



South Dakota / North Dakota Pipeline Safety Seminar

**April
2009**



*Pipeline and Hazardous Materials
Safety Administration*



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YOUR INSTRUCTOR



WELCOME

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*. . .First
A
Little
History. . .*



Corrosion - History



Gold, occurring naturally is prized
Copper & bronze discovered, can be easily smelted
Spartans discover “steel”
Romans use iron extensively - swords, ship bottoms, tools

B.C – Before Corrosion

A.D.

1824

Humphrey Davies has iron or zinc anodes attached to copper bottoms of war ships - He gets Knighted, ships don't sink as often!

1924

Evans publishes paper “Newer Electrochemical View on Corrosion of Metals”



...now that we know

a little

about its origins



Lets talk

about

what

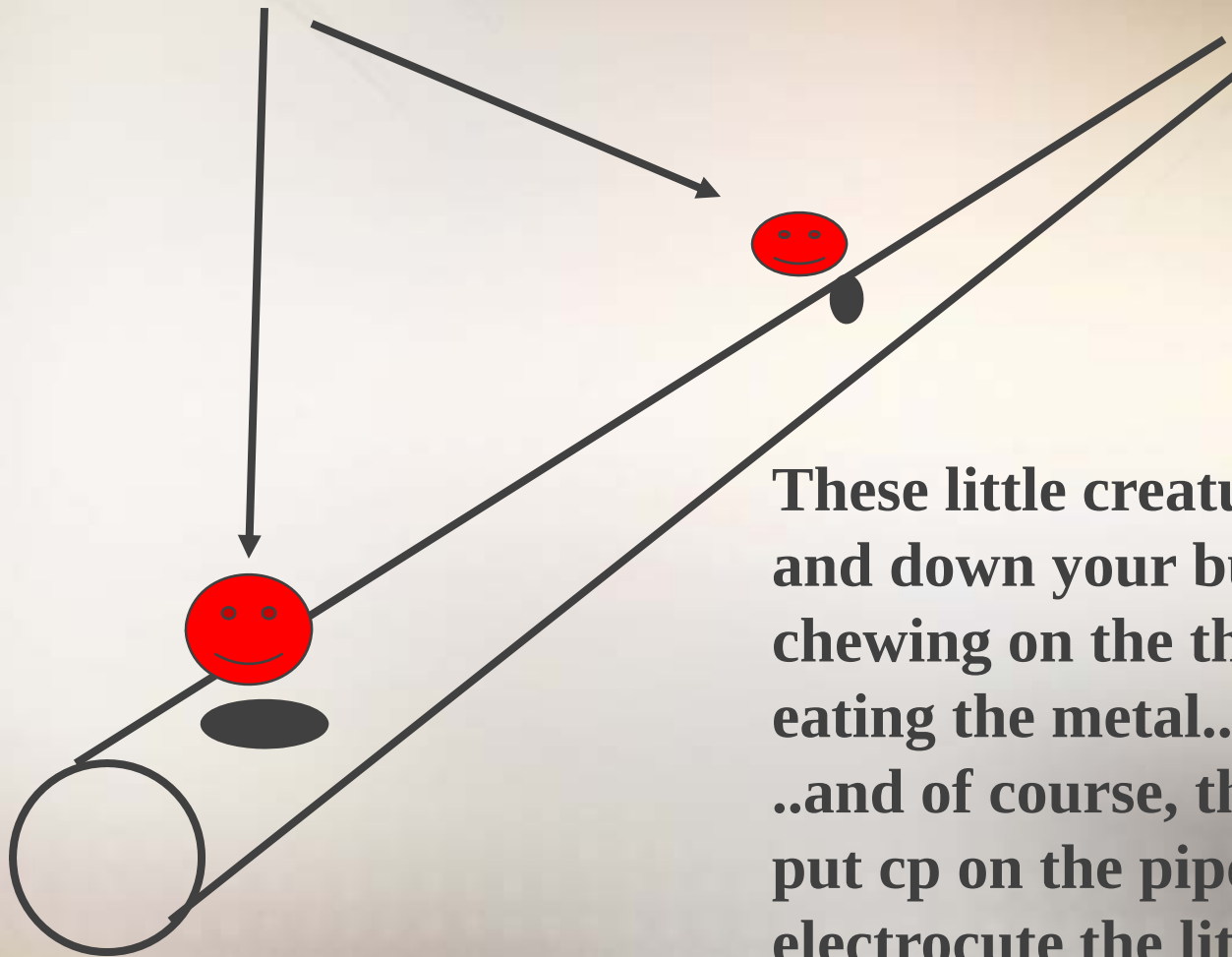
it

is



Corrosion - What it ain't

An actual, unretouched photo of the famous
“*OHMITES*”



These little creatures run up
and down your buried pipes
chewing on the them, merrily
eating the metal..
..and of course, the reason we
put cp on the pipes is to
electrocute the little
buggers....



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.**



Corrosion - What it is

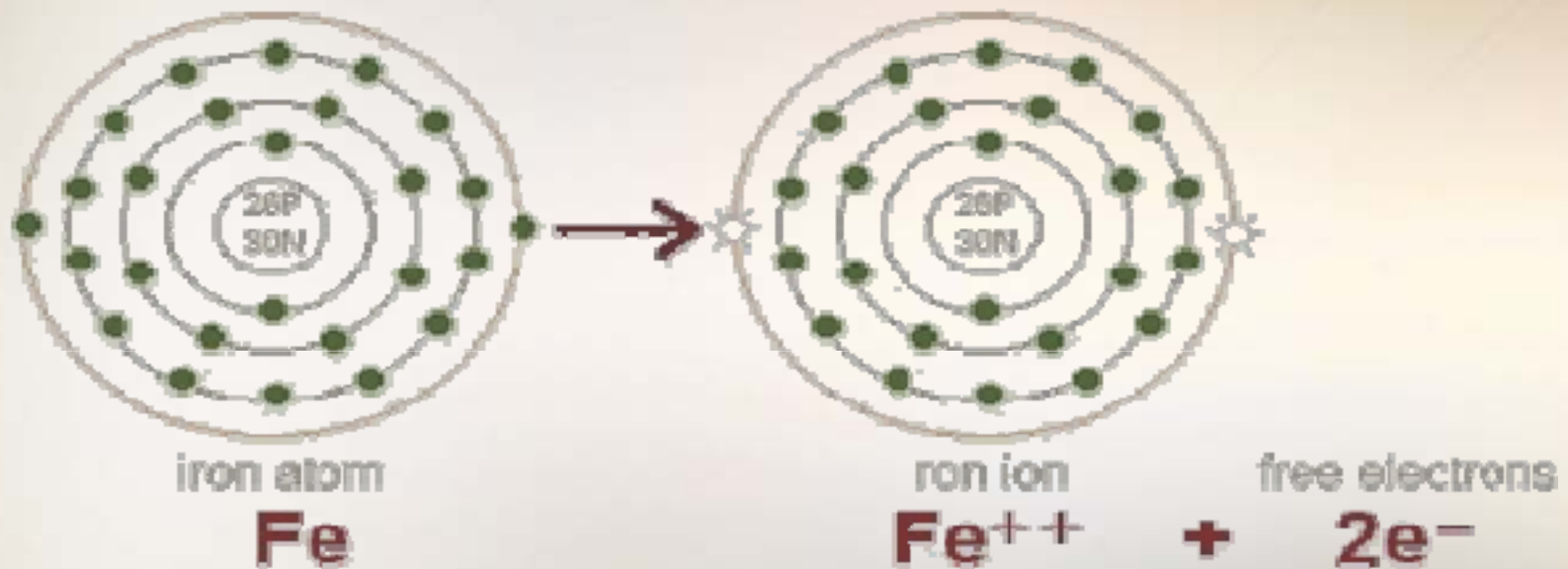
The electro-chemical process where alloys revert back to their naturally occurring form(s).

(Alloy: a substance composed of 2 metals or a metal & a non-metal)

For Example: Steel reverts back to iron oxide which is exactly the way it is found in the earth.

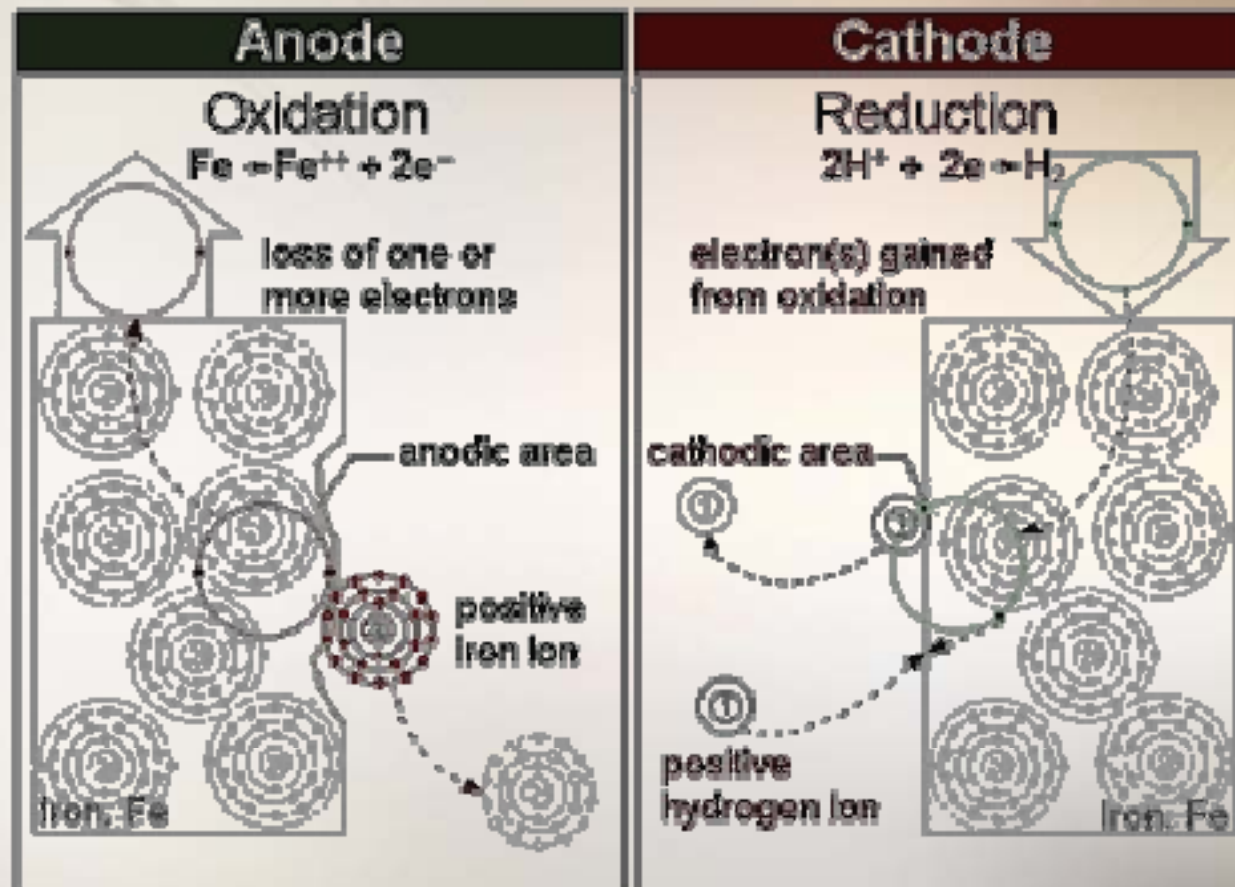


Definition of Corrosion





Definition of Corrosion





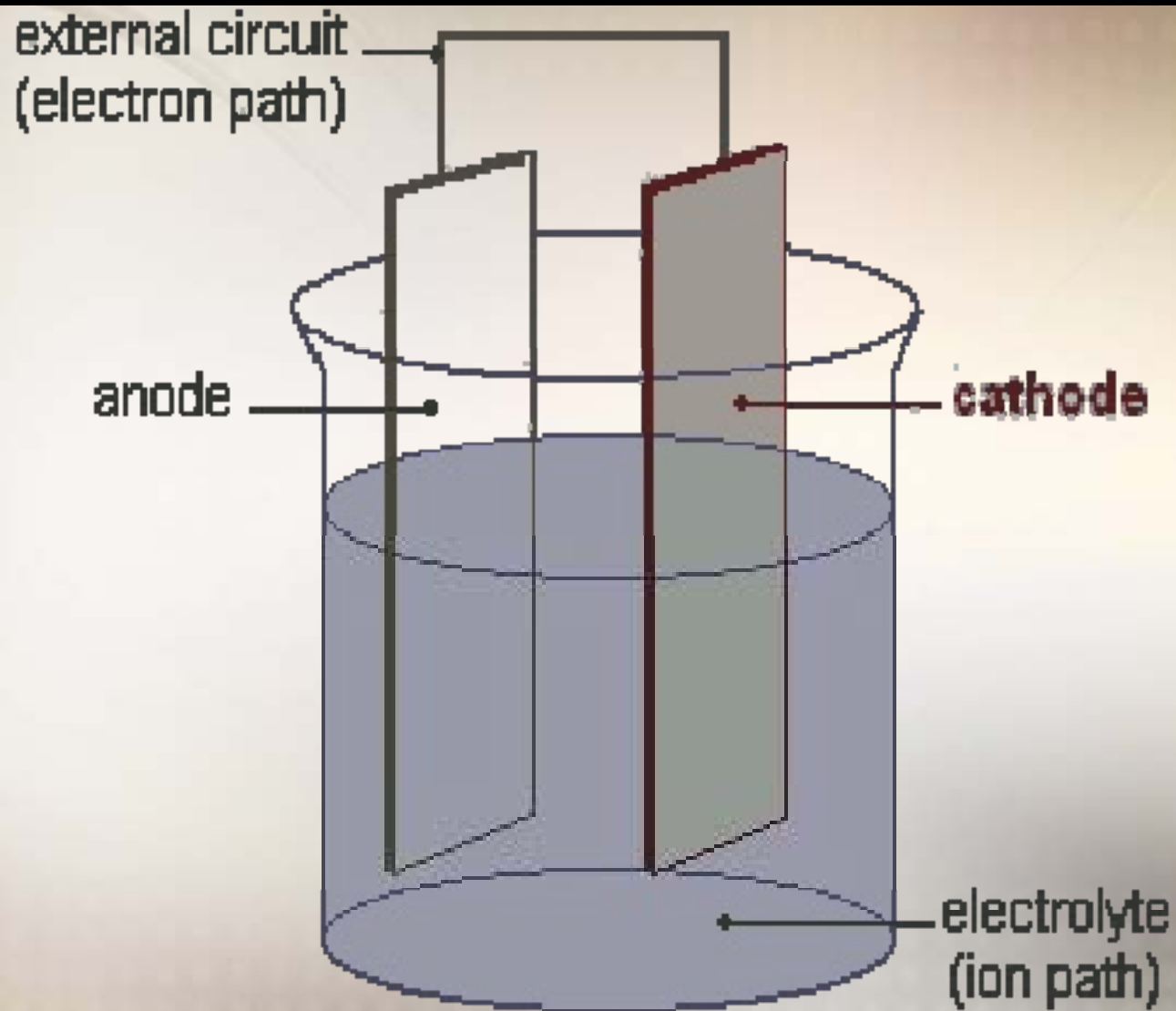
What then is cathodic protection?

Just a very thin layer of Hydrogen (H_2) gas deposited on the surface of the material being protected.





