Methods of Controlling Corrosion

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Appalachian Underground Corrosion Short Course

Methods of Controlling Corrosion

- Main point of the chapter is that there is no easy “quick-fix” for stopping corrosion

- Several methods and in many instances, more than one method is used in conjunction with another to control corrosion.

Controlling Two Types of Corrosion

- Galvanic - localized corrosion cells, small voltages - electro chemical

- Stray Current - External current, Possibly large voltages. DC external to the structure. Pick-up and discharge areas.

Galvanic

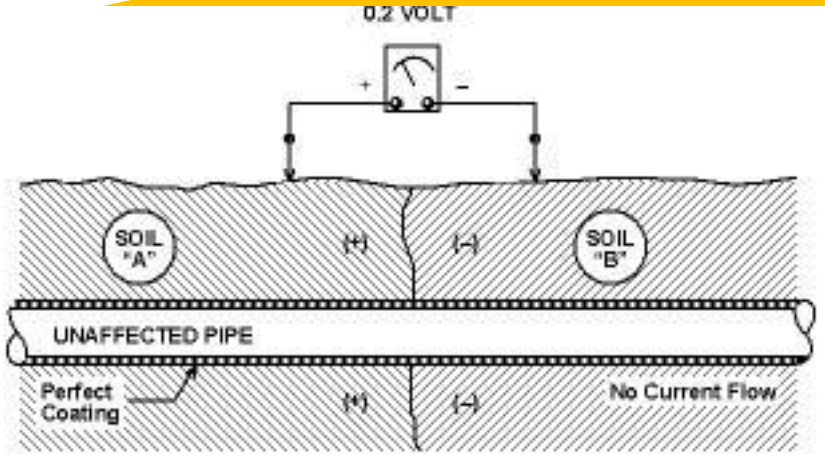
- Coatings
- Cathodic Protection
- Isolators

Stray Current – Outside Current Source

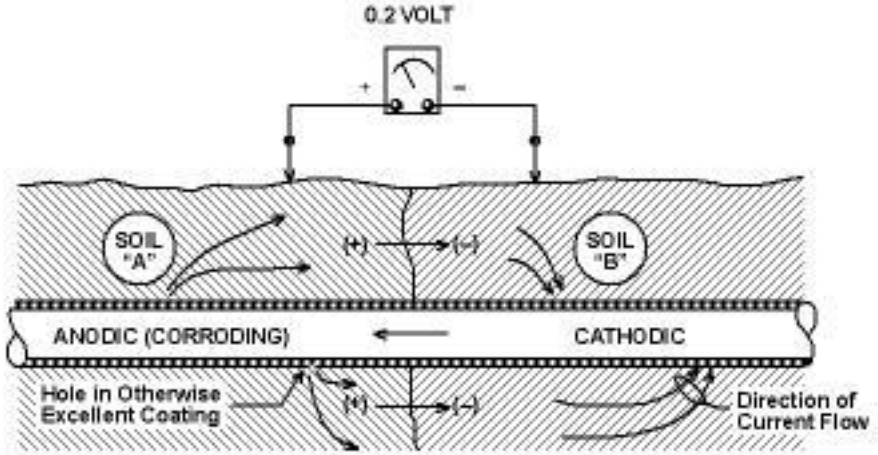
- Coatings
- Cathodic Protection
- Isolators
- Drainage Bond and Forced Drainage Bonds
- Reverse Current Switches

Coatings (Fig. 3-1)

- Isolating barrier
- Stops the flow of current from the underground metallic structure to the electrolyte
- No current flow – therefore no corrosion at anodic areas
- Coating must be perfect and remain perfect
- Impractical on large underground structures to achieve perfect coating



PART A – PIPE WITH PERFECT COATING IN DISSIMILAR SOILS



PART B – PIPE WITH FLAWED COATING IN DISSIMILAR SOILS

USE OF COATING ON UNDERGROUND STRUCTURE

FIGURE 3-1

Factors Causing Coating Holidays

- Handling Damage
- Stones or debris in backfill
- Soil Movement
- Tree Roots
- Third Party Damage
- 99.9% Perfect

Coatings – Stray Current

- Reduces stray current damage by increase in circuit resistance
- Reduces amount of current pick up
- However concentration effect is much more intense than galvanic corrosion cell.
- Supplemental Corrosion control methods are needed in addition to coatings.

Cathodic Protection (Fig. 3-2)

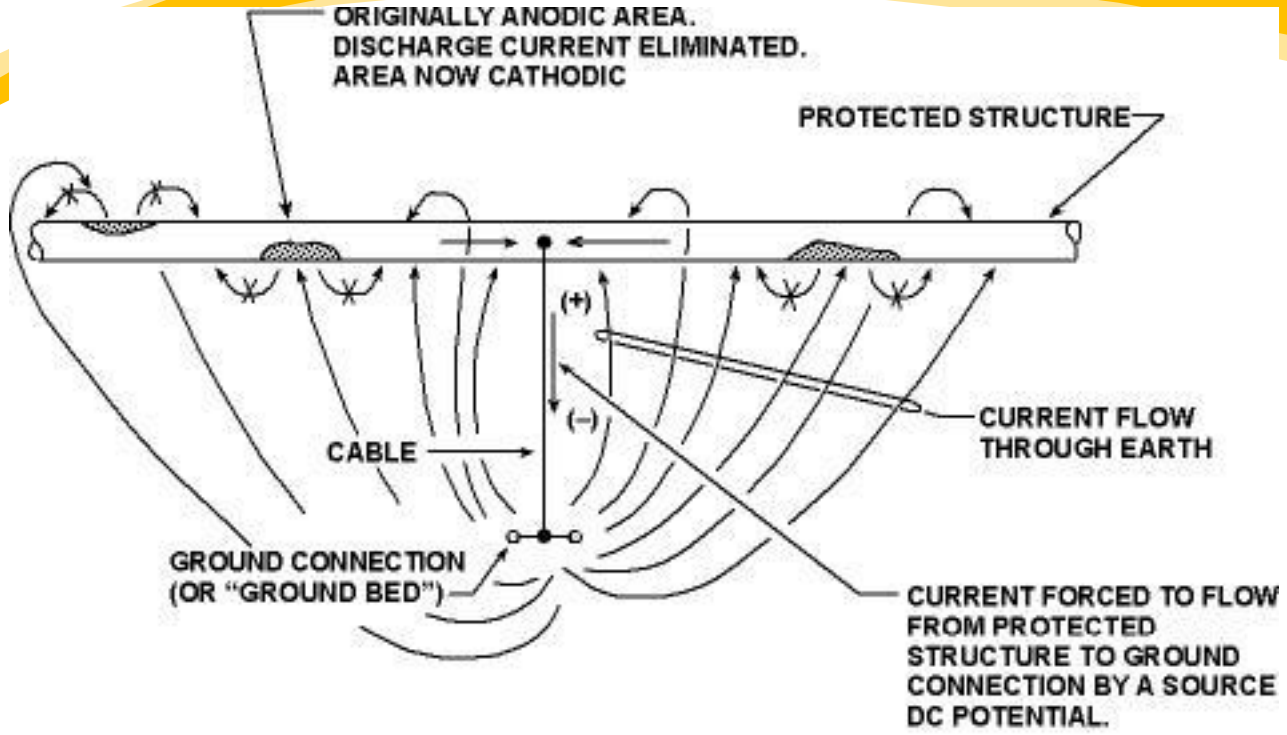
- Definition
- Theory
- Criteria
- Types
  - Galvanic
  - Impressed Current
- Advantages
- Disadvantages

