Fundamentals Course

Basic Corrosion

Fundamental introduction and theory behind the corrosion process

Presented By: Heather Groll

AUCSC

Appalachian Underground Corrosion Short Course

What is Corrosion?

The deterioration of a material, usually a metal, due to a reaction with its environment

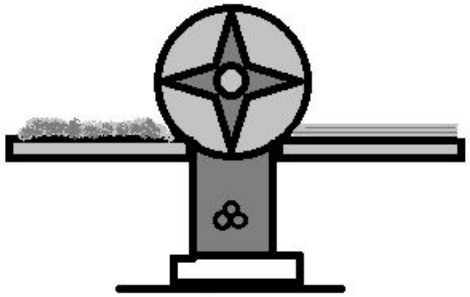
Or

The tendency of a refined metal to return to its natural state as an ore

What is Corrosion?

Iron Oxide Extracted from the Earth

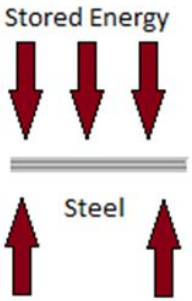
Refining Process



Milling Process

Steel

Steel



Steel
Corroding Away

Steel Returning back to its natural form as Iron Oxide

AUCSC

Appalachian Underground Corrosion Short Course

What is Corrosion?

The deterioration of a material, due to a reaction with its environment

AUCSC
Appalachian Underground Corrosion Short Course

Causes of a Corrosion Cell

Naturally Occurring Corrosion

- Dissimilar metals
- Dissimilar surface
- Dissimilar Soils (Electrolyte)
- Different Aeration (including Oxygen Concentration)
- Cinders
- Stress
- Graphitization
- Microbiological Influenced Corrosion

What is a Corrosion Cell?

Corrosion cannot occur without the **four** components of a corrosion cell;

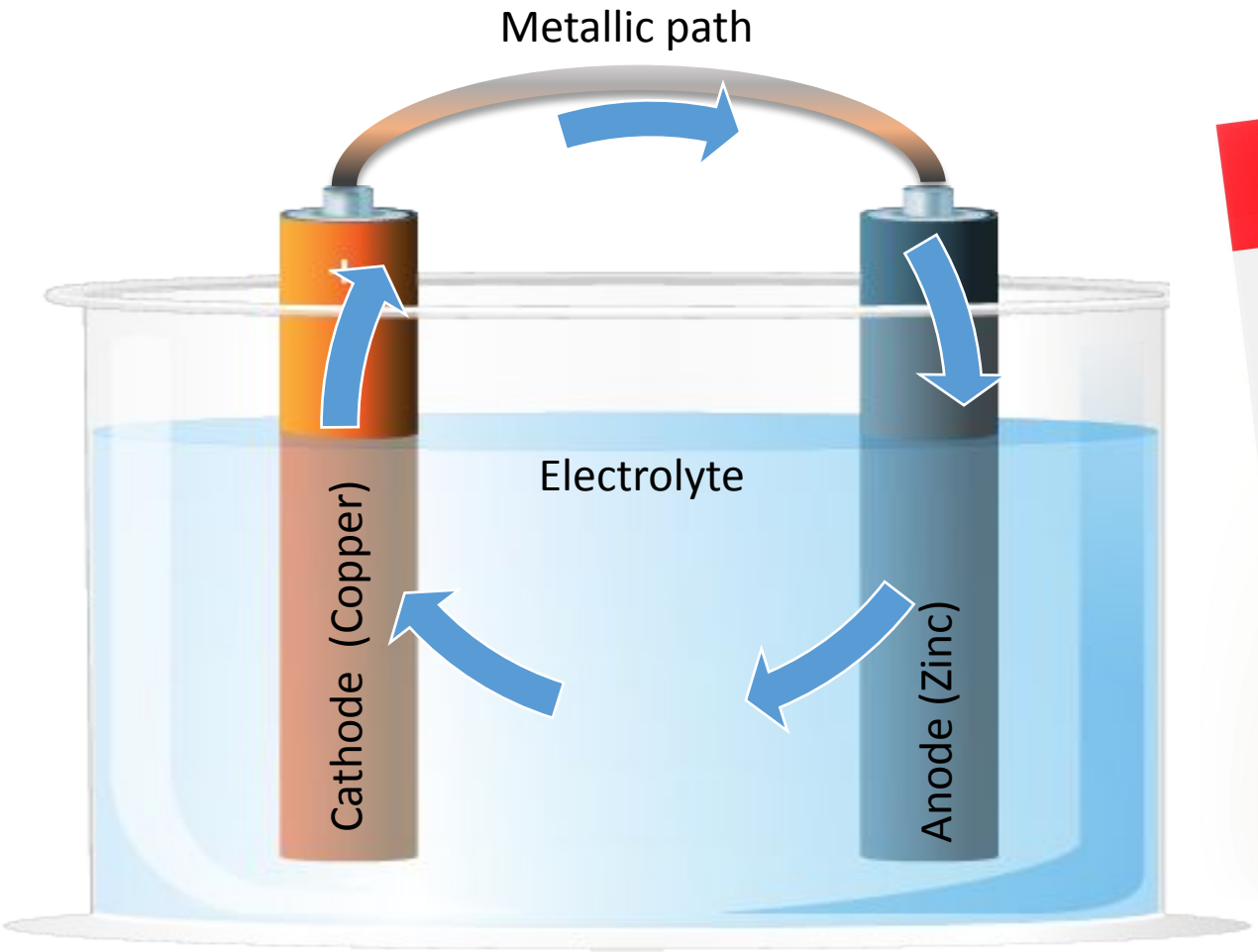
1. ANODE
2. CATHODE
3. METALLIC PATH
4. ELECTROLYTE

*Take one of the four away and corrosion will be mitigated.

AUCSC
Appalachian Underground Corrosion Short Course

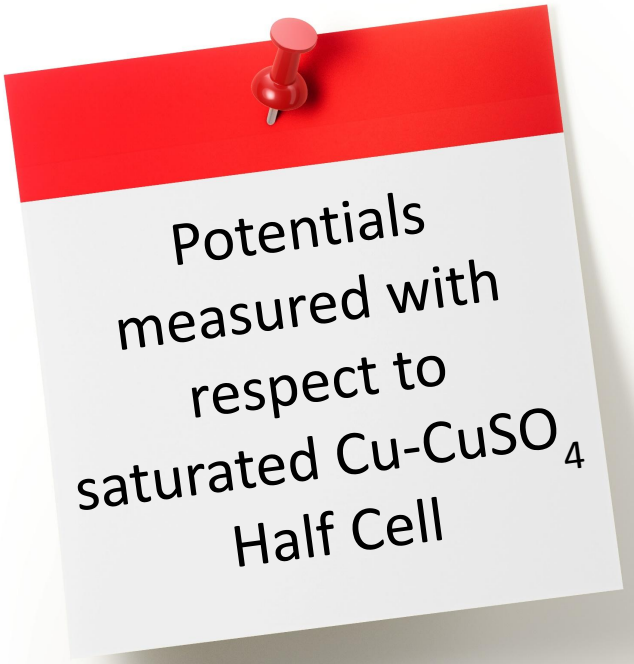
Corrosion Cell

*Image shown in terms of conventional current



Current flowing due to a difference in potential

Galvanic Series



Active (More Electro-Negative)

(-)

- High Potential Magnesium (-1.75 v)
- Magnesium Alloy (-1.5 v)
- Zinc (-1.1 v)
- Aluminum Alloys (-1.05 v)
- Clean Carbon Steel (-0.5 to -0.8 v)
- Rusted Carbon Steel (-0.2 to -0.8 v)
- Lead (-0.5 v)
- Copper (-0.2 v)
- High Silicon Iron (-0.2 v)
- Gold (+0.2V)
- Graphite, Carbon (+0.3v)

Noble (More Electro-Positive)

(+)

AUCSC

Appalachian Underground Corrosion Short Course

Galvanic Series

Defining an Anode and Cathode

*Anode is more electro-negative than the cathode

*Cathode is more electro-positive than the anode

Active (More Electro-Negative)

- High Potential Magnesium (-1.75 v)
- Magnesium Alloy (-1.5 v)
- Zinc (-1.1 v)
- Aluminum Alloys (-1.05 v)
- Clean Carbon Steel (-0.5 to -0.8 v)
- Rusted Carbon Steel (-0.2 to -0.8 v)
- Lead (-0.5 v)
- Copper (-0.2 v)
- High Silicon Iron (-0.2 v)
- Gold (+0.2V)
- Graphite, Carbon (+0.3v)

Noble (More Electro-Positive)

Galvanic Series

Defining an Anode and Cathode

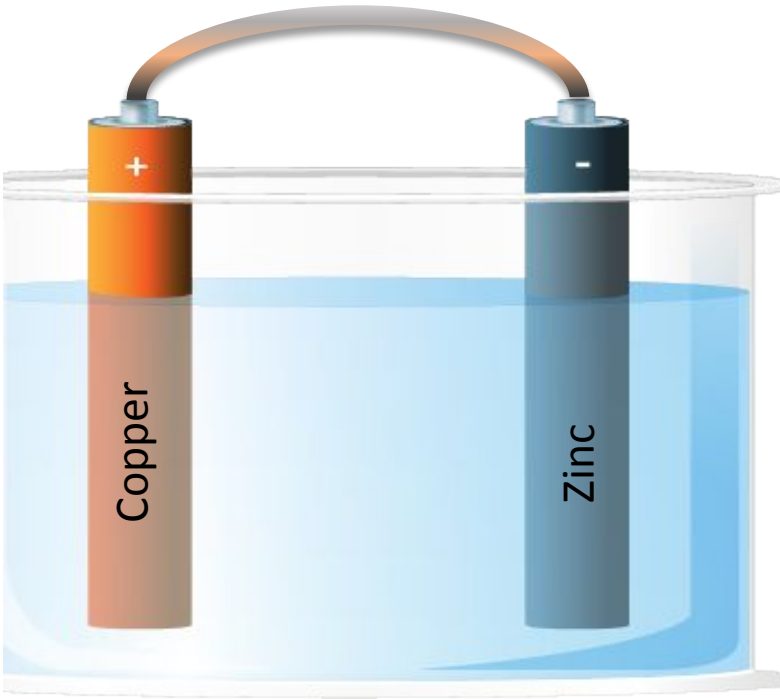
*Anode is more electro-negative than the cathode

