



# **MEA Construction Inspector Training**

## **Corrosion Control Theory and Application**

# Agenda

1. Basic Corrosion Theory
2. Methods of Corrosion Control
  - a) Coatings
  - b) Galvanic Anodes
  - c) Impressed Current Systems
3. Construction Practices for Safe and Reliable Corrosion Control
  - Coating Application and Maintenance
  - Jeeping and Surveying
  - A/C Safety
  - Isolation
  - Casings
  - Test Station/Anode Installation
  - Rectifier Installation

# Basic Corrosion Theory

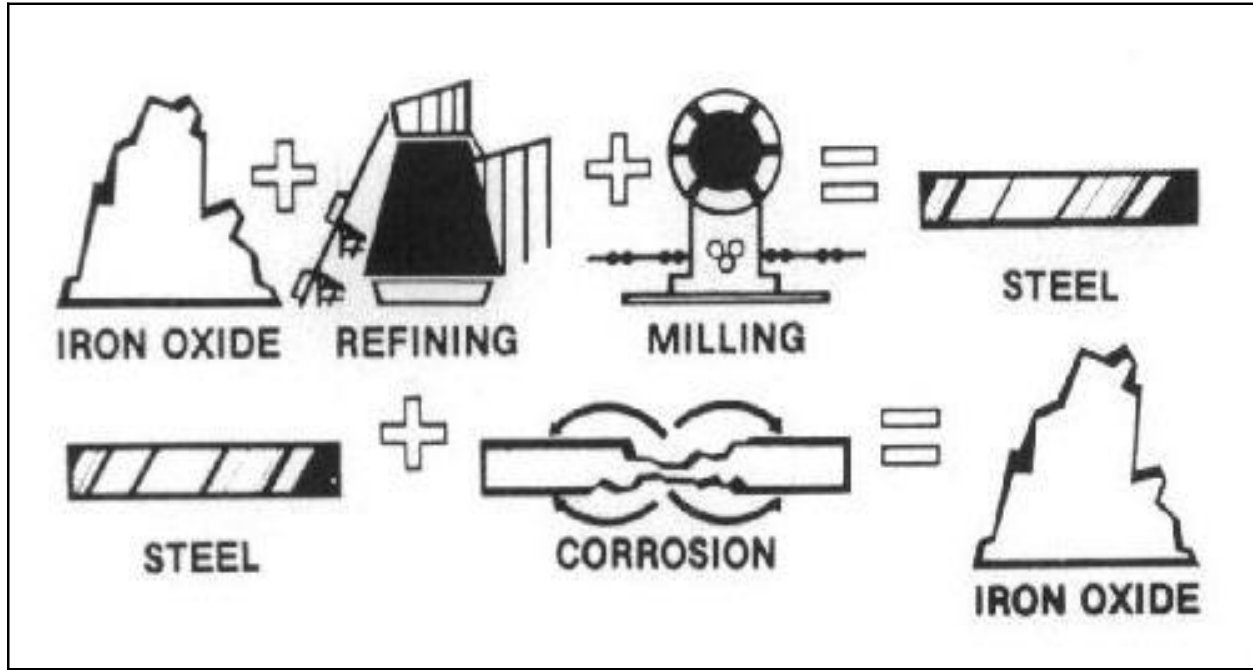
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# Basics of Corrosion

- It is the process of a metal releasing energy to return to its natural state
- This is an electrochemical reaction between the metal and its environment
- It is a natural occurring process common to all metals that have undergone a change
- There are two primary aspects of corrosion:
  1. A physical change in the metal occurs
  2. With this change, direct electric current is generated

# Basics of Corrosion



- Energy is added to iron ore in the refining and milling processes
- Once the addition of energy ceases, the metals begin to return to their natural state

# Basics of Corrosion

## Elements of the Corrosion Cell

- Anode: Higher level energy area where corrosion takes place

*(**loss** of electrons)*

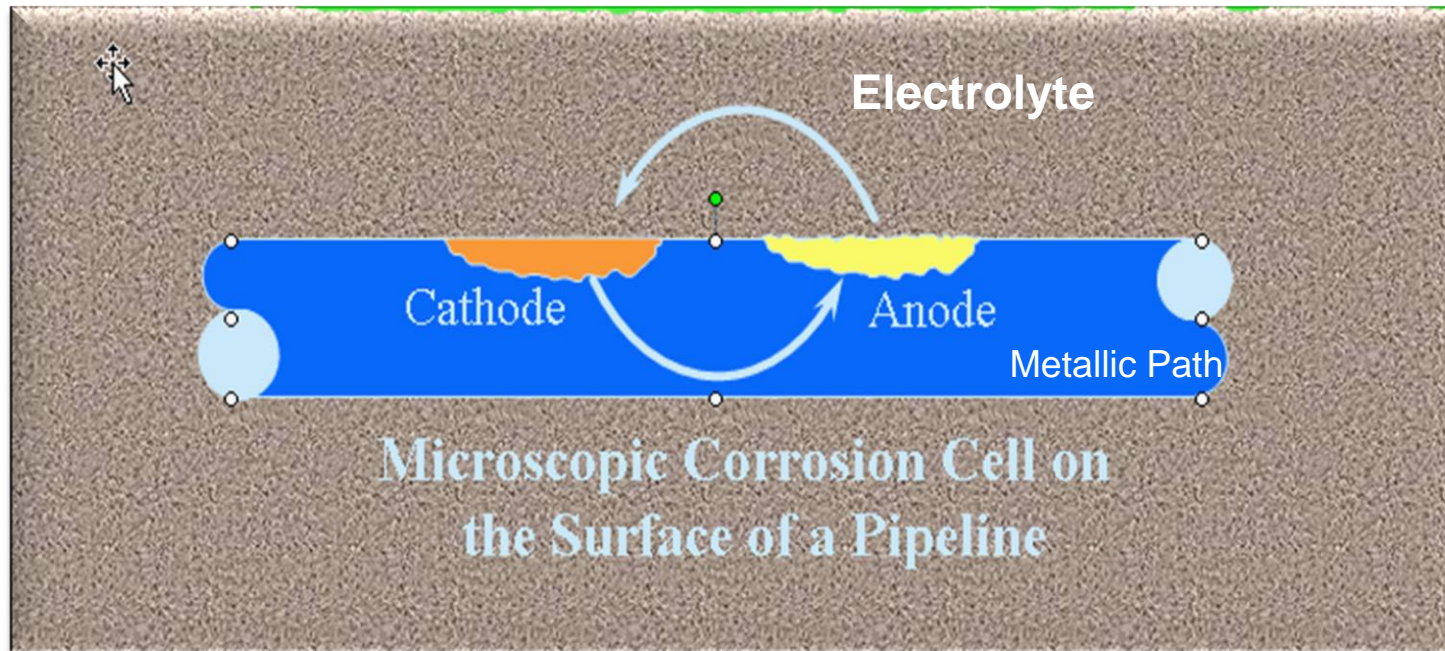
- Cathode: Lower level energy area where a reduction reaction takes place

*(**gain** of electrons)*

- Electrolyte: Path for ionic energy transfer
- Metallic Connection: Path for electron energy transfer

