Fundamentals Course

Basic Corrosion

Fundamental introduction and theory behind the corrosion process

Presented By: Heather Groll

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Appalachian Underground Corrosion Short Course

What is Corrosion?

CORROSION

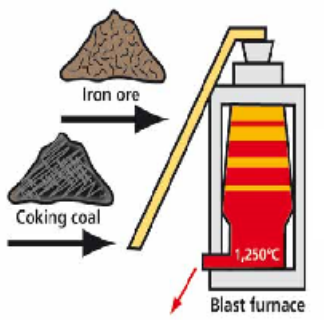
THE DETERIORATION OF A MATERIAL, USUALLY A METAL, DUE TO A REACTION WITH ITS ENVIRONMENT

OR

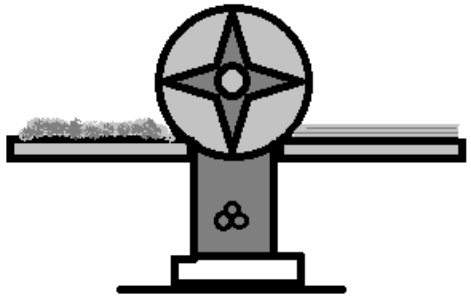
THE TENDENCY OF A REFINED METAL TO RETURN TO ITS NATURAL STATE AS AN ORE

What is Corrosion?

Iron Oxide Extracted from the Earth



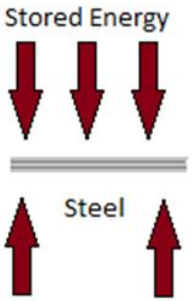
Refining Process



Milling Process

Steel

Steel



Steel
Corroding Away

Steel Returning back to its natural form as Iron Oxide

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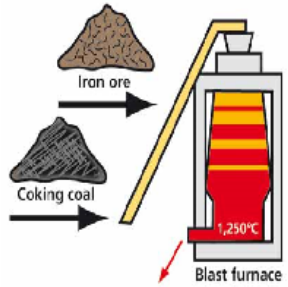
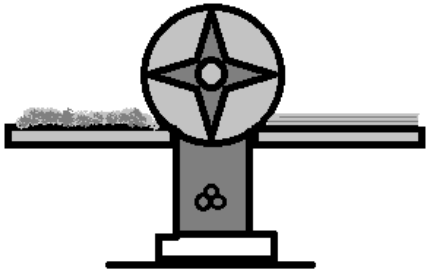
What is Corrosion?

Iron Oxide Extracted from the Earth



Refining Process



Milling Process

Steel

THE <u>DETERIORATION</u> OF A MATERIAL, DUE TO A <u>REACTION WITH ITS ENVIRONMENT</u>

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Types of Corrosion

Naturally Occurring Corrosion

- Dissimilar metals
- Dissimilar surface
- Dissimilar Soils
- Differential Aeration
- Cinders
- Stress
- Graphitization
- Microbiological Influenced Corrosion

Stray Current Corrosion: Man-Made and Natural

- Dynamic Stray Current
- Steady State Stray Current

What is a Corrosion Cell?

There are many different causes for corrosion. But for the pipelines that we work on, we are going to be a little more specific about certain types of corrosion. Corrosion cannot be present without these **four things**;

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

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

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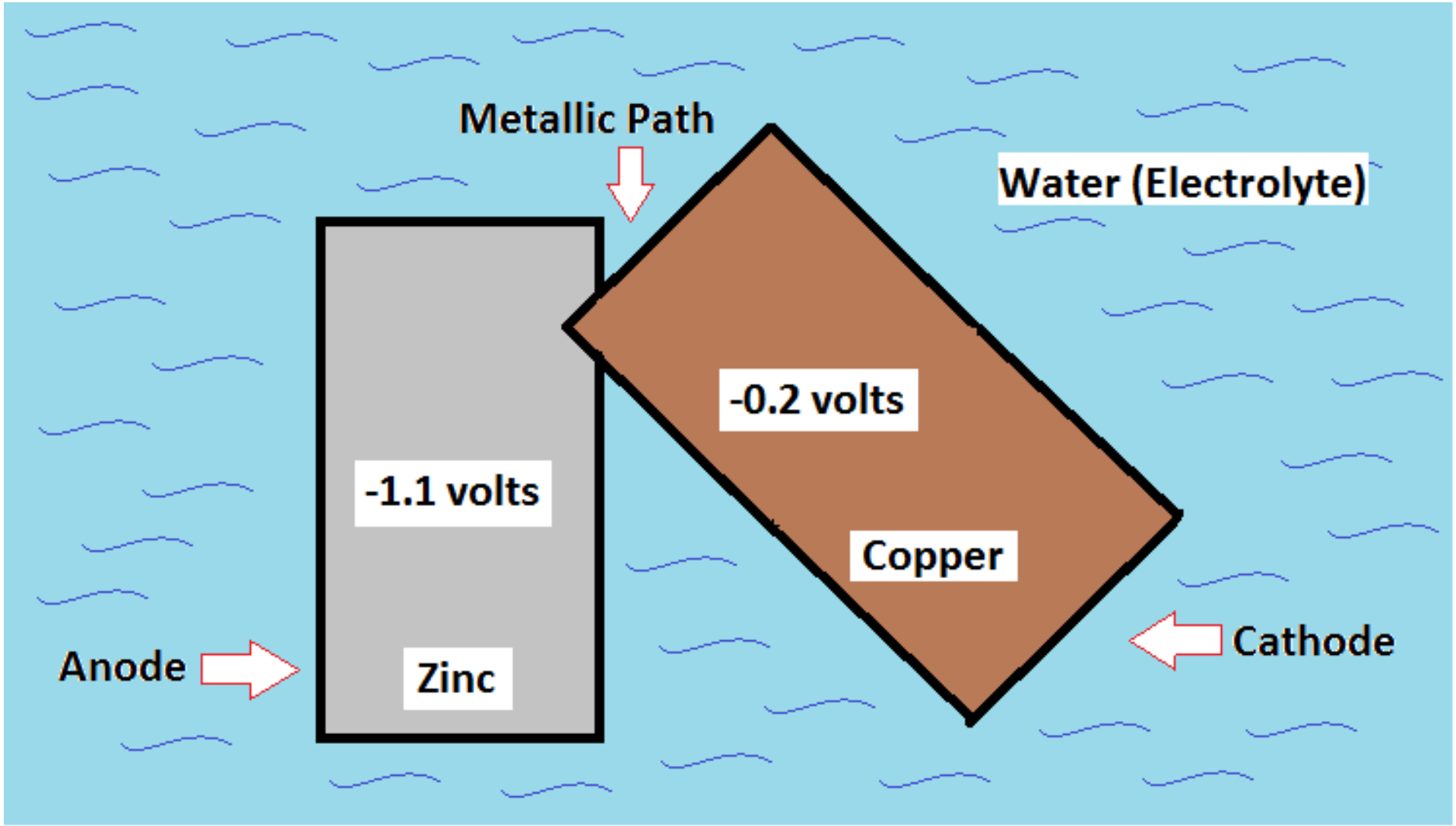
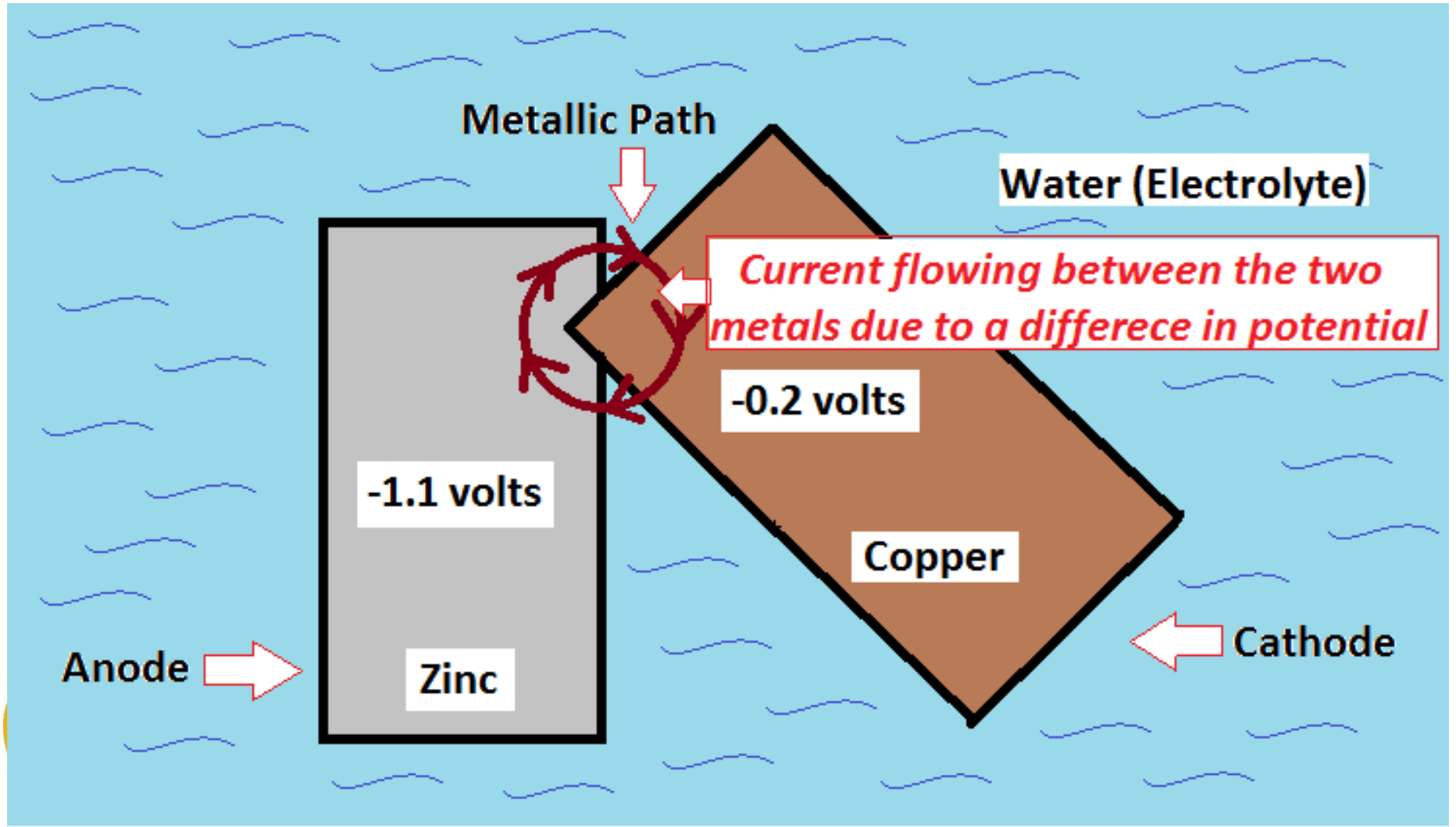
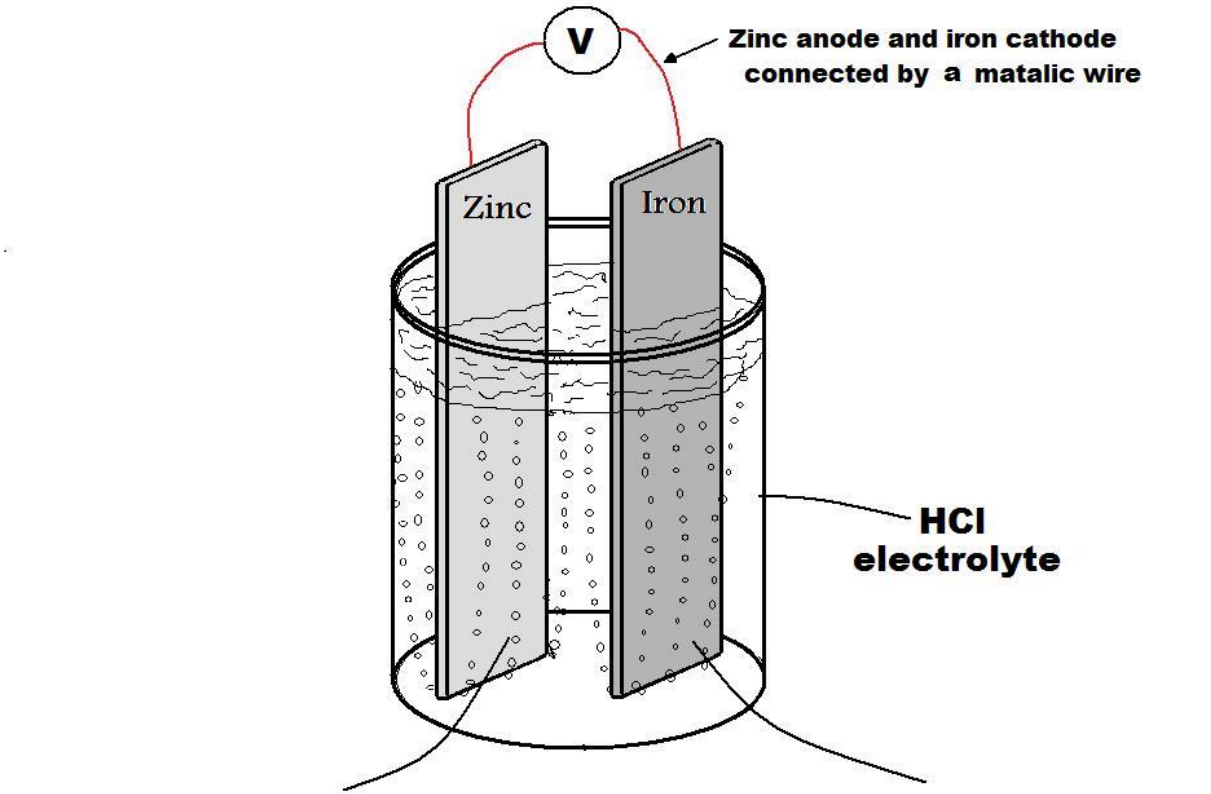
Defining an Anode and Cathode



