

# Corrosion Control of Water Systems



**Presented By:**  
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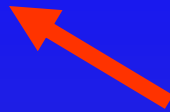
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# Corrosion



# Temporary Fix ?



# Corrosion Can be Defined as Either:

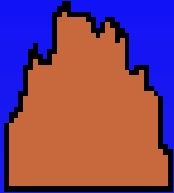
## ▶ Practical

Tendency of a Metal to Revert to its Native State

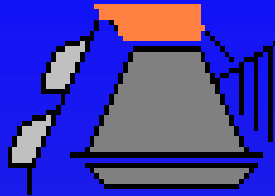
## ▶ Scientific

Electrochemical Degradation of Metal as a Result of a Reaction with its Environment

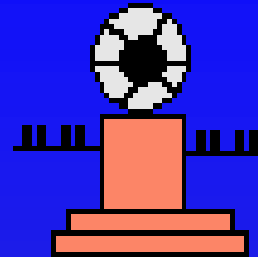
# Corrosion - A Natural Process



IRON OXIDE



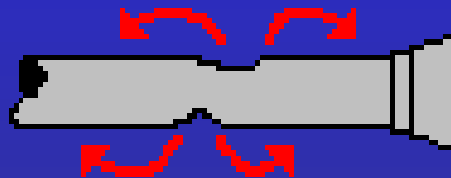
REFINING



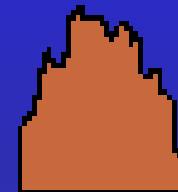
MILLING



IRON, STEEL, PCCP

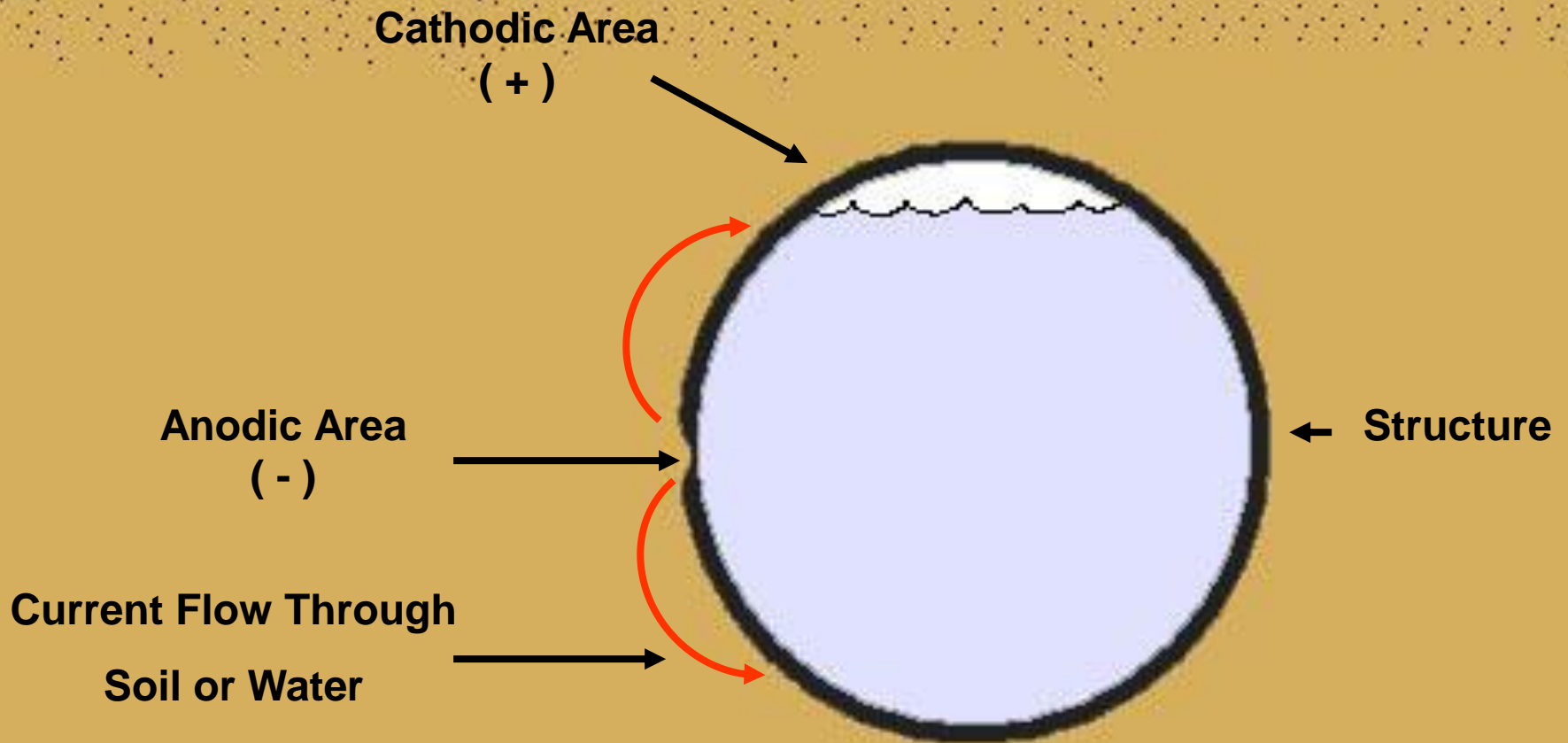


CORROSION

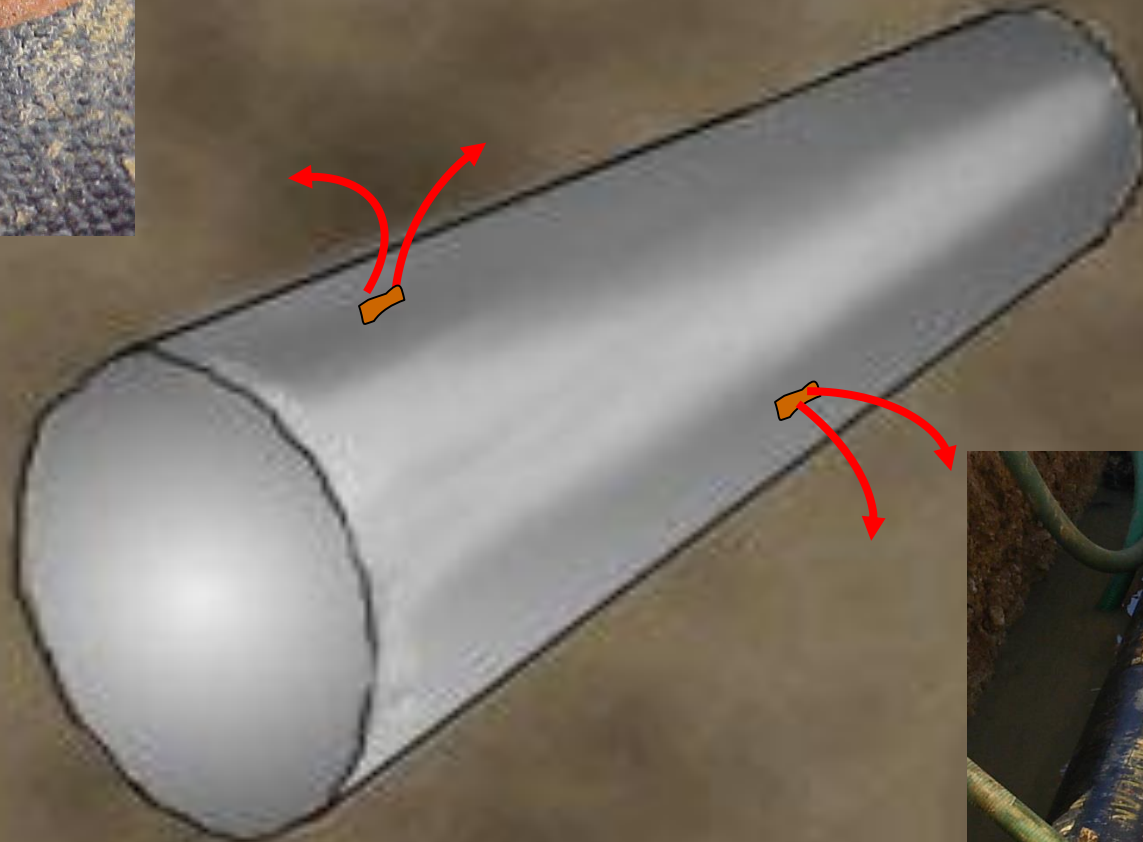


IRON OXIDE

# Corrosion Cell on Buried Piping

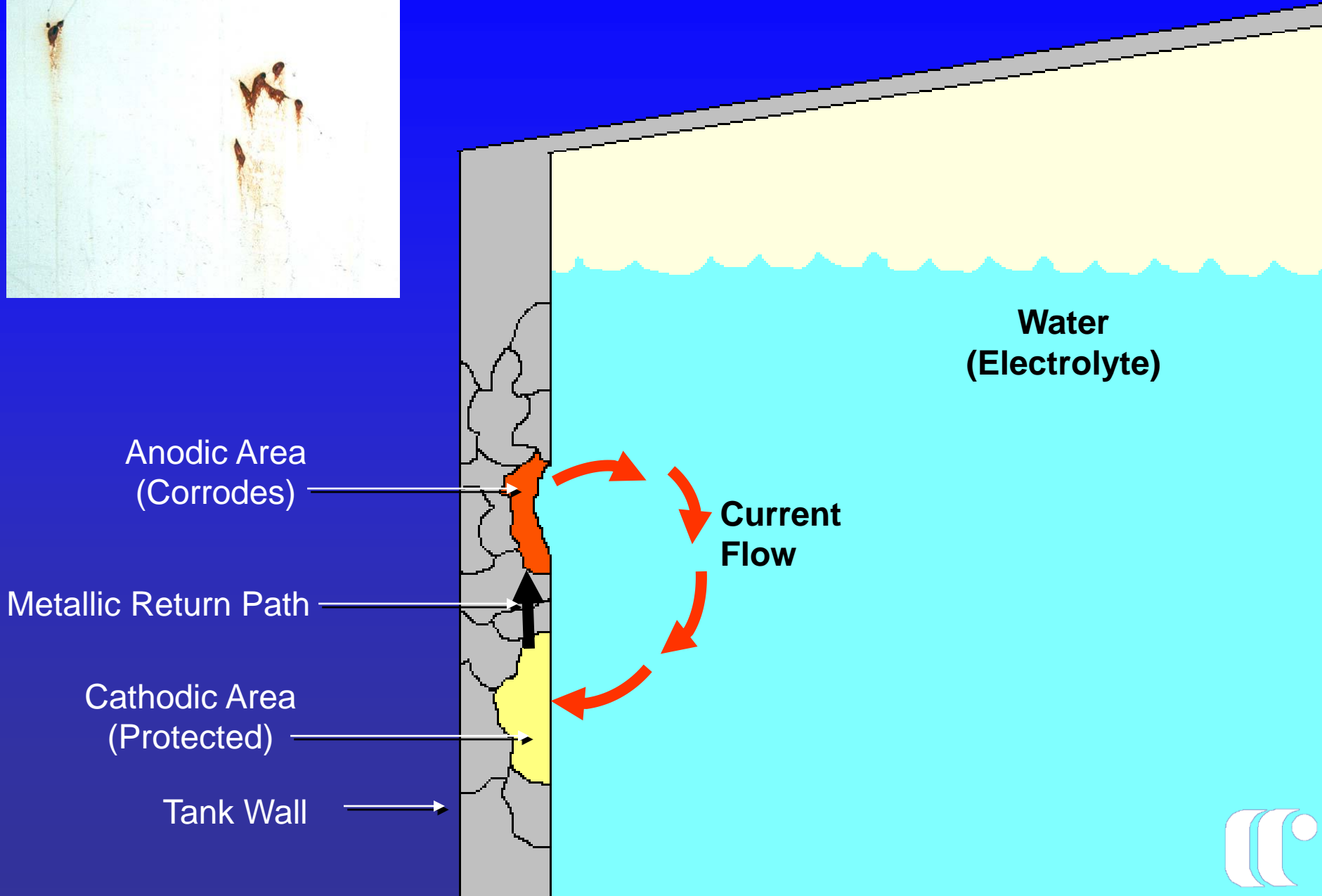


# Corrosion of Metallic Structure









Anodic Area  
(Corrodes)

Metallic Return Path

Cathodic Area  
(Protected)

Tank Wall

Water  
(Electrolyte)

Current  
Flow





# History of Iron Pipe

## Cast Iron

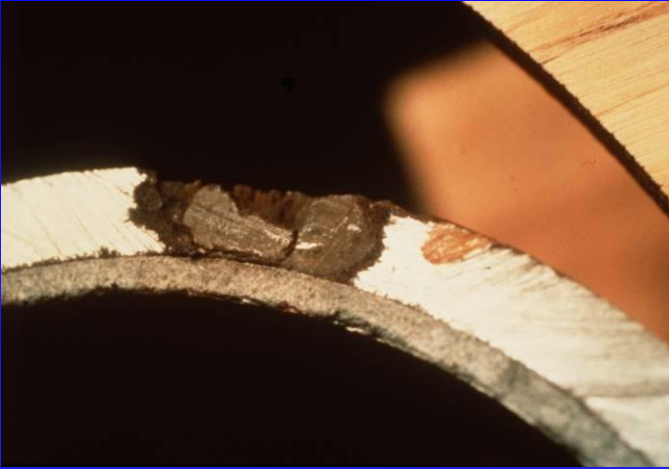
- Introduced to North America during the 1800's and installed till the 1970's.
- Early on, statically cast process produced a thick walled, heavy pipe.
- No longer produced in North America.

## Ductile Iron

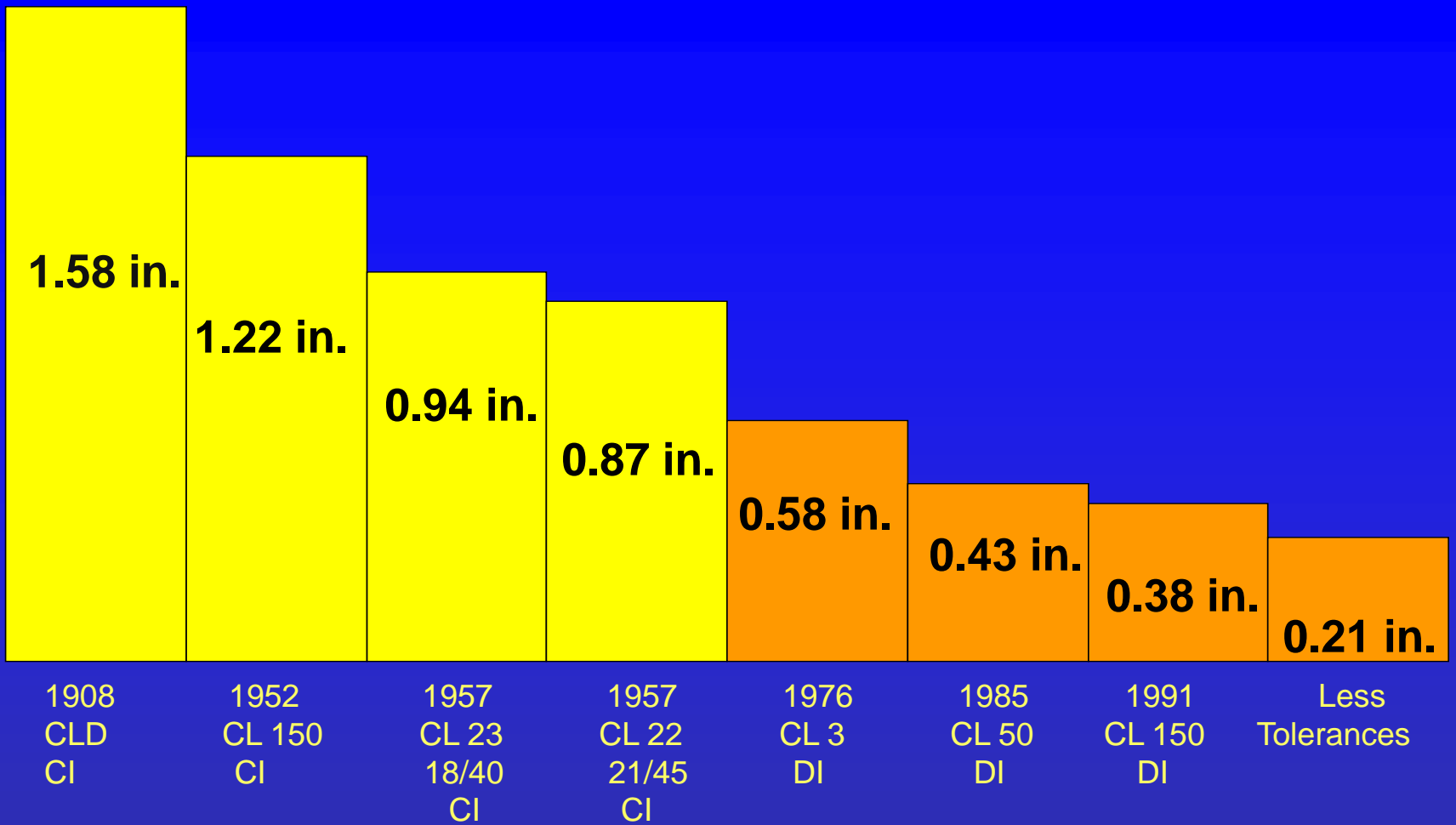
- Introduced in 1955 as an improvement to cast iron.
- Centrifugal casting process produces a thinner walled, lighter pipe which is stronger and more ductile than cast iron.