Basic Corrosion Cell



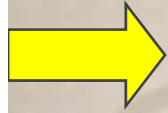


Corrosion - What it is

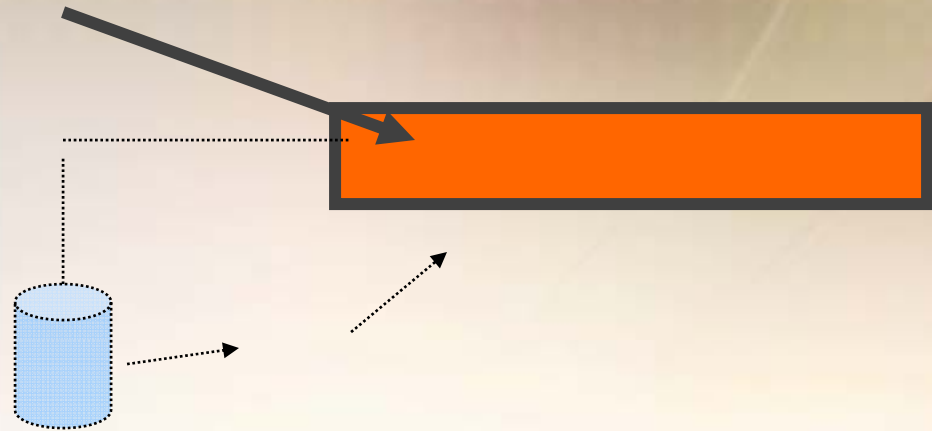
There are four (4) parts that make up a corrosion cell. They are:

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

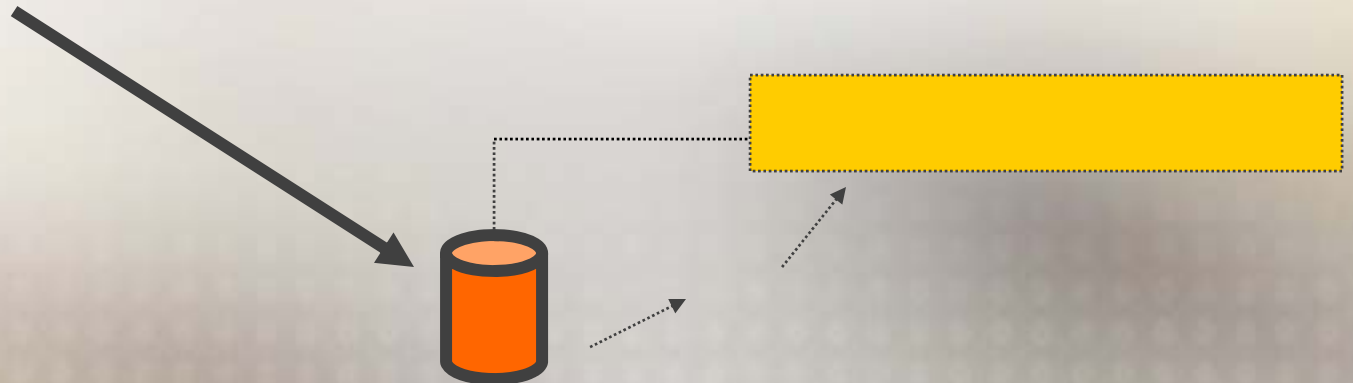
I like to call it “MACE”



Cathode - the area or material **being protected** (area receiving electrons)

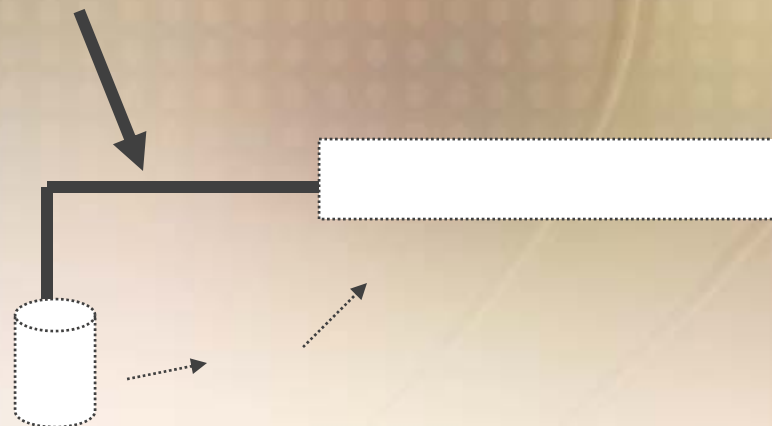


Anode - the area or material **sacrificing itself** to protect another area (Area giving up electrons)





Metallic Return Path - any piece of metal that connects the anode and cathode

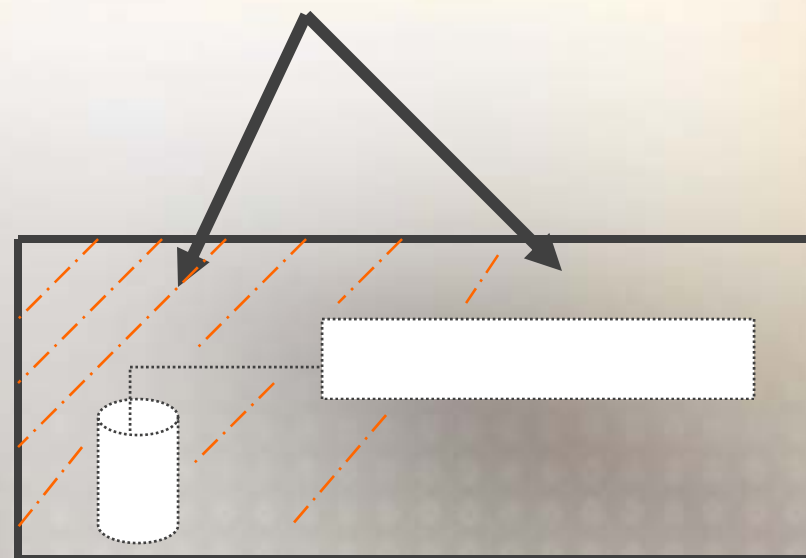


Electrolyte - a fluid that conducts electricity (soil)

Really good fluids - salt water

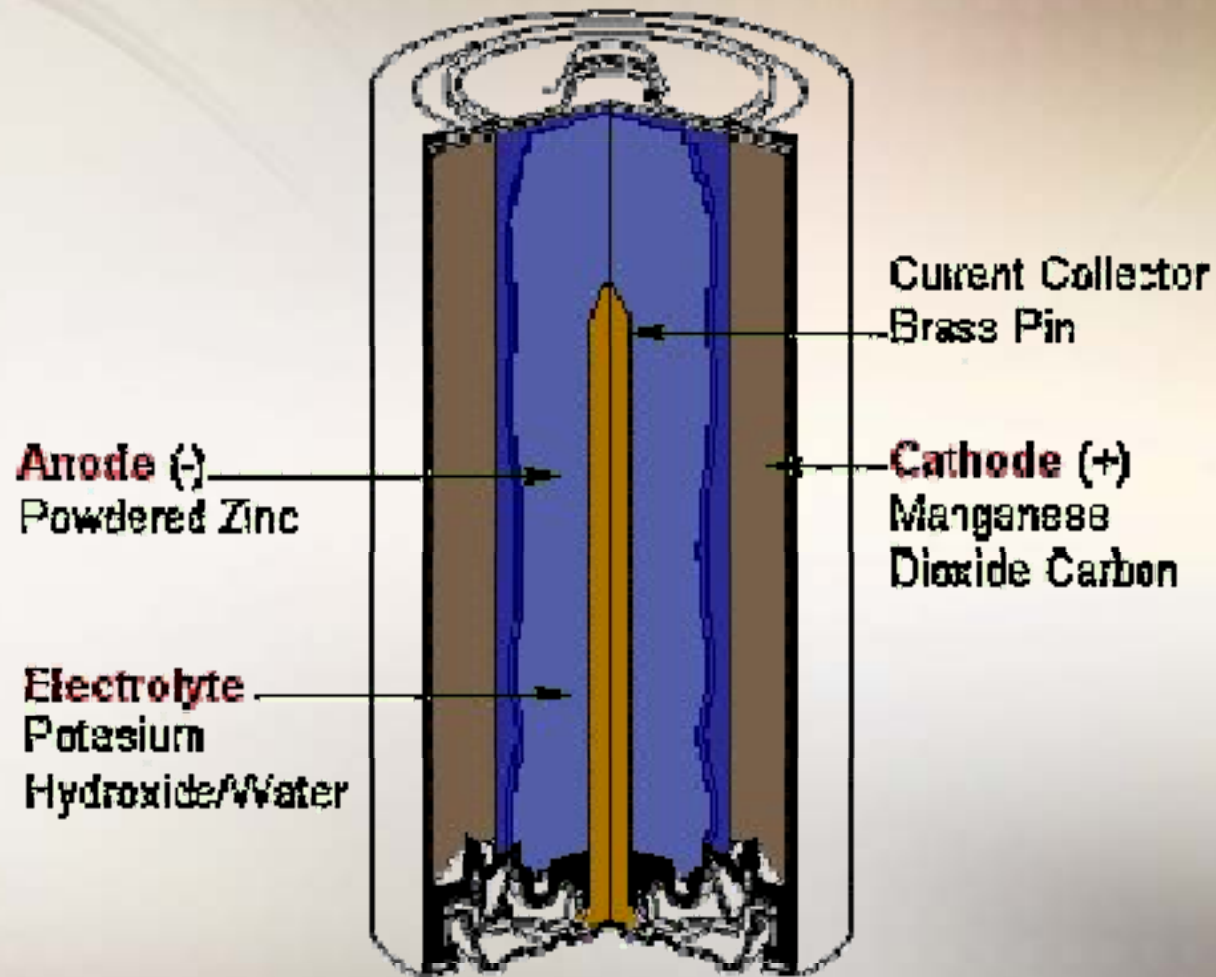
Body fluids

Fresh Water



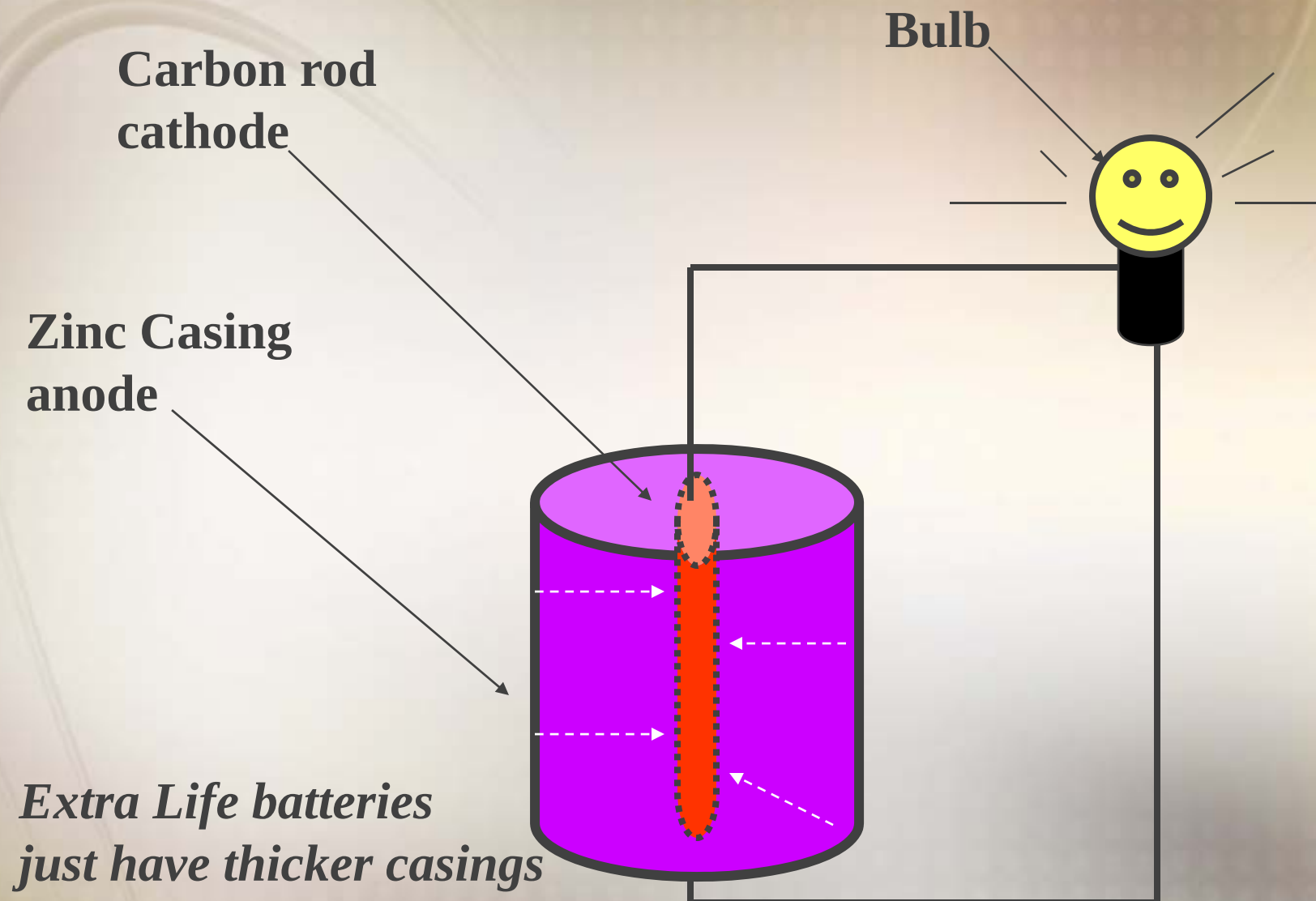


Basic Corrosion Cell





Corrosion - an example





Corrosion

...a common myth...

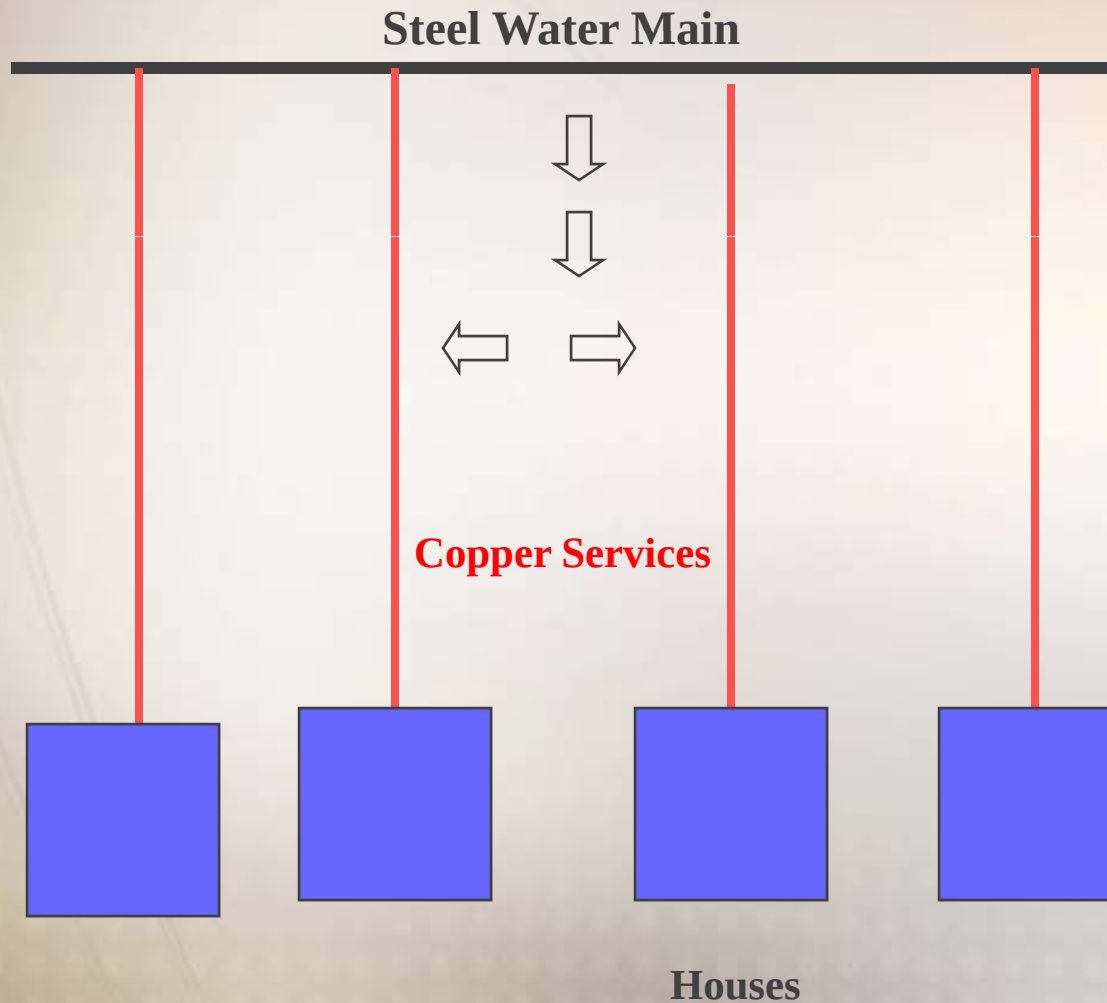
“Copper does not corrode...”

WRONG!!!!!!!!!!!!!!!!!!!!!!



What breaks first???

Hmmmm never hear much about service breaks, do ya!!



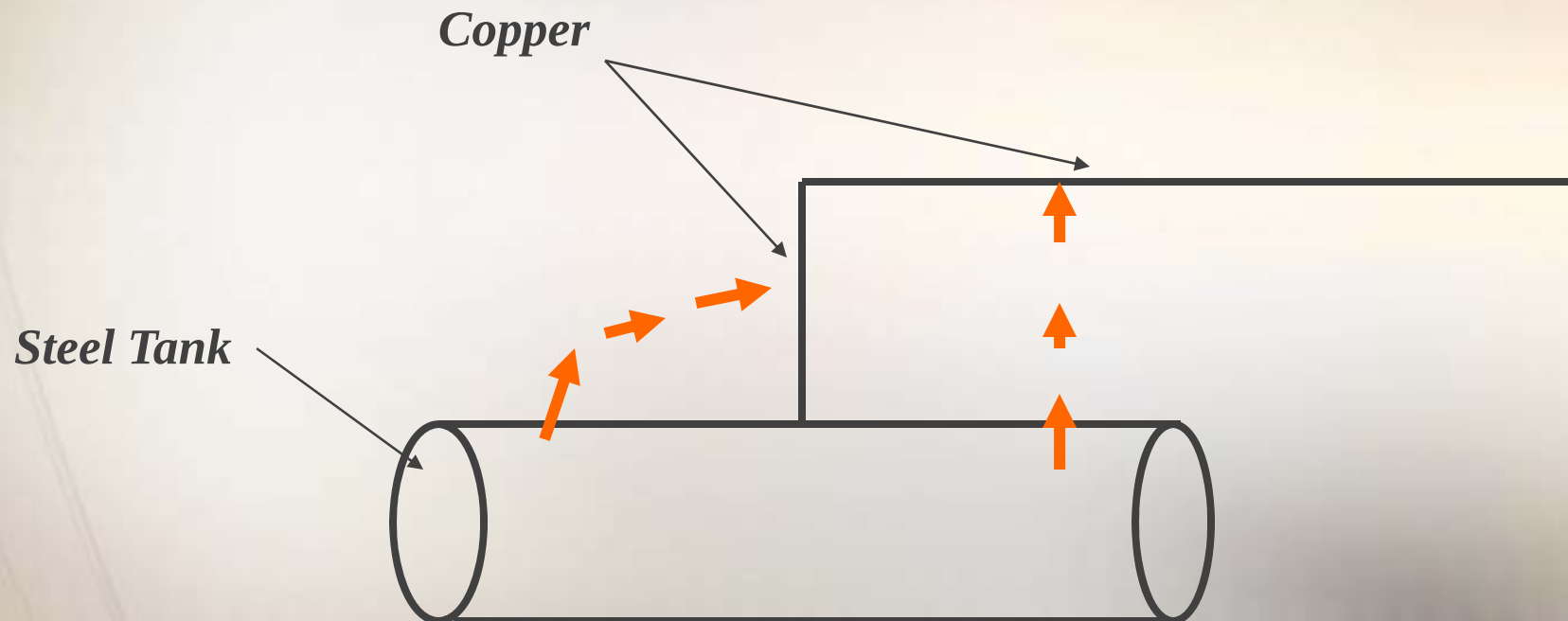
Galvanic Series

↓
magnesium
zinc
aluminum
iron
steel
copper
etc.

