



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

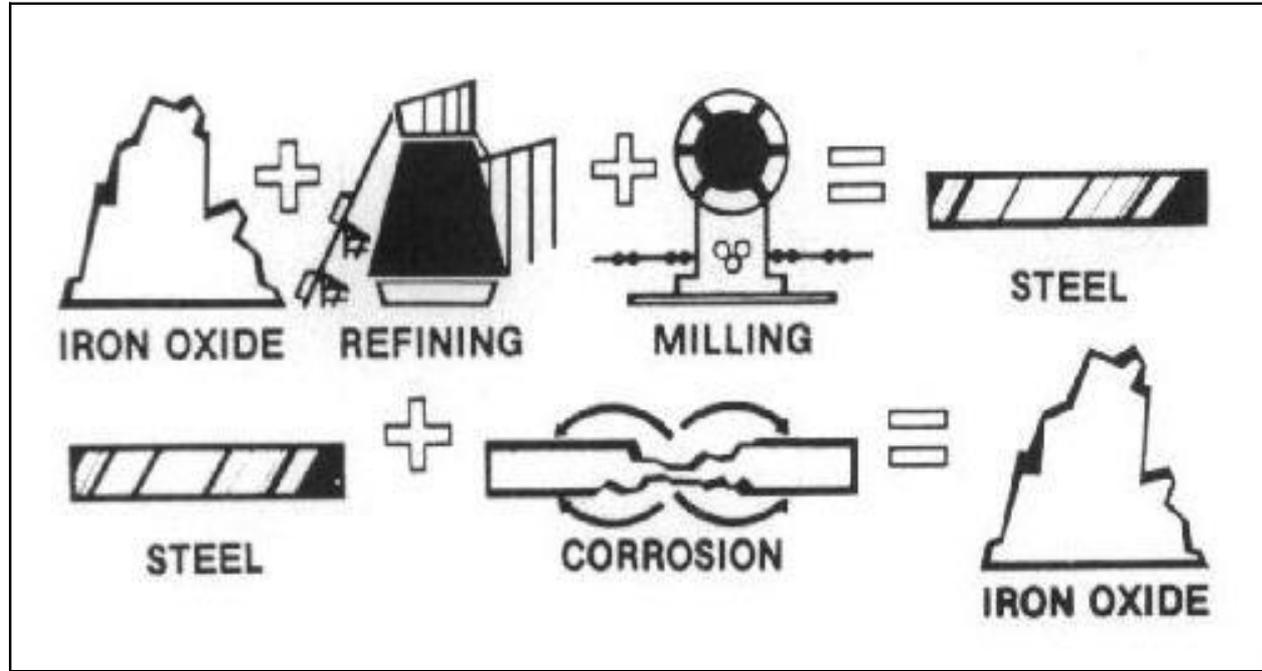
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Basics of Corrosion

- 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)

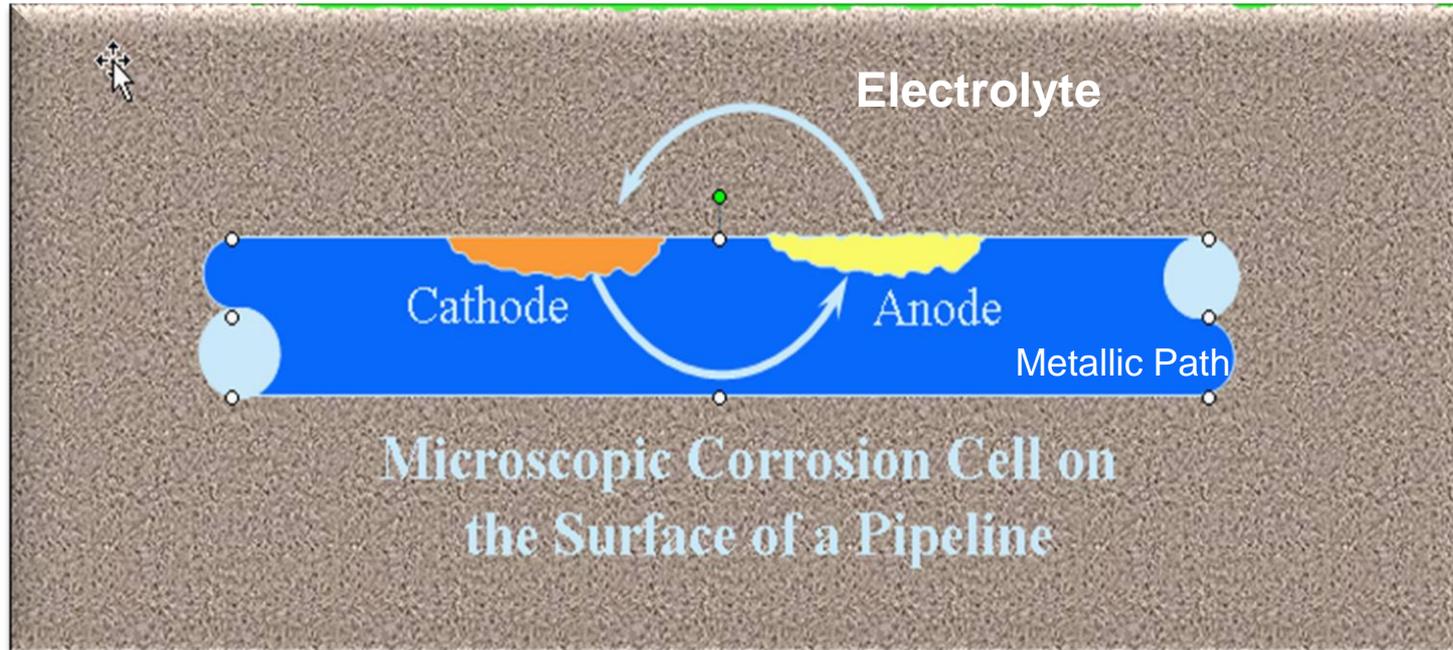
- Cathode: Lower level energy area where a reduction reaction takes place