# Cast (Grey) Iron Failures



Graphitization leaves pipe brittle and weakened.



Actual size of AWWA Specification Thickness Reductions for 36-inch Diameter Cast and Ductile Iron Pipe - 1908 to Present (150 PSI Operating pressure)

# Ductile Iron



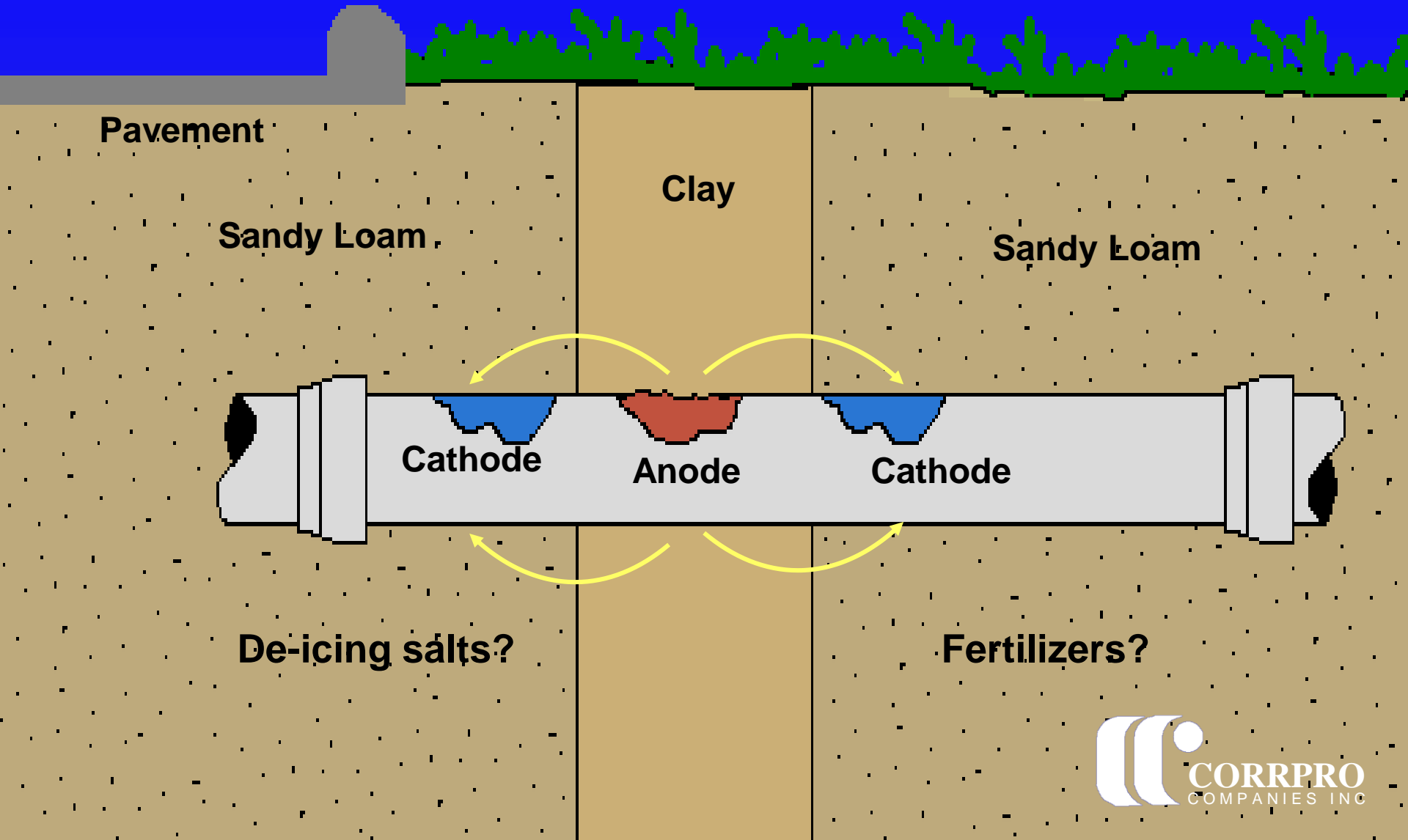
Pitting (concentrated) corrosion attack on ductile iron pipe.

# ***Adverse Conditions for Metallic Pipe***

- ***High Chlorides***
- ***Low Soil/Water Resistivity***
- ***High Sulfates***
- ***Acidic Soils***
- ***Wet/Dry Fluctuations***
- ***Bimetallic Couplings***
- ***Stray Current Interference***

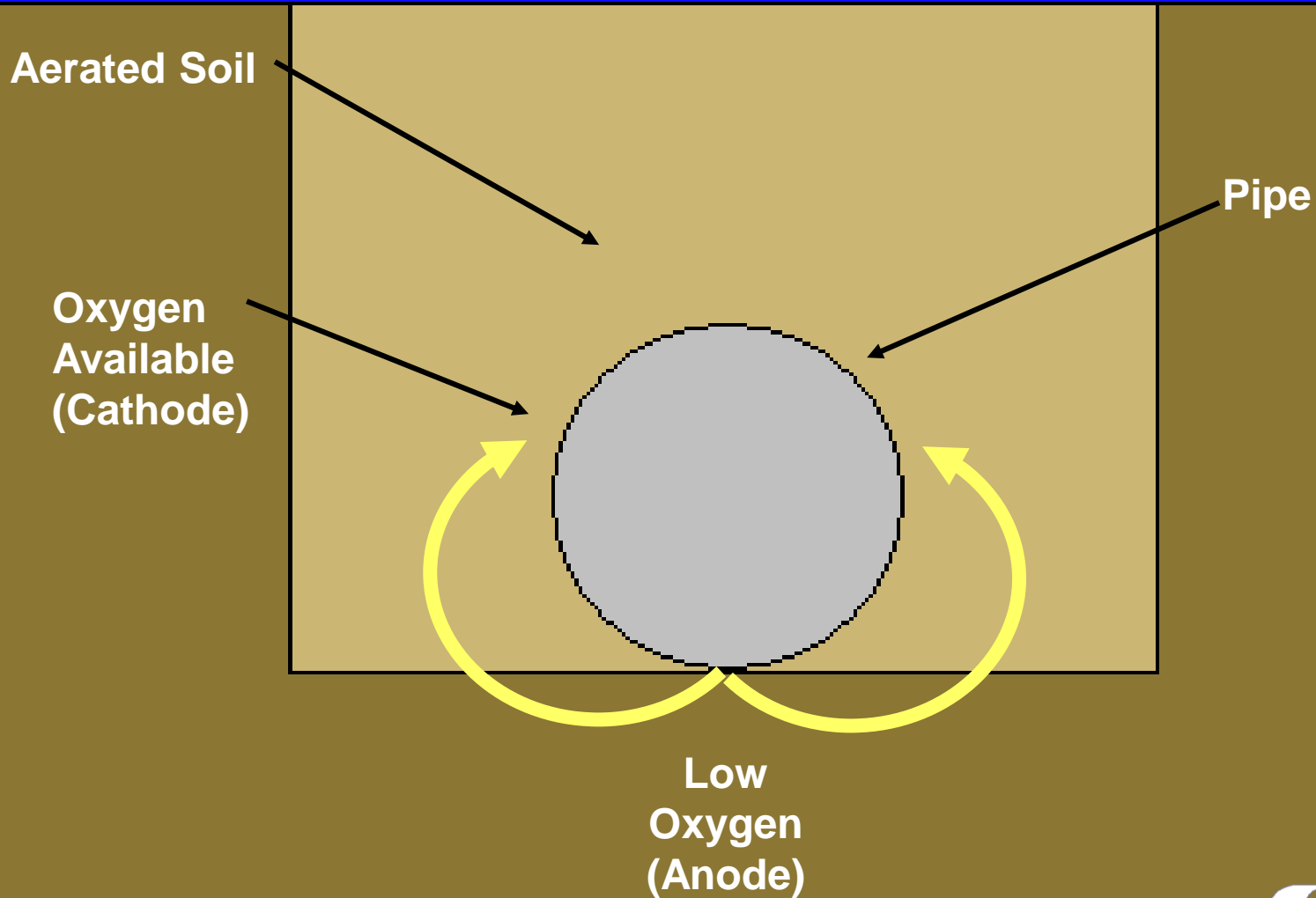


# Dissimilar Soils

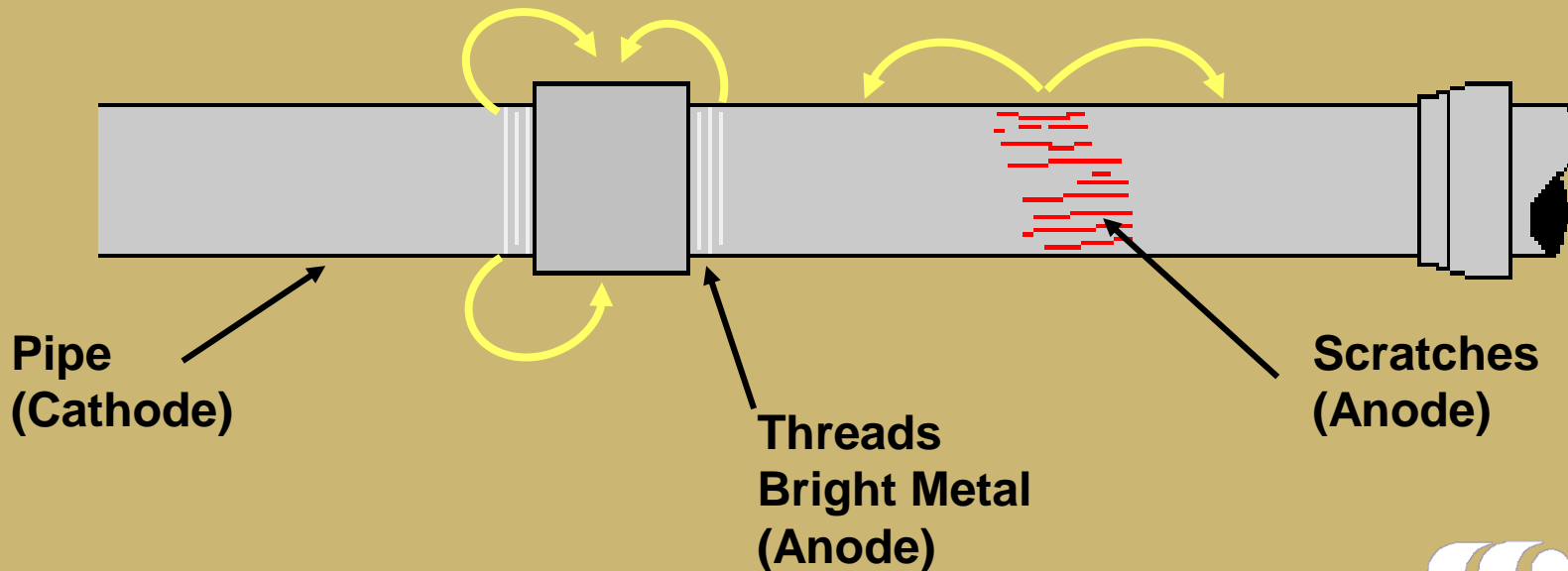


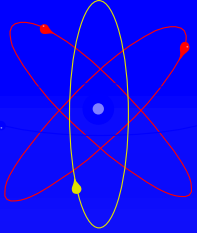


# Corrosion Caused by Differential Aeration



# Dissimilar Surface Conditions



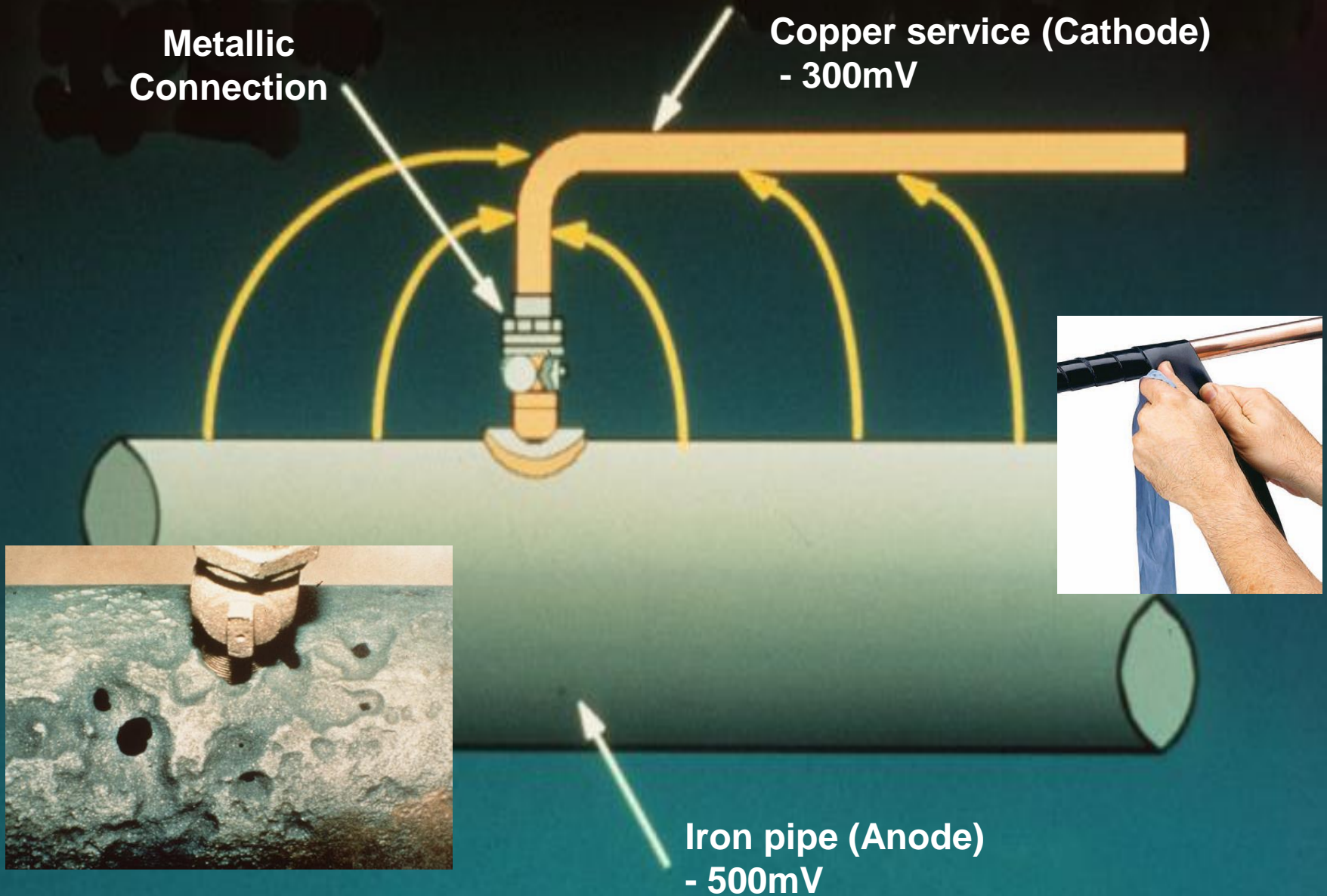


# PRACTICAL GALVANIC SERIES

Material	Potential*
Pure Magnesium	-1.75
Zinc	-1.10
Aluminum Alloy	-1.00
Cadmium	-0.80
Mild Steel (New)	-0.70
Mild Steel (Old)	-0.50
Cast/Ductile Iron	-0.50
Stainless Steel	-0.50 to + 0.10
Copper, Brass, Bronze	-0.20
Gold	+0.20
Carbon, Graphite, Coke	+0.30

