Corrosion Control

Part 192, Subpart I

- External
- Internal
- Atmospheric

Added To Part 192 By Amendment 4, 8/1/71

Definition of Corrosion

- The Deterioration of a Material, Usually a Metal, that Results from a Reaction with its Environment.

- Galvanic Corrosion of a Metal Occurs because of an Electrical Contact with a More Noble (Positive) Metal or Non-metallic Conductor in a Corrosive Electrolyte.

Galvanic Series of Metals

Practical Galvanic Series for Materials in Neutral Soils and Water

Material	Potential Volts (CSE)[a]
Carbon, Graphite, Coke	+0.3
Platinum	0 to −0.1
Mill Scale on Steel	−0.2
High Silicon Cast Iron	−0.2
Copper, Brass, Bronze	−0.2
Mild Steel in Concrete	−0.2
Lead	−0.5
Cast Iron (Not Graphitized)	−0.5
Mild Steel (Rusted)	−0.2 to −0.5
Mild Steel (Clean and Shiny)	−0.5 to −0.8
Commercially Pure Aluminum	−0.8
Aluminum Alloy (5% Zinc)	−1.05
Zinc	−1.1
Magnesium Alloy (6% Al, 3% Zn, 0.15% Mn)	−1.6
Commercially Pure Magnesium	−1.75

[a]Typical potential normally observed in neutral soils and water, measured with respect to copper sulfate reference electrode.

Basic Corrosion Cell

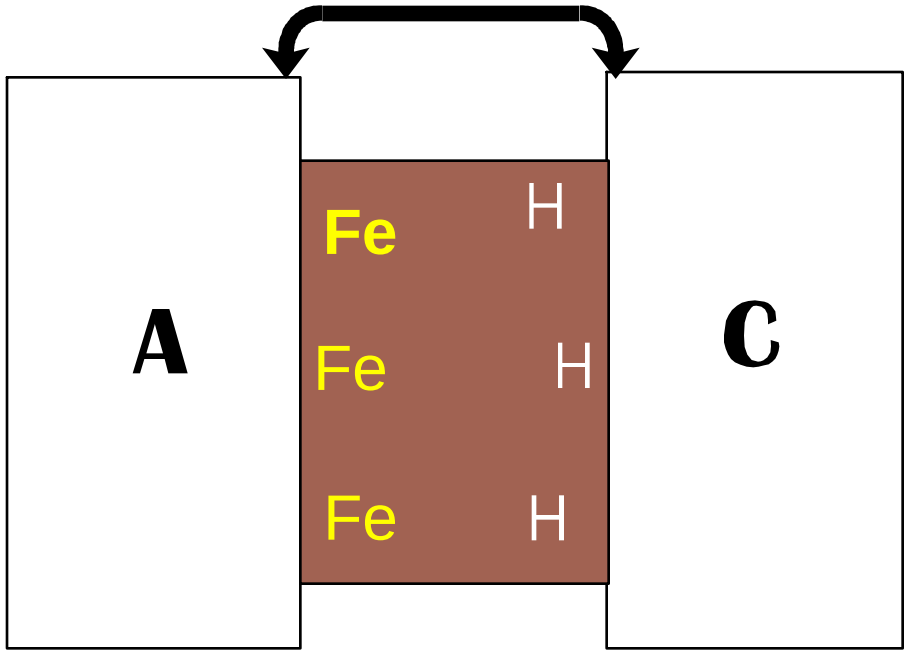
Metallic Path

ANODE

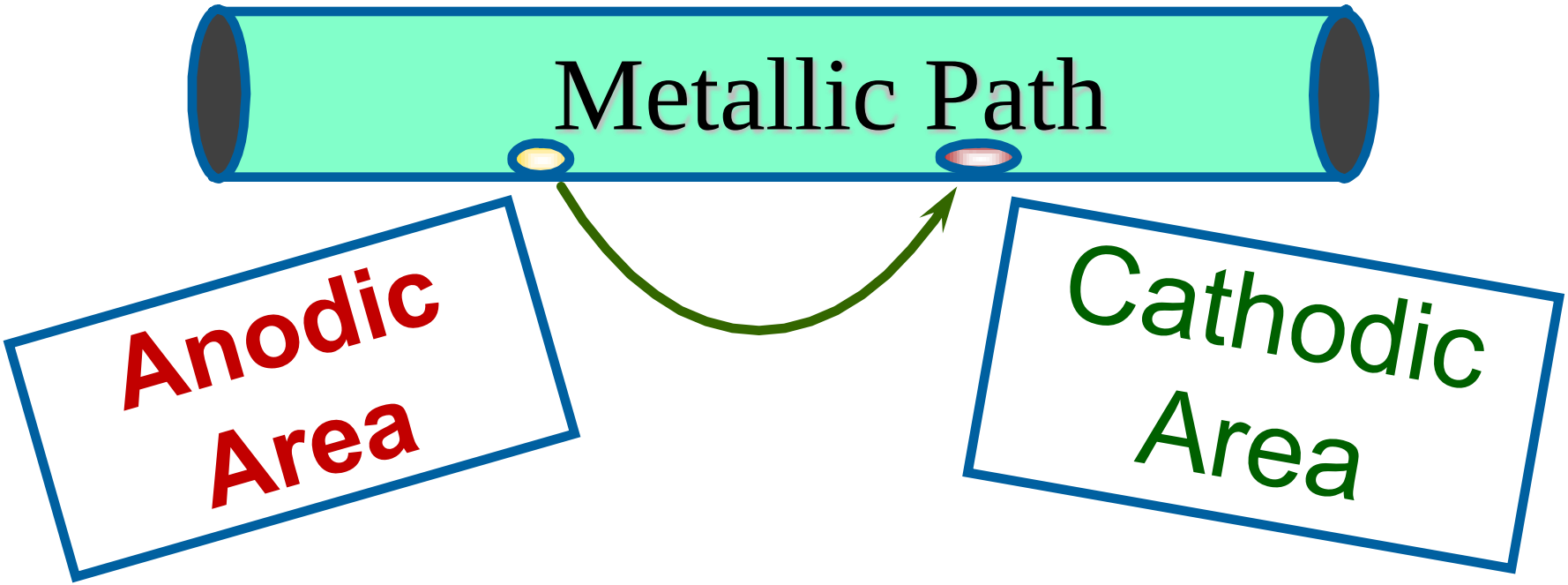
CATHODE

ELECTROLYTE

METALLIC PATH



Pipe Corrosion



Corrosion on Pipelines

- Dissimilar Metals
- Dissimilar Soils
- Differential Aeration
- Mill Scale Corrosion

Soil Resistivity vs. Corrosivity

Soil Resistivity vs. Degree of Corrosivity	
Soil Resistivity (ohm-cm)	**Degree of Corrosivity**
0 – 500	Very corrosive
500 – 1,000	Corrosive
1,000 – 2,000	Moderately corrosive
2,000 – 10,000	Mildly corrosive
Above 10,000	Minimally corrosive