Definition of Cathodic Protection

- *"Cathodic Protection makes the entire surface of an underground metallic structure the cathode of a purposely designed electrochemical cell."*

Theory of Cathodic Protection (Fig. 3-2)

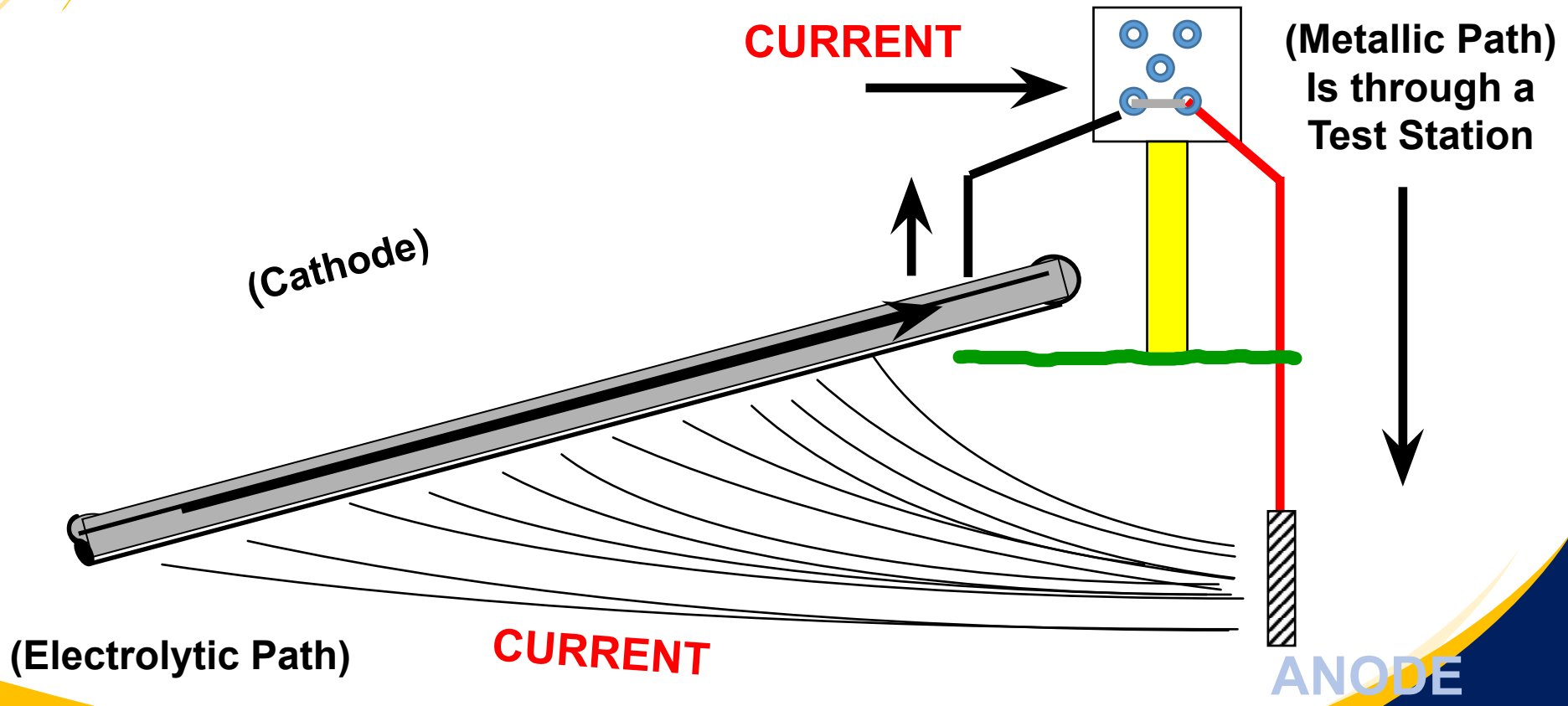
- Corrosion is an electrochemical process consisting of an anode, cathode, electrolyte and metallic path
- Unprotected structures have both anodic and cathodic areas
- Anodic - discharge current - corrode
- Cathodic - picks up current - does not corrode
- Basic theory - make the entire object a cathode and corrosion is mitigated.



HOW CATHODIC PROTECTION WORKS

FIGURE 3-2

Galvanic Anode Cathodic Protection System (Current flow from positive to negative)



Bare vs. Coated Structures

- Bare structure requires a tremendous amount of current to achieve cathodic protection vs the same structure with a good coating

Bare vs. Coated Structures

- Generally if we figure two milliamperes per square foot of bare surface - a 1 mile 12” bare pipeline would require 33 amperes to protect
- The same structure - well coated with a 99.5% perfect coating would only take 165 milliamperes of current to protect.
- The first pipeline would take an impressed current system to protect it while the second pipeline could be protected by magnesium anodes.
- CP and coatings are cost effective method of protecting underground metallic structures.

Criteria for Cathodic Protection

- Several criteria have been established that enable us to determine if adequate cathodic protection has been achieved
- Measure potential of the structure to a standard electrode -CuCuSO4.
- Unprotected steel - 0.2v to -0.7v
- Apply cathodic protection and the structure becomes more negative.
- Protection potential of at least -0.850v is good practical indication of protection.