\* Potentials With Respect to Saturated Cu-CuSO<sub>4</sub> Electrode

# Coupling to Dissimilar Metals



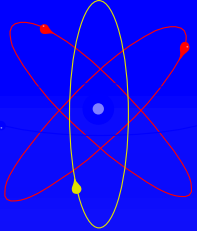
# Proper Handling & Installation of Polyethylene Ductile Iron Pipe



# Polyethylene Encasement of Ductile Iron Pipe



- Follow DIPRA installation procedures
- Clean pipe before installing polywrap
- Repair tears or damage to encasement
- Engage an inspector to oversee installation

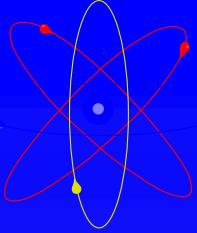


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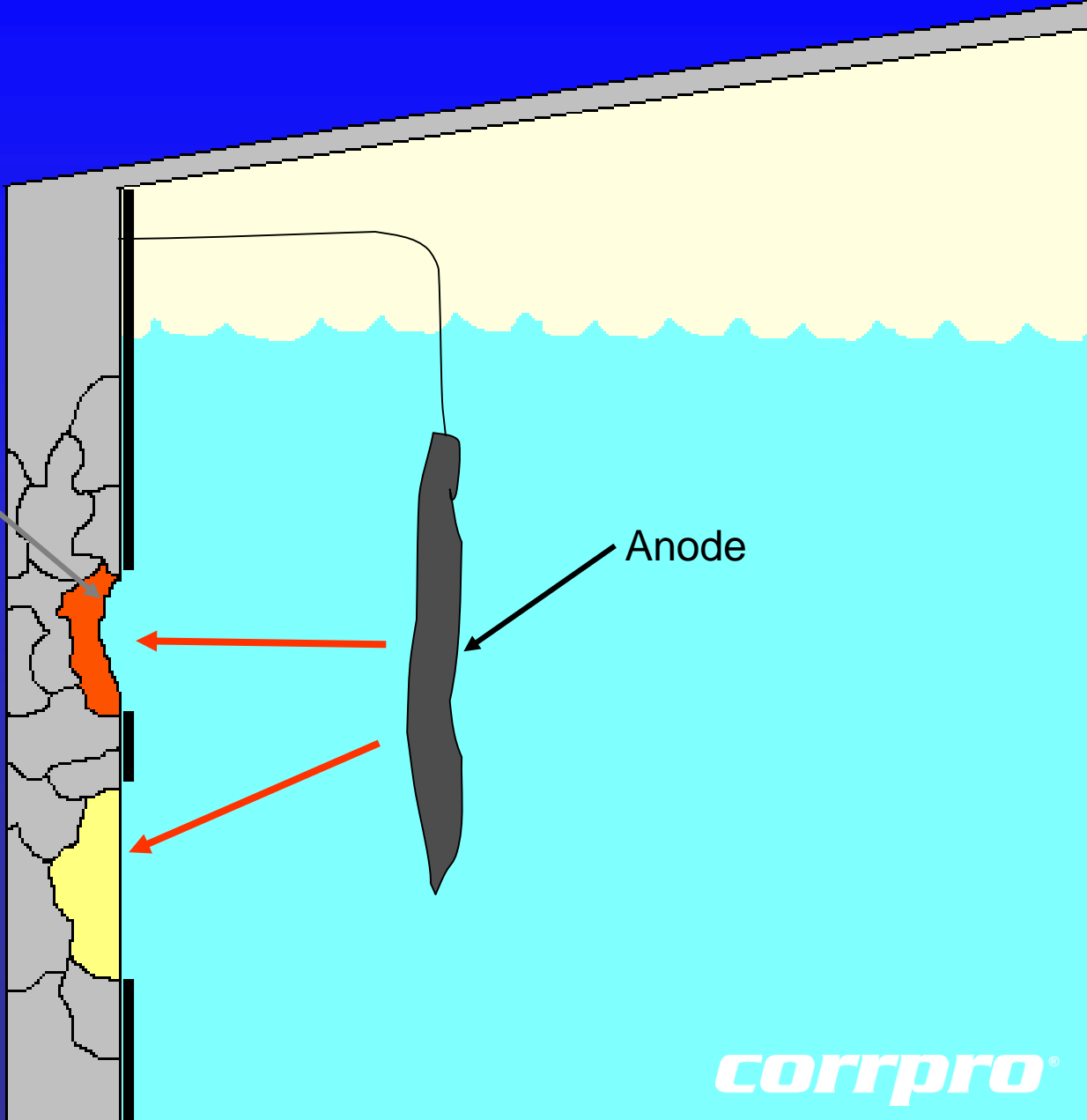
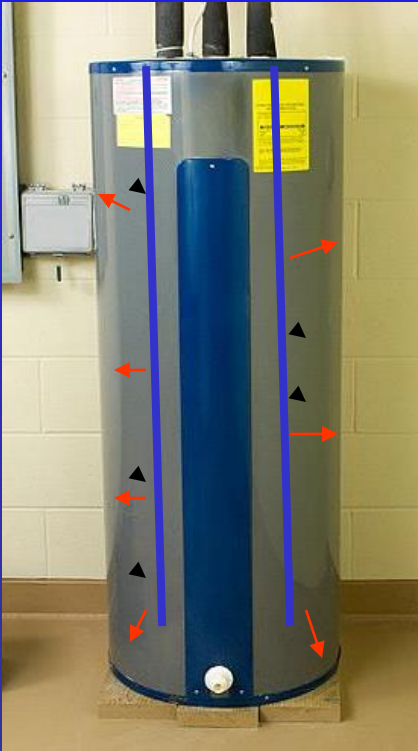
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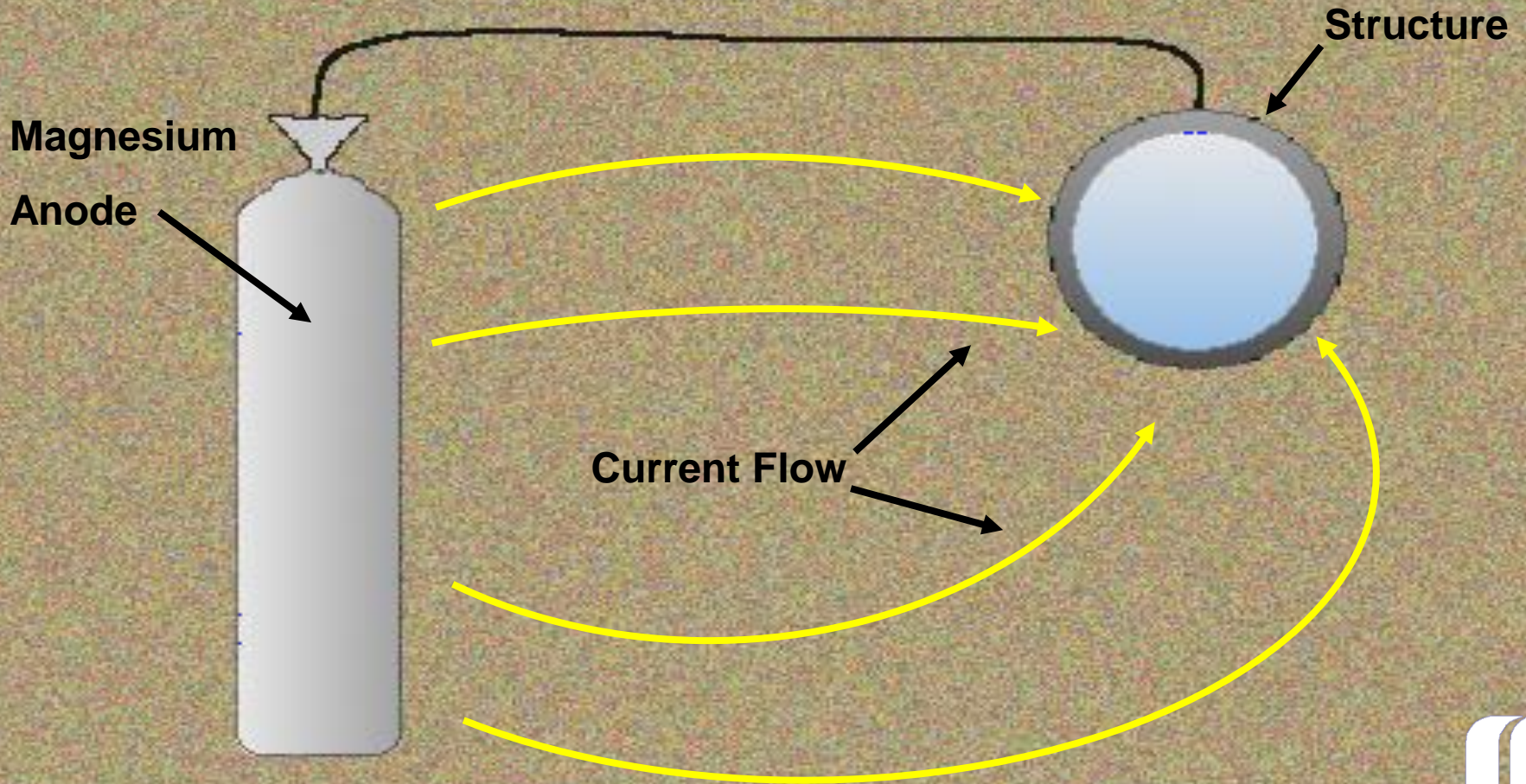


Cathode  
(Protected)

