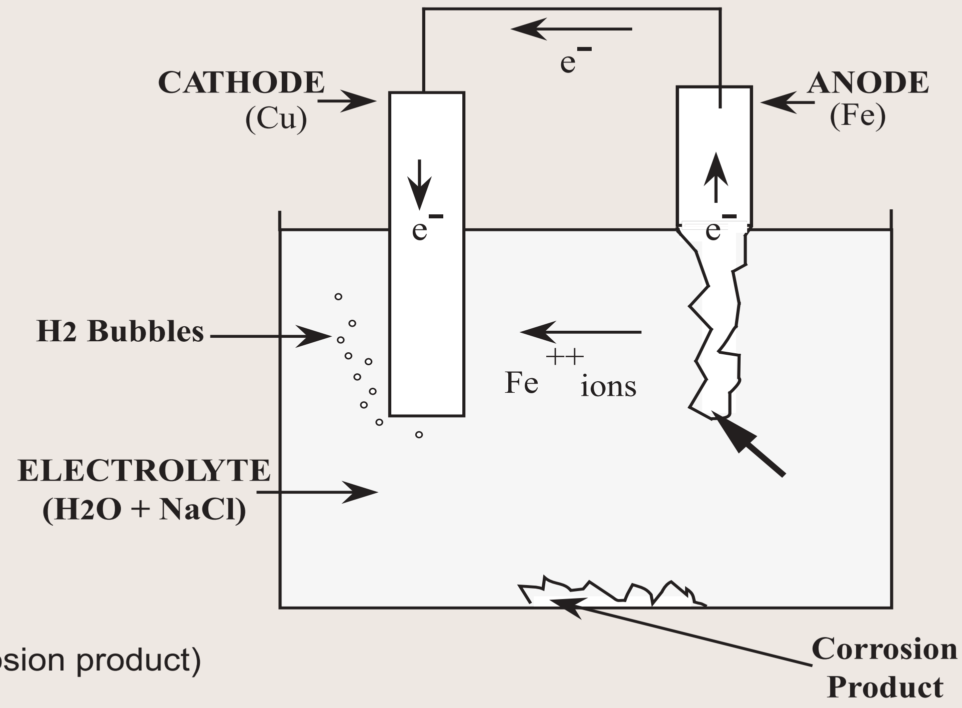
At the Cathode:

$2e^{-} + 2H^{+} \rightarrow H_2$ (bubbles)

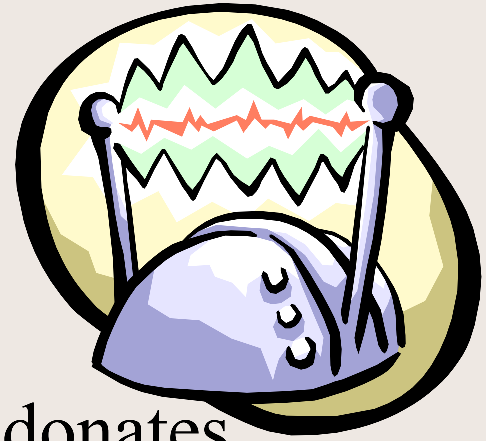
In the Electrolyte:

$H_2O \rightleftharpoons OH^{-} + H^{+}$

$Fe^{++} + 2\ OH^{-} \rightarrow Fe\ (OH)_2$ (corrosion product)