*Cathode is more electro-positive than the anode

Active (More Electro-Negative)

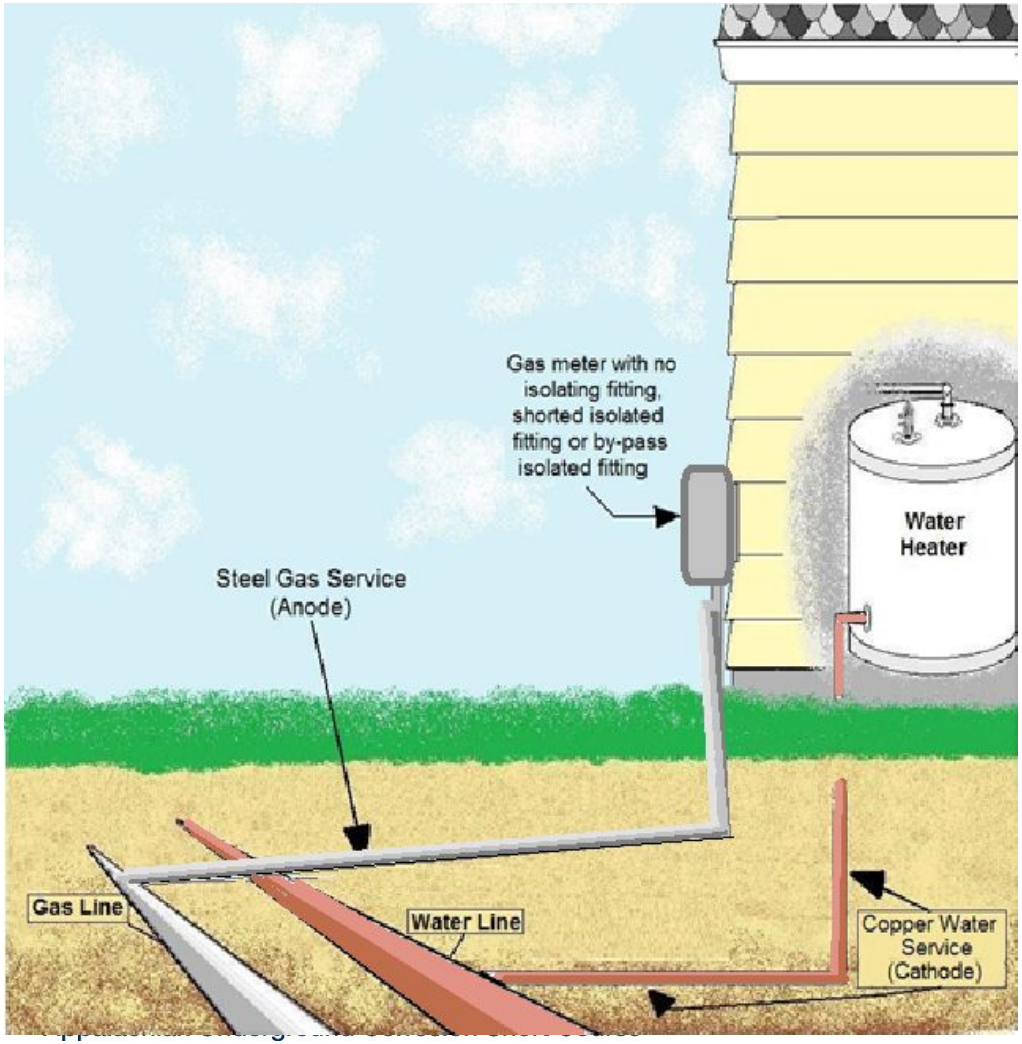
- High Potential Magnesium (-1.75 v)
- Magnesium Alloy (-1.5 v)
- Zinc (-1.1 v)
- Aluminum Alloys (-1.05 v)
- Clean Carbon Steel (-0.5 to -0.8 v)
- Rusted Carbon Steel (-0.2 to -0.8 v)
- Lead (-0.5 v)
- Copper (-0.2 v)
- High Silicon Iron (-0.2 v)
- Gold (+0.2V)
- Graphite, Carbon (+0.3v)

Noble (More Electro-Positive)



Dissimilar Metal Corrosion

Steel Gas Line and Copper Water Line



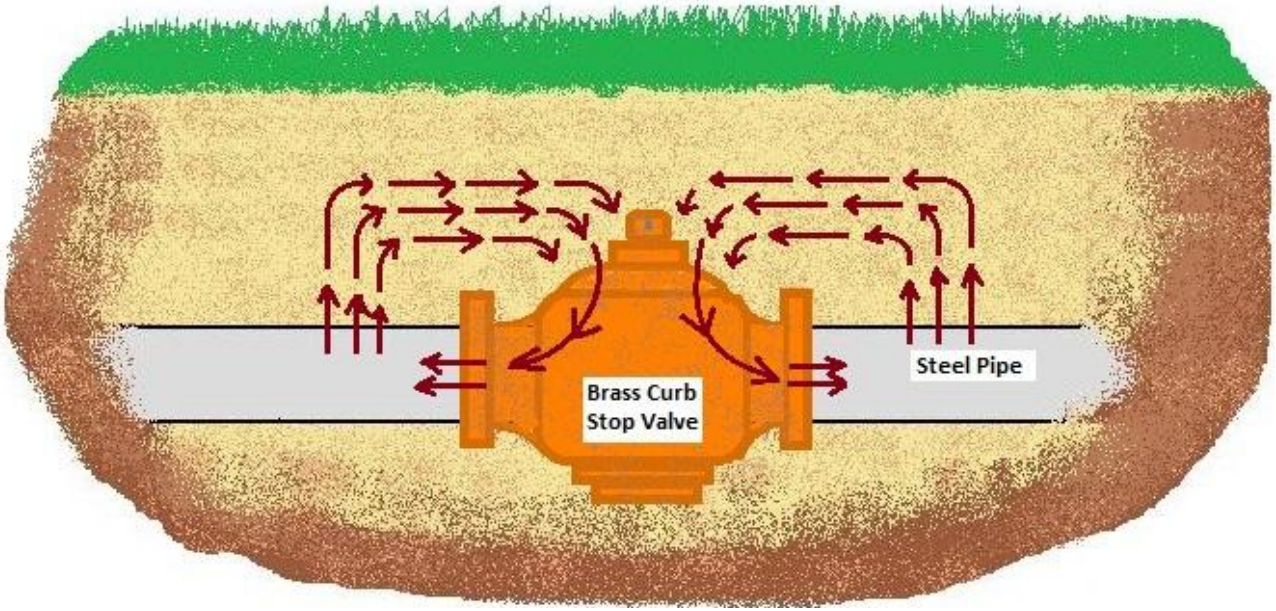
Active (More Electro-Negative)

- High Potential Magnesium (-1.75 v)
- Magnesium Alloy (-1.5 v)
- Zinc (-1.1 v)
- Aluminum Alloys (-1.05 v)
- Clean Carbon Steel (-0.5 to -0.8 v)
- Rusted Carbon Steel (-0.2 to -0.8 v)
- Lead (-0.5 v)
- Copper (-0.2 v)
- High Silicon Iron (-0.2 v)
- Gold (+0.2V)
- Graphite, Carbon (+0.3v)

Noble (More Electro-Positive)