Why - because the steel mains corrode to protect the copper water service lines



The same applies to your tanks or pipeline **if** you have copper lines attached



Now you know why you should only use covered copper wire for your test leads



How can we stop this?

We have 3 choices:

- 1. Use another metal rather than copper**

Steel for example (yes - but then you still have to protect the steel pipe)

- 2. Use plastic**

- 3. Isolate (or insulate) the piping from the tank**

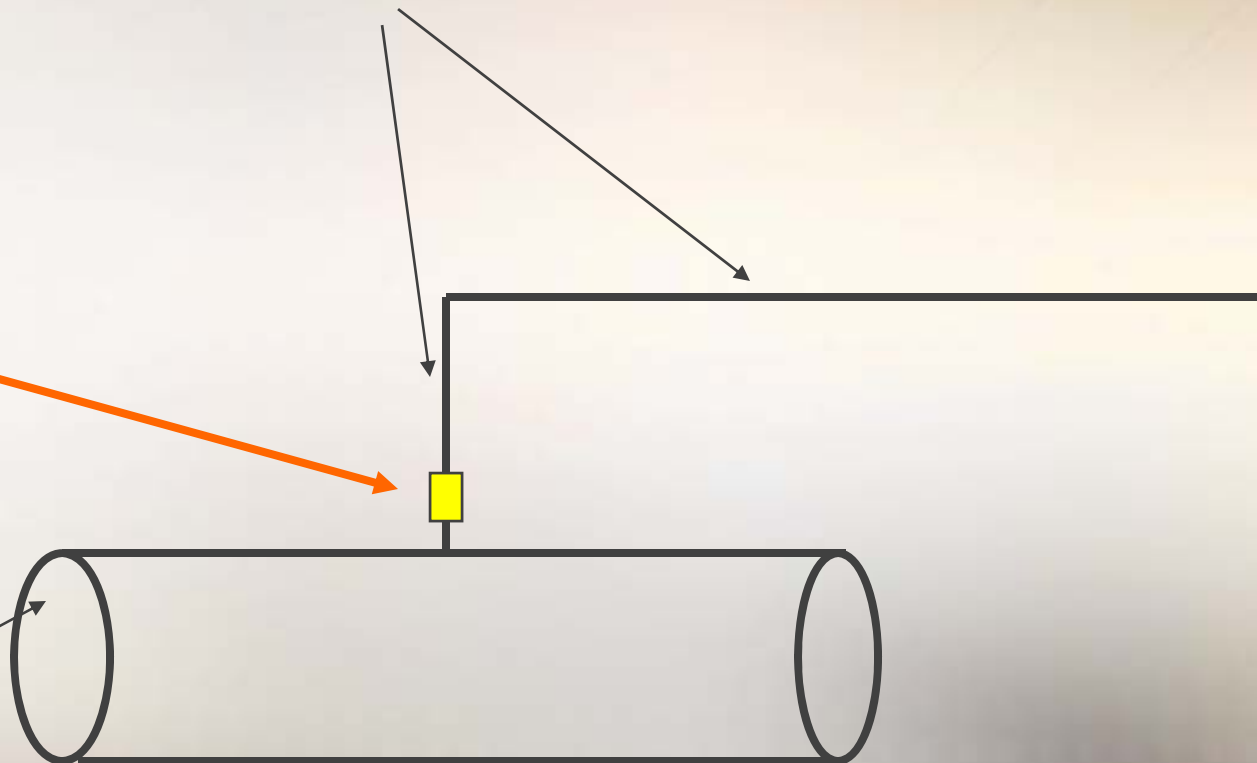


If we insert a insulator in the line, we separate the tank or pipe from the line-electrically and stop the process

Copper, steel, or any other metal

insulator

*Steel Tank
or pipe*





Corrosion - What it is

**Interrupt, stop, delete, cancel - whatever you want to call it,
- any one part of the four and you can stop corrosion**

(...how 'bout slowing it down, hmmm, since its an electro-chemical reaction, what effects these kinds of processes)

- well certainly temperature

If you want to keep batteries or film, indefinitely, throw 'em in the freezer, they will normally last for years, just remember to thaw 'em out before you try using them!

...ever wonder why your car battery usually fails during the winter



The same is true with buried pipelines, tanks, etc.

**→ The same is also true with sunken ships...\
The Titanic for example...**

**At its depth in the ocean, the water temperature is very
close to freezing**

And there is little dissolved oxygen present

**→ Another example is the “junk” left on the moon during the
Apollo missions...There is no atmosphere and half of the
time, the moon is in darkness(-200 degrees F) so
consequently there is little or no corrosion to speak of**

**Do you think it's a good idea to take your annual
p/s readings during January?**



Corrosion Control

Part 192, Subpart I



External



Internal



Atmospheric



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



Galvanic Series of Metals

Galvanic Series for Metals In Neutral Soils or Water

anodic ↑ ↓ cathodic	<u>Metal</u>	<u>Potential^a</u>
	Magnesium, Mg	-1.75V
	Zinc, Zn	-1.10V
	Aluminum, Al	-0.80V
	Iron, Fe	-0.44V
	Copper, Cu	0

^a Potentials measured in relation to copper-copper sulfate reference electrode.



Our Modern Corrosion Theory is based on:



Galvanic Series

magnesium

zinc

galvanized steel

aluminum alloys

low carbon steels

wrought iron

cast iron

stainless steels

copper alloys

silver

Titanium

graphite

gold

platinum

Anodes

Cathodes

Anodos

- Greek for “way up”

As we go down the list, the metals get more cathodic

Kathodos

- Greek for way down

(most of this derived by good old Sir Humphrey Davies)

Occur naturally, only subject to atmospheric corrosion-tarnishing

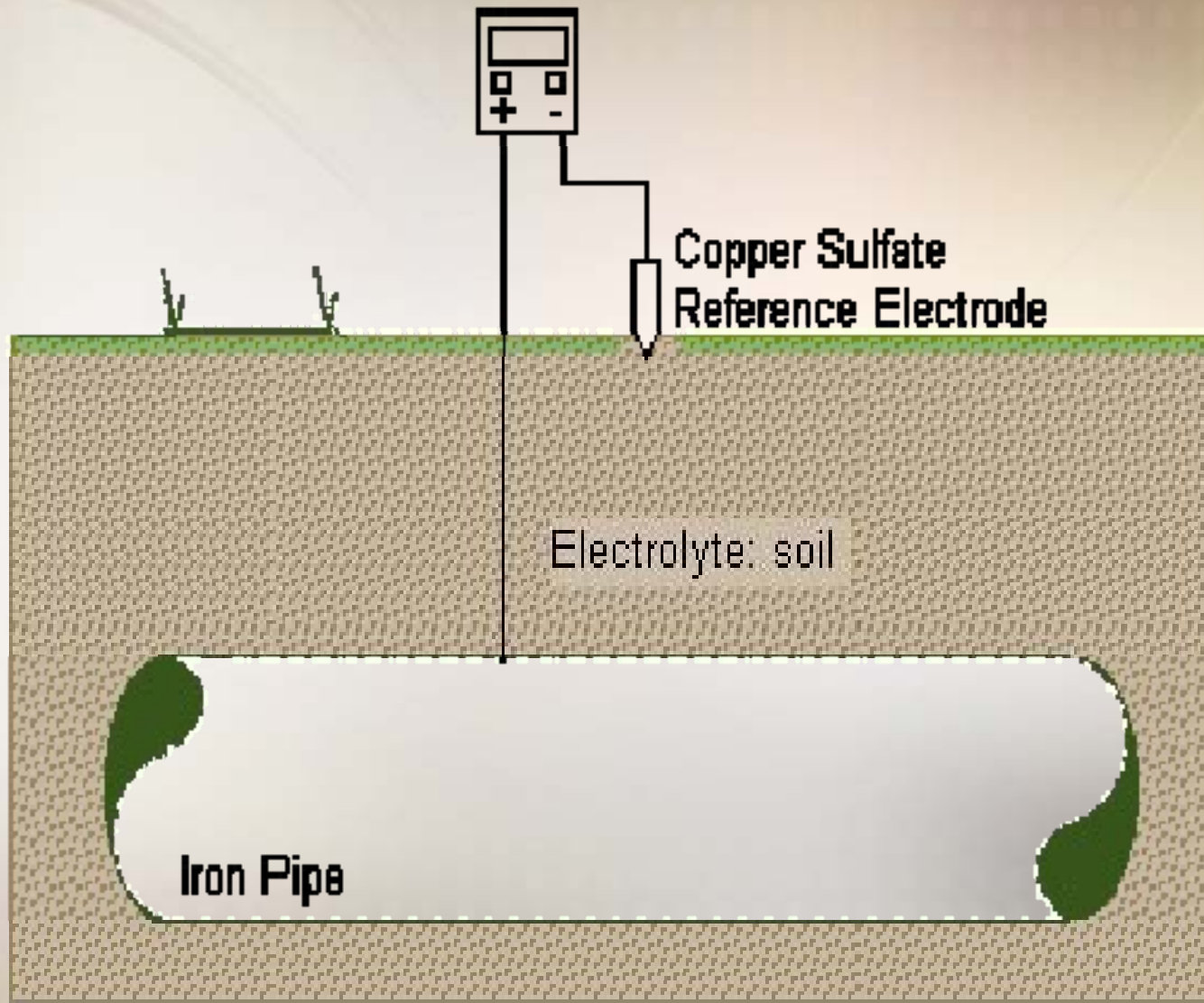


▼ Galvanic Series of Metals



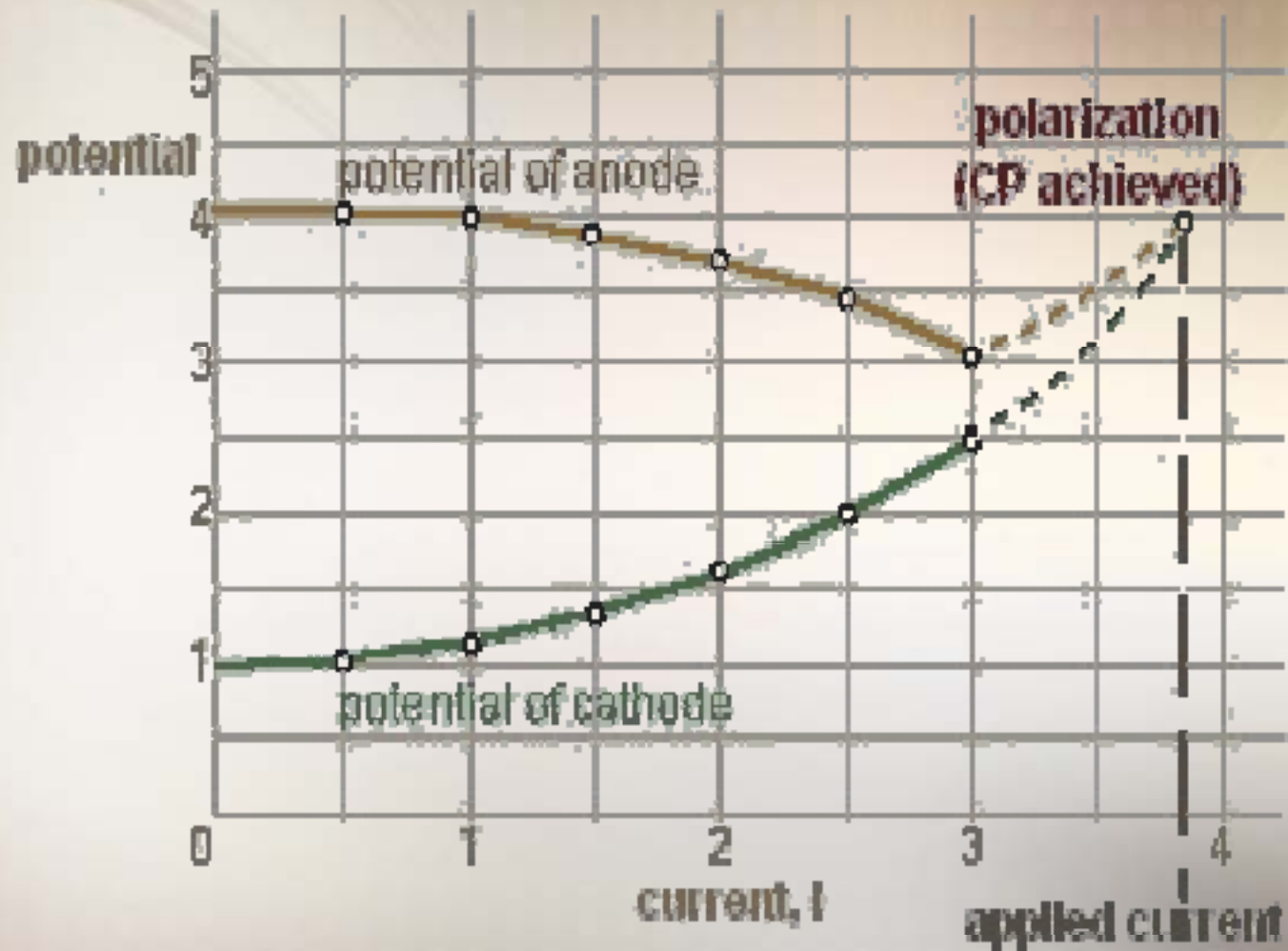


Pipe Corrosion



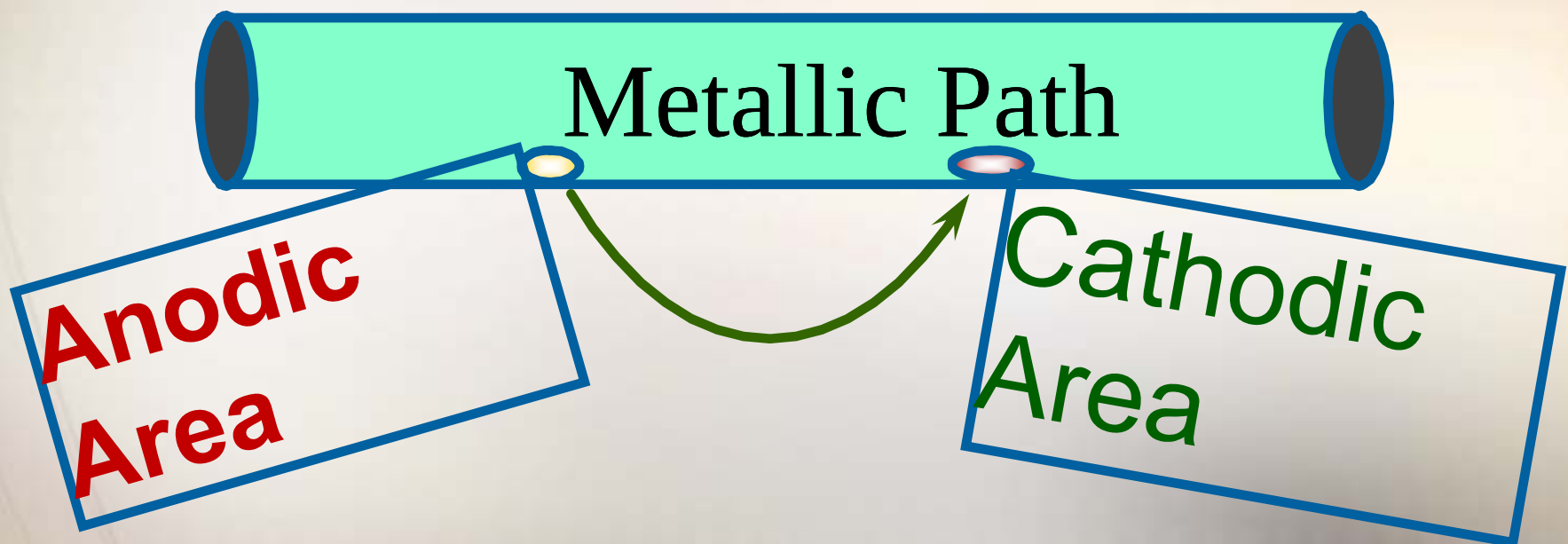


Pipe Corrosion





Pipe Corrosion





Corrosion on Pipelines

- ✉ Dissimilar Metals
steel/copper
- ✉ Dissimilar Soils
pH In/Out Concrete
- ✉ Differential
Aeration
bottom n compacted s
- ✉ Mill Scale
Corrosion