(gain of electrons)

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

Basics of Corrosion

Example of a Corrosion Cell



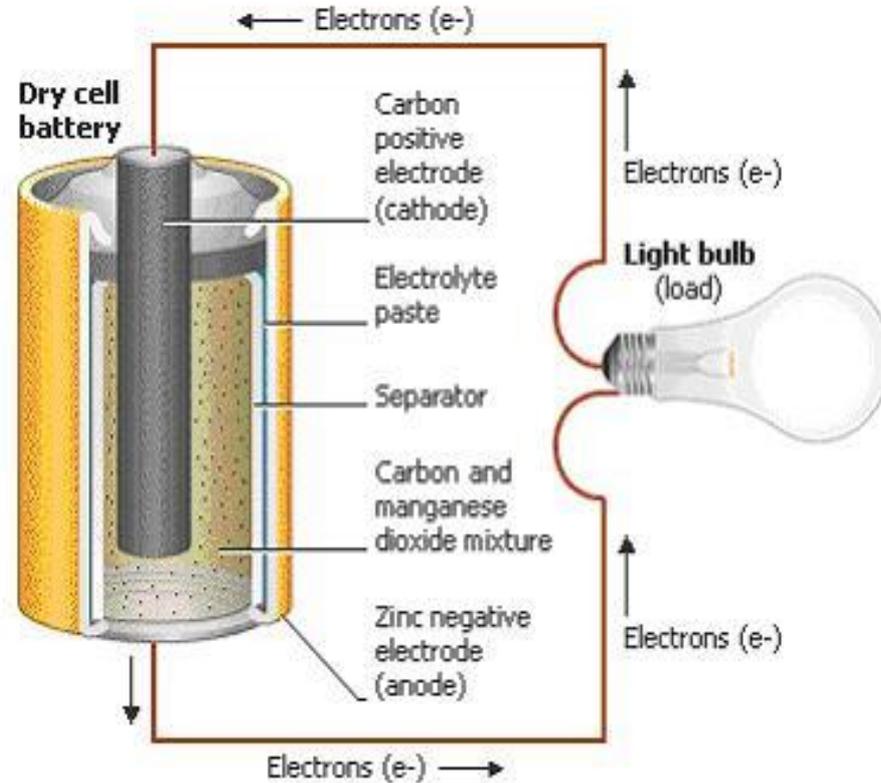
Basics of Corrosion

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

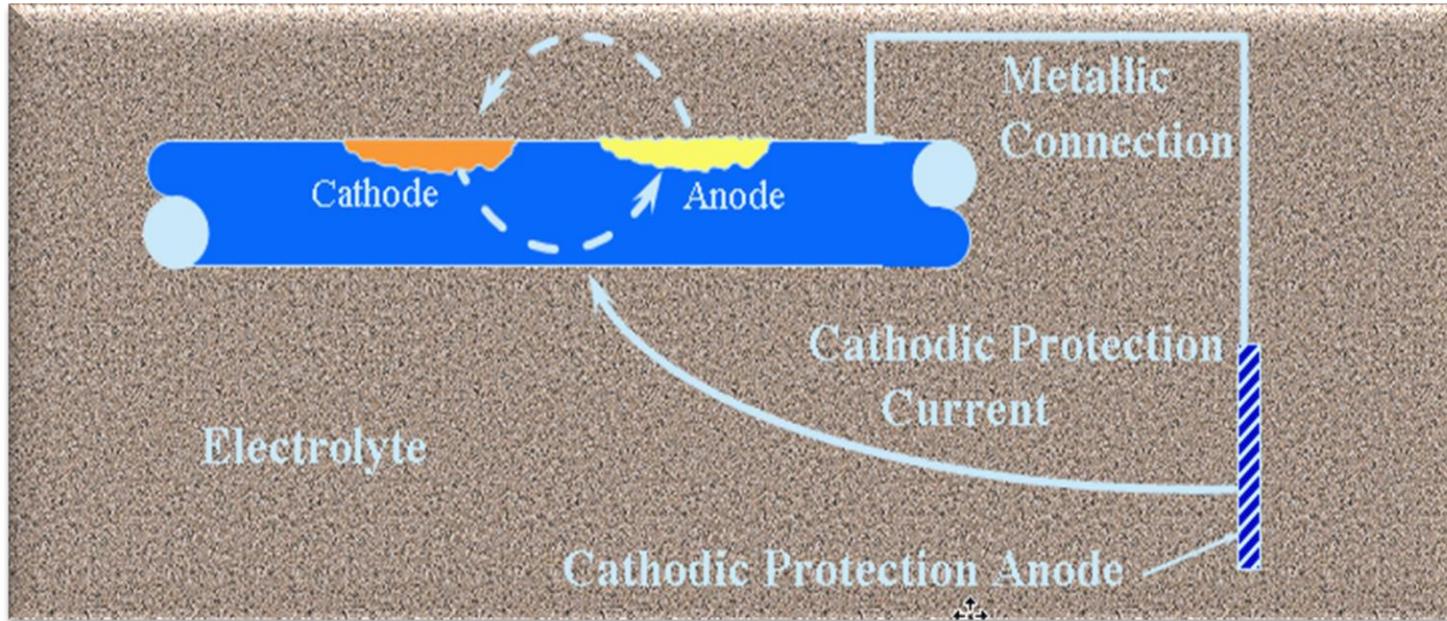
Methods of Corrosion Control

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-CuSO₄ Electrode

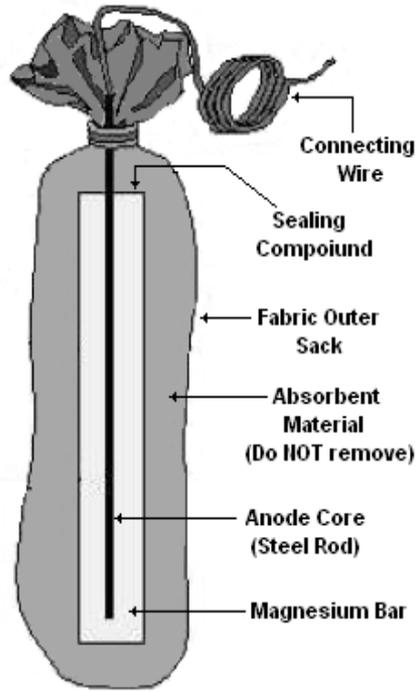
Methods of Corrosion Control

