Corrosion Cells in Action

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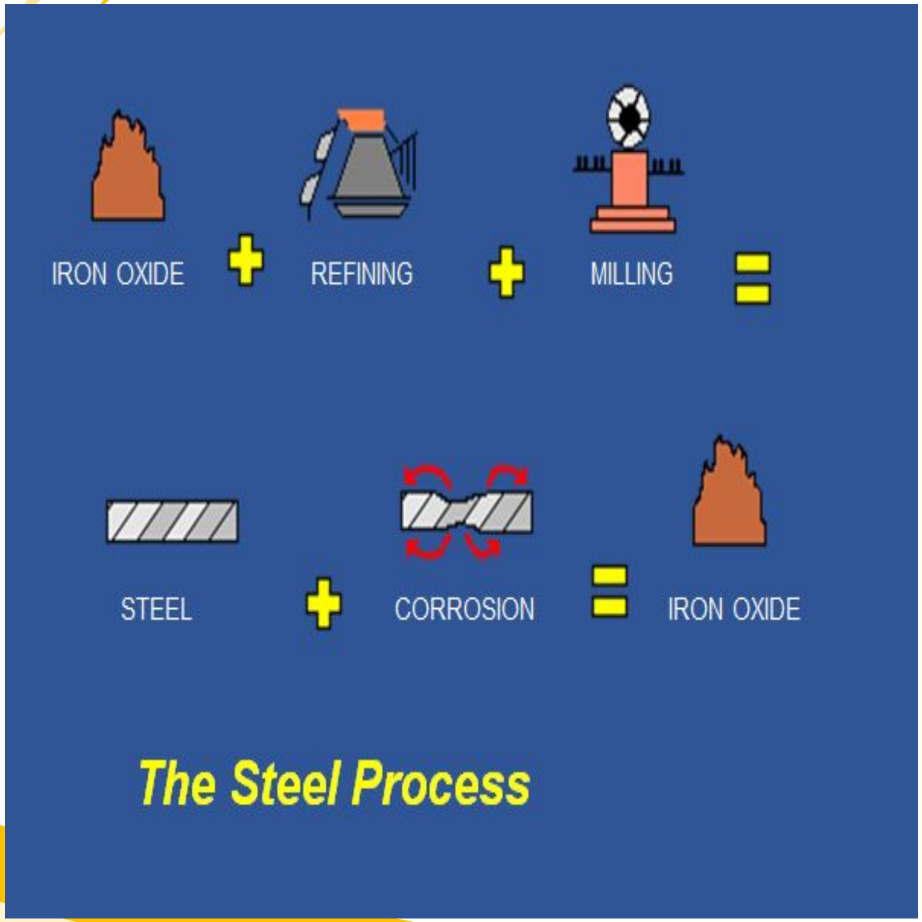
Appalachian Underground Corrosion Short Course

Objectives

- Review Basic Corrosion Cell Concepts.
- Show how various corrosion cell conditions result in active corrosion.
- Show how cathodic protection can be used to prevent corrosion.

Why are we here?



- Corrosion costs are in the hundreds of billions annually.
- <- The Why.

Basic Concepts

- The need to know!
  - Understanding of the basic corrosion cell and its chemistry will allow us to understand the various problems we have in the field. This in turn will help us determine an informed corrective solution.

Basic Concepts

- Four Elements of a Corrosion Cell
  - There MUST be an Anode.
  - There MUST be a Cathode
  - There MUST be a conductive electrolyte. *
  - There MUST be a metallic conductor.

Basic Concepts – Corrosion Cell Functions

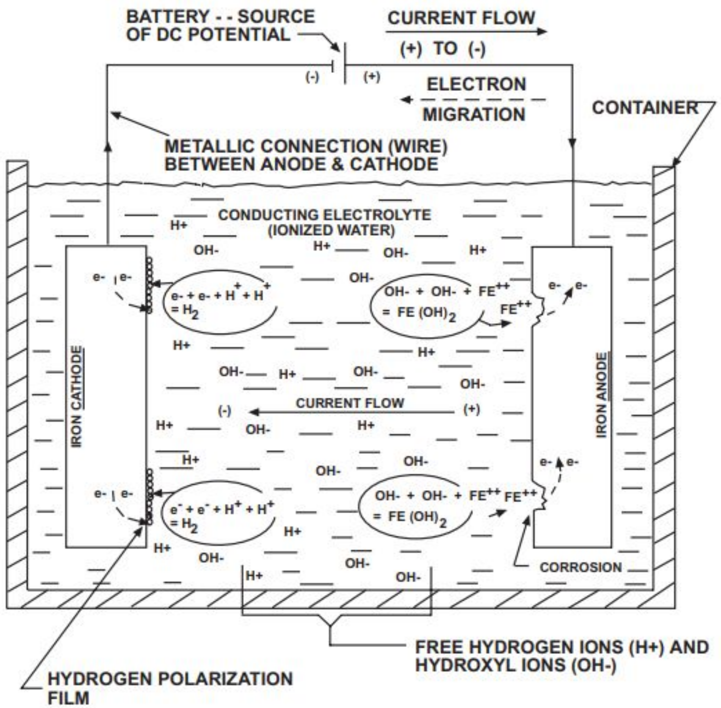
Anode

- Discharges Ions (oxidation reaction)
- Current Discharge Location
- The thing that Corrodes.

Cathode

- Collects Ions (Reduction Reactions)
- Location of Current Pickup
- Protected Structure

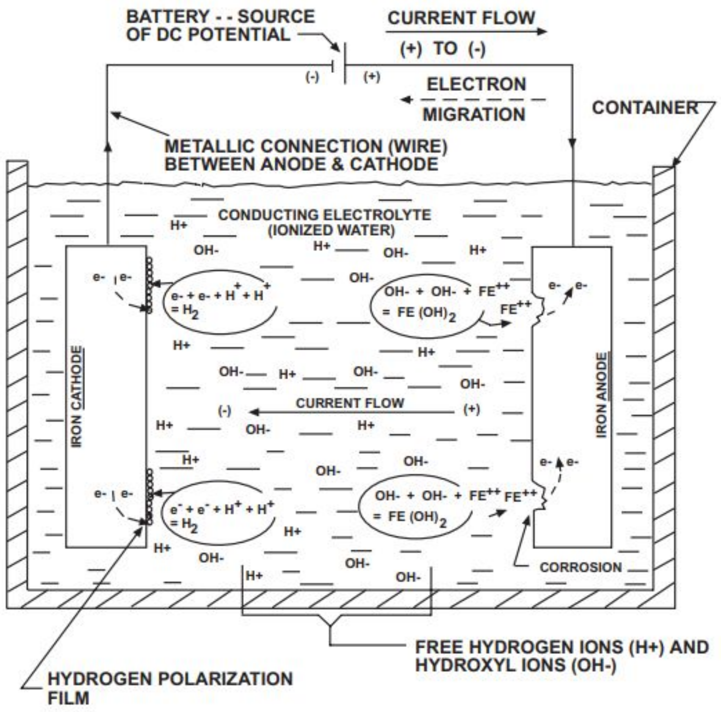
Basic Concepts - Electrolyte



Water is the electrolyte.