Defining an Anode and Cathode



Defining an Anode and Cathode



Galvanic Series:
Defining an Anode and Cathode

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)
- Cast/Ductile Steel (-0.5 v)
- Lead (-0.5 v)
- Steel in Concrete (-0.2 v)
- Copper (-0.2 v)
- High Silicon Iron (-0.2 v)
- Gold (+0.2V)
- Graphite, Carbon (+0.3v)

Noble (More Electro-Positive)

(-)

(+)

* Potentials with respect to saturated Cu-$CuSO_4$ Electrode

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Dissimilar Metal Corrosion

Defining an Anode and Cathode

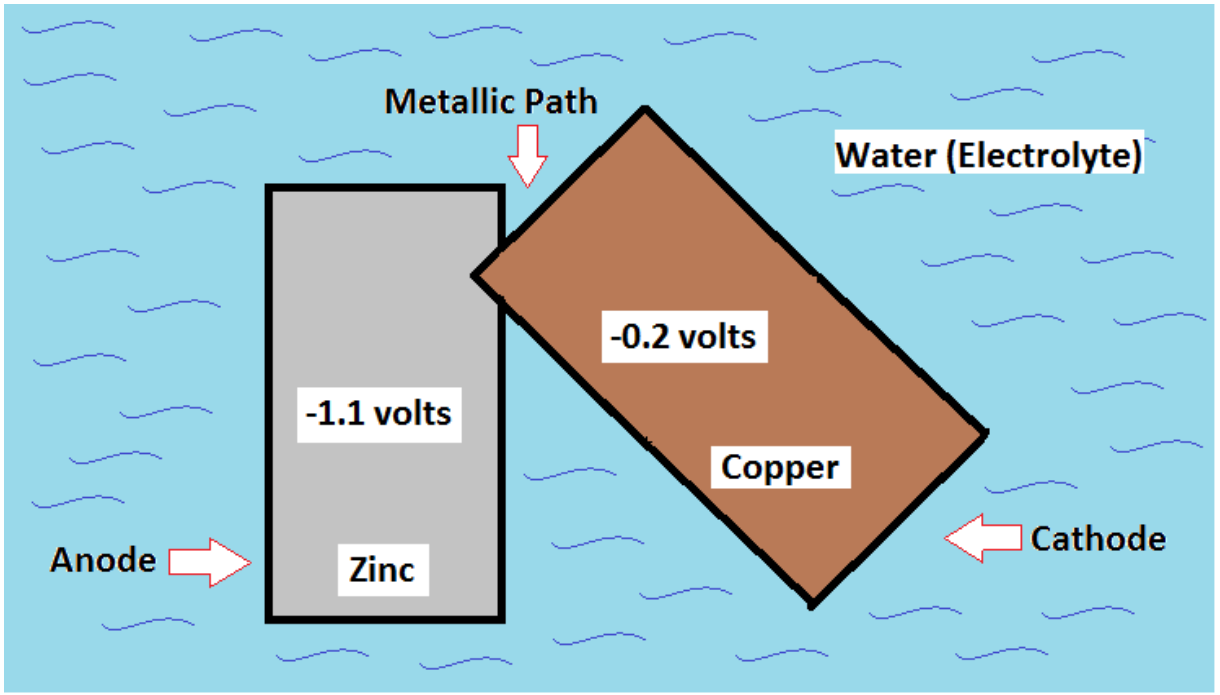
*Anode is more electro-negative than the cathode

*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)
- Cast/Ductile Steel (-0.5 v)
- Lead (-0.5 v)
- Steel in Concrete (-0.2 v)
- *Copper (-0.2 v)*
- High Silicon Iron (-0.2 v)
- Gold (+0.2V)
- Graphite, Carbon (+0.3v)

Noble (More Electro-Positive)



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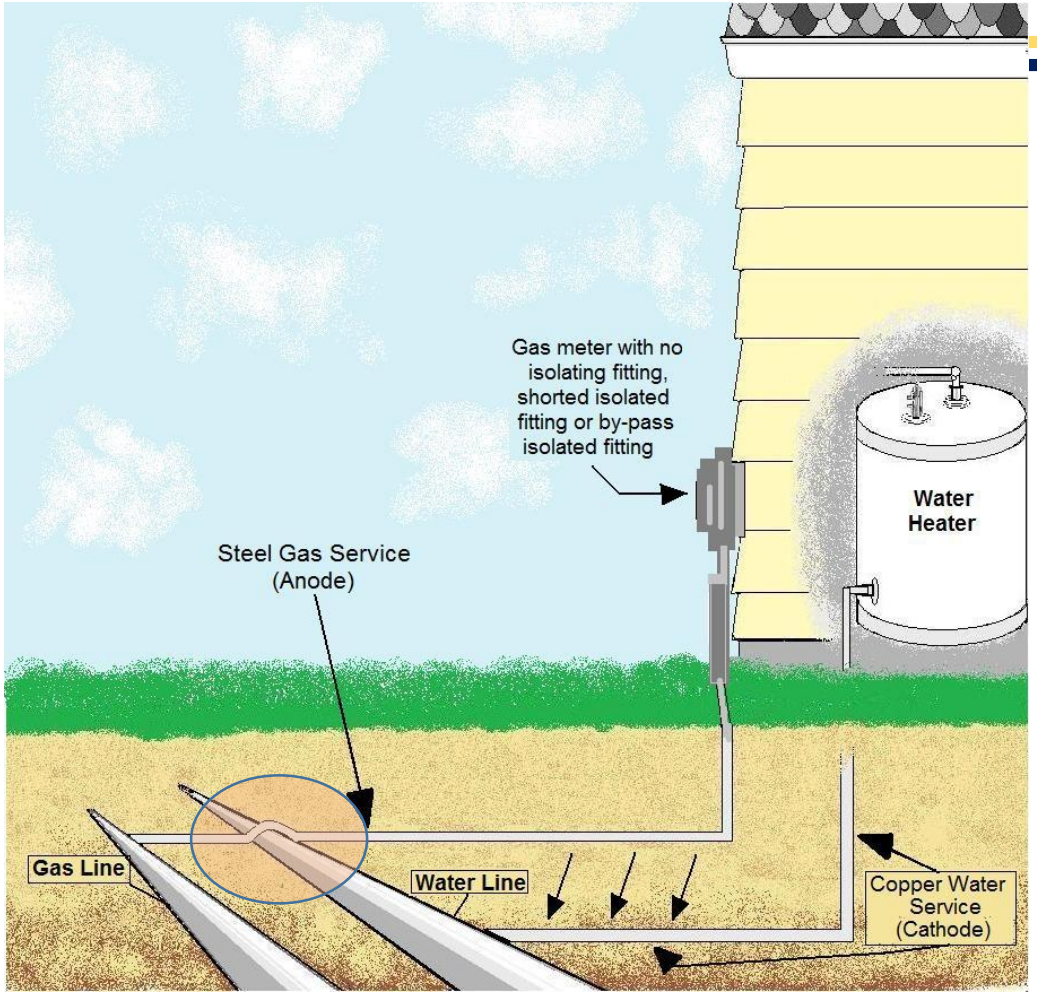
Dissimilar Metal Corrosion

Steel Gas Line and Copper Water Line



Active (More Negative)

- High Potential Magnesium (-1.75 v)
- Magnesium Alloy (-1.5 v)
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- *Clean Carbon Steel (-0.5 to -0.8 v)*
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- Lead (-0.5 v)
- Steel in Concrete (-0.2 v)
- *Copper (-0.2 v)*
- High Silicon Iron (-0.2 v)
- Gold (+0.2V)
- Graphite, Carbon (+0.3v)

Noble (More Positive)