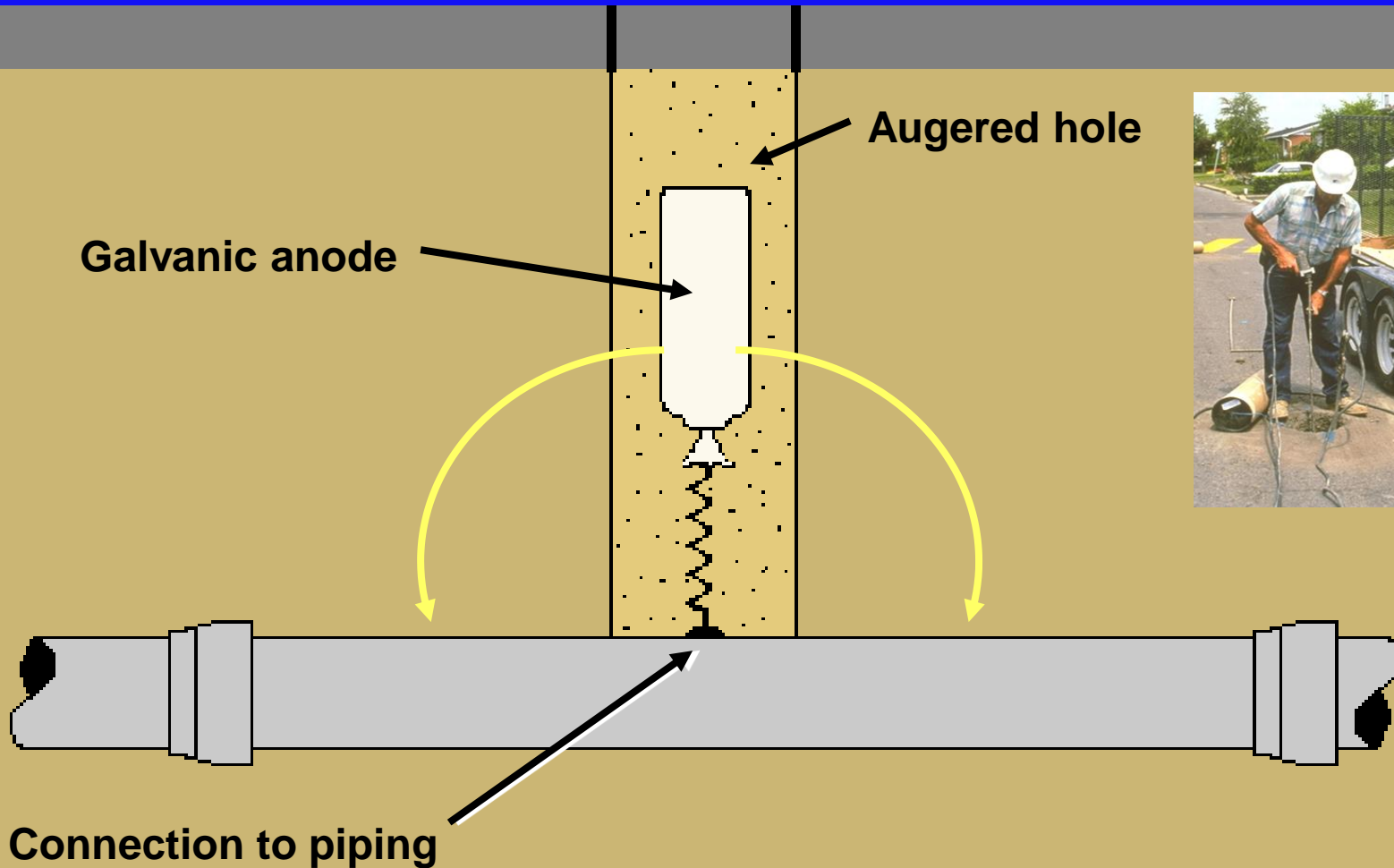


Anode

# Galvanic Anode



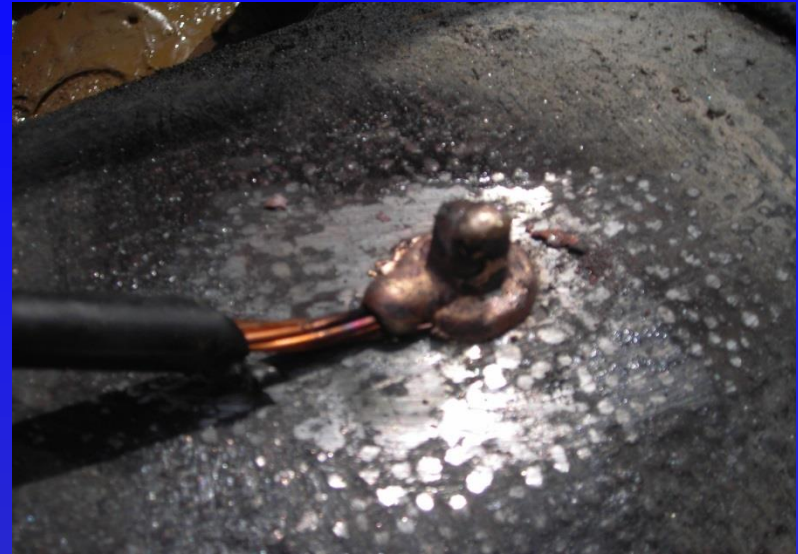
# Anode Installation



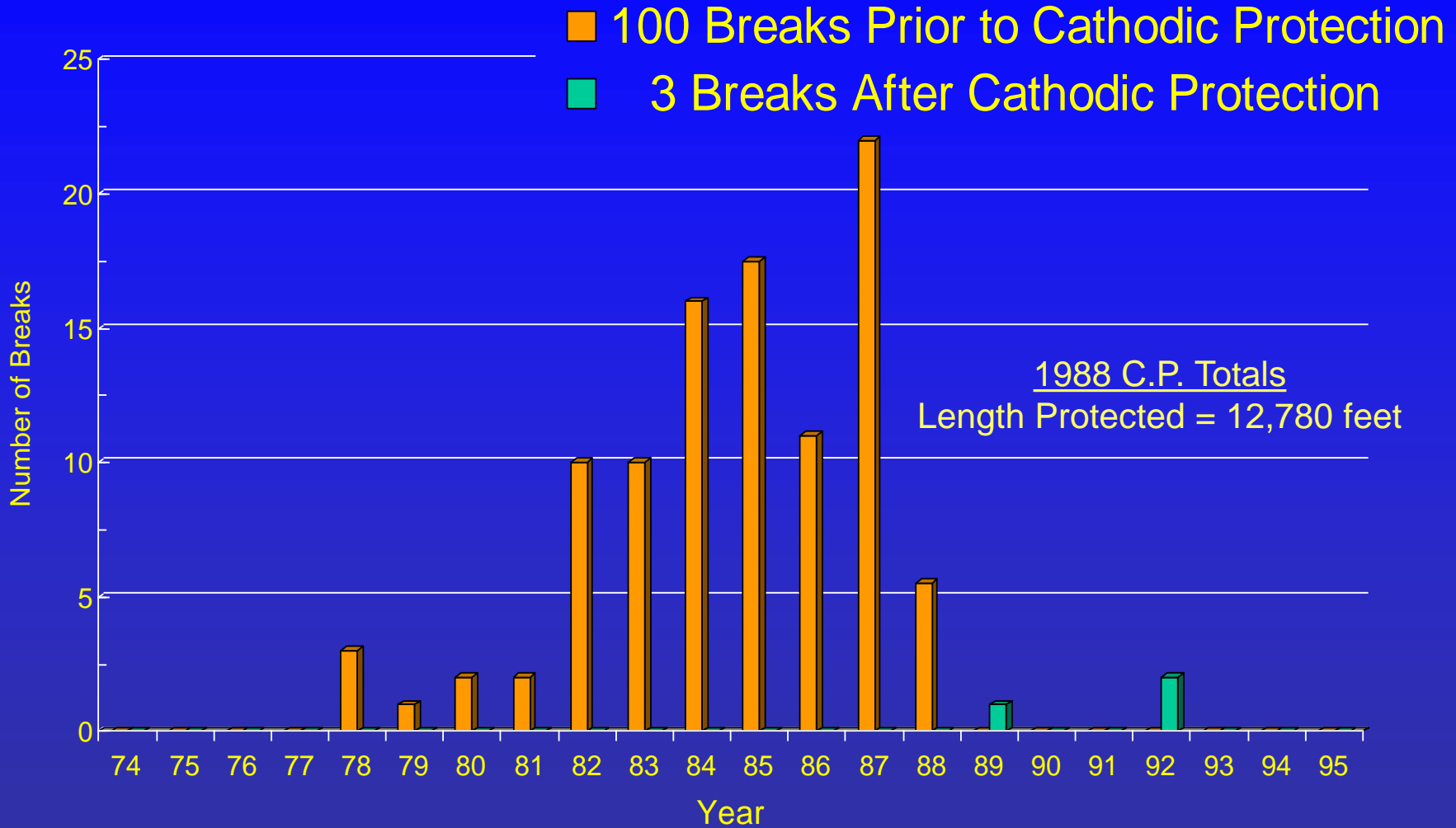


# Access to Pipe

# Thermit Weld to Pipe

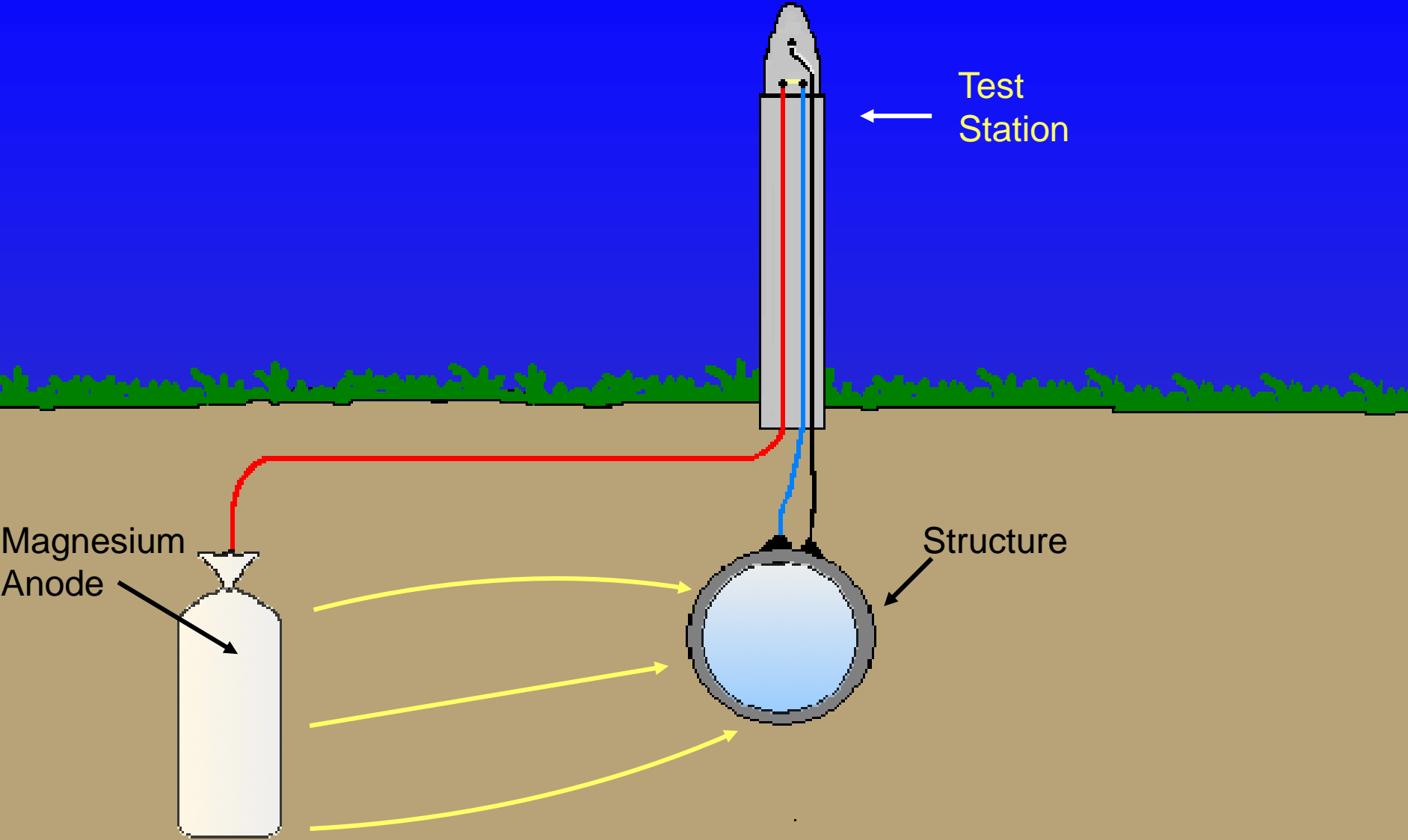






**Break Records for Water Mains Cathodically Protected in 1988**

# Cathodic Protection Test Station





# Temporary Fix ?



# Repair of Break Should Include Anode Installation



**Incomplete**



**Complete**

# Water Leak Repair Kit



*Includes:*

**Installation instructions.**

**One day onsite technical assistance.**

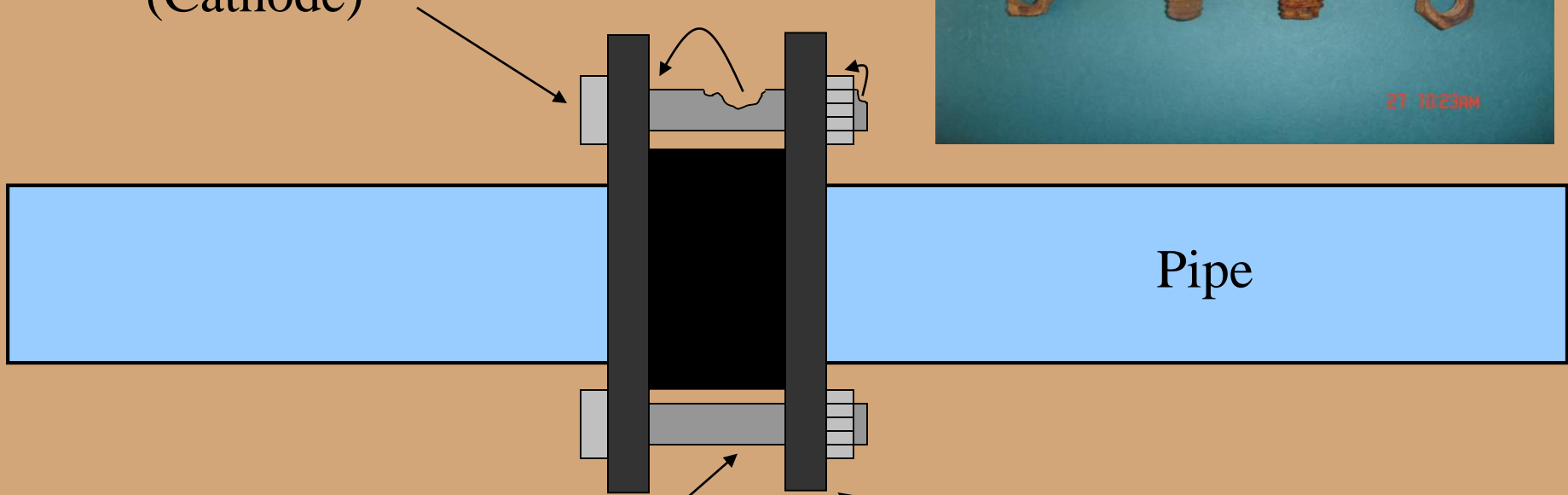
**Cathodic protection components/connection materials suitable for 10 repairs.**

# Polyethylene Encasement



- Follow manufacture's and AWWA recommendations to insure proper installation of polyethylene encasement.
- In extremely corrosive areas, additional methods (bonding of joints, cathodic protection, may be required).

Lower Stress Area  
(Cathode)



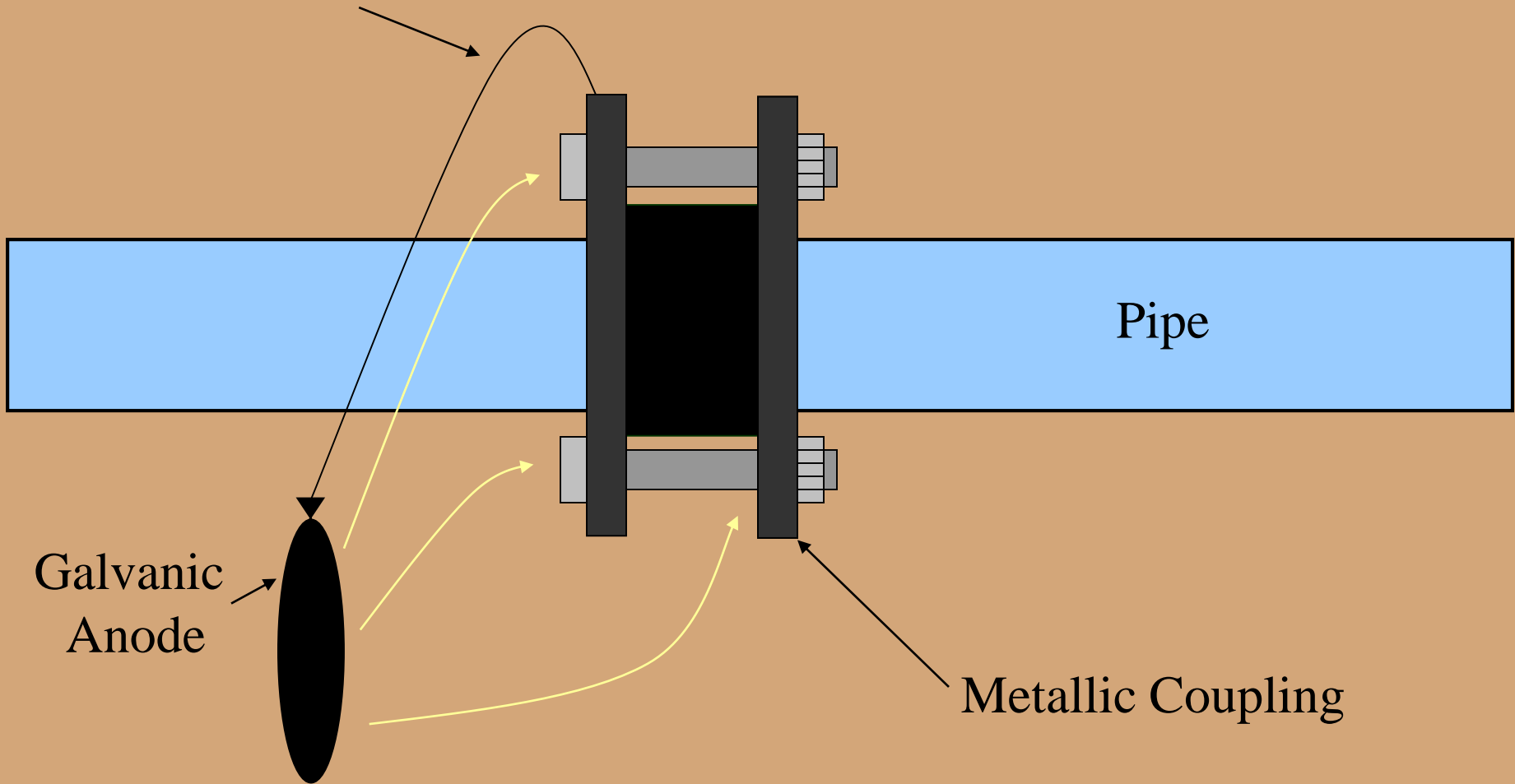
Threaded Bolt  
Higher Stress Area  
(Anode)