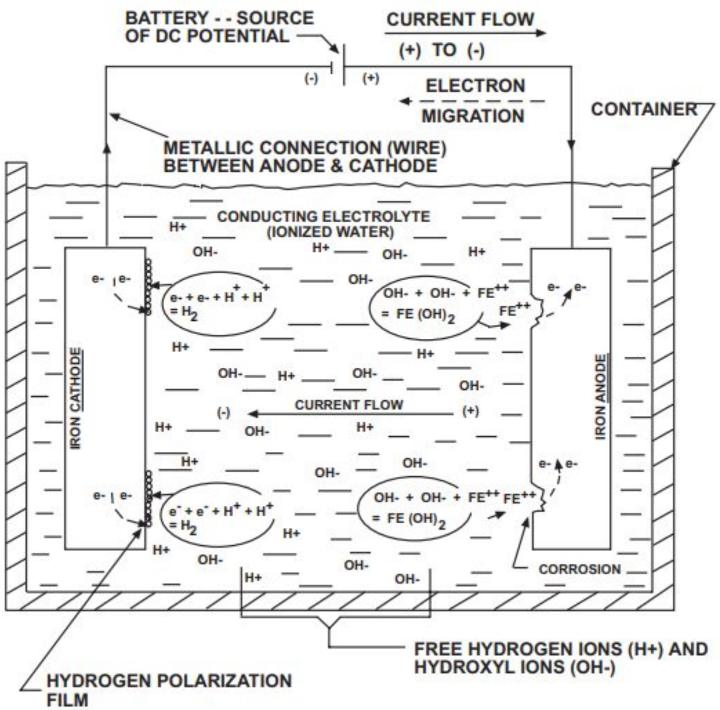
Naturally ionized aqueous component with Positively Charged Hydrogen Ions (H+) & Negatively Charged Hydroxyl Ions (OH-)

Basic Concepts – Anode and Cathode



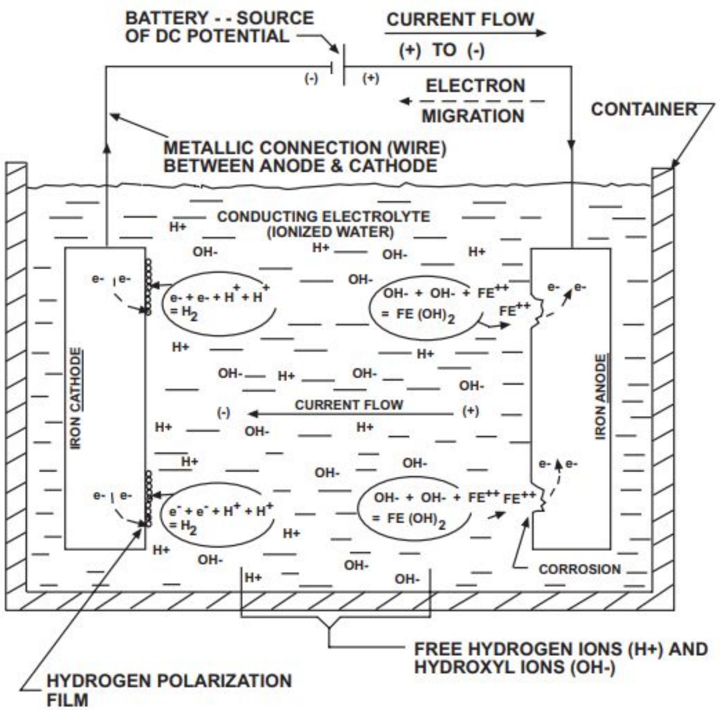
- The anode is discharging Ions into the electrolyte and corroding.
- The Cathode is collecting Ions from the electrolyte and does not corrode.

Basic Concepts – Metallic Conductor



- For current to flow there must be a driving voltage between the anode and cathode.
- Iron structure on both sides will have little to no driving voltage.
- A battery is inserted in the wire connecting the anode to the cathode.

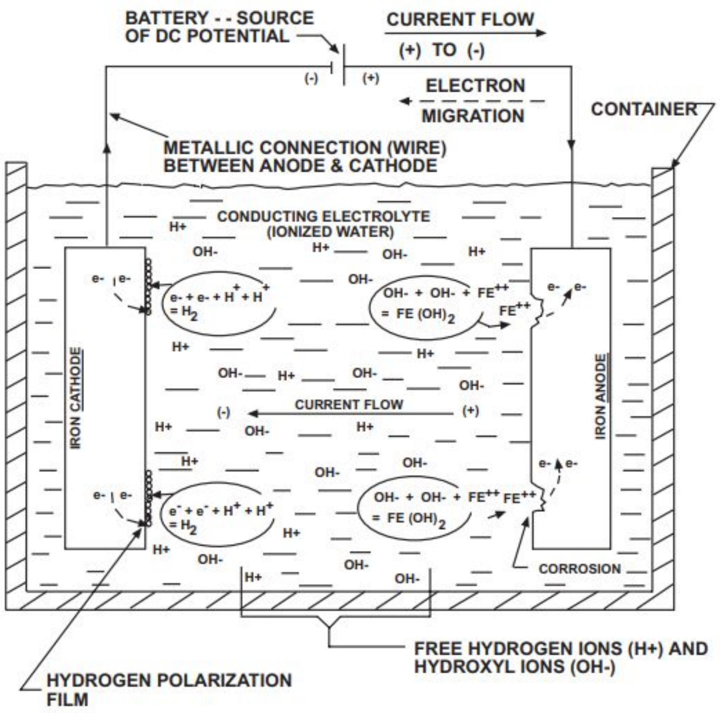
Basic Concepts – Electrochemical Reactions



- Surplus of positively charged Iron Ions (Fe++) at the anode. The are attracted to and combine with negatively charged hydroxyl ions (OH-) in the ionized electrolyte.

- OH- + OH- + Fe++ = Fe(OH-)2 is Ferrous Hydroxide.