Types of Cathodic Protection

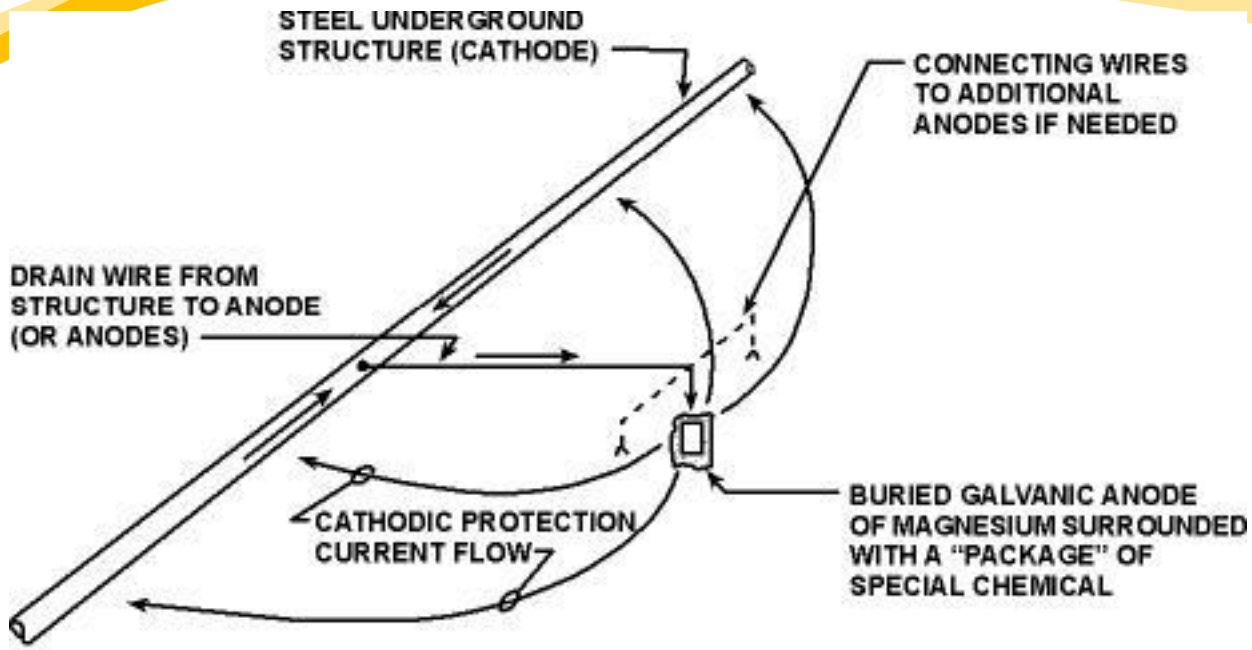
- Two General Types
  - Galvanic (sacrificial) anode
  - Impressed current

Galvanic Anode Cathodic Protection (Fig. 3-3)

- Utilizes dissimilar metals
- Galvanic potential (from galvanic series)
- Use available driving voltage
- Magnesium 0.8v to 1.4V – Driving Voltage
- Magnesium is anodic to steel

Galvanic Anode Cathodic Protection (Fig. 3-3)

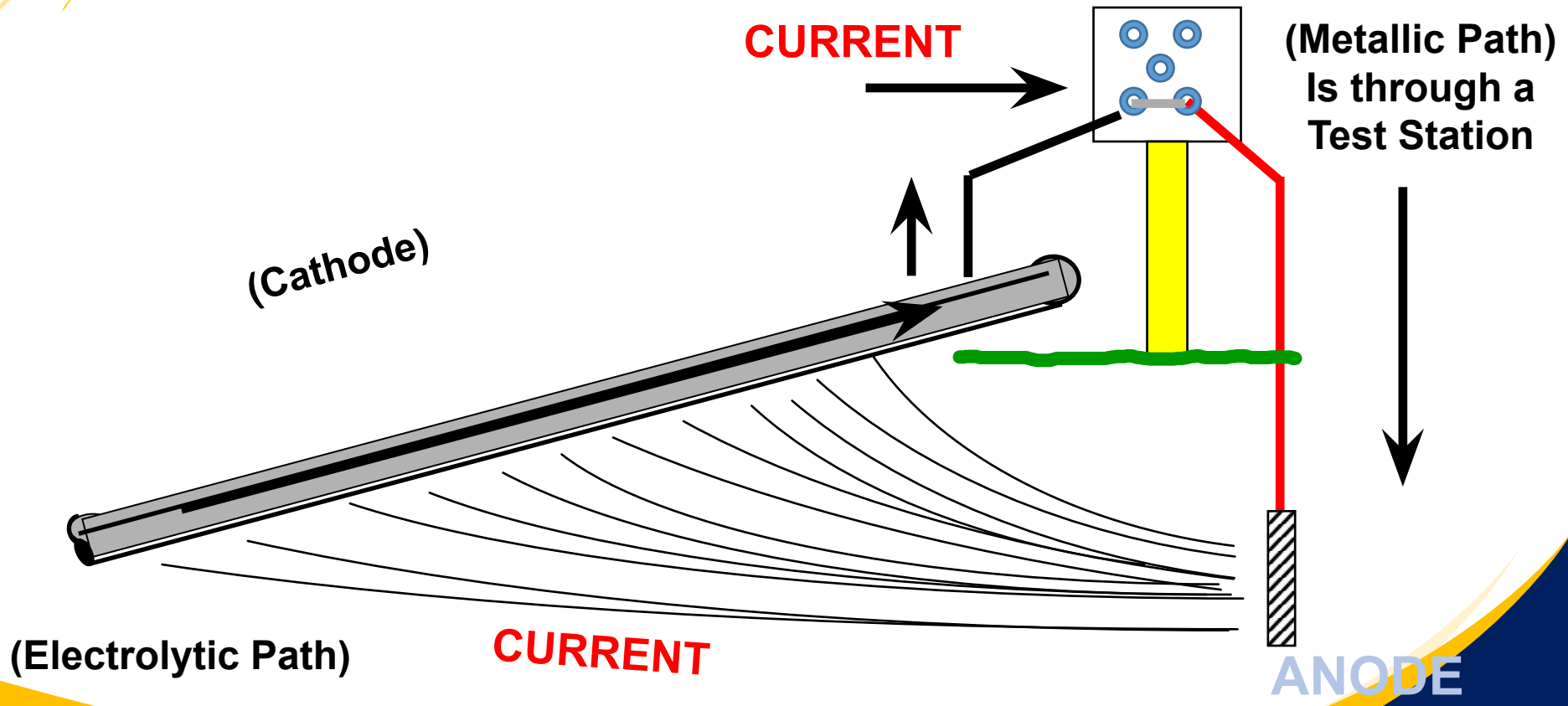
- Other metals
- Magnesium (Most common)
- Zinc - Low resistivity soils
- Aluminum - Sea Water
- Chemical Backfill



GALVANIC ANODE CATHODIC PROTECTION

FIGURE 3-3

Galvanic Anode Cathodic Protection System (Current flow from positive to negative)