# Basics of Corrosion

## Example of a Corrosion Cell



# Basics of Corrosion

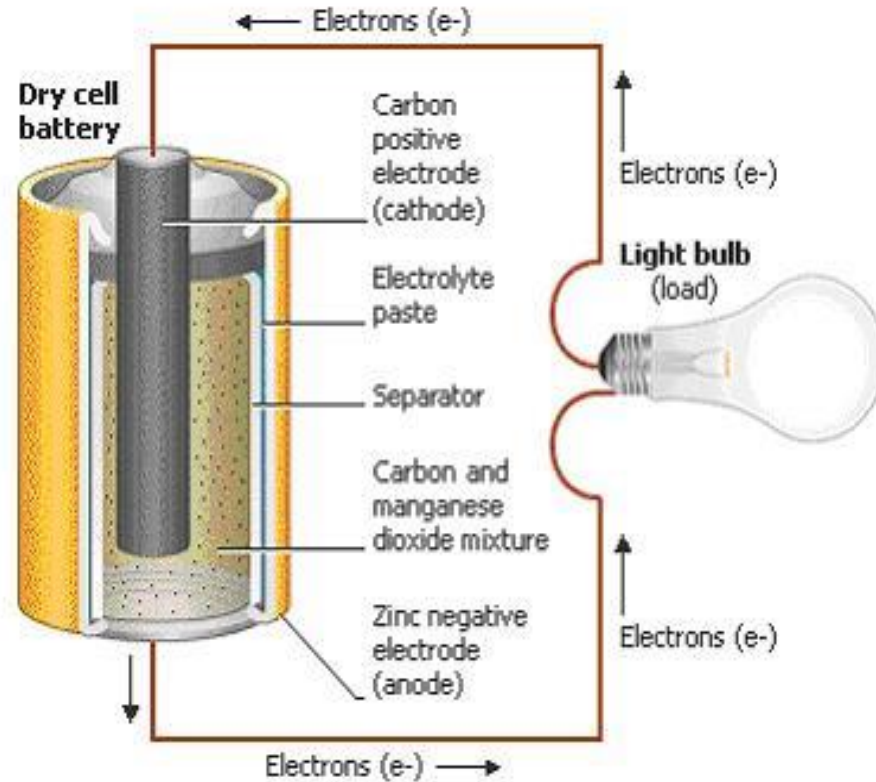
*Question:*

*Can anyone name an example of a corrosion cell that is actually desirable?*



# Basics of Corrosion

## Alkaline Battery



# Basics of Corrosion

***The key to minimizing the effects of corrosion is to eliminate one or more elements of the corrosion cell.***

- Material Changes
- Design Changes
- Environmental Changes
- **Coatings**
- **Cathodic Protection**

# Methods of Corrosion Control

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# Methods of Corrosion Control

## Coatings

- Application of a pipe coating in order to eliminate the pipe's exposure to its environment (electrolyte)
- Coatings application is the primary means of slowing the corrosion process
- Numerous different types, from coal/tar based coatings, hot and cold applied tapes, multi-part liquid epoxies, to modern factory applied Fusion Bonded Epoxies (FBE)
- Proper pipe surface preparation, as well as adherence to manufacturer's application directions is key

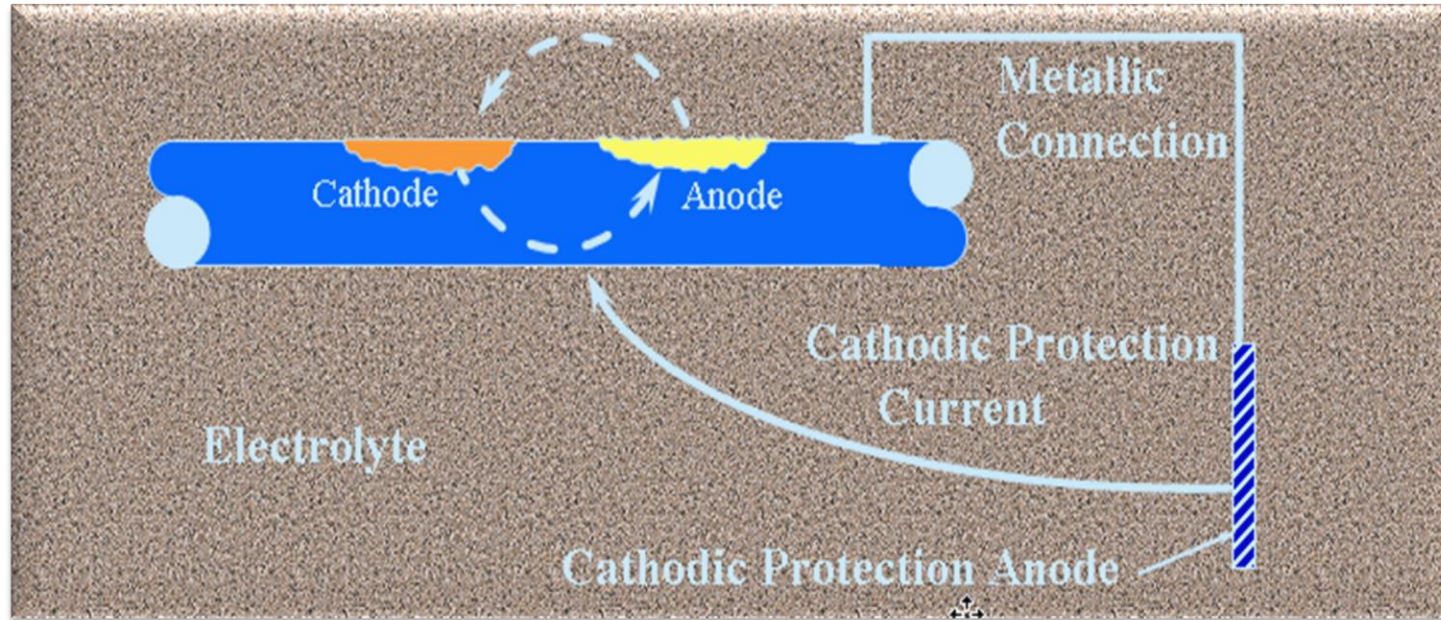
# Methods of Corrosion Control

## Cathodic Protection

- The theory of cathodic protection is to force a structure (pipeline) to become a cathode by connecting an external anode
- The external anode can either be sacrificial, or part of an impressed current system
- DC current, the generation of which is one of the primary aspects of corrosion, flows from the external anode to the cathode
- An effective cathodic protection system is one that transfers all corrosion to the external anode, and in turn, protects the structure

# Methods of Corrosion Control

## Cathodic Protection



# Methods of Corrosion Control

## The Practical Galvanic Series

<u>Material</u>	<u>Potential*</u>
Pure Magnesium	-1.75
Magnesium Alloy	-1.55
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 are with respect to a saturated  
CU-CuSO<sub>4</sub> Electrode