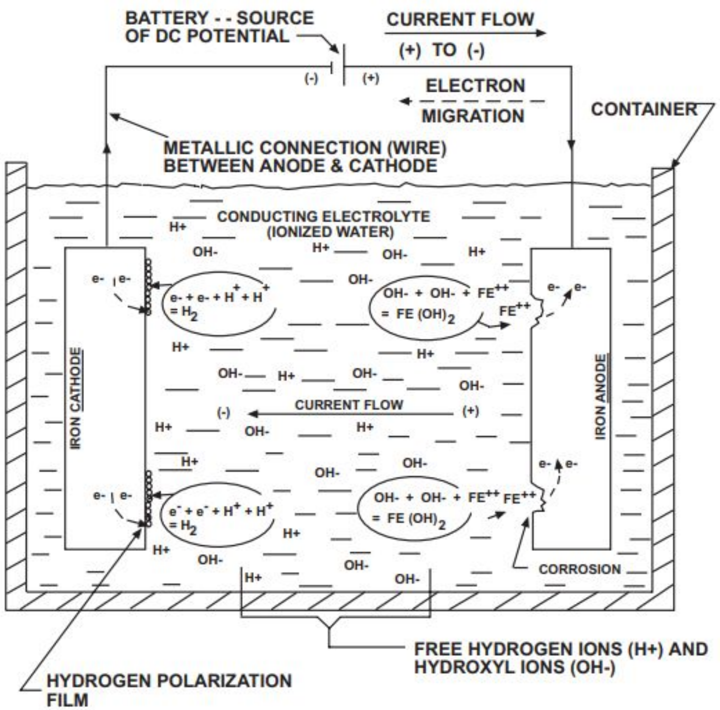
Basic Concepts – Electrochemical Reactions



- The negatively charged electrons migrate from the anode to the cathode and combine with positively charged hydrogen ions in the electrolyte.

- e- + e- + H+ + H+ = H2 is Hydrogen.

Basic Concepts – Electrochemical Reactions



- At the anode we are left with the corrosion product ferrous hydroxide Fe(OH-)2.
- At the cathode we are left with a Hydrogen 2H+ cathodic polarization film.

Basic Concepts – Electrochemical Reactions

In this naturally ionized electrolyte water molecules break down to achieve balance.

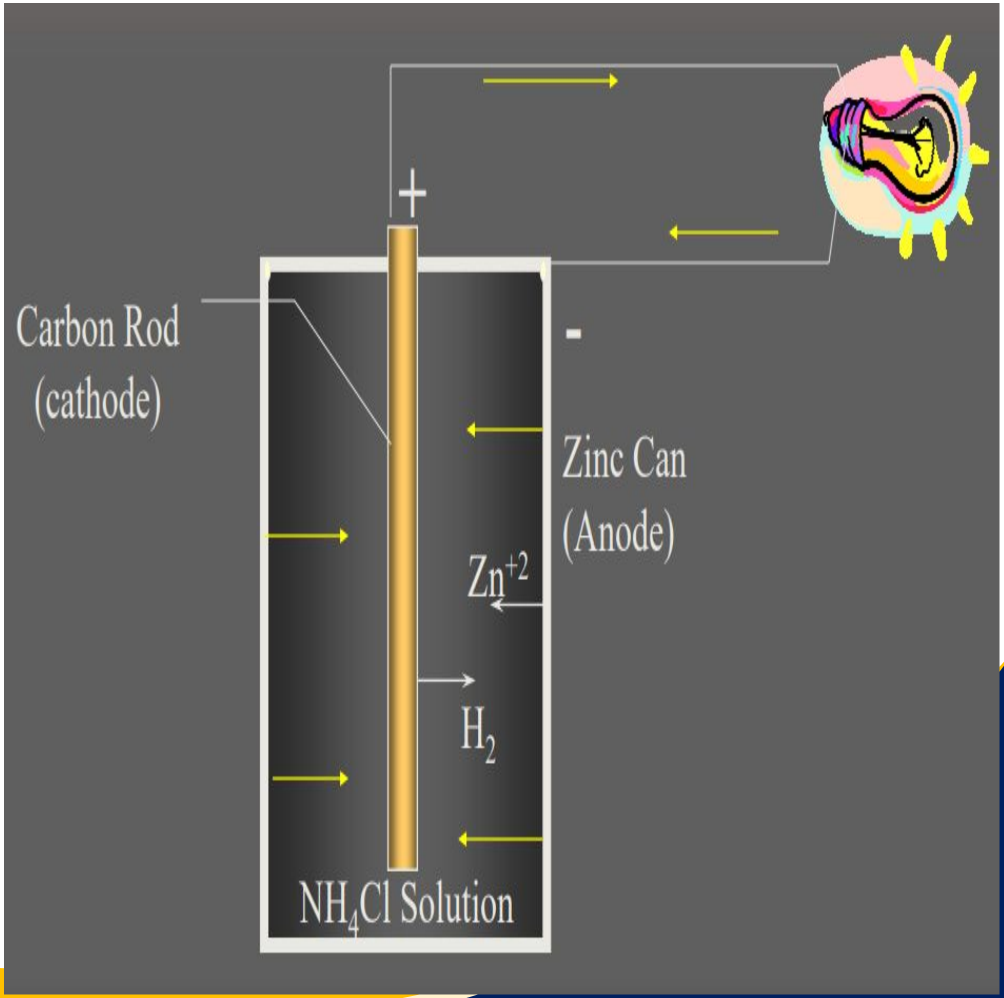
The break down of water molecules into positively charged hydrogen ions and negatively charged hydroxyl ions looks like -
$2H_2O = 2H^+ + 2(OH^-)$.

These ions must be present in the electrolyte.

The equation for the corrosion of iron at the ANODE looks like -
$Fe + 2H_2O = Fe^{++} + 2H^+ + 2(OH^-)$.

Dry Cell Example of Corrosion Cell

- Common Zinc-carbon household battery.
- Natural potential between the dissimilar materials. Approx 1.6 V for a new zinc-carbon battery.



Electromotive Force

- The more negative material (most active) will corrode to the more electropositive material.
- The less active noble materials are the most electropositive.
- This is a guide only due to environmental differences in soil or water that change the potentials.

