

# CATHODIC PROTECTION SYSTEM DESIGN

- Presented By  
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# **Corrosion Fundamentals**

# What is corrosion?

**It is defined as the degradation or deterioration of a material, usually a metal, due to a reaction with its environment.**

**What does that mean???**

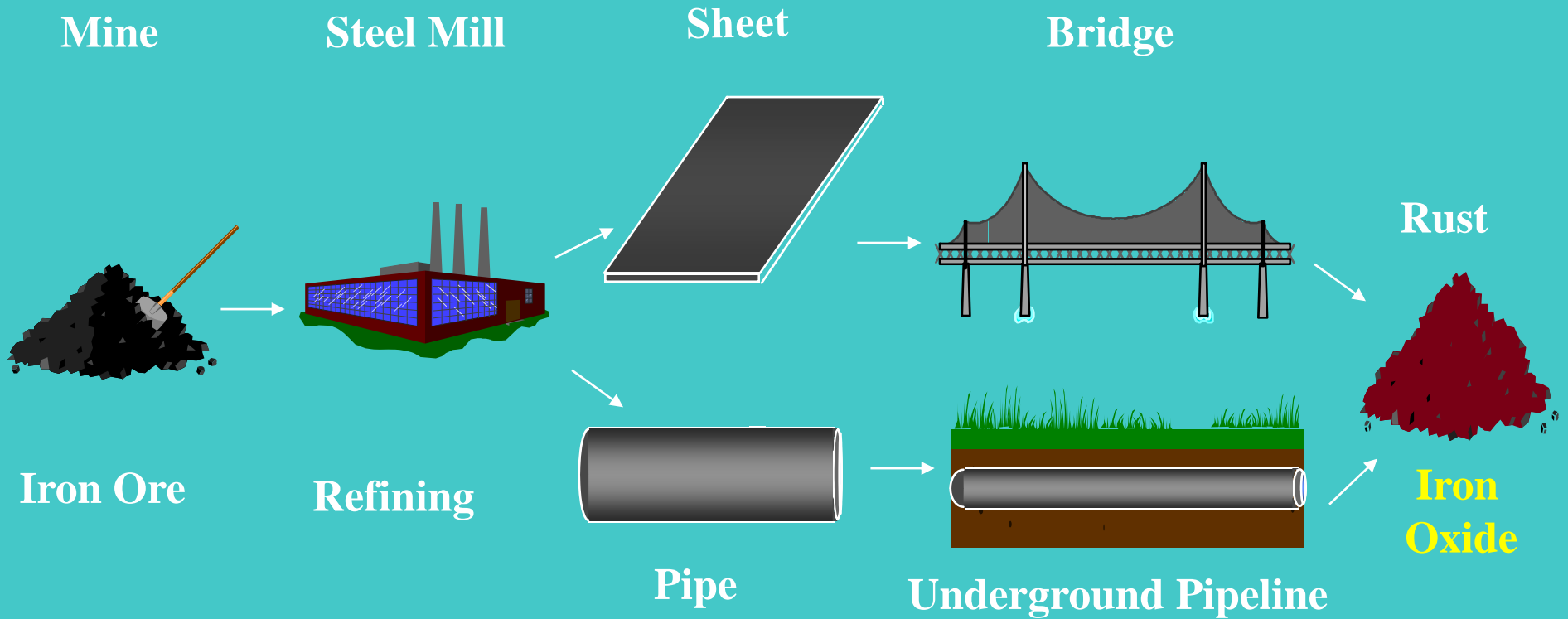


Corrosion is a natural process. Metals don't like being metals, they prefer remaining as ores.

In the process of converting ores into metals, energy is added in the form of heat, this places the metal into a high-energy state.

It is this energy that is given off from the metal, as the metal is returning to an ore, lower-energy state, is what we call corrosion.

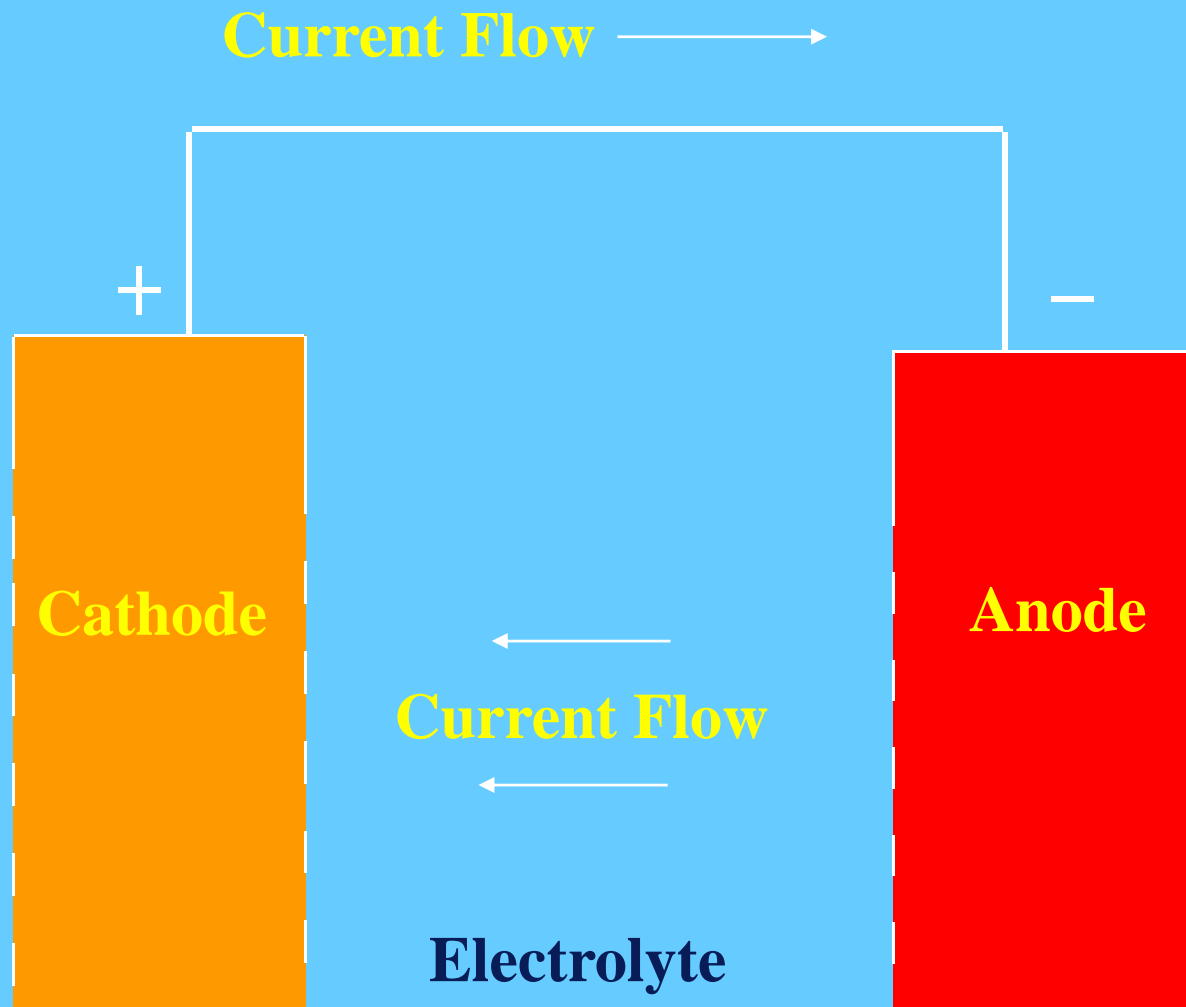
# Steel - Rust to Rust



# Components of a corrosion cell

- **Anode**
  - Metal loss or corrosion occurs at the anode
- **Cathode**
  - Little or no corrosion occurs at the cathode
- **Return Circuit/Metallic Path**
  - Provides a path for electrons to flow, between the anode and cathode
- **Electrolyte**
  - Ionized solution capable of conducting electricity