# Methods of Corrosion Control

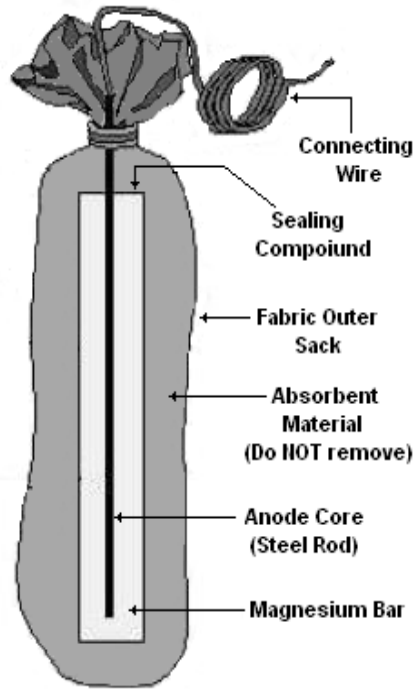
## Galvanic Anode Selection

- Aluminum: Primarily used in sea water, offshore applications
- Zinc: Alloys for either sea water or fresh water/soil applications
- Magnesium: Primarily used for fresh water offshore or soil applications
  - H-1 – Produced from recycled magnesium and has an open circuit potential of app. -1.55V
  - High Potential – Made of 99% pure magnesium and has an open circuit potential of up to -1.80V. Used in applications with very high soil resistivity (i.e. 10k $\Omega$ -cm)



# Methods of Corrosion Control

## Galvanic Anode Example



*Today, the most commonly used backfill consists of:*

*75% Hydrated Gypsum  
20% Bentonite Clay  
5% Sodium Sulfate*

# Methods of Corrosion Control

## Impressed Current Systems

- Impressed current systems are another way to cathodically protect a structure
- They consist of:
  - Power Source (Rectifier)
  - Anodes (different than those used in galvanic systems)
  - Wiring, splices, and impressed current specific backfills
- Typical Applications:
  - Where large current outputs are required
  - Where galvanic anodes have either dissipated or are difficult to replace
  - Where stray current or cathodic interference problems exist

# Methods of Corrosion Control

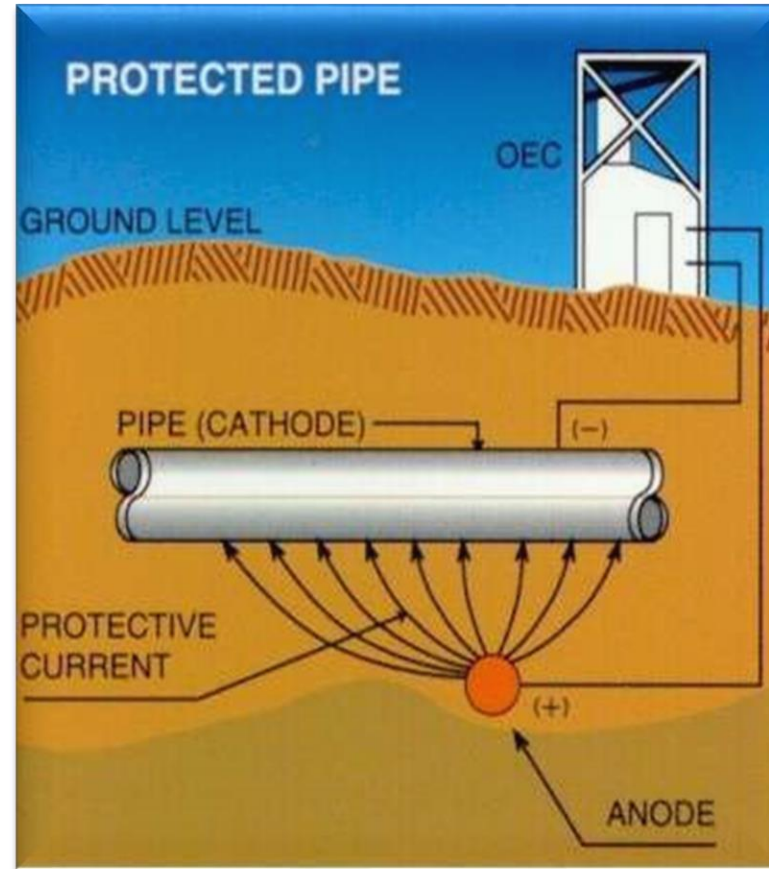
## Impressed Current System Components

- ▶ Anodes
- ▶ Rectifier
- ▶ Wiring



# Methods of Corrosion Control

## Impressed Current System Diagram



# Construction Practices for Safe and Reliable Corrosion Control

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# **Safe and Reliable Corrosion Control**

## **Pipeline Coating - Handling**

- Skids used during all phases of pipe handling should be well padded
- Slings and calipers should be padded with canvas, belting, or other pliable insulating material
- Never use chains, hooks, cables or unpadded fork lifts or backhoe buckets
- Where necessary, pad bottom of ditch with sand bags or other protective material
- Use rock-free spill or sand for padding prior to backfilling
- Remove all welding rods from ditch

# **Safe and Reliable Corrosion Control**

## **Common Girth Weld Coatings**

- Cold applied tapes
  - Maintain proper tension at all times
- Hot applied tapes
  - Follow manufacturer temperature recommendations (pipe temperature)
  - Follow manufacturer surface preparation directions
- Two part liquid epoxy coatings
  - Follow manufacturer temperature recommendations (pipe temperature)
  - Follow manufacturer surface preparation directions
  - Follow manufacturer mixing directions



# **Safe and Reliable Corrosion Control**

## **Common Girth Weld Coatings**

- Shrink Sleeves
  - Follow manufacturer temperature recommendations (pipe temperature)
  - Follow manufacturer surface preparation directions
  - Follow manufacturer application directions
- Fusion Bond Epoxy
  - Use induction heaters ( about 400 degrees )
  - Spray on powder in temporary booth



# Safe and Reliable Corrosion Control

## Pipeline Coating - Holiday Detection (Jeeping)



# **Safe and Reliable Corrosion Control**

## **Pipeline Coating - Holiday Detection (Jeeping)**

- Jeepers are used to identify pipe coating pinholes, or “holidays”
- A high voltage electrode is passed along the length of the pipe
- When the tool encounters a holiday, a tone or alert is emitted, notifying the user of the condition
- Operators may specify holiday detection at the mill, after stringing, and/or prior to lowering into the excavation

# Safe and Reliable Corrosion Control

## Pipeline Coating - Holiday Detection (Jeeping)



# **Safe and Reliable Corrosion Control**

## **Pipeline Coating - Holiday Detection (Jeeping)**

- The tool must be calibrated and inspected before use
- The pipe must be properly grounded
- The detector's trailing ground must be in contact with soil
- Proper voltage must be used for the coating on the pipe
- If the soil is excessively dry, the detector ground may need to be connected directly to the pipe
- A test holiday is a good way to ensure the detector is working properly
- Holidays should be marked for repair

# **Safe and Reliable Corrosion Control**

## **Pipeline Coating - Holiday Detection (Jeeping)**

- Holiday repairs must follow the standards provided
  - Tapes
  - Melt sticks
  - Liquid epoxies
- Retest repaired areas!