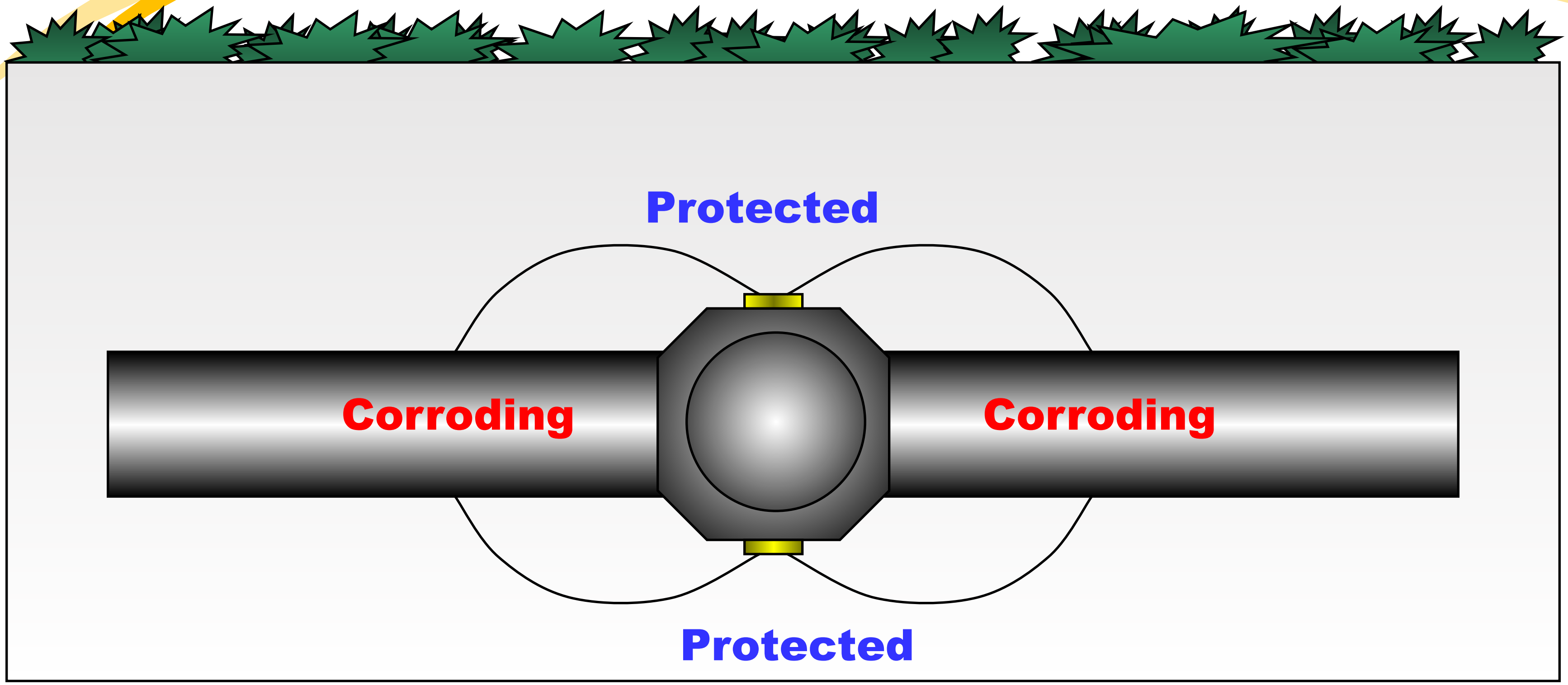
METAL	VOLTS
Magnesium	-2.37
Aluminum	-1.66
Zinc	-0.76
Iron	-0.44
Tin	-0.14
Lead	-0.13
Hydrogen	0.00
Copper	+0.34 to +0.52
Silver	+0.80
Platinum	+1.20
Gold	+1.50 to +1.68

MEASURE WITH RESPECT TO HYDROGEN REFERENCE ELECTRODE

Dissimilar Metal aka Galvanic Corrosion Examples

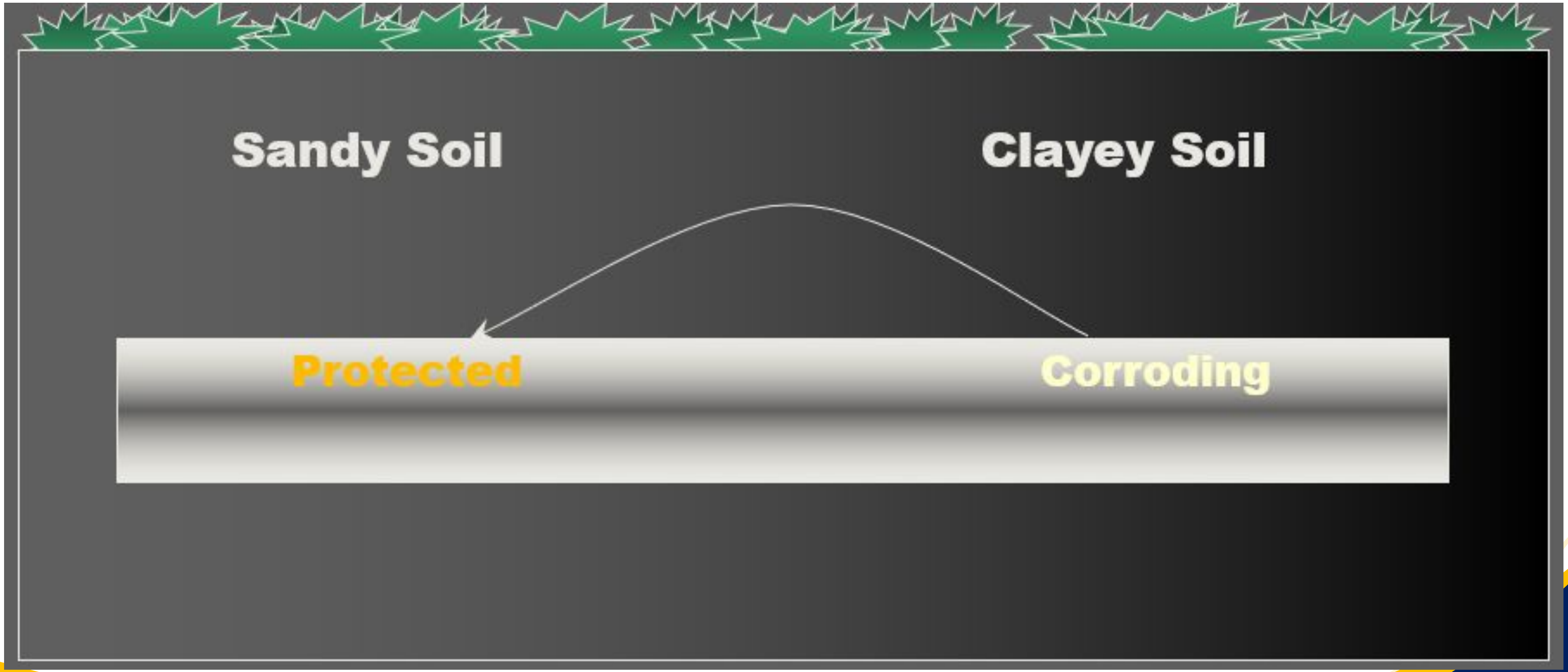
- Dissimilar Metal Couple
- Non-Homogeneous Soils
- Differential Aeration / Chemistry
- Dissimilar Surface Conditions
- Stray Current
- Effects of Stress