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. 10kΩ-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

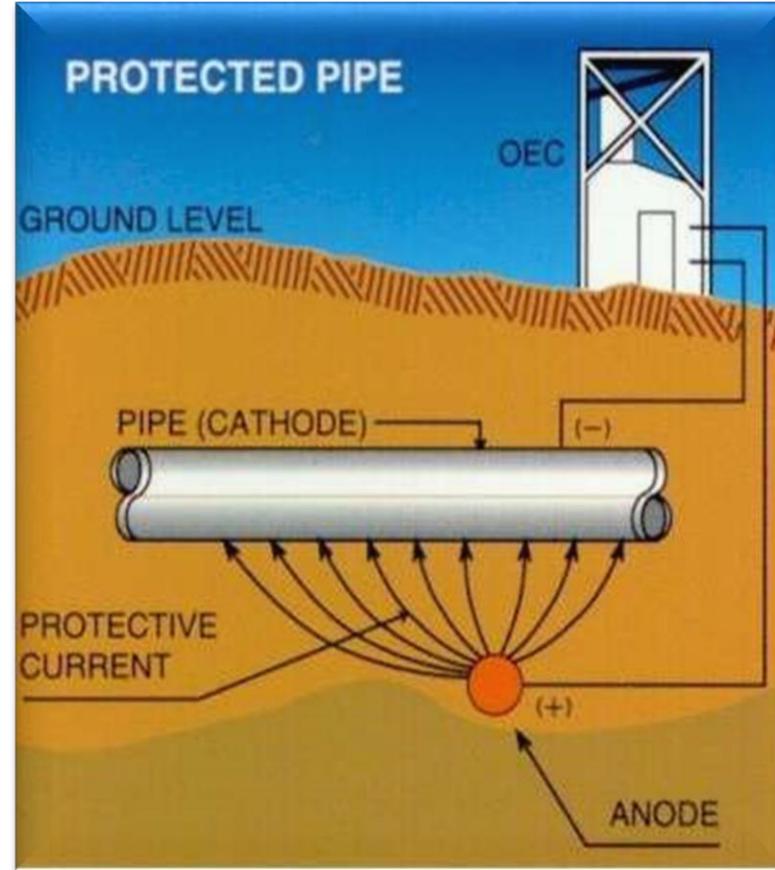
Impressed Current System Components

- ▶ 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



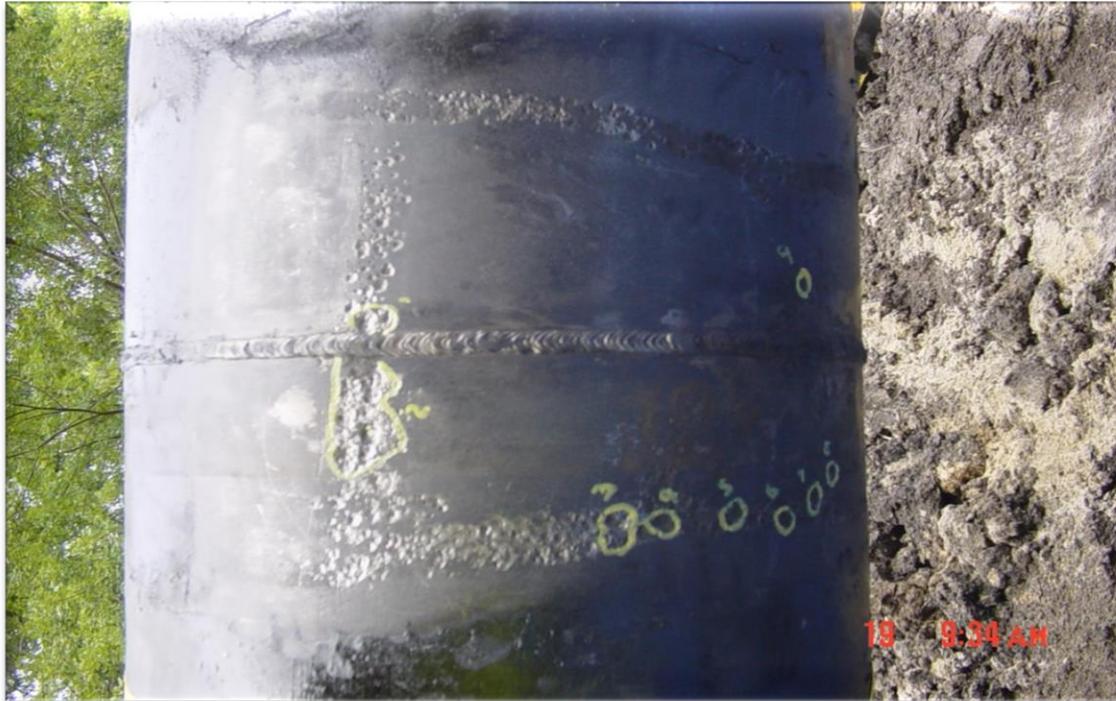
Safe and Reliable Corrosion Control

Coating Defect Found with DCVG



Safe and Reliable Corrosion Control

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Safe and Reliable Corrosion Control