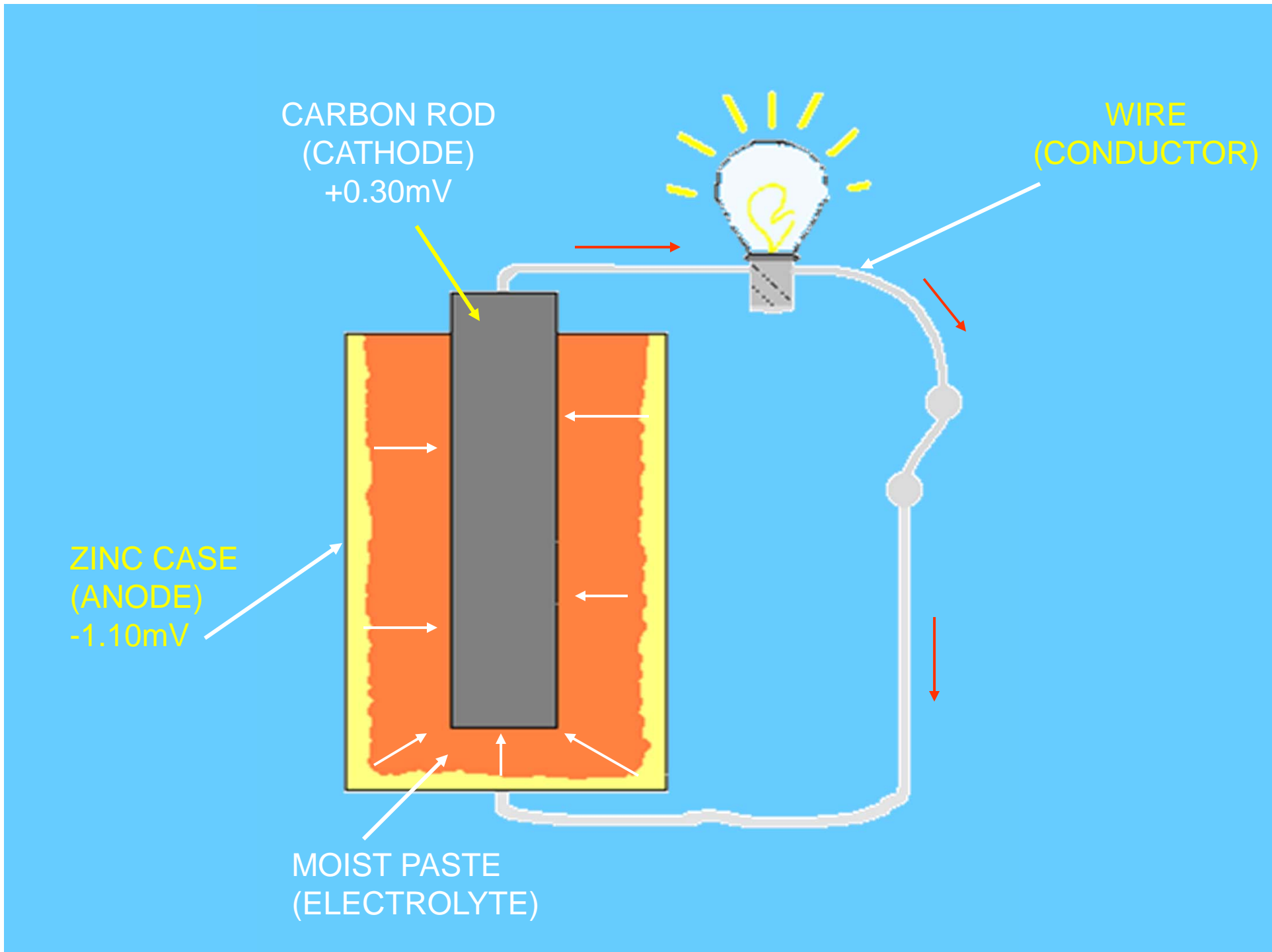
# Corrosion of Metals



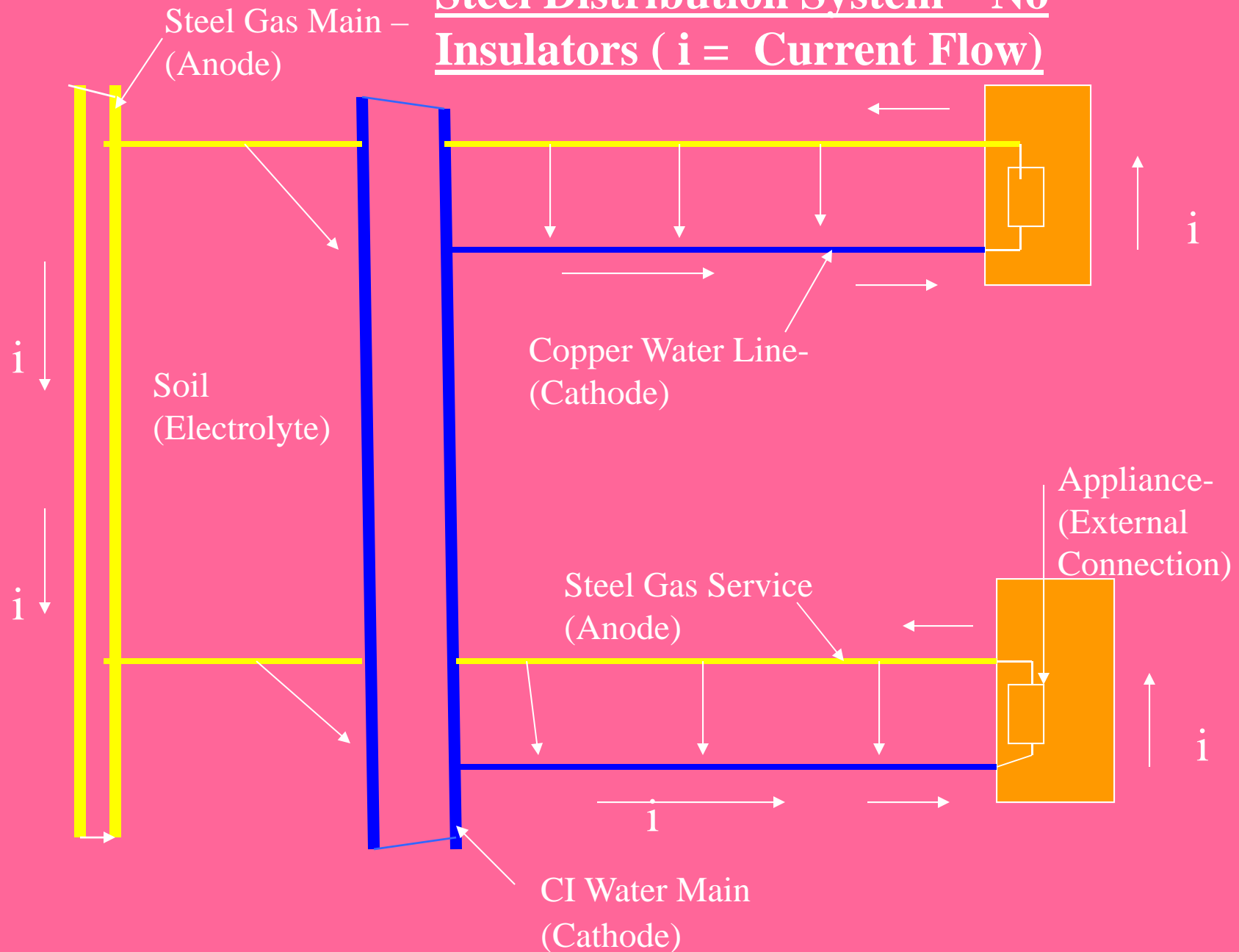


# Practical corrosion cell

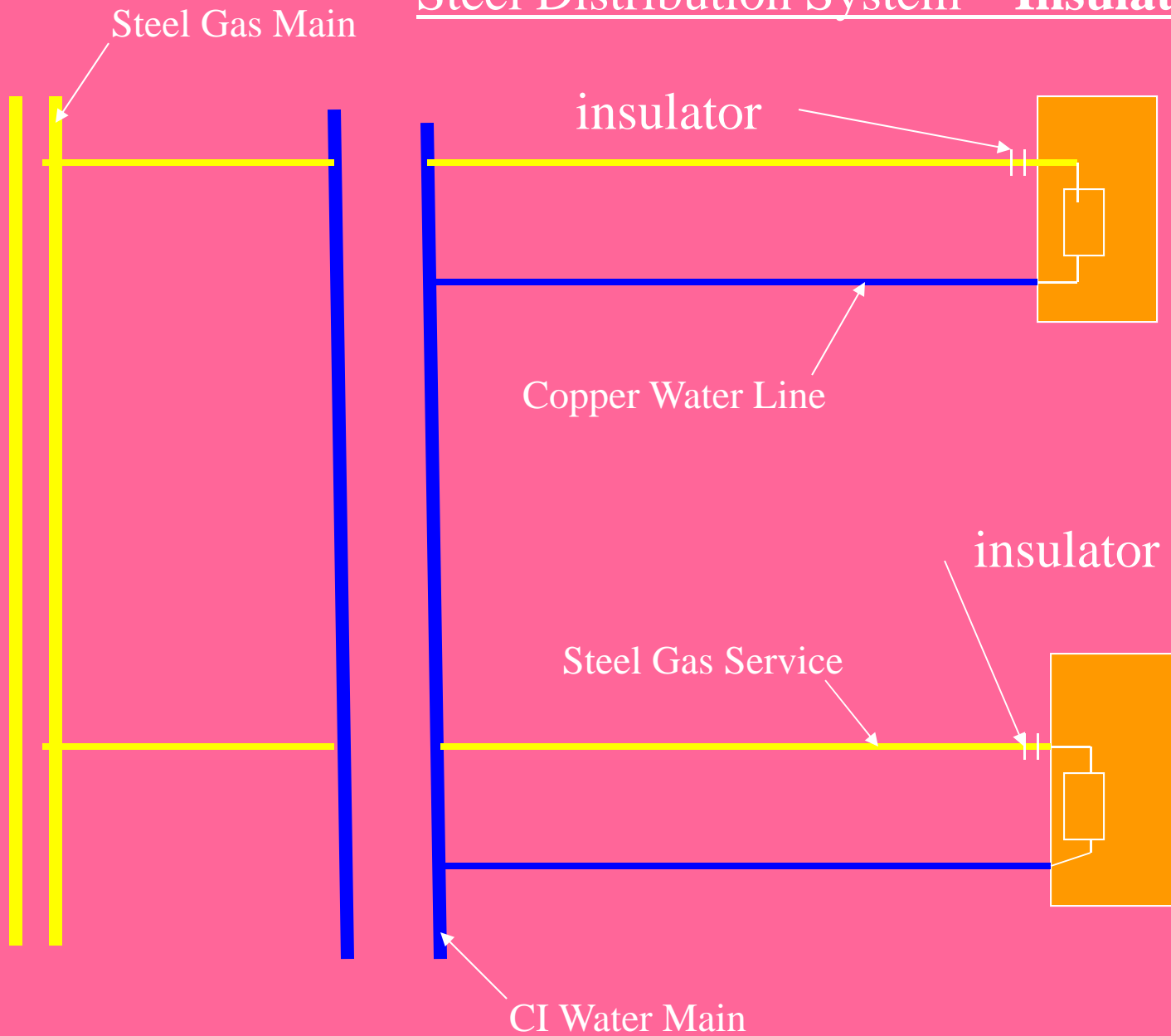
- Anode – bare steel gas service
- Cathode – cast iron gas main
- Electrolyte – soil that main and service are buried in
- Return path – service tee threaded into gas main

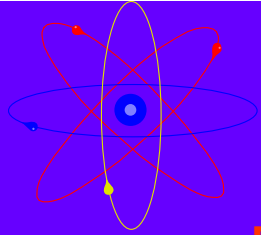


## Steel Distribution System – No Insulators ( $i$ = Current Flow )



## Steel Distribution System – Insulators





# PRACTICAL GALVANIC SERIES

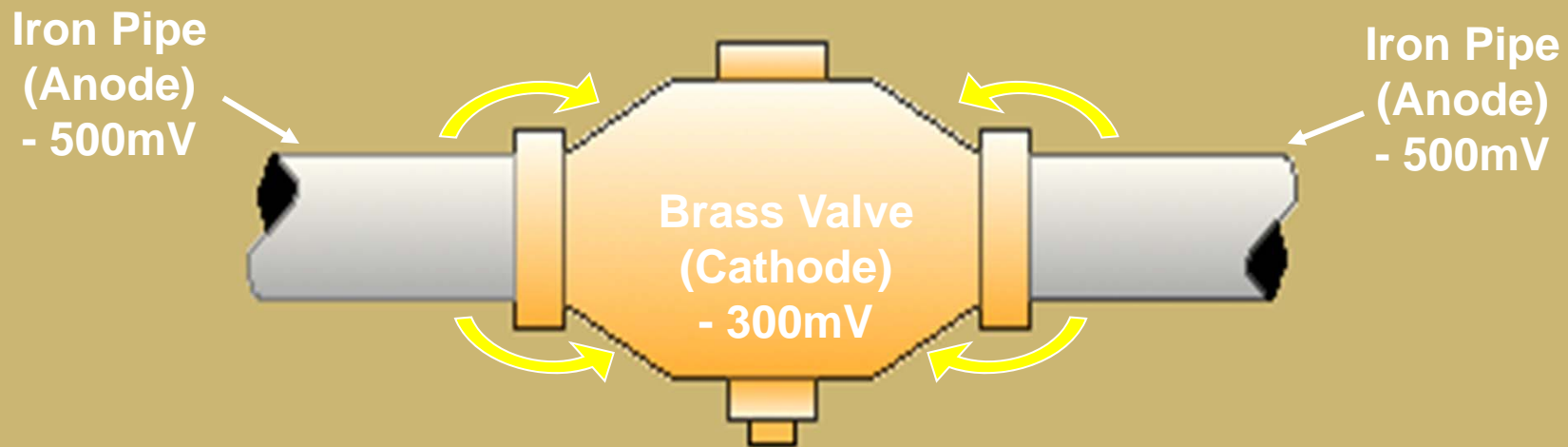
Material	Potential*
Pure Magnesium	-1.75
Magnesium Alloy	-1.60
Zinc	-1.10
Aluminum Alloy	-1.00
Cadmium	-0.80
Mild Steel (New)	-0.70
Mild Steel (Old)	-0.50
Cast Iron	-0.50
Stainless Steel	-0.50 to + 0.10
Copper, Brass, Bronze	-0.20
Titanium	-0.20
Gold	+0.20
Carbon, Graphite, Coke	+0.30

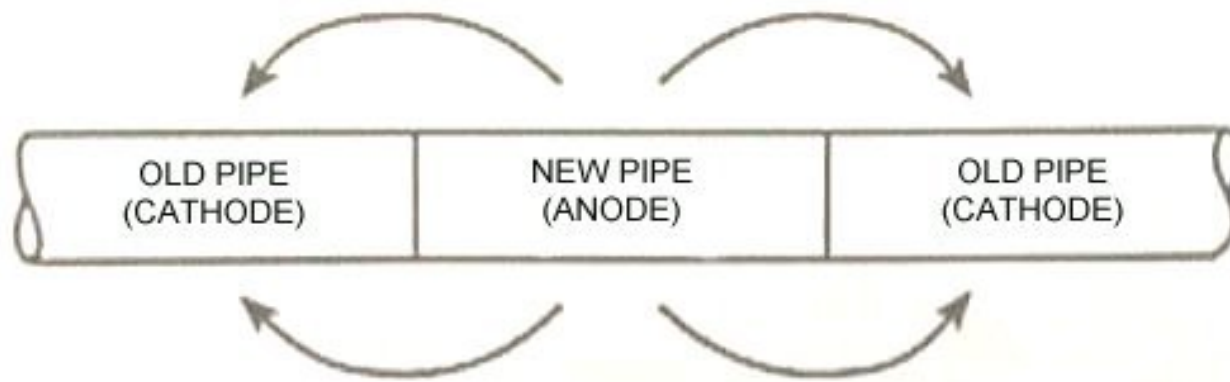
\* Potentials With Respect to Saturated Cu-CuSO<sub>4</sub> Electrode

# Factors causing corrosion on a pipeline

- Dissimilar metals
  - Galvanic corrosion
    - Brass valve or copper pipe connected to carbon steel pipe
    - Old carbon steel pipe connected to new steel pipe
- Dissimilar Soils
  - Varying oxygen content
  - Varying resistivities
- Mechanical Stresses
  - Bending and Gouges
  - Cutting of threads
- Stray Currents