Metallic Coupling

Stress Corrosion



Anode Lead Wire Connection



Galvanic Anode

Pipe

Metallic Coupling

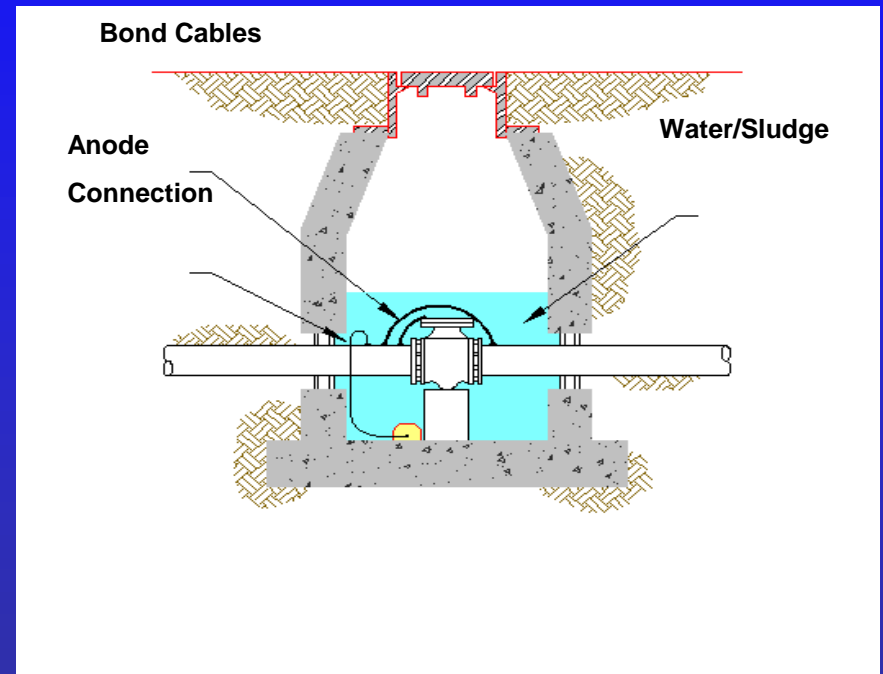
Cathodic Protection of Metallic Fitting

# Anode Installed on Metallic Fitting





**Meter Vault Corrosion**



**Meter Vault with Anode**



# Gate Valve Corrosion



# Stainless Steel Corrosion



# Stray Current

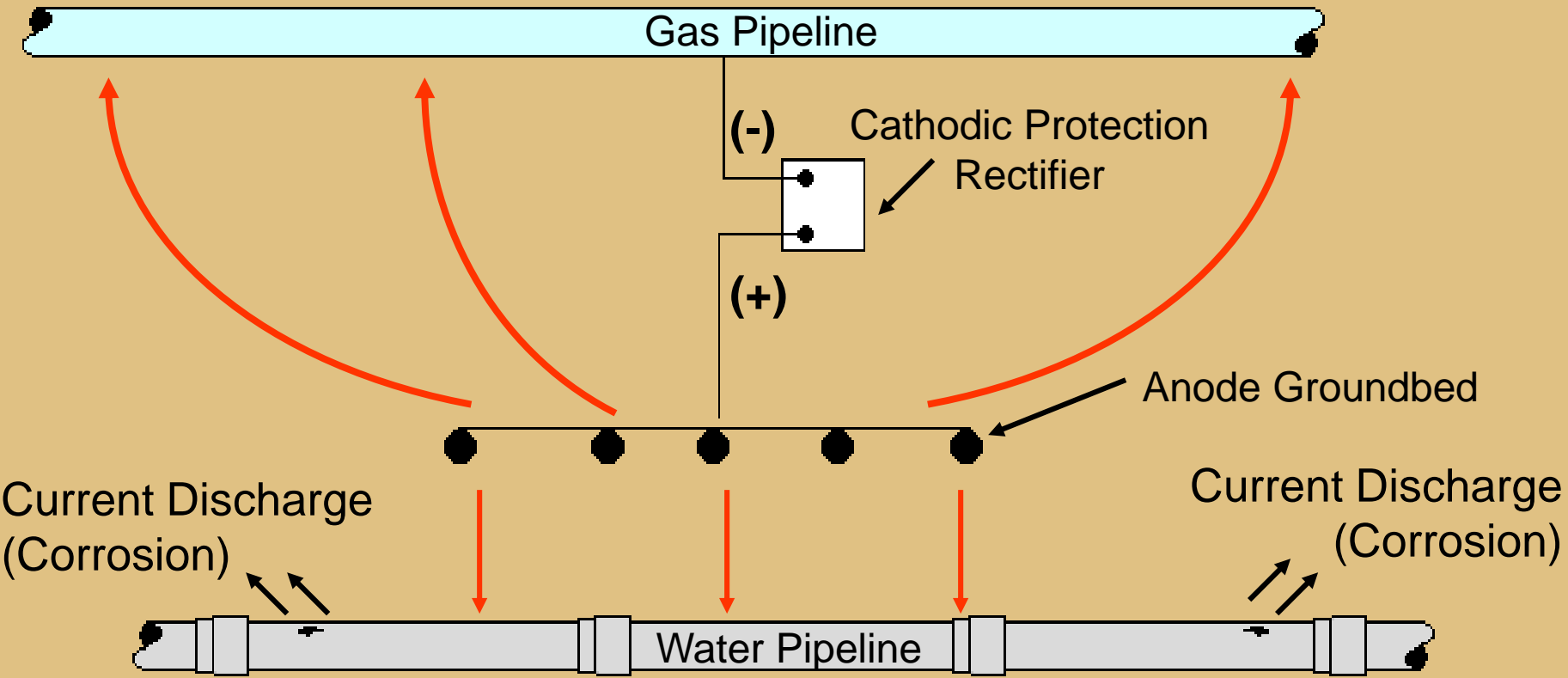


# Impressed Current CP System on Oil/Gas Lines can Create Stray Current Problem on Water Lines



**corrpro**<sup>®</sup>

An Aegion<sup>™</sup>  
Company



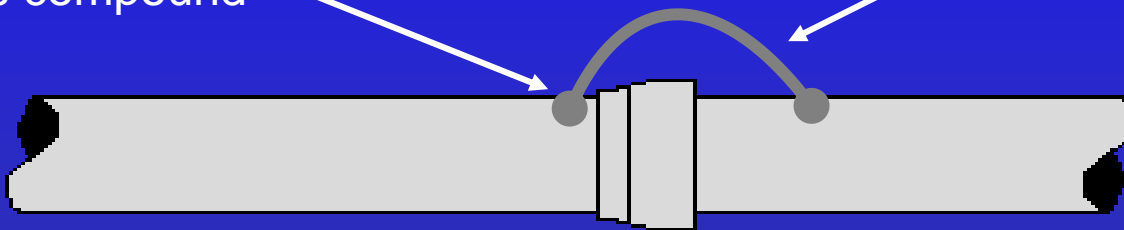
# Stray Current Due to Impressed Current Cathodic Protection System



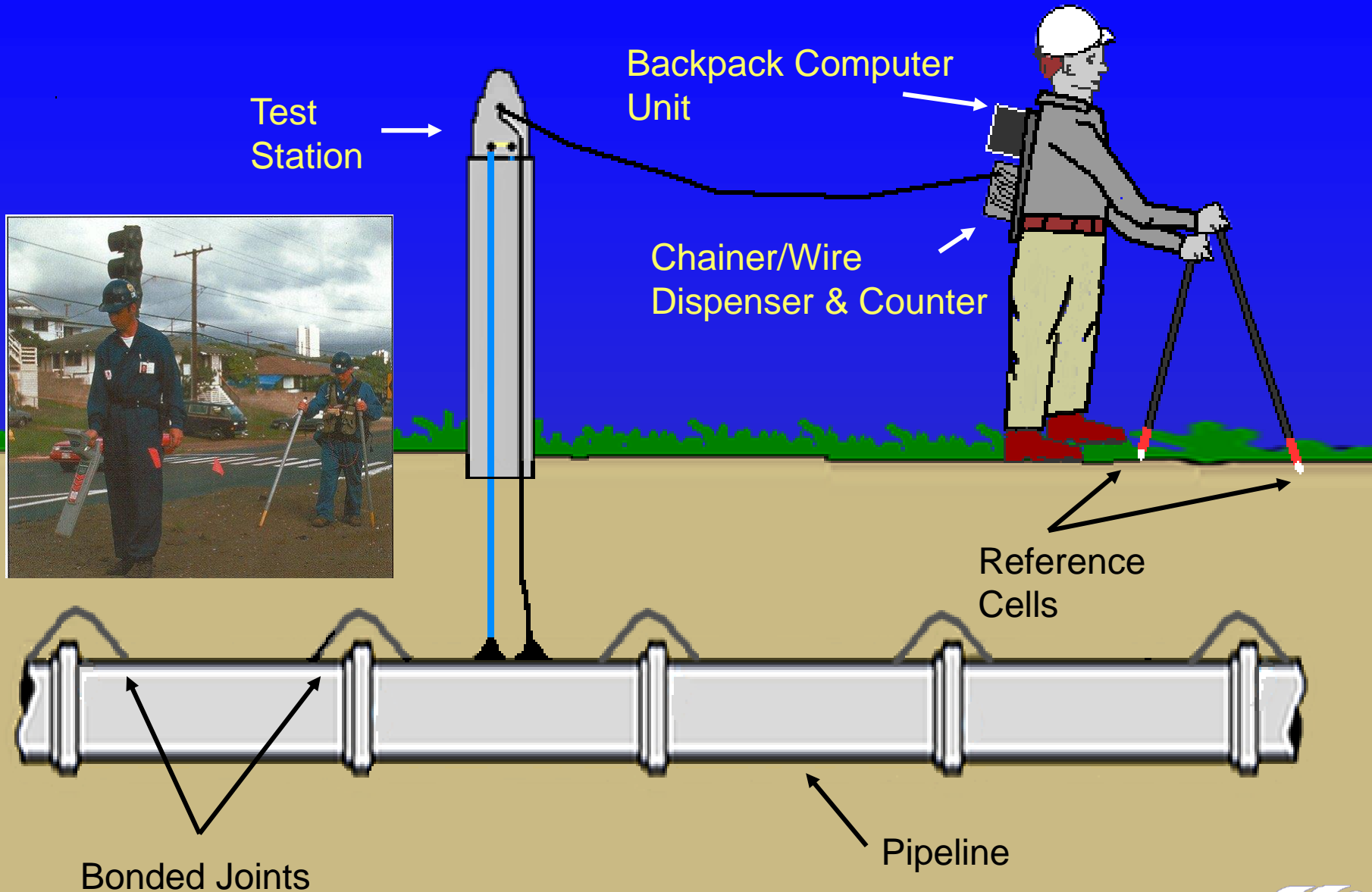
# Bonding Across a Bell and Spigot or Slip-joint

Thermite brazed connection coated with bitumous compound

Copper wire with direct burial insulation



# Computerized Potential Logging Survey



# AC Mitigation

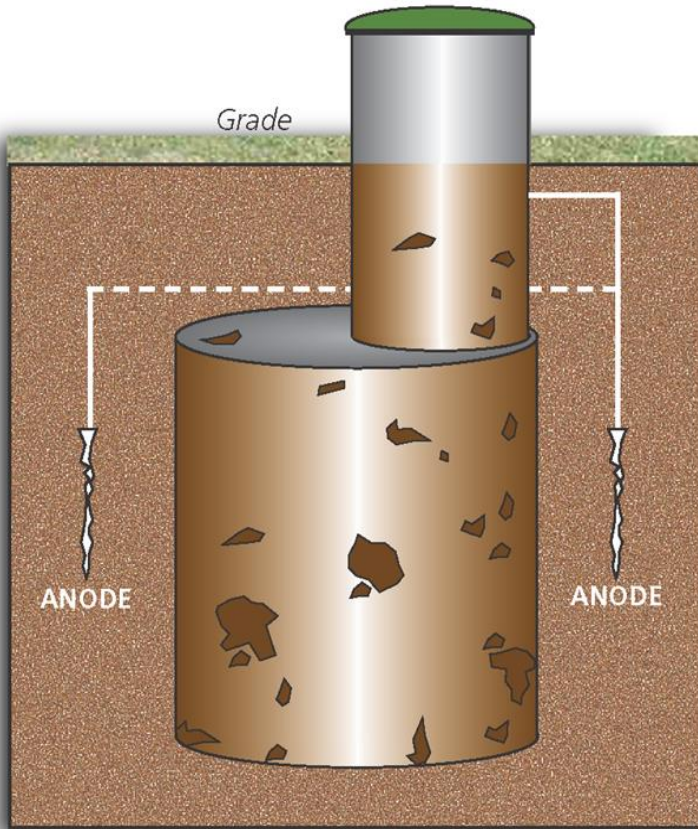




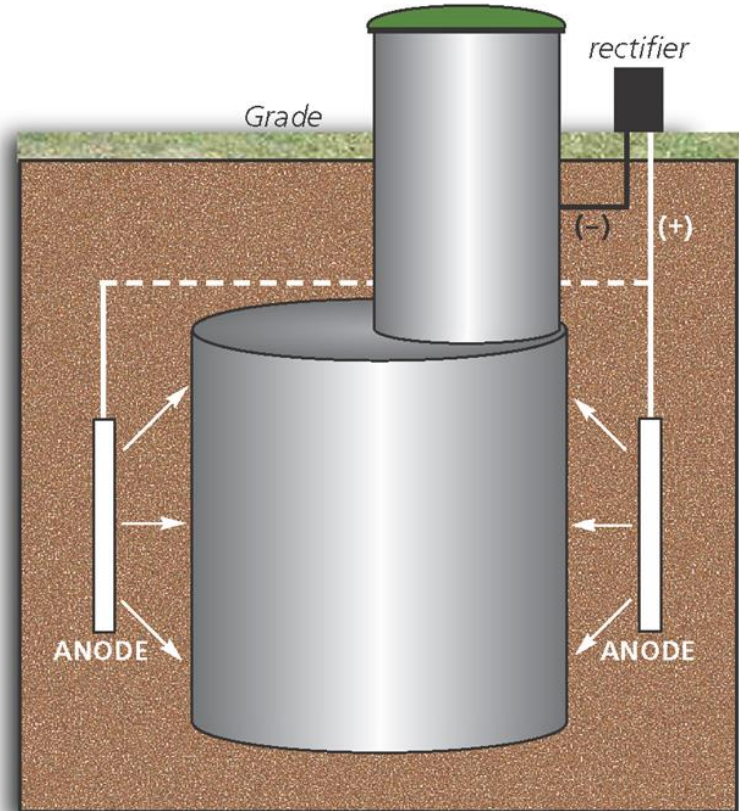
# Pumping Stations



# Depleted & Refurbished Cathodic Protection for Lift Stations



Depleted cathodic protection system allows corrosion to occur.



Effective cathodic protection system prevents corrosion and extends life of lift station.