Magnesium Anodes

Anodes Connected Through a Test Station

Advantages of Galvanic CP

- Self Powered
- Low Maintenance
- Minimum Stray

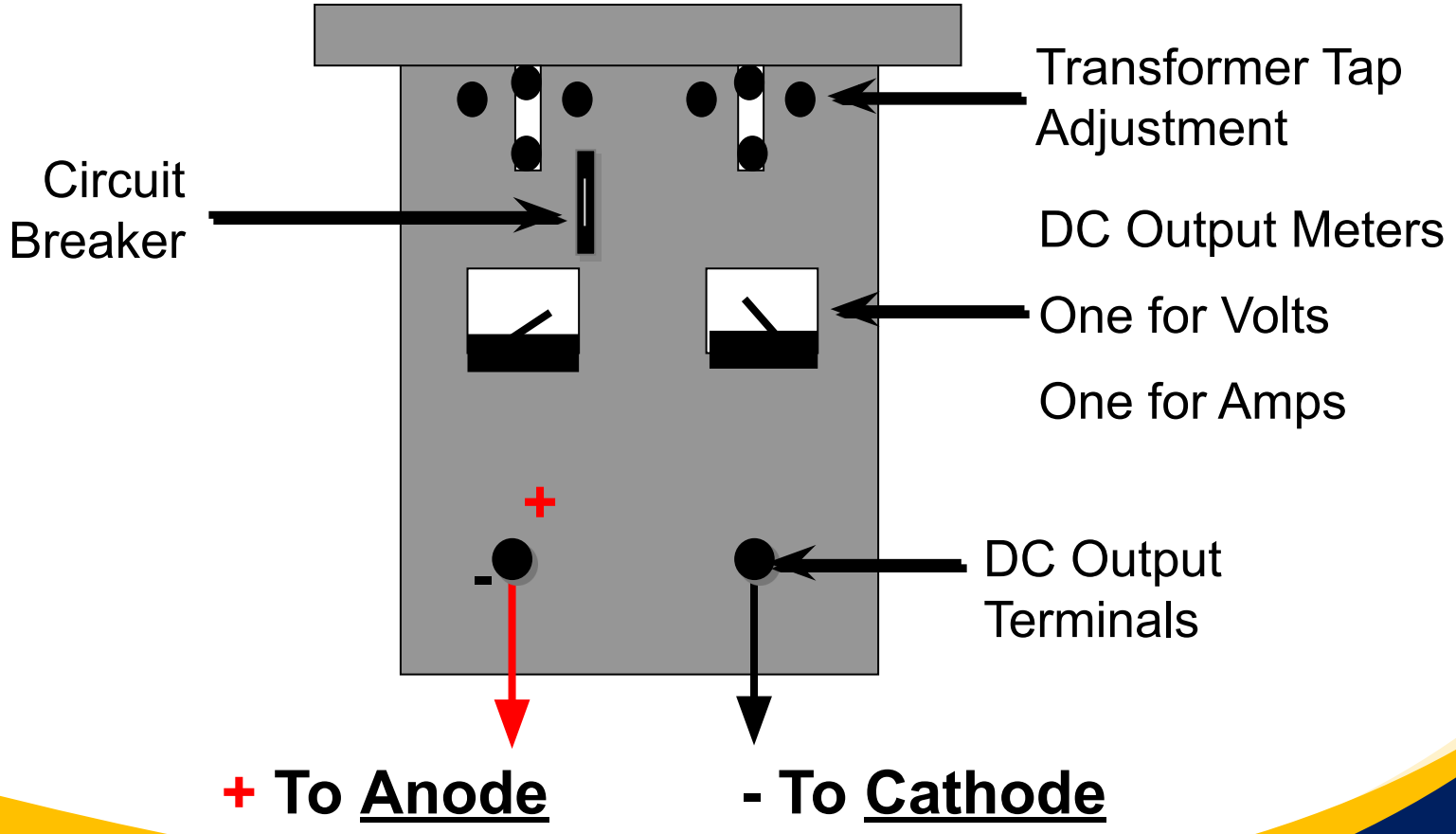
Disadvantages of Galvanic CP

- Low driving voltage
- Low current output not suitable for high resistivity soil (milliamps)

Impressed Current CP (Fig. 3-4)

- Outside source of current
- AC power - rectifier steps down rectifies AC to DC
- Adjustable DC output
- Automatically controlled rectifiers
- Desired current output
- Desired structure potential

Typical Impressed Current Rectifier

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D
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2
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4
5
6
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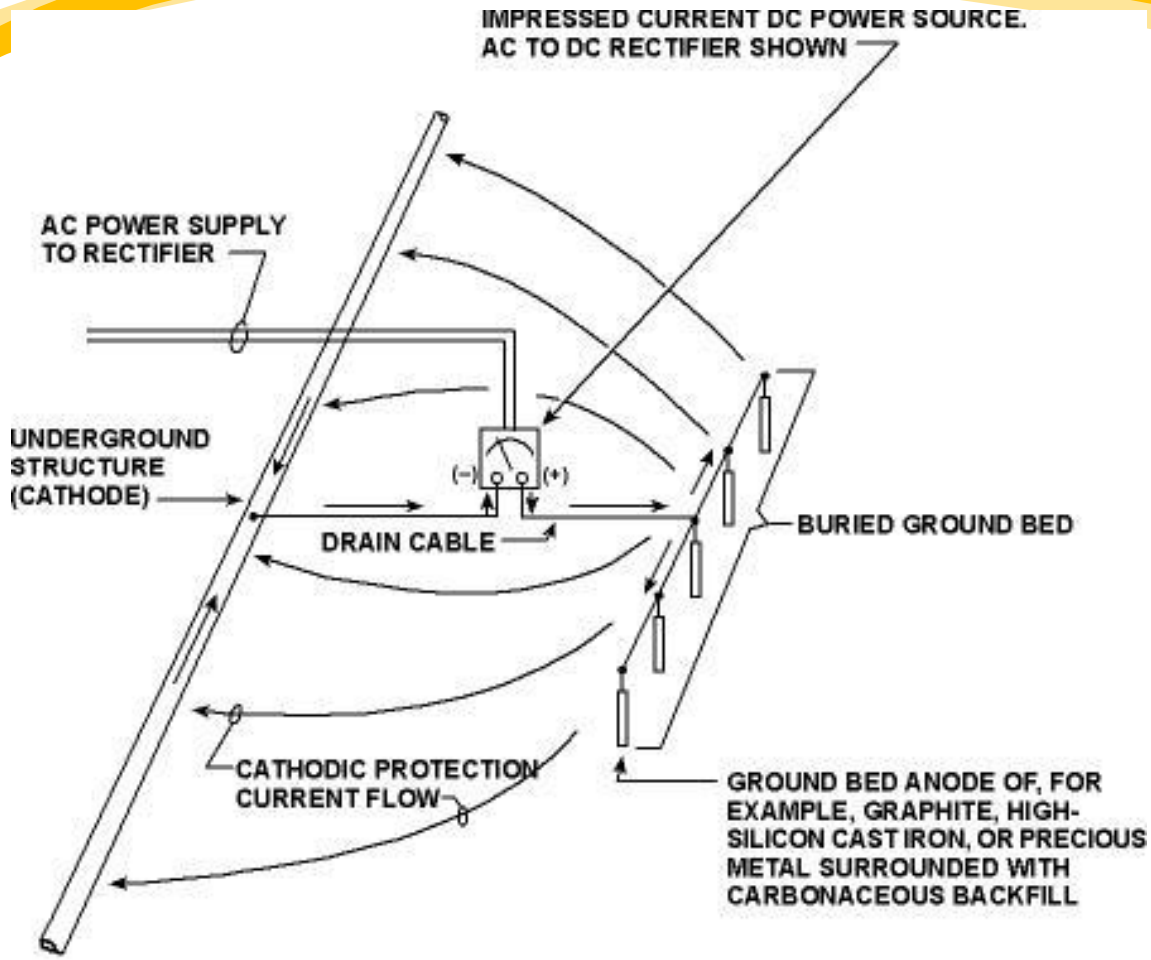
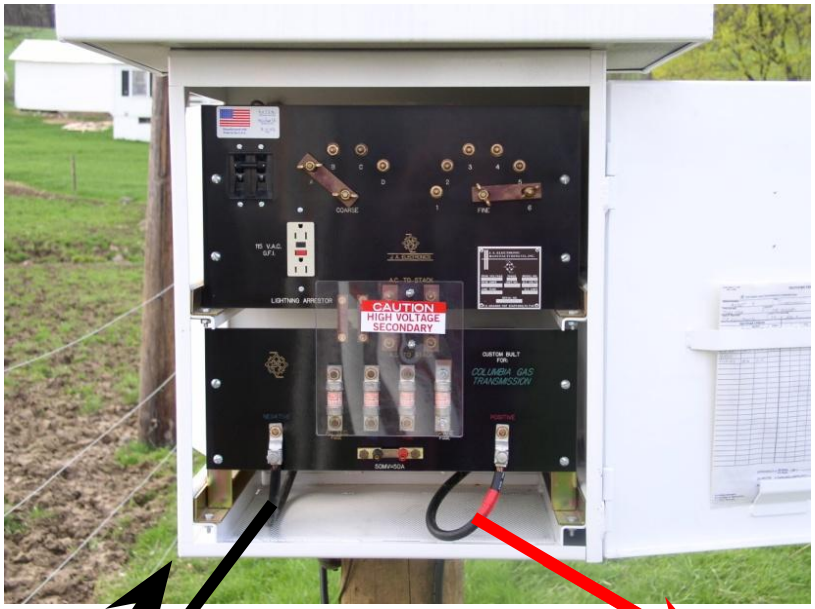
POSITIVE
SPARE
FUSE
50MV=50A