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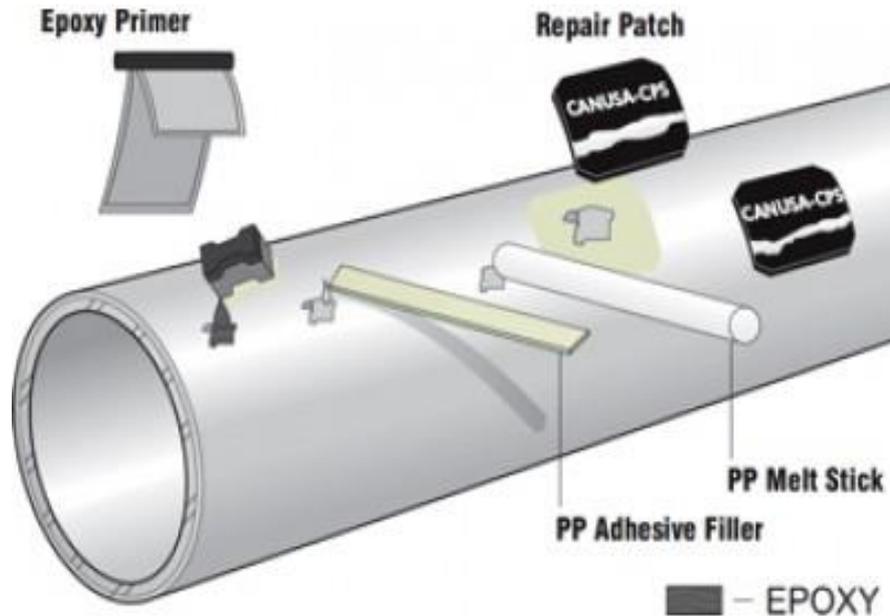
Safe and Reliable Corrosion Control

Coating Defect Found with DCVG



Safe and Reliable Corrosion Control

Pipe Coating - Reconditioning



Safe and Reliable Corrosion Control

Common Rehabilitation Coatings

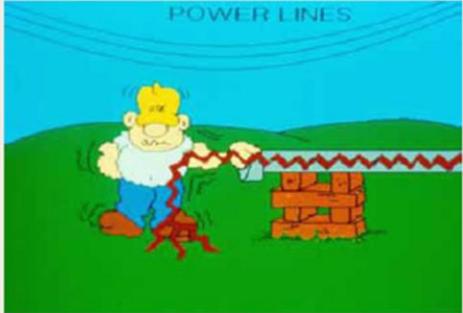
- Cold applied tapes
 - Maintain proper tension at all times
- Hot applied tapes
 - Follow manufacturer temperature recommendations (pipe temperature)
 - Follow manufacturer surface preparation directions
- Two part liquid epoxy coatings
 - Follow manufacturer temperature recommendations (pipe temperature)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

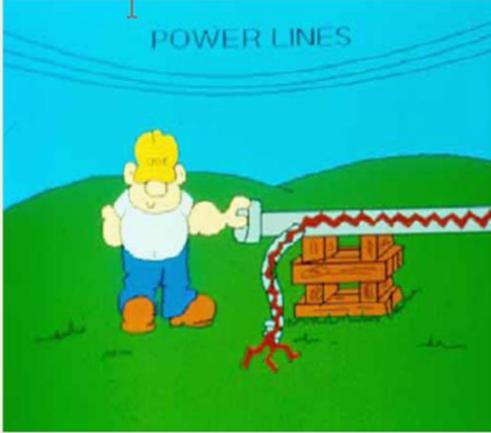


AC Safety



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.