Dissimilar Metal Couple

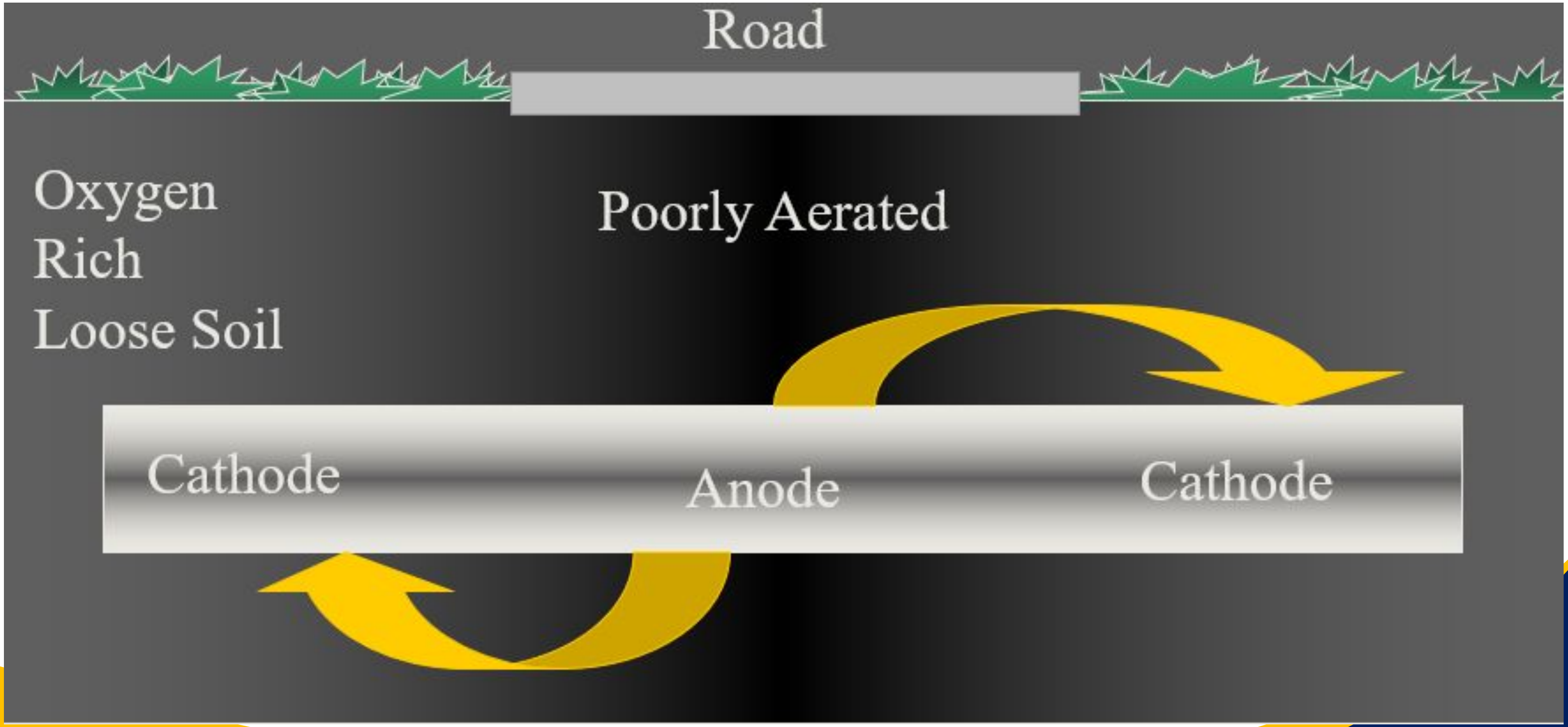


- Cast Iron Valve and Black Steel Pipe

Non – Homogeneous Soil

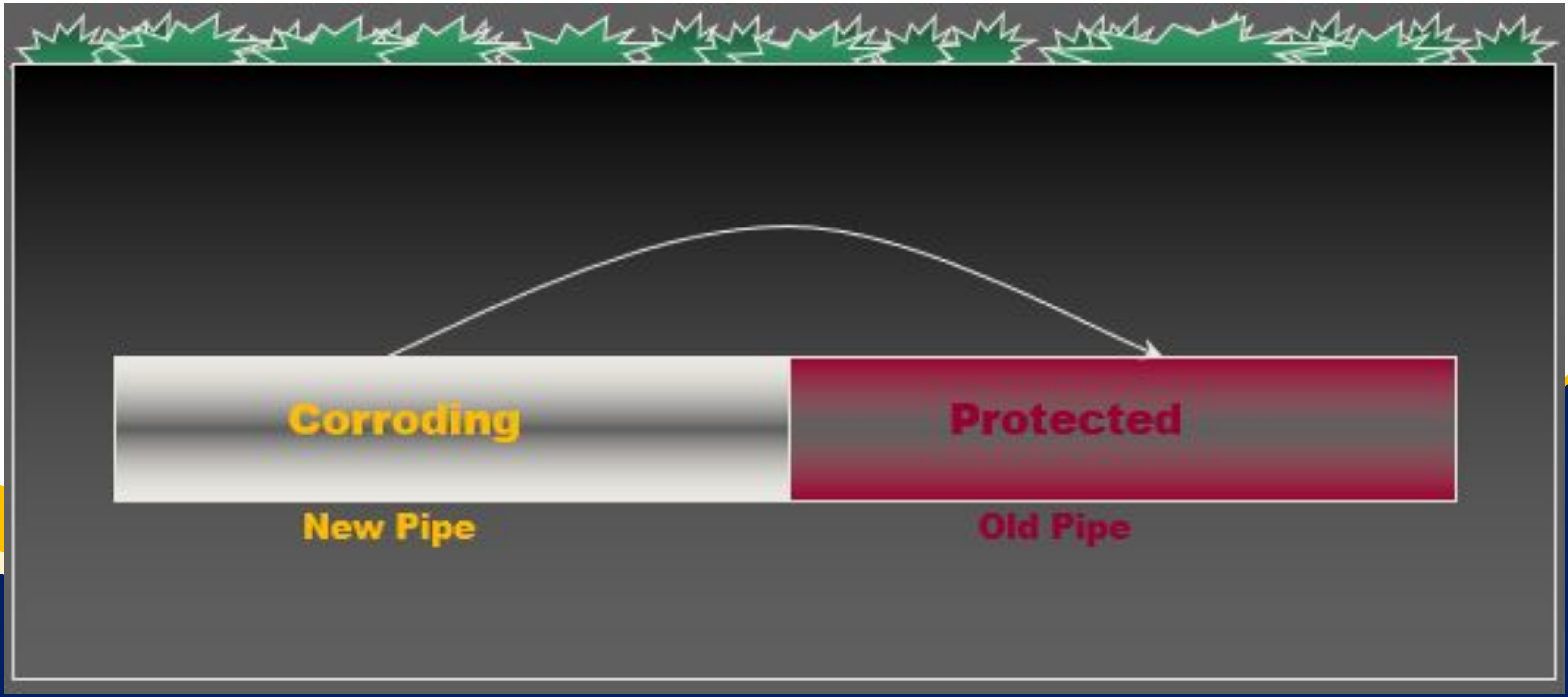


Differential Oxygen Concentration