Dissimilar Metal Corrosion

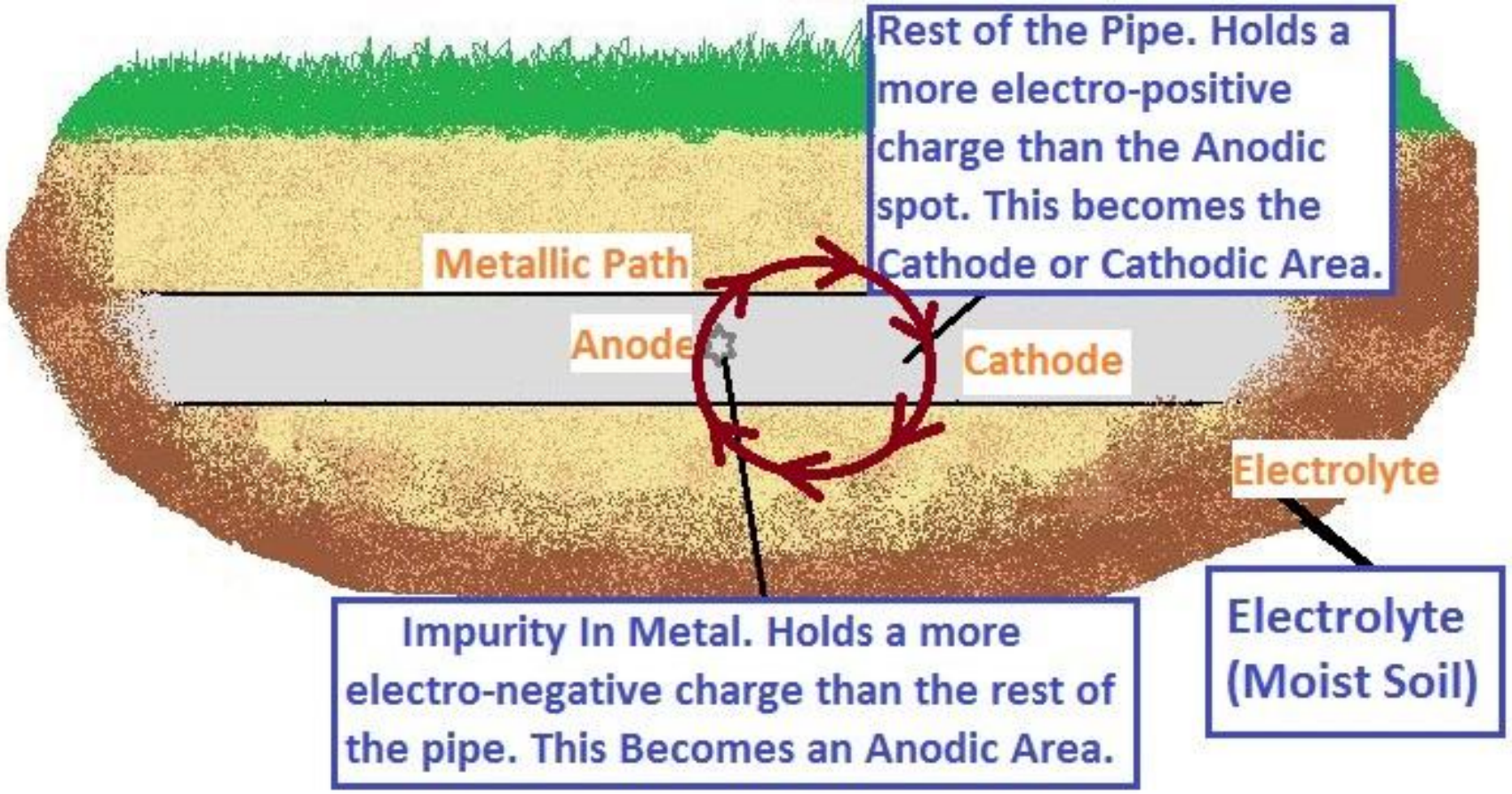
Brass Stop in a Steel Line



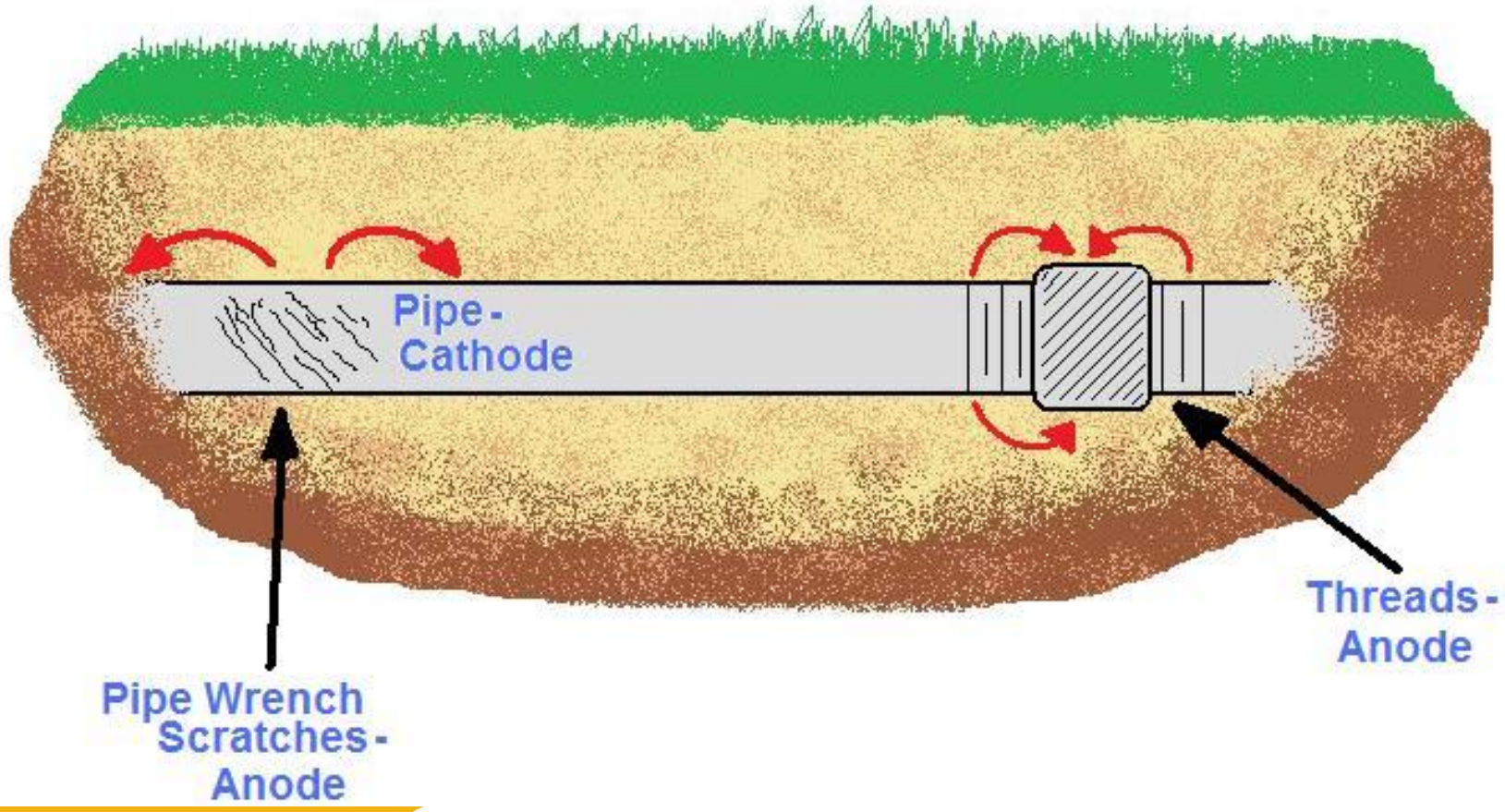
AUCSC

Appalachian Underground Corrosion Short Course

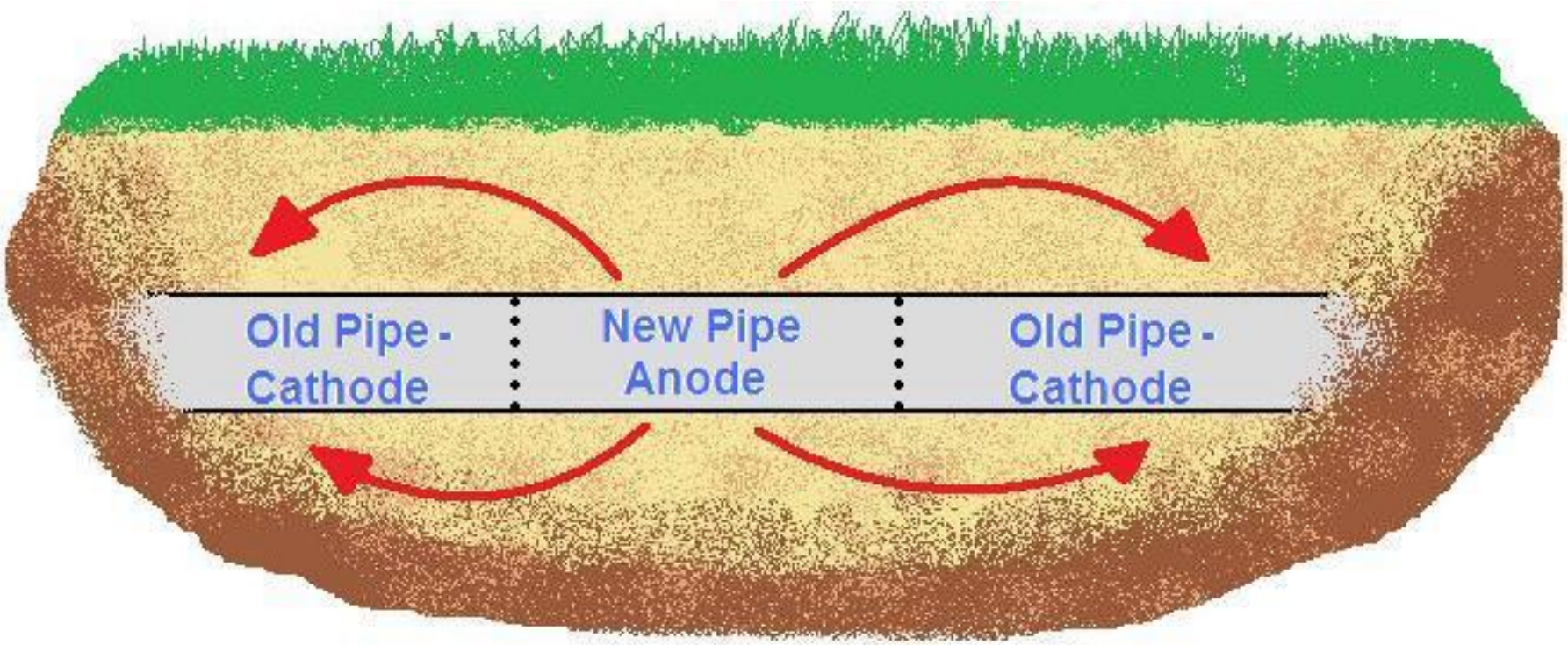
Surface Conditions



Surface Conditions

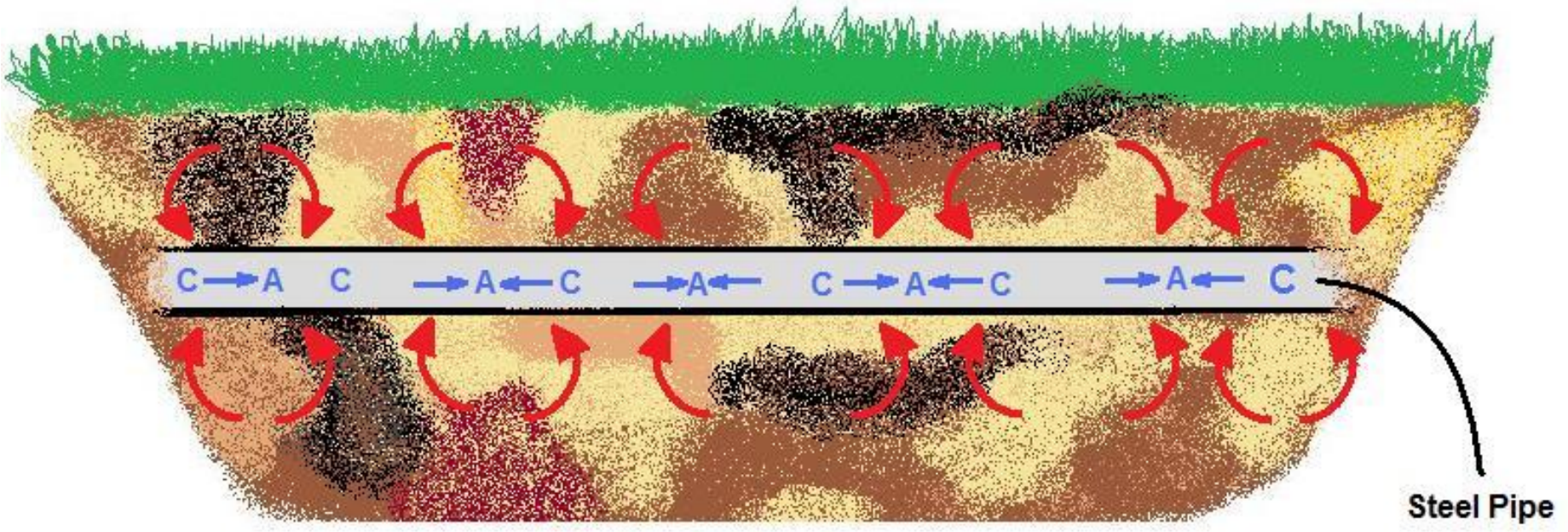