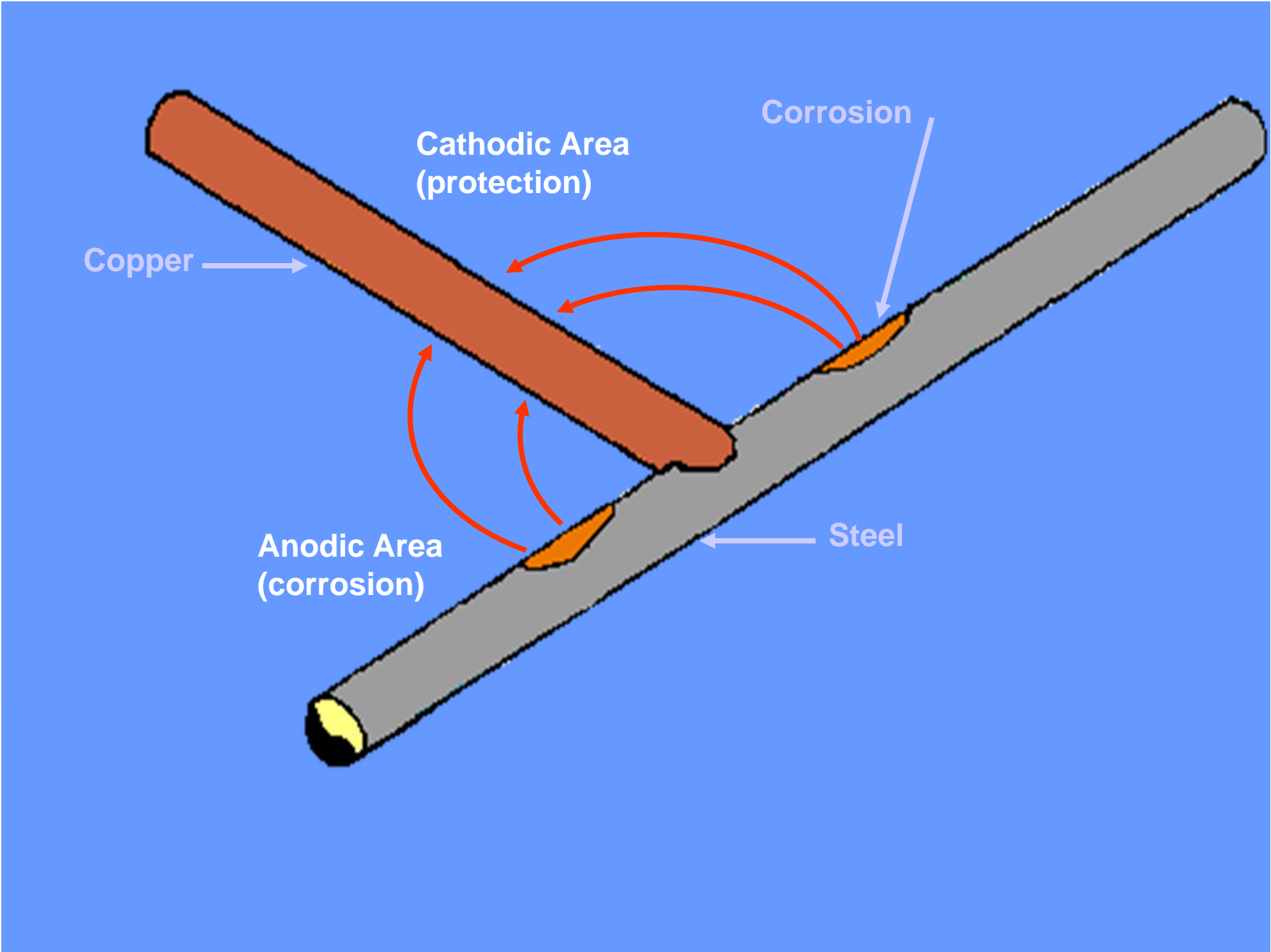
# Coupling to Dissimilar Metals

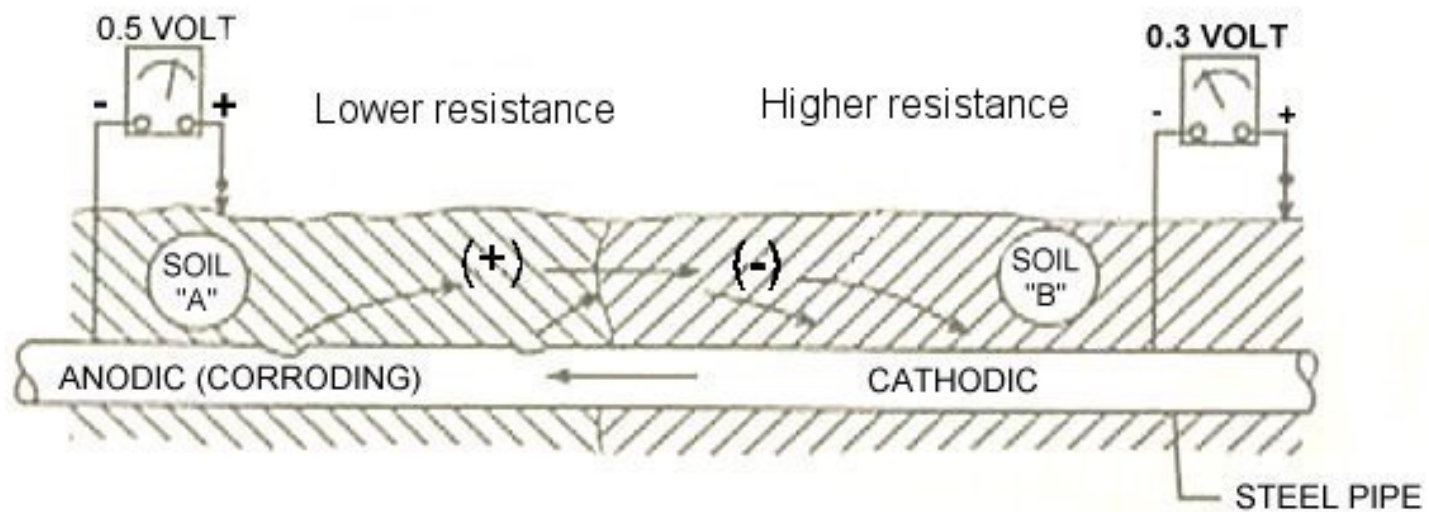




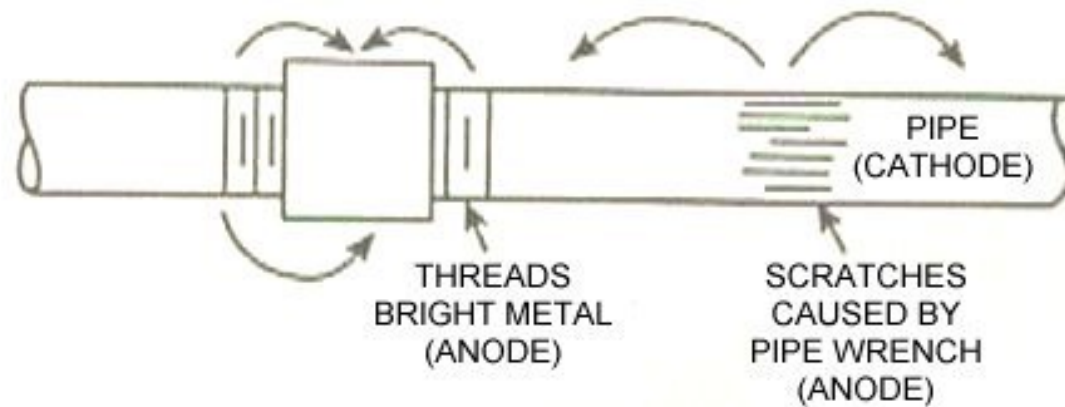
**Dissimilar Metals**  
**Old and New Steel**





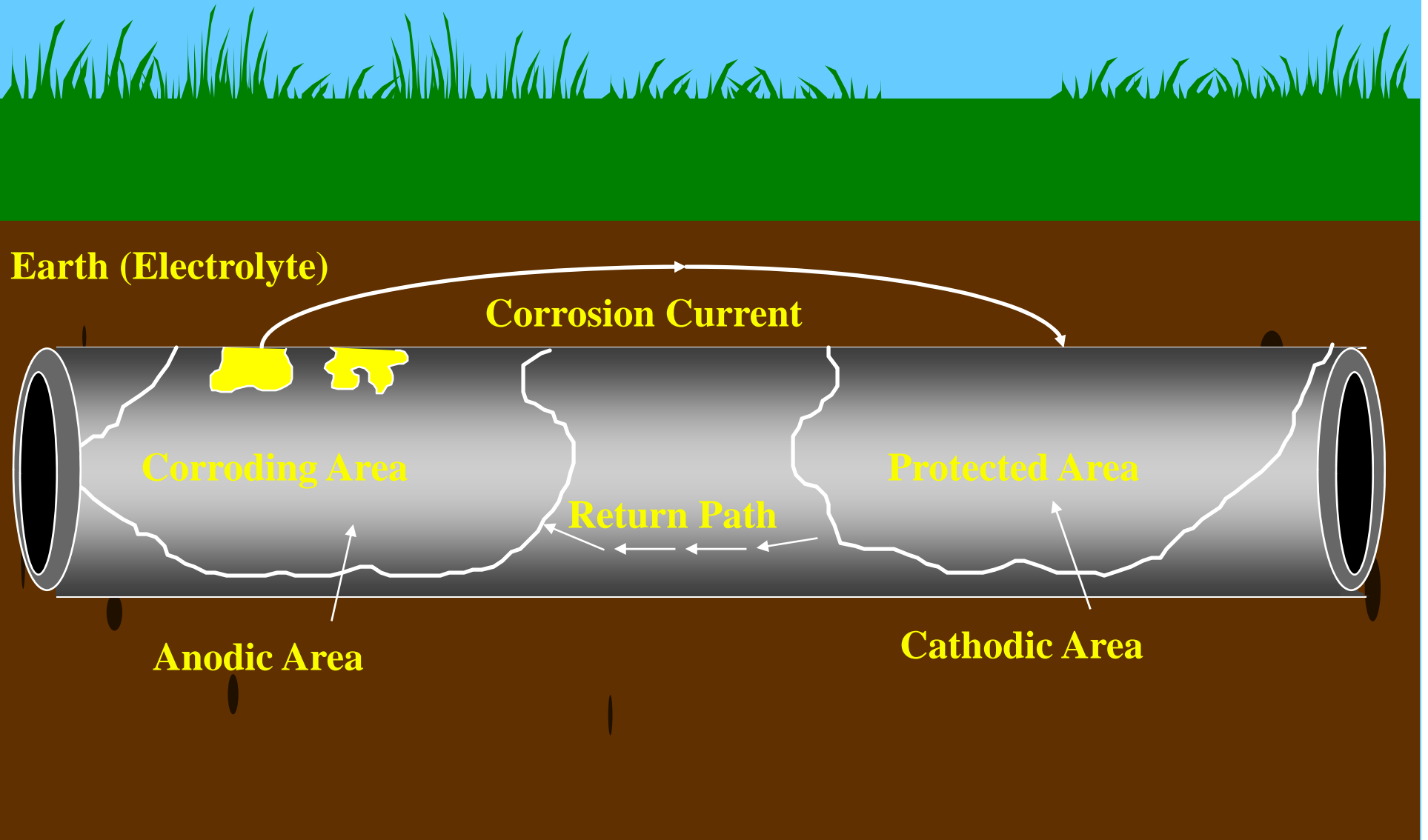


## Differences in soil resistivities



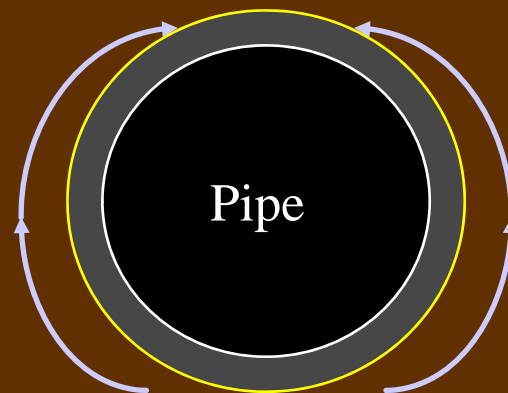
## Corrosion caused by Mechanical Stresses