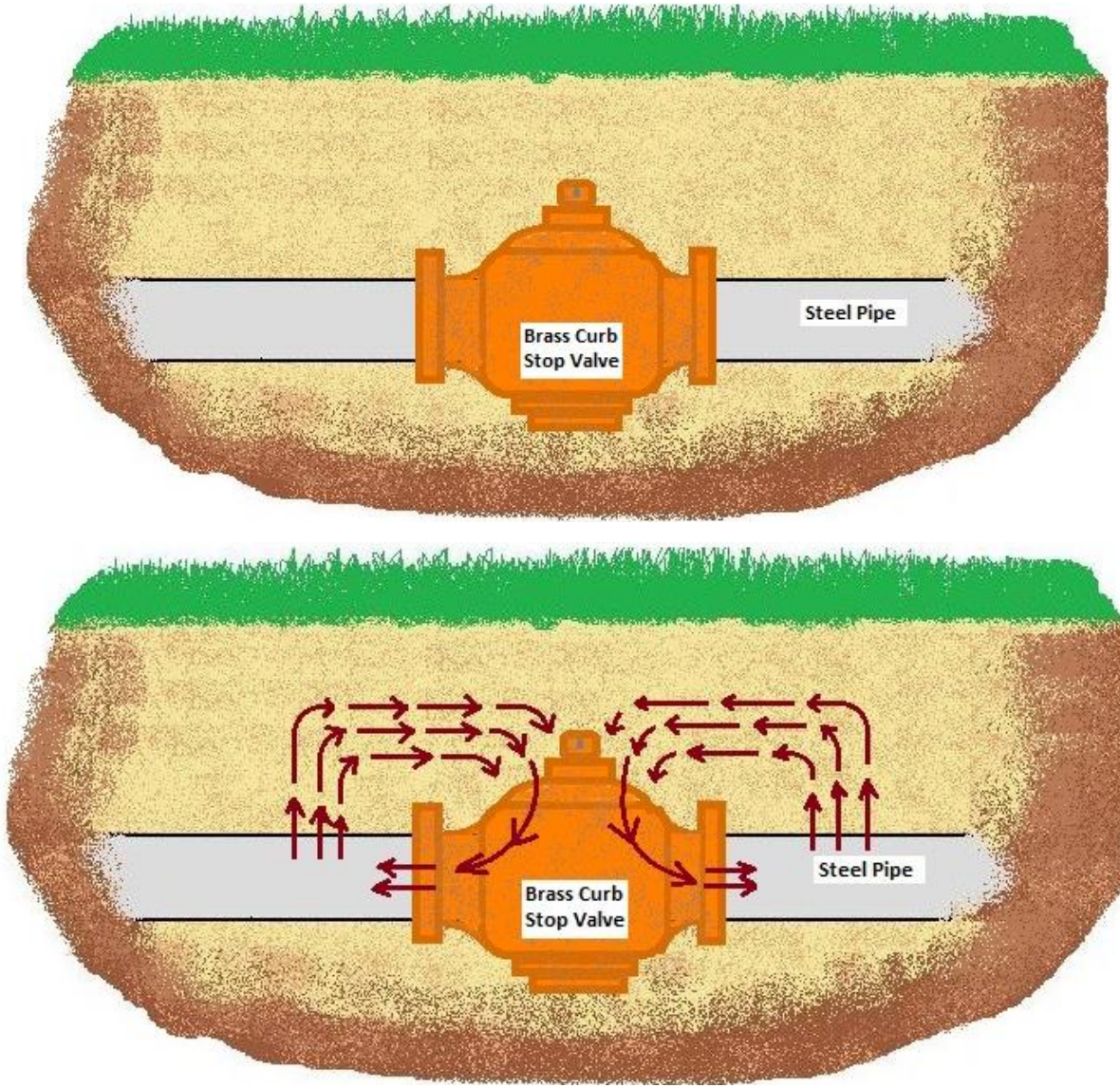
Dissimilar Metal Corrosion

Brass Stop in a Steel Line

Active (More 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)
- Cast/Ductile Steel (-0.5 v)
- Lead (-0.5 v)
- Steel in Concrete (-0.2 v)
- *Brass (-0.2 v)*
- Copper
- High Silicon Iron (-0.2 v)
- Gold (+0.2V)
- Graphite, Carbon (+0.3v)

Noble (More Positive)



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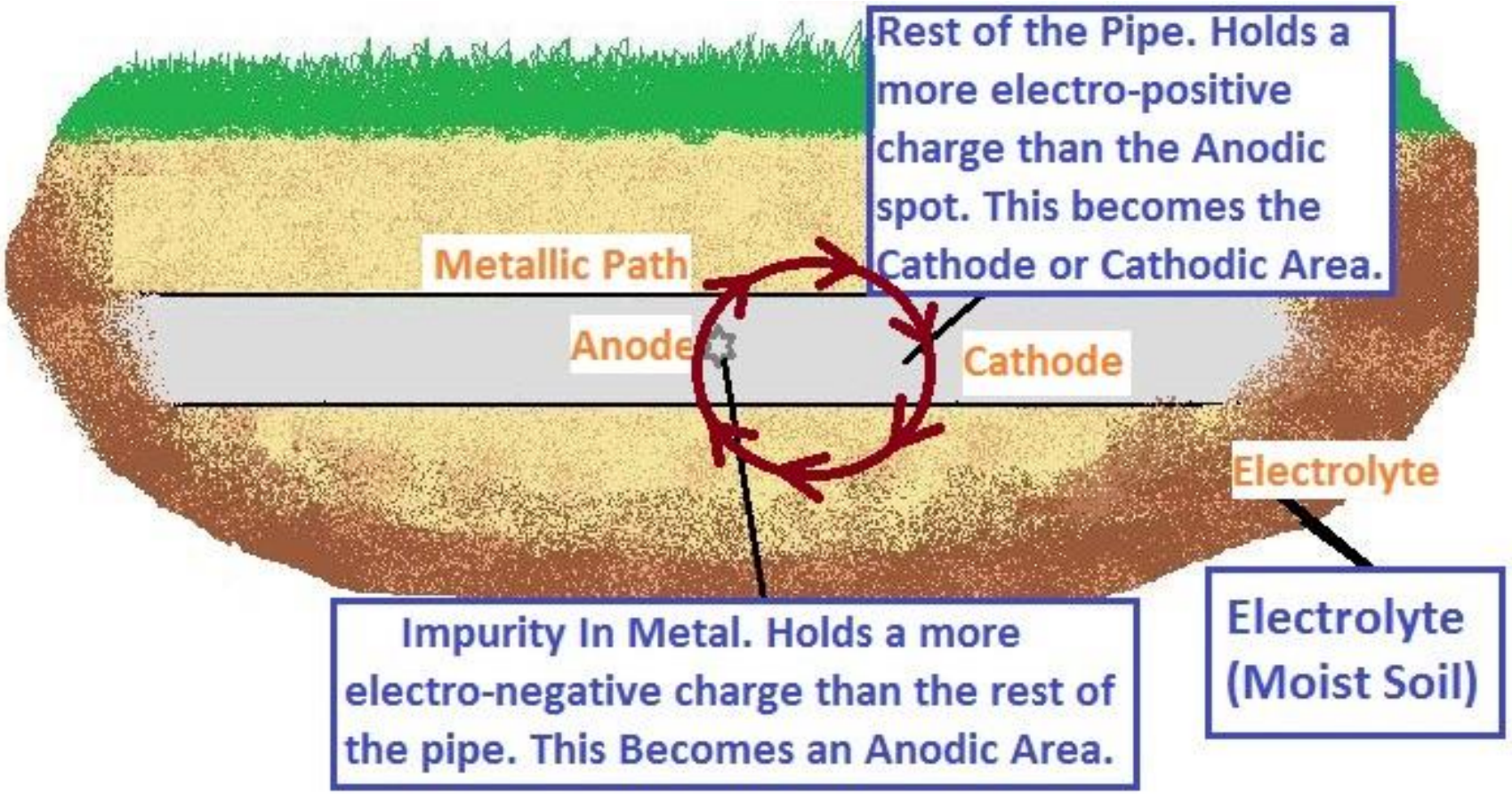
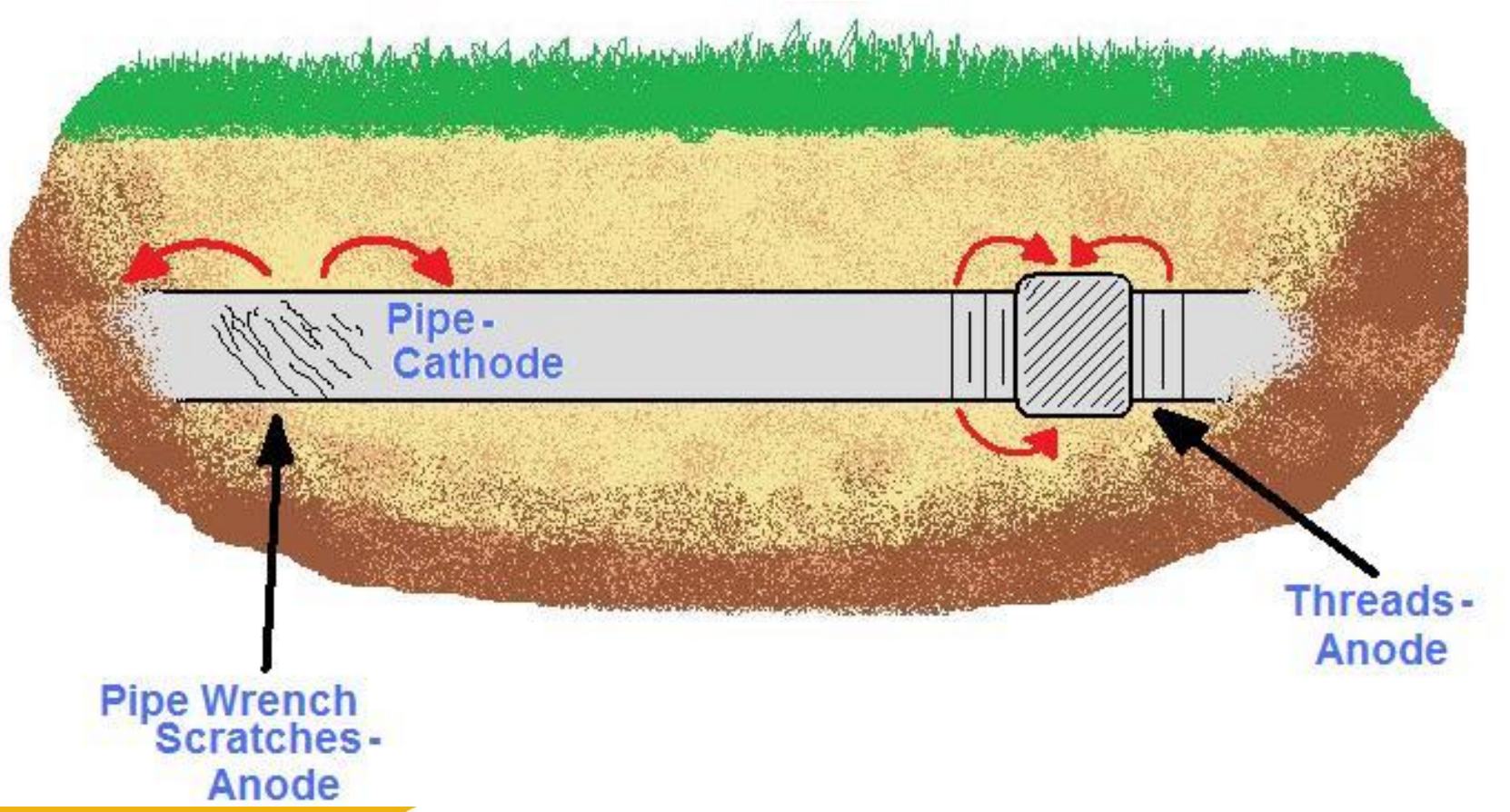
Corrosion caused by Dissimilarity of Surface Conditions