New-Old Pipe Corrosion Cell



AUCSC
Appalachian Underground Corrosion Short Course

Dissimilar Electrolyte



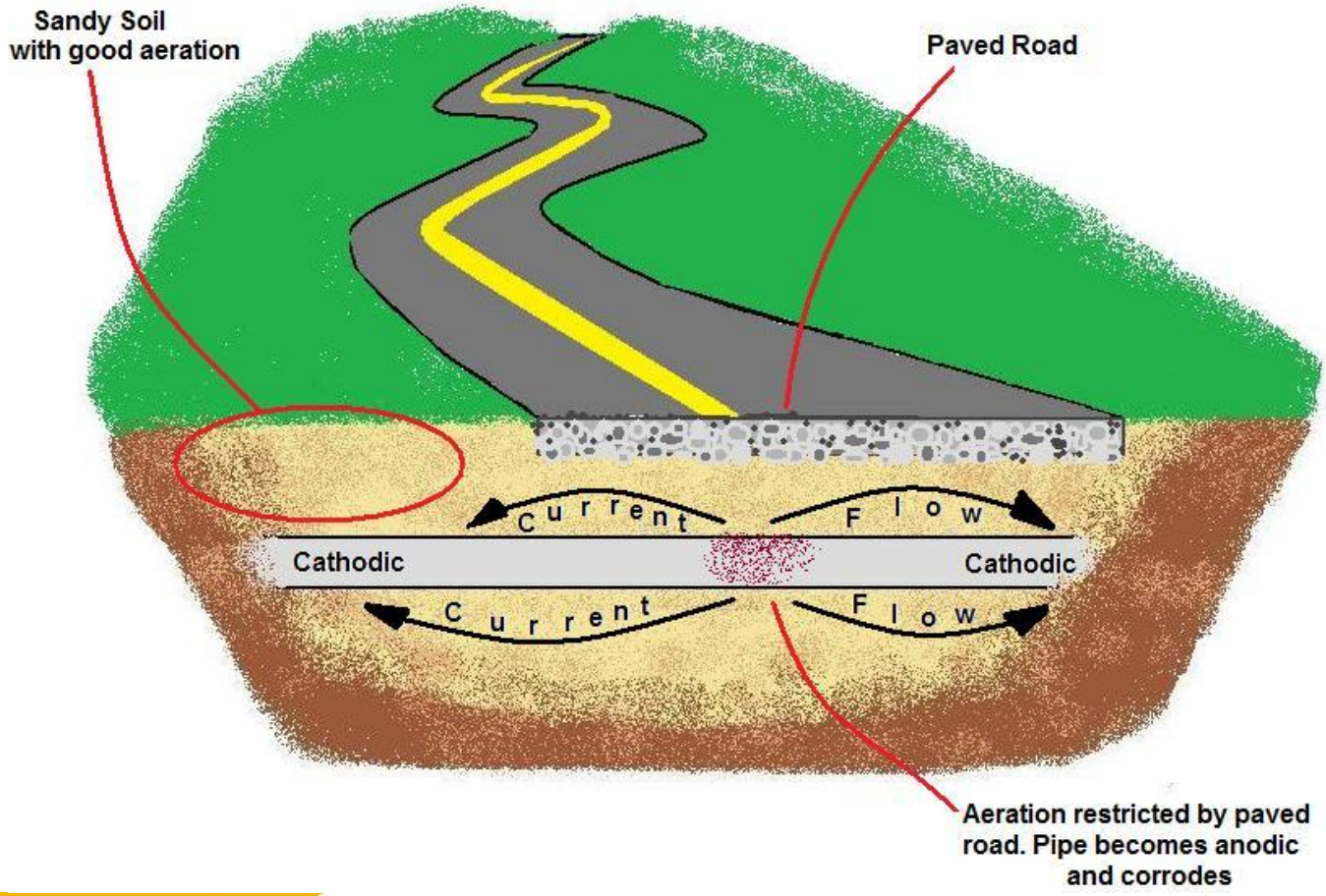
A= Anodic Areas

C= Cathodic Areas

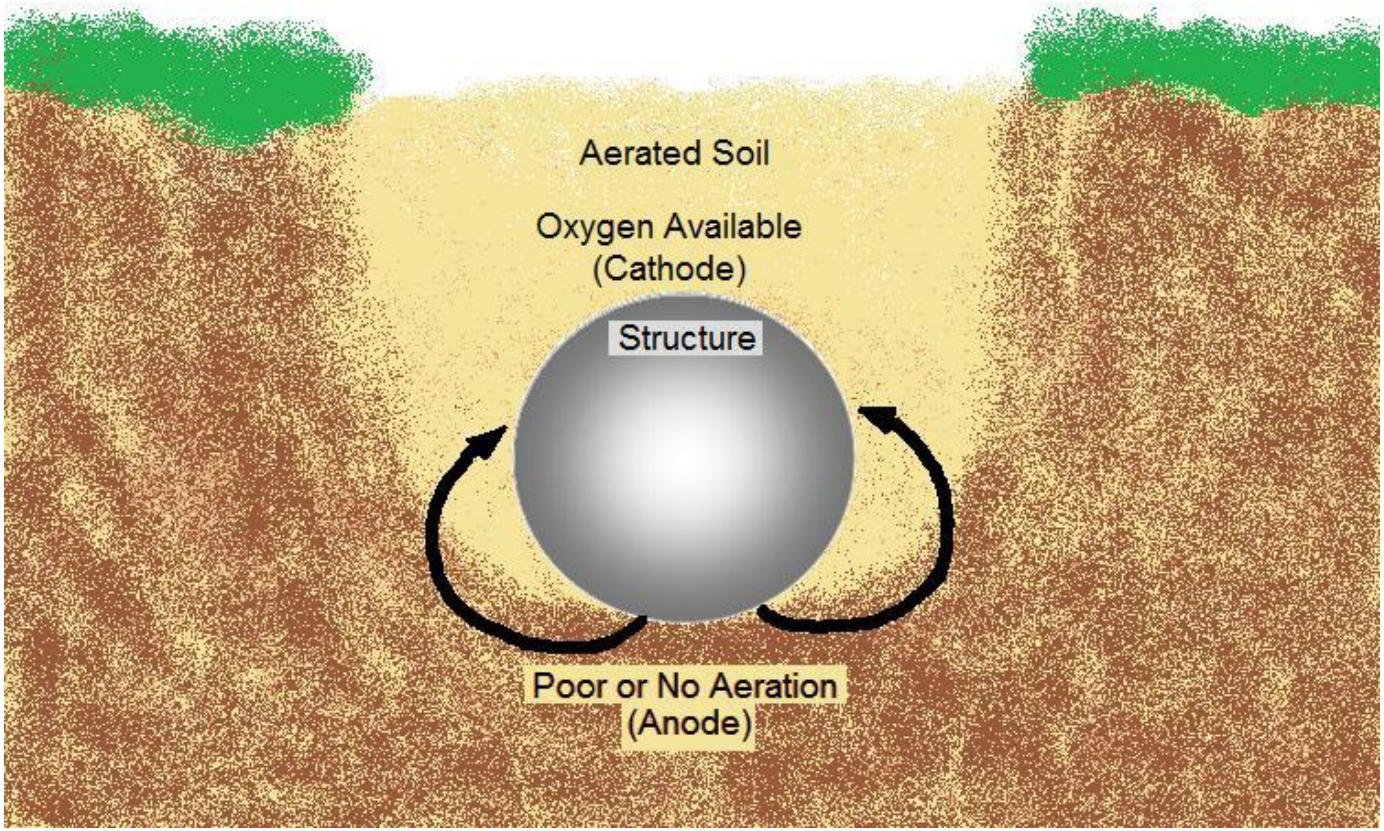
AUCSC

Appalachian Underground Corrosion Short Course

