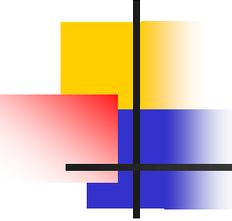
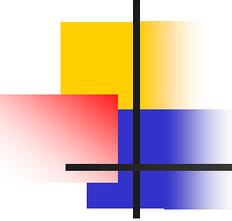


Basic Fundamentals of Corrosion and Cathodic Protection



Overview

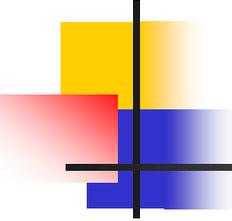
- What is Corrosion and a Corrosion Cell
- The Basic Theory of CP
- Some Basic Applications
- CP Criteria that is used
- Design & Some Test Equipment
- Basic Monitoring



The Definition of Corrosion

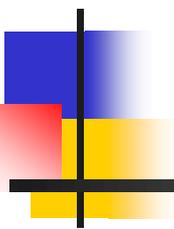
- Corrosion is the deterioration of a substance (usually a metal) or its properties because of an electrochemical reaction with its environment.

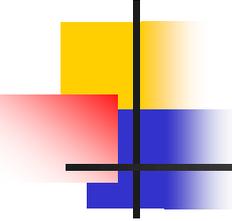
The Definition of Cathodic Protection



- CP is, very simply, the use of direct current electricity from an external source to oppose the discharge of corrosion current from anodic areas so the entire surface in contact with an electrolyte becomes a single cathodic area.

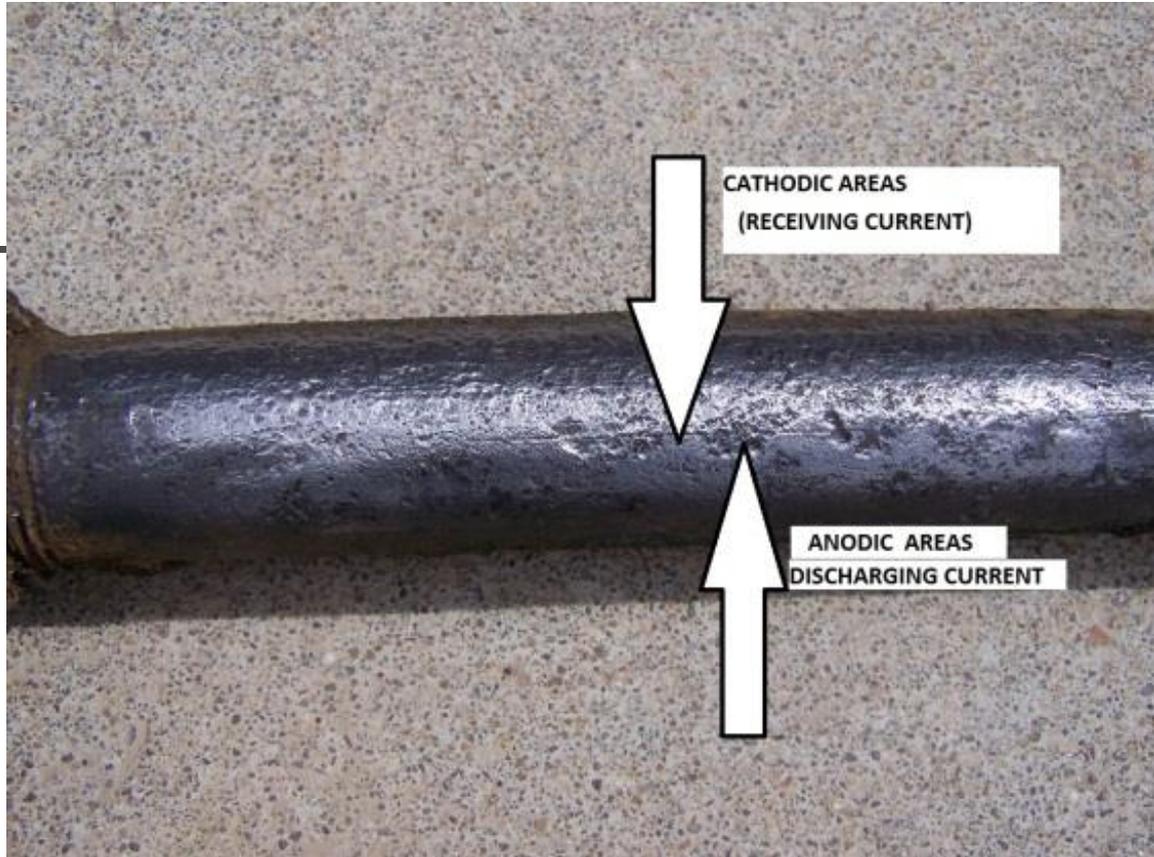
The 4 Parts of a Corrosion Cell

- 
-
1. Anode
 2. Cathode
 3. Metallic Path
 4. Electrolyte



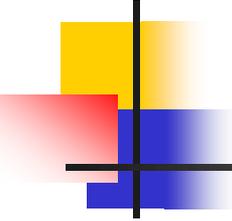
Why are some metals more active than others?

A significant amount of energy is put into a metal when it is extracted from its ores, placing it in a high-energy state. Steel (iron ore) is usually alloyed with other metals such as nickel, carbon, or other metals thus giving it “anodes and cathodes”.



Corrosion of Pipe

THIS IS AN EXAMPLE OF A CORROSION CELL: PIPE BURIED IN SOIL (ELECTROLYTE) ANODE AND CATHODES, AND THE PIPE ITSELF IS THE METALLIC PATH.



Metal Removal Power of Corrosion Current

- In one year's time, ***a single milliamp***, if restricted to a few small points of discharge, (such defects on a coated pipeline), could cause ***seven*** 1/4 inch diameter holes in 2" steel pipe of standard wall thickness.