Corrosion caused by Dissimilarity of Surface Conditions



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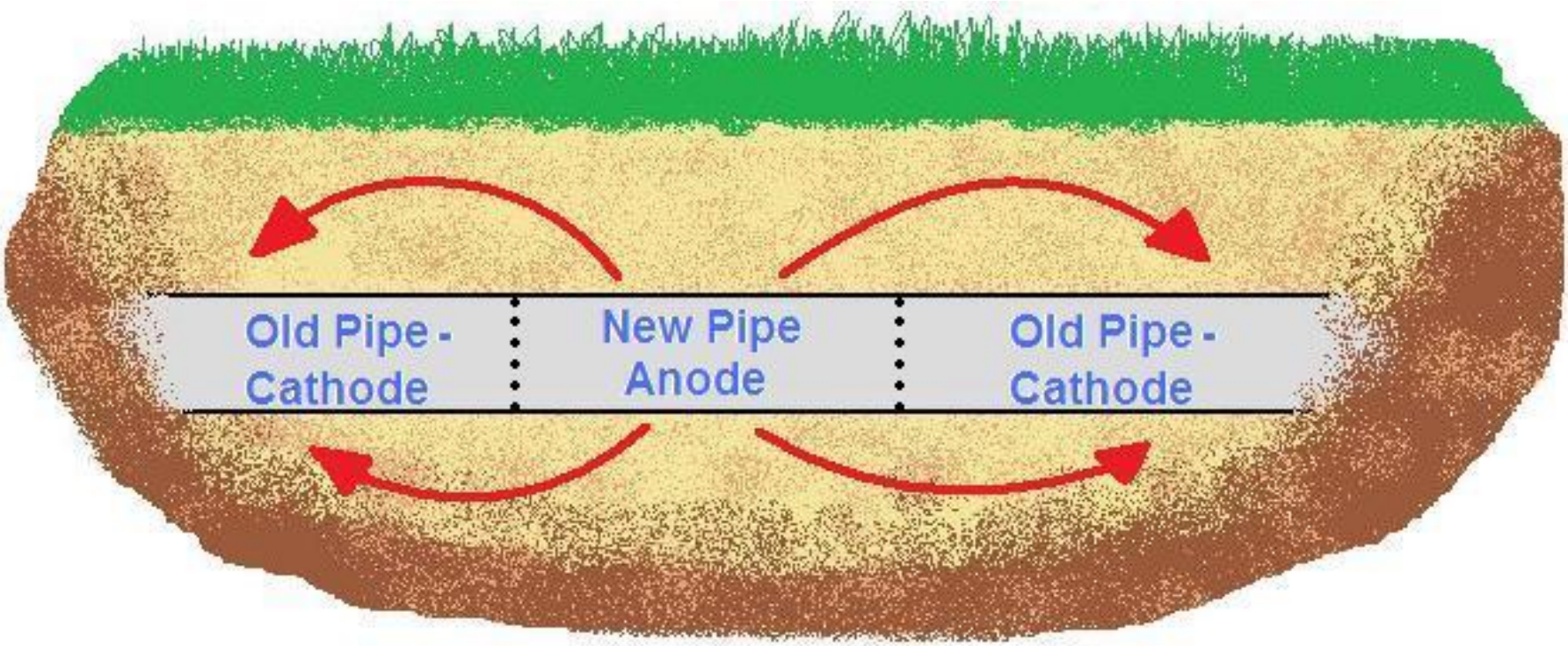
New-Old Pipe Corrosion Cell



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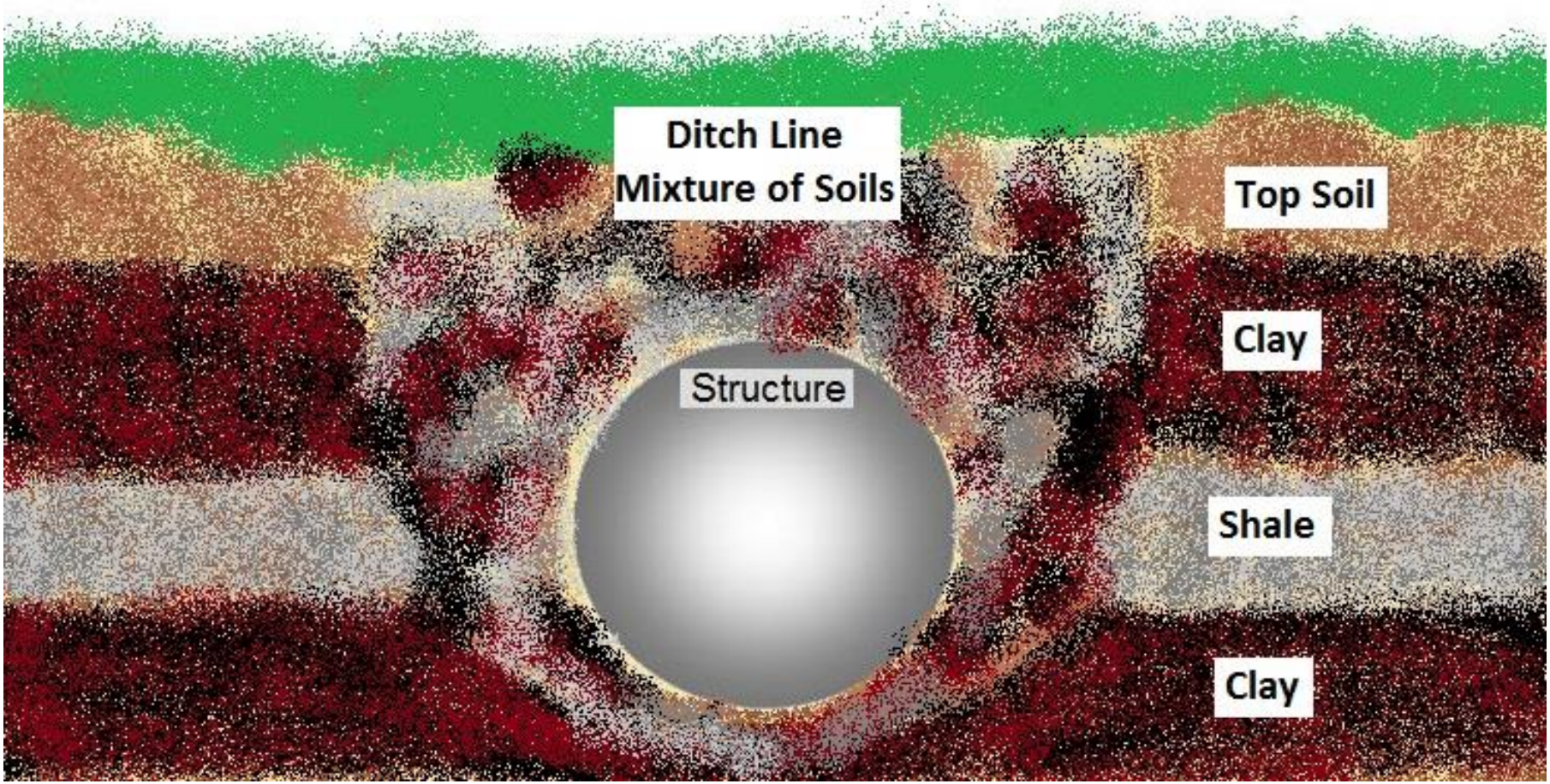
Corrosion caused by Mixture of Different Soils



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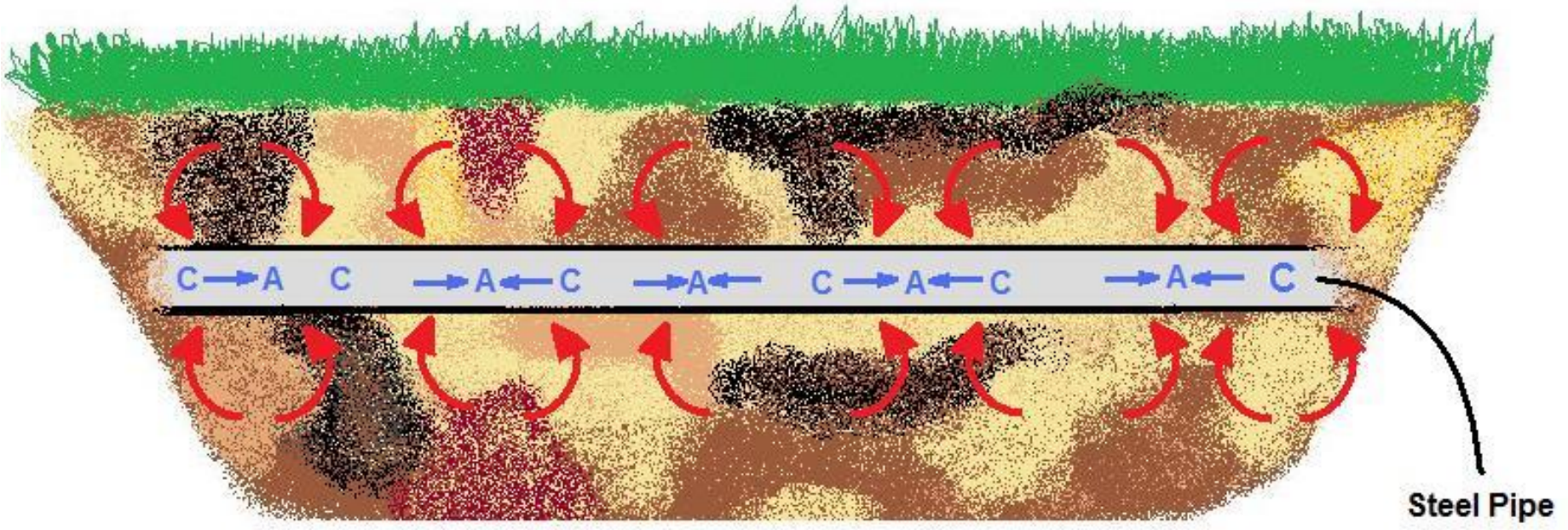
Corrosion caused by Mixture of Different Soils