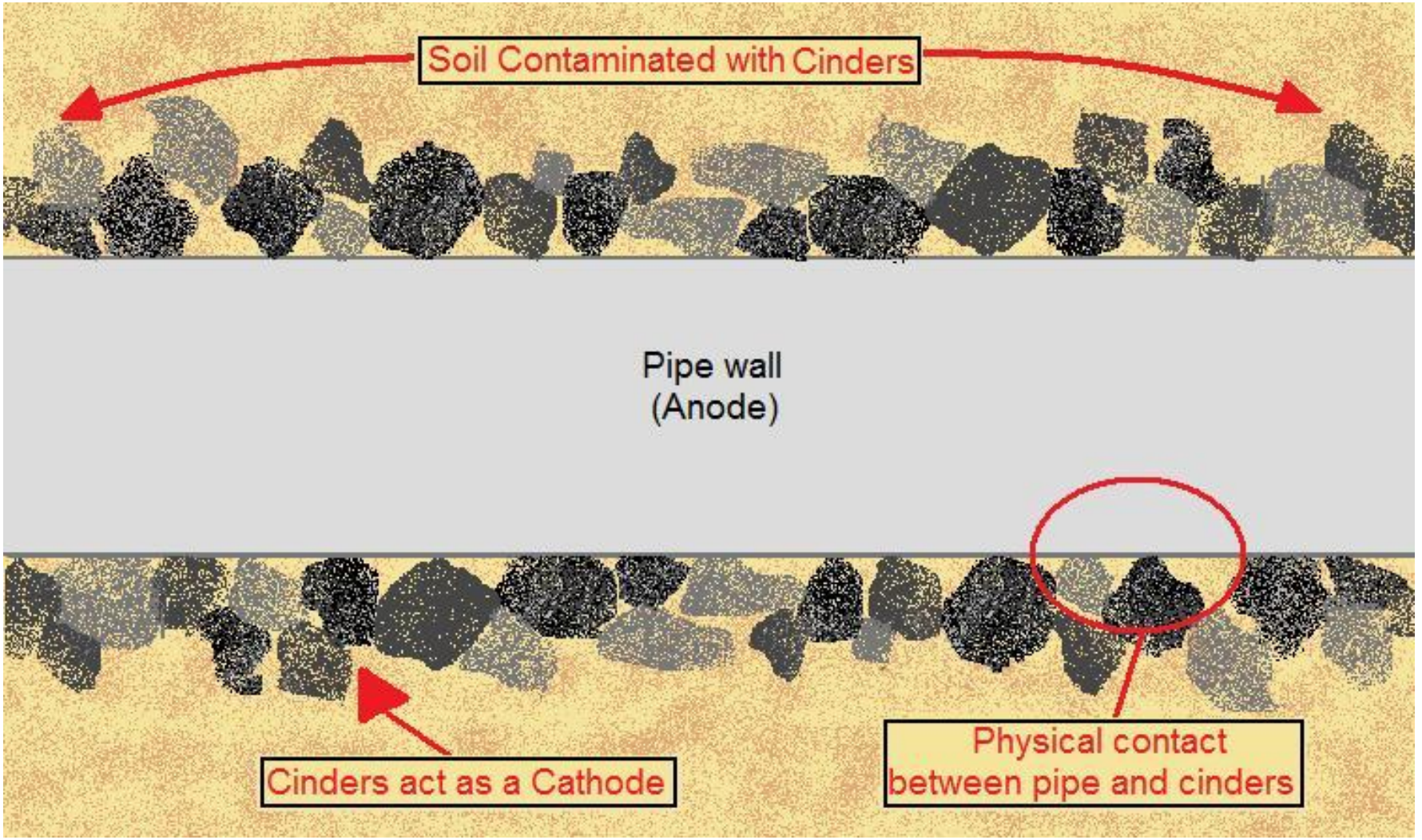
Different Aeration



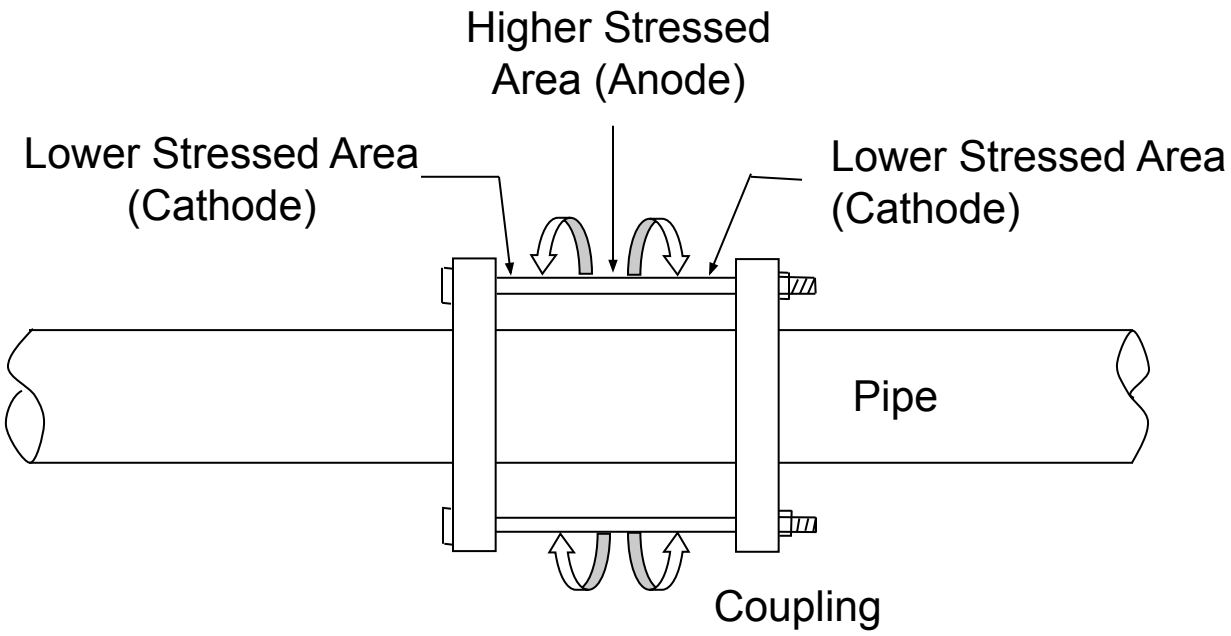
Different Aeration



Cinders

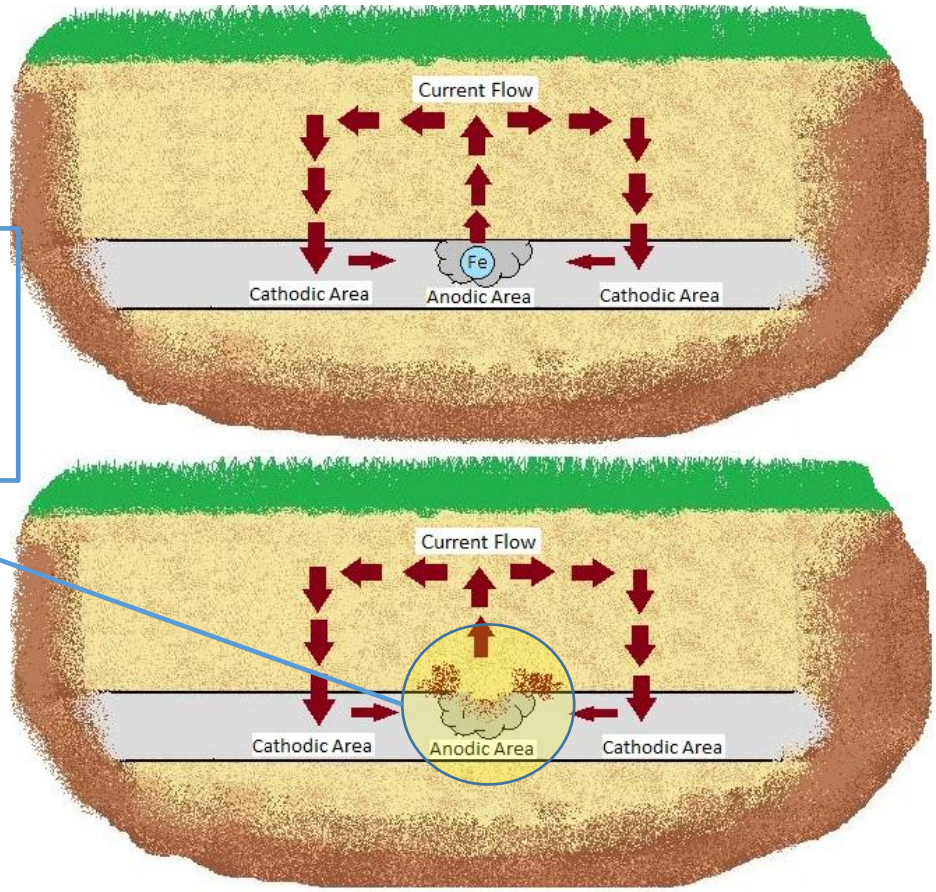

Soil Contaminated with Cinders
Pipe wall
(Anode)
Cinders act as a Cathode
Physical contact
between pipe and cinders