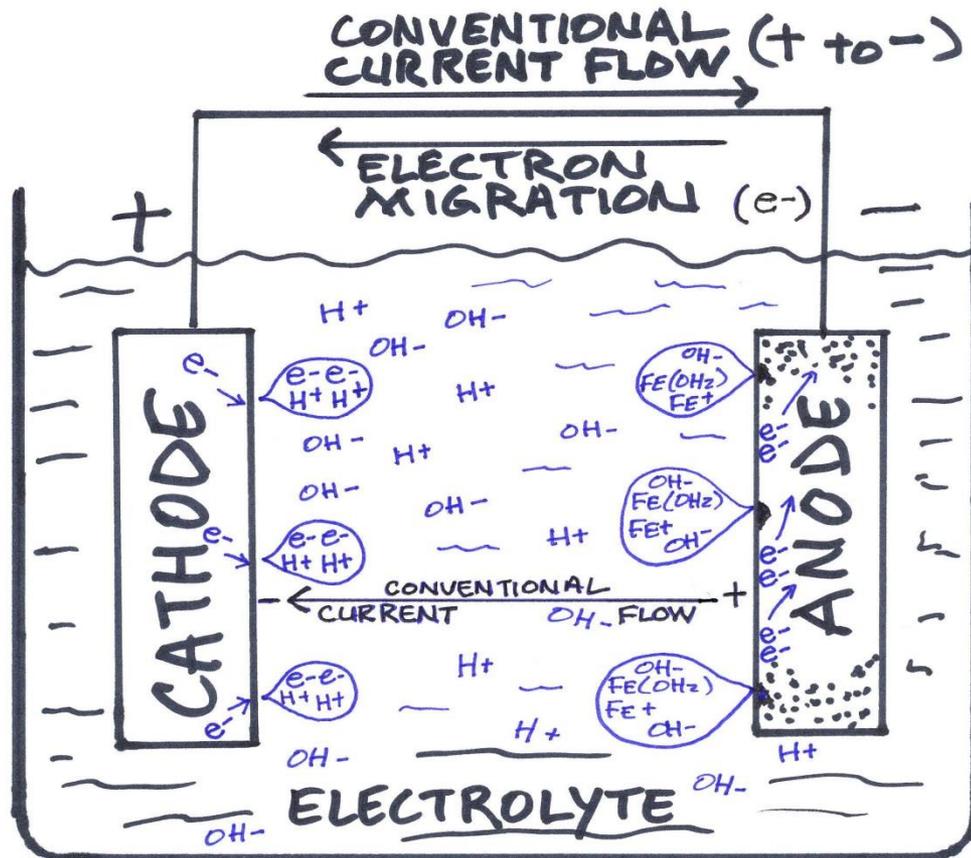
Galvanic Series of Metals

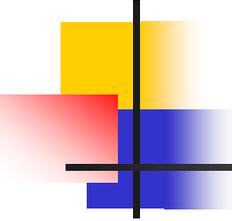
Metals at the top of the list are more electrically active than the ones at the bottom of the list.

- Each metal will sacrifice (corrode) to protect all listed below it

Metal	Volts
Pure Magnesium	-1.75
Magnesium Alloy	-1.60
Zinc	-1.11
Aluminum alloy (5% zinc)	-1.05
Commercially pure aluminum	-0.80
Mild steel (clean and shiny)	-0.5 to -0.8
Mild steel (rusted)	-0.2 to -0.5
Cast iron (not graphitized)	-0.50
Lead	-0.50
Mild steel in concrete	-0.20
Copper, brass, bronze	-0.2 to -0.3
High silicon cast iron	-0.20
Mill scale on steel	-0.20
Carbon, graphite, coke	+0.30