A= Anodic Areas

C= Cathodic Areas

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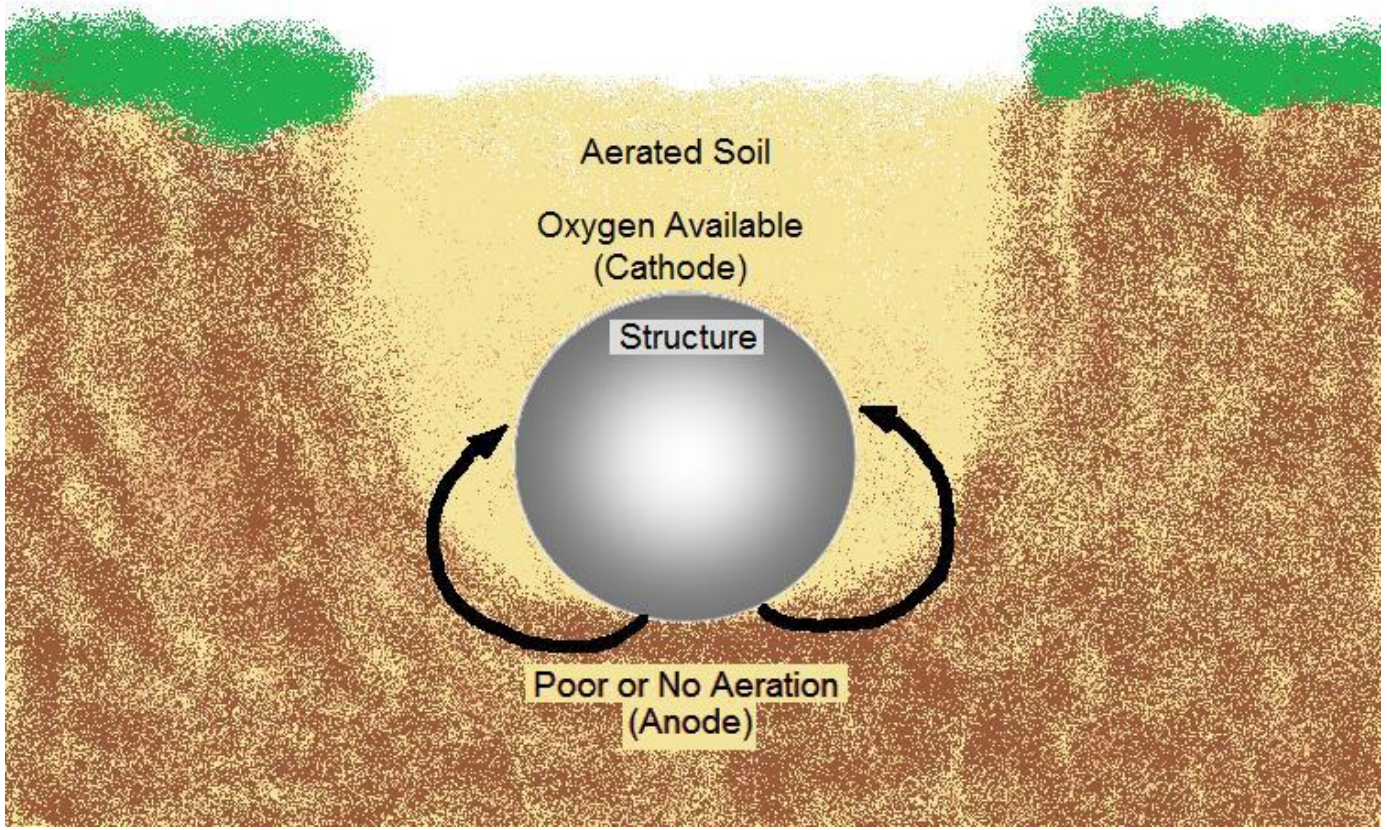
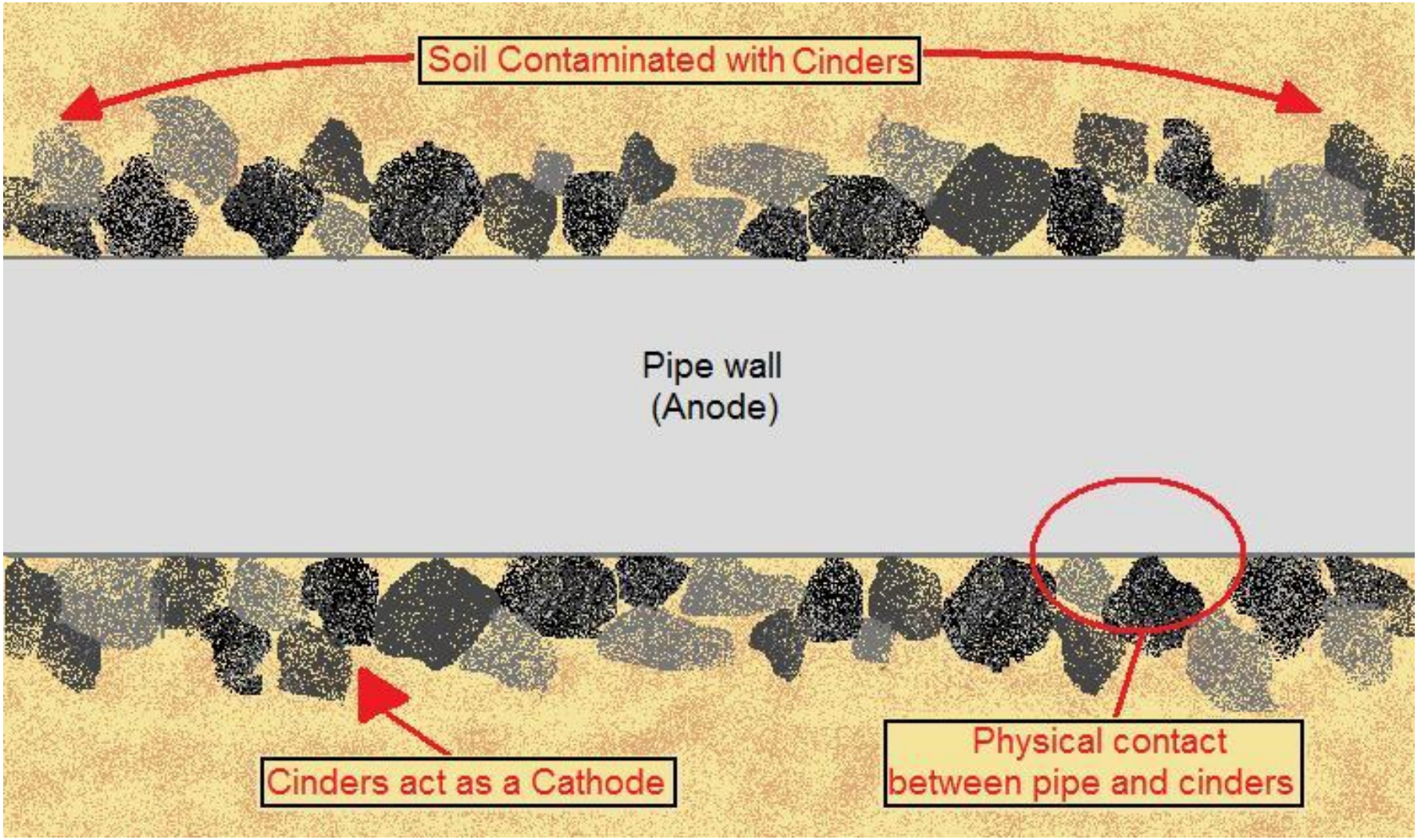
Corrosion caused by Differential Aeration of Soil

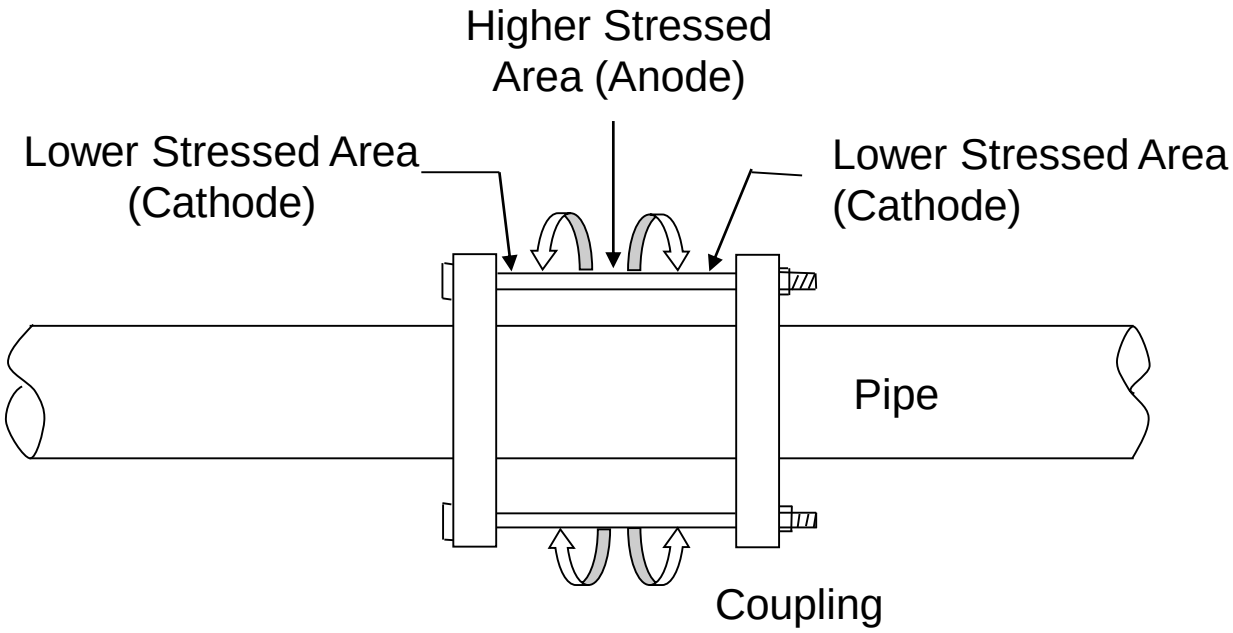


Corrosion due to cinders

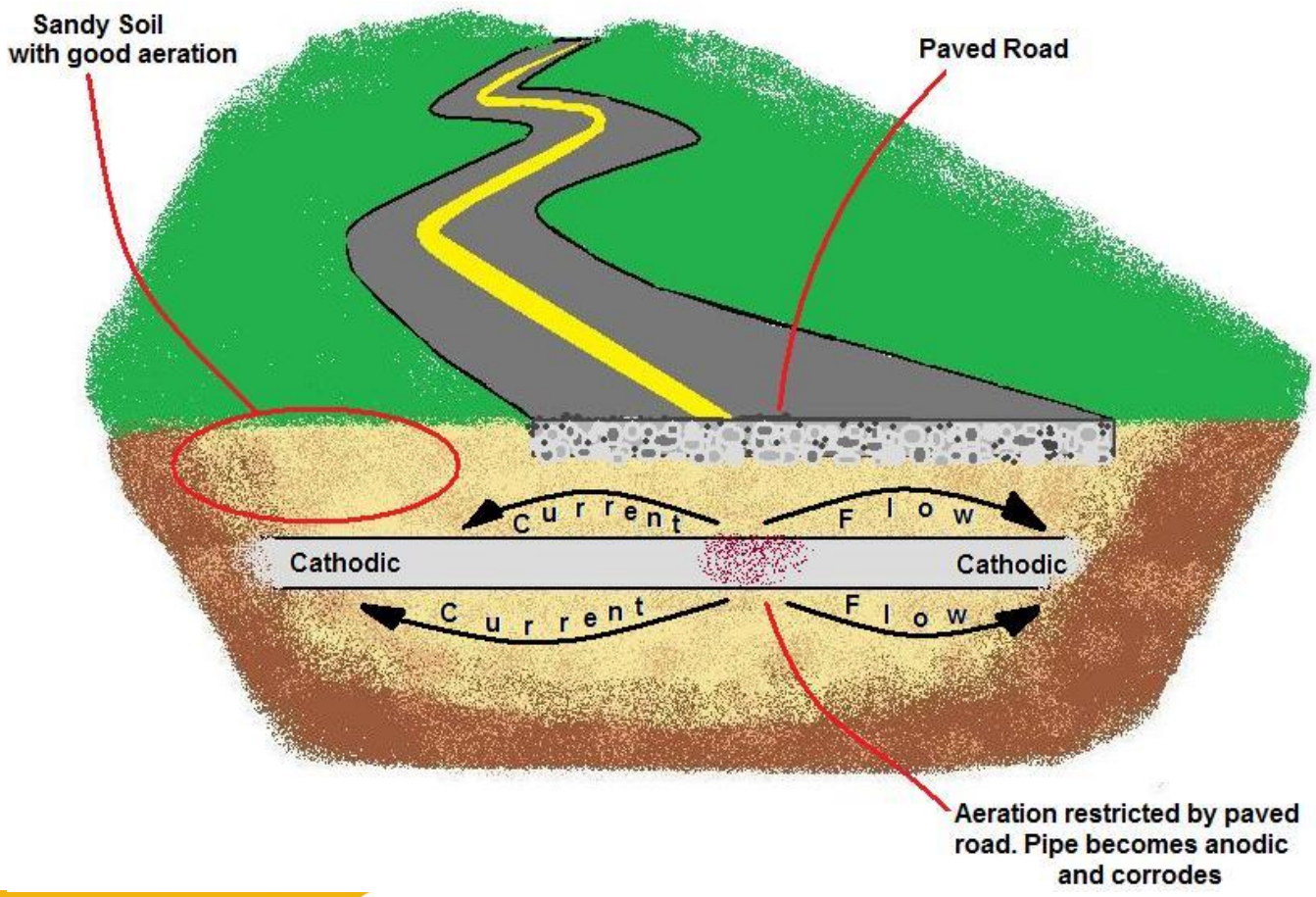
Physical contact between Pipe and Cinders