POWER LINES

AC Safety

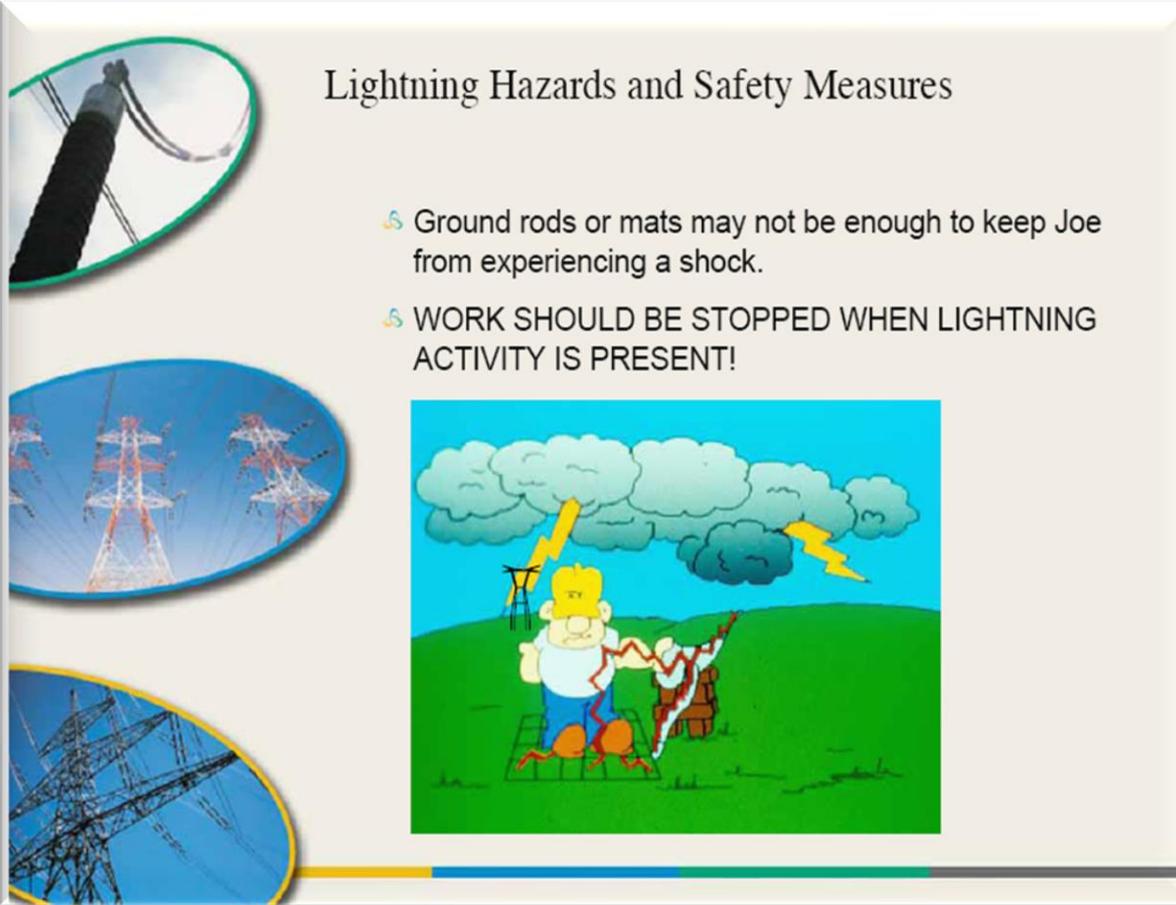


Lightning Hazards and Safety Measures

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



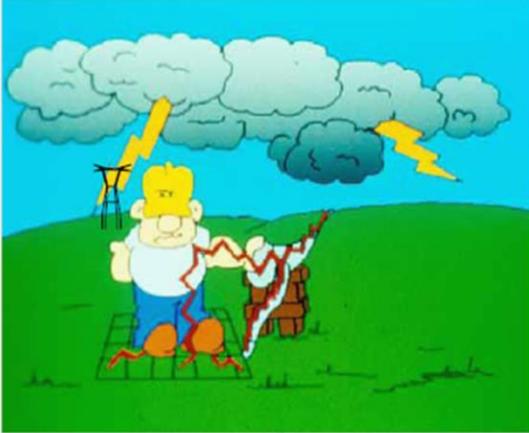
AC Safety



The slide features three circular inset images on the left side: the top one shows a close-up of a power line tower with a lightning rod; the middle one shows several high-voltage power line towers against a blue sky; the bottom one shows a close-up of a power line tower structure.

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!

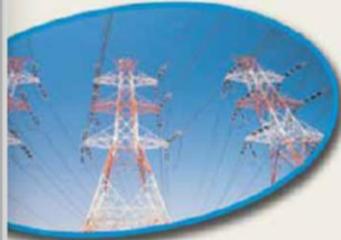


A cartoon illustration of a worker named Joe on a ladder, working on a power line. He is wearing a white shirt, blue pants, and a yellow hard hat. A lightning bolt strikes the power line he is working on, and another lightning bolt strikes a nearby tower. The scene is set on a green hill under a blue sky with grey clouds.

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.