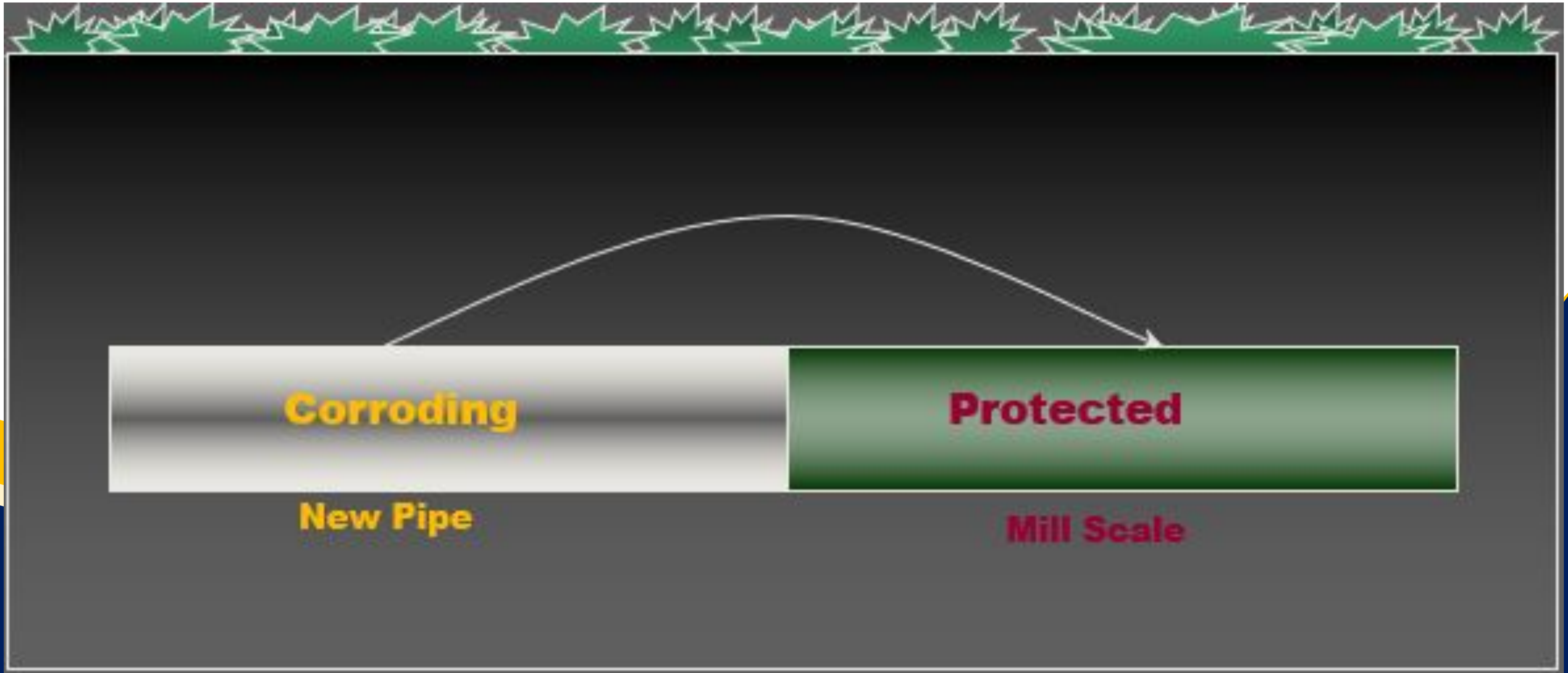
Dissimilar Surface Conditions

- New Steel vs Rusted Steel



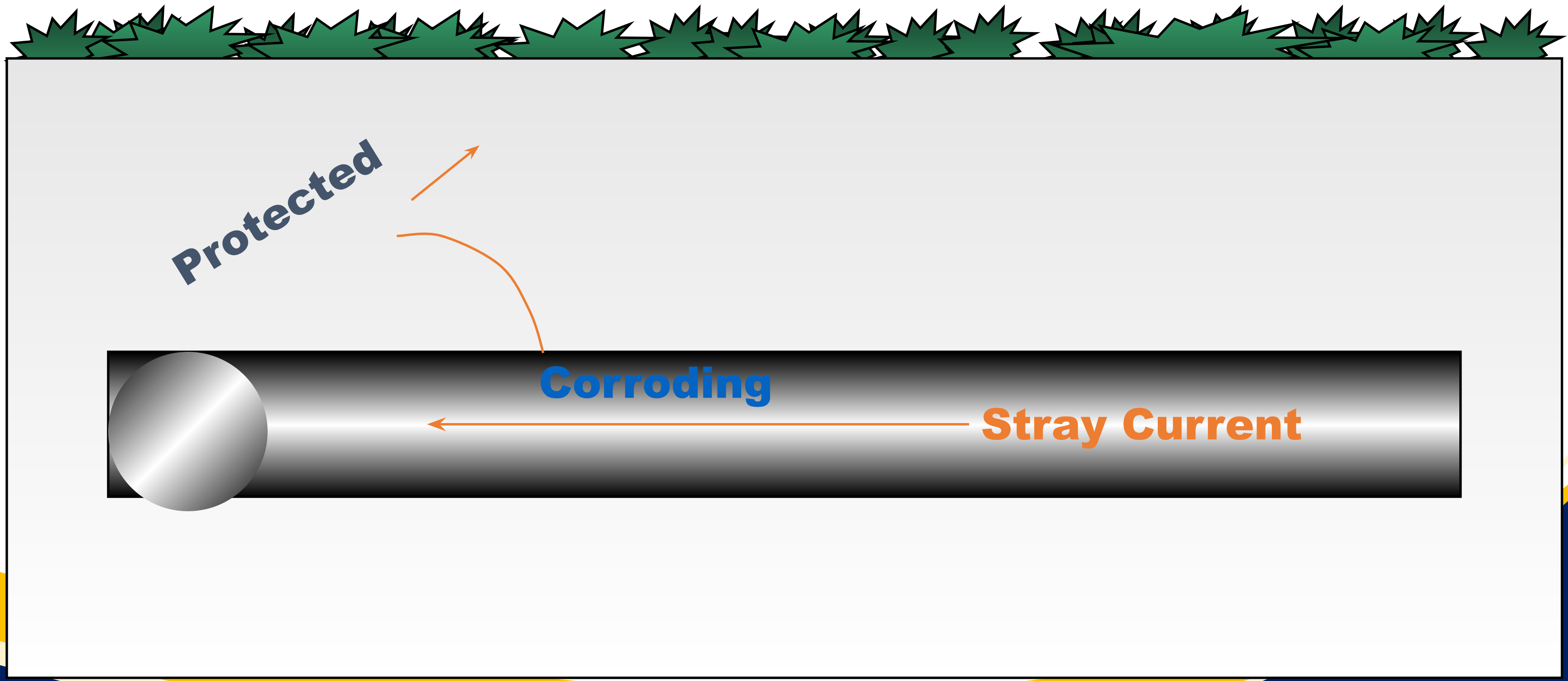
Dissimilar Surface Conditions

- All new pipe. Some of the pipe is bare and some has inadequate removal of mill scale.