Stress Points



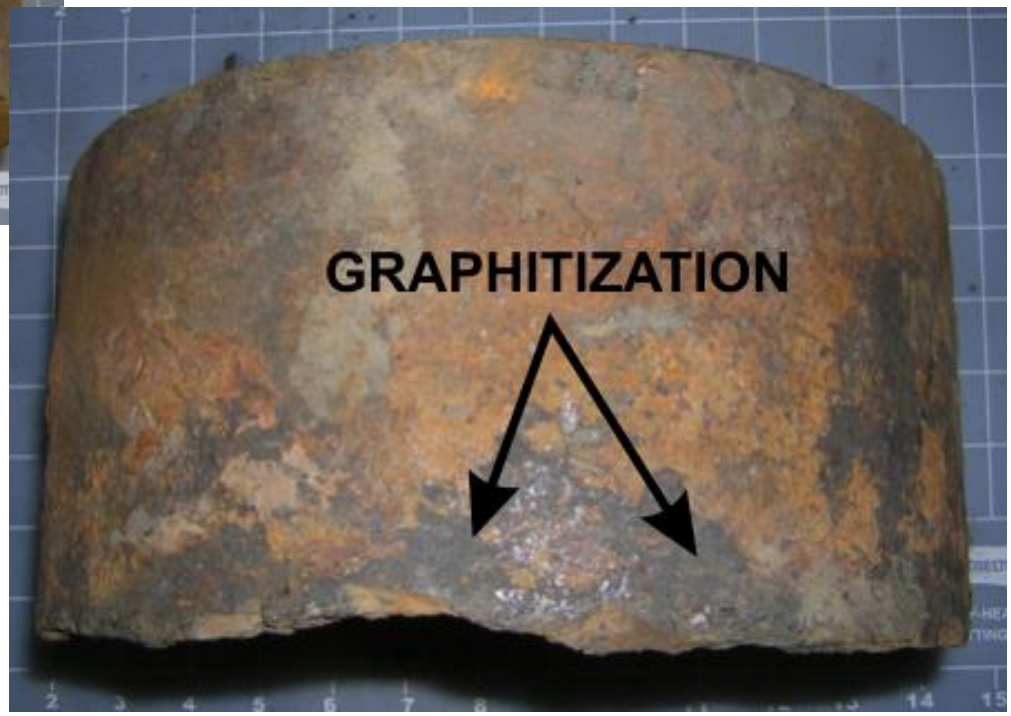
The Big Picture

Reaction happens here, at the anode/cathode interface



Graphitization

Grey blotchy areas



Can also lead to inner granular cracking (separation between the grains)

AUCSC

Appalachian Underground Corrosion Short Course

Microbiologically Influenced Corrosion (MIC)

Identified by: white pasty material; turns light brown when exposed to the air

- Black, flaky substance

Causes: Old pieces of rope, rags, wood, leaves: organic material in contact with metal

AUCSC

Appalachian Underground Corrosion Short Course

Microbiologically Influenced Corrosion (MIC)

- Can occur internally and externally.
- Mitigated internally: use of chemical inhibitors, added to the gas stream, or by removing the water from the system.
- Mitigated externally: certain types of coatings, or CP with potentials over 1.5 volts.

Microbiologically Influenced Corrosion (MIC)

Two types:
Acid Producing Bacteria (APB)
Sulfur Reducing Bacteria (SRB)

Unique pitting of metal:
Step wise pitting
Smooth “Thumb print” pitting
Worm hole pitting

The bacteria does not eat the pipe, but rather their waste by products, when mixed with water can create acids- which dissolve the metal.

Stray Current

Stray Current is current traveling a path in which it was not intended to go

Electricity Reminder:

- Current takes the path of least resistance
- Flows from positive to negative (conventional current)
- Returns to the source

Stray Current

Alternating current, is mainly a safety issue. AC can be induced from overhead high voltage power lines. A measured voltage over 15 volts AC, must be mitigated. Can be measured by setting meter on AC volts, and taking a structure to electrolyte reading.

Direct current, is a large concern to the corrosion person. Due to the fact that 1 ampere leaving a steel structure, removes 20 pounds of iron per year. DC stray currents can be a rather large amount. There is two types of DC stray current, **static** or steady state and **dynamic** or fluctuating current.

Example:
2 amps per year
2amps X 20 pounds = 40 pounds lost
Times 3 years = 120 pounds of lost iron
6 inch pipe weights 18.974 pounds per foot

Stray Current

Sources: Man-Made and/or Natural

Dynamic Stray Current

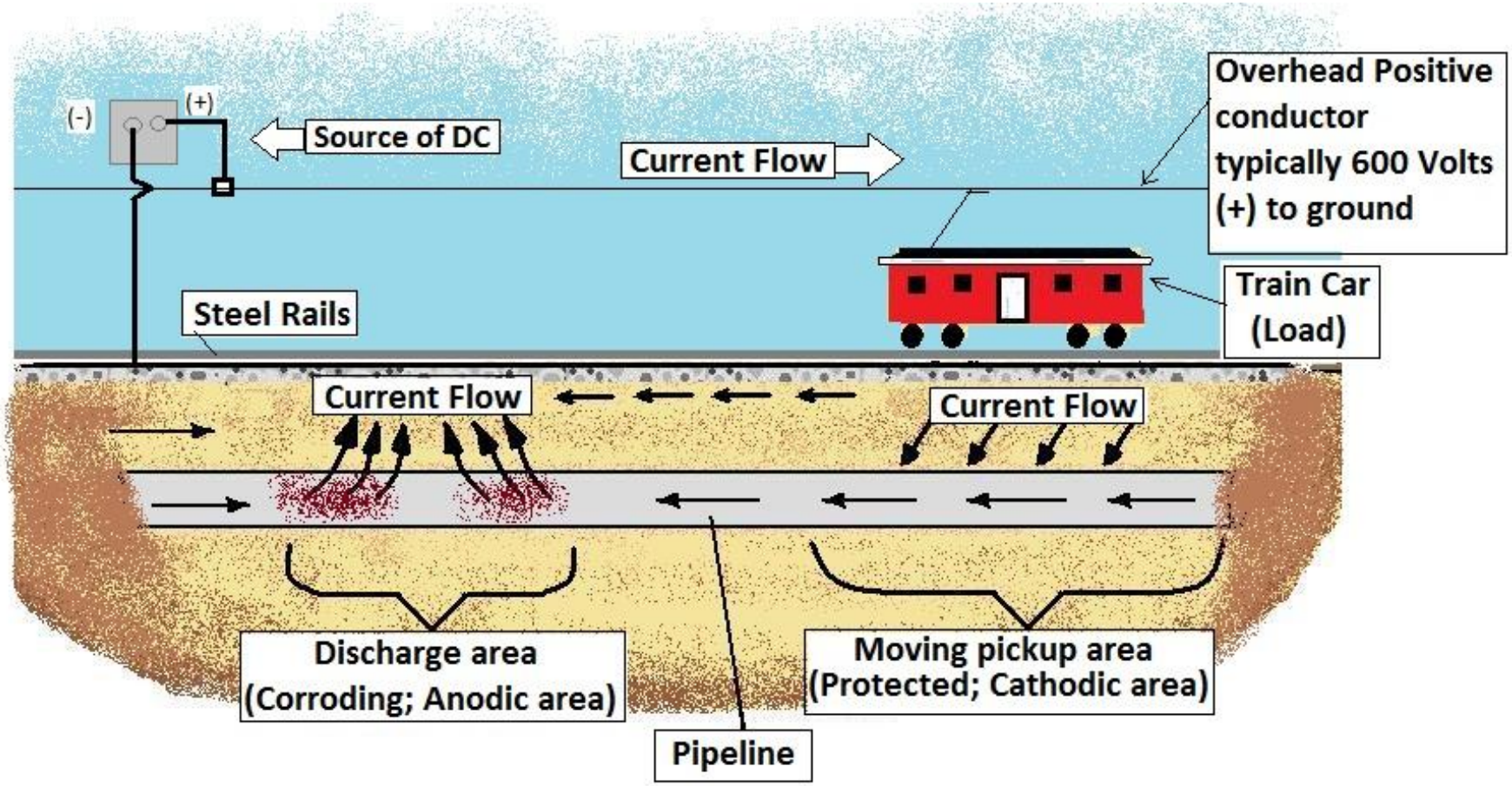
- Electrified railroads/Transit systems
- Underground mine railroads
- High Voltage AC Transmission Lines
- Telluric Currents