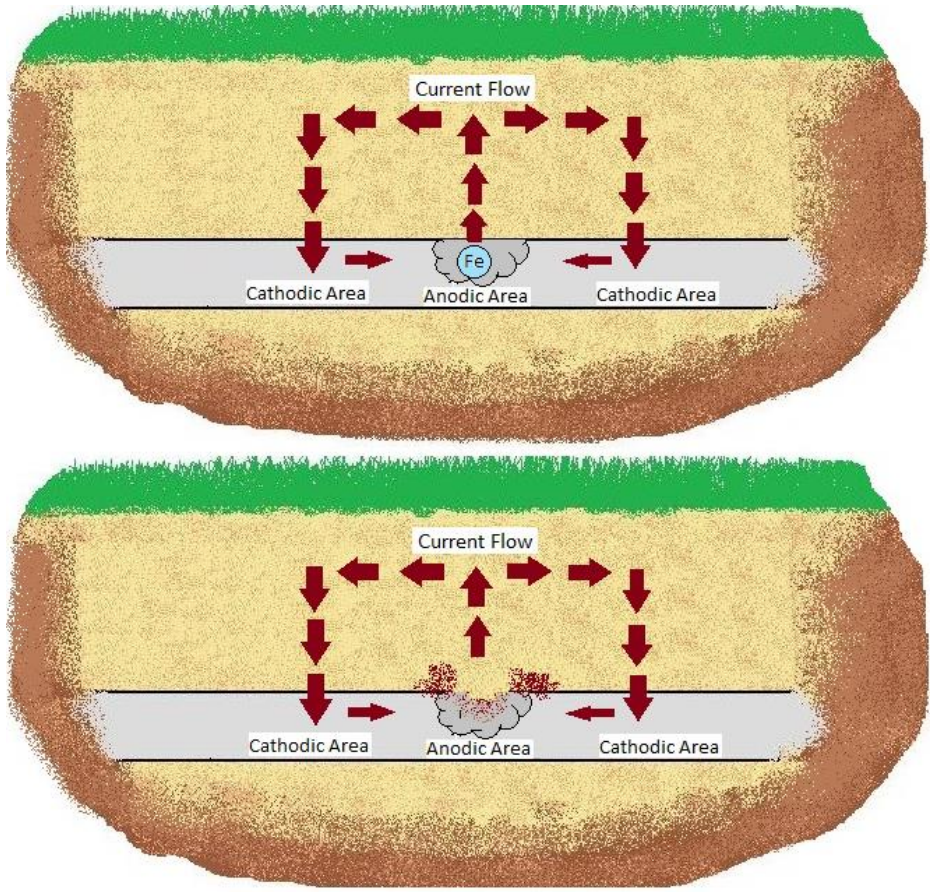


Stress Corrosion



Stress Corrosion





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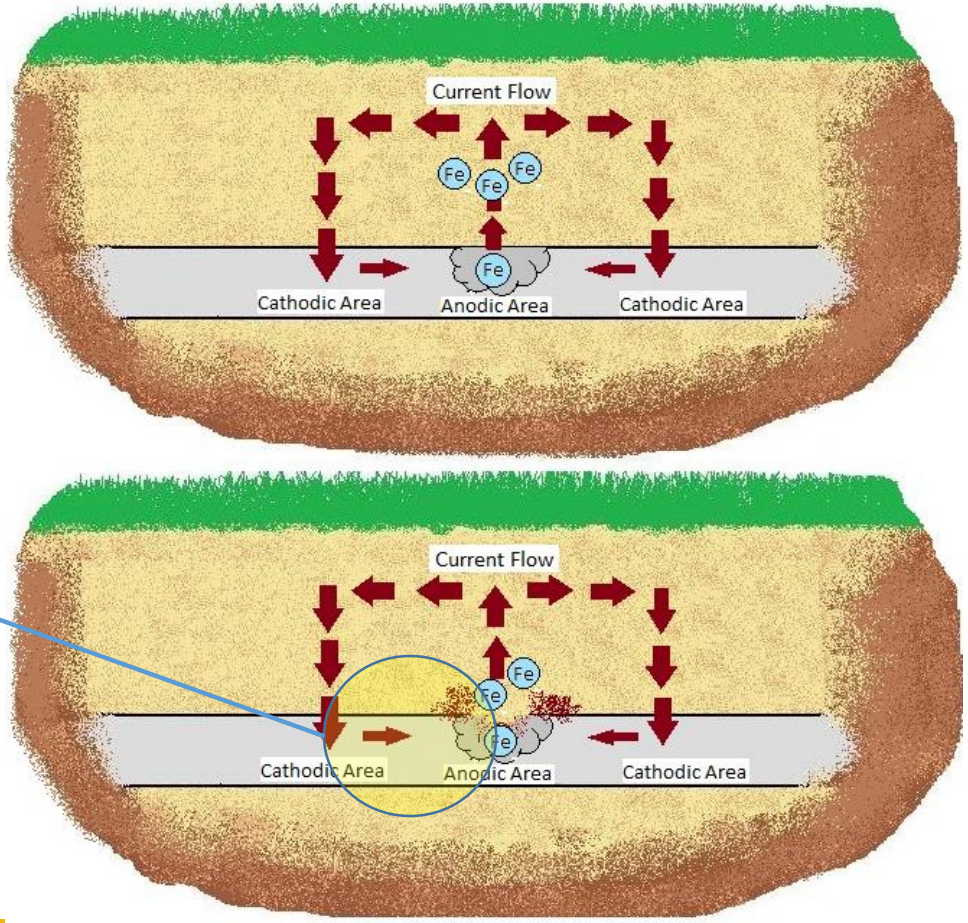
Reaction happens here, at the anode/cathode interface



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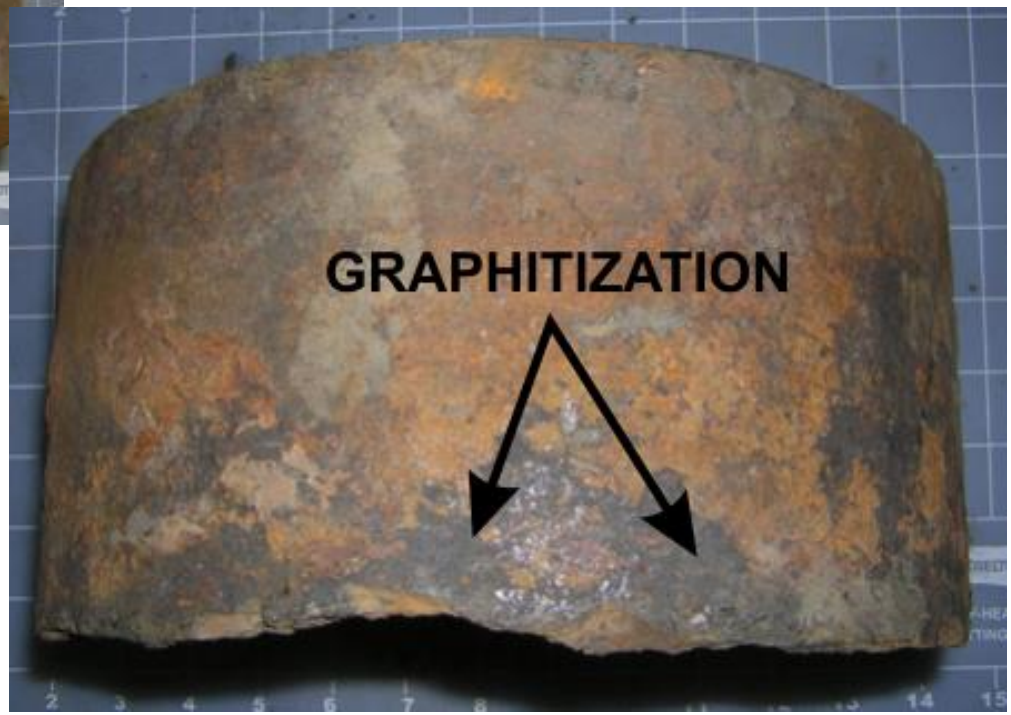
Graphitization

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

Grey blotchy areas



Microbiologically Influenced Corrosion (MIC)

Identified by:

- Metal being covered with a 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

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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.

Microbiologically Influenced Corrosion (MIC)

- Can occur internally and externally.
- Can be mitigated internally, by use of chemical inhibitors, added to the gas stream, or by removing the water from the system.
- Can be mitigated externally by certain types of coatings, or with enhanced cathodic protection, pipe surface potentials over 1.5 volts.

Types of Corrosion

Naturally Occurring Corrosion

- Dissimilar metals
- Dissimilar surface
- Dissimilar Soils
- Differential Aeration
- Cinders
- Stress
- Graphitization
- Microbiological Influenced Corrosion

Stray Current Corrosion: Man-Made and Natural

- Dynamic Stray Current
- Steady State Stray Current

Types of Corrosion

Stray Current Corrosion: Man-Made and 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

Stray Current Corrosion

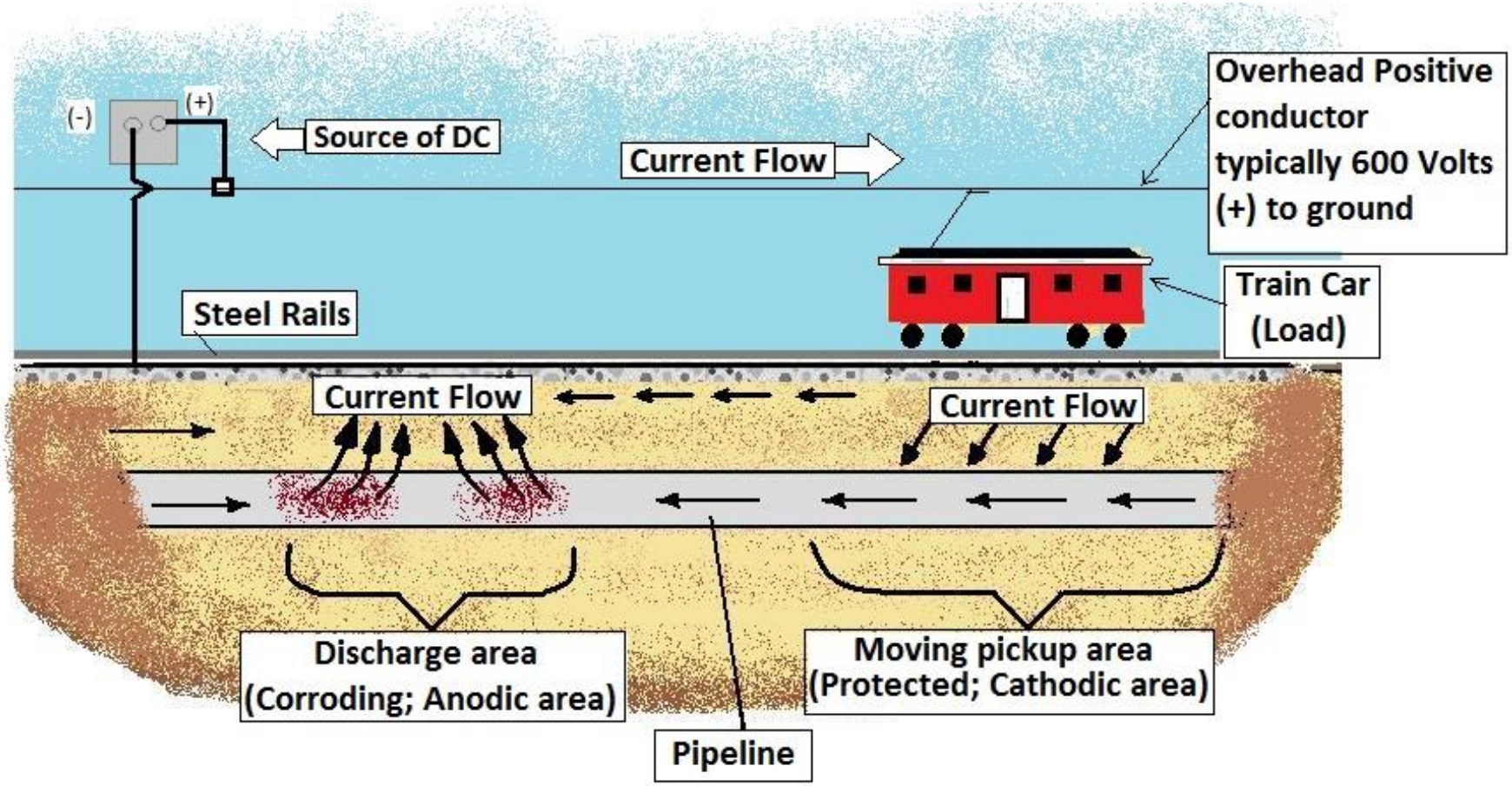
Alternating current, is mainly a safety issue. AC can be induced from overhead high voltage power lines. A measured voltage over 15 volts AC, must be mitigated. Can be measured by setting meter on AC volts, and taking a pipe to soil reading.