# **Safe and Reliable Corrosion Control**

## **In Service Pipeline Coating Inspection**

- Performed using Direct or Alternating Current Voltage Gradient
  - Uses an interrupted power supply and meter to measure voltage changes over small spans of the underground pipeline
  - Generally used as part of annual surveying or troubleshooting of known cathodic protection deficiencies

# Safe and Reliable Corrosion Control

## In Service Pipe Coating - DCVG





# Safe and Reliable Corrosion Control

## Coating Defect Found with DCVG





# Safe and Reliable Corrosion Control

## Coating Defect Found with DCVG



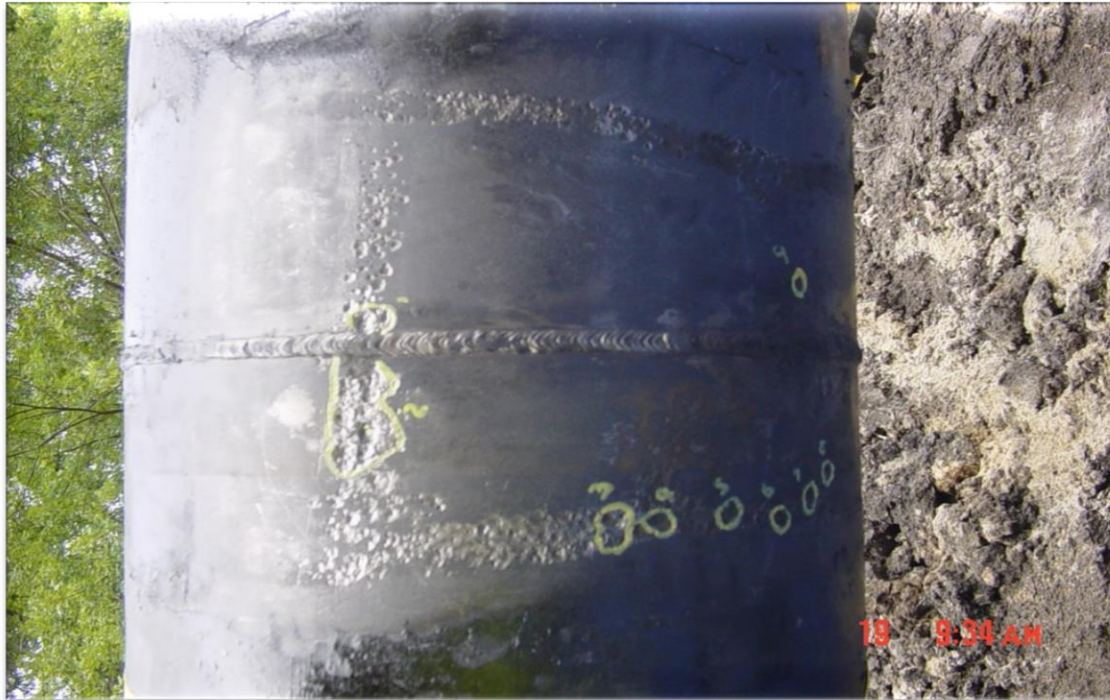
# Safe and Reliable Corrosion Control

## Coating Defect Found with DCVG



# Safe and Reliable Corrosion Control

## Coating Defect Found with DCVG





# Safe and Reliable Corrosion Control

## Coating Defect Found with DCVG



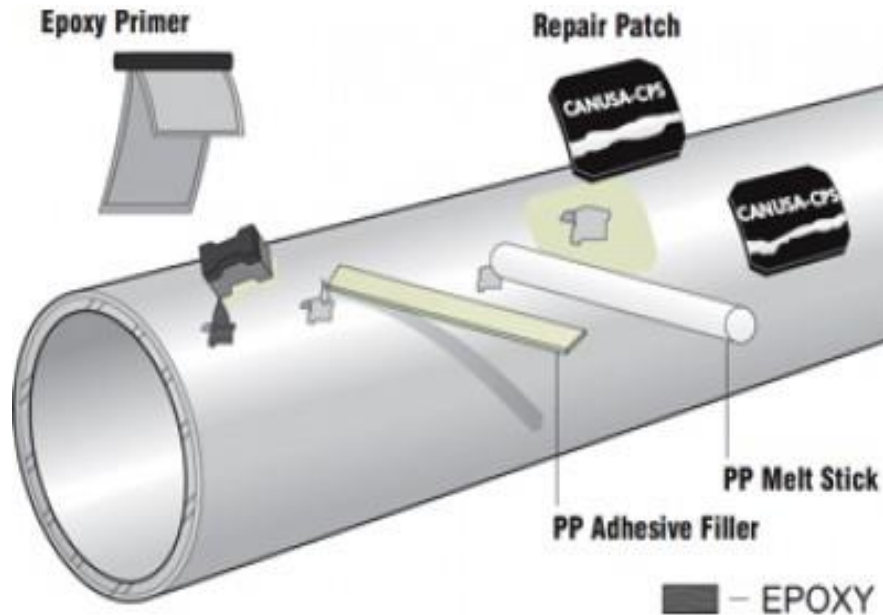
# Safe and Reliable Corrosion Control

## Coating Defect Found with DCVG



# Safe and Reliable Corrosion Control

## Pipe Coating - Reconditioning




# **Safe and Reliable Corrosion Control**


## **Common Rehabilitation Coatings**


- Cold applied tapes
  - Maintain proper tension at all times
- Hot applied tapes
  - Follow manufacturer temperature recommendations (pipe temperature)
  - Follow manufacturer surface preparation directions
- Two part liquid epoxy coatings
  - Follow manufacturer temperature recommendations (pipe temperature)
  - Follow manufacturer surface preparation directions
  - Follow manufacturer mixing directions



# AC Safety

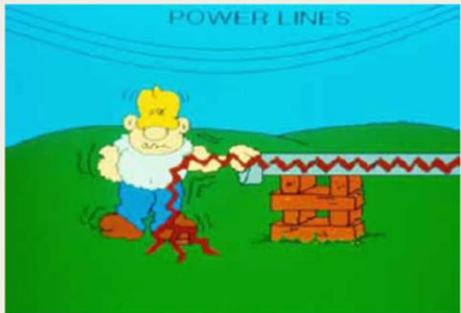







## Dangerous Exposure to Currents and Ways to Avoid Exposure

- ⚡ Joe touches pipe that is strung out on skids under some power lines, and gets zapped!
- ⚡ Joe needs to notify a safety supervisor about the condition.
- ⚡ If the pipe is long enough the zap can be serious.
- ⚡ A properly grounded pipe will keep Joe from getting zapped.



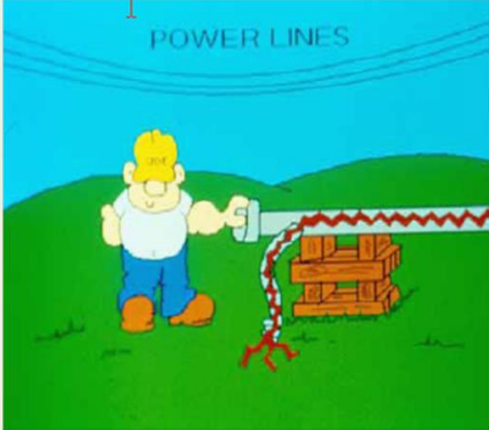


# AC Safety



## Dangerous Exposure to Currents and Ways to Avoid Exposure



- ⚡ Even with grounds, the conditions may be unsafe.
- ⚡ Qualified personnel should inspect the grounding system and measure the pipe voltage to ground to verify that conditions are safe to work.



# AC Safety

Lightning Hazards and Safety Measures

Even if lightning strikes far away, Joe can still be zapped.



# AC Safety

## Lightning Hazards and Safety Measures

- ⚡ Ground rods or mats may not be enough to keep Joe from experiencing a shock.
- ⚡ WORK SHOULD BE STOPPED WHEN LIGHTNING ACTIVITY IS PRESENT!