The Corrosion Cell

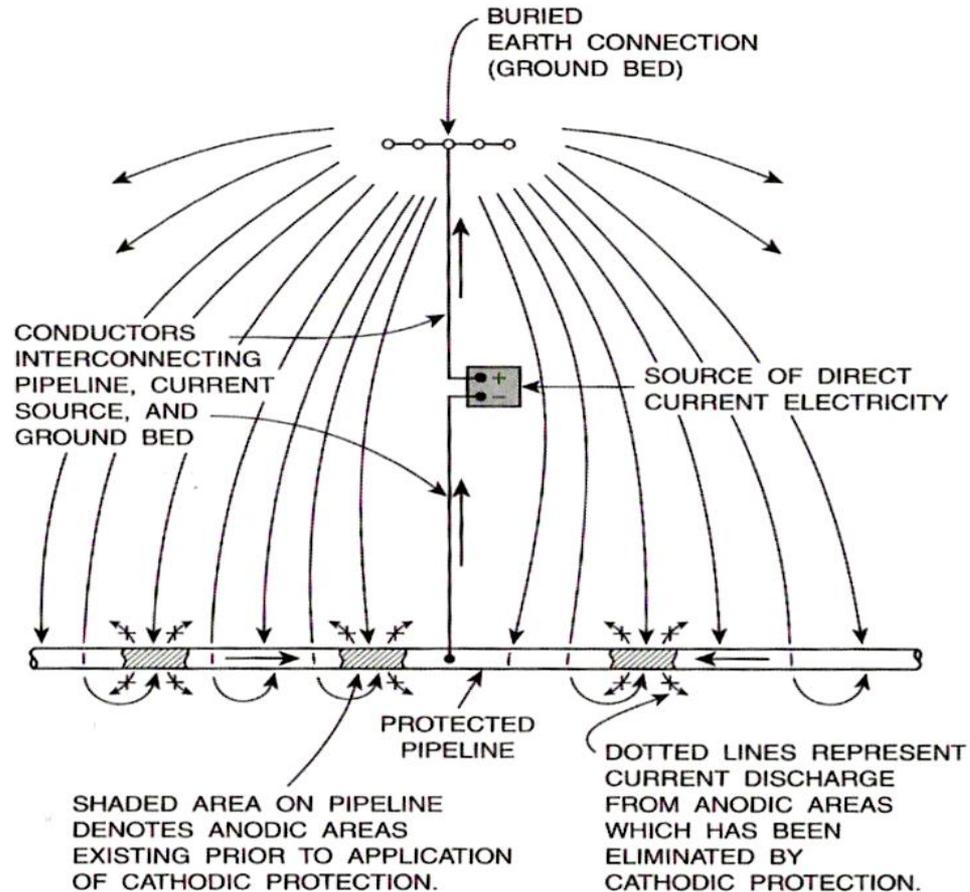




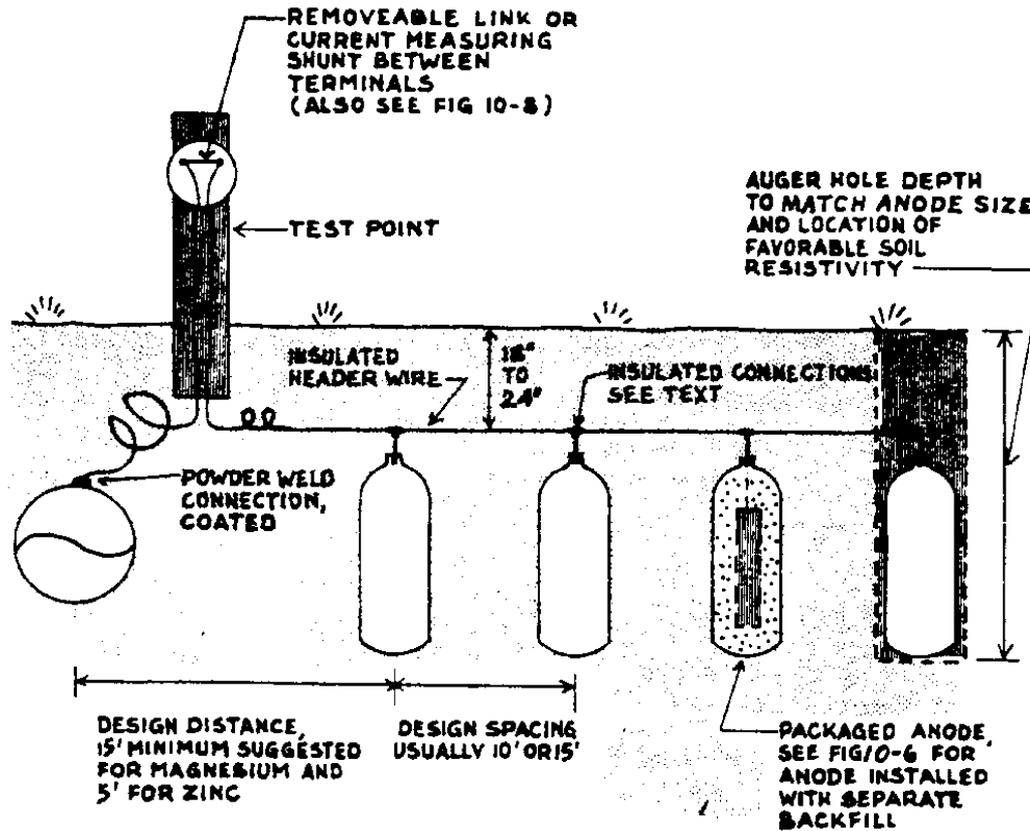
Basic Theory

- Cathodic and Anodic areas present
- CP causes metals to collect current
- DC Current is forced onto the metal
- CP shifts cathode potential negative
- Overpowers natural corrosion currents
- Corrosion rates are reduced

Basic Theory



Application – Galvanic Anodes



Packaged Magnesium Anodes (Galvanic)



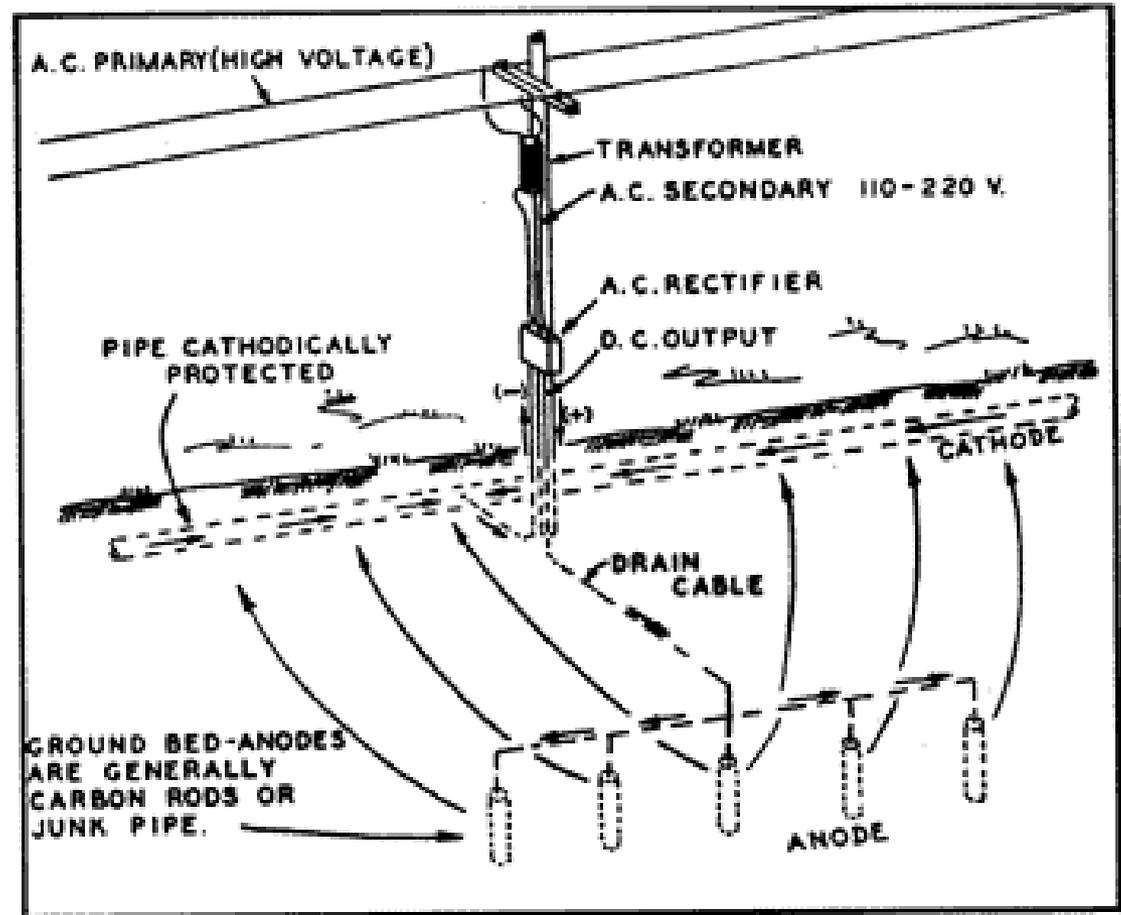
(Left to Right)