Soil pH

ACIDIC **ALKALINE**

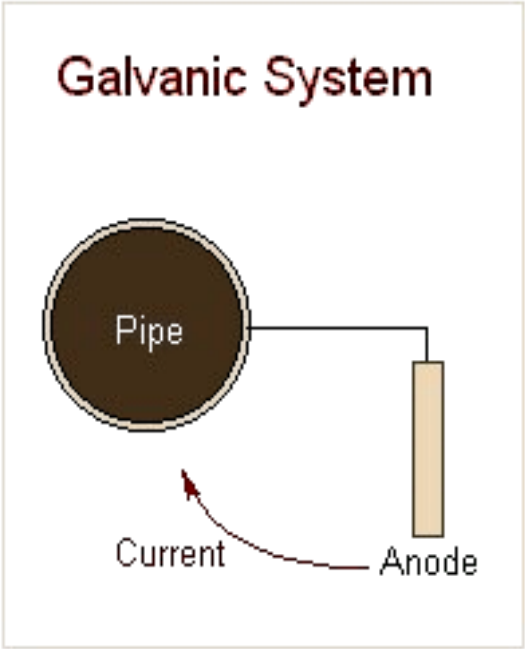
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

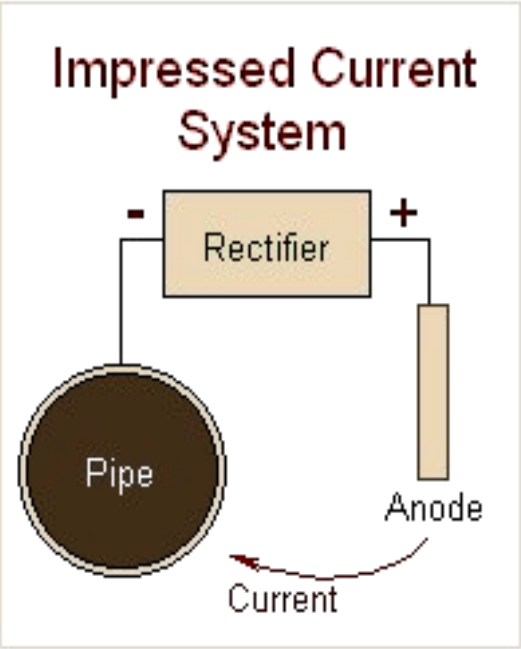
Cathodic Protection

- The Decrease of Corrosion of a Metal by Forcing Current to Flow to the Metal from a Solution (Electrolyte).

Cathodic Protection

- Galvanic Sacrificial Anodes
- Impressed Current Systems





* Properly Designed & Installed

Qualified Person §192.453

- Must be carried out by, or under the direction of, a person qualified in pipeline corrosion control methods.

"OQ" Qualified Person

- Operator Qualification requires that an unqualified person must be under the direct observation of a qualified person.

Required System Information

- Date of Installation
- Transmission or Distribution
- Coated or Bare

CP Required

- Coated Metallic Pipelines Installed after 7/31/71 ~ §192.455 (a)

- Coated Transmission Lines (except station piping) Installed prior to 8/1/71 ~ §192.457 (a)

CP Required

- Areas of Active Corrosion - Installed prior to 8/1/71 §192.457 (b)
  - Bare or Ineffectively Coated Transmission Lines
  - Station Piping (Bare or Coated)
  - Bare or Coated Distribution Lines

CP Not Required

- Bare TEMPORARY lines installed after 7/31/71
  §192.455 (c)(2)&(d)
- Bare or ineffectively coated lines installed prior to 7/31/71 with no evidence of active corrosion
  §192.457 (b)

Active Corrosion

- Continuing corrosion which, unless controlled, could result in a condition that is **DETRIMENTAL to PUBLIC SAFETY**

Per §192.3

CP Not Required (cont.)

- Electrically isolated metal alloy fittings in plastic pipeline systems §192.455 (f)

- Pipelines in NON-CORROSIVE environments §192.455 (b)

Non-Corrosive Environment

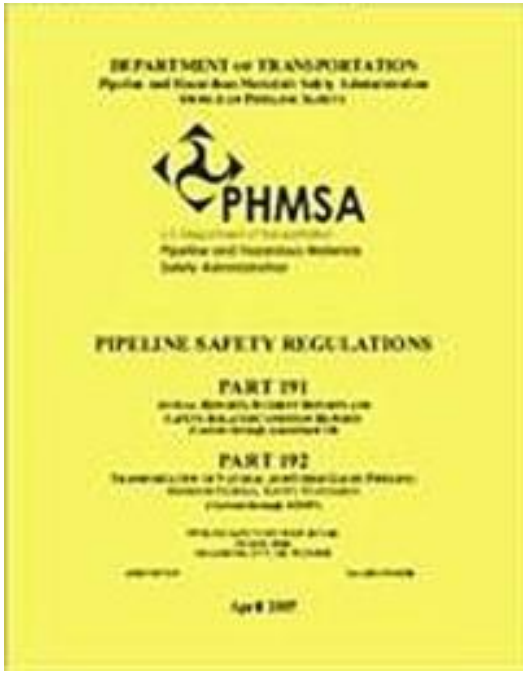
Tests Needed to Demonstrate:

- ☒ Soil Resistivity Measurements
- ☒ Corrosion Accelerating Bacteria
- ☒ Leak Frequency
- ☒ Soil Composition
- ☒ pH
- ☒ Bell Hole Examinations
- ☒ Internal Inspections

- ☒ *POST- INSTALLATION TESTS (< 6 MONTHS)*
  - * Close Interval Potential
  - * Soil Resistivity

Cathodic Protection Criteria

- §192.463 Requires Cathodic Protection to a Level that Complies with Appendix "D"



Cathodic Protection Criteria

- Negative 850 mV
- 100 mV Negative Polarization Decay
- Negative 300 mV Shift
- Net Protective Current
- E log I (Gas)

Components of IR Drop

Resistances

Measuring Lead (+)