# AC Safety



## Electrical Hazards Exist Even If You Can't Feel Them

- ⚡ Adequate bonding across the point to be cut will eliminate the hazard.
- ⚡ Bond across the site BEFORE beginning the cut.
- ⚡ A gradient control mat may also be required at this site.
- ⚡ See CAN/CSA – C22.3 No. 6-M91 Typical Temporary Gradient Control Mat




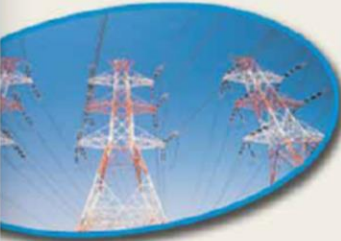
- ⚡ Note: Joe checked that the pipe was safe before connecting the bond and touching the pipe.






# AC Safety

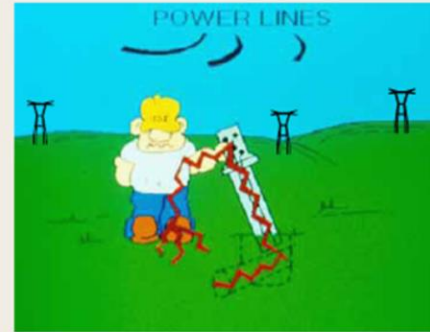







## More Examples of Electrical Hazards and Personal Protection Measures

- ⚡ To avoid a shock, Joe should have followed correct procedures before touching the pipe or appurtenance.
- ⚡ If Joe identifies a shock hazard at the test station or another aboveground appurtenance, he must stop and notify the safety supervisor.





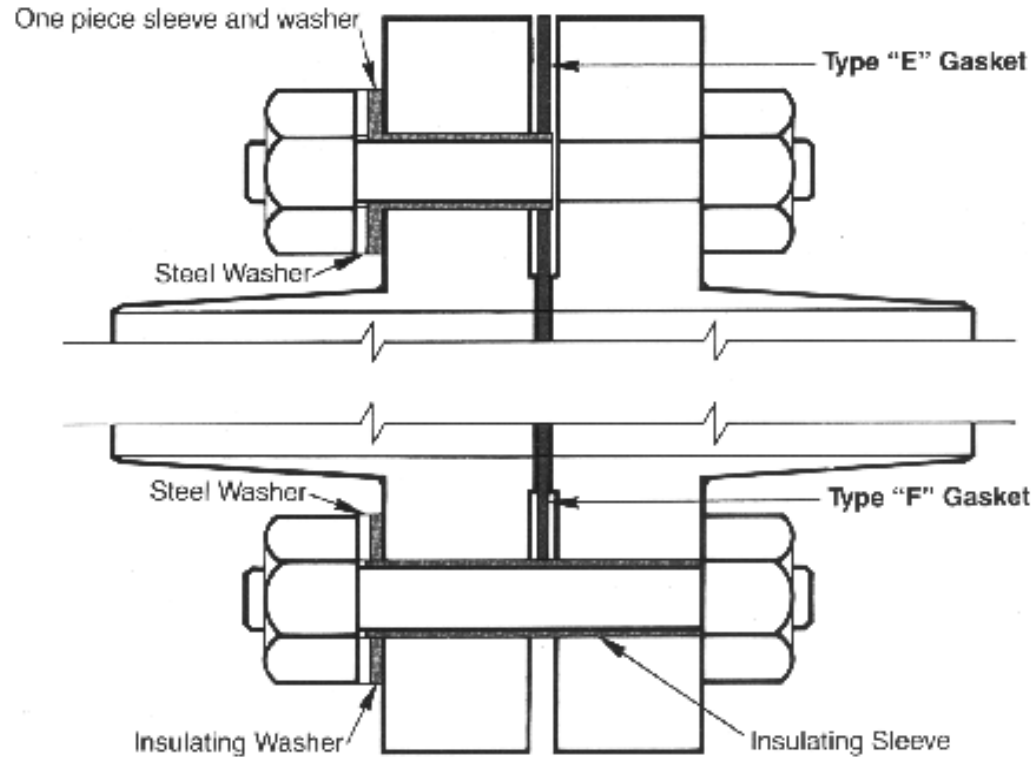
# Safe and Reliable Corrosion Control

## Isolation

- Isolation is the practice of insulating two similar or dissimilar elements from each other to protect against electrical contact
  - Fittings
  - Hardware Kits
  - Sheeting
  - FRP Shields
  - Hangers / Rollers
- Used in a number of different applications
  - Cast / Ductile Iron to CP Steel
  - Buried CP Steel to Exposed Steel
  - CP Steel to CP Steel