# Basic Corrosion Cell



# Oxygen Concentration Corrosion Cell

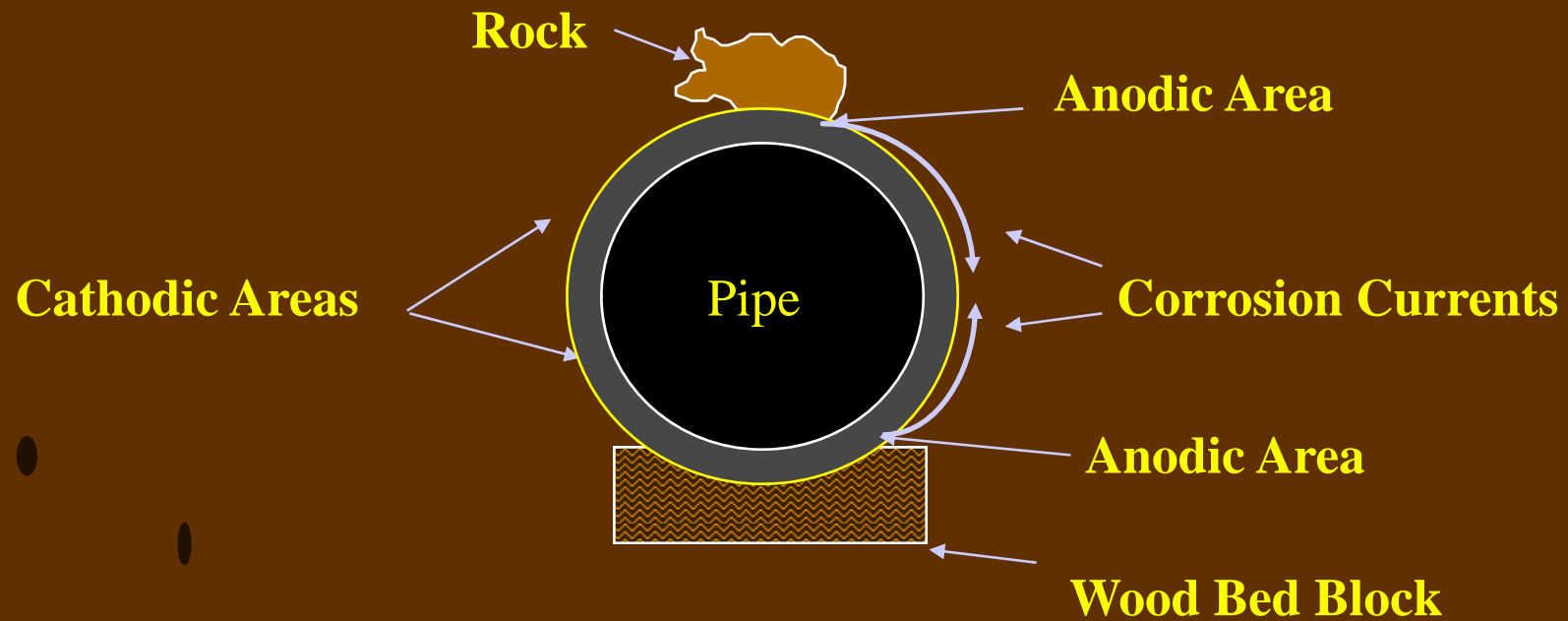
**Backfill**  
**More Oxygen - Cathodic - Protected**



**Corrosion Currents**

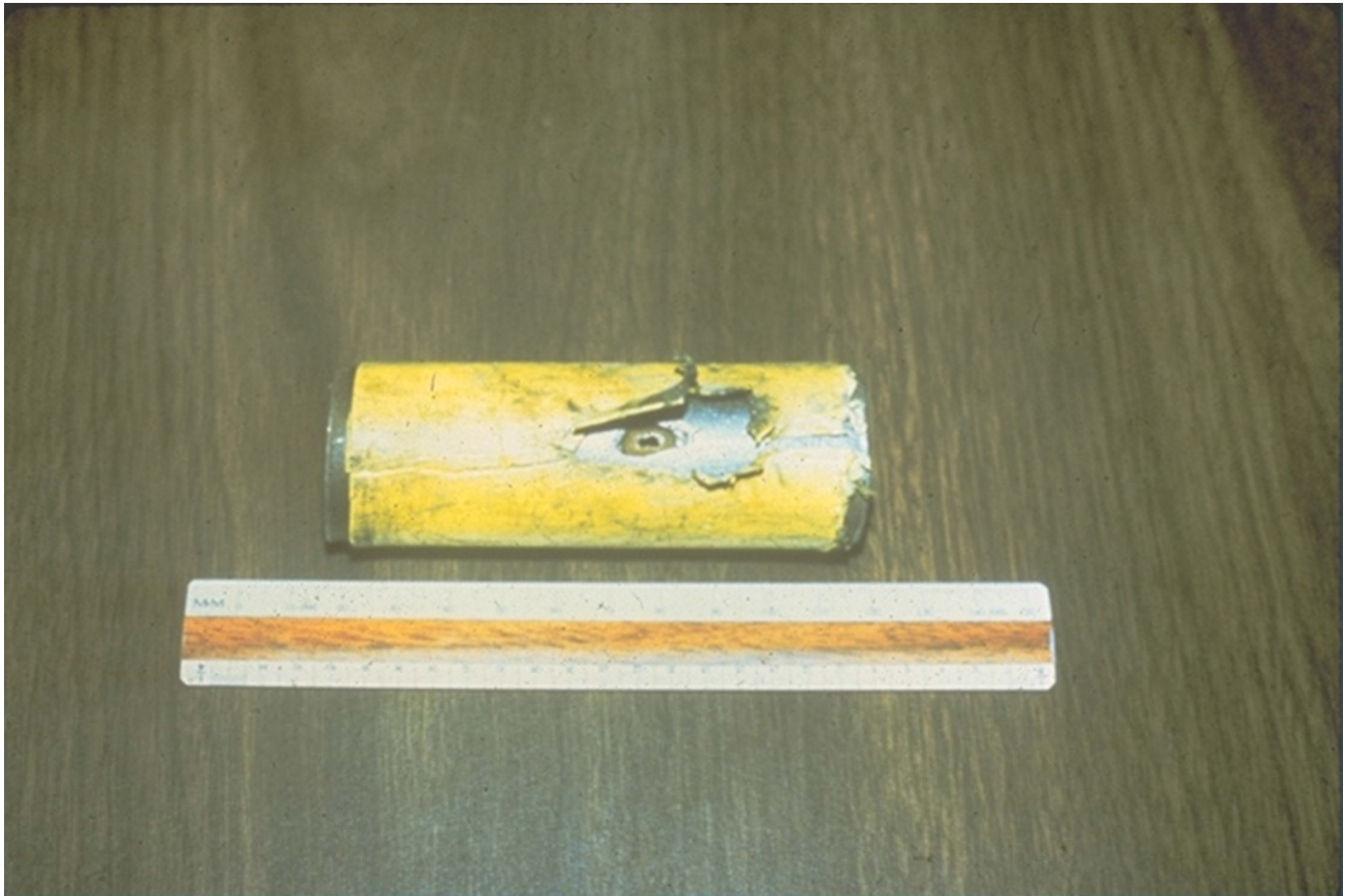
**Less Oxygen - Anodic - Corroding**  
**Undisturbed Earth**

# Oxygen Concentration Corrosion Cell



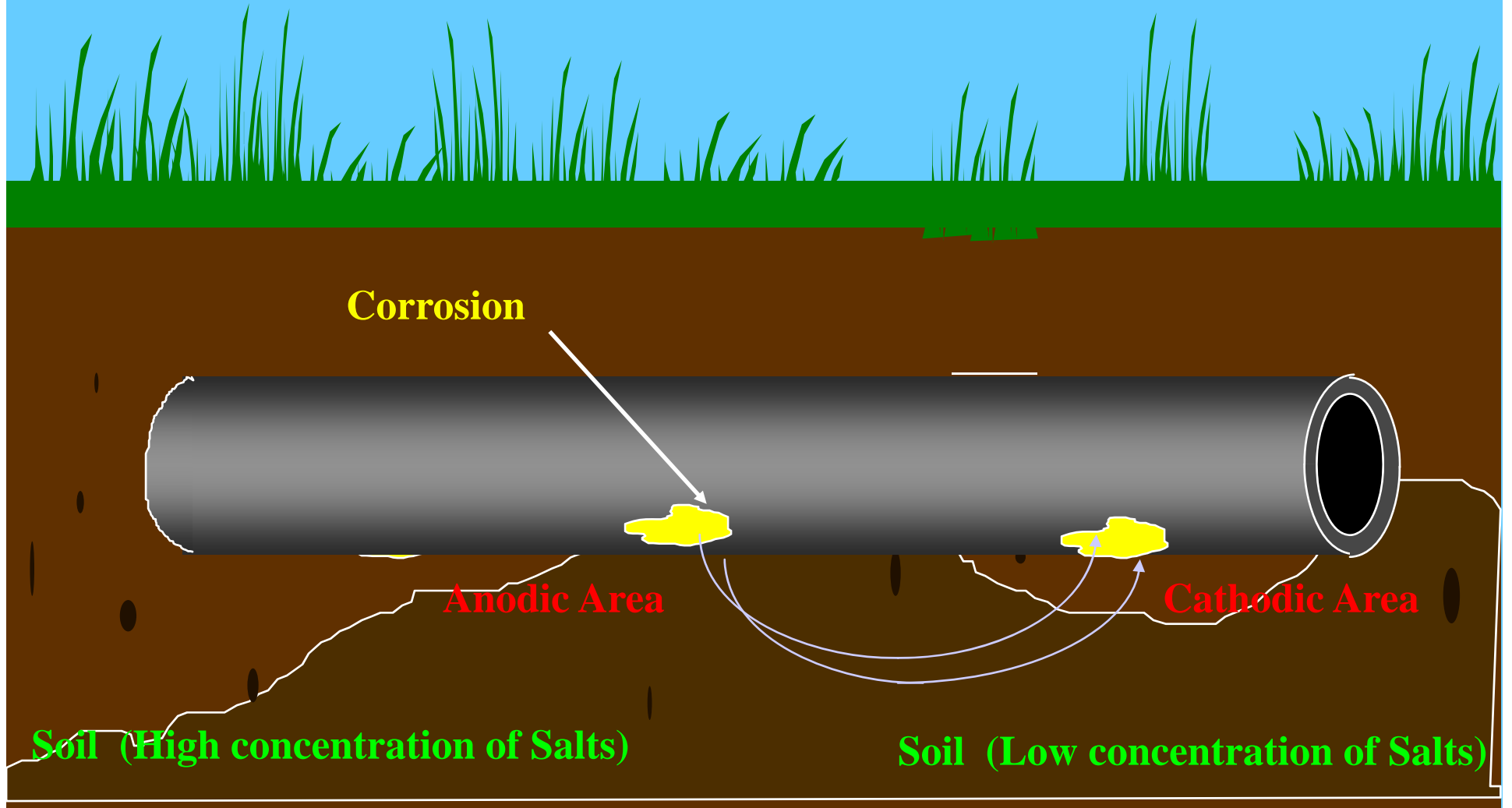
# Scarred/Damaged Surface Corrosion

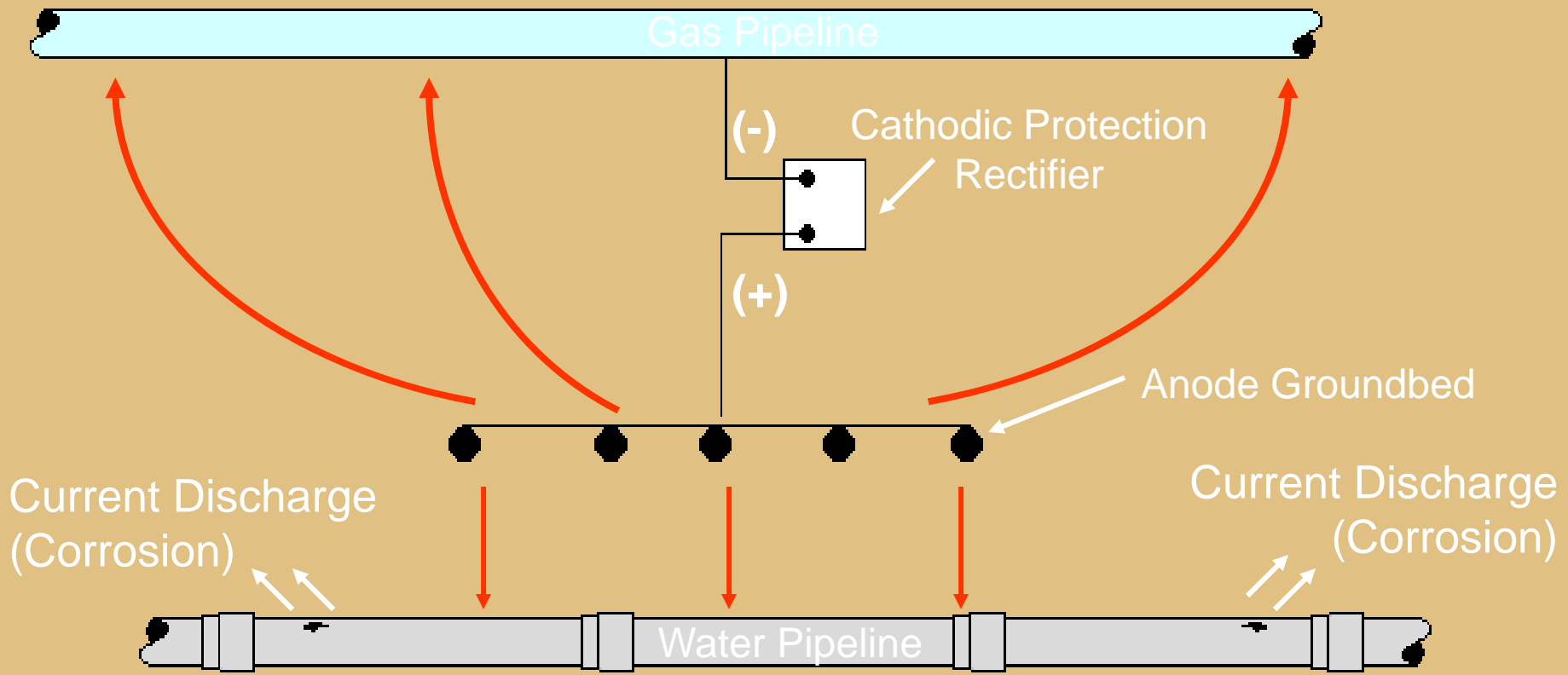
**Threads, scratches and dents are anodic  
to undisturbed surfaces along the pipe.**