▼ Soil Resistivity vs. Corrosivity

Ohm - cm	Description
Below 500	very
500 - 1000	corrosive
1000 - 2000	moderately corrosive
2000 - 10,000	mildly
> 10,000	<< corrosive



Soil pH

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





Cathodic Protection

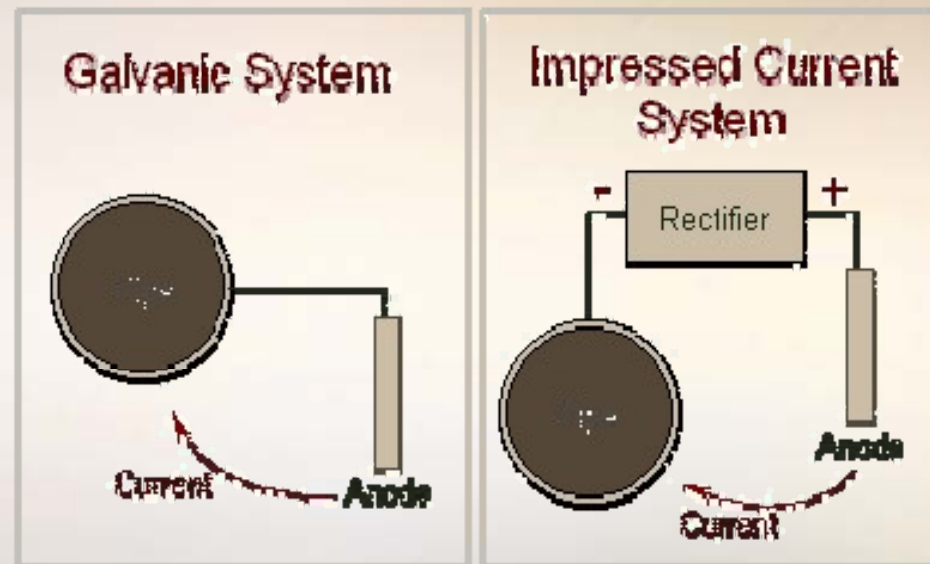
 **The Decrease of Corrosion of a Metal by Forcing Current to Flow to the Metal from a Solution (Electrolyte).**



Cathodic Protection

✉ Galvanic
Sacrificial Anodes

✉ Impressed
Current Systems



* Properly Designed & Installed



Cathodic Protection

Sacrificial Anode System





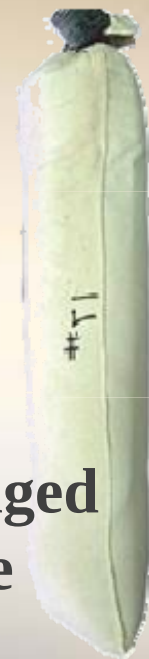
Cathodic Protection

Galvanic Series for Metals In Neutral Soils or Water

anodic ↑ ↓ cathodic	<u>Metal</u>	<u>Potential*</u>
	Magnesium, Mg	-1.75V
	Zinc, Zn	-1.10V
	Aluminum, Al	-0.80V
	Iron, Fe	-0.44V
	Copper, Cu	0

reference

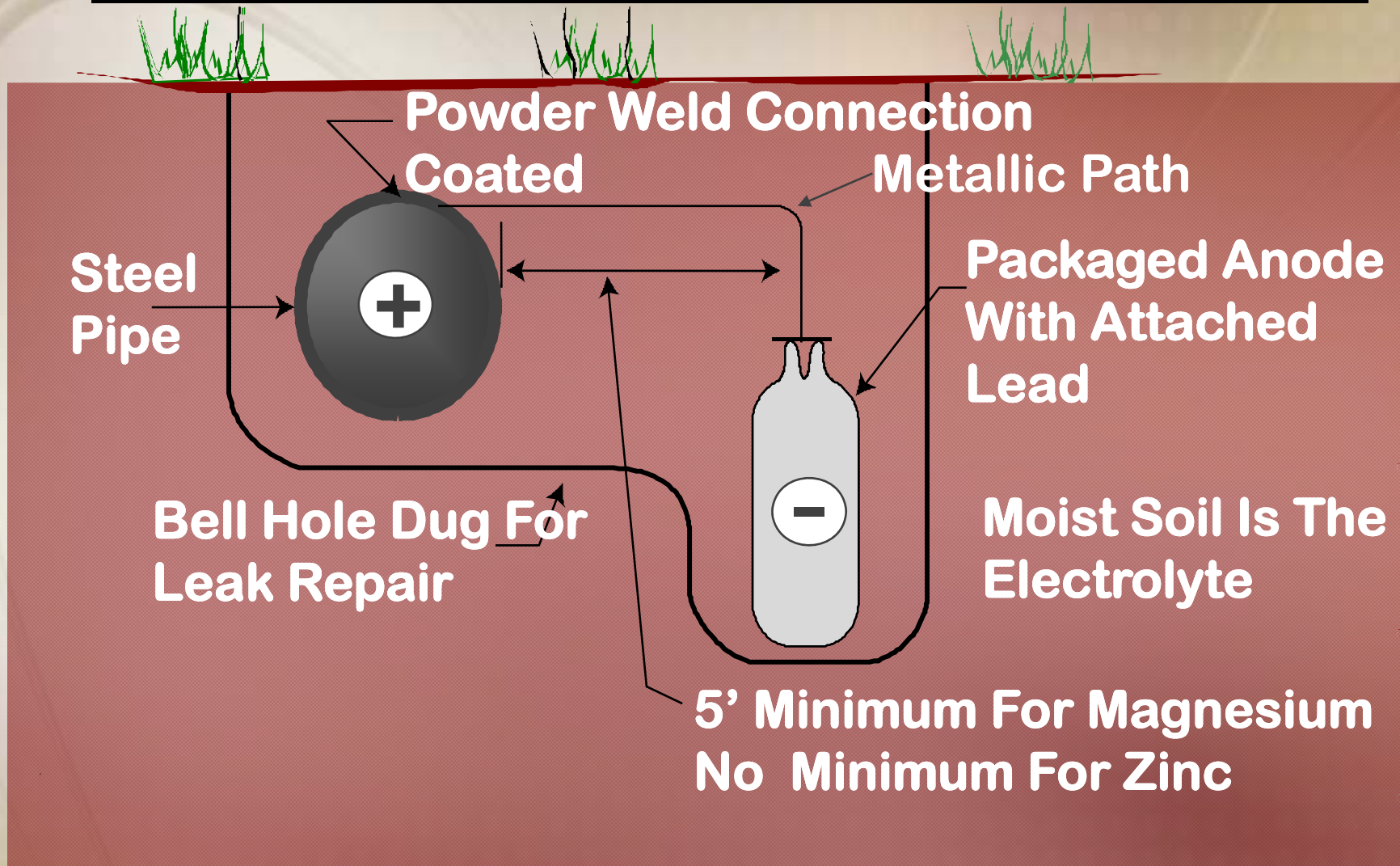
Packaged
Anode



* Potentials measured in relation to copper-copper sulfate reference electrode.

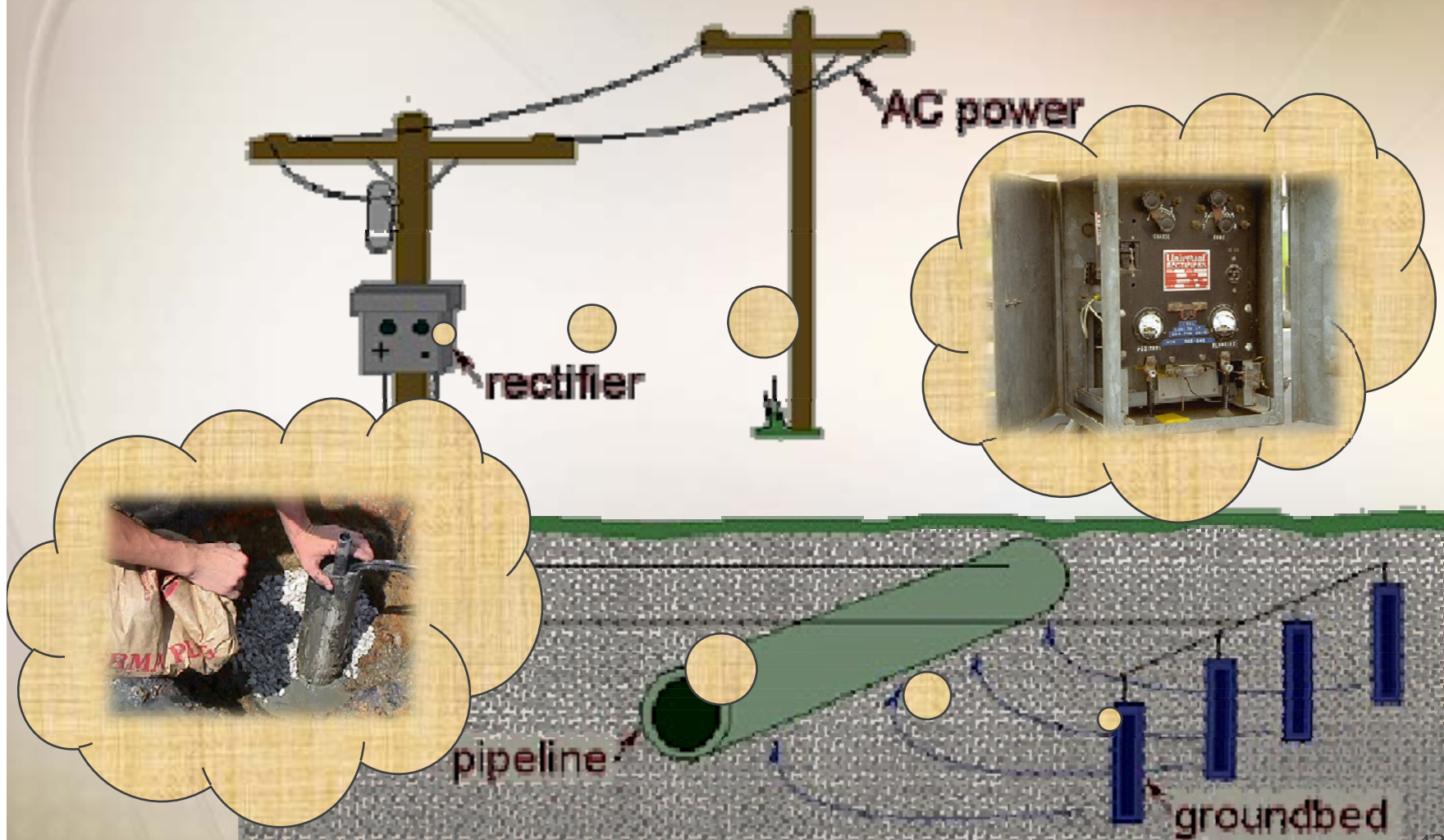


Galvanic Anode System





Impressed Current System





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 < 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

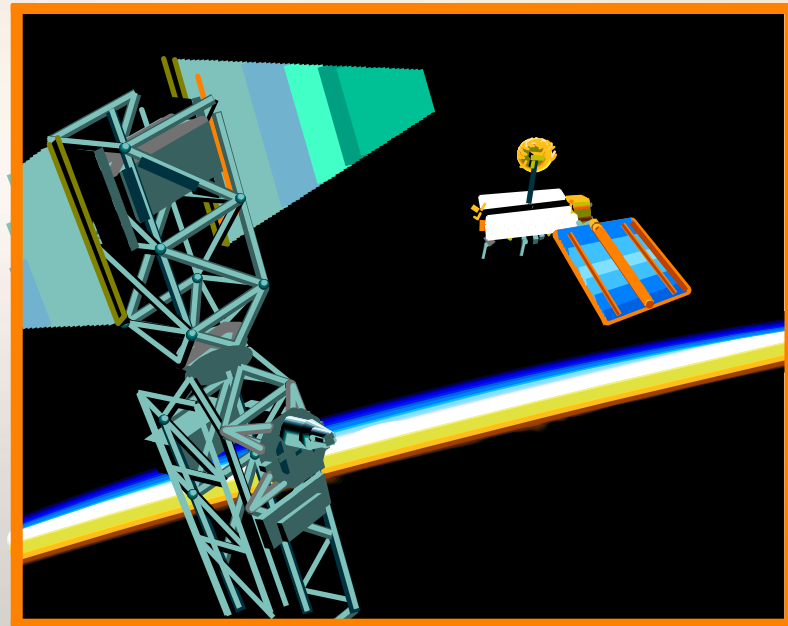
- ✉ **Bare TEMPORARY lines installed after 7/31/71 (§192.455(c)(2)&(d)).**
- ✉ **Bare or ineffectively coated lines installed prior to 7/31/71 with no evidence of active corrosion ~ (§192.457(b)).**



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.**





Corrosion

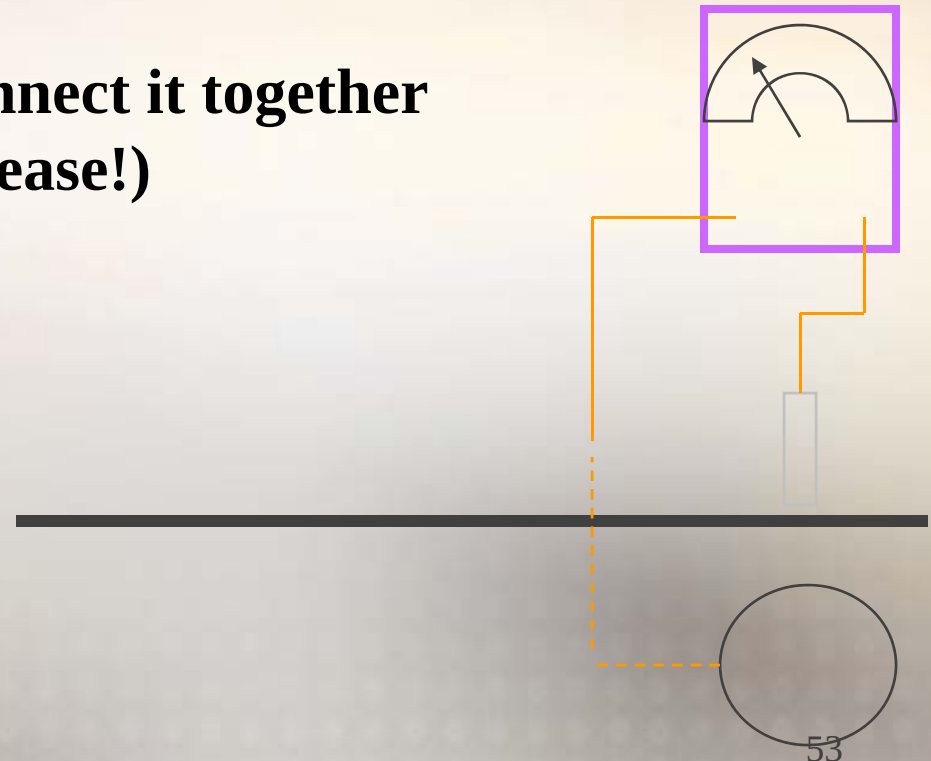
Now lets talk about...