Contact Lead (+)/Ref. Cell

Reference Cell

Contact Reference Cell to Electrolyte

Electrolyte

Polarization

Structure

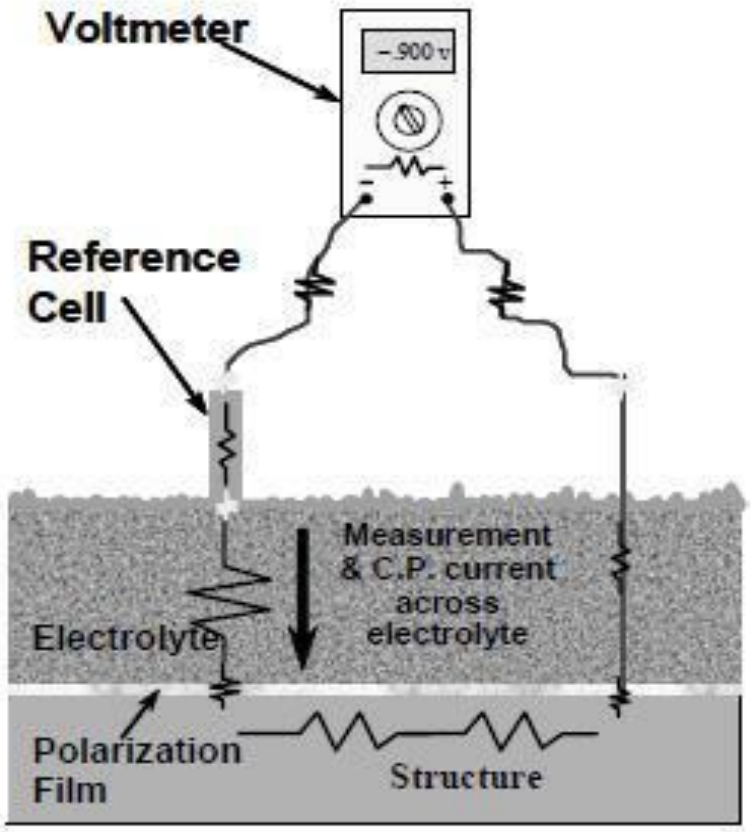
Contact Test Lead/Structure

Test Lead

Contact Test/Measuring Lead

Measuring Lead (-)

Internal Meter



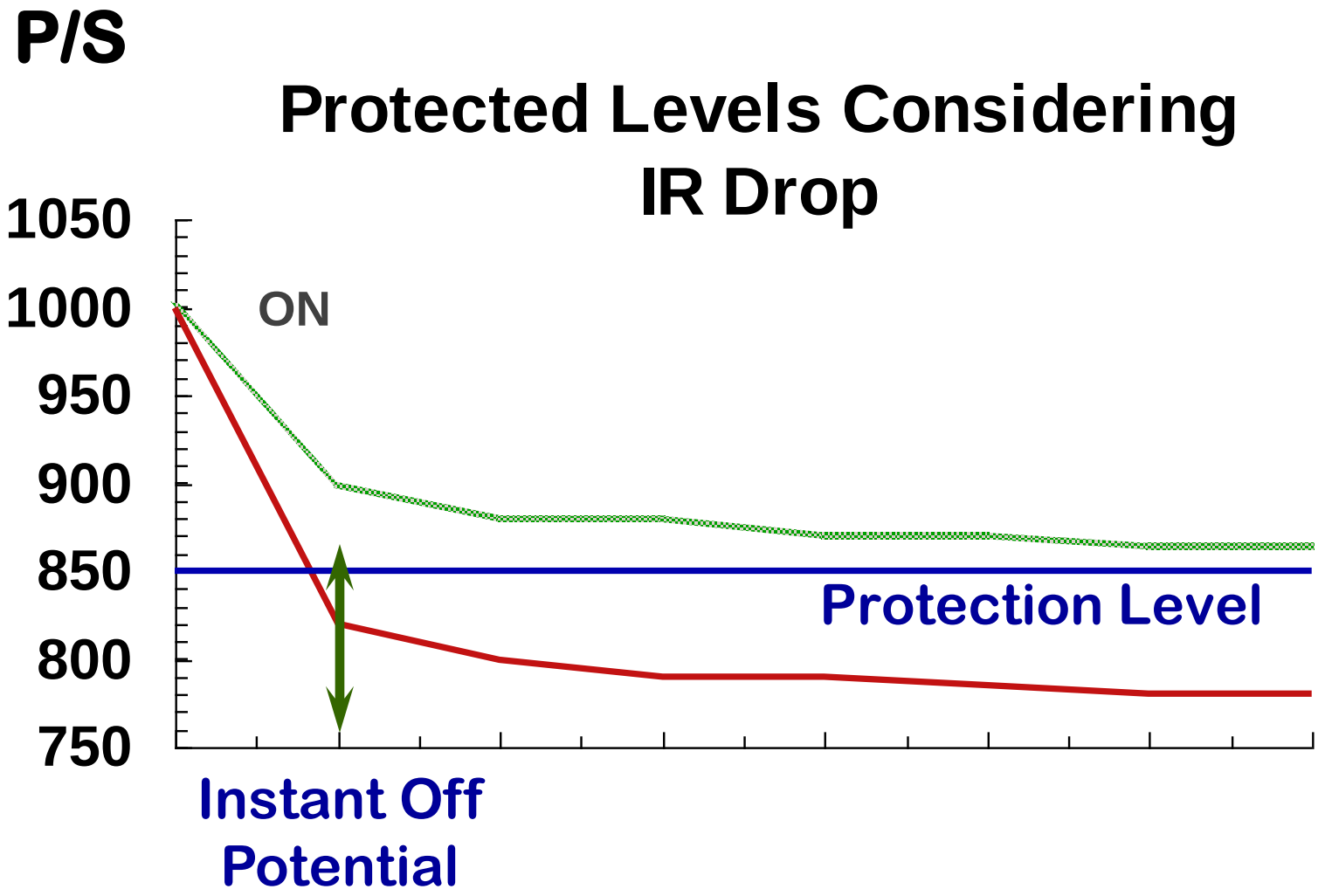
IR Drop Major Contributors

- Contact between the reference cell and the soil.
- Electrolyte (soil)
- Polarization at the pipe coating / soil interface

C. P. Criteria - 850 mV

- - 850 mV
- Measured with Current Applied
- Consider IR Drop
- Cu/$CuSO_4$ Reference Electrode
- - 800 mV - Ag/Ag Cl (Silver/Silver Chloride) for sea water