# Dissimilar Soils



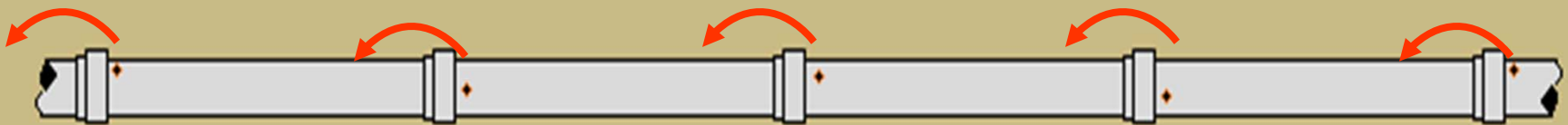
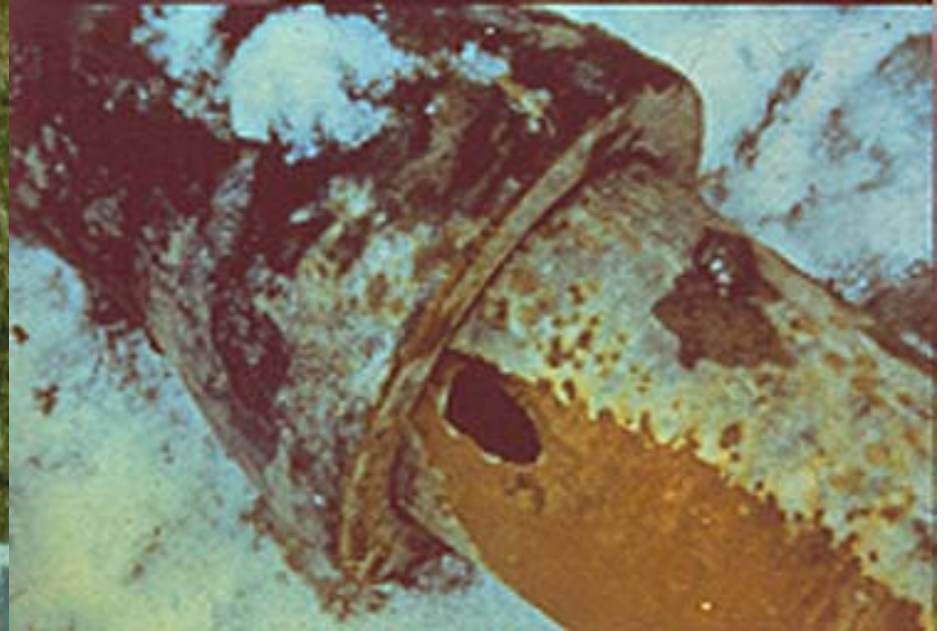


# Stray Current Due to Impressed Current Cathodic Protection System

# Corrosion Current vs Metal Loss

- **Metal loss is directly proportional to corrosion current**
- **1 amp per year = 20 pounds of steel lost**
- **Larger area of steel exposed - more current required for cathodic protection**
- **For given current - faster wall penetration at smaller exposed surface area**

# Stray Current



# Summary

- **Corrosion Cell**

- \* Anode

- \* Cathode

- \* Electrolyte

- \* Metallic Connection

# Rules & Regulations

- Department of Transportation
  - Part 192
- Operations And Maintenance Manual









# What Has to be Cathodically Protected ?

- All steel pipe installed after 1971 must be protected from external corrosion.
  - Regardless of size
  - Regardless of Length
- **What does that mean ?**
- **All new steel pipe MUST have:**

# Protective Coating

- Applied on a properly applied surface
- Have sufficient adhesion to the pipe
- Sufficient strength to resist cracking
- Have sufficient strength to resist damage due handling and soil stress.
- Compatible with cathodic protection currents
- Coatings must also be:
  - Inspected for damage prior to lowering in the ditch
  - Must be protected from damage from adverse ditch conditions.
  - Precautions must be taken to protect coated pipe that is to be installed by boring.

# Cathodic Protection

- Provide a level of cathodic protection for the entire length of the underground structure.
- Cathodic protection levels must be controlled so as not to damage coatings.

# Electrical Isolation

- Insulating devices must be installed on the steel pipe so as to facilitate electrical isolation.
  - Mains – @ Tie-ins and crossings with other utilities
  - Services - @ the main and the service riser
  - Casings – insulated from the carrier unless both carrier and casing are cathodically protected as a single unit.

# Test Leads and Boxes

- Test leads must be securely attached and minimize stress concentration on the pipe.
- All test lead connections at the pipe must be coated.
- Test leads must extend out of the test box by at least 18”.
- Test box locations and dimensions will be indicated on the design drawings.
- Test leads will be connected as required.

## Pipe installed prior to 1971

- Bare or coated steel pipe determined to be in areas of continuing corrosion must be cathodically protected.
- Hot Spot Protection.

# Atmospheric Corrosion

- Pipelines that are exposed to the atmosphere must be cleaned and either coated or jacketed with a material suitable for the prevention of atmospheric corrosion.
- Steel service risers and meter installations must be coated to the outlet side of the meter bar.



# Other

- Exposed Pipe Inspection
  - Further Investigation if additional corrosion is evident.
    - Inspect coatings for damage
    - Inspect bare pipe for pitting and uniform wall loss.
- Internal Pipe inspection
- Inspection Data to be kept for the LIFE of the pipe.