# Safe and Reliable Corrosion Control

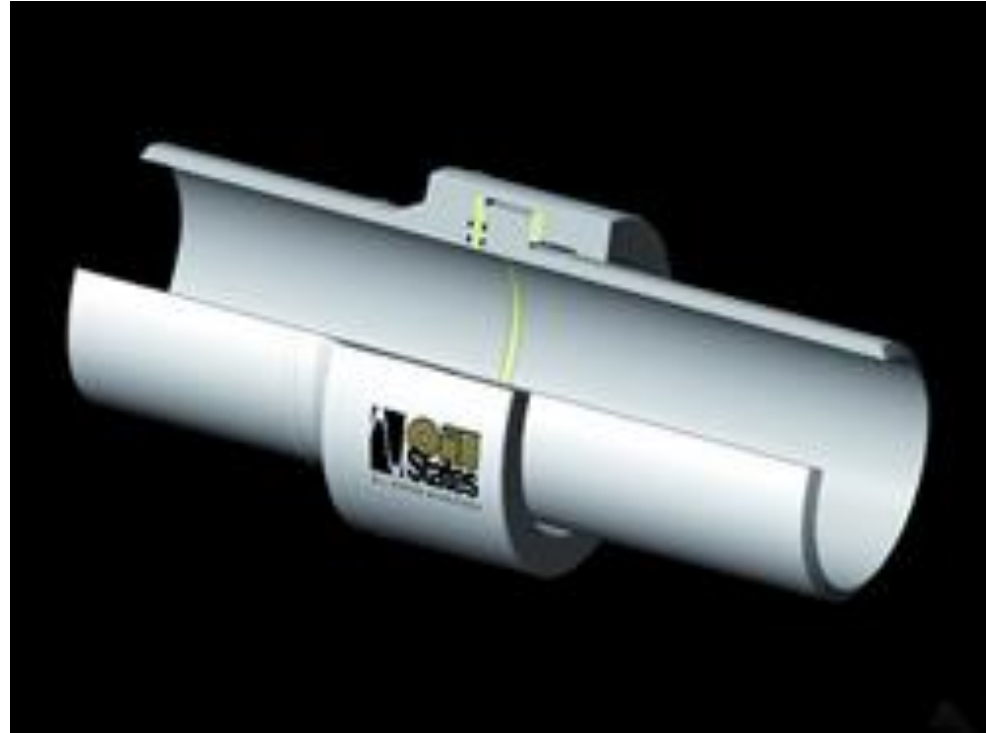
## Isolating Flange with Hardware





# Safe and Reliable Corrosion Control

**Monolithic  
Type  
Insulator**



# Safe and Reliable Corrosion Control

**Fiberglass  
Reinforced  
Plastic**



# Safe and Reliable Corrosion Control

**Insulating  
Rollers**



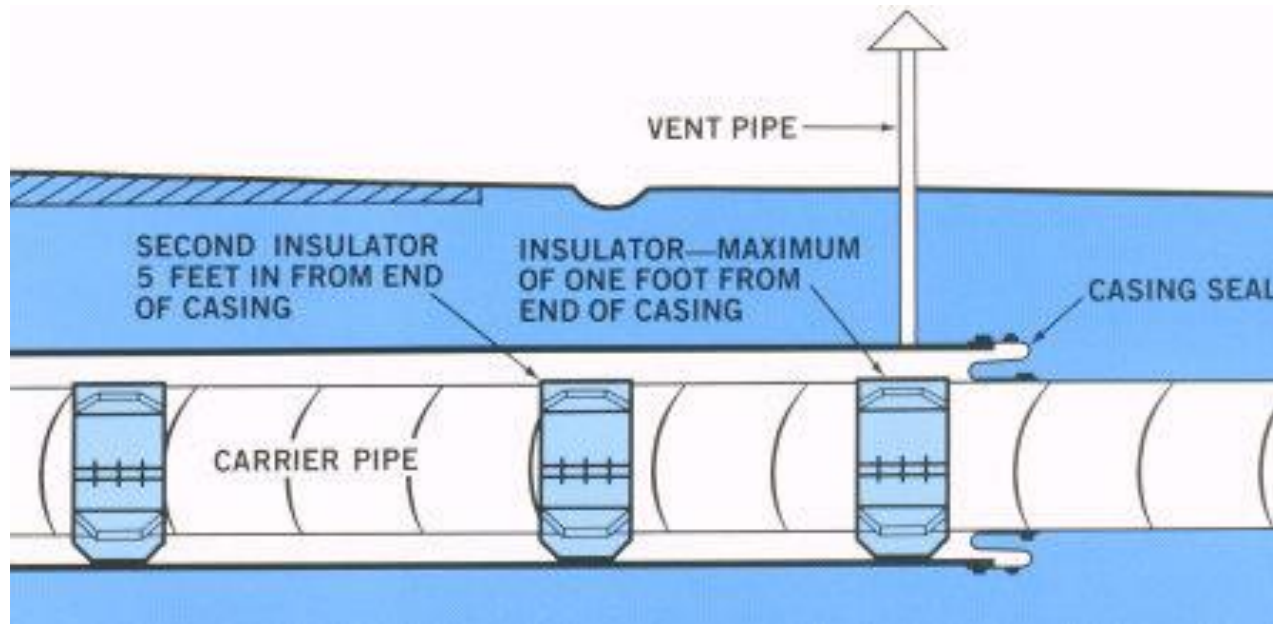
# Safe and Reliable Corrosion Control

## Casings

- Used in a number of different applications
  - Highway Crossings
  - Railroad Crossings
  - Areas where pipe protection from loading is deemed necessary
  - Areas where diversion of potential gas leaks is deemed necessary
- Require proper installation to ensure long term pipeline integrity
  - Spacing of insulators
  - Link Seals
  - End Boots
  - Vents

# Safe and Reliable Corrosion Control

## Casings



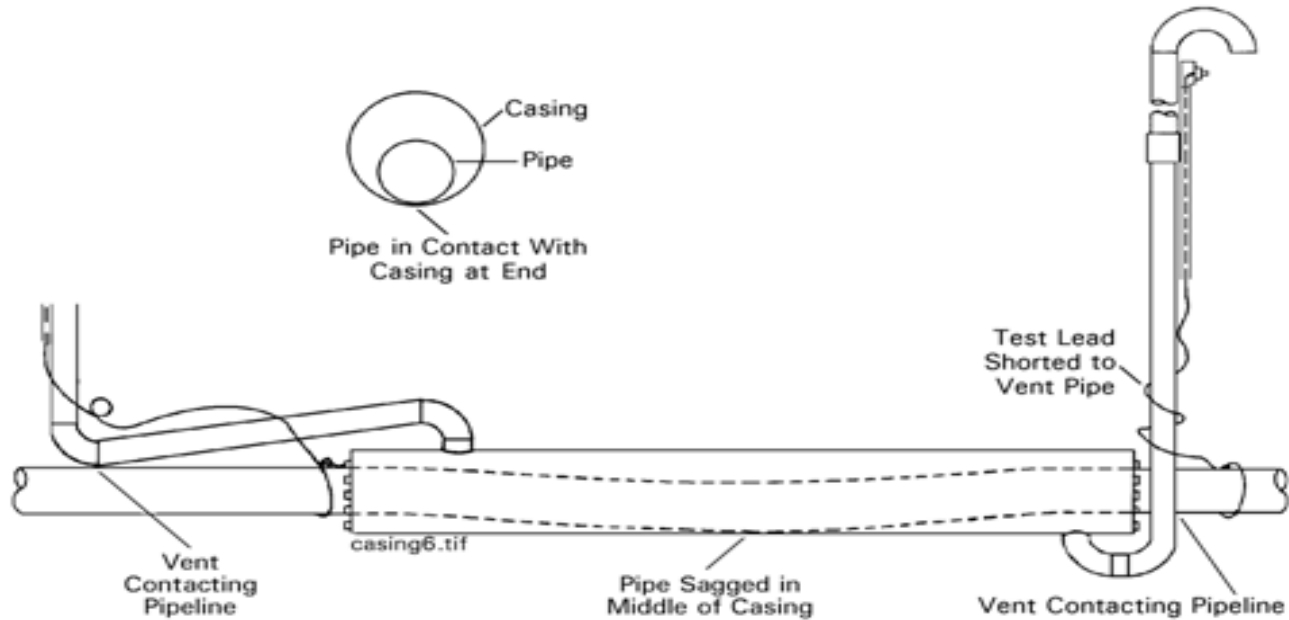
# Safe and Reliable Corrosion Control

## Casings - Issues

- Improper Installation
  - Poor spacing of insulators causing carrier pipe to “bow out”
  - Poor installation of seals causing annular space infiltration
  - Vent pipes not supported causing contact to carrier pipe
- Cathodic Protection and Casings
  - Casings cause a shielding effect on carrier pipe
  - Pipe to Soil inspections on carrier only are no longer sufficient for proving proper CP
  - What is the pipe condition inside the casing?
  - Removal or remediation of casing is incredibly cost prohibitive

# Safe and Reliable Corrosion Control

## Casings - Issues





# Safe and Reliable Corrosion Control

## Test Station and Anode Installation



# **Safe and Reliable Corrosion Control**

## **Test Station and Anode Installation**

- Cathodically protected steel pipelines require periodic corrosion inspections
  - Annual
  - 10 Year Cycles
- Proper testing cannot be performed without physical contact to the structure
- This physical contact comes in the form of test wires welded to the pipeline that are terminated in an accessible roadway box or fink
- Test wires that are improperly installed or identified can lead to erroneous conclusions
- Test wires that are installed but subsequently lost during clean up or restoration are of no benefit