Cathodic Protection

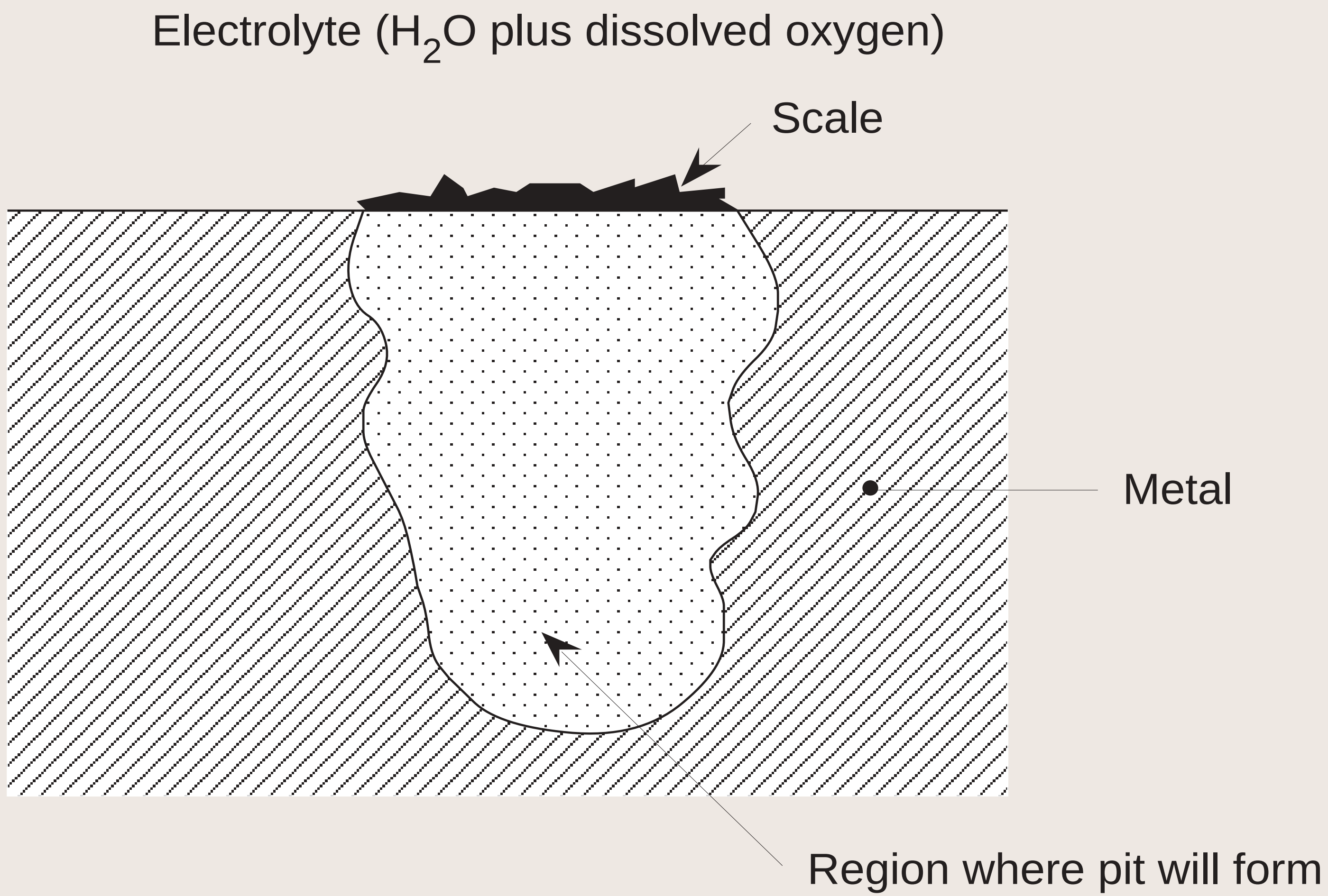


- Each metal has a different potential to donate electrons
- Anode always corrodes
- To protect a metal
  - Select a metal that more easily donates electrons
  - Build a cell with metal to be protected as cathode