# Cathodic Protection

# Elements of a Corrosion Control System

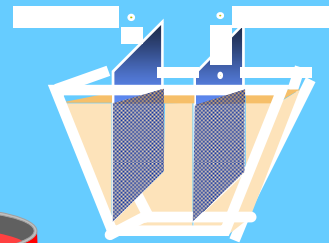
Connect to more negative metal

Break electrical path to what's not being protected

Cathodic Protection Current



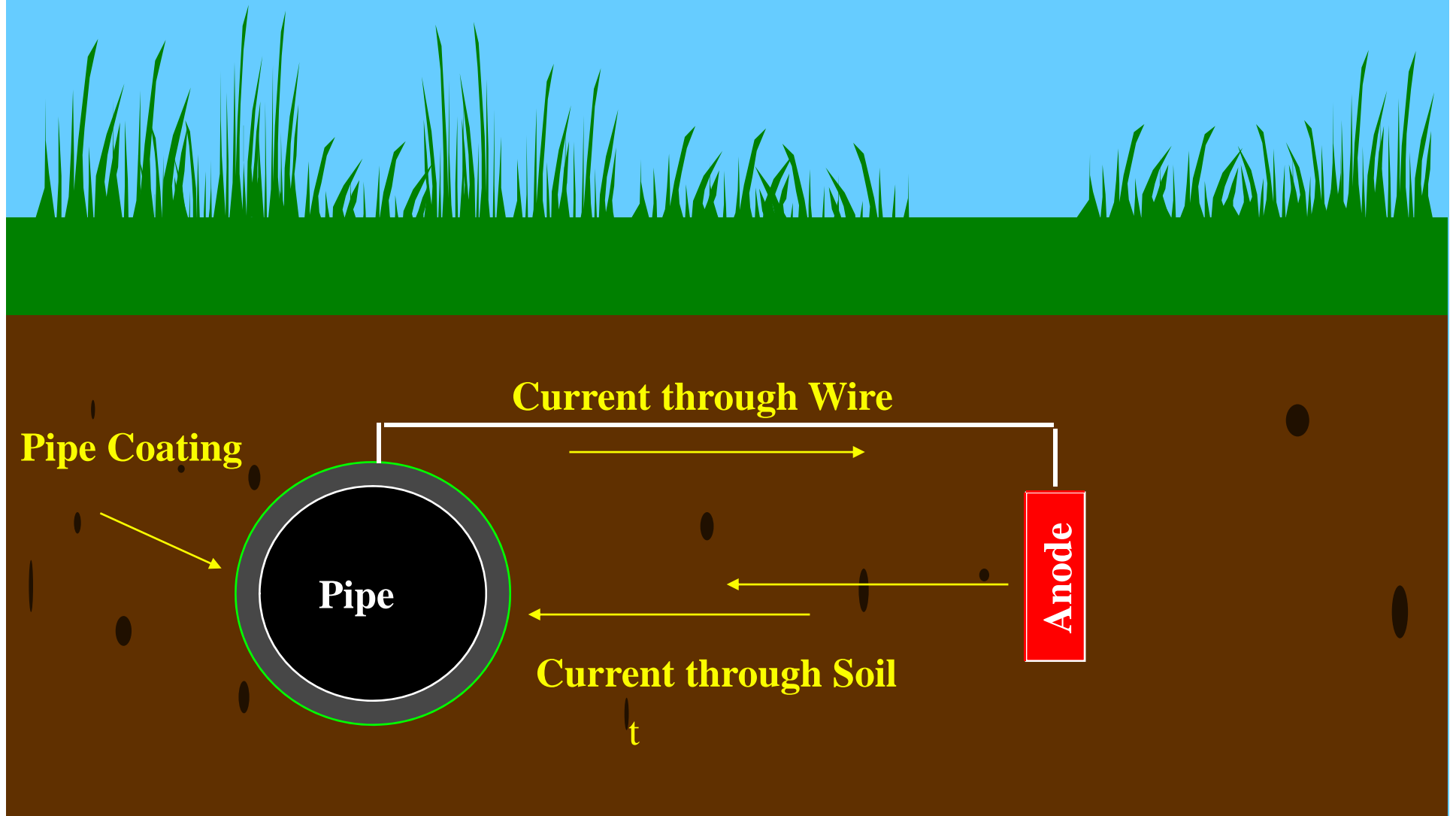
Isolation



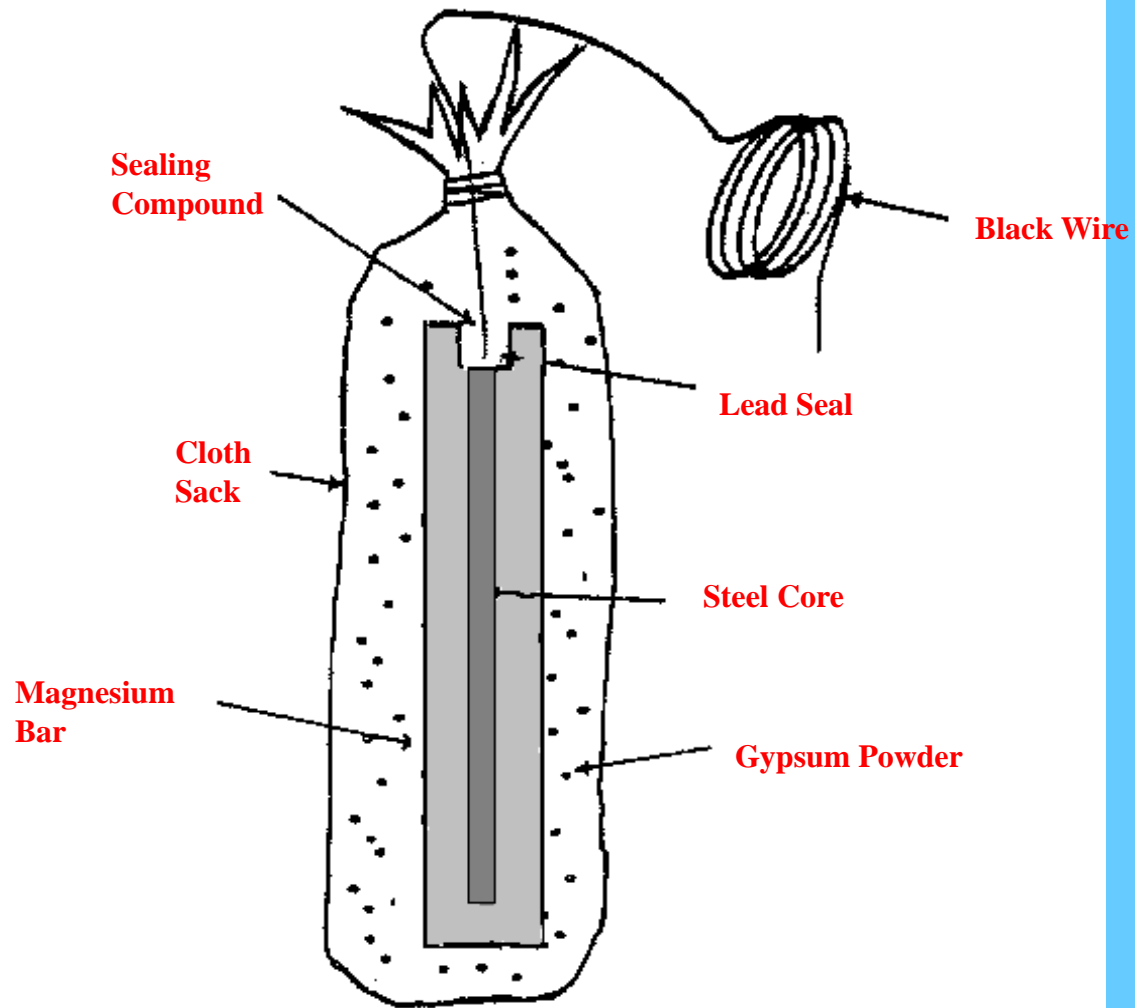
Coating

Limit Area in Contact with Electrolyte

# Protection of a Pipeline with a Sacrificial Anode



## Magnesium Anode

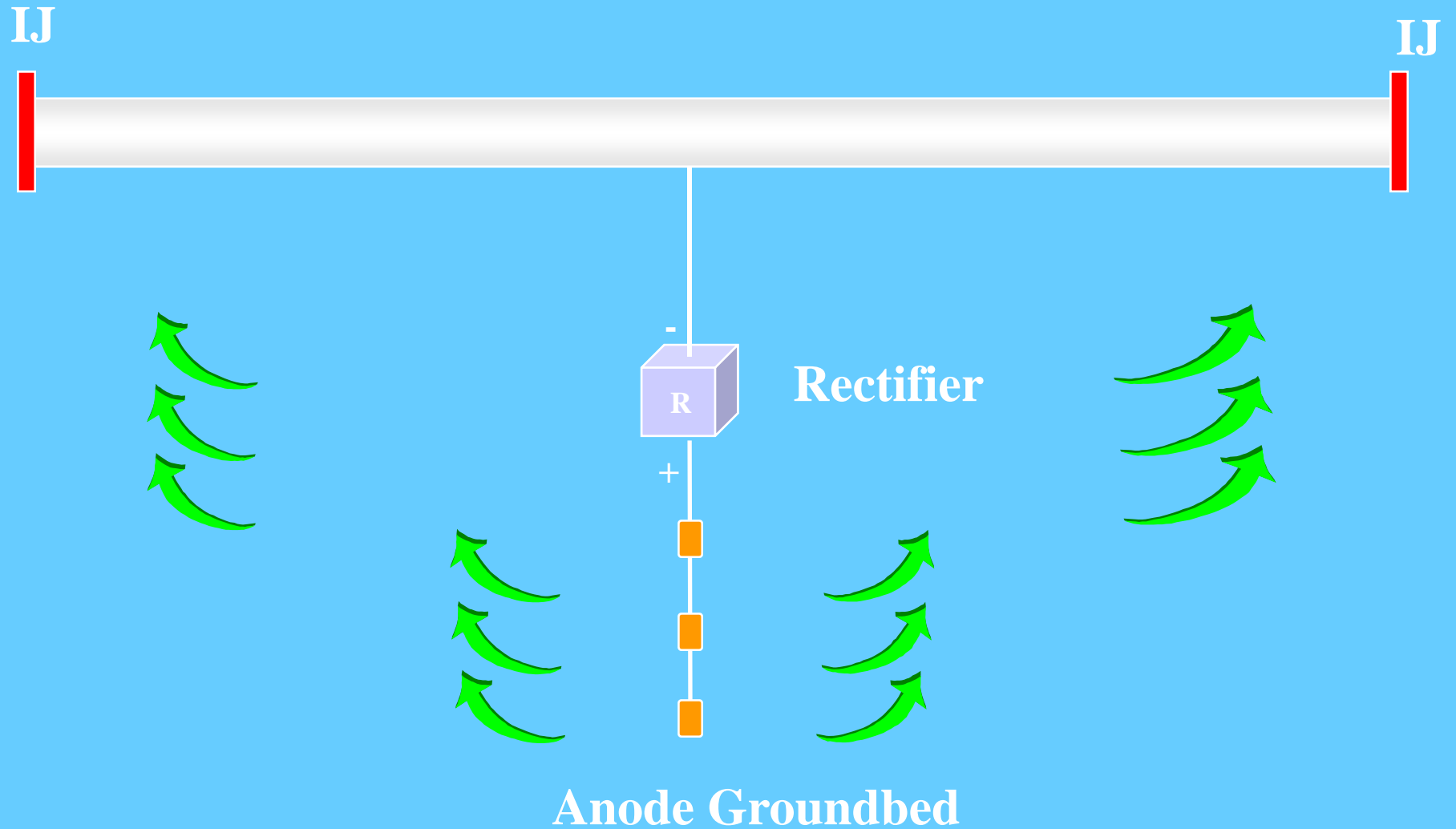


**Note:** Anodes should be installed 18" below and 18" to the side of the pipe. The anode should be also be soaked with water before backfilling. Do not carry by the wire.

# Sacrificial Magnesium Anode



# Rectifier Groundbed

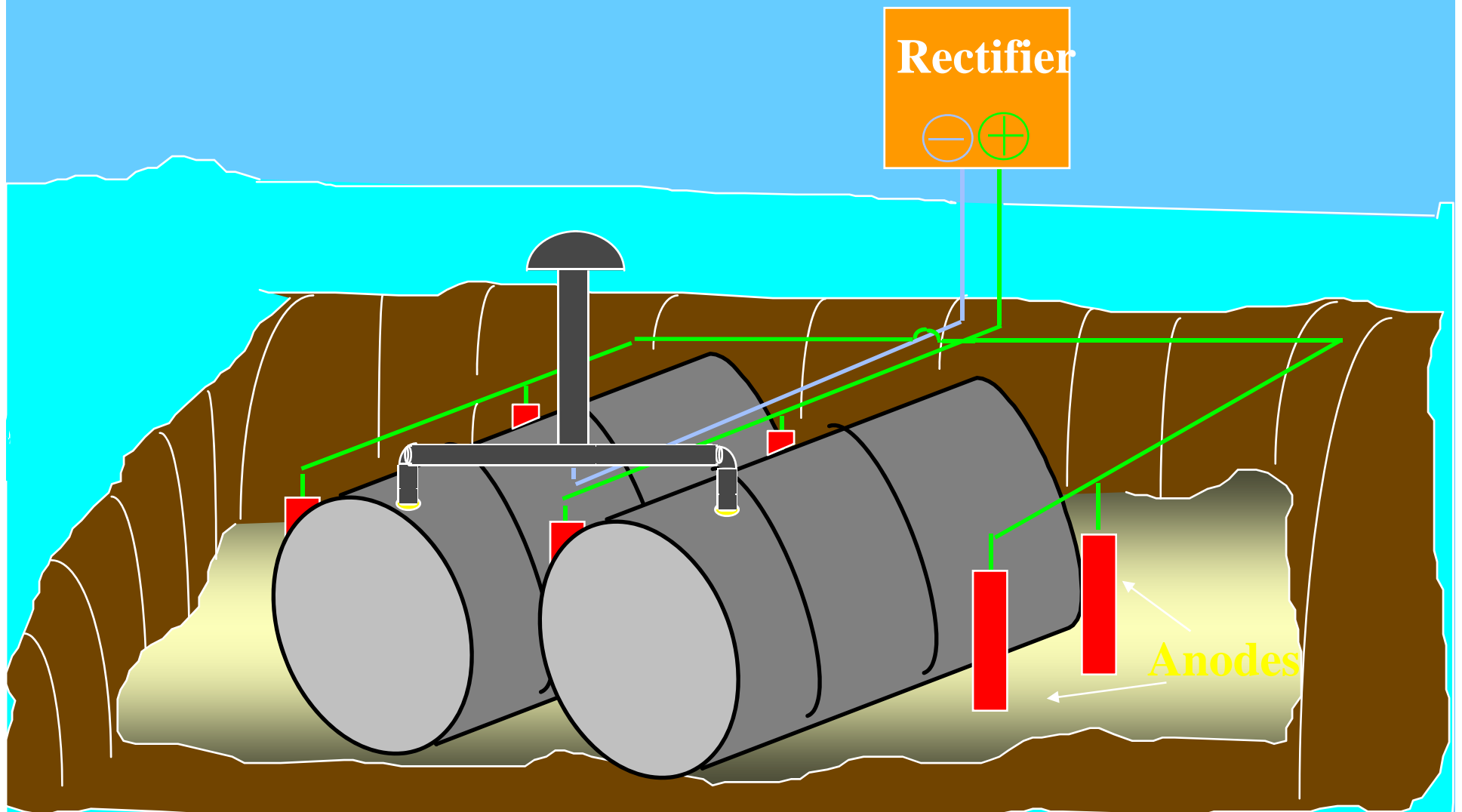


# POLE MOUNTED RECTIFIER





# Typical Arrangement of Cathodic Protection For Tanks



# Tidal Zone Cathodic Protection

Structure Section

Cathodic Protection is Afforded to Steel in Tidal Zone During Periods of High Tides.