Steady State Stray Current

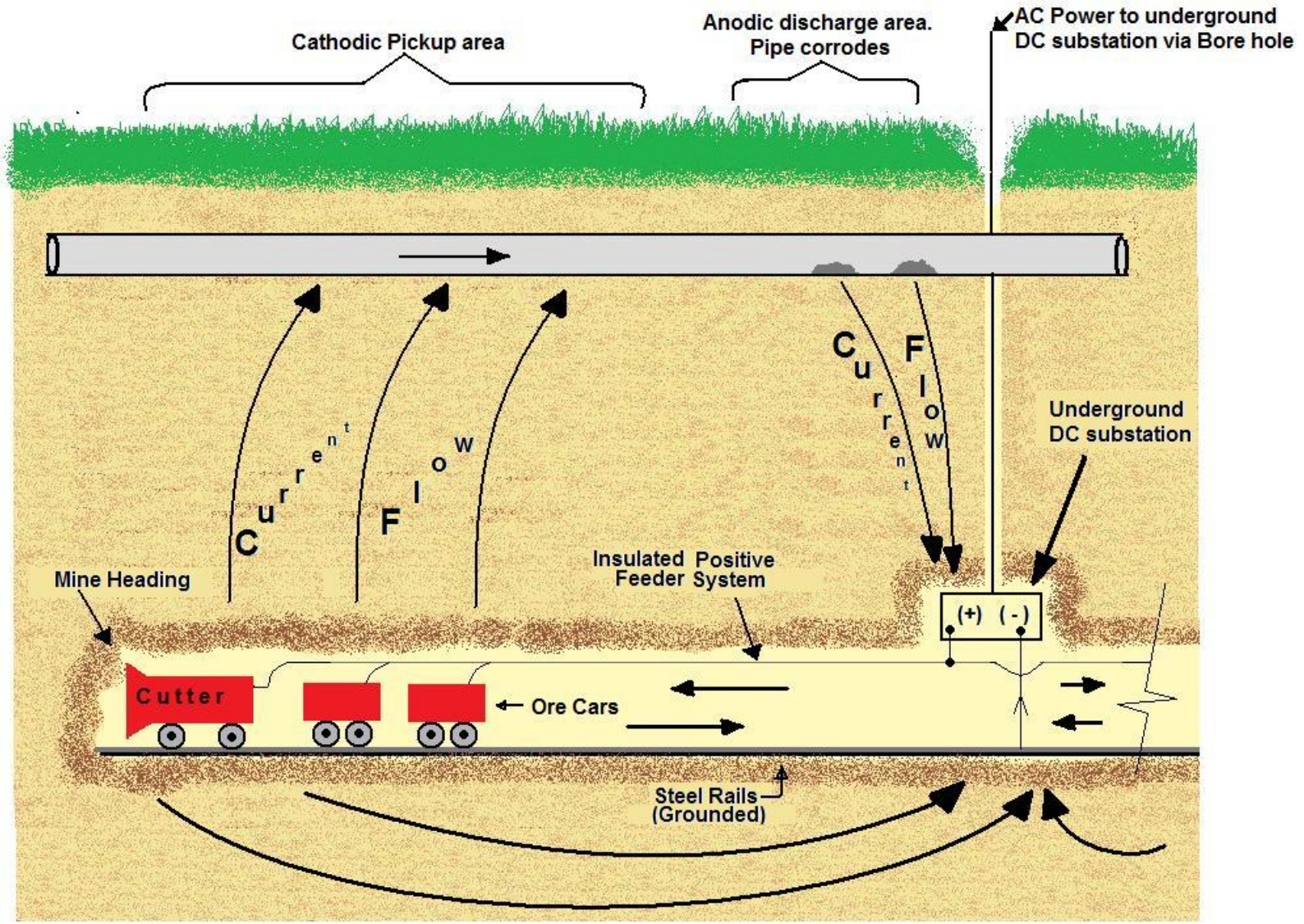
- Impressed Current Cathodic Protection
- High Voltage DC Transmission Lines