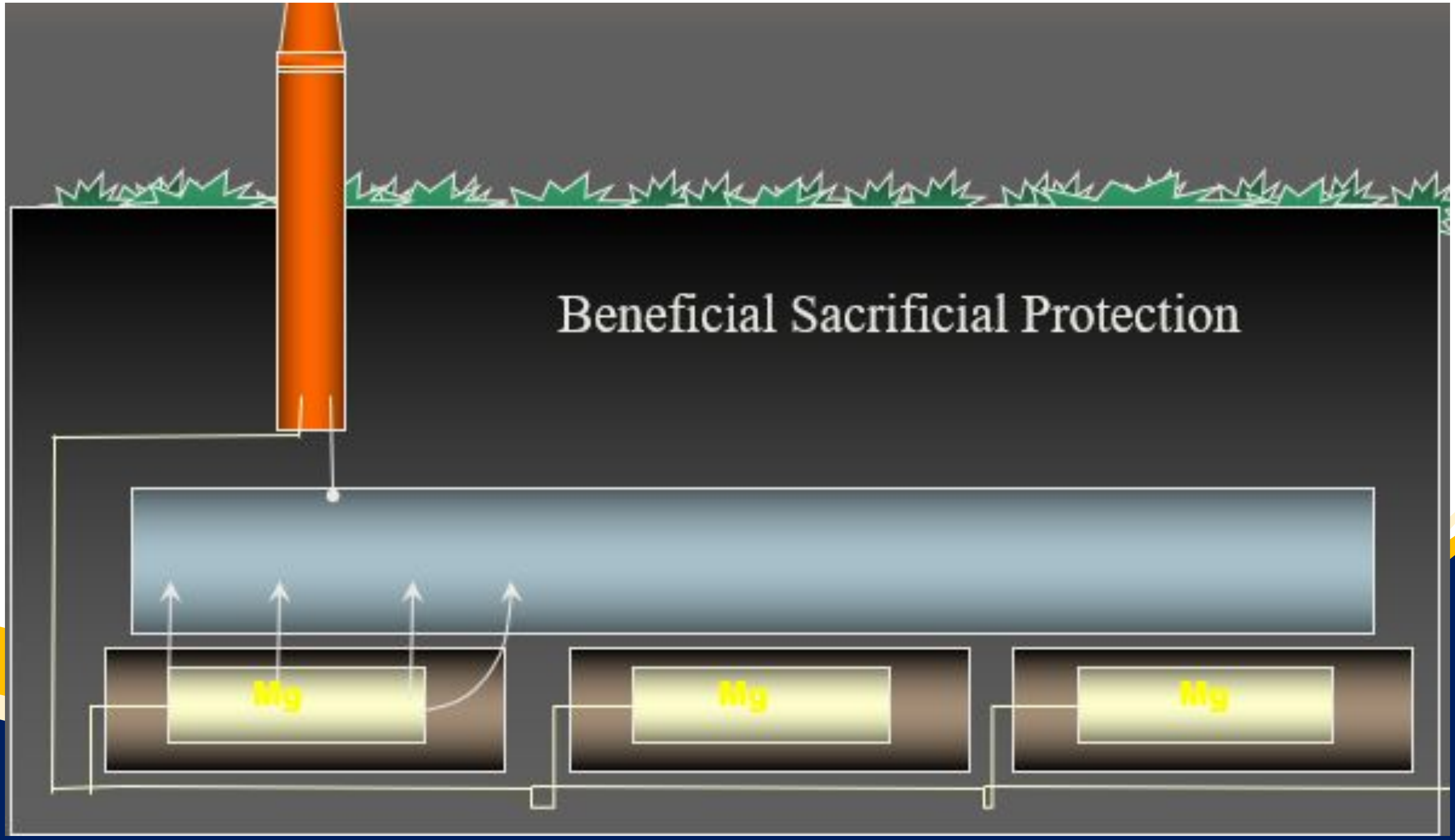
Stray Current

- Current will follow every path of resistance. The amount of current on each path of resistance is inversely proportional to the amount of resistance.