**Transformer Rectifier**



# For New or Refurbished Tanks

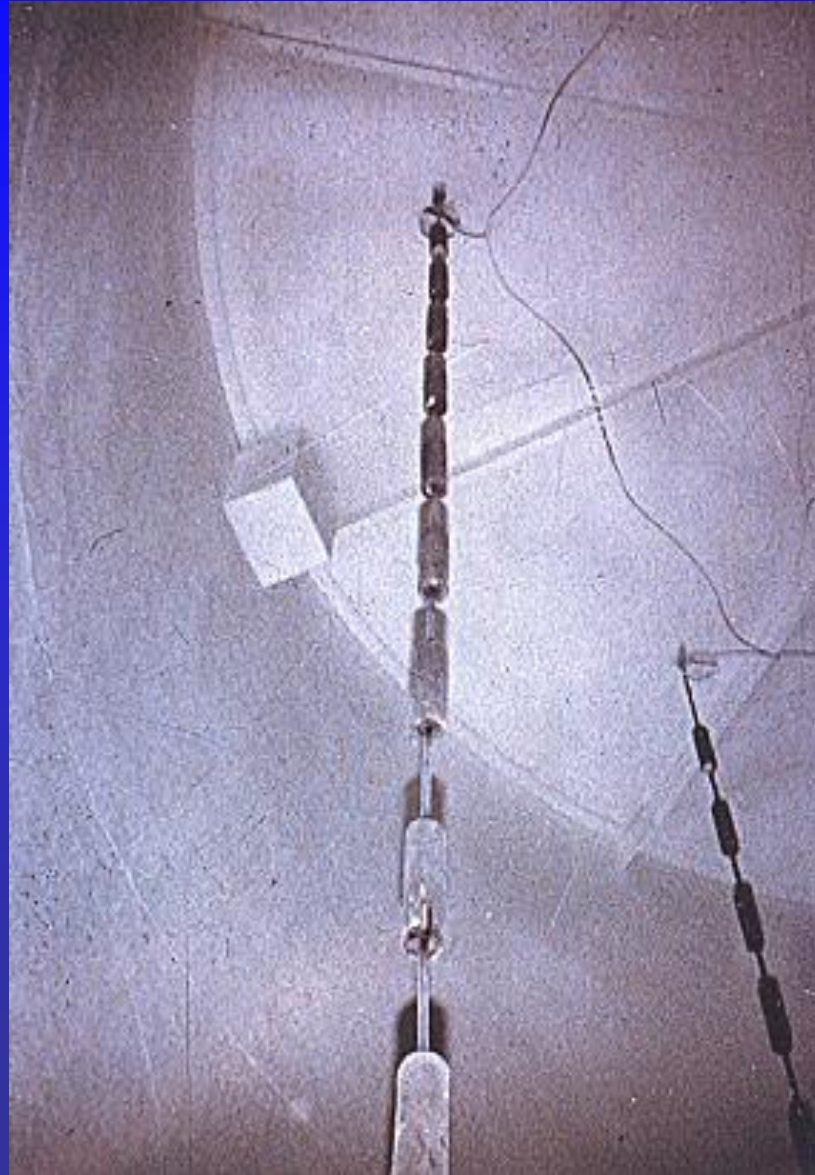


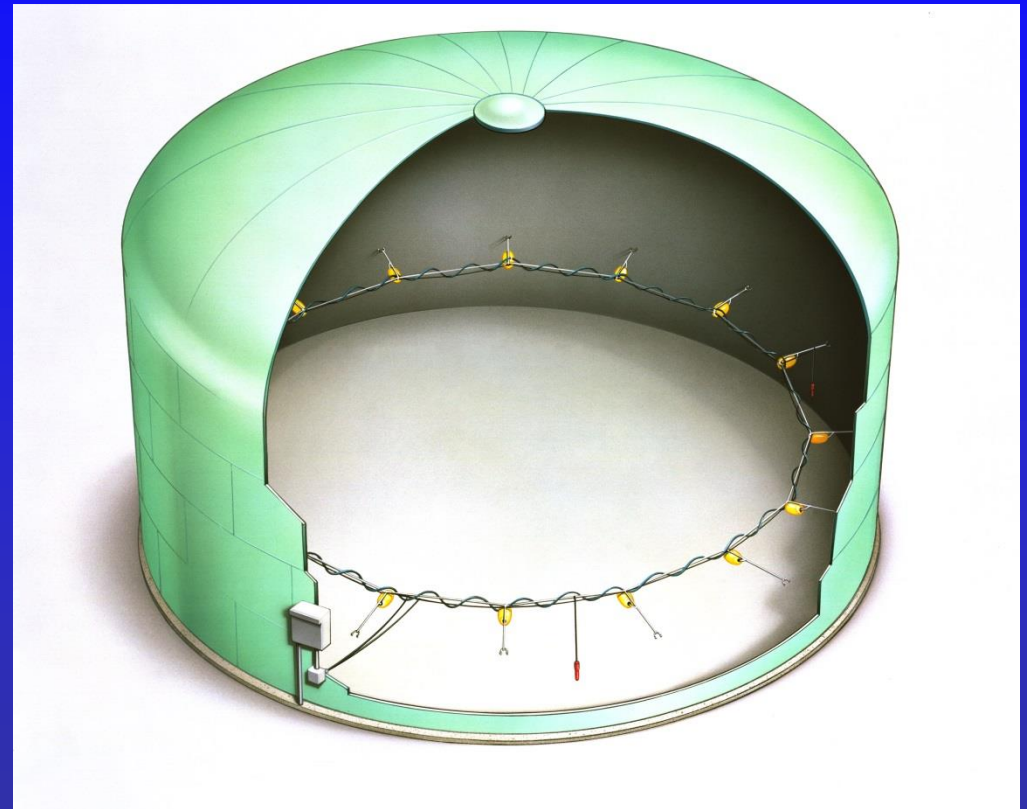
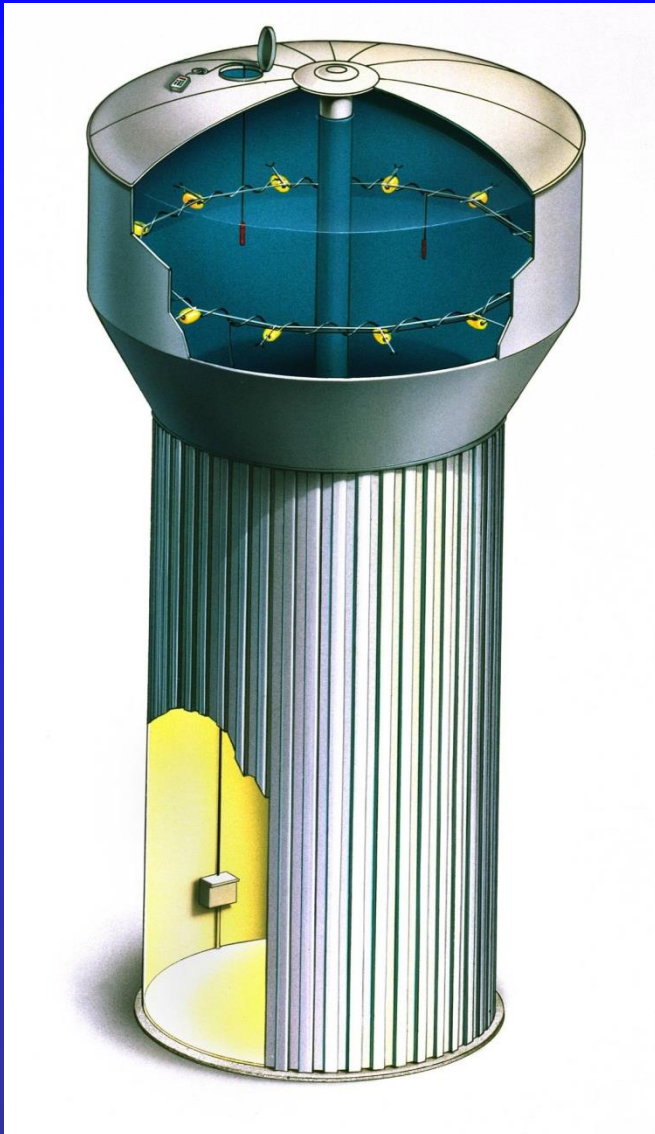
**corrpro**<sup>®</sup>

# Horizontally Submerged Cathodic Protection System in Water Storage Tank



# Vertically Suspended High Silicon Cast Iron Anode String



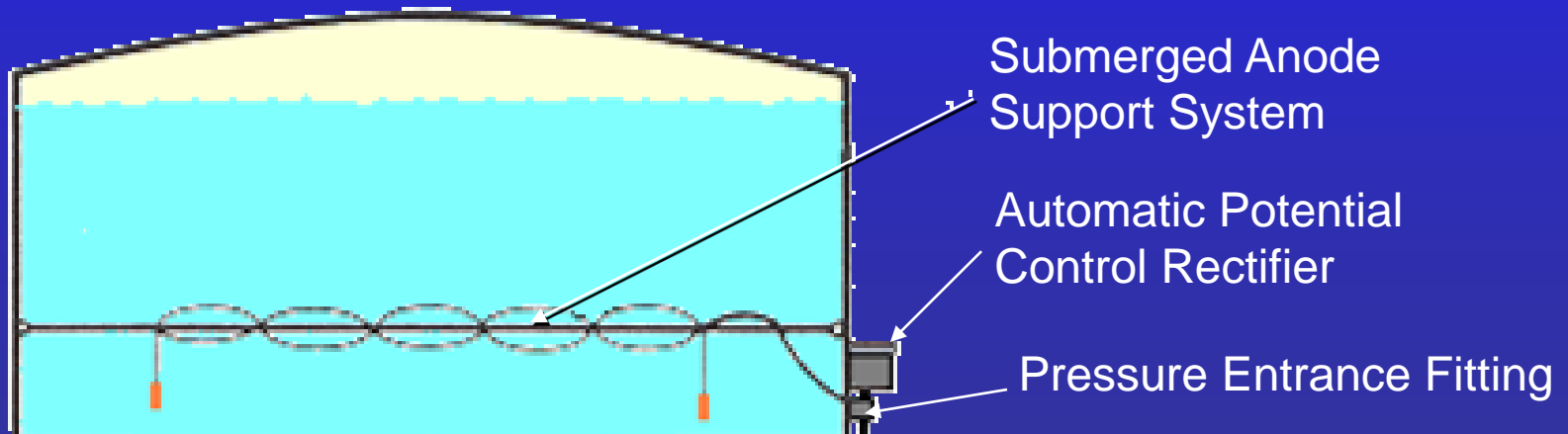
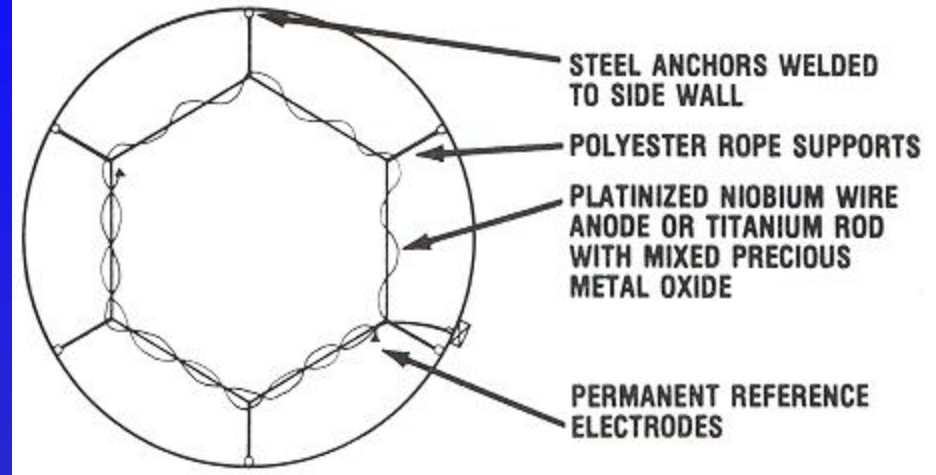


**CP Benefits:** - Triple life of coating  
- Reduce maintenance cost



# Suspended Horizontal Anode System

Top View Diagram



# Corrosion of Clarifier Center Well



# Annual Maintenance



# *Internal Corrosion of Force Mains....*



**Solids  
Buildup**

# Force Main Inspections



# 36" Above Ground Crossing

- Failure of force main at above ground crossing
- Crown of pipe attacked by hydrogen sulfide gas



# Rehabilitation Options



# Investigative Structure (Existing)

## Corrosion Assessment

- Review of General Characteristics of Water System
  - Age
  - Material Type
  - Wall Thickness
  - Construction Practices
- Review Break / Leak History
- Field Survey
  - Soil Conditions (Resistivity, Moisture Content, Chemical Analysis)
  - Electrical Test
- Data Analysis & Risk Management
- Priority Index (Identification of Opportunities to Reduce Replacement / Repair Costs)





# New Piping

## PHASE I

- Obtain drawings of proposed route
- Conduct independent field investigation:
  - a) Soil resistivity study
  - b) Identify foreign pipeline crossing
  - d) Identify AC potential influence
  - e) Collect soil samples (moisture content, chlorides, pH, sulfate ions concentration, conductivity)
- Stray current investigation



# Corrosion Protection Design Phase II

## Prepare Bid Quality Specifications for:

- Coatings or Polyethylene Encasement
- Test Stations (Monitor Corrosion Rates)
- Bonded Joints
- Stray DC/AC Mitigation
- Cathodic Protection
- Combination of Multiple Items
  
- Review Submittals/Onsite Periodic Inspection

# Summary

- ◆ **Reducing corrosion rates on existing water distribution piping will result in a reduction of the number of breaks and also extend the operational life.**
- ◆ **Corrosion control measures should be considered during the design stage for any new metallic piping and storage tank installations.**

**Traffic  
Disruptions**



**Water Loss**



**Fire  
Protection**



**Legal &  
Environmental  
Claims**

**Damages**



# ***QUESTIONS ?***

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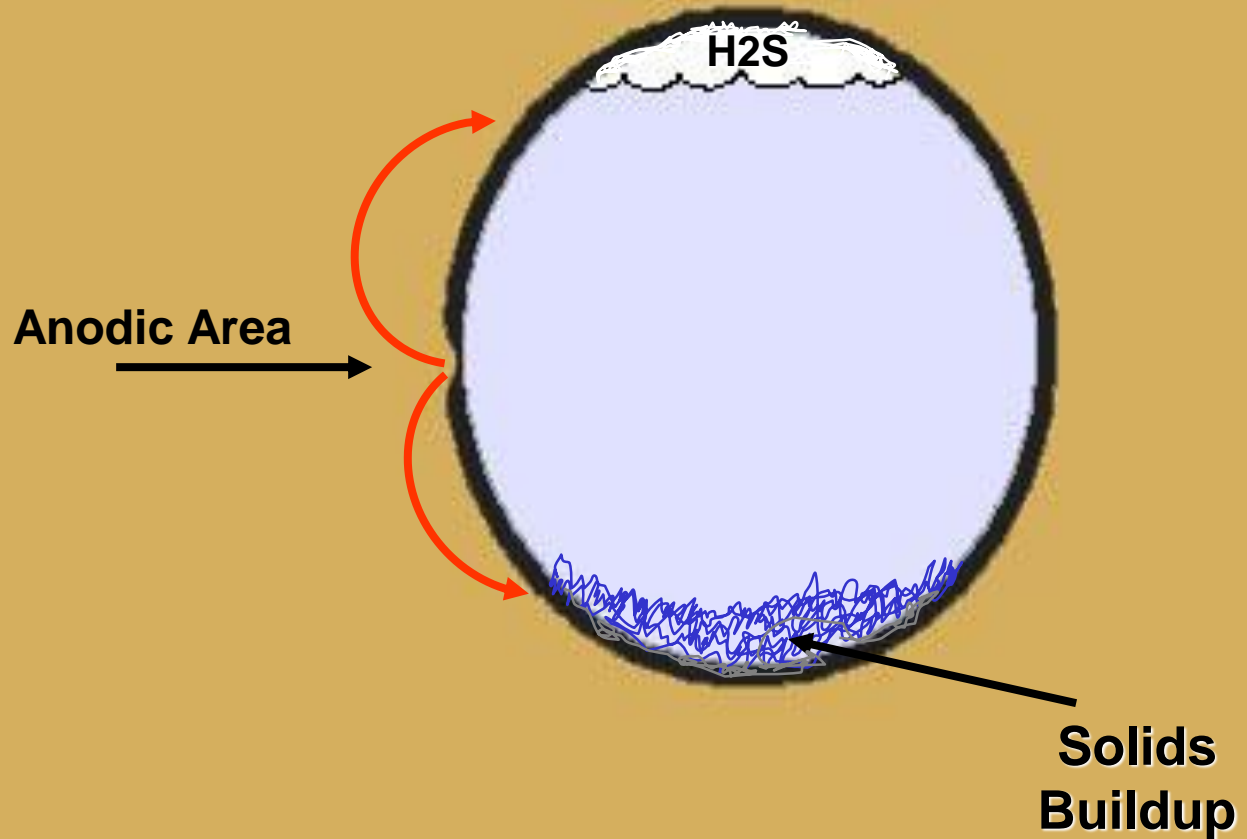
***corrpro***<sup>®</sup>