POWER LINES

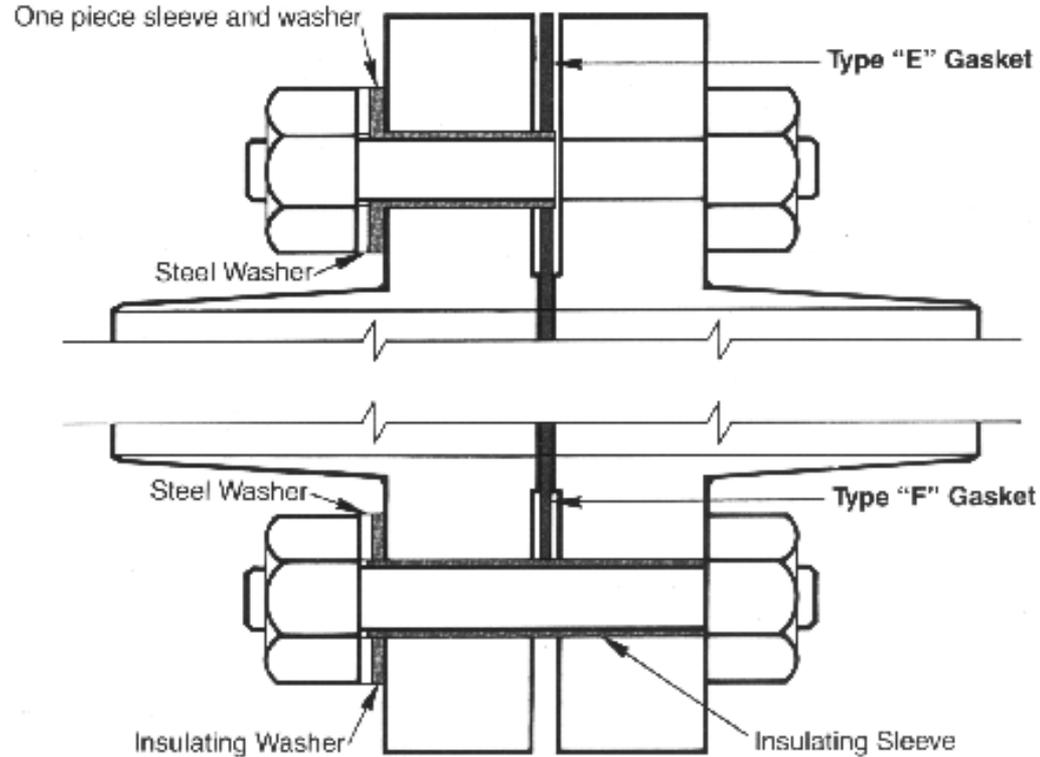
Safe and Reliable Corrosion Control

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

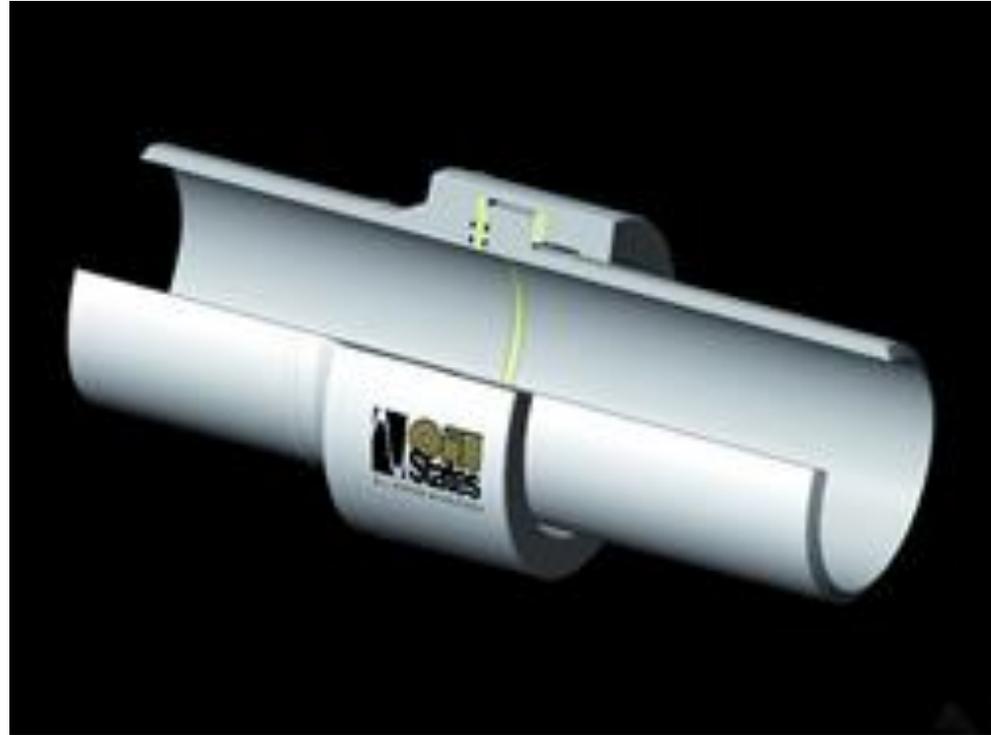
Safe and Reliable Corrosion Control

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**



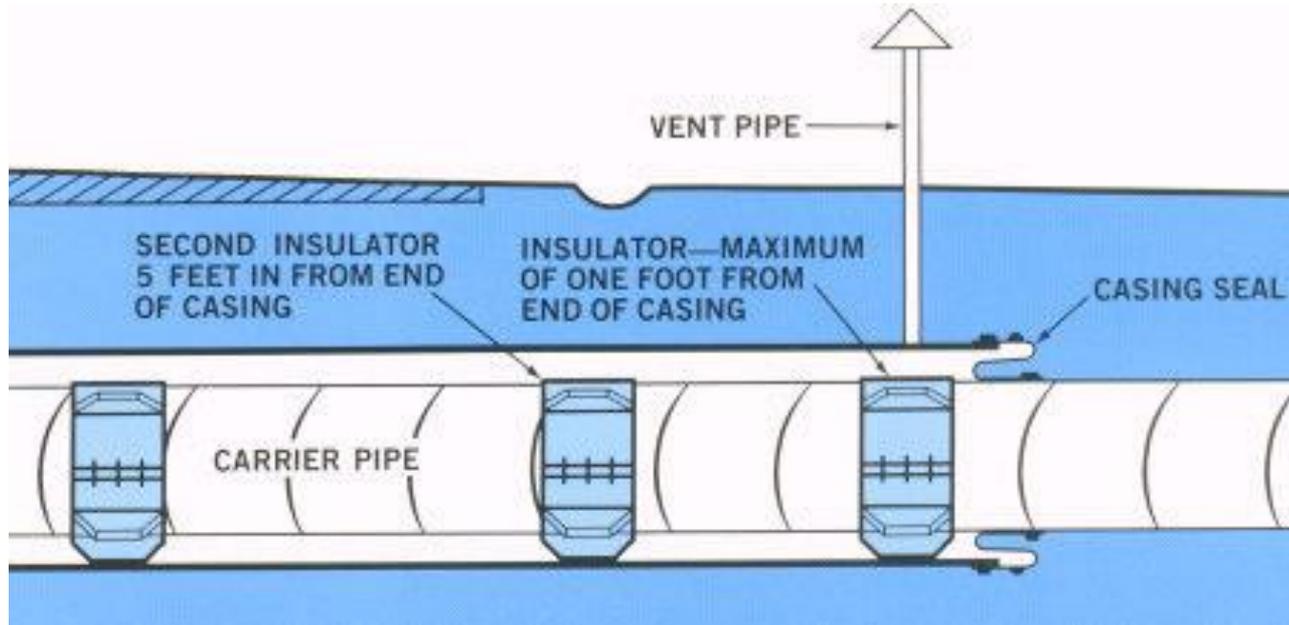
Safe and Reliable Corrosion Control