Some Tools of the Trade

Voltmeter - can be either analog or digital

Half Cell

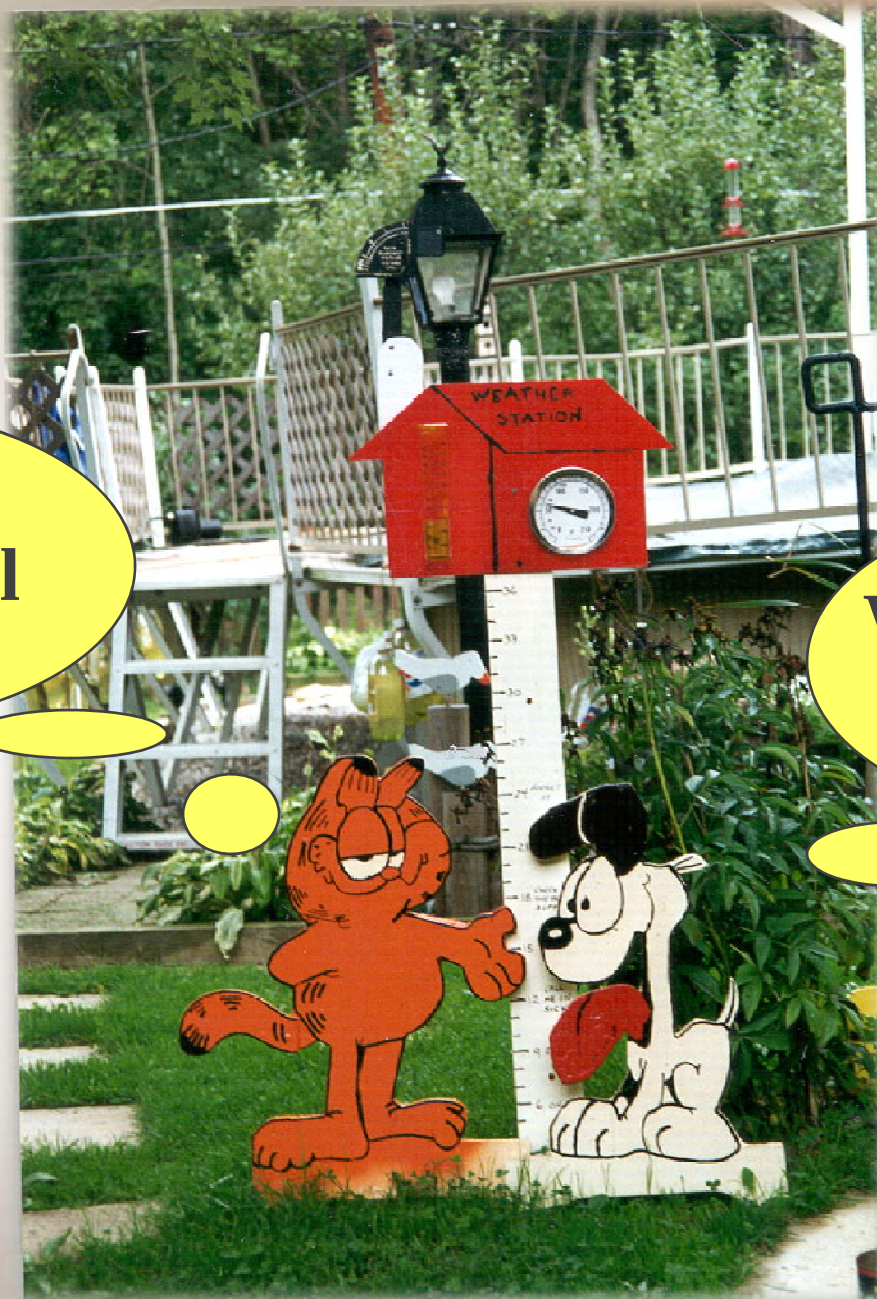
**Some copper wire to connect it together
(covered or insulated-please!)**





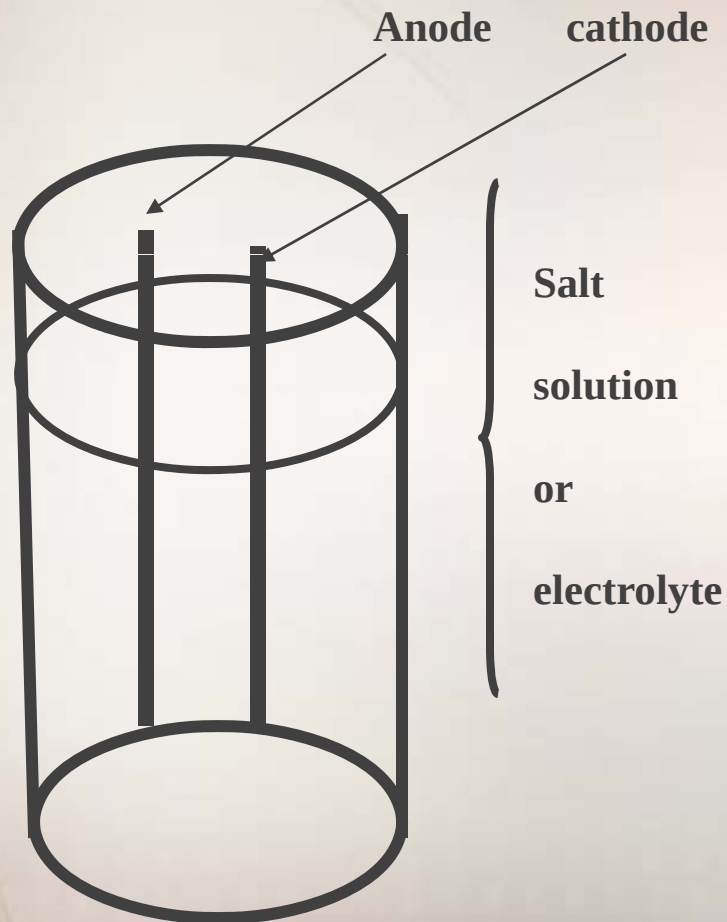
The half cell

**What the heck
is that??!**



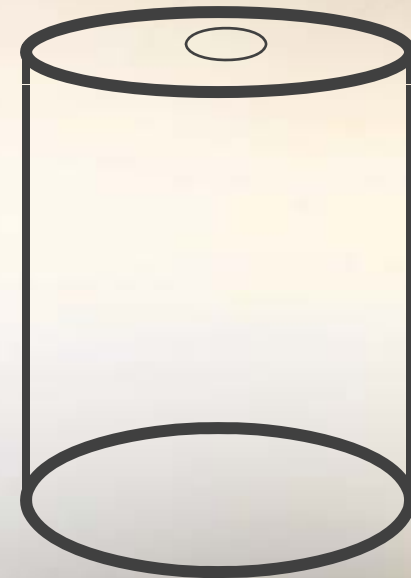


The Cell - a definition used by chemists for an electro-chemical SYSTEM consisting of: an anode; a cathode; and an electrolyte



Some commercially available “cells”

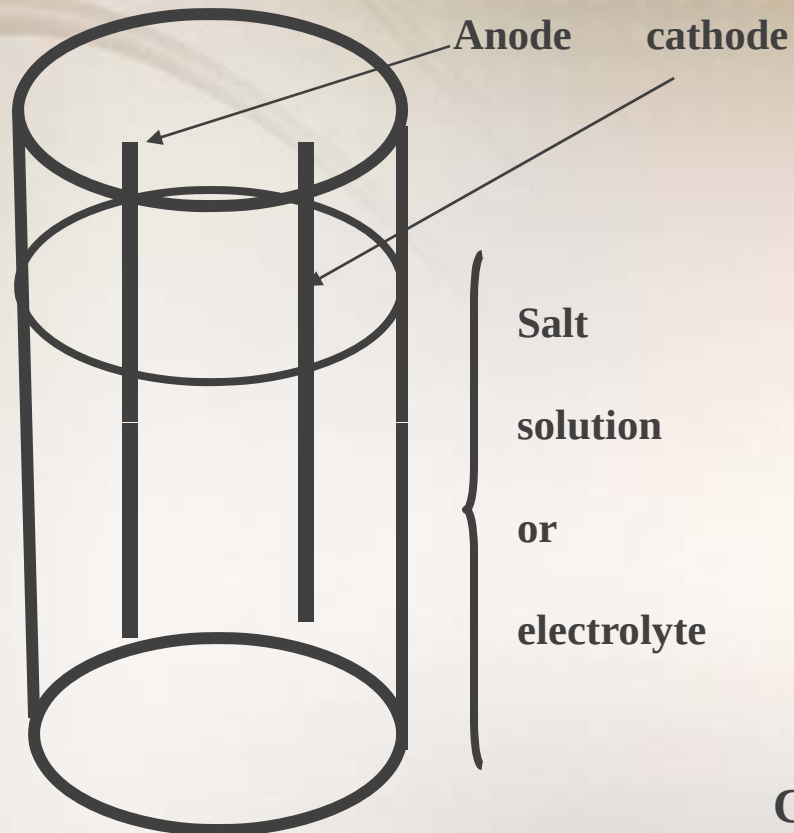
..a flashlight cell..



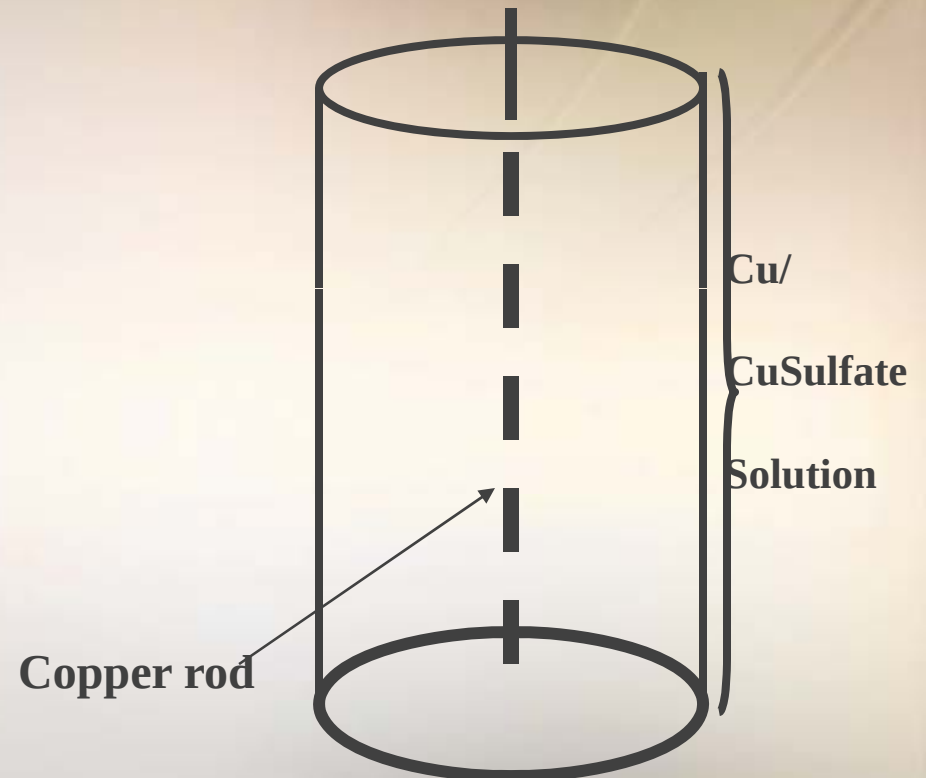
*Other examples are:
car batteries
galvanized pipe*



The Cell



..a Half Cell...

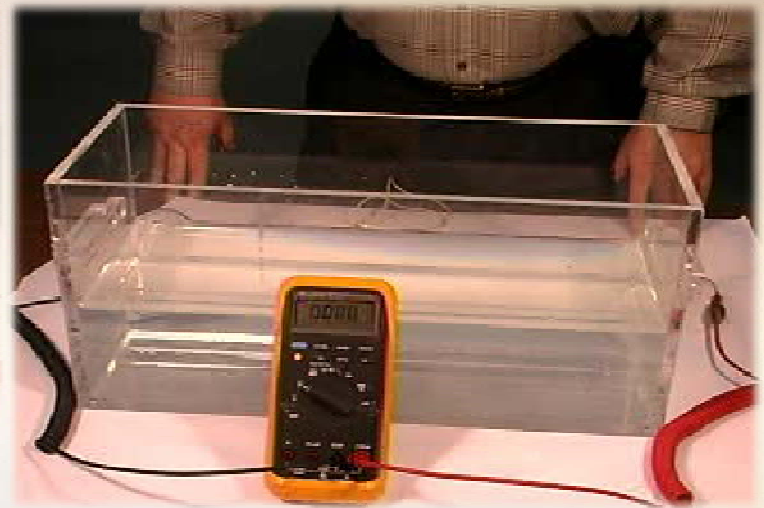
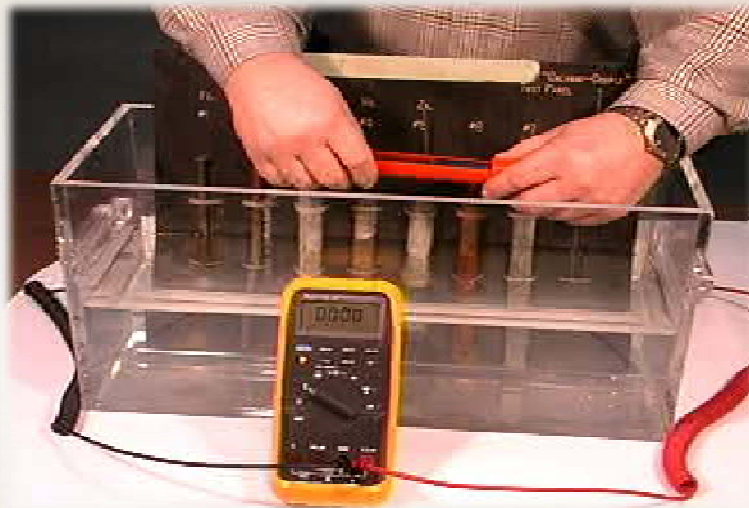


Things to remember:

- 1. It's a electrical connection to the soil (a way of getting a consistent reading)*
- 2. Copper/ Copper-Sulfate is E X T R E M E L Y poisonous !!!!!*



Cu/CuSO₄ Reference Electrode





▼ Cathodic Protection Criteria

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





C. P. CRITERIA (850 mv)

- ✉ **850 mv.**
- ✉ **Measured with Current Applied**
- ✉ **Consider IR Drop**
- ✉ **Cu/CuSO₄ Reference Electrode**



- ✉ **800 mv. Ag/Ag Cl for sea water**



Components of IR Drop

Resistances

Measuring Lead (+)
Contact Lead (+)/Ref. Cell
Reference Cell
Contact Ref. Cell/Electrolyte
Electrolyte
Polarization
Structure
Contact Test Lead/Structure
Test Lead
Contact Test/Measuring Lead
Measuring Lead (-)
Internal Meter

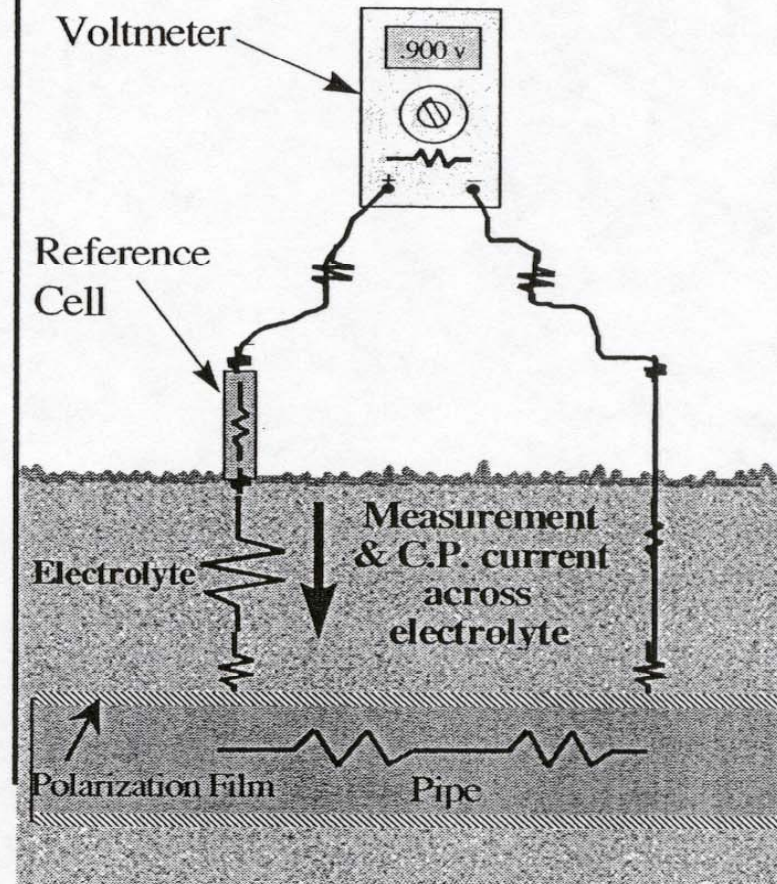


Figure 3.9 Voltage Drops in a Measuring Circuit



▼ IR Drop ~ Major Contributors

Major Contributors to IR Drop

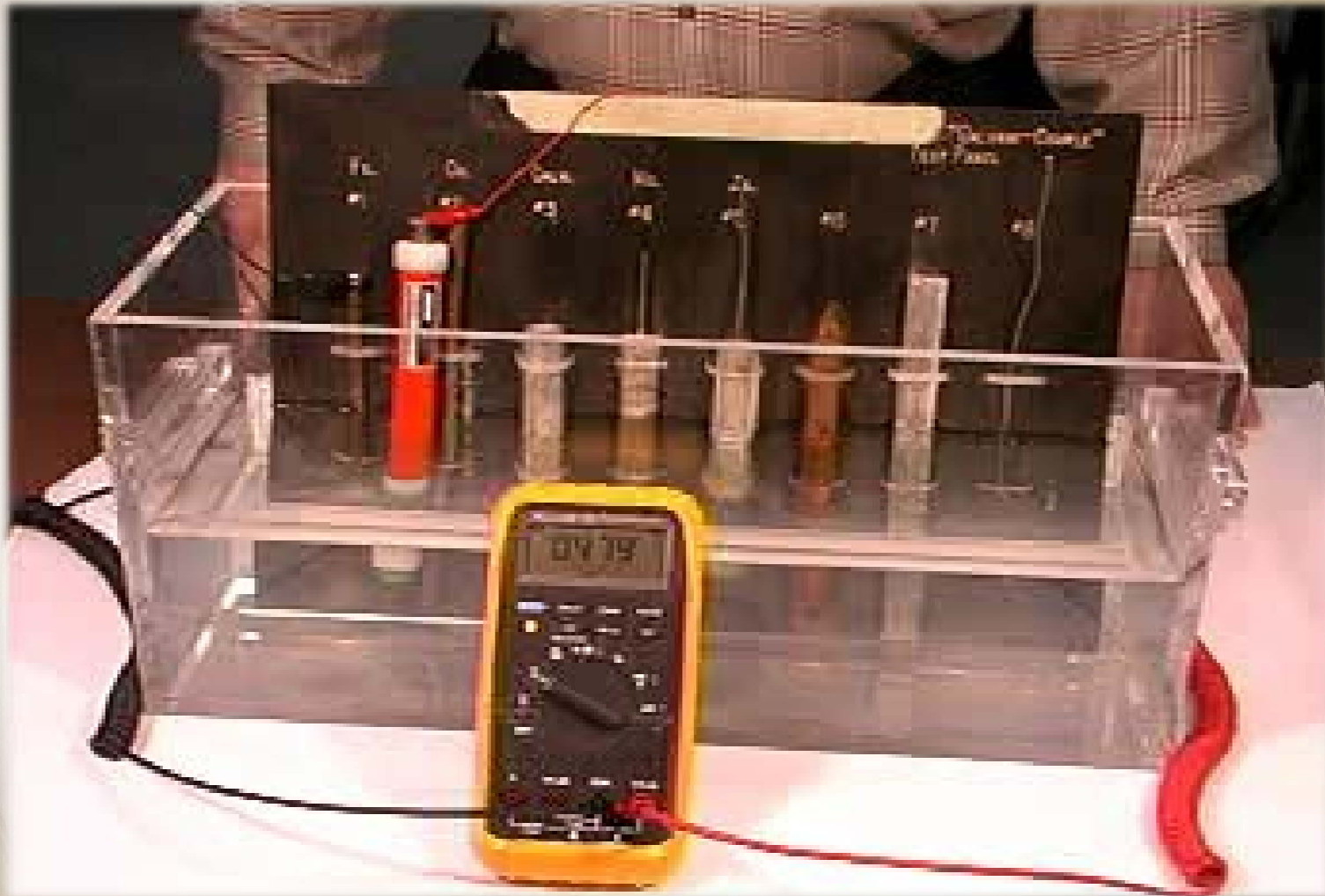
- Polarization at the pipe/coating interface
- Electrolyte (soil)
- Contact between the reference cell & soil