IMPRESSED CURRENT CATHODIC PROTECTION

FIGURE 3-4

Rectifier and Anode Bed Layout



(Metallic Path)

Cable & Anodes
+ Positive

(Anode)

(Cathode)

Pipeline - Negative

(Electrolytic Path)

Sources of DC Power

- Engine-generators
- Solar panels
- Thermo electric generator
- Windmills

Different Types of Ground Beds

- Point ground bed (Conventional)
- Distributed ground bed
- Deep well ground bed

Materials for Impressed Current Anodes

- Graphite
- High silicon cast iron
- Precious metals
- Mixed metal oxides
- Coke breeze backfill
  - Consumed before anodes

Pre-Packaged Anodes

Advantages of Impressed Current CP

- Wide range of voltage and current outputs
- Single installation can protect large structures

Disadvantages of Impressed Current CP

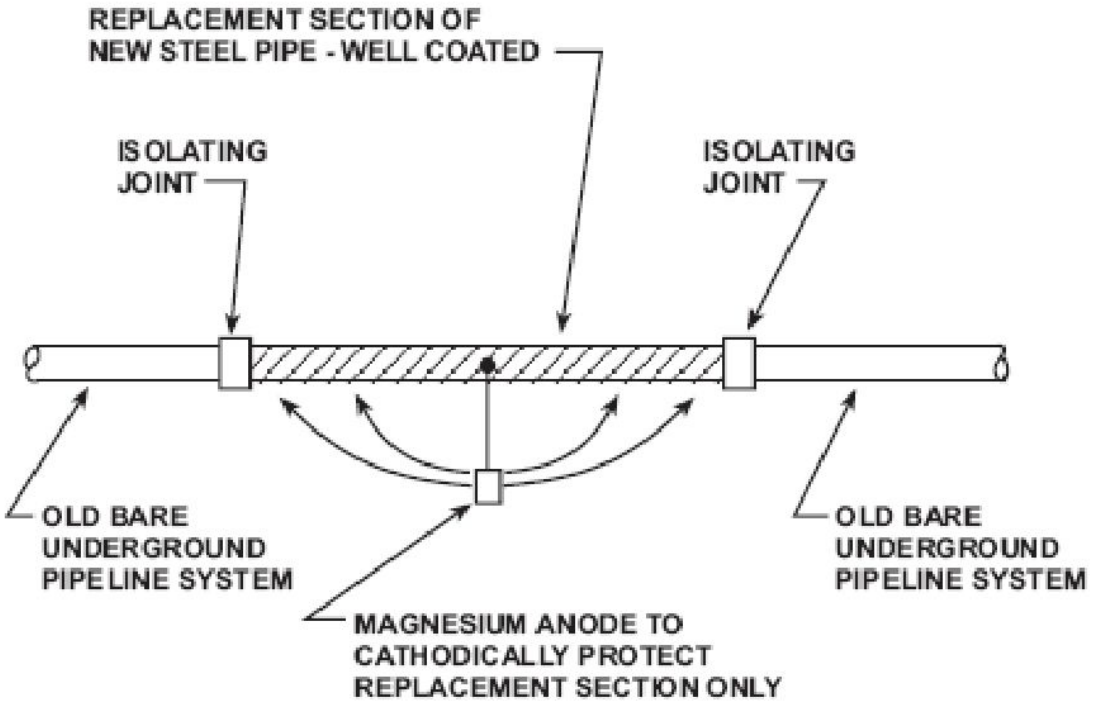
- High maintenance
- Availability of power source
- Cost
- Stray Current

Additional Corrosion Control Measures

- Isolated Joints
- Drainage bonds and Forced Drainage bonds
- Reverse current switches

Isolated Joints (Fig. 3-5)

- Separate dissimilar metals
- Confine C.P. to a structure or parts of a structure
- Confine and reduce the effects of stray current