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



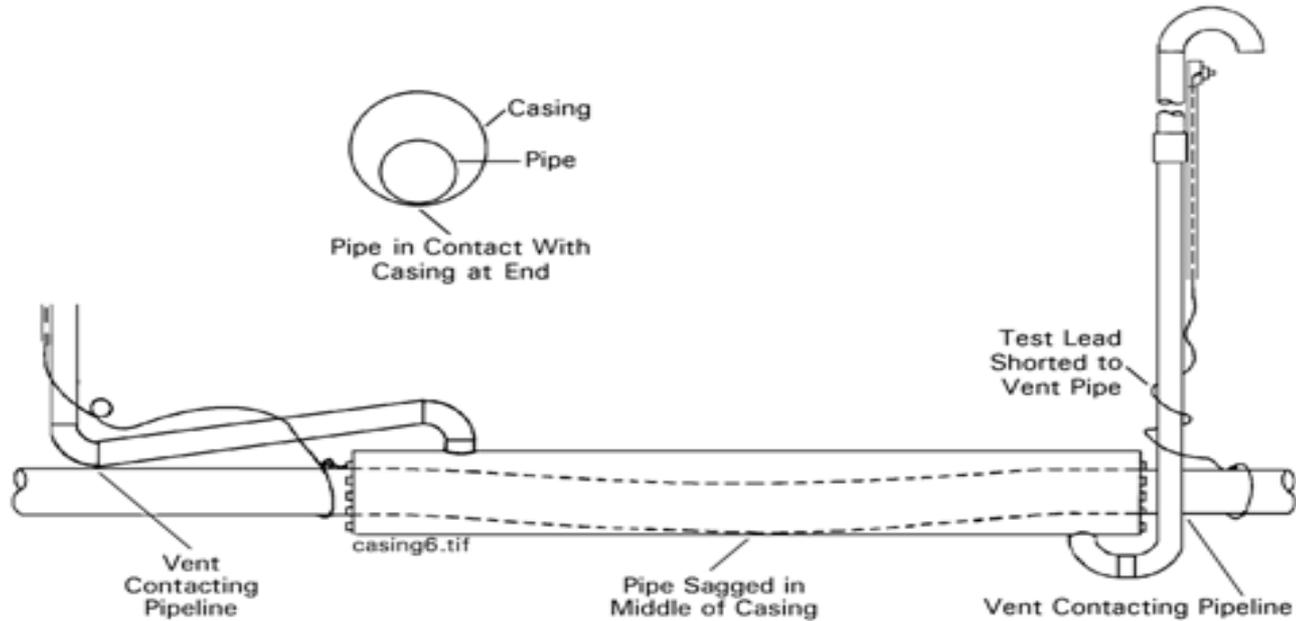
Safe and Reliable Corrosion Control

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

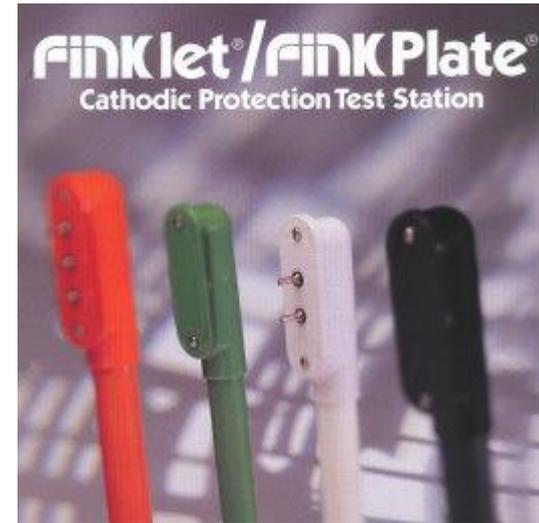
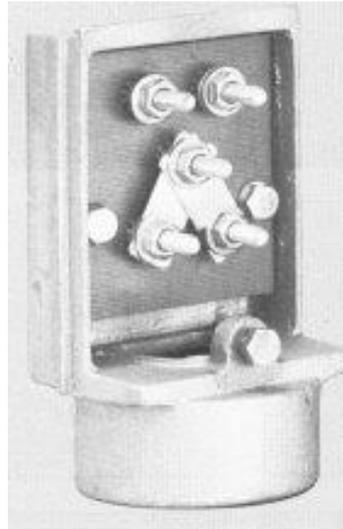
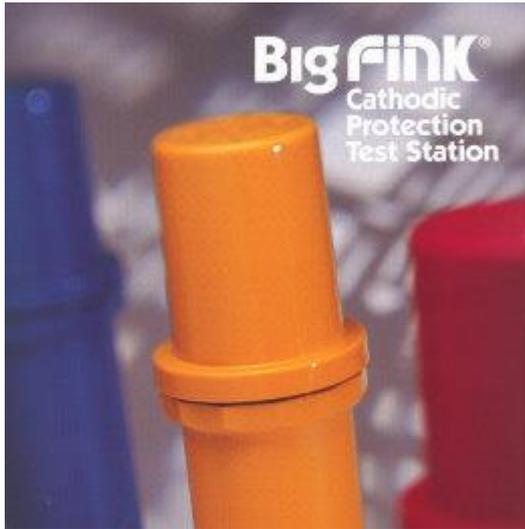
Safe and Reliable Corrosion Control

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.