Factors Affecting Galvanic Corrosion

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

Pitting and Crevice Corrosion



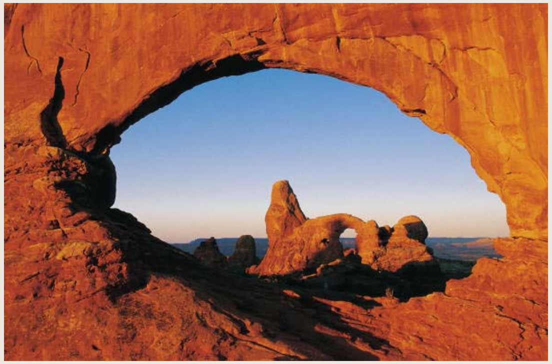
Stress Corrosion Cracking

- 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

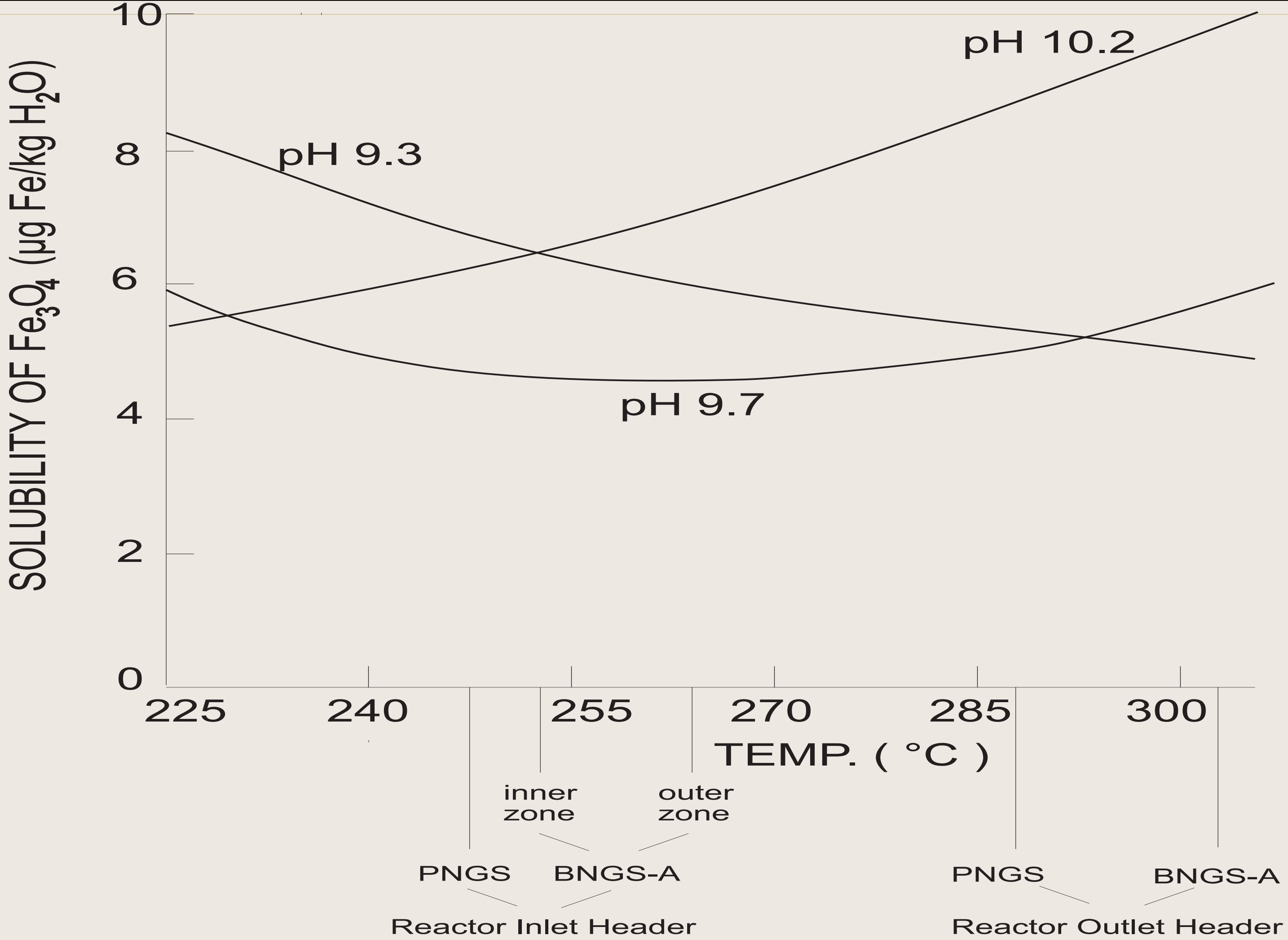
Microbiologically Induced Corrosion

- 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

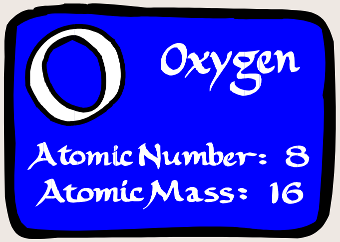