AN APPLICATION OF ISOLATING JOINTS

FIGURE 3-5

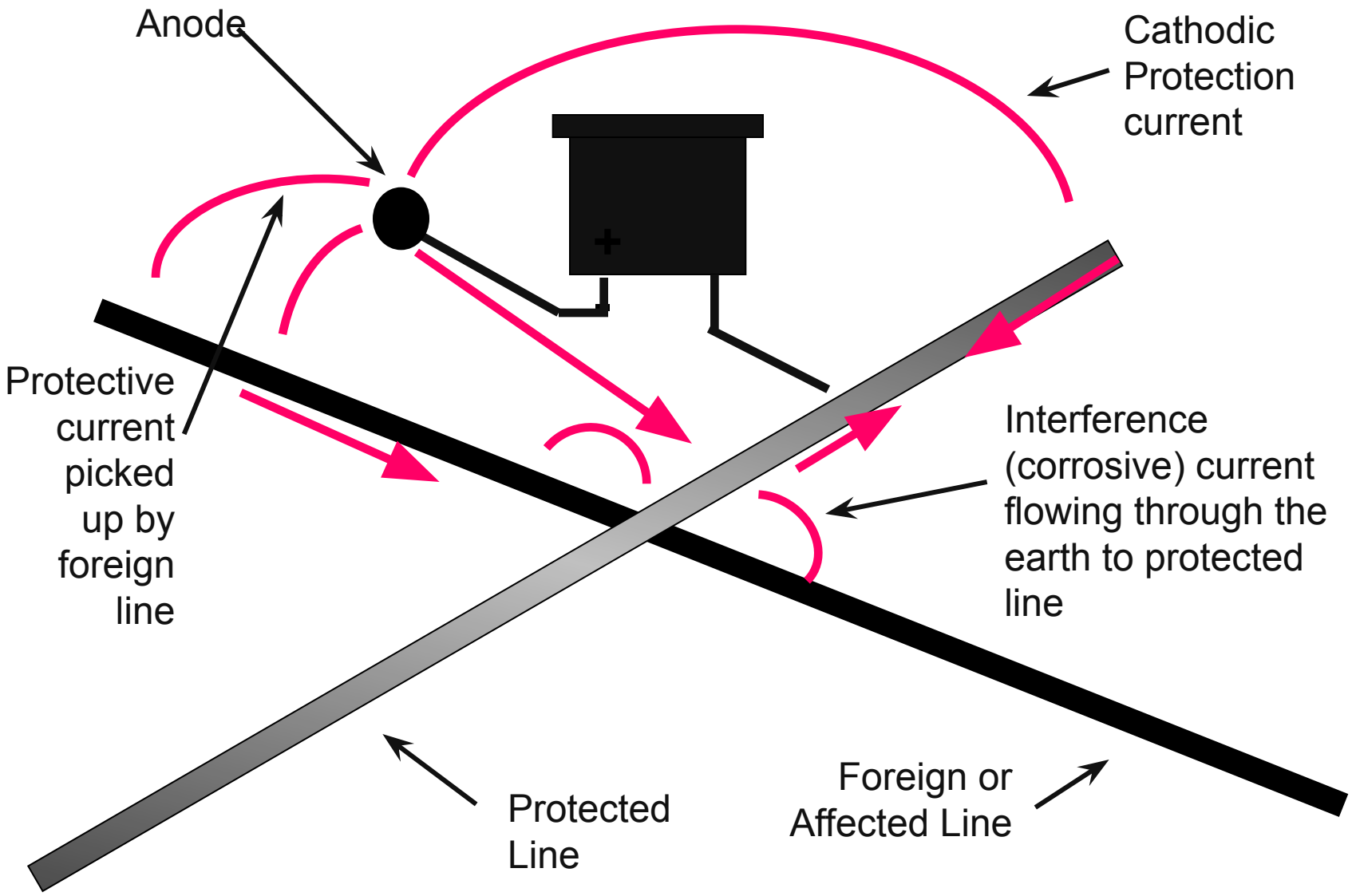
Types of Isolation

- Flanges
- Couplings
- Unions/Bushings
- Weld-In Isolators

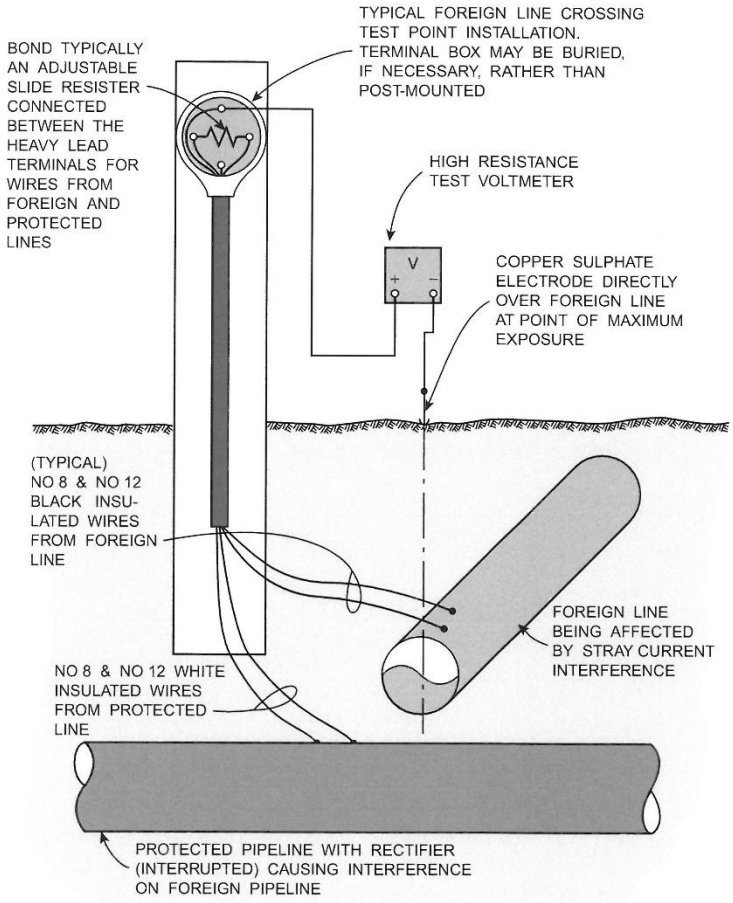
Drainage Bonds (Fig. 3-6)

- Reduce the effects of stray current
- Drain current back through a metallic path
- DC drained through a metallic path, by way of a wire or cable does not cause corrosion
- Make sure the metallic path is large enough to drain the current, and is as short as possible
- Objective is to drain the maximum current with minimum voltage drops