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
expanded 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

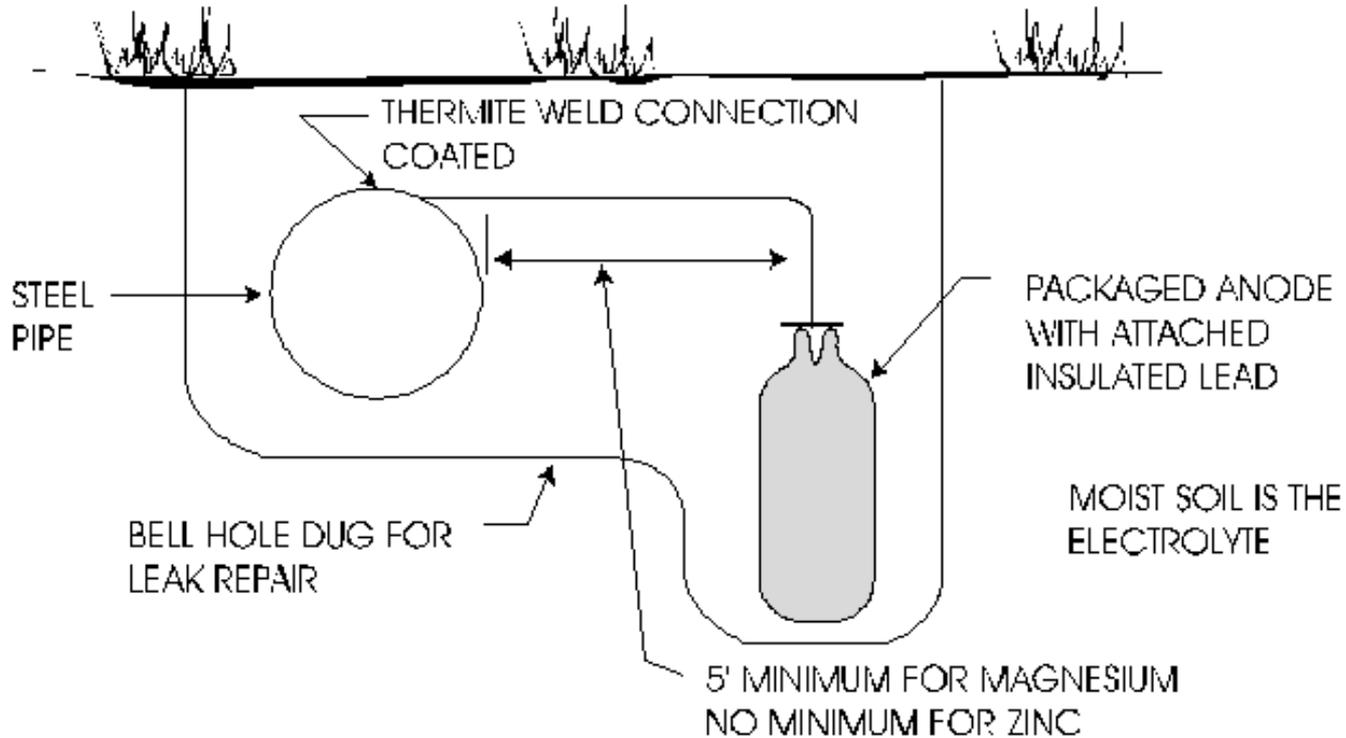
Safe and Reliable Corrosion Control

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

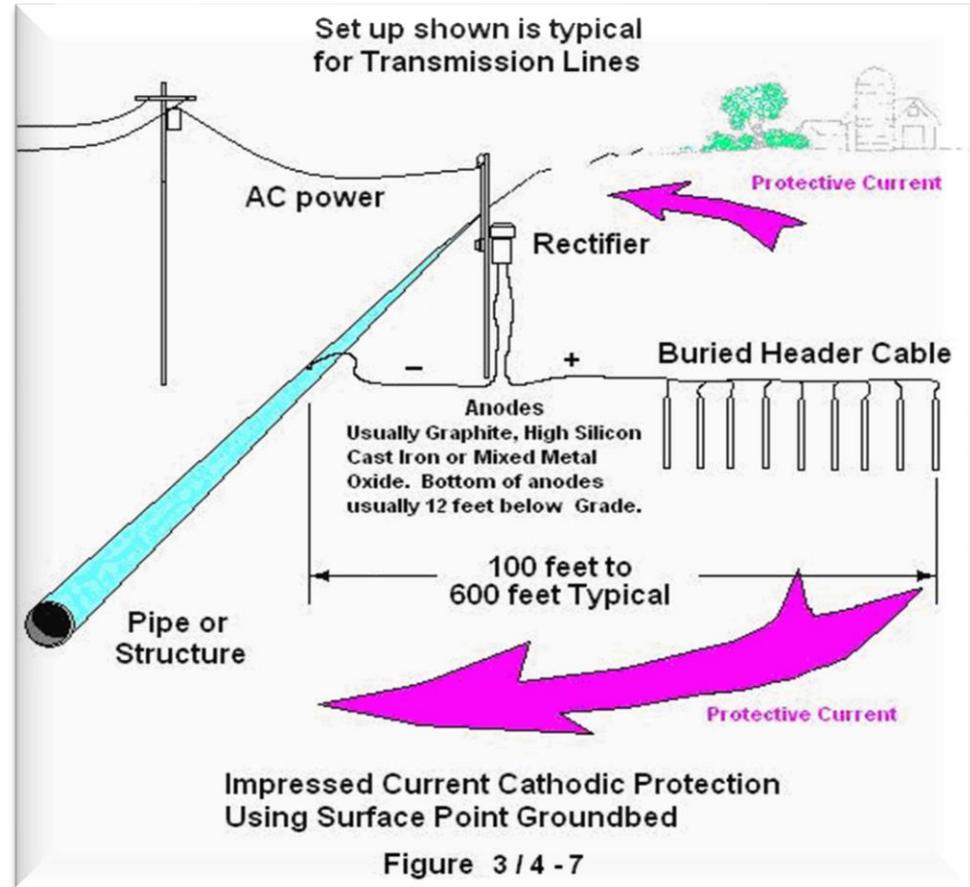
Anode Installation



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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