# Impressed Current CP System on Oil/Gas Lines can Create Stray Current Problem on Water Lines





# *Internal & External Corrosion of Force Mains....*



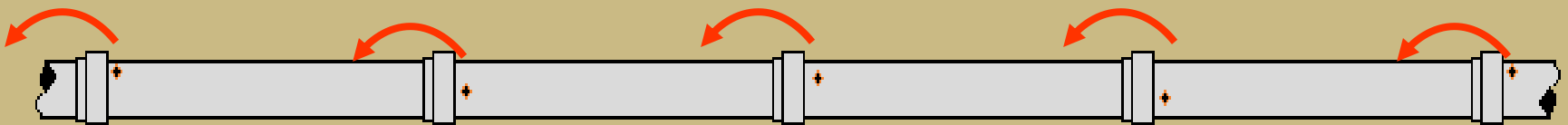
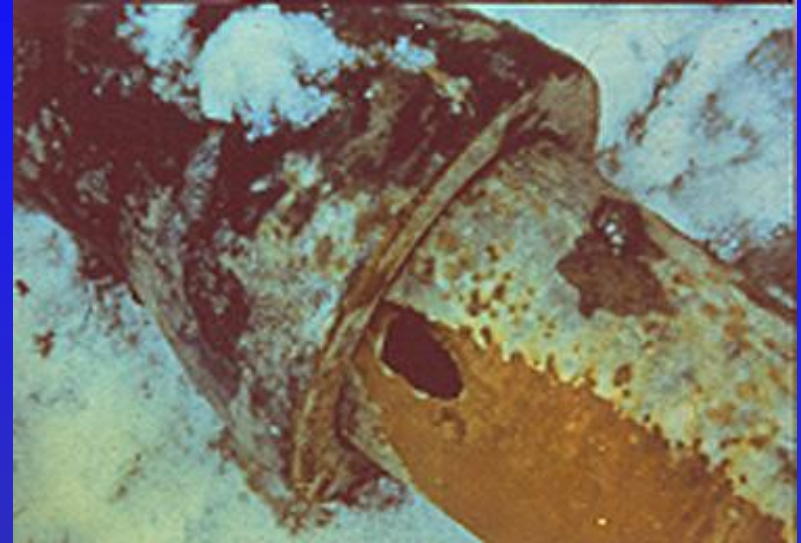


# 36" Above Ground Crossing

- Failure of force main at above ground crossing
- Crown of pipe attacked by hydrogen sulfide gas



# Stray Current



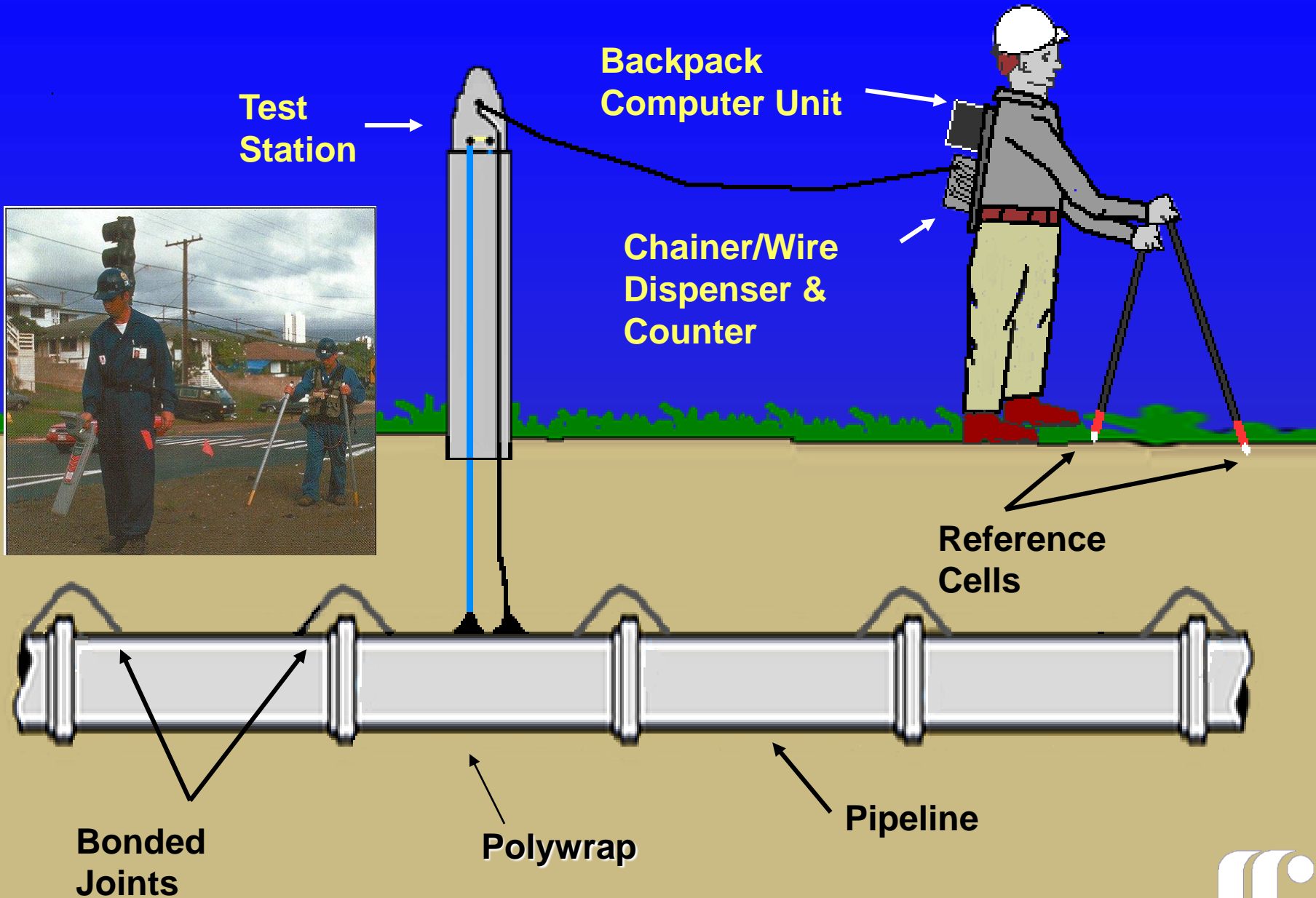
# 24" Ductile Iron Force Main



- Internal failure following loss of internal mortar lining
- Failure was along top of pipe due to formation of hydrogen sulfide gas



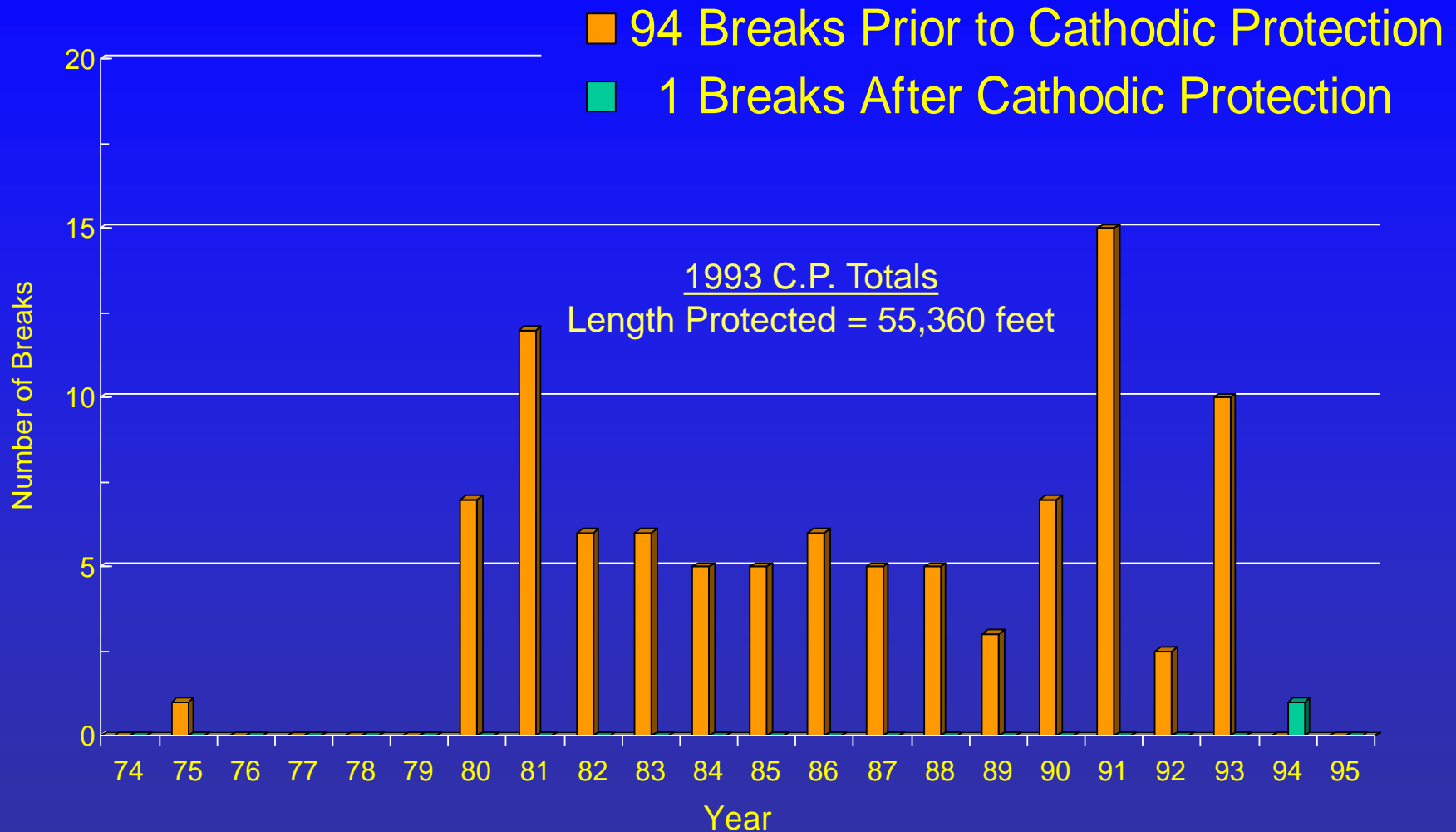
# Computerized Potential Logging Survey



# Dual 26" Force Mains

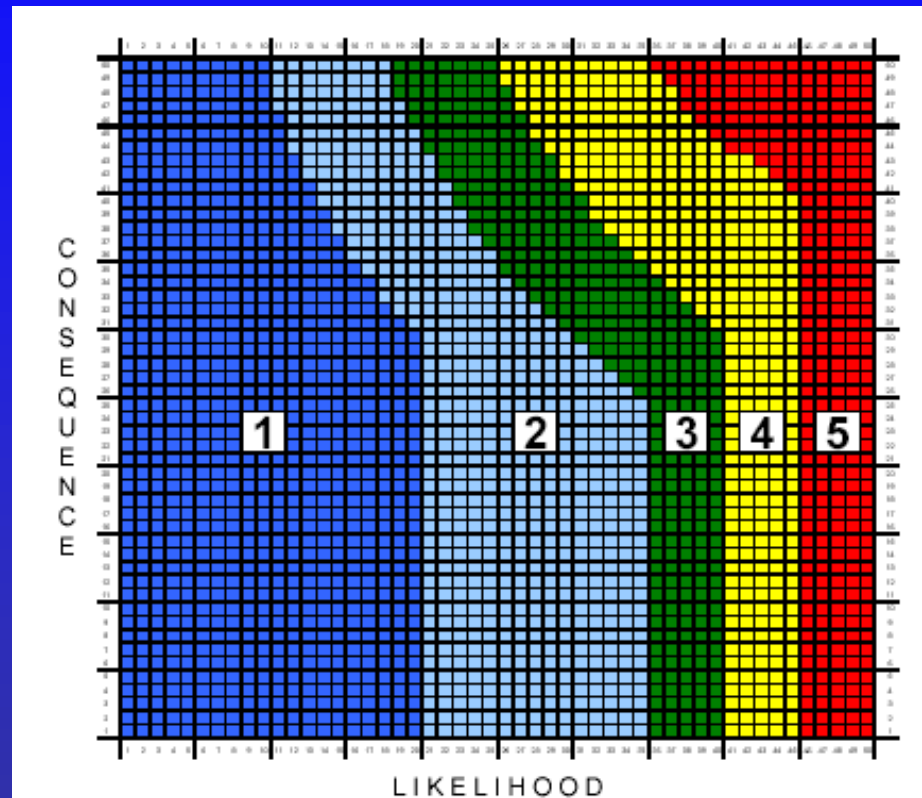


- Internal failures at bottom of pipe
- Failure following loss of internal mortar lining
- Failures concentrated at low areas (dips) in pipeline alignment
- Cause is corrosion under accumulated solids