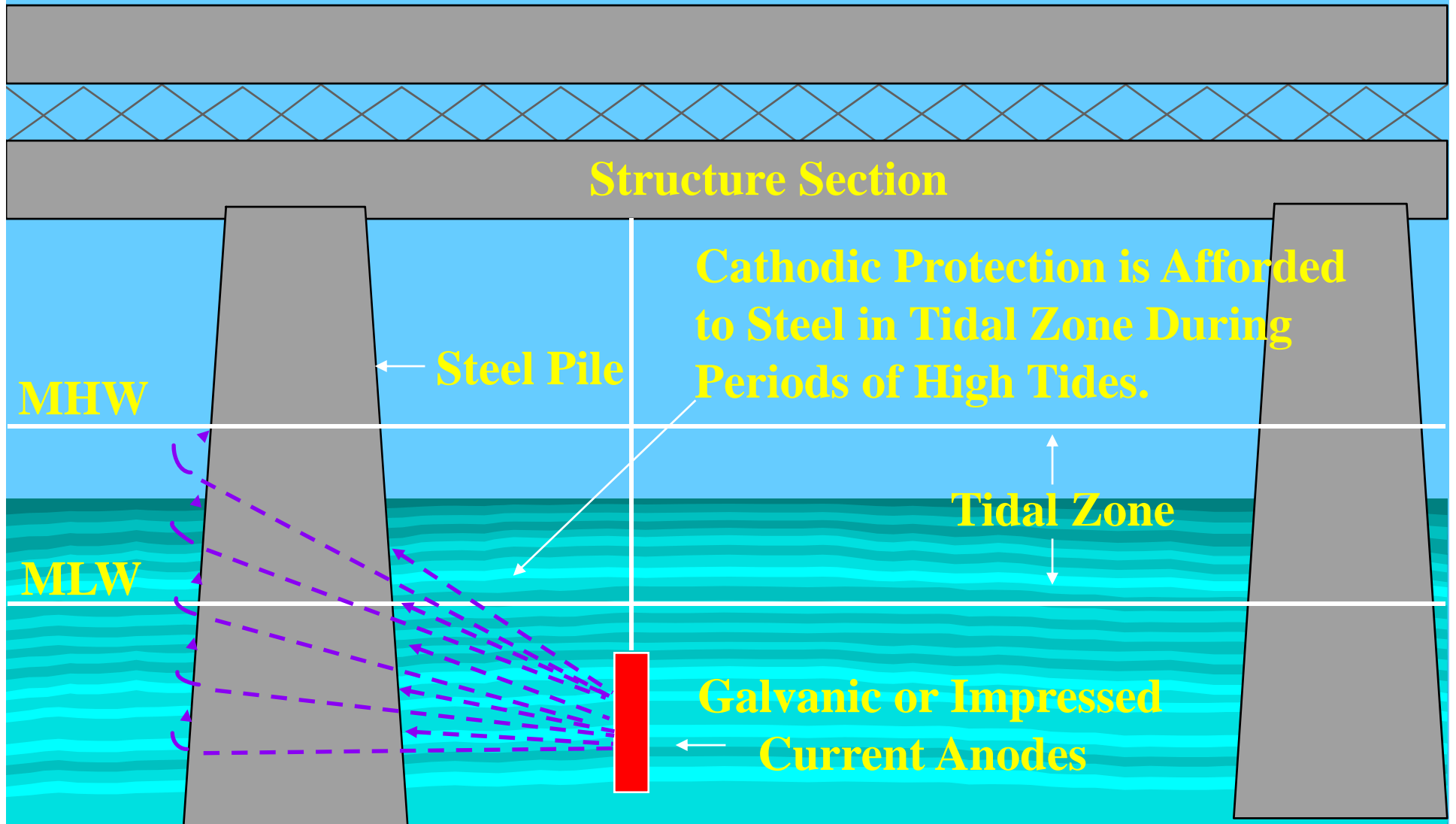
MHW

Steel Pile

Tidal Zone

MLW

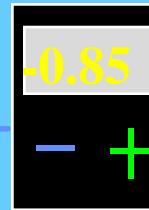
Galvanic or Impressed Current Anodes



# Corrosion Testing

# Pipe-to-Soil Potential Test

Multimeter

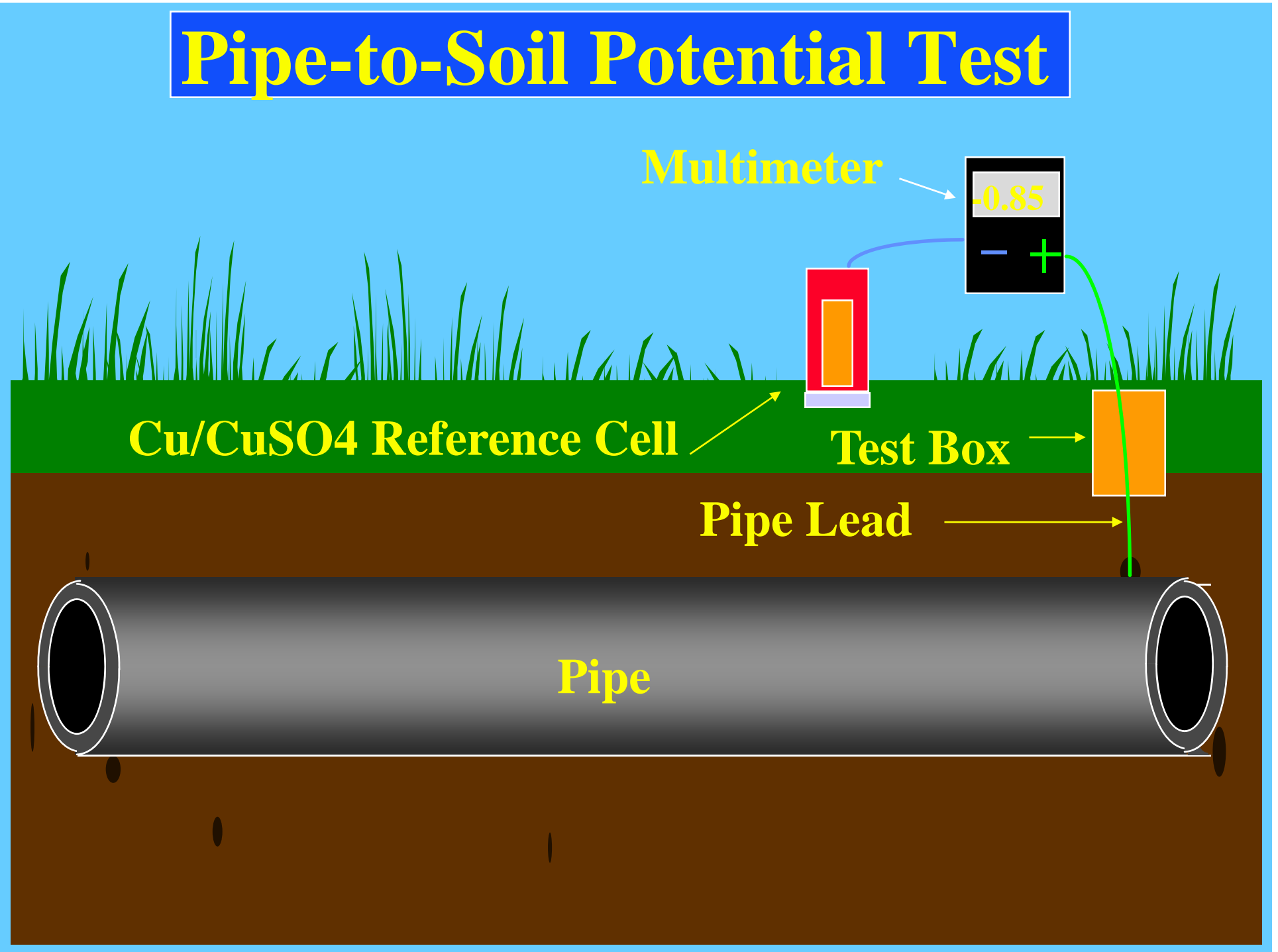


Cu/CuSO<sub>4</sub> Reference Cell

Test Box

Pipe Lead

Pipe



# Corrosion Monitoring

- Mains - Once a Year
  - Ensure Test Box Availability
- Services – Once every Ten Years
  - Ensure Test Wires are Connected
- Rectifiers and Bonds – 2 Months
- Record Keeping – For the life of the pipe.