3#, 5#, 9#, 17# & 32#

Contents of Bag consists
of 75% Gypsum
20% Bentonite and
5% Sodium Sulfate

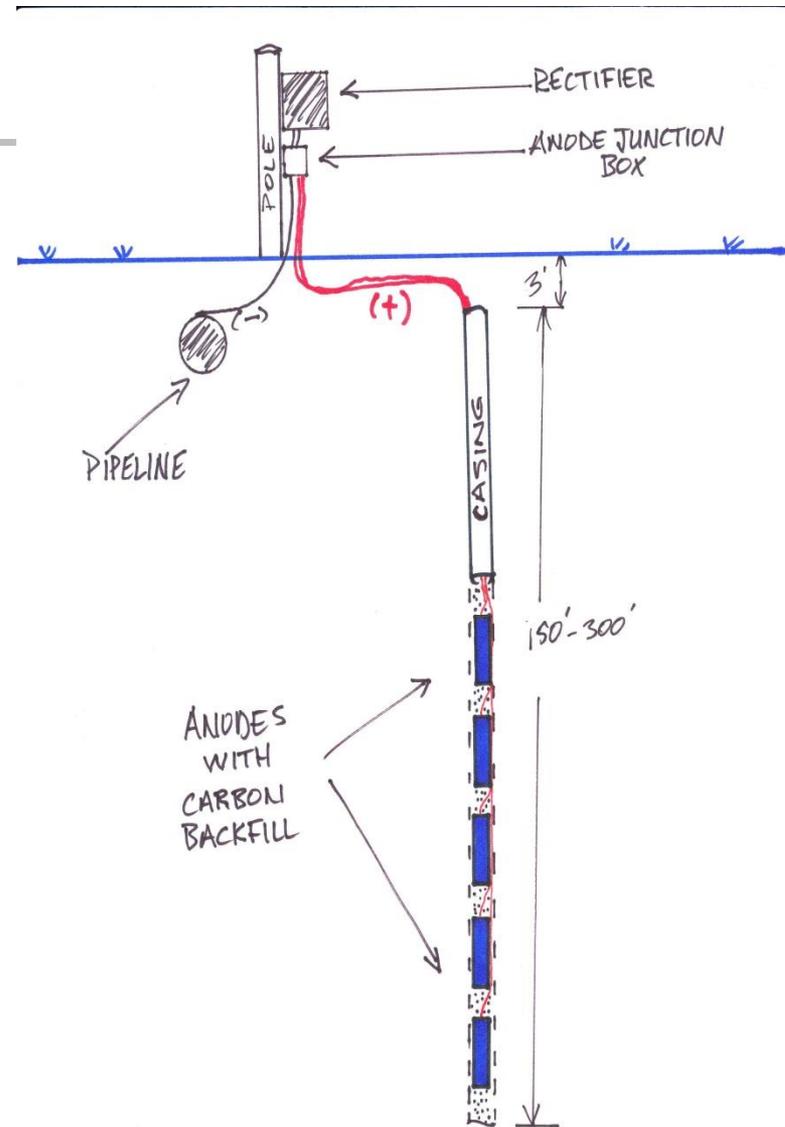
Application – Impressed Current

Typical
Rectifier &
Ground Bed
Surface Anode
Bed



Application – Impressed Current

Typical Rectifier & Groundbed
(Deep Anode Bed)



Impressed Current Anodes

(Left to Right)

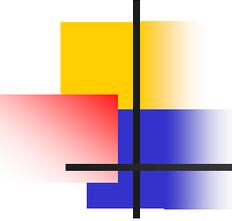
2.2" x 60" Tubular

High Silicon Cast
Iron

3" x 60" Wax

Treated Graphite

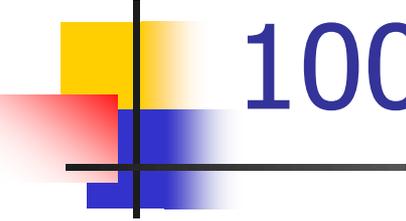




Criteria Used

- -850 mV (or more negative)
- 100 mV Depolarization (Must prove the **decay** or **formation** of at least 100mV)

* Each Criteria is dependent upon the condition of the system.



100mV Depolarization Test

MIDWEST ENERGY, INC.

* FIELD TEST FOR DETERMINATION OF 100mv POLARIZATION CRITERIA *

DATE: 7-12-13 _____

CITY: Hays

ZONE TESTED: H51.0

TECH: DE SULTZER

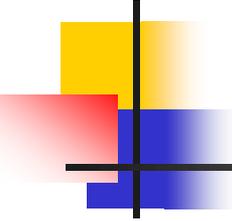
CURRENT INTERRUPTED: 12 sec. "ON" / 2 sec. "OFF"

P/S Potentials MV = OFF - BASE

TEST STATIONS	LOCATION	ON P/S	OFF P/S	BASE P/S	MV
T-1	418 West 5th	-0.847	-0.661	-0.513	148
T-2	416 West 4th	-0.829	-0.607	-0.503	104
T-3	309 Ash	-0.752	-0.579	-0.476	103
T-4	410 West 3rd	-0.771	-0.596	-0.488	108
T-5	207 Ash	-0.822	-0.591	-0.487	104
T-6	101 Ash	-0.879	N/A	-0.544	N/A
T-7	211 Ash	-0.769	-0.646	-0.538	108
T-8	PE MAIN	N/A	N/A	N/A	N/A
T-9	T.S. 501 Elm	-0.769	-0.602	-0.498	104
T-10					
T-11					
T-12					

Comments: _____

Rectifier Output : South Elm Rectifier = 5.70 amps _____



Design

- THINGS TO CONSIDER
 - Galvanic or Impressed?
 - Magnitude of Current Required?
 - Pipe Size and Coating (if any)
 - Number of Test Points
 - Isolation from Foreign Structures (YARD & FUEL LINES, Other CP Zones)
 - Stray DC Current Sources

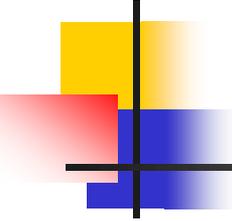
Types of Insulating (Isolation) Devices

Meter Insulation



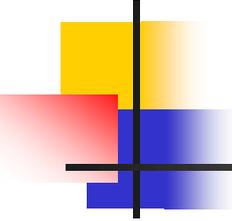
Electrostops & Flange Bolt Sleeves





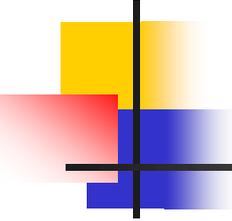
Design

- MORE REQUIRED INFORMATION
 - Environment Corrosivity
 - Soil Resistivity and Structure
 - Bare or Coated
 - Coating quality
 - Electrical strength
 - Coating deterioration



Design - Coating

- Eliminate 99% of exposed steel
- Reduce current requirements
 - Current only flows to exposed areas
- Coating qualities
 - Not a perfect insulator
 - Depends on resistivity and thickness
 - Current through coating is negligible



Design – Bare vs. Coated

- Coating reduces current required

2" Pipe = O.D. of 2.375"

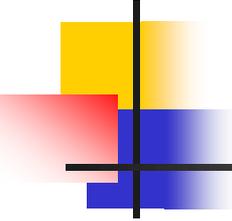
$2.375 \times 3.142 / 12'' = .622$ sq. ft of surface area

Bare Pipe takes anywhere from 1 to 3 mA of current per sq. ft. to protect.