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 from DC Transit System

Dynamic Stray Current



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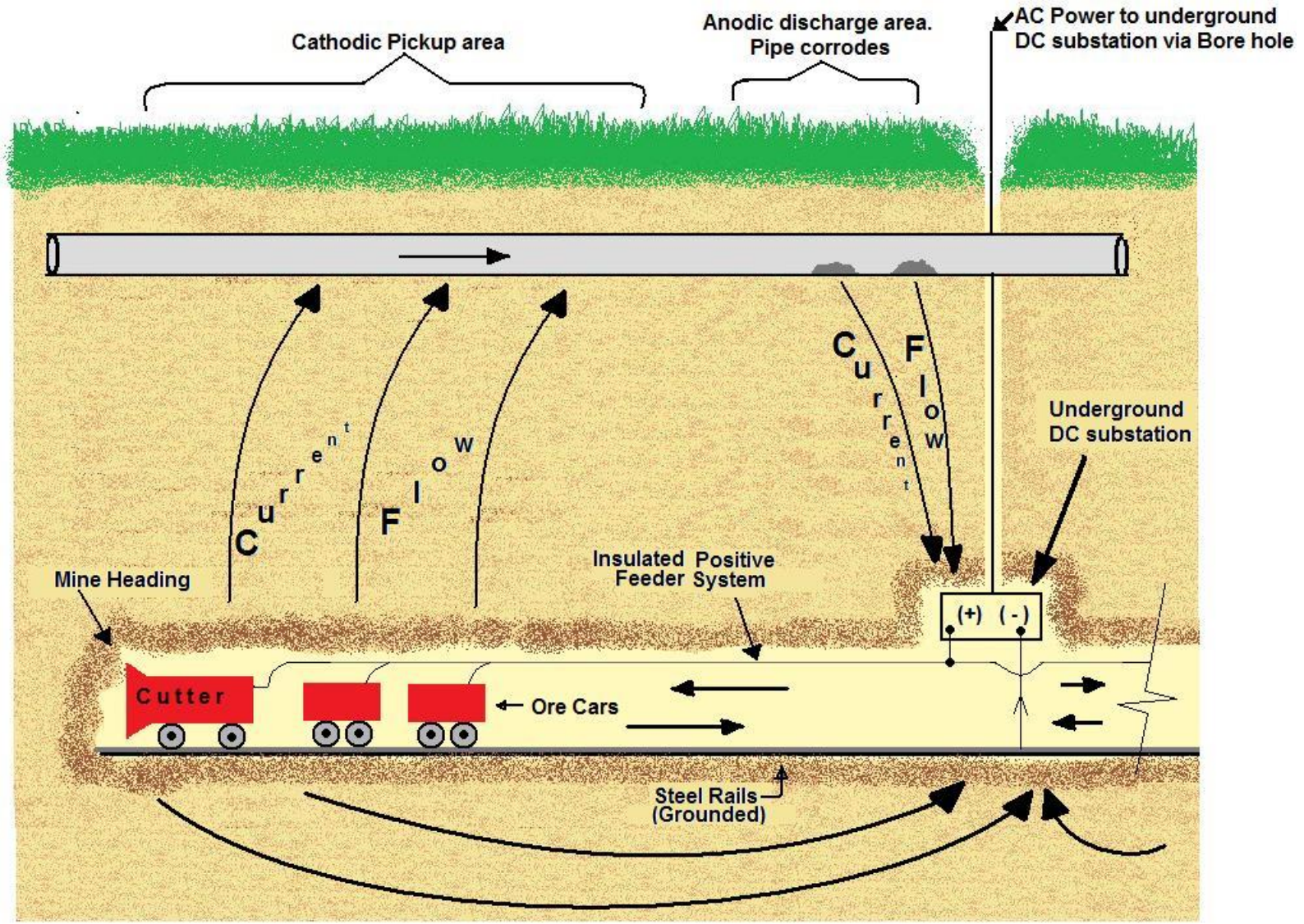
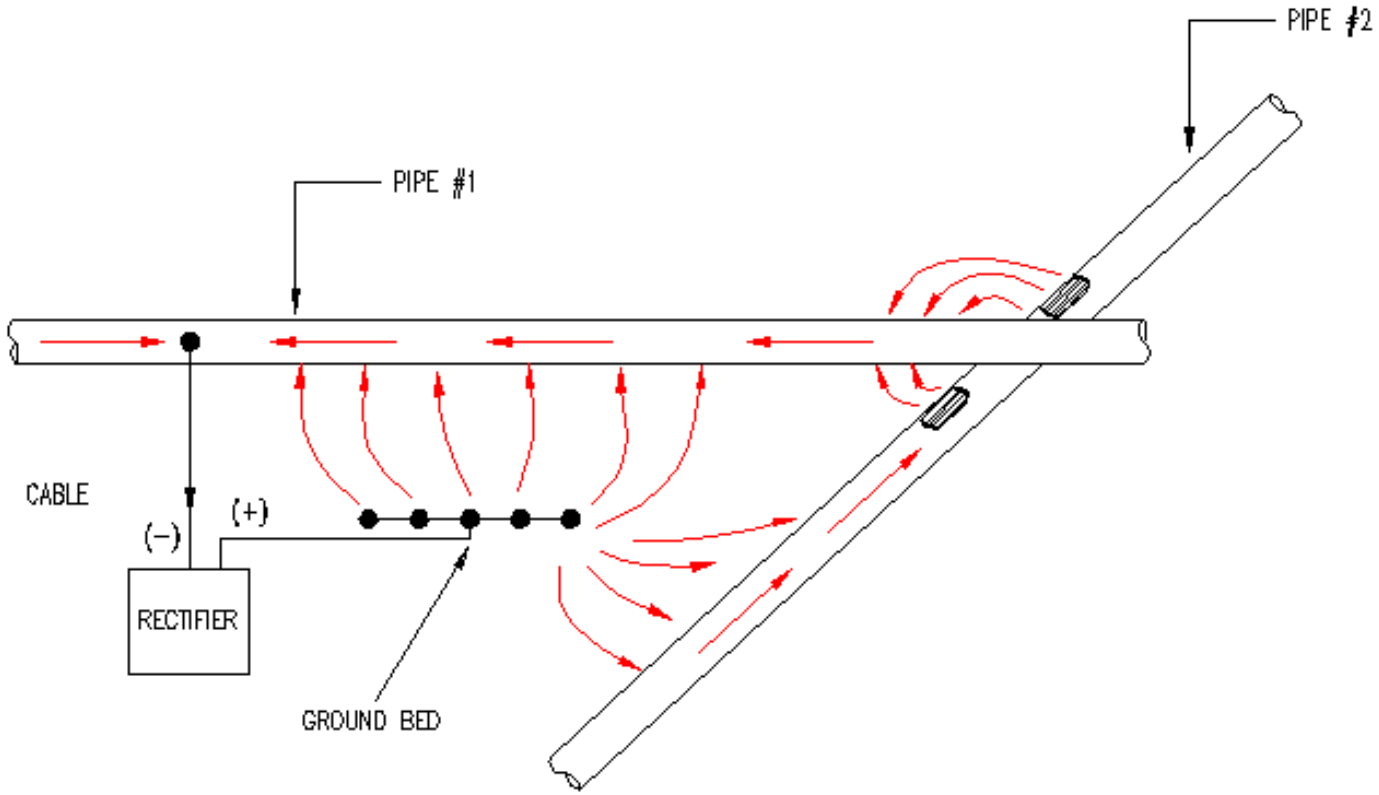
Stray Current from Underground Mining Operation

Dynamic Stray Current



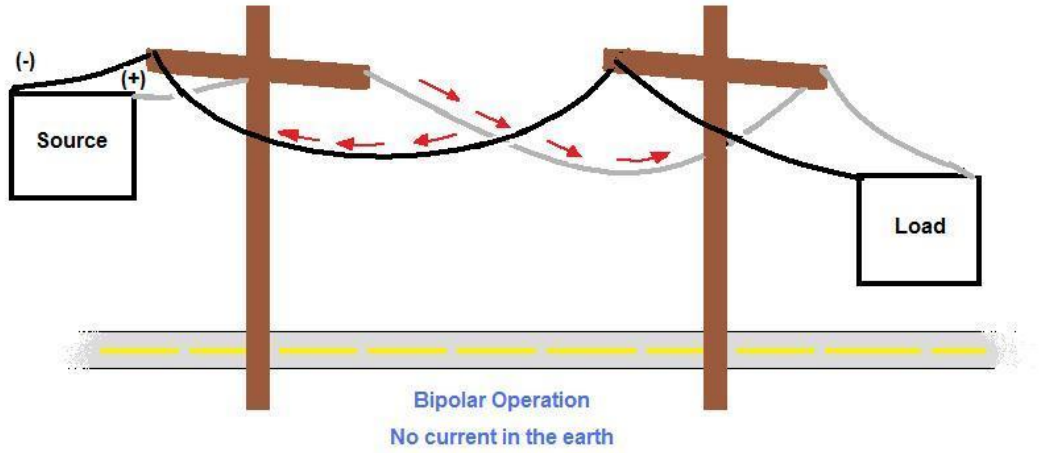
Stray Current from Impressed Current System