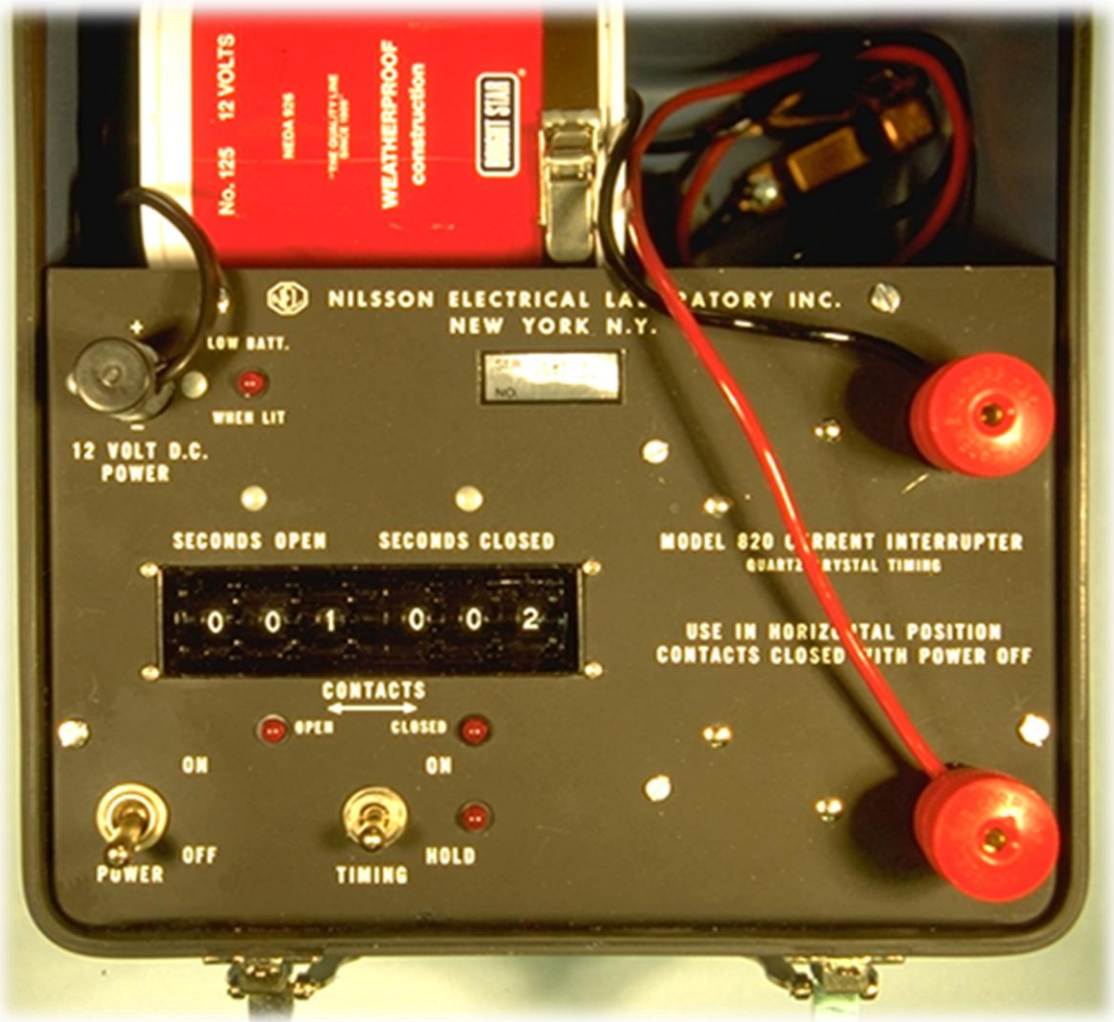
Cathodic Protection Criteria (-850 mV)