1 Ampere removes 20 pounds of iron per year, from structure

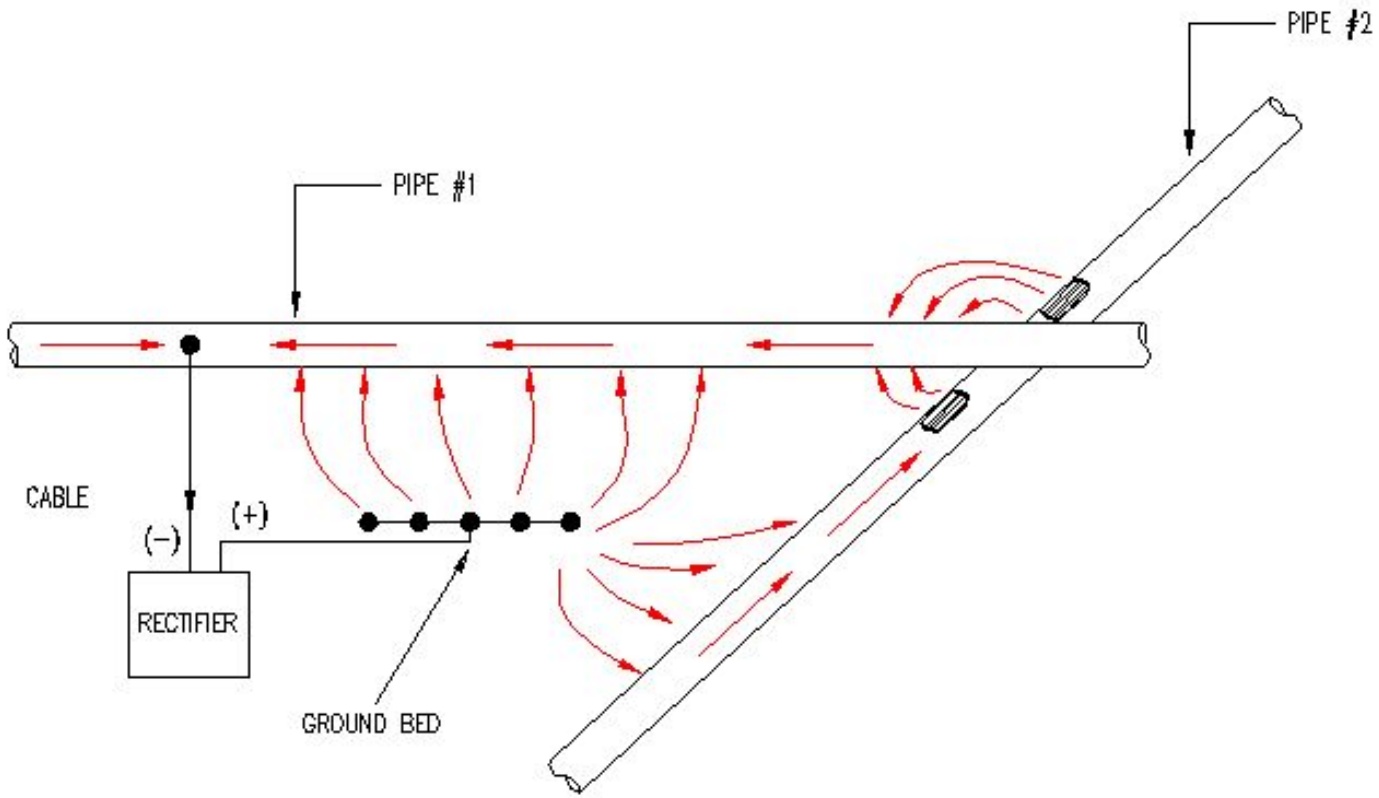
Dynamic Stray Current



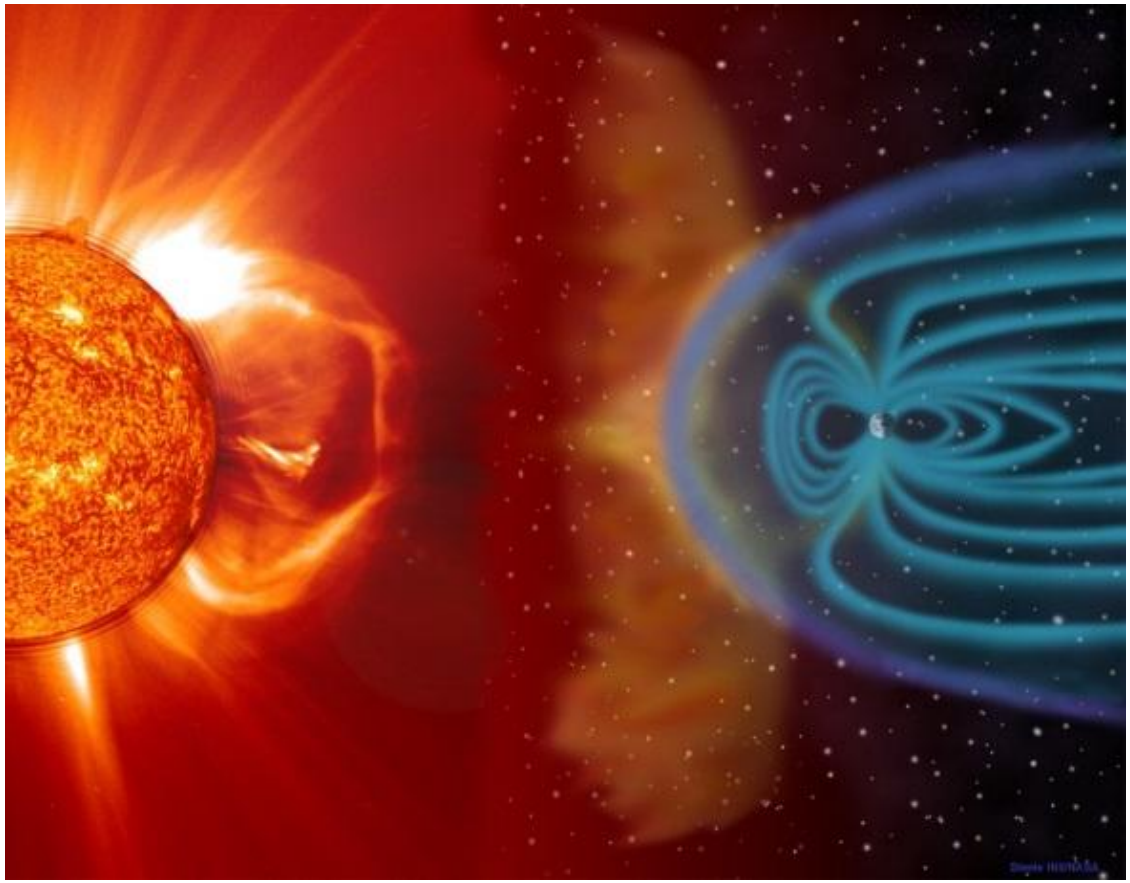
Dynamic Stray Current



Steady State (Static) Current



Telluric Currents



AUCSC

Appalachian Underground Corrosion Short Course

Rate of Corrosion

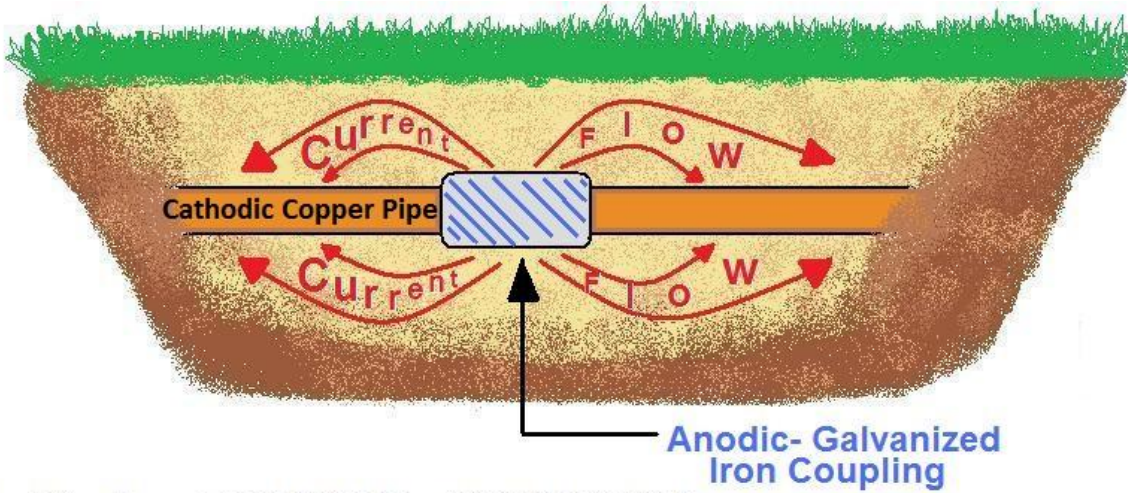
Factors Effecting Rate of Corrosion:

- Soil Resistivity
- Anode/Cathode Ratio
- Potential Difference between
- Polarization

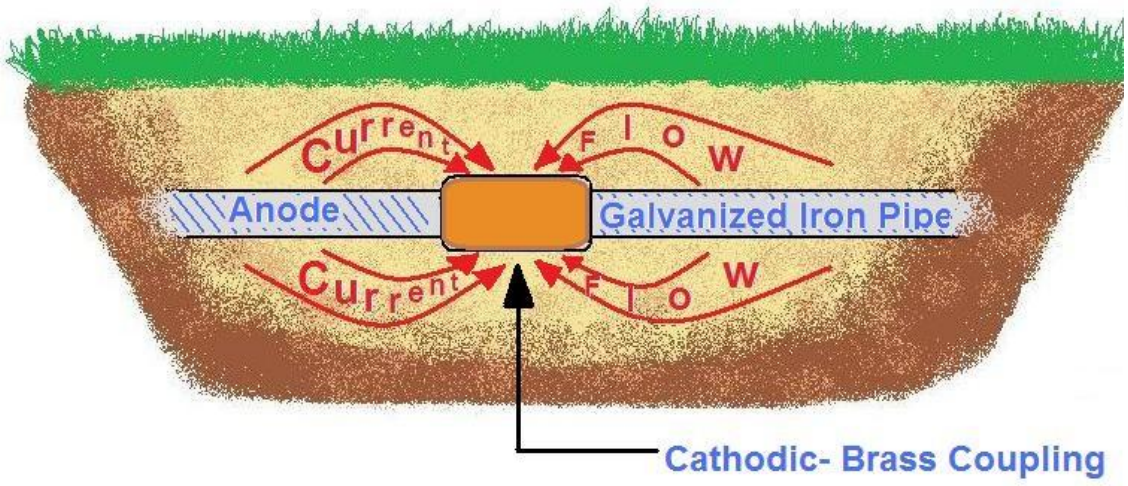
Soil Resistivity

Below 500 ohm-cm	Very Corrosive
500 to 1000 ohm-cm	Corrosive
1000 to 2000 ohm-cm	Moderate Corrosive
2000 to 10,000 ohm-cm	Mildly corrosive
10,000 ohm-cm and above	Progressively less Corrosive

Anode to Cathode Ratio



Small Anode + Large Cathode = intense corrosion



Large Anode + Small Cathode = less intense corrosion

Small Anode vs Large Cathode

current discharge is concentrated in smaller area resulting in more severe material loss

Potential Difference

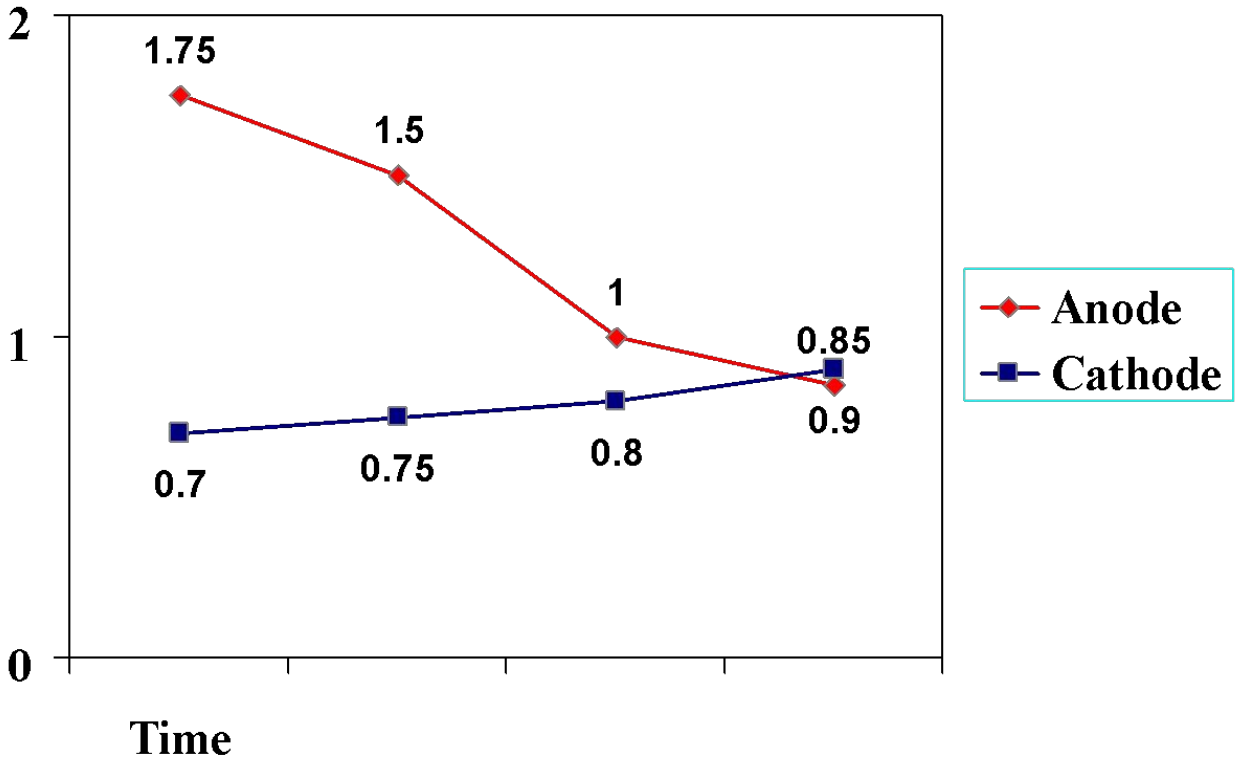
Active (More Electro-Negative)

- High Potential Magnesium (-1.75 v)
- Magnesium Alloy (-1.5 v)
- Zinc (-1.1 v)
- Aluminum Alloys (-1.05 v)
- Clean Carbon Steel (-0.5 to -0.8 v)
- Rusted Carbon Steel (-0.2 to -0.8 v)
- Lead (-0.5 v)
- Copper (-0.2 v)
- High Silicon Iron (-0.2 v)
- Gold (+0.2V)
- Graphite, Carbon (+0.3v)

Noble (More Electro-Positive

Polarization

High Potential Magnesium	-1.75 Volts
Clean Carbon Steel	-0.50 to –0.80 Volts



Questions???

Heather Groll
AMPP
Heather.Groll@ampp.org