Minor Contributors to IR Drop

- Test lead wires & connections
- Internal resistance of voltmeter
- Internal resistance of reference cell
- Wall of pipeline

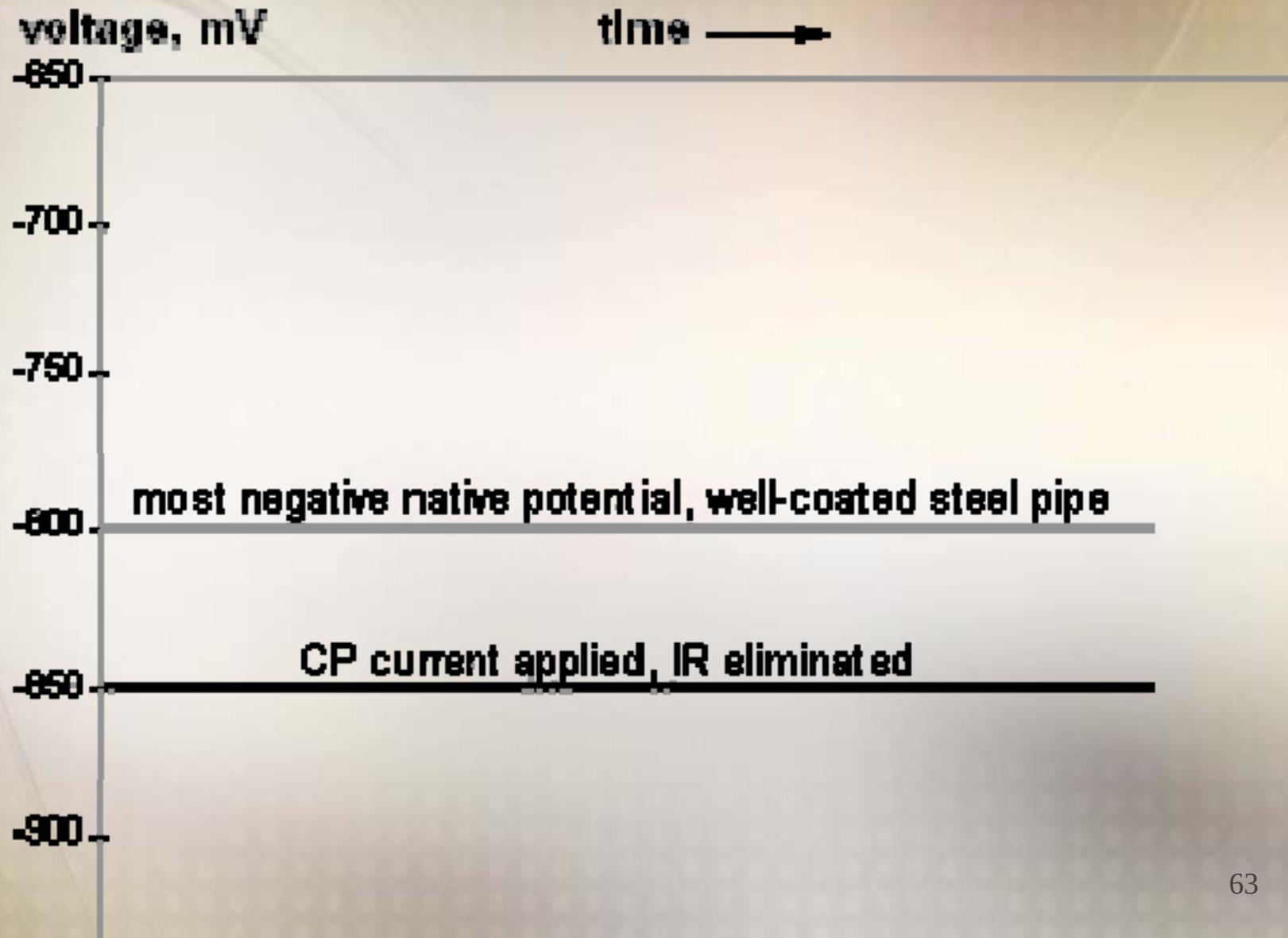


▼ Cathodic Protection & IR Drop



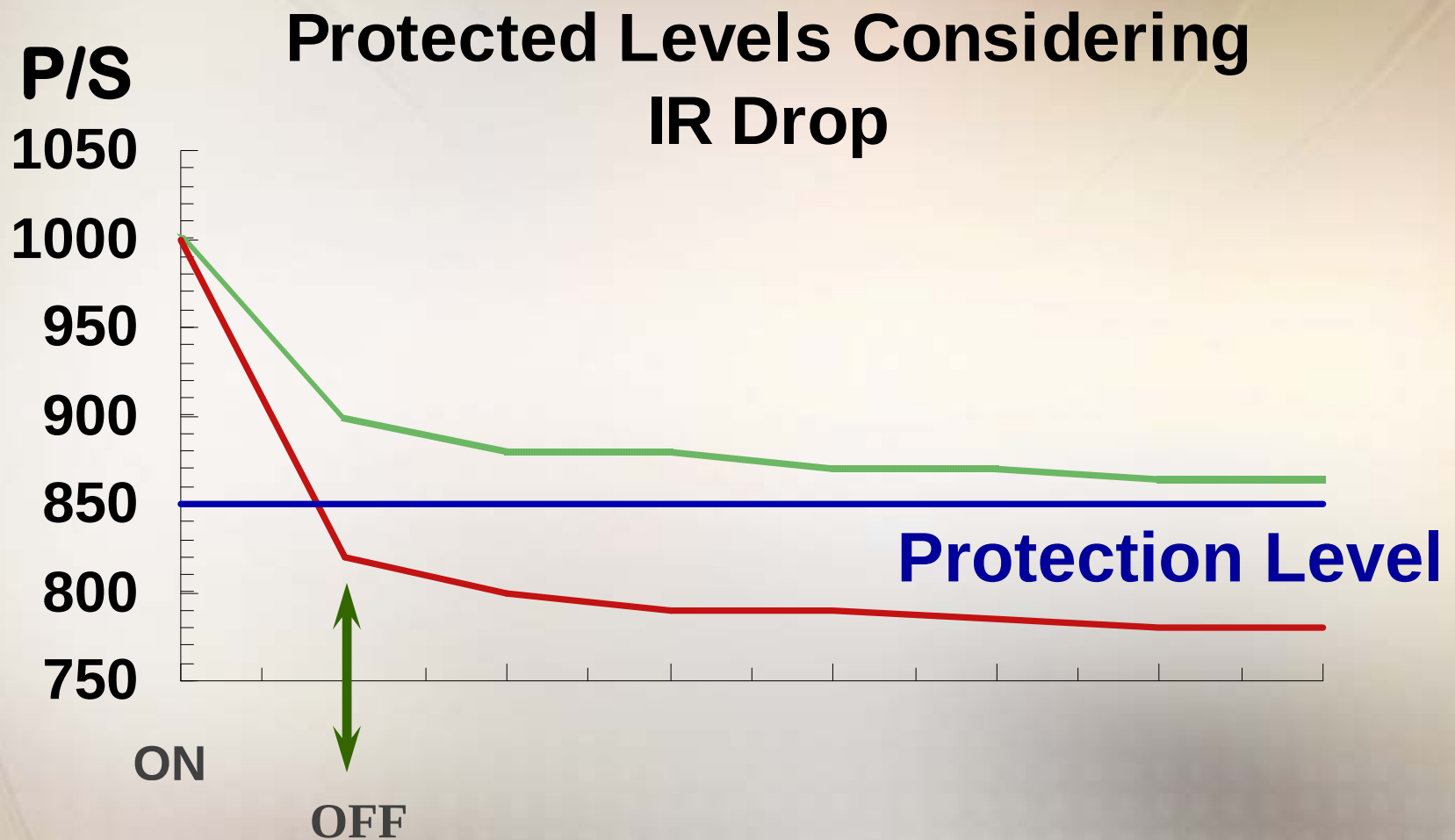


C. P. CRITERIA (850 mV)



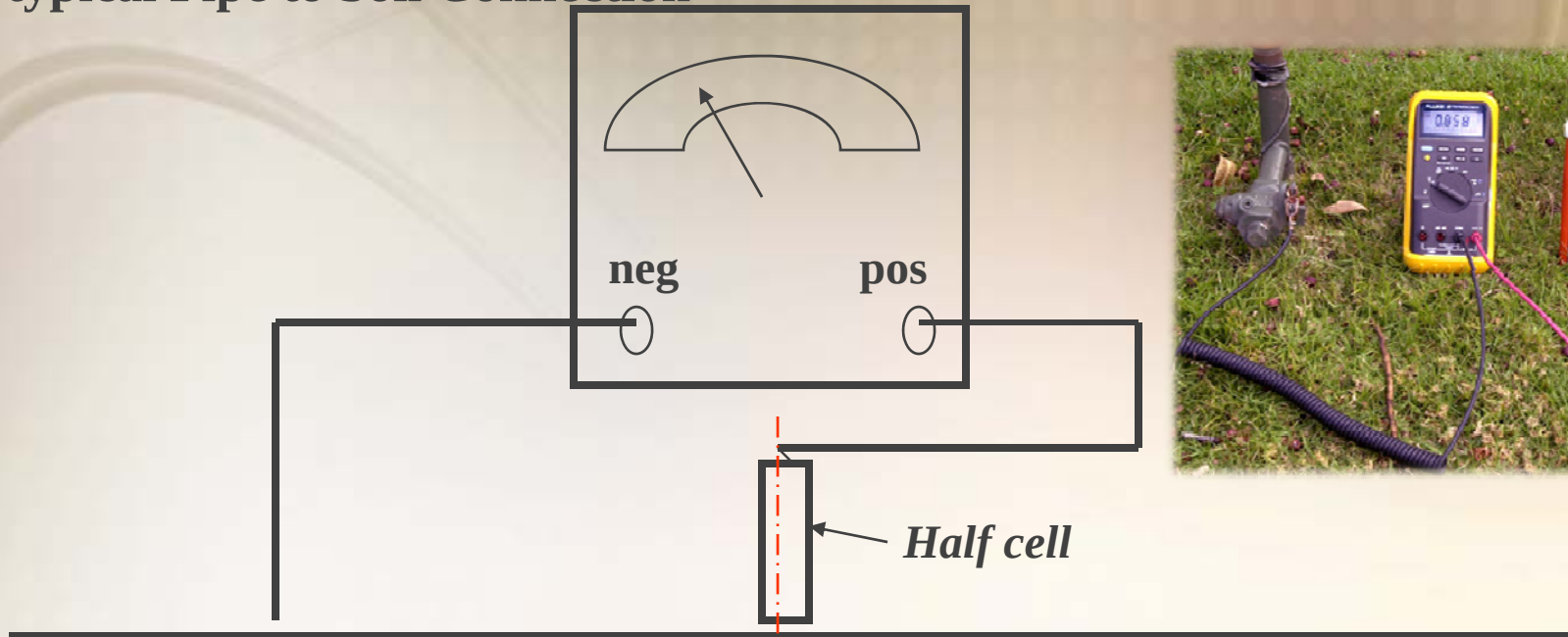


C. P. CRITERIA (850 mv)





A typical Pipe to Soil Connection

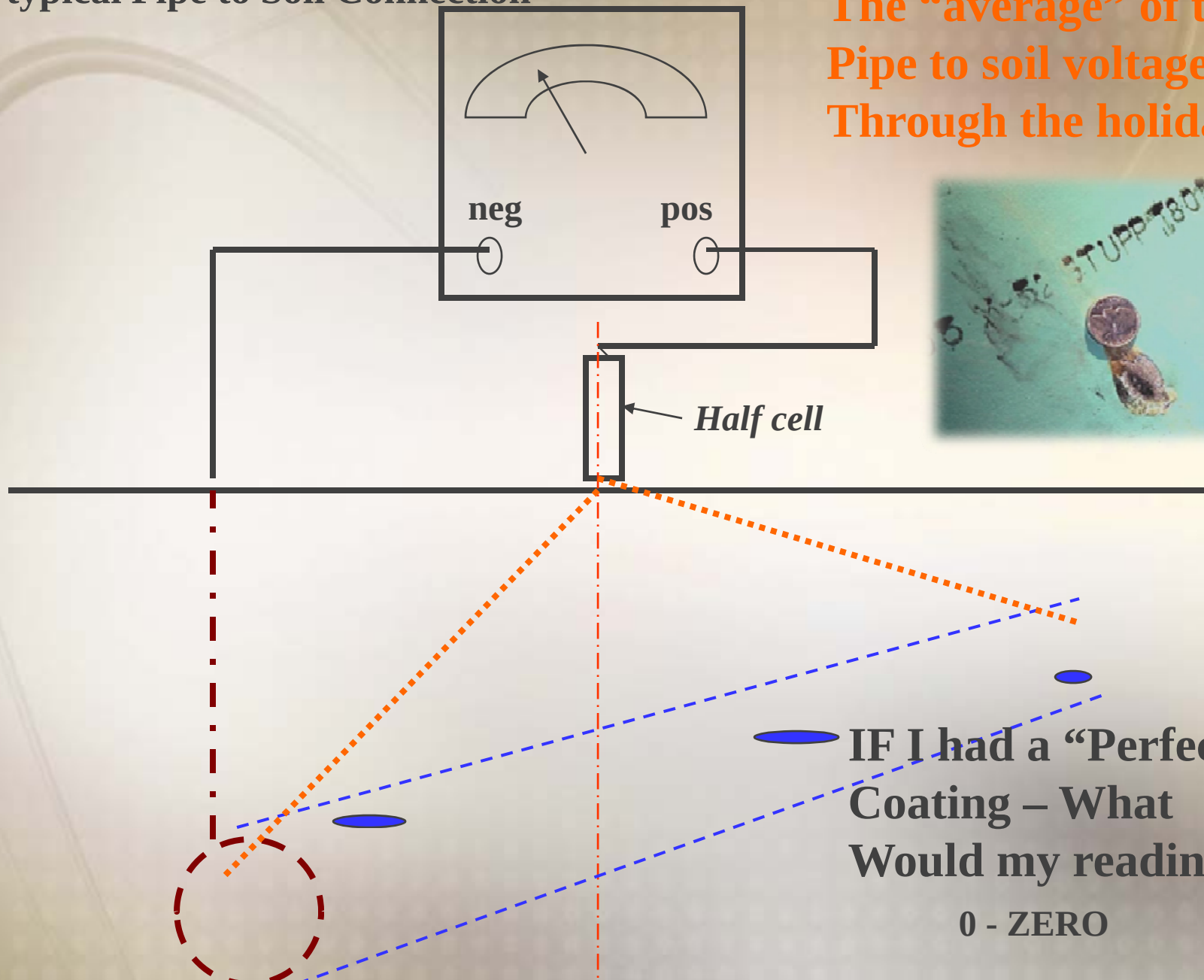


I take a reading..

What am I getting a reading of??



A typical Pipe to Soil Connection



The “average” of the
Pipe to soil voltages
Through the holidays!

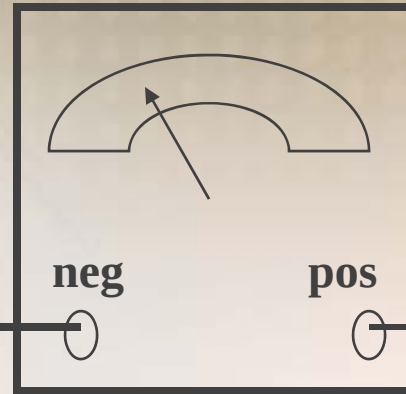


IF I had a “Perfect”
Coating – What
Would my reading be??