Example: 1 mile of bare 2" pipe - $.622 \times 5,280 \text{ ft} = 3,284$ sq ft. x $.003 = \mathbf{9.85 \text{ Amps}}$

Coated Pipe takes anywhere from a tenth to a quarter of a mA per sq. ft. to protect.

Example: $3,284$ sq. ft. x $.00025 = \mathbf{82 \text{ mA}}$



Design - Location

- Surface vs. Deep Ground Beds
- Galvanic vs. Impressed Current
- CP creates a potential difference between the pipeline and the earth.
- Pipe is negative
- Earth is positive

Basic Test Equipment

TYPICAL MUTI - METER
WITH HALF - CELL
AND CONTACT PROBE



MULTI - METER WITH MORE
FUNCTIONS TO TEST
COMPONENTS IN RECTIFIERS



Monitoring – Pipe to Soil Testing



Pipe to Soil Testing / 2 wire Test Station



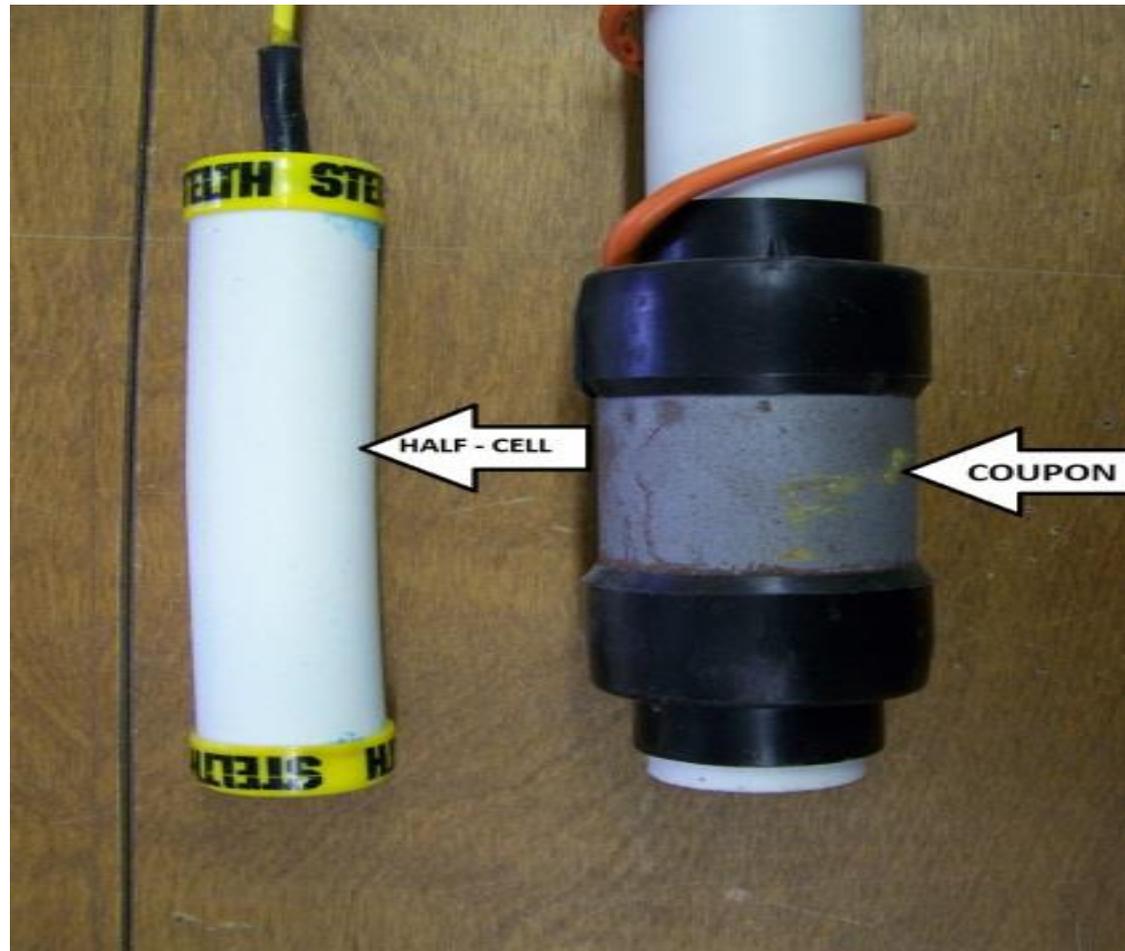
Pipe to Soil Testing / 2 wire Test Station