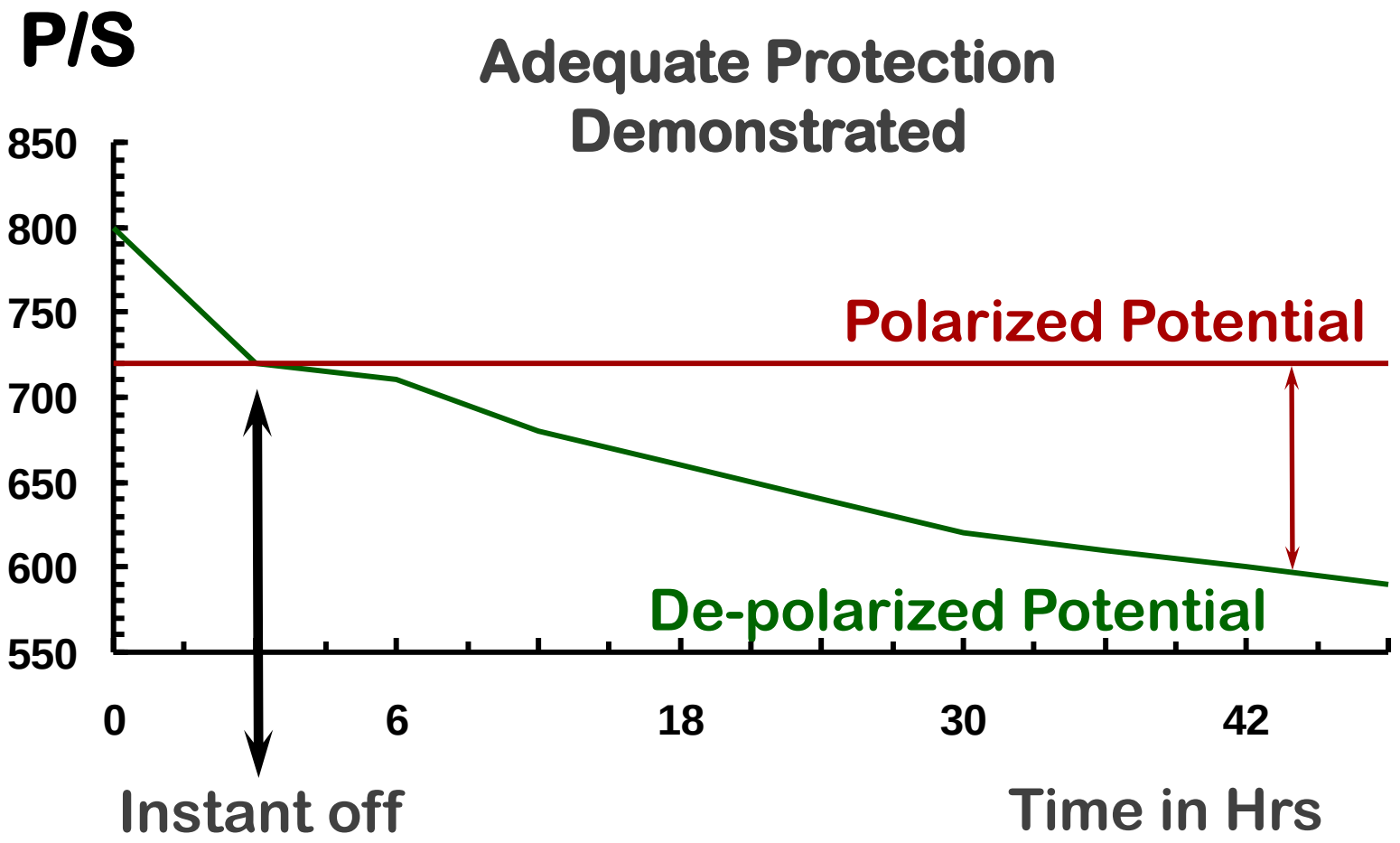
Cathodic Protection Criteria

100 mV Polarization Decay

- Current Interruption
- $Cu/CuSO_4$ Reference Electrode

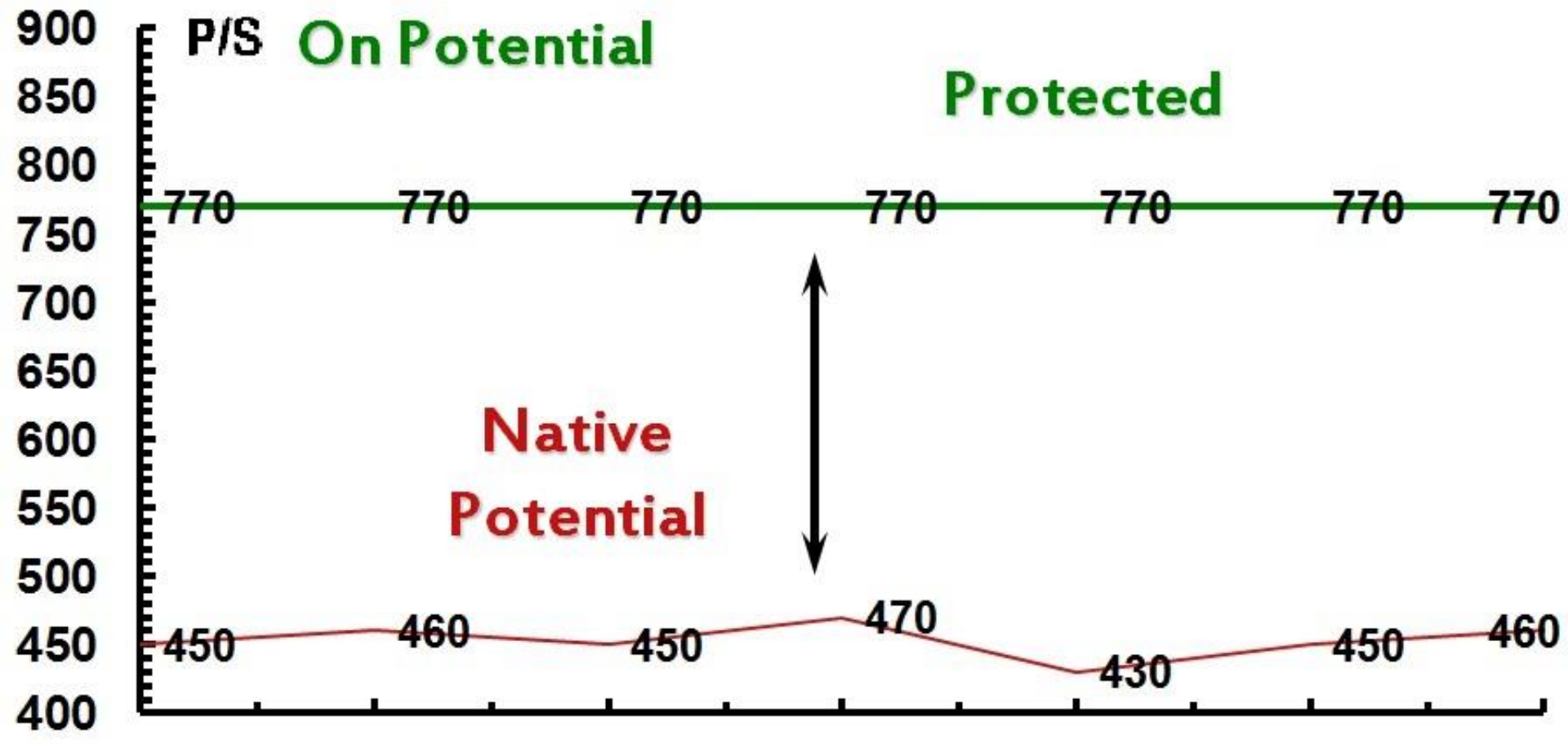


100 mV Polarization Decay



C. P. Criteria - 300 mV Shift

Does NOT Apply to Structures with Different Anodic Potentials



Cathodic Protection Criteria

Net Protective Current

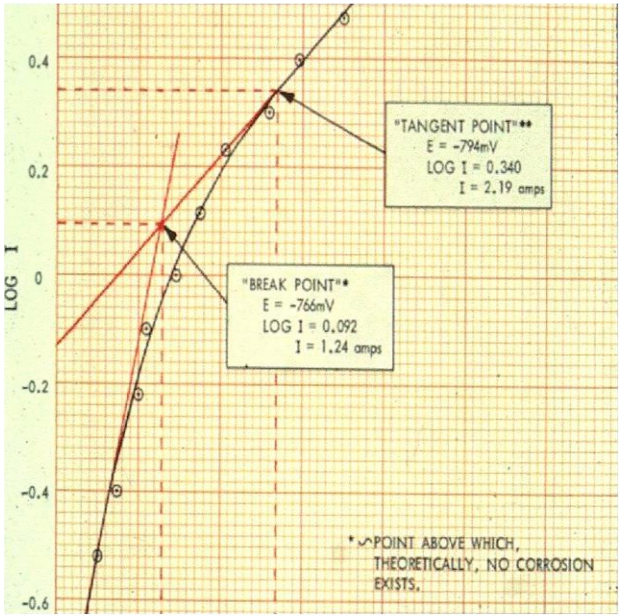
- Current Flow from Electrolyte to Structure

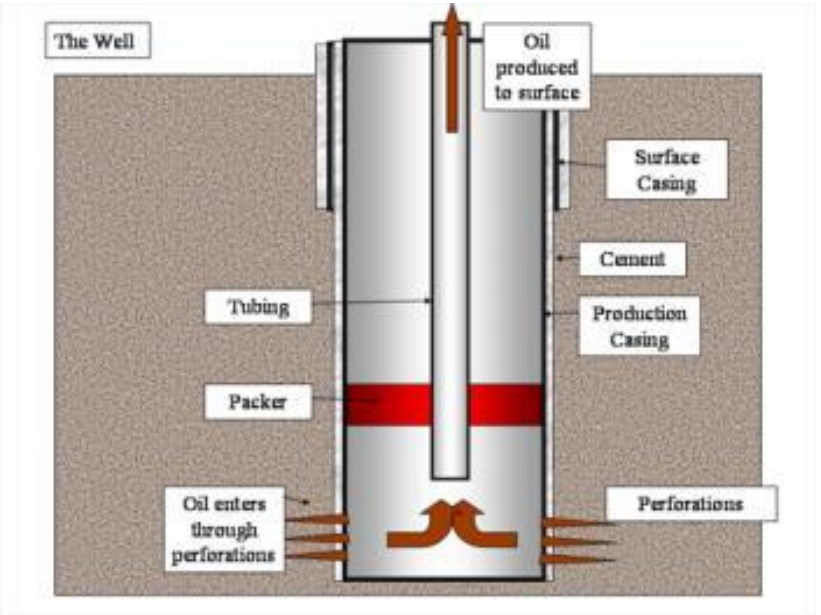
- At Predetermined Anodic Areas

Cathodic Protection Criteria

E Log I

- Tafel Slope
- $Cu/CuSO_4$ Reference





Monitoring §192.465 (a)&(c)

- Cathodically Protected Zones
- Isolated Sections less than 100 ft. (Gas Mains or Transmission) 10% Sampling Per Yr.
- Non-Critical Bonds