Static Stray Current Interference from a CP System

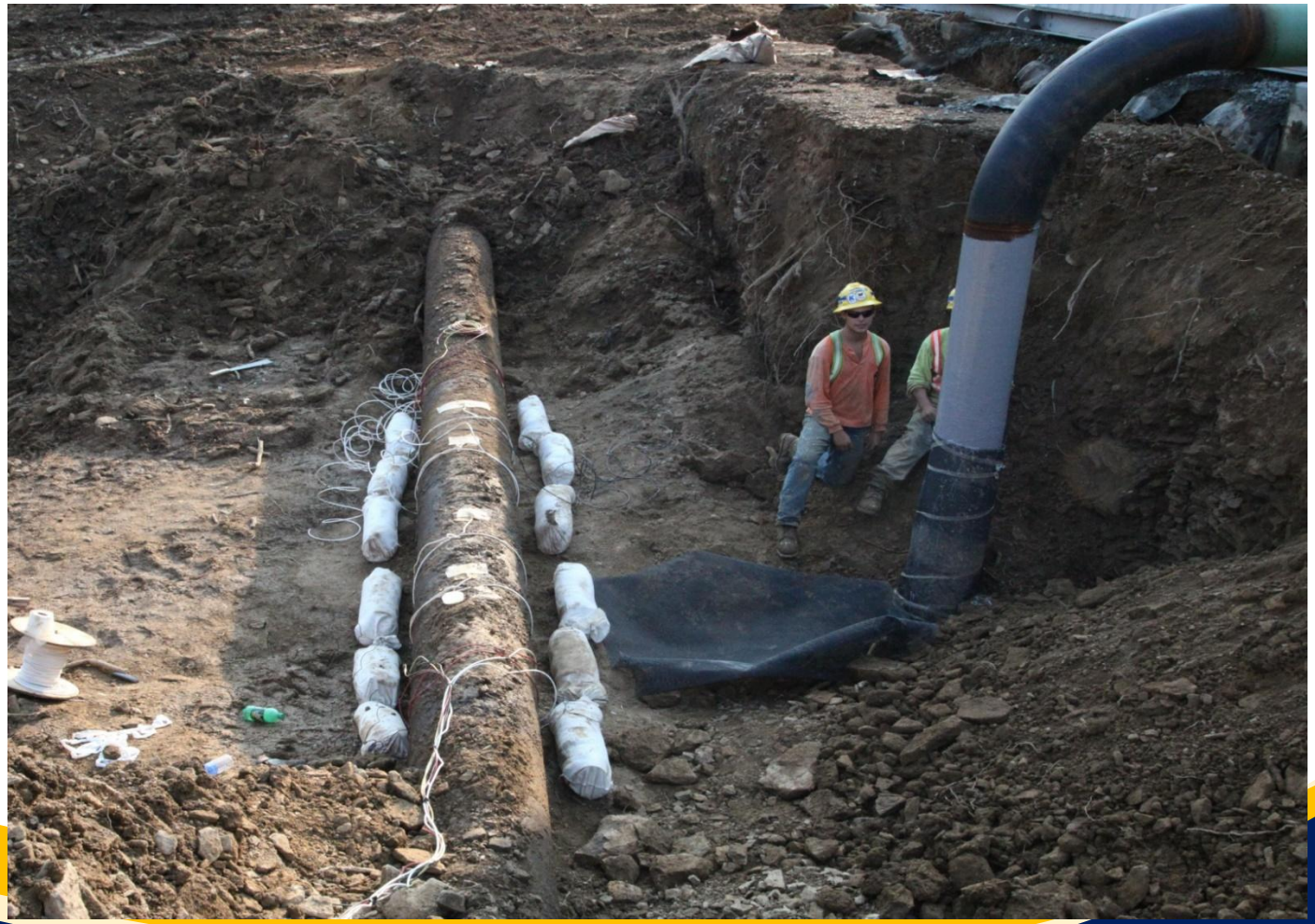


Typical Resistance Bond



Resistance Bond Test Station

Mag Anode Drain Installation



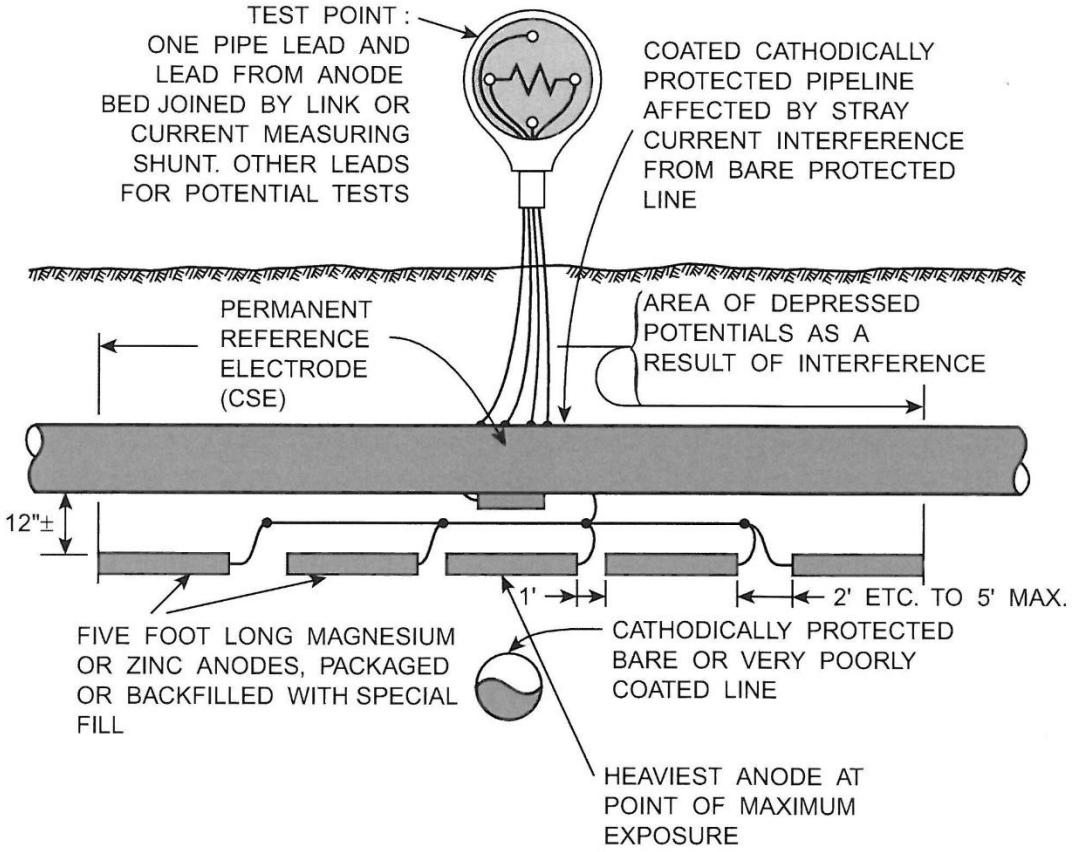


Figure 11.10 Use of galvanic anodes to correct interference at foreign pipeline crossing.

Reverse Current Switches (Fig. 3-7)

- Multiple DC Substations
- One or more shutting down
- Can cause current to flow in the reverse direction back to the underground structure.
- The reverse current switch acts as a diode, or a check valve to block the reverse flow of current.