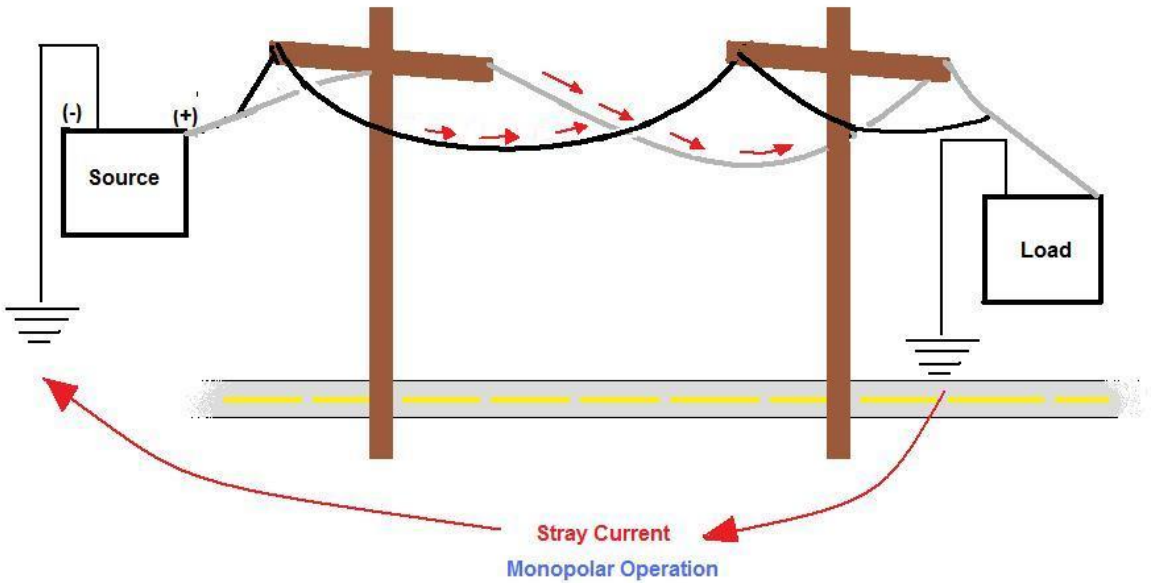
Static Stray Current



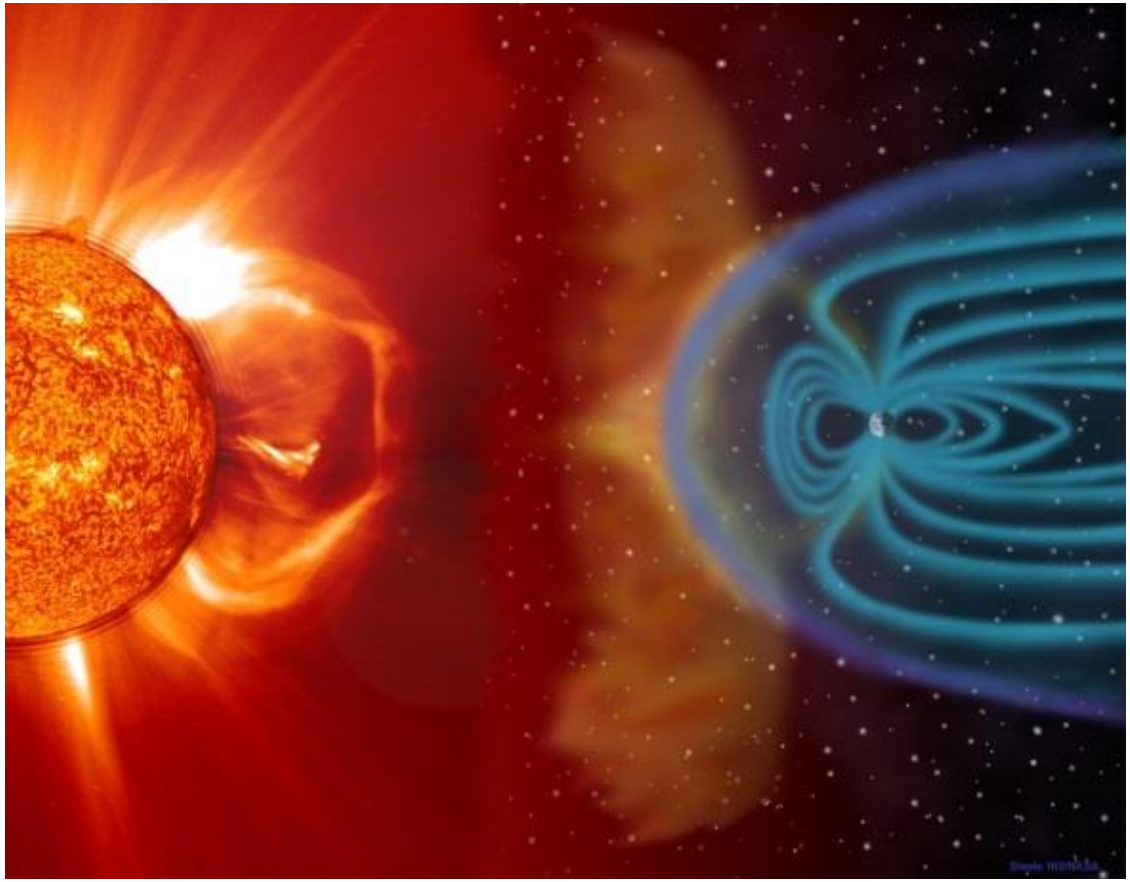
Stray Current from High Voltage DC Transmission Lines

Static Stray Current





Telluric Currents



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Factors Affecting the Rate of Corrosion

Soil Resistivity

Anode/Cathode Relationship

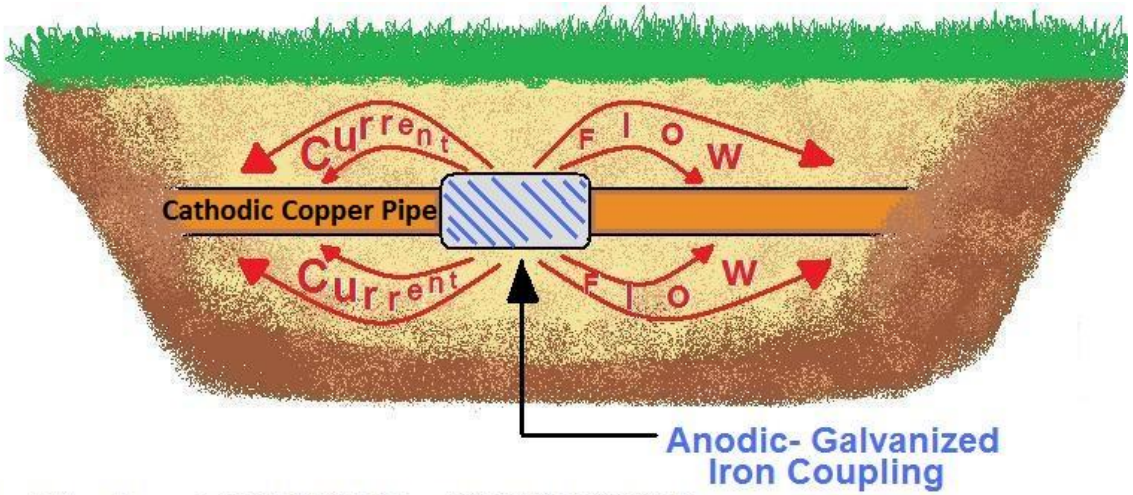
Potential Difference between Anode/Cathode

Polarization

Soil Resistivity

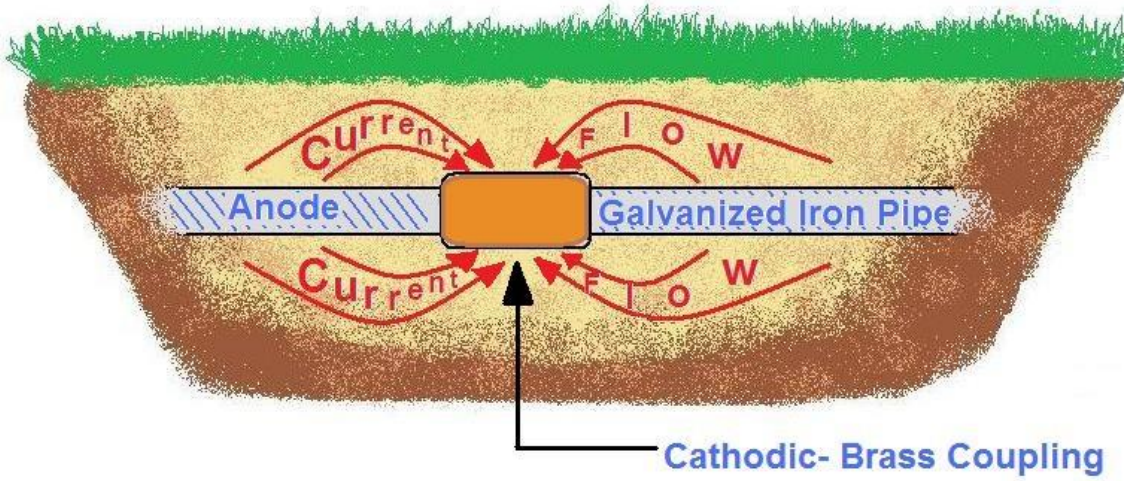
Below 500 ohm-cm	Very Corrosive
500 to 1000 ohm-cm	Corrosive
1000 to 2000 ohm-cm	Moderate Corrosive
2000 to 10,000 ohm-cm	Mildly corrosive
10,000 ohm-cm and above	Progressively less Corrosive

Anode to Cathode Ratio



Small Anode + Large Cathode = intense corrosion

Large cathode to small anode, the rate of corrosion at the Anode is much more severe. Because the area at which to Discharge current is concentrated, to a smaller area.



Large Anode + Small Cathode = less intense corrosion

Large anode to small cathode, the rate of corrosion at the anode is must less severe. Because there is a larger surface area from which the current will discharge.

Potential Difference between the Anode and Cathode

Practical Galvanic Series

Active End

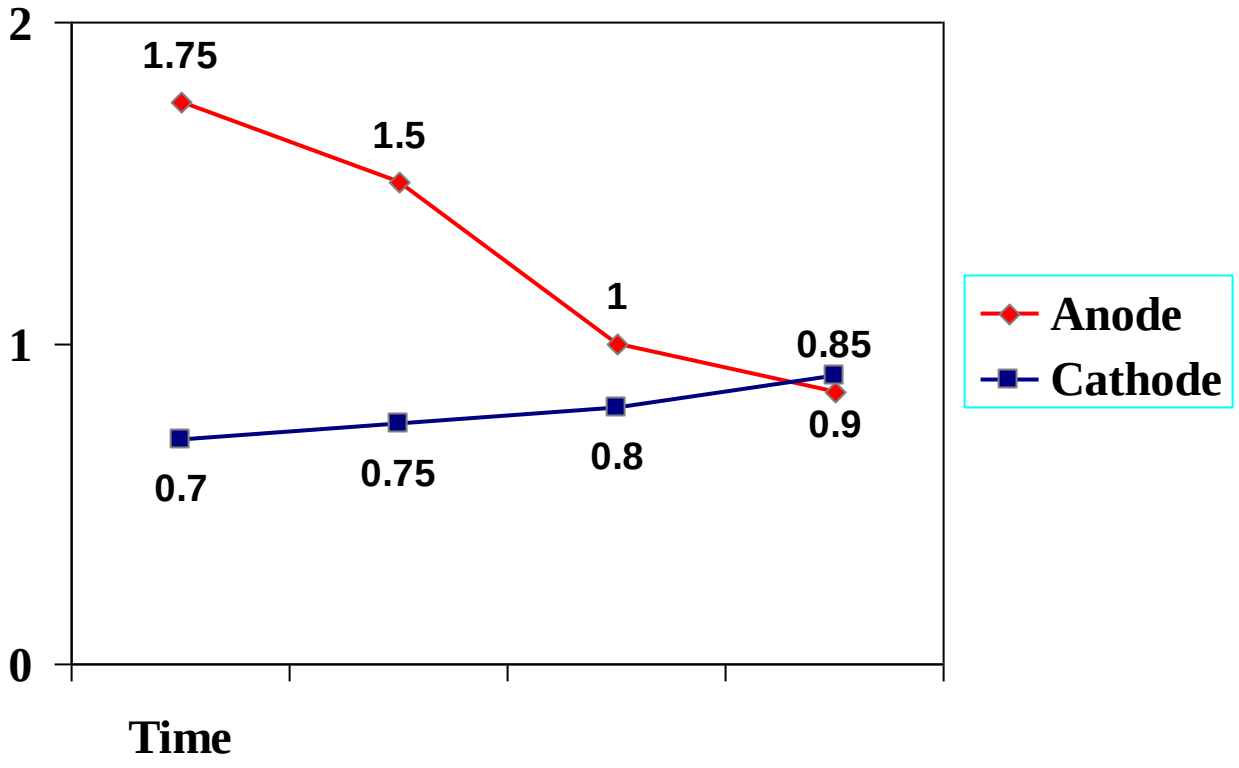
Material	Potential*
High Potential Magnesium	-1.75
Magnesium Alloy	-1.50
Zinc	-1.10
Aluminum Alloy	-1.05
Clean Carbon Steel	-0.50 to –0.80
Rusted Carbon Steel	-0.20 to –0.50
Cast/Ductile Steel	-0.50
Lead	-0.50
Steel in Concrete	-0.20
Copper	-0.20
High Silicon Iron	-0.20
Carbon, Graphite	+0.30

Passive or Noble End

* Potentials with respect to saturated Cu-$CuSO_4$ Electrode

Polarization

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



Questions???

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9 Rules to remember in corrosion work:

1. **The hardest problem to solve is the one that doesn't exist.**

2. **Don't take for granted the work done before you, was correct.**

3. **Never criticize the work done before you came aboard. (They had a reason, right or wrong.)**

4. **Always start with the simplest fix.**

5. **If one thing doesn't work try something else.**

6. **Don't assume the way you were taught is the right way.**

7. **Whatever works for you is the way you should work. (Note: I didn't say it's the best way.)**

8. **Don't dismiss a fresh idea.**

9. **Use common sense.**

N.A.C.E. Certified Corrosion Technician
Bertman J. Smith