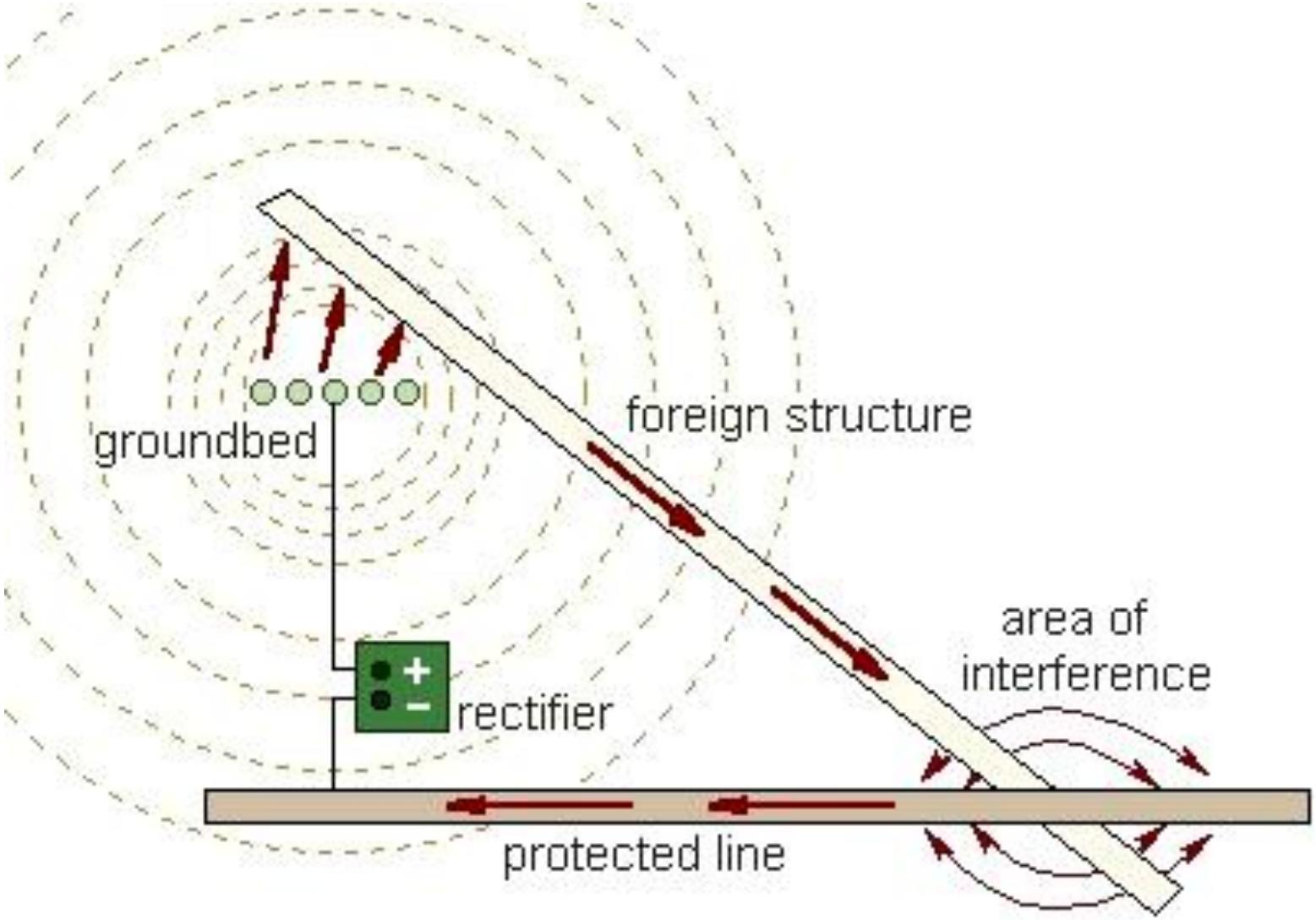
Once Each Calendar Year Not to Exceed 15 Months

Monitoring §192.465 (b)&(c)

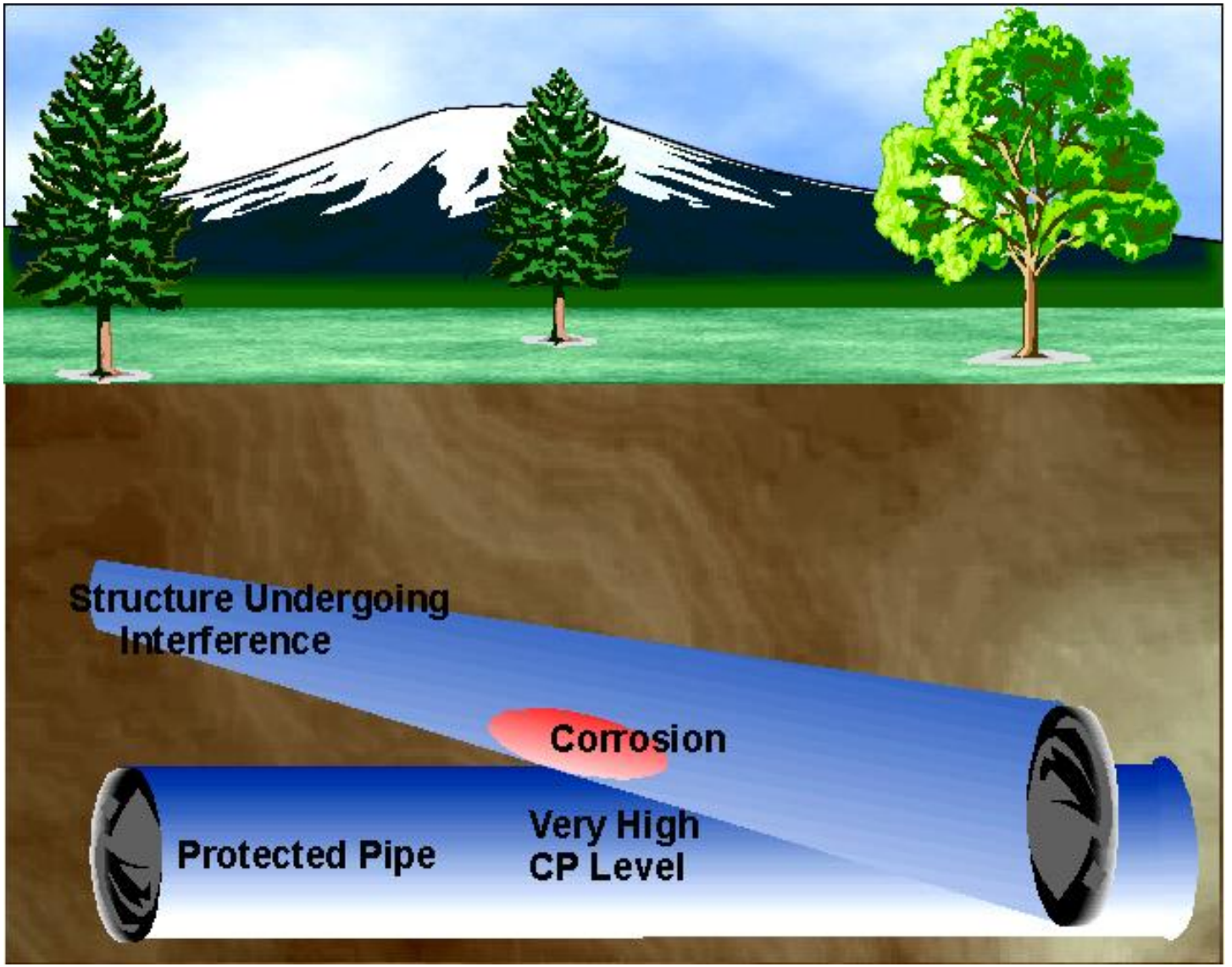
- Rectifiers
- Critical Bonds
- Reverse Current Switches
- Diodes