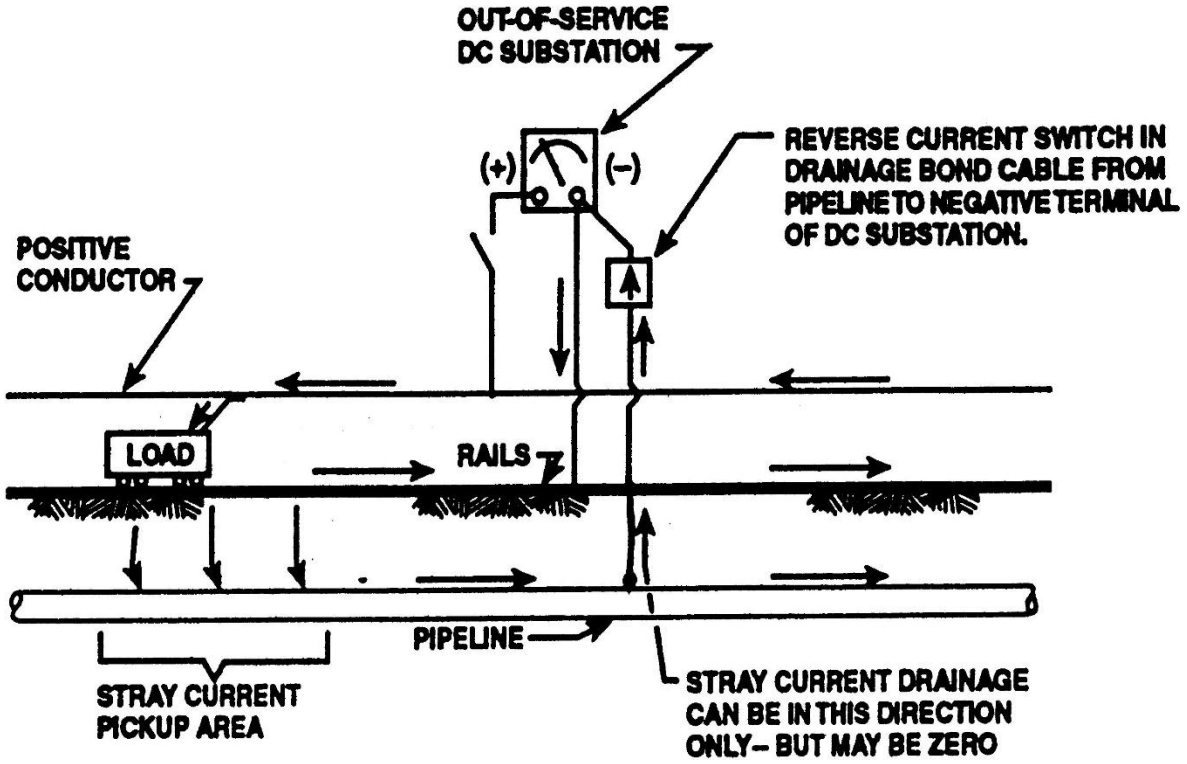


FIGURE 3-7

APPLICATION OF REVERSE CURRENT SWITCH IN STRAY CURRENT DRAINAGE BOND

Forced Drainage Bond (Fig. 3-8)

- Long distance causes too much resistance in the circuit to allow draining enough current back to clear the corrosive condition.
- Insert a voltage into the circuit
- Adjust the voltage to force current to flow through the bond
- Current carrying capacity matches the stray current to be drained, and clears the interference condition

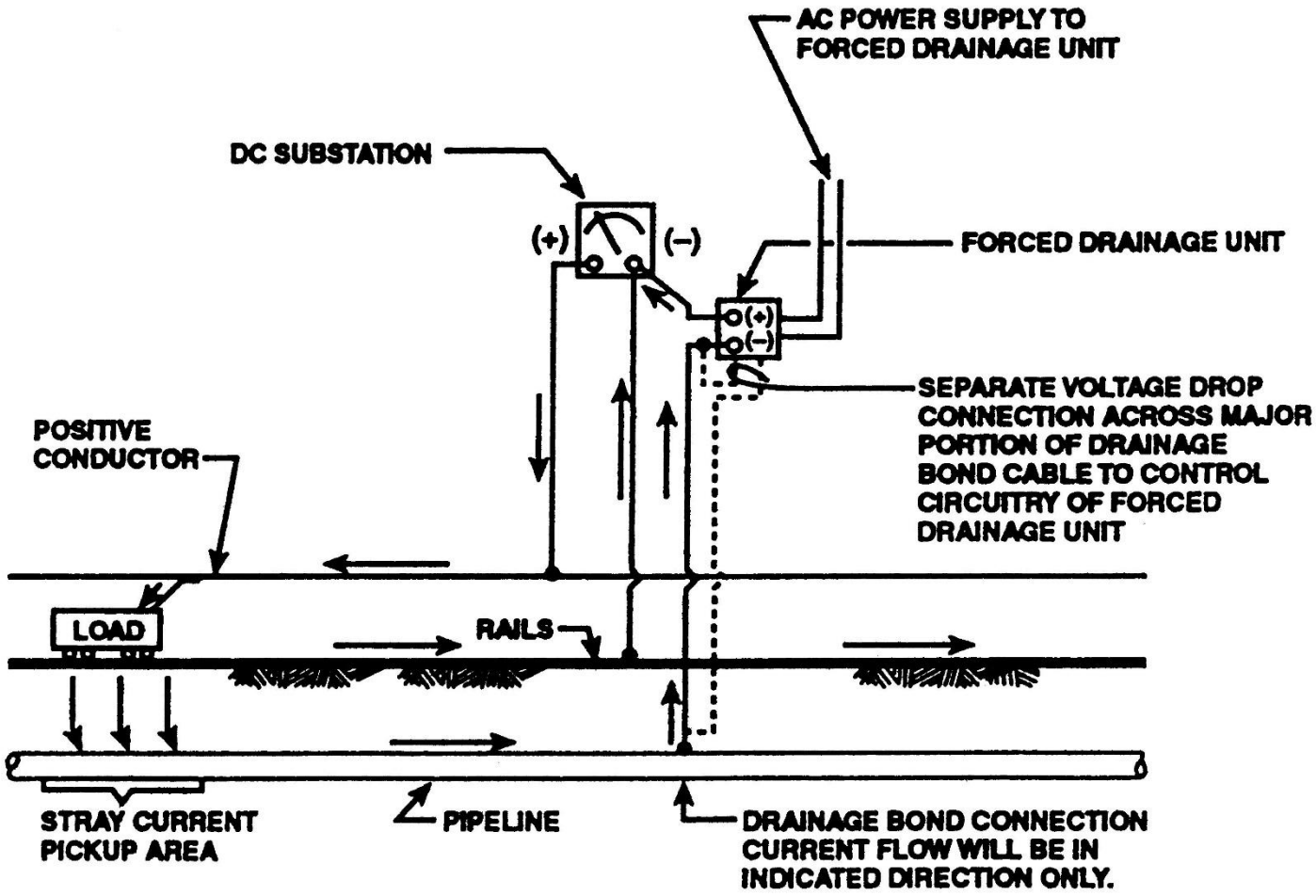


FIGURE 3-8
APPLICATION OF FORCED DRAINAGE
STRAY CURRENT DRAINAGE BOND

Questions?