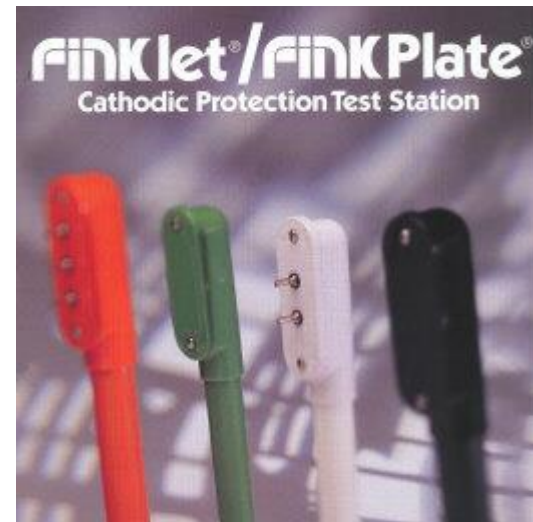
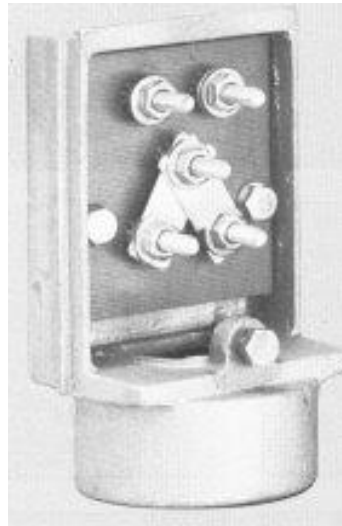
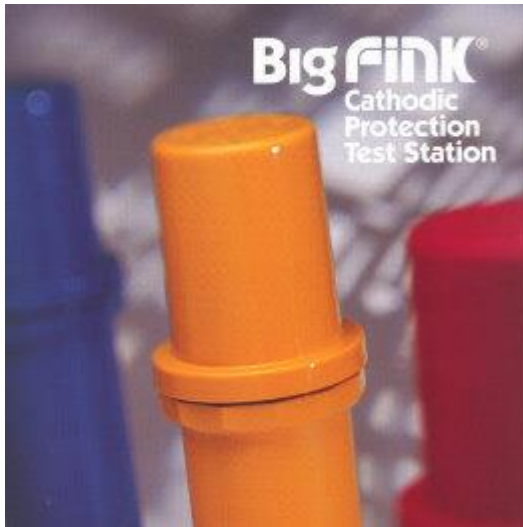
# **Safe and Reliable Corrosion Control**

## **Test Station and Anode Installation**

- One of the final duties of the inspector should be to review the job and determine that:
  - All test stations were installed according to job specs and are accessible
  - Locations of the test stations are properly documented
  - For any test stations were installed incorrectly, notice should be given to the construction contractor to return to job site and either locate or reinstall them
  - Installation of a test station is much cheaper before final restoration!

# Safe and Reliable Corrosion Control

## Test Station Examples



# Safe and Reliable Corrosion Control

## Testing for Proper Cathodic Protection

- Pipe to Soil Inspection
  - A voltage potential is taken from the structure with respect to ground using a reference cell
  - Pipelines may require multiple tests depending on length
- Testing across Insulators
- Line Current
- Structure to Foreign Objects
- Electrical Continuity
- Galvanic Anode Current



# Safe and Reliable Corrosion Control

## Methods of Test Lead Attachment





# Safe and Reliable Corrosion Control

## Test Station Installation – Thermite Welding

- Thermite welding is the standard for reliable test wire / anode installation
- Consists of a crucible, disc, igniter, and powdered thermite charge
- **DANGER – Goggles and Gloves Must be Worn!**
- Use only clean, dry crucibles to prevent splatter
- Use crucible that is sized appropriately for the pipe
- Pipeline coating must be removed, and pipe filed to shiny metal
- Use a half-hitch tie to secure the wire to the pipe, trim and crimp
- Insert disc, empty powder and starter into crucible, close and lock
- Center the crucible over the wire
- Ignite and hold in place for 30 seconds



# **Safe and Reliable Corrosion Control**

## **Test Station Installation – Thermite Welding**

- After weld has cooled, strike sharply with a hammer to ensure weld holds
- Remove slag
- Coat and wrap

# Safe and Reliable Corrosion Control

## Test Station Installation – Thermite Welding



# Safe and Reliable Corrosion Control

## Test Station Installation – CadWeld Plus System



**Step 1**  
Insert CADWELD PLUS package  
into mold.



CADWELD PLUS installation - s

**Step 2**  
Attach Control Unit termination  
clip to ignition strip. Place baffle  
onto mold.

# Safe and Reliable Corrosion Control

## Test Station Installation – CadWeld Plus System



### Step 3

Press and hold Control Unit switch and wait for ignition.



### Step 4

Open the mold and remove the expended steel cup - no special disposal required.

# **Safe and Reliable Corrosion Control**

## **Test Station Installation – Coating of Thermite Weld**

- Thermite Weld must be sealed and coated just as all other metallic pipe
- Coatings:
  - Tape Wrap
  - “Handycap” Adhesive Patches
  - Two part epoxies
- All coatings must be applied in accordance with the instructions and specifications outlined by the manufacturer