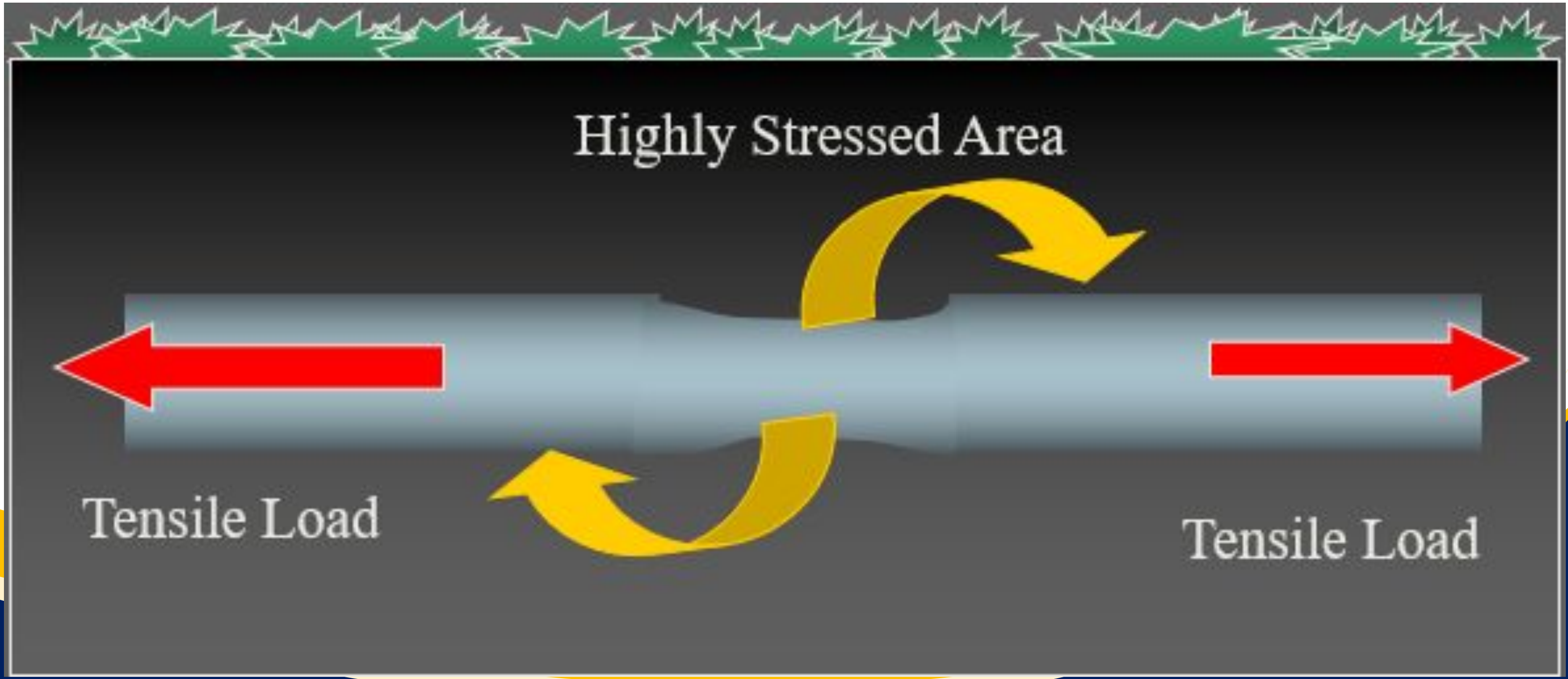
Dissimilar Metal Couple

- Using dissimilar metal couple to our advantage.

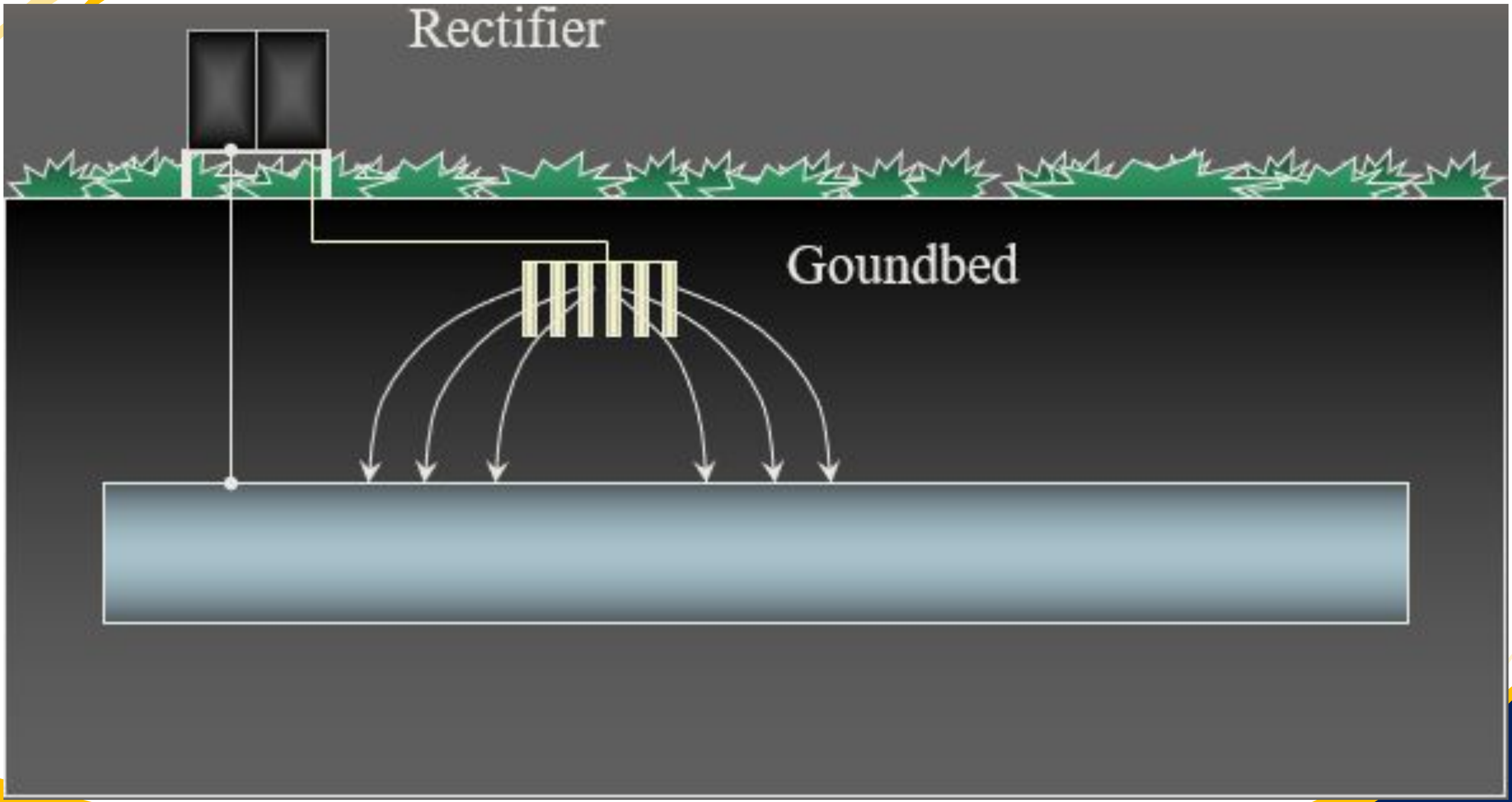


Effects of Stress

- Residual stresses in metal are anodic to non-stressed portions of the same structure.



Cathodic Protection



Corrosion Cells in Action

Developed by the late Col. George C. Cox.

Demonstration set-up starting on page 1-5 of your book.

The examples visually show –

- Anodic areas with Potassium Ferricyanide.
  - Turns Blueish Green in the presence of Fe++.
- Cathodic areas with Phenolphthalein.
  - Turns bright pink or red as pH increases. (OH-)

Corrosion Cells in Action

- Each demonstration can be shown on a screen for viewing. The chemical indicators will show the anodic and cathodic areas .