0 - ZERO

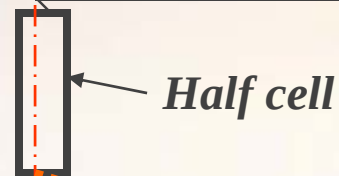


A typical Pipe to Soil Connection

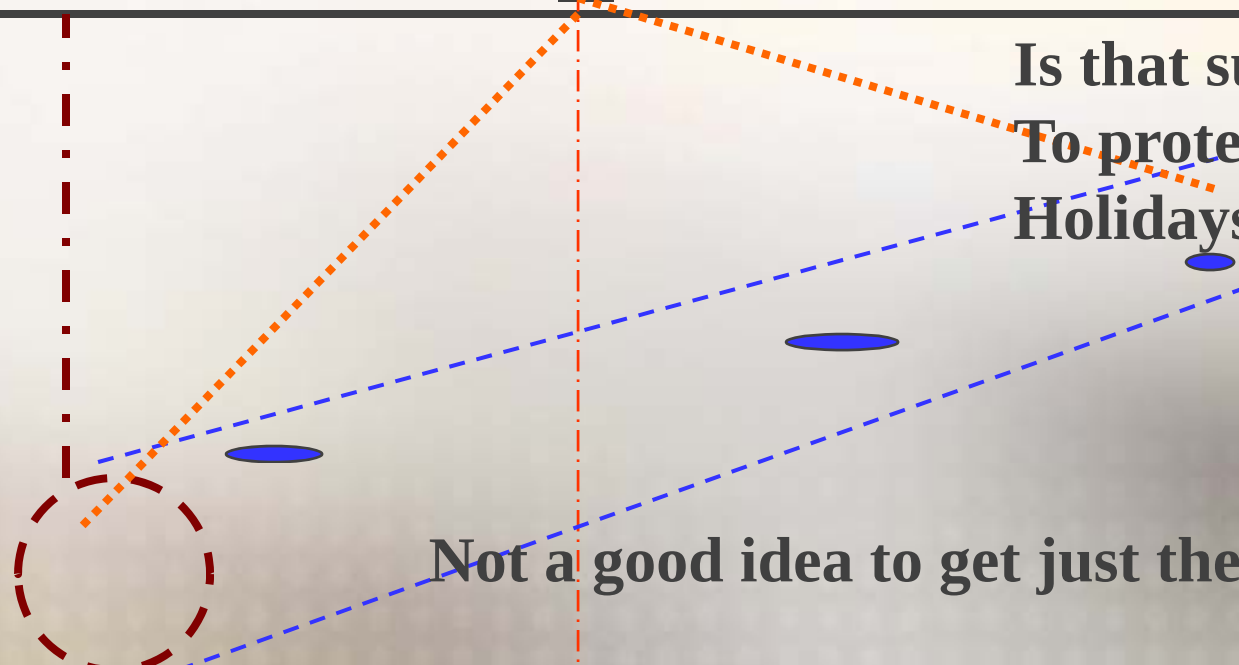
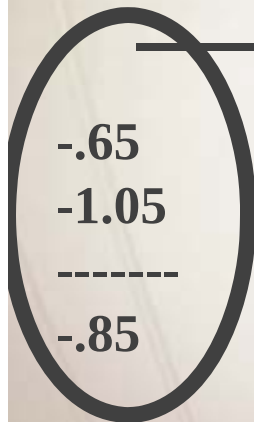


The “average” of the
Pipe to soil voltages
Through the holidays!

If I get a $-.85$ volt
Reading...



Is that sufficient
To protect all
Holidays??



Not a good idea to get just the minimum!!

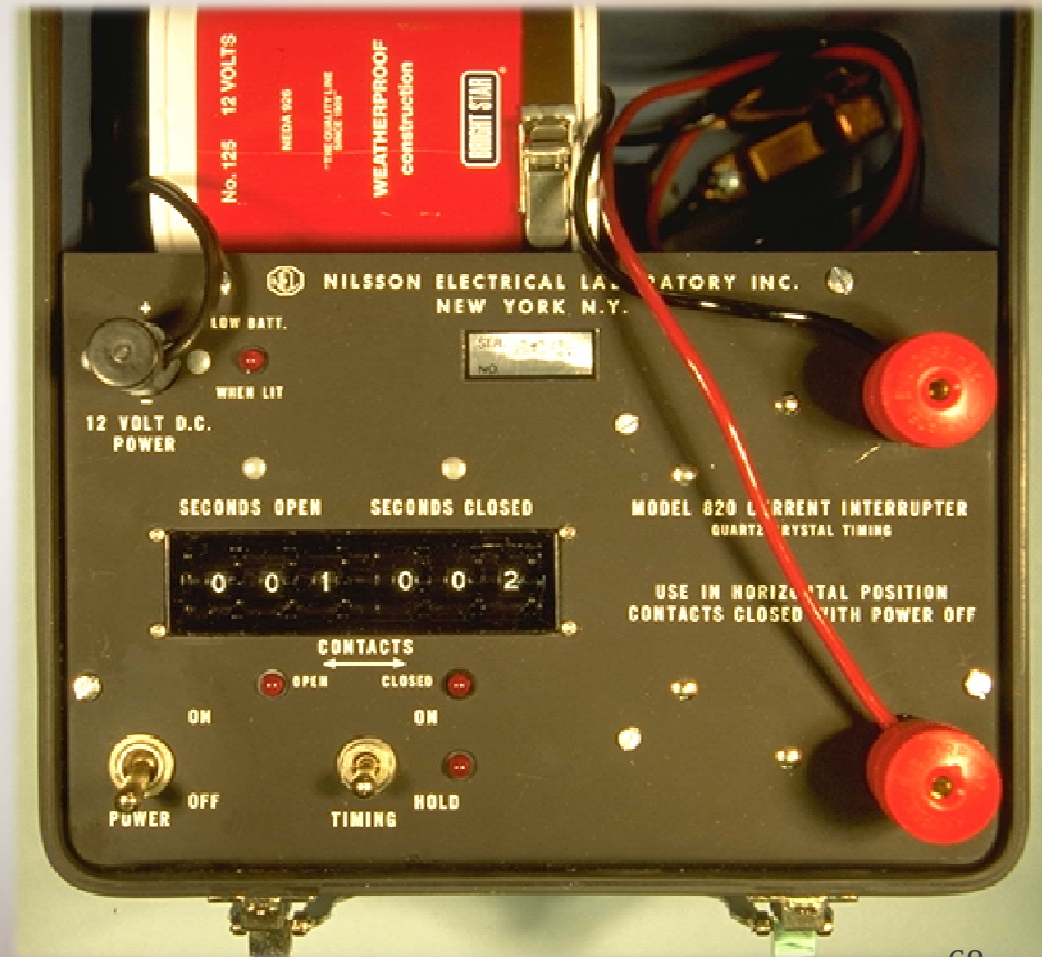


▼ Cathodic Protection Criteria

100 mv. Polarization Decay

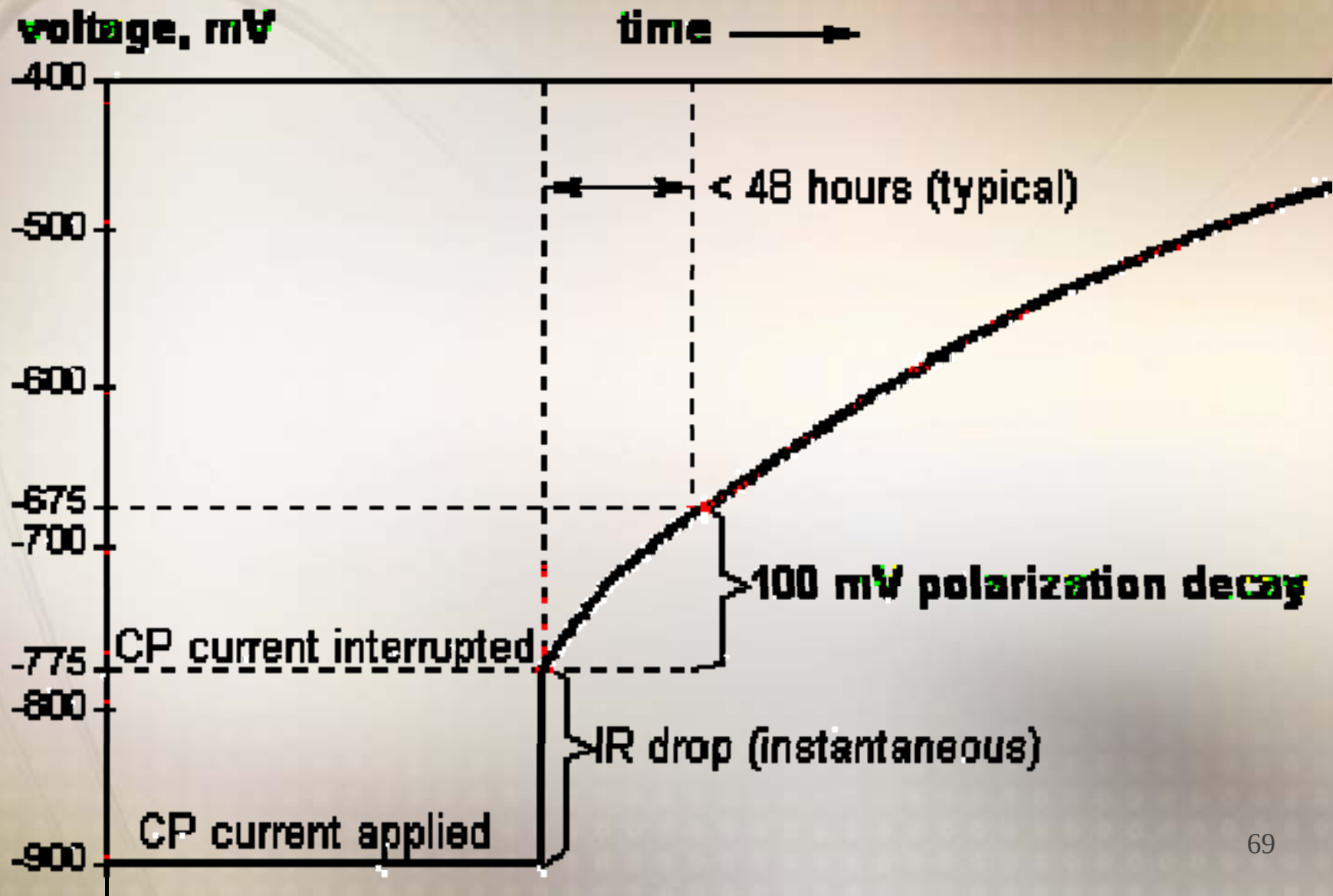
✉ Current Interruption

✉ Cu/CuSO₄ Reference





100 MV Polarization Decay





▼ Monitoring ~ §192.465(a)&(c)

✉ **Cathodically Protected Zones**

✉ **Isolated Sections
< 100 ft. (Gas Mains
or Transmission)
10% Sampling Per Yr.**

✉ **Non-Critical Bonds**



Each Calendar Year Not Exceeding 15 Months



▼ **Monitoring ~ §192.465(b)&(c)**

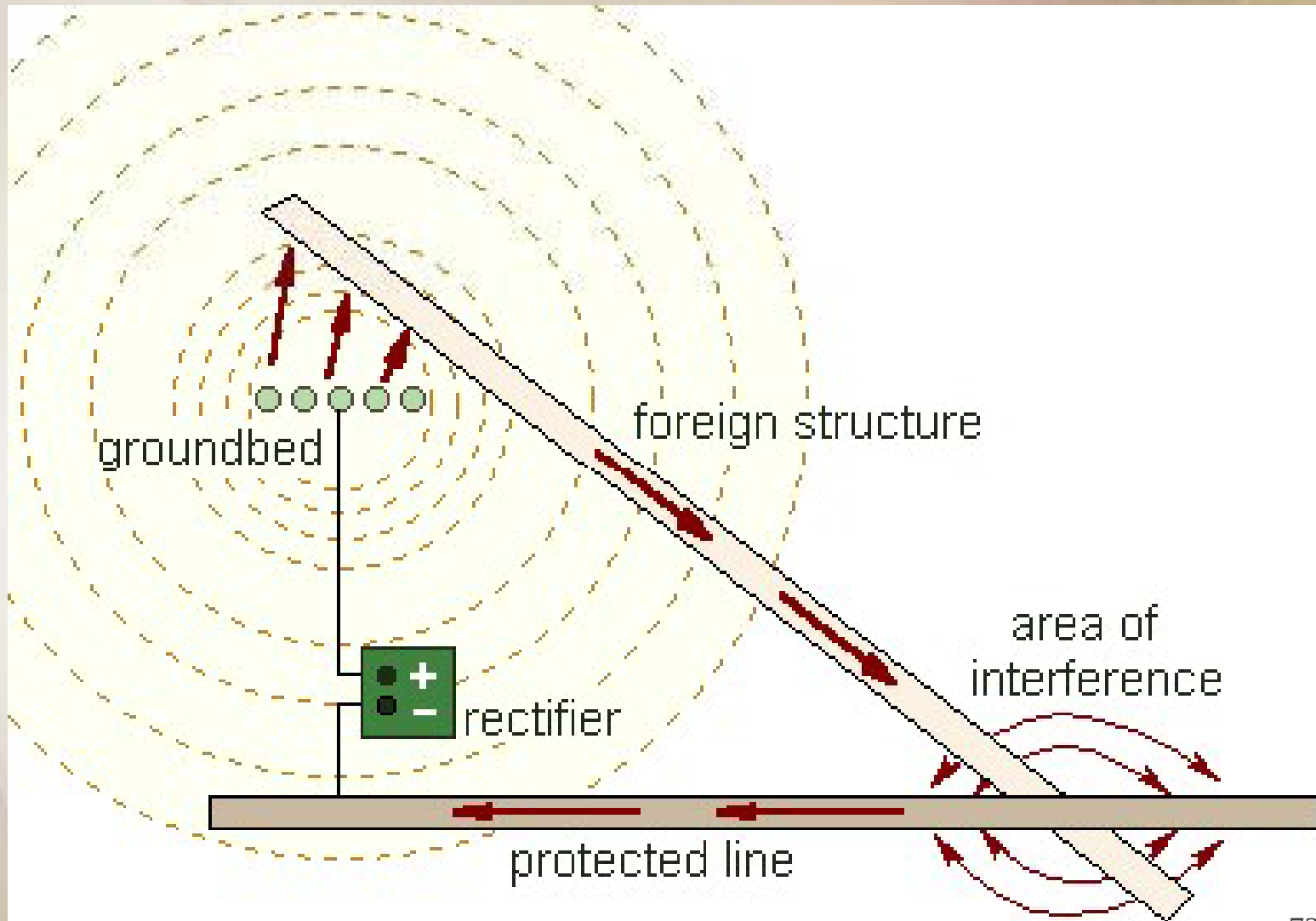
- ✉ **Rectifiers**
- ✉ **Critical Bonds**
- ✉ **Reverse Current Switches**
- ✉ **Diodes**

***6 x year - Intervals
Not Exceeding
2 1/2 Months***



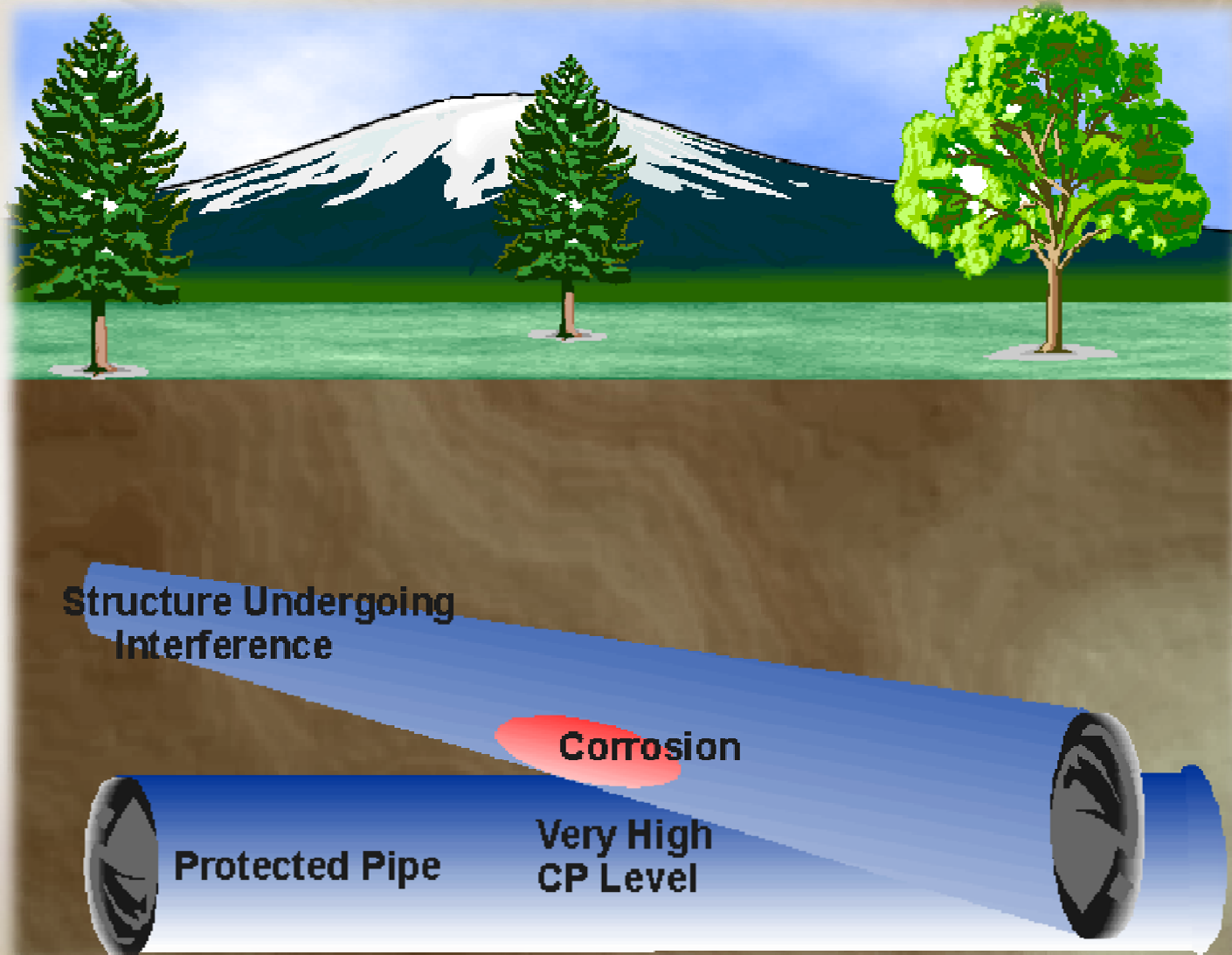


Monitoring ~ §192.465(e)