6 Times Each Calendar Year not to Exceed 2 1/2 Months

Monitoring §192.465 (c)



Monitoring §192.465 (c)



Monitoring ~ §192.465 (e)

- Re-evaluation of Unprotected Lines
  - Every 3 Years not to exceed 39 Months

- Determine Areas of Active Corrosion
  - Electrical Survey (Where Practical)
  - Corrosion and Leak History
  - Leak Survey
  - Exposed Pipe Inspection Records
  - Pipeline Environment

Detrimental to Public Safety Considerations

- Pipeline Location
  - Population Density
  - Road Crossings
- Pressures
- Corrosion Rate (3 Year Intervals)

Electrical Survey

- **Definition ~ (Per §192.3)**

A series of closely-spaced pipe-to-soil readings over a pipeline that are subsequently analyzed to identify locations where a corrosive current is leaving the pipeline

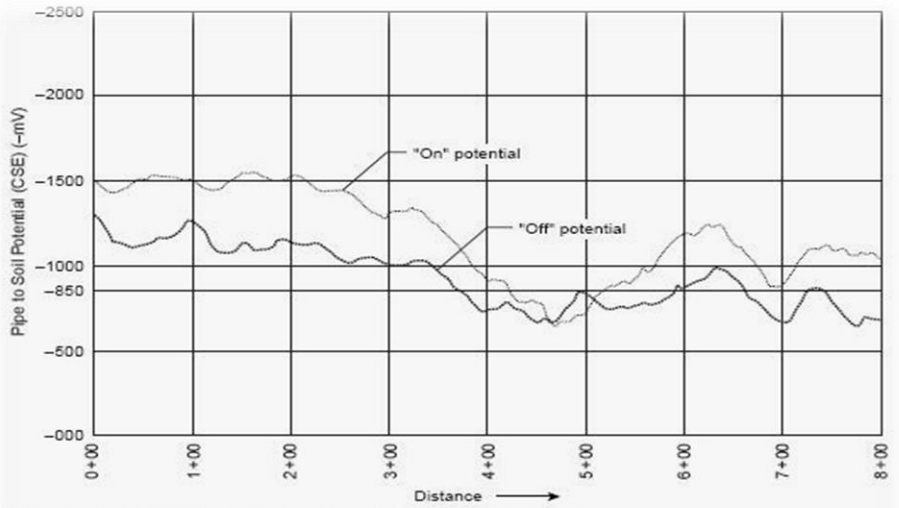


Figure 5.5 Over-the-line survey (with cathodic protection).

Electrical Surveys

What's Impractical

- Wall to Wall Paving
- Common Trench
- "Stray Current" Areas
- Pipeline Cover In and Out of Paving

Pipeline Environment

- Soil Resistivity (High or Low)
- Soil Moisture (Wet or Dry)
- Soil Contaminants
- Other Known Conditions

Monitoring ~ §192.459

- Examination of Pipelines When Exposed <u>for Any Reason</u>

- Check Condition of Coating and Pipe

Exposed Pipelines

- Investigate to determine whether corrosion or coating deterioration exists
- If corrosion found, investigate beyond exposed area (visual or other means)
- Repair any problems
- Keep records

Remedial Actions §192.465 (d)

- "Within Monitoring Period"
- "Prompt"

Consider:

- Population Density
- Environmental Concerns
- Rate of Corrosion
- Climatic Conditions
- Availability of Materials

Electrical Isolation ~ §192.467

- From Other Underground Structures
- From Casings
- Effective Insulation
- Protection From Arcing

Shorted Casings

- P/S reading **ESSENTIALLY** the Same as Casing reading

Other Tests May be Necessary to Demonstrate Isolation

Shorted Casings

- Remedial Measures
  - (1) Clear the Short
  - (2) Fill Annular Space with Dielectric

  - (3) If 1 or 2 Impractical, Monitor with Gas Detection Equipment at Intervals Specified in §192.705 & §192.721, or Smart Pig
  - (3) May Not be Applicable in HCA Areas

See PHMSA Guidelines for Integrity Assessment of Cased Pipe for Gas Transmission Pipelines in HCA's

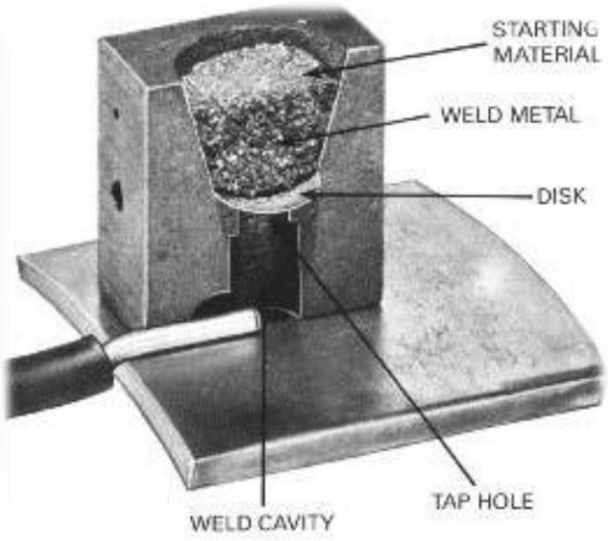
Test Stations/Test Leads

§192.469 & §192.471

- Must Have **SUFFICIENT** Test Stations or Other Contact Points to Determine the Adequacy of Protection.