HTS pH Control



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

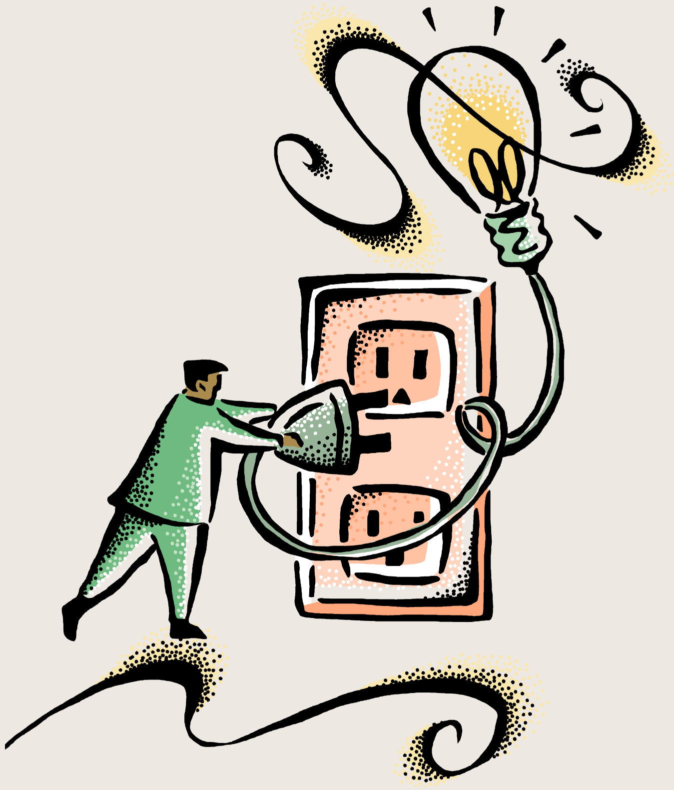
Dissolved Oxygen HTS



- 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 O_2 Secondary Side

- O_2 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

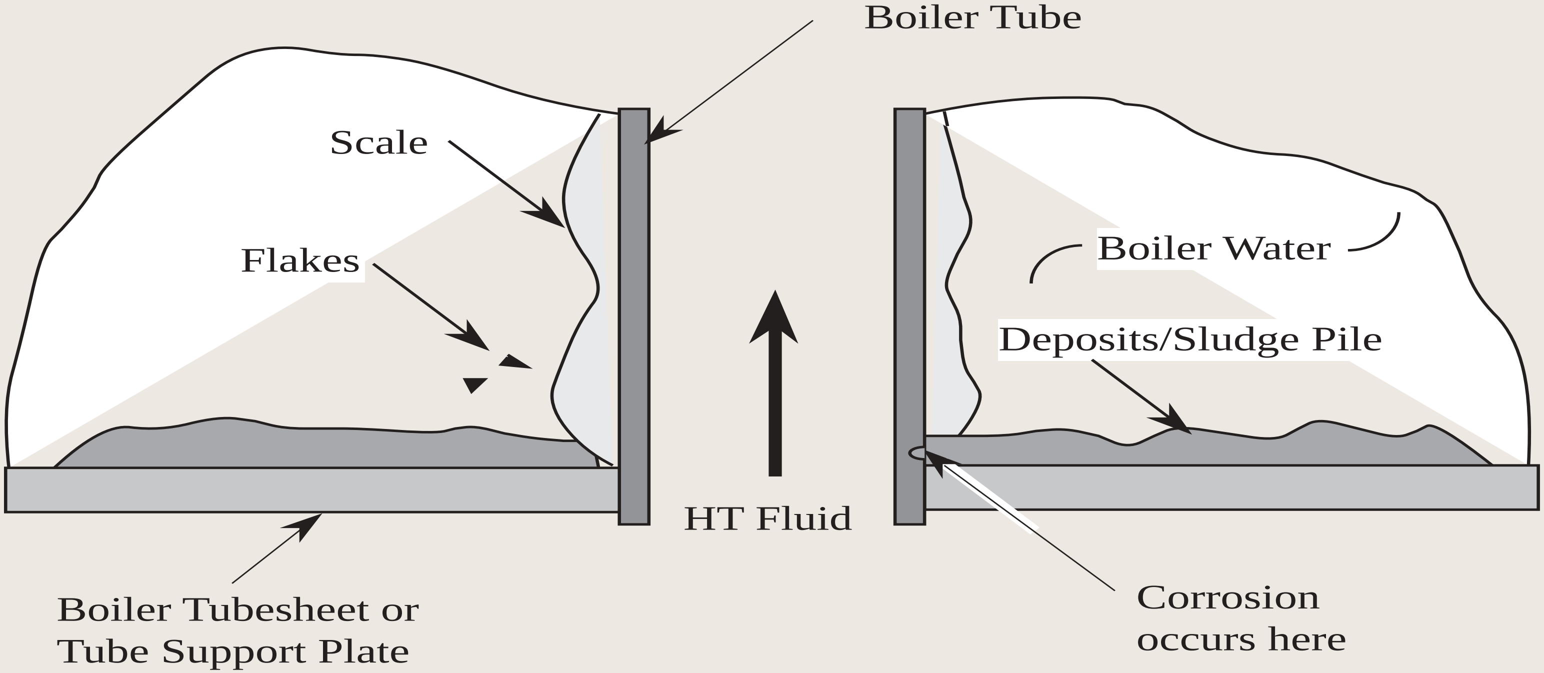
Moderator Over Poisoned

- 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