# Common Corrosion Problems

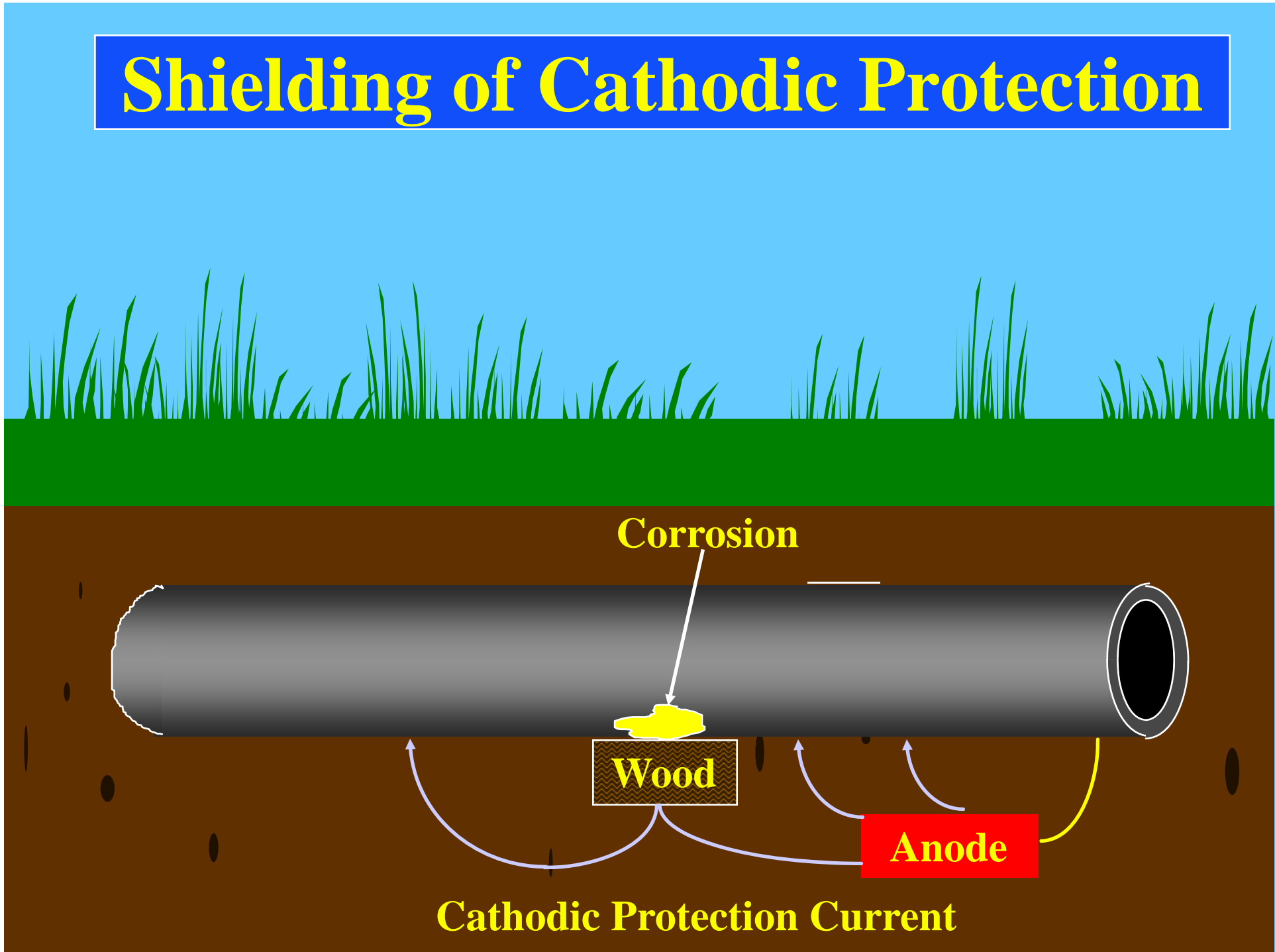
# Shielding of Cathodic Protection

Corrosion

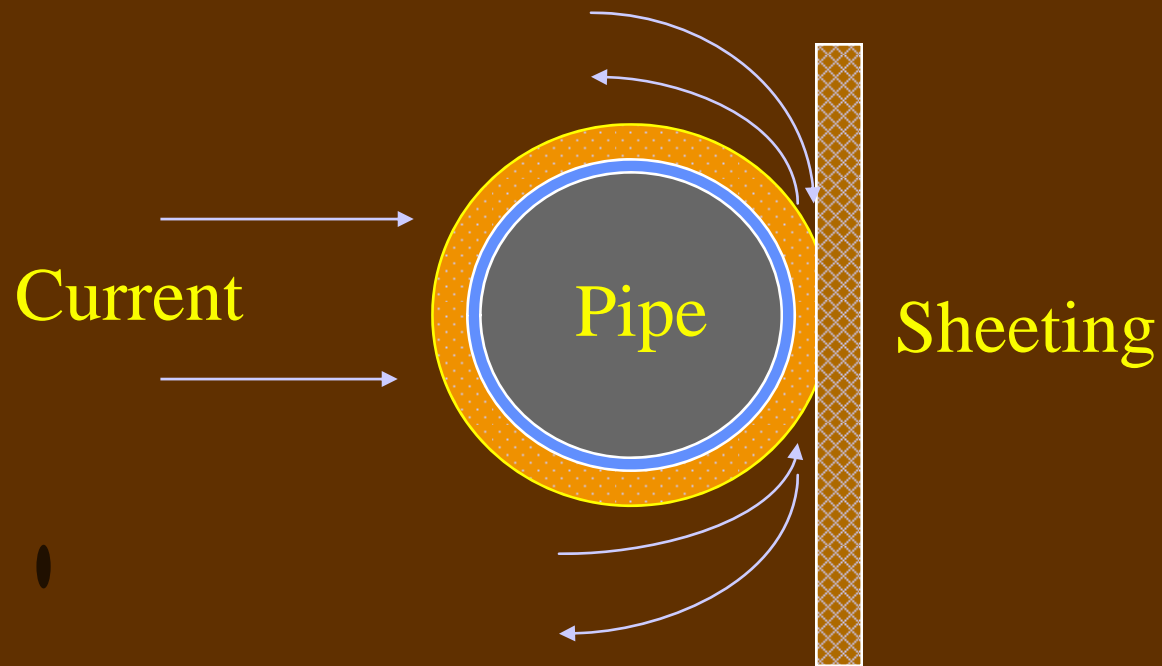
Wood

Anode

Cathodic Protection Current



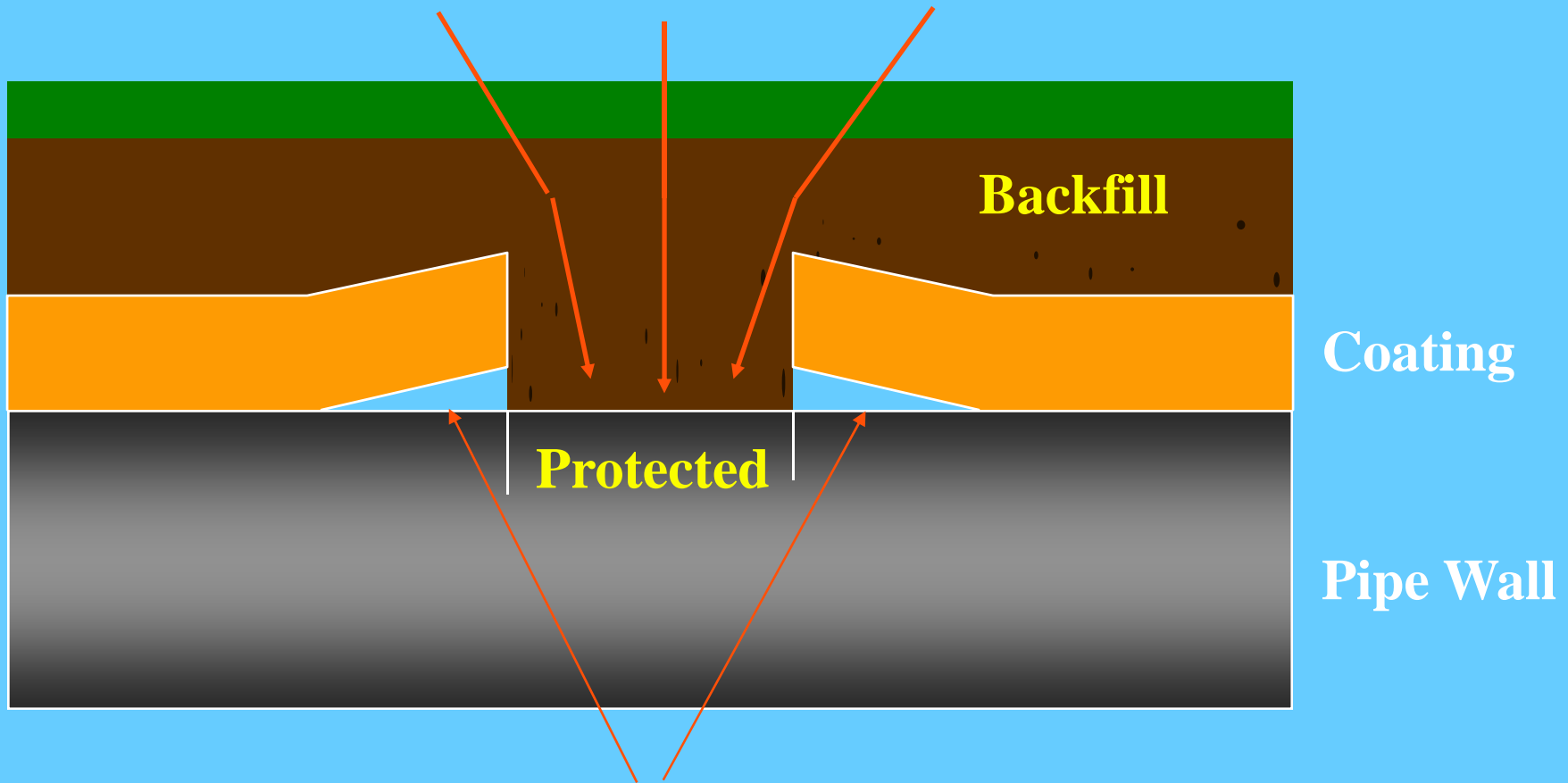
# Shielding Of Protective Currents





# Coating Disbondment & CP Shielding

Cathodic Protection Current  
Protects Exposed Area

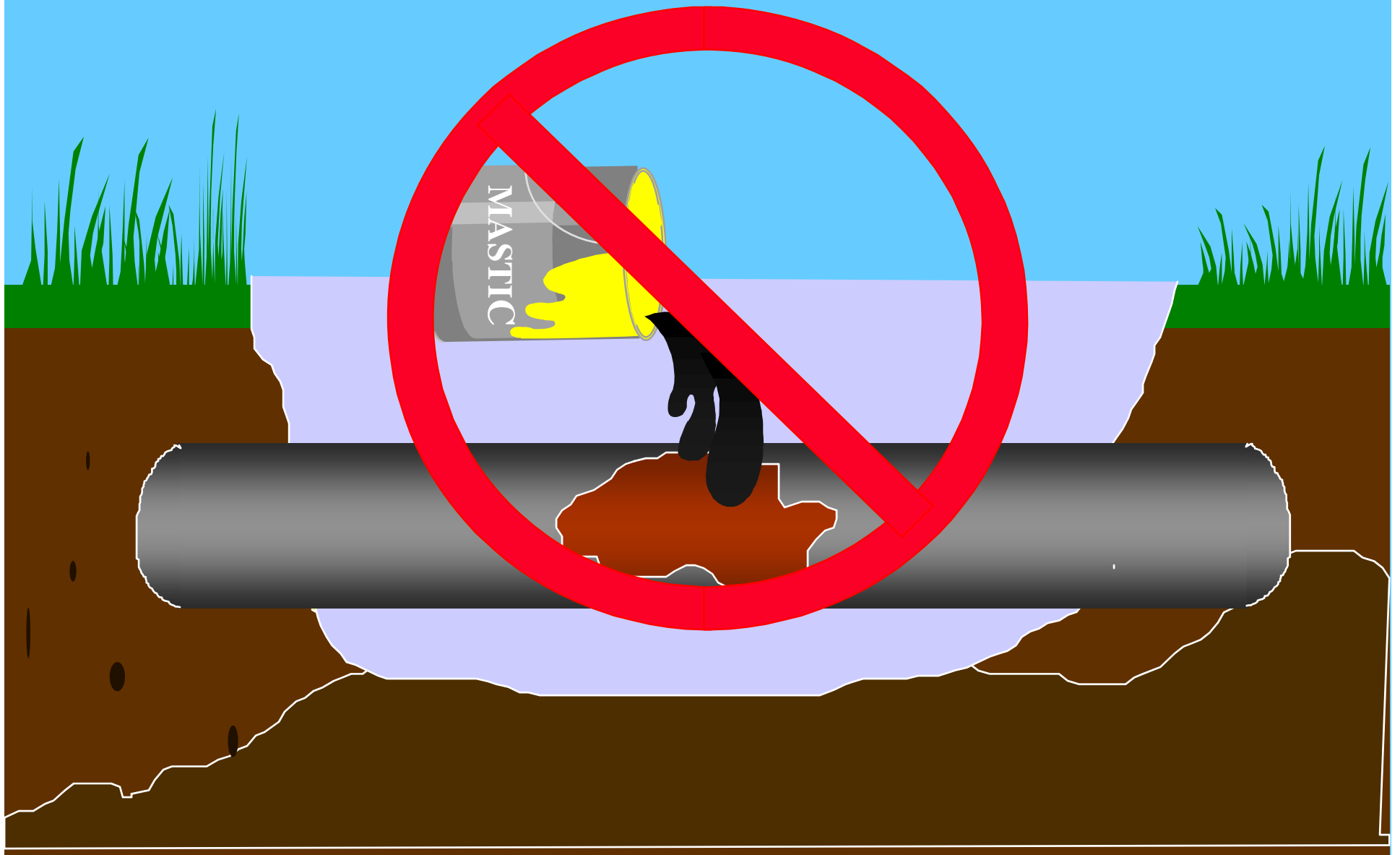


Cathodic Protection Current Does Not Protect  
Area Under Disbonded Coating

# Faulty Service Isolators



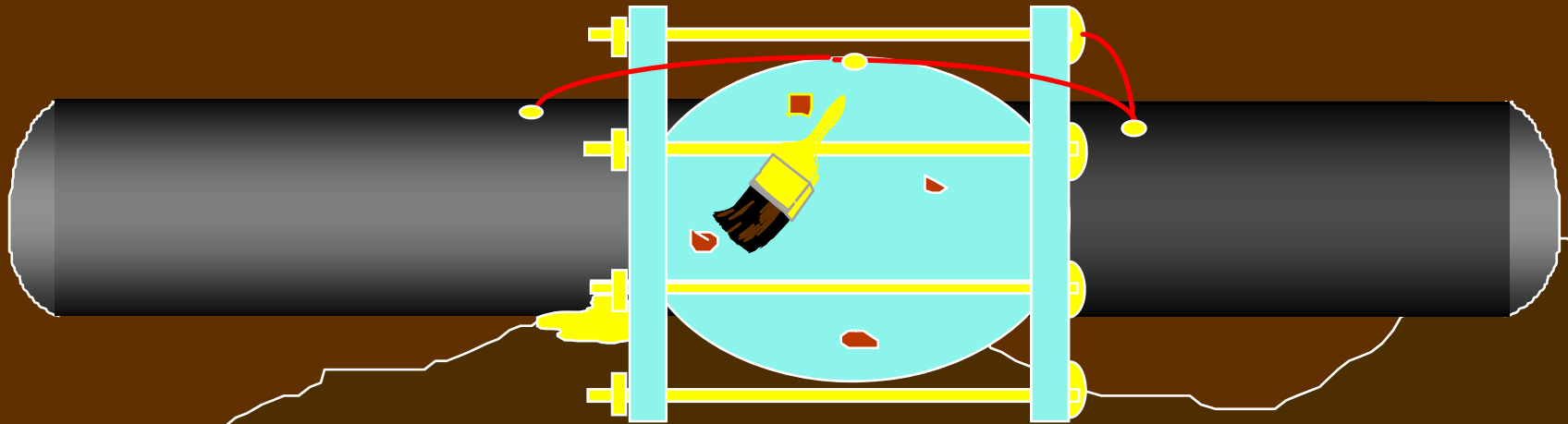
# Mastic Application



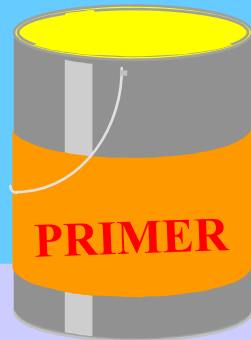
# Proper Mastic Application



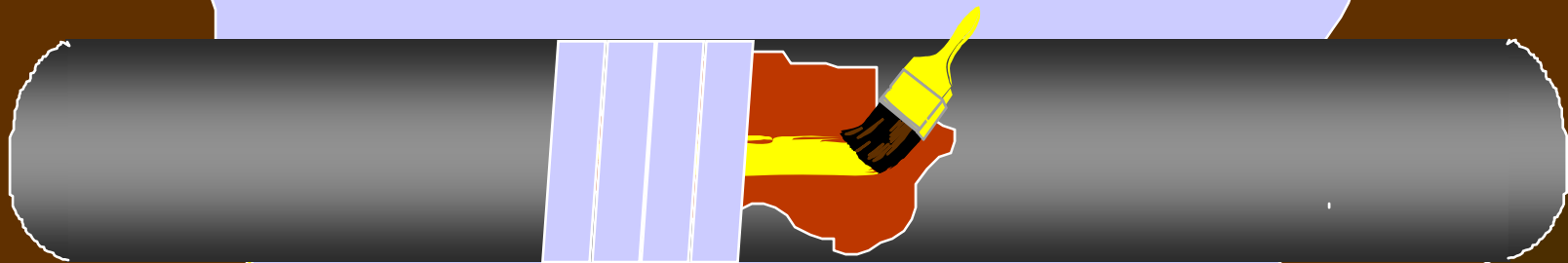
**Wire brush damaged areas**  
**Apply two thin coats (paint)**  
**Let dry between coats (15 min)**  
**Let dry before backfilling.**



# Proper Coating Repairs with Cold Applied Tape



Clean pipe with wire brush.  
Apply primer to clean pipe.  
Wrap tape around pipe.



# Other

- Test Wires not connected to anode.
- No dielectric union on service entrance or service regulator vent.
- Underground electrical contact with other metallic structure.
- Isolator installed incorrectly or not at all.
- Isolator installed and not indicated.
- Test boxes paved over.
- Telemetry not isolated.

# Summary

- **Corrosion Cell**

  - Anode

  - Cathode

  - Electrolyte

  - Metallic Connection

- **Corrosion Control System**

  - Coating - Mastic and Cold Applied Tape

  - Isolation - Insulating Joints

  - Cathodic Protection - Magnesium Anode