# **Safe and Reliable Corrosion Control**

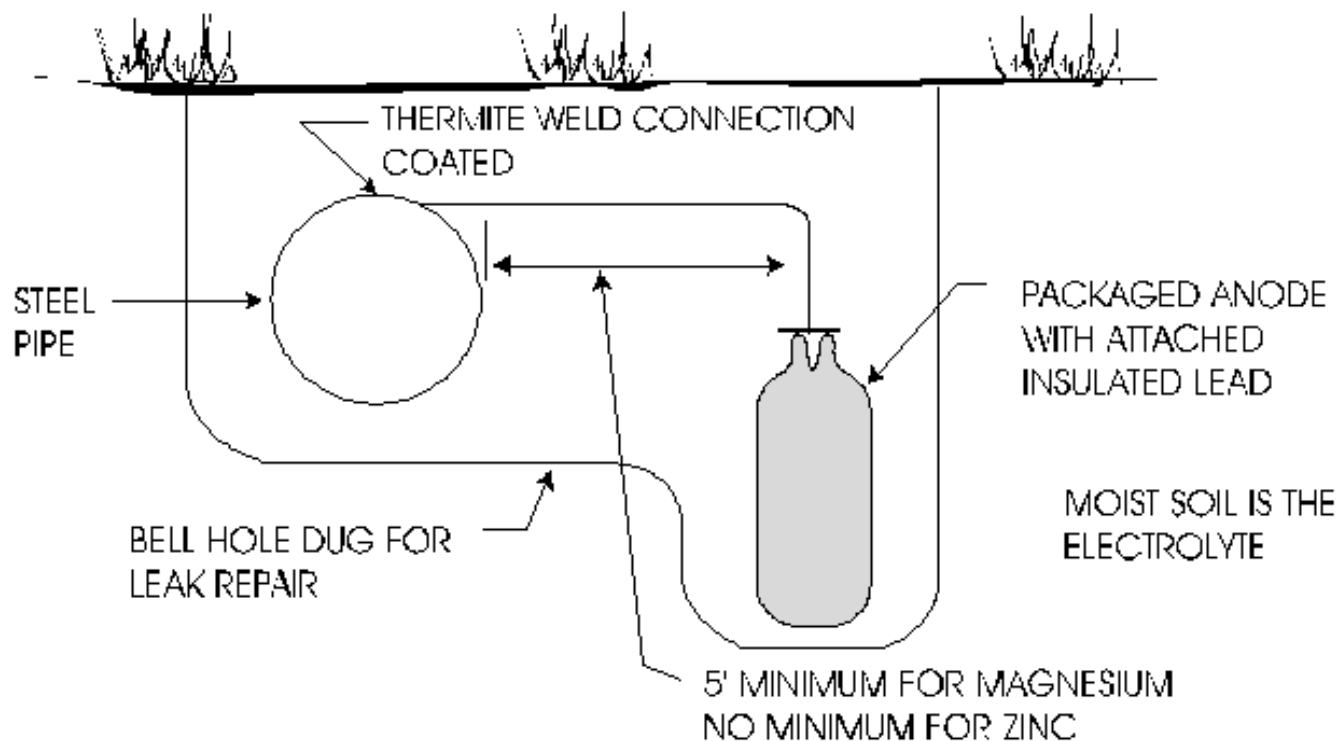
## **Anode Installation**

- Anodes should generally be placed at least 5' from the pipeline
- Can be installed horizontally or vertically
- Remember to remove the bag!
- After placing the anode, stretch out the anode connecting wire and extend to the connection point on the structure
- Cover the anode with approximately 6" of backfill
- Saturate the anode and backfill with water to activate it, or presoak the anode before installation
- Beware of shrinkage



# Safe and Reliable Corrosion Control

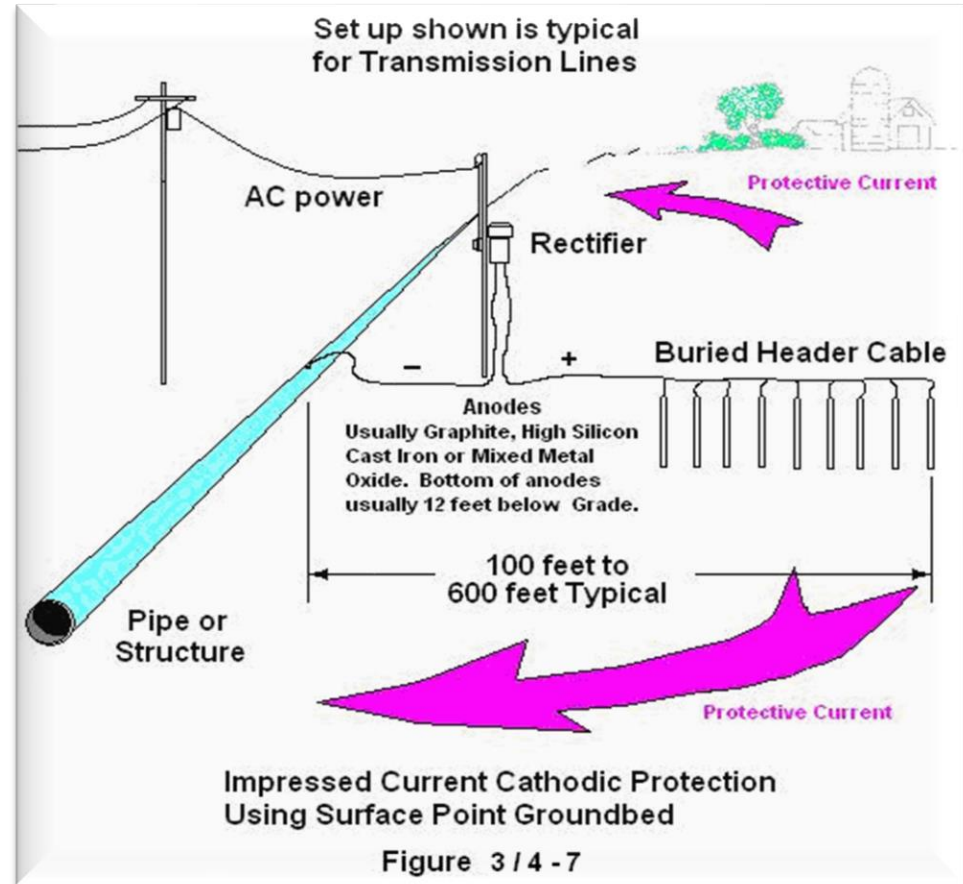
## Anode Installation



# Safe and Reliable Corrosion Control

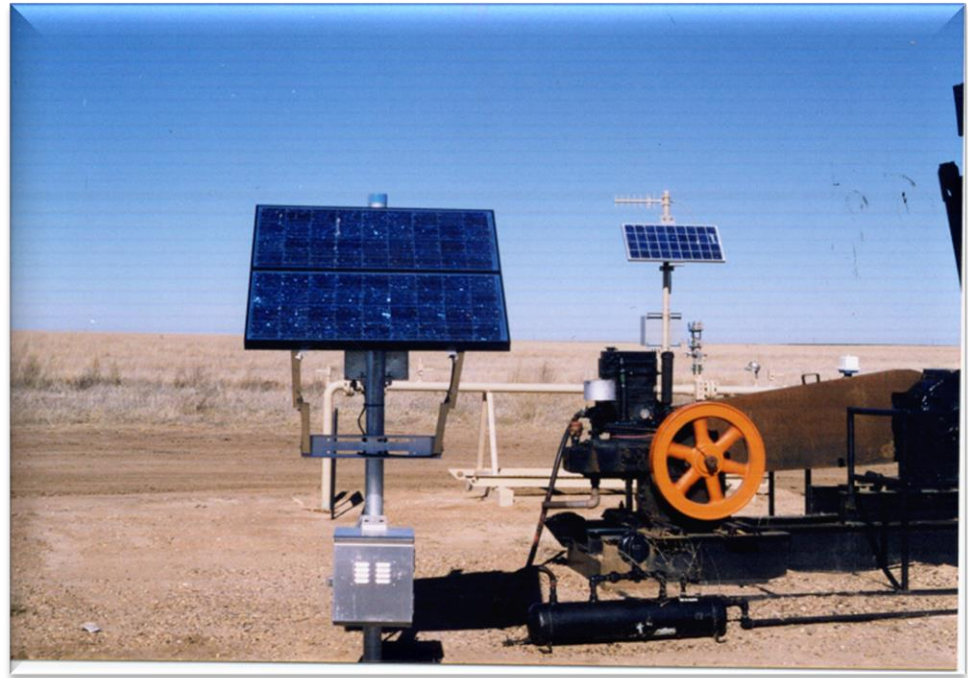
## Rectifier Installation

- Power Source
- Negative and Positive Connections
- Anode Splices to Header Cable
  - Epoxies
  - Shrink Sleeves
  - Tape Systems
- Anode Types
  - Cast Iron
  - Graphite
  - Mixed Metal Oxide
- High Molecular Weight Polyethylene Cable



# Safe and Reliable Corrosion Control

## Rectifier Installation – Alternative Power Sources



# **Safe and Reliable Corrosion Control**

## **Rectifier Installation – Alternative Power Sources**



# Summary and Conclusion

- Properly installed and inspected pipe coatings are critical to an effective cathodic protection system
- There are many coating varieties today. Reach out to manufacturers to find what solutions work best for your specific application.
- Follow manufacturers' instructions
- Cathodic Protection employees rely on properly installed test stations to monitor CP systems
- Galvanic and Impressed Current systems each have their own advantages and disadvantages

**Good construction practices can provide decades of reliable corrosion control!**

# Questions?

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