Test Leads ~ §192.471

- Attach to Minimize Stresses on Pipe
- Coat the Bared Wire/Pipe Connection
- Maintain Mechanically Secure & Electrically Conductive



Internal Corrosion Control §192.475

- Corrosive Product Transported
  - Test to Determine Effect on Pipeline
  - Take Steps to Minimize Effect
- Whenever a Segment is Removed
  - Inspect Internal Surfaces
  - Replace if Required By Remedial Measures

Internal Corrosion Control §192.476

- Design and Construction
  - New or Replacement Line Pipe, Valves, Fittings, or other Components Must be Designed and Constructed to Reduce the Risk of Internal Corrosion
    - Configure to Reduce Risk of Liquid Collection
    - Have Effective Liquid Removal Features Wherever Liquids Might Collect

Internal Corrosion Control §192.476

- Design and Construction
  - Allow use of Monitoring Devices where Significant Internal Corrosion Potential Exists
- Exceptions (Does Not Apply To)
  - Offshore Pipelines
  - Pipelines or Components Installed or Replaced Before 05/23/2007

Internal Corrosion Control §192.476

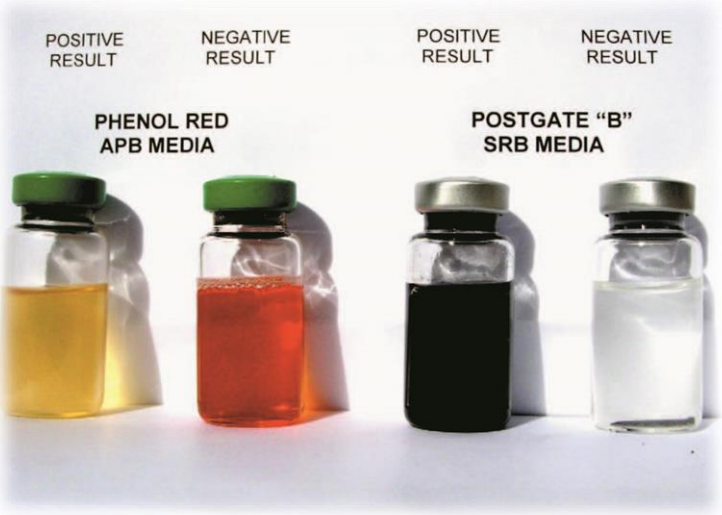
- Design and Construction
  - Change to an Existing Transmission Line
    - Must Evaluate the Impact of Change to Internal Corrosion Risk for Downstream Portions of Existing Transmission Line
    - Must Maintain Records to Demonstrate Compliance with this section
      - Written Procedures Supported by As-Built Drawings or other Construction Records

Internal Corrosion Control

Monitoring ~ §192.477

- When Corrosive Product is Transported
  - Must Be Monitored For Internal Corrosion
  - Twice Each Calendar Year Not to Exceed 7 ½ mos.

Coupons
Water Analysis
Microbiological Analysis
Inhibitors



Atmospheric Corrosion Control

§192.479

- Pipeline Exposed to Atmosphere
  - Cleaned
  - Coated (Suitable Material)

Unless Non-Corrosive Environment or Only "Light Surface Oxide"

Atmospheric Corrosion Control §192.479

- Non-Corrosive Environment and Light Surface Oxide <u>Not Applicable</u> to Offshore Splash Zones or Soil-to-Air Interfaces

Atmospheric Corrosion Control Monitoring §192.481

- Onshore

Every 3 Calendar Years at Intervals Not Exceeding 39 Months

Atmospheric Corrosion Control Monitoring §192.481

- **Offshore**

Once Each Calendar Year with Intervals not Exceeding 15 Months

Atmospheric Corrosion Control Monitoring §192.481

Inspections Must Include Pipe:

- At Soil-to-Air Interfaces
- Under Thermal Insulation
- Under Disbonded Coatings
- At Pipe Supports
- In Splash Zones
- At Deck Penetrations
- In Spans Over Water

Remedial Measures ~ General §192.483

- Pipe that Replaces Pipe because of External Corrosion must be:

Cleaned
Coated
Cathodically
Protected

Remedial Measures

Transmission §192.485

- General Corrosion
  - Replace
  - Lower
    MAOP / MOP
  - Repair

- Localized
  Corrosion
  - Replace
  - Repair
  - Reduce Operating Pressure

Remedial Measures

Transmission §192.485

- General Corrosion
  - Closely Grouped Pitting Affecting Overall Strength of the Pipe
- Localized Corrosion Pitting

Guides: GPTC & RSTRENG

Remedial Measures

Gas Distribution §192.487

(Except for Cast & Ductile Iron)

- General Corrosion or Less Than 30% Remaining Wall Thickness
  - Replace
  - Repair
- Localized Corrosion
  - Repair
  - Replace

Remedial Measures

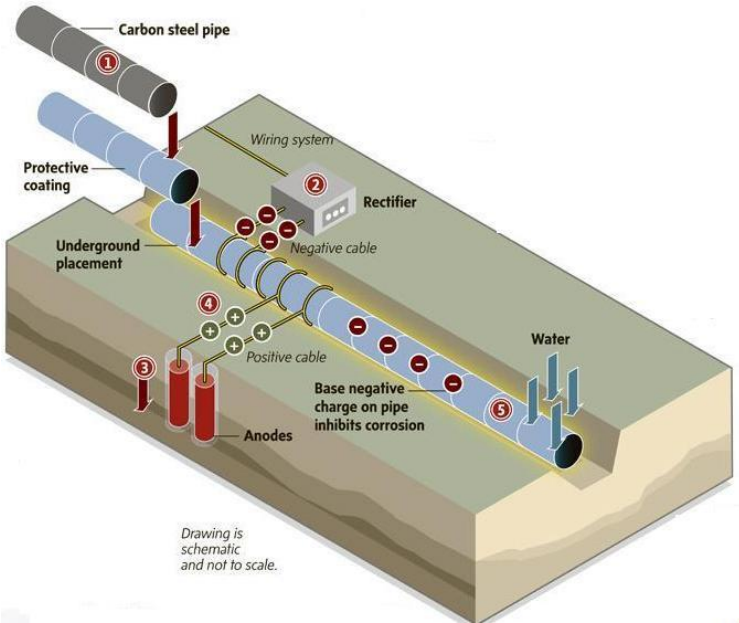
Cast & Ductile Iron §192.489

- General Graphitization
  - If Fracture May Result – Replace
- Localized -
  - If Leakage Might Result
    - Repair
    - Replace
    - Seal Internally

Corrosion Control Records

§192.491 (a)

- Records or Maps
  - Location of Protected Piping
  - Cathodic Protection Facilities
  - Galvanic Anodes
  - Bonds to Other Structures



Corrosion Control Records

§192.491 (b)

- Records or Maps Required by §192.491(a)
  - Retain for as Long as the Pipeline Remains in Service

Corrosion Control Records §192.491 (c)

- Tests, Surveys, or Inspections
  - Required by Subpart I
  - Retain for at least 5 Years
  - Specified Exceptions
  - Check with Attorneys

Corrosion Control Records

§192.491 (c)

- Exceptions/Retain for Service Life
  - Annual P/S Surveys ~ §192.465(a)
  - 3-Year Reevaluations ~ §192.465(e)
  - Inspections for Internal Corrosion ~ §192.475(b)

Corrosion Control