▼ Monitoring ~ §192.465(e)





Monitoring ~ §192.465(e)

-  **Reevaluation 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**



Active Corrosion

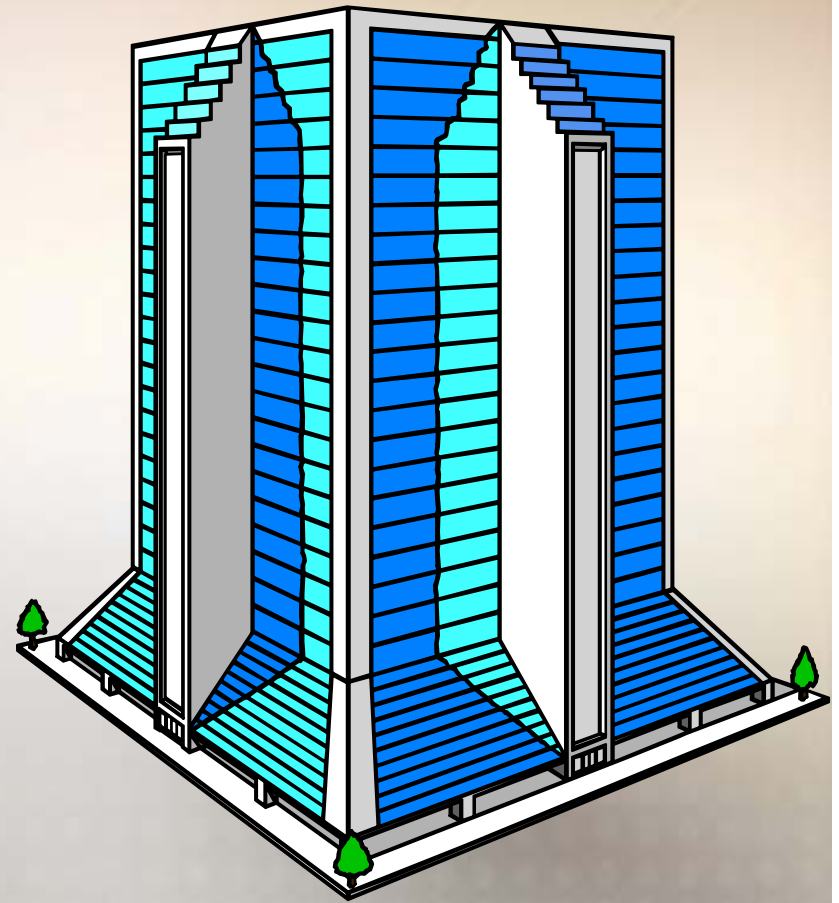
✉ Continuing corrosion which, unless controlled, could result in a condition that is **DETRIMENTAL to PUBLIC SAFETY -- §192.465(e)(1) [was 457(c)]**





Detrimental to Public Safety Considerations

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





Electrical Survey

✉ **Definition ~ (Per §192.465 (e)(2))**

...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



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 for Any Reason --



**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 .705 & .721, or Smart Pig





Test Stations/Test Leads

§192.469 & 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**



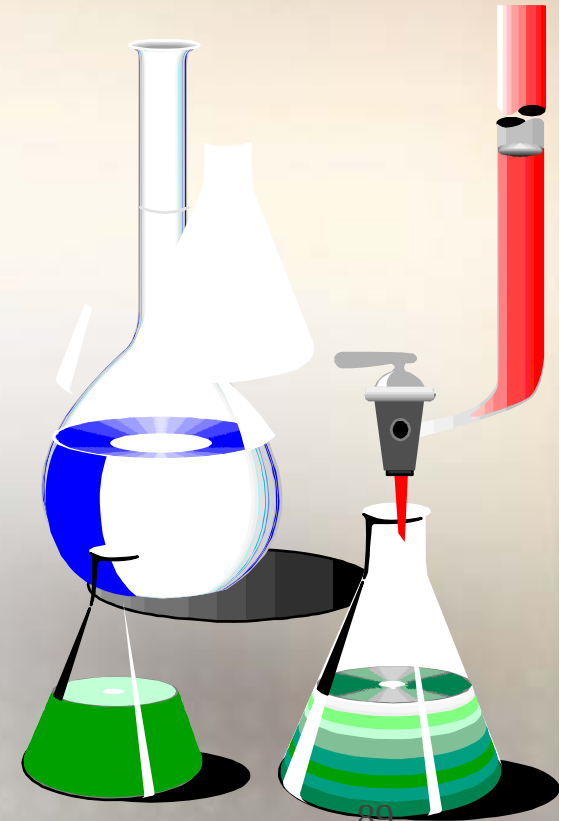
Internal Corrosion Control

Monitoring ~ \$192.477

When Corrosive Product is Transported

-  Must Be Monitored For I.C.
-  2x Calendar Year
N.T.E. 7 ½ mos.

Coupons
Water Analysis
Microbiological Analysis
Inhibitors



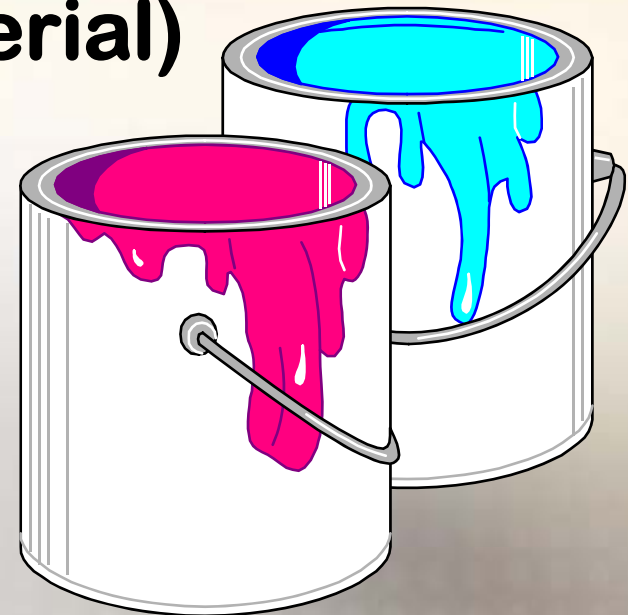


Atmospheric Corrosion Control

§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 not applicable
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**

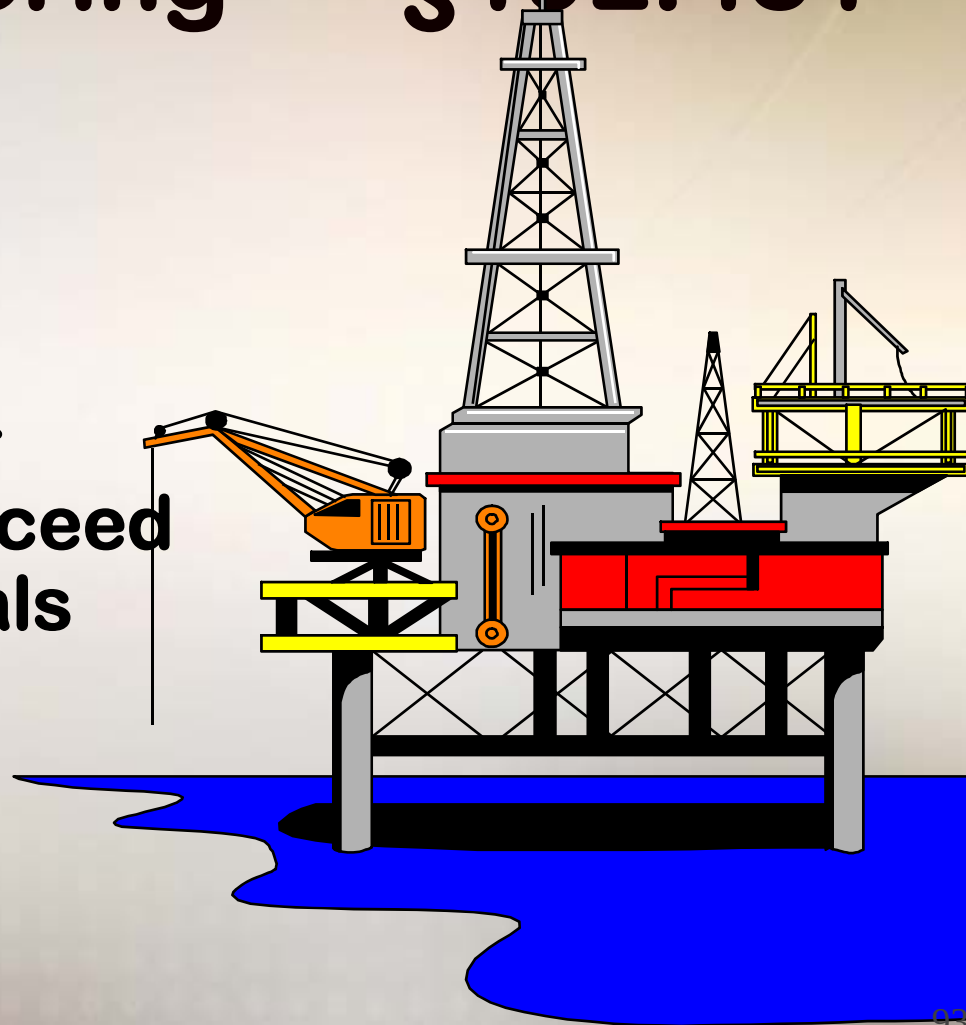




Atmospheric Corrosion Control Monitoring ~ \$192.481

Offshore

**Every Calendar
Year Not To Exceed
15 mos. Intervals**





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**

**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 (exc. CI & DI) ~ \$192.487

✉ **General Corrosion or W.T. <30%
Remaining**

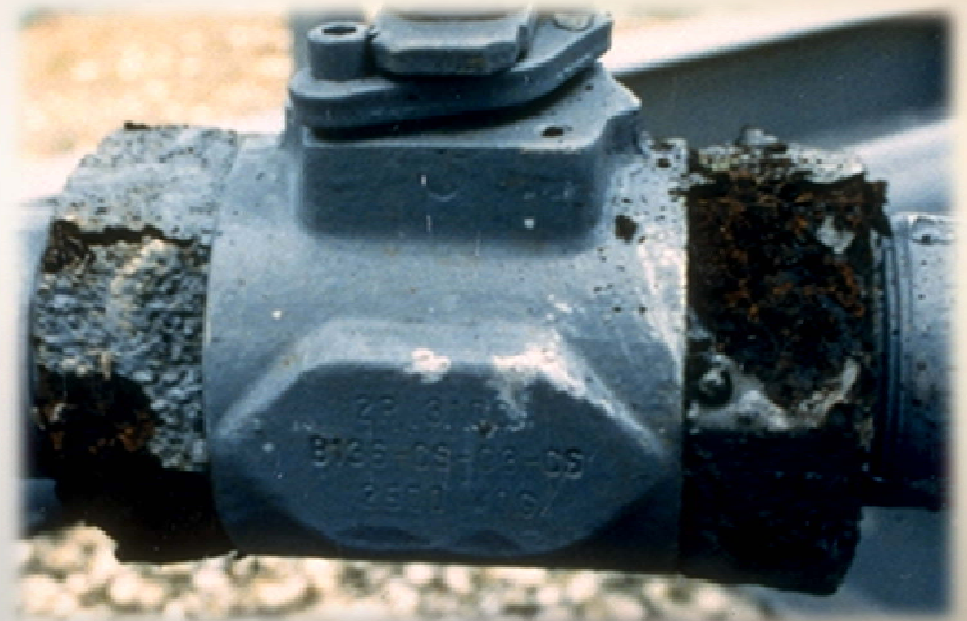
✉ **Replace**

✉ **Repair**

✉ **Localized
Corrosion**

✉ **Repair**

✉ **Replace**





Remedial Measures (Gas)

Cast & Ductile Iron ~ \$192.489

- ✉ Graphitization General
 - ✉ 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**



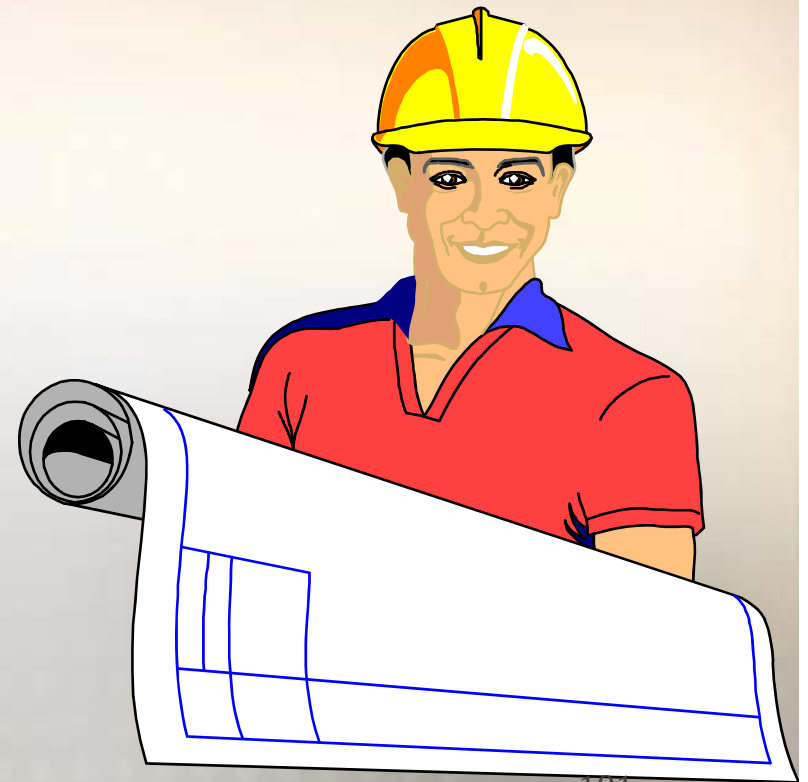


Corrosion Control Records

§192.491(b)



 **Retain for Service
Life of System**

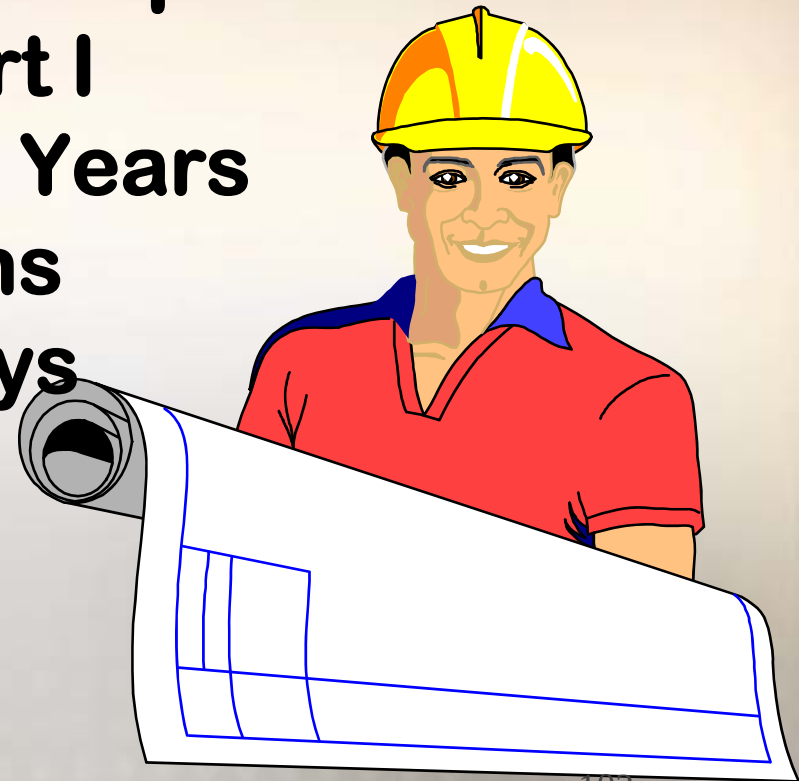




Corrosion Control Records

§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 ~ 465(a)**
 -  **3-Year Reevaluations ~ 465(e)**
 -  **Inspections for Internal Corrosion ~ 475(b)**