Pipe to Soil Testing / Coupon Test Station...Top End



Coupon Test Station..... Bottom End

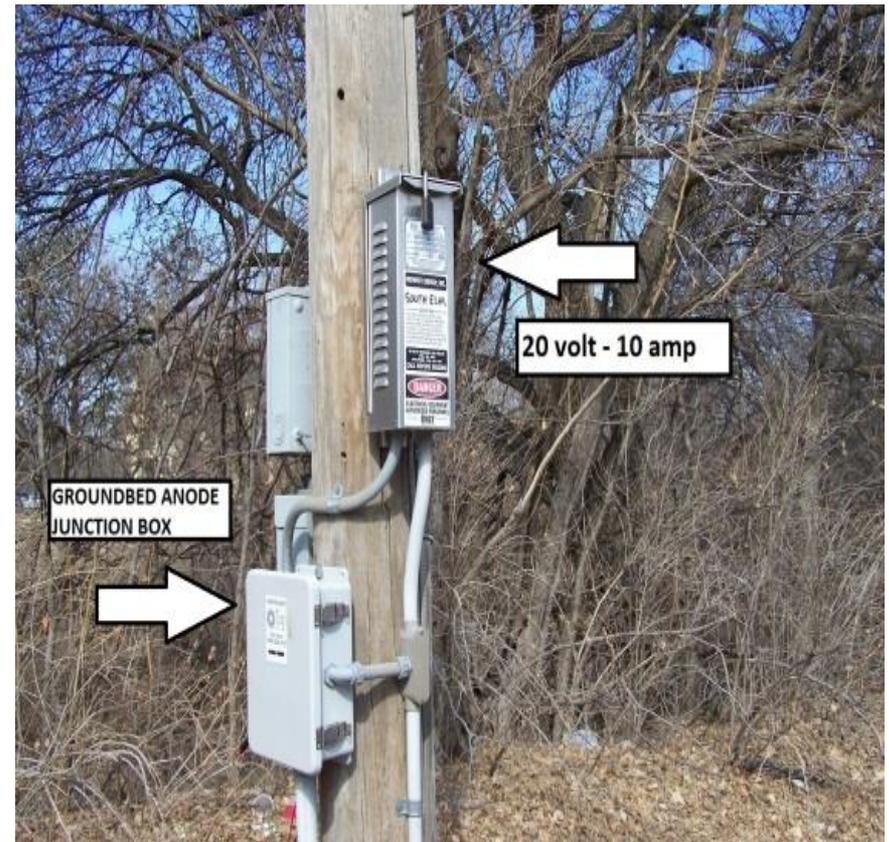
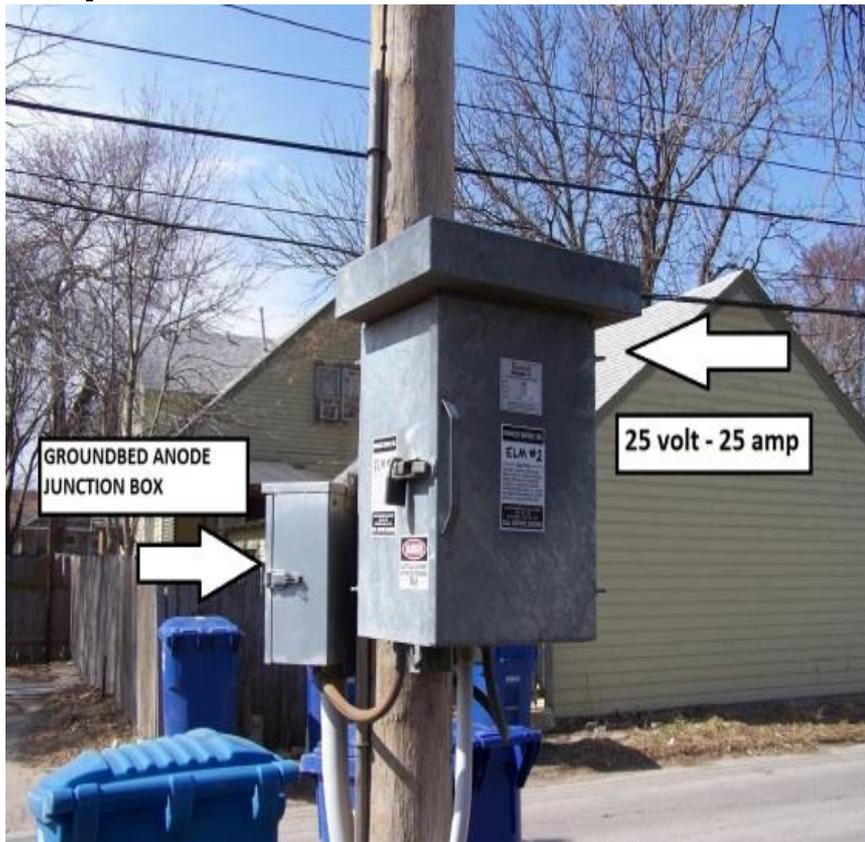




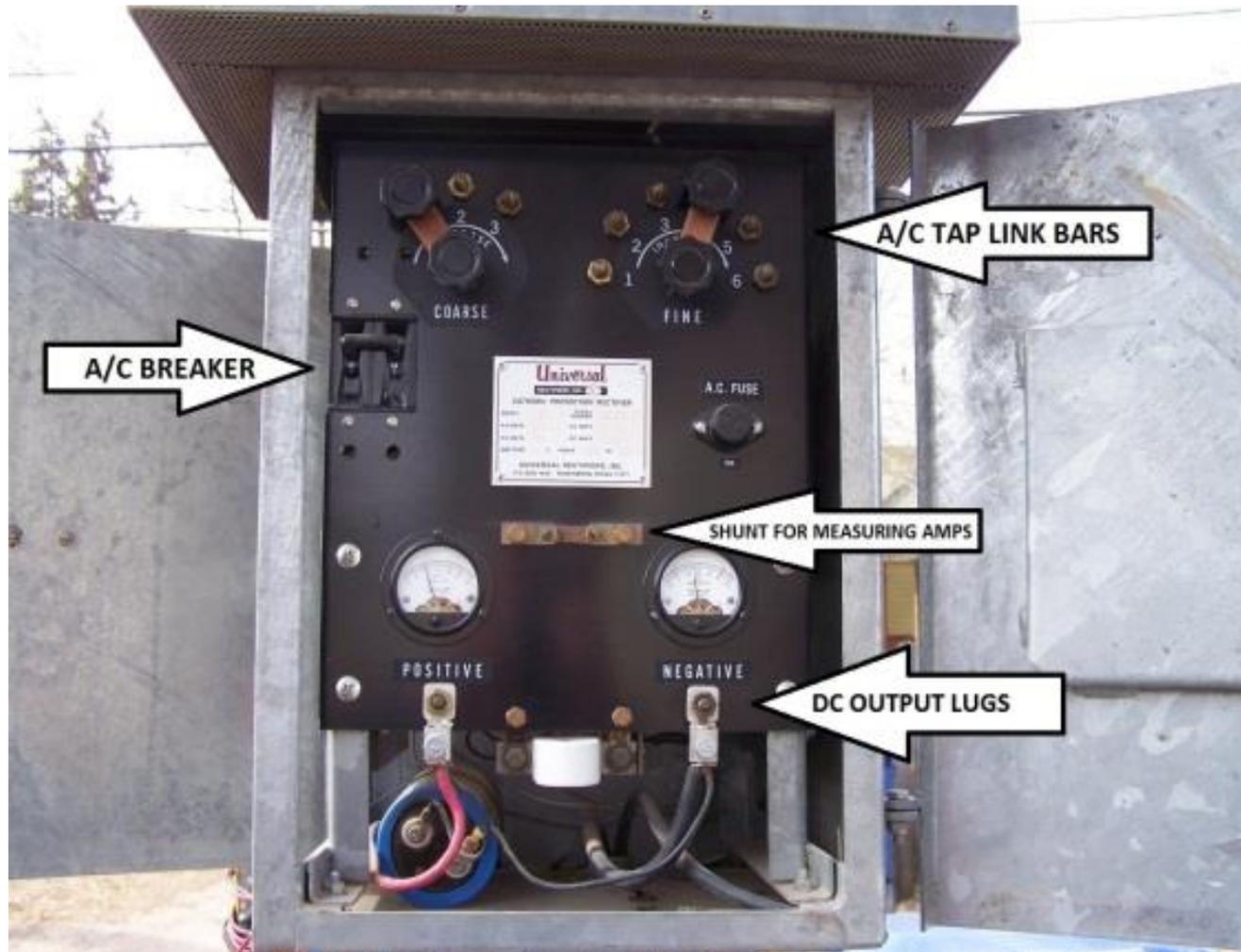
Calculating Current Requirements

Setting up a temporary "Rectifier" and Groundbed

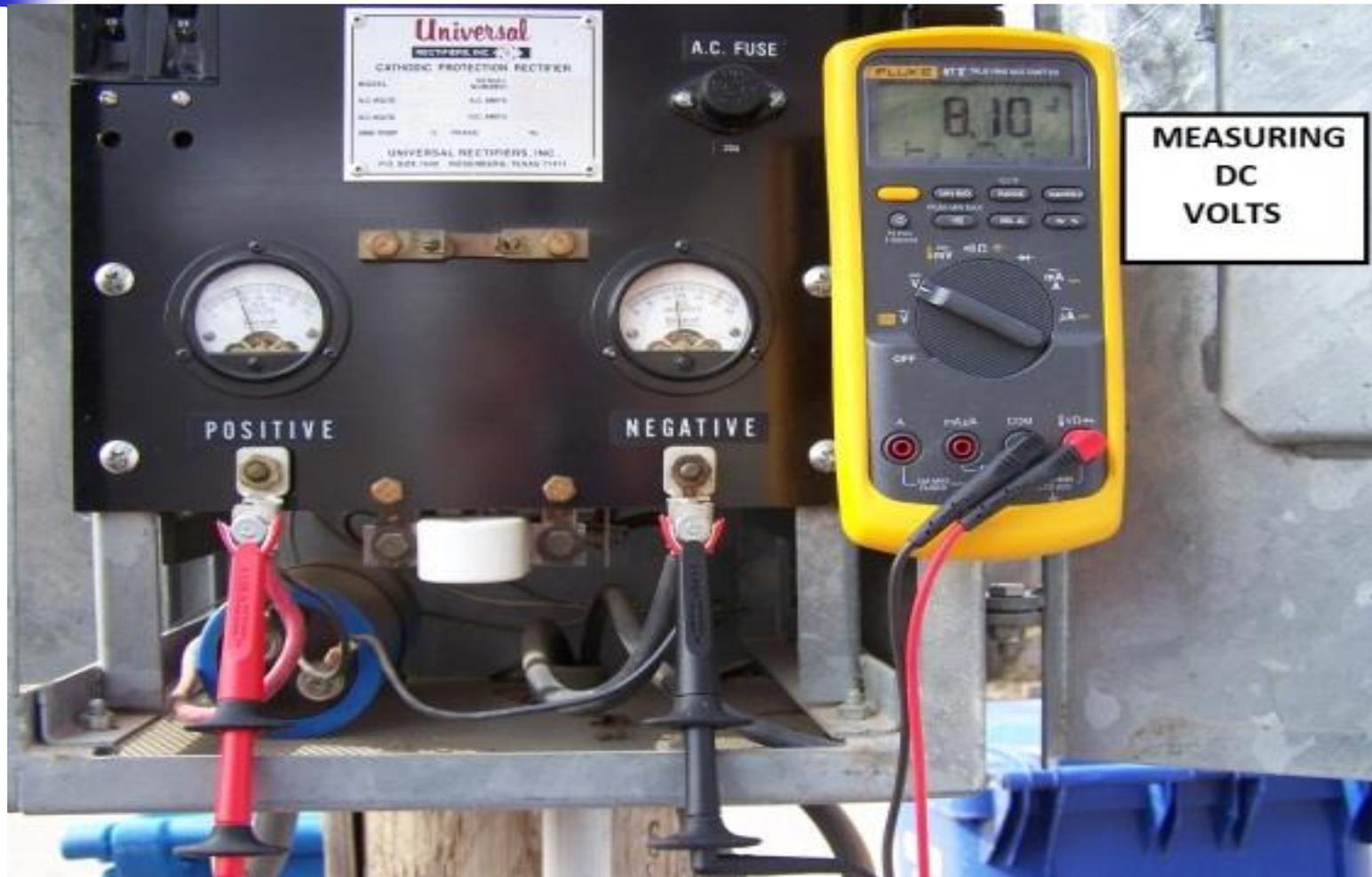
Typical Rectifier Units



Monitoring – Rectifier Testing



Monitoring – Rectifier Testing



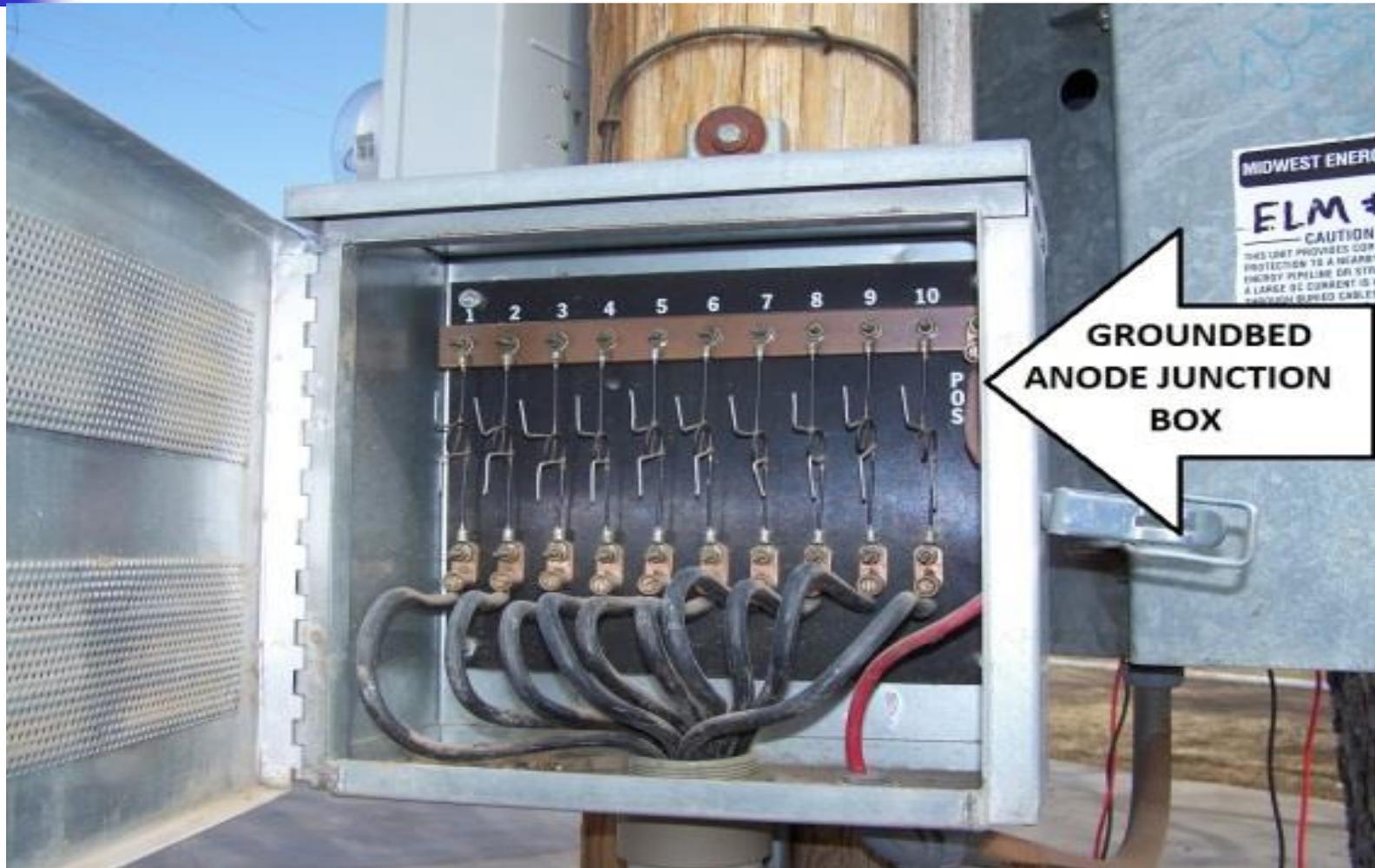
Monitoring – Rectifier Testing



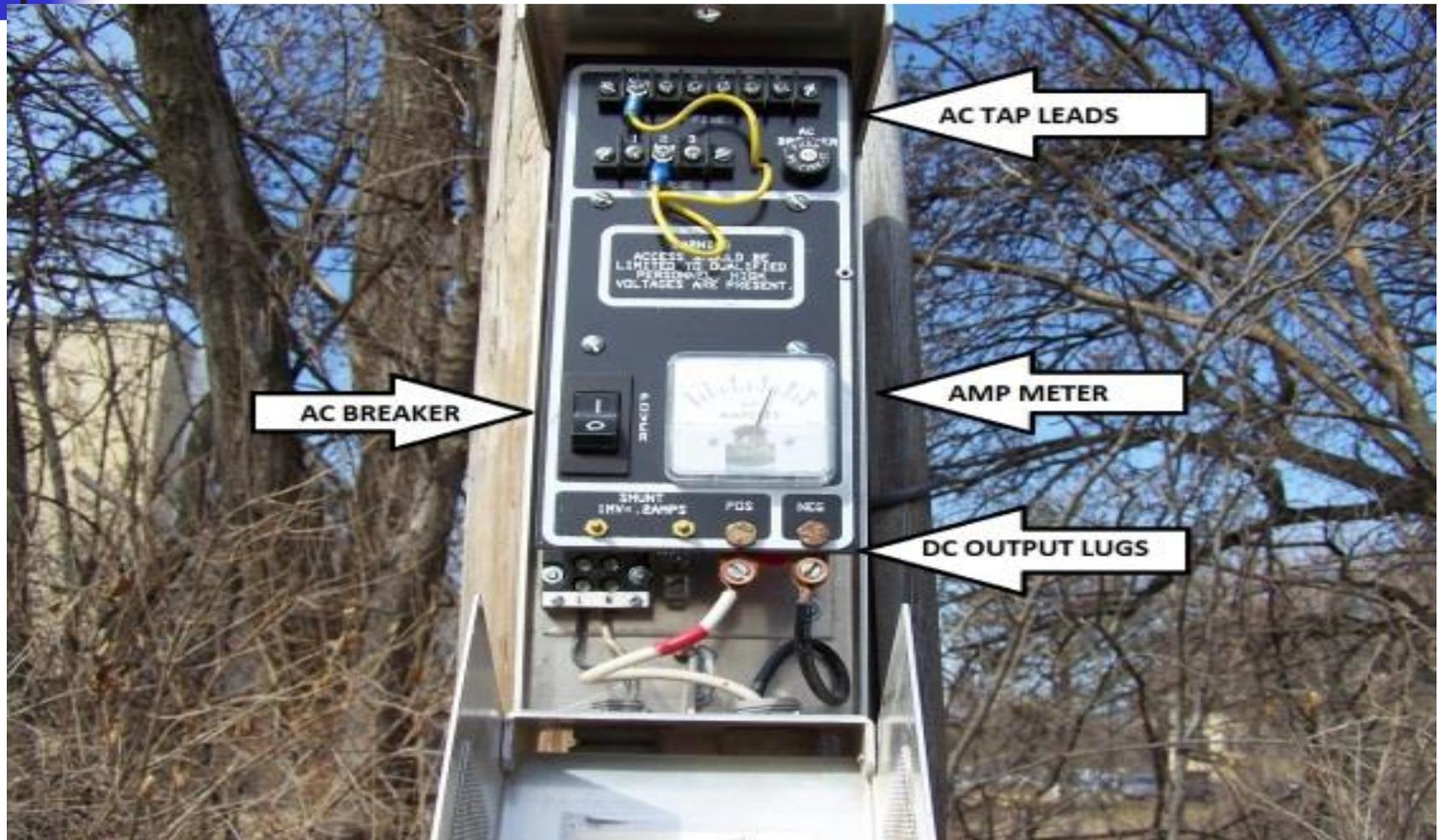
Monitoring – Rectifier Testing

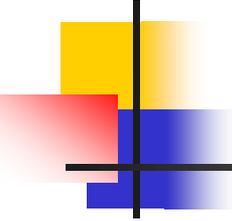


Monitoring – Groundbed Anodes



Monitoring – Most rectifiers are tested in the same manner.





Review

- 4 Parts to a corrosion cell
- Eliminate any 1 to stop corrosion
- CP drastically eliminates anodic areas
- Design for useful life
- Design to adequately protect
- Maintain to avoid problems.

Air to Soil Interface (Coated?)





CUT AWAY LOOSE COATING



WRAP OR COAT WITH AN APPROVED MATERIAL