**Break Records for Water Mains Cathodically Protected in 1993**

# Design Decision Model

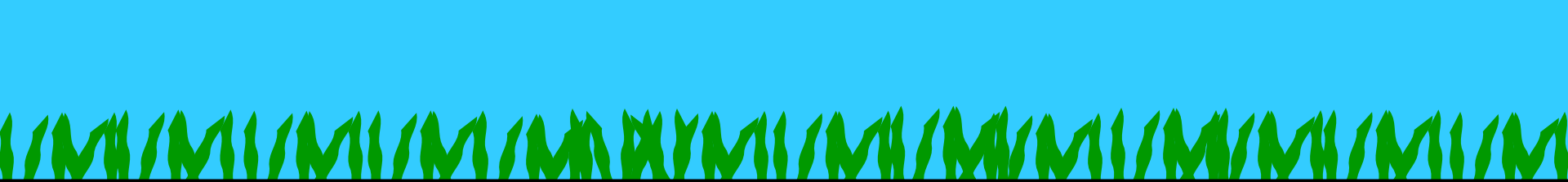


*For Ductile Iron Pipe*

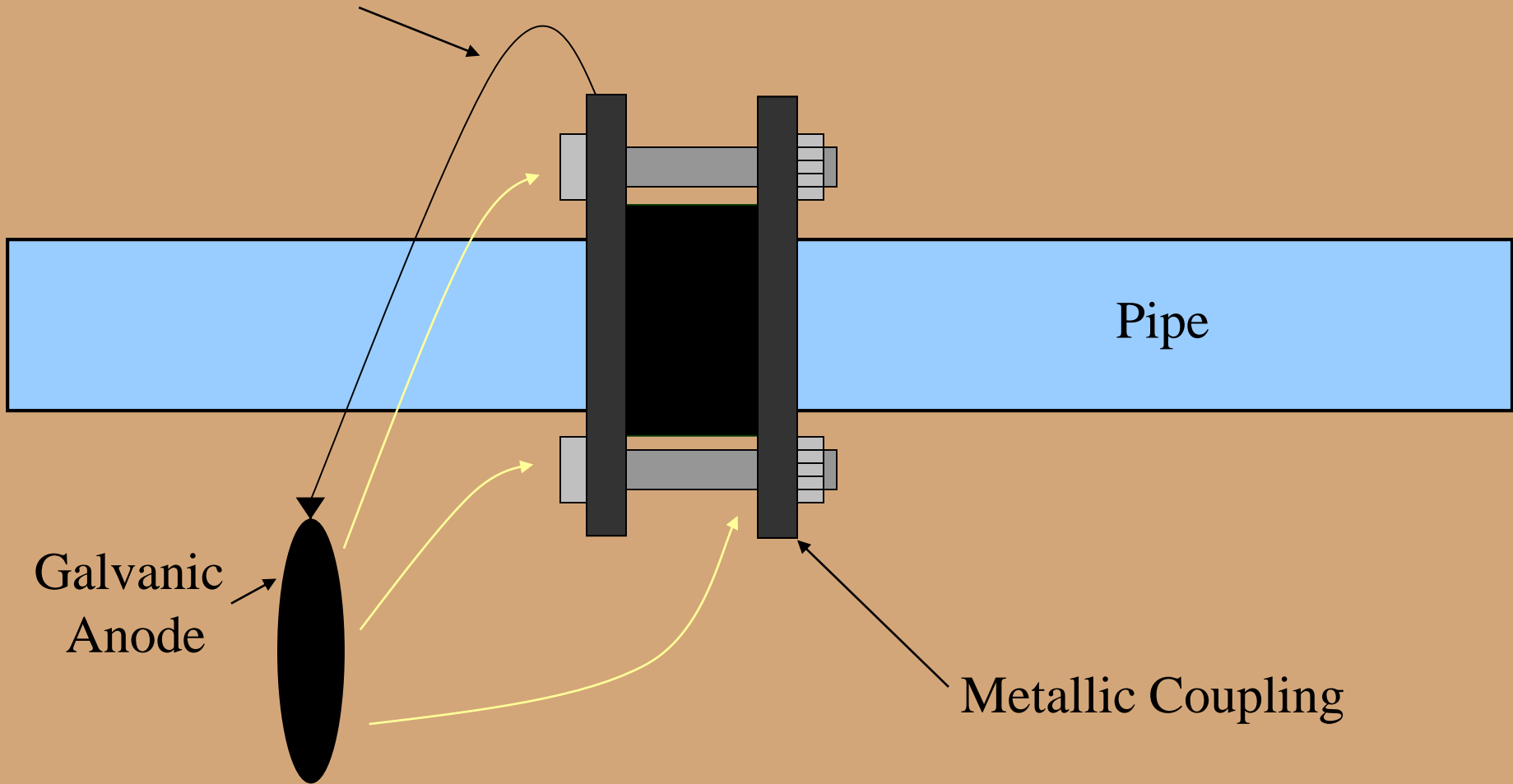
# Insituform







Anode Lead Wire Connection



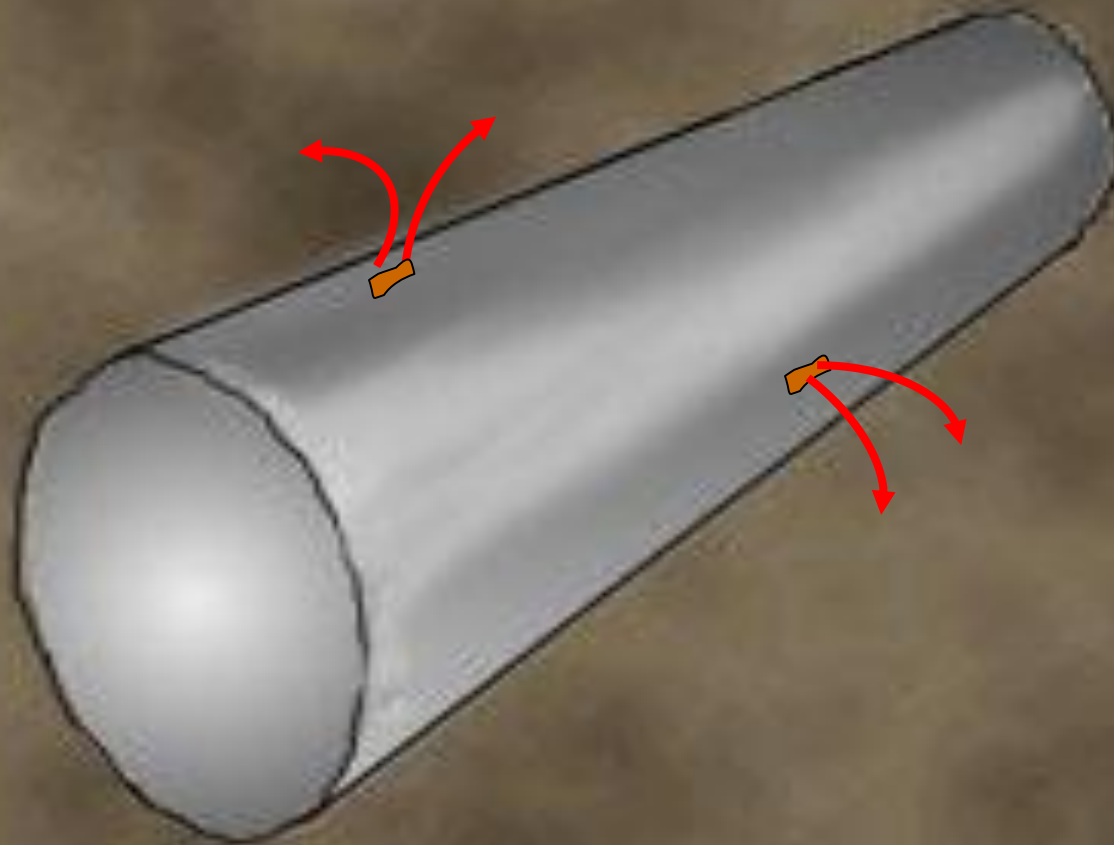
Galvanic Anode

Pipe

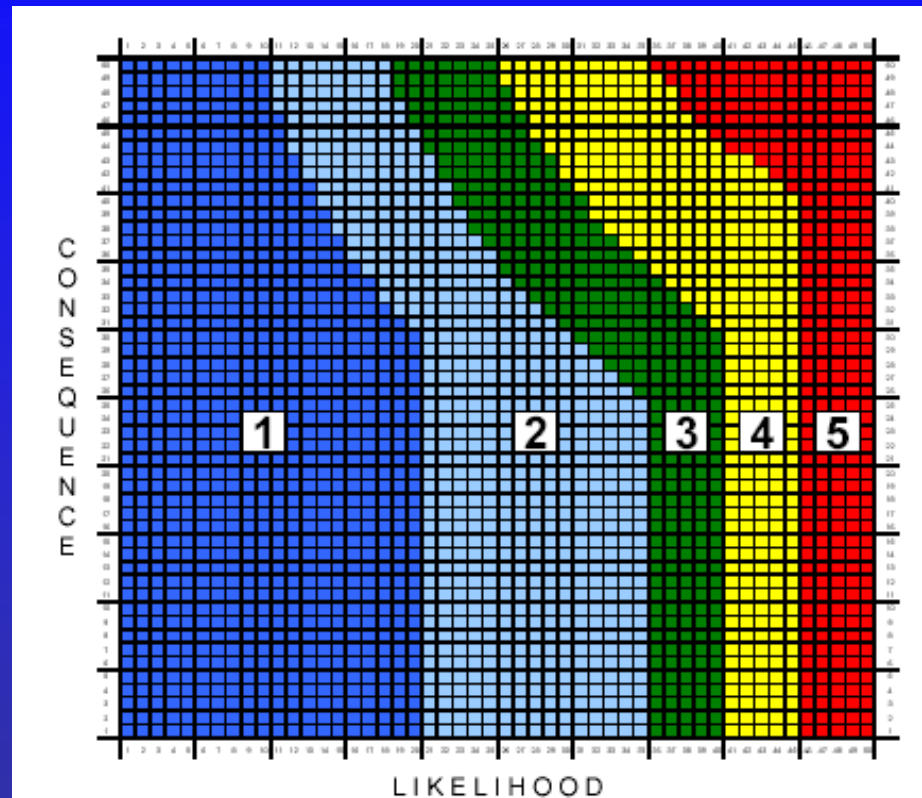
Metallic Coupling

Cathodic Protection of Metallic Fitting

# Corrosion of Metallic Structure



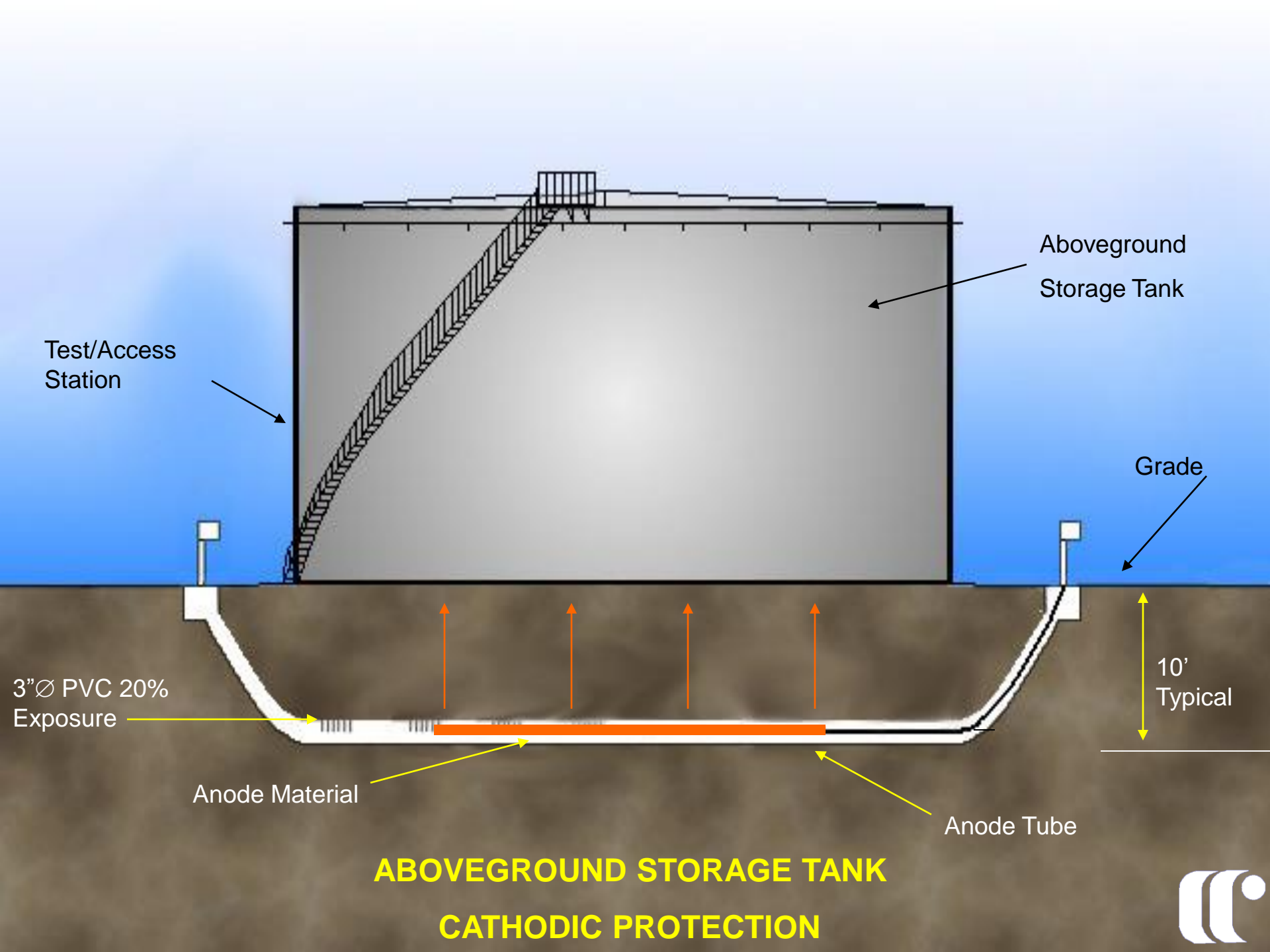
# Design Decision Model



*For Ductile Iron Pipe*



27 10:23AM



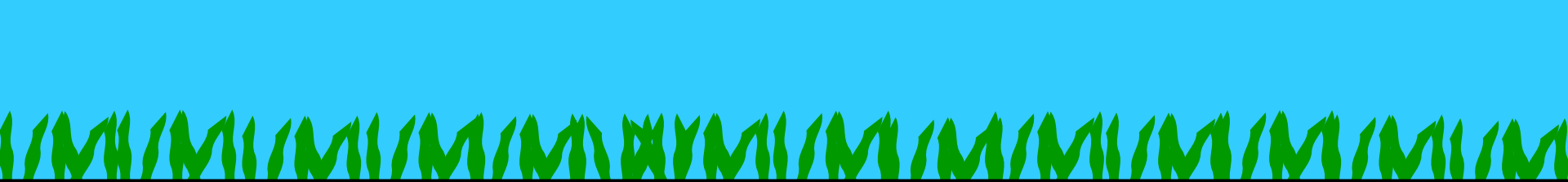
The estimated annual cost to repair water piping breaks in North America alone is estimated to be\*:

**\$1.5 Billion**

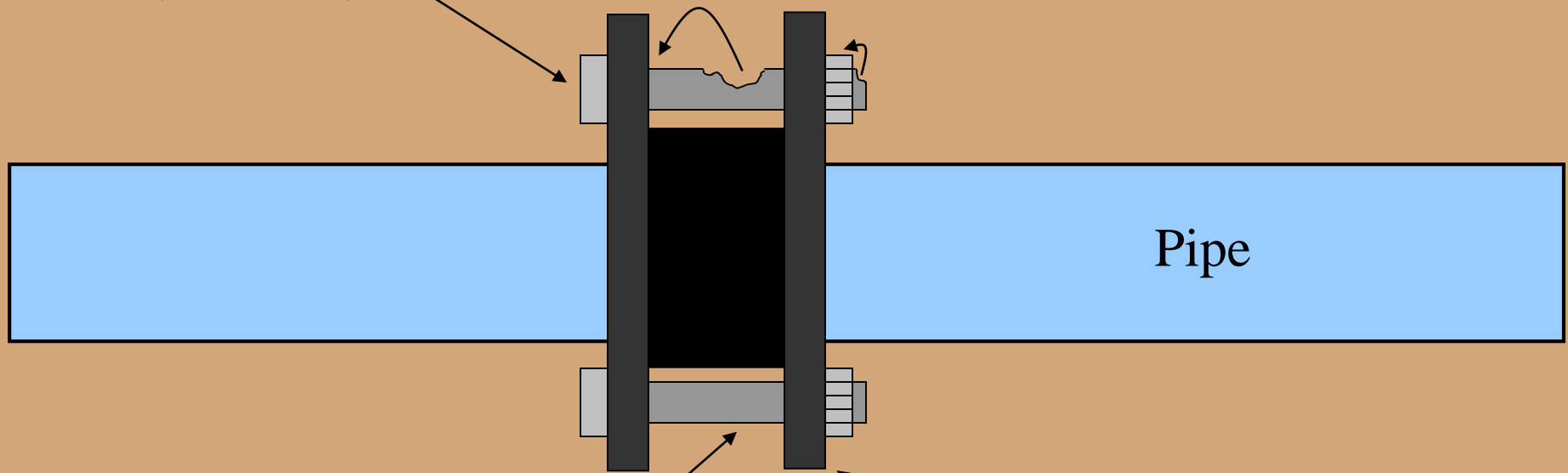
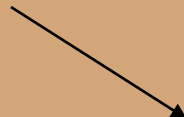
& based on 250,000 breaks at a repair cost of \$5,875.00 U.S.D. each

**Budget Estimate for Complete  
Cathodic Protection System for  
1MMG Water Tank**

**\$12,000**

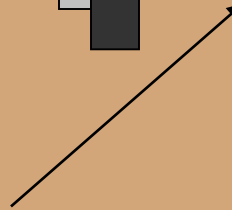


Lower Stress Area  
(Cathode)

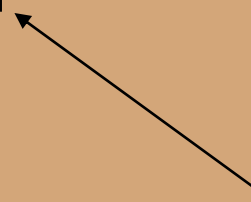


Pipe

Threaded Bolt  
Higher Stress Area  
(Anode)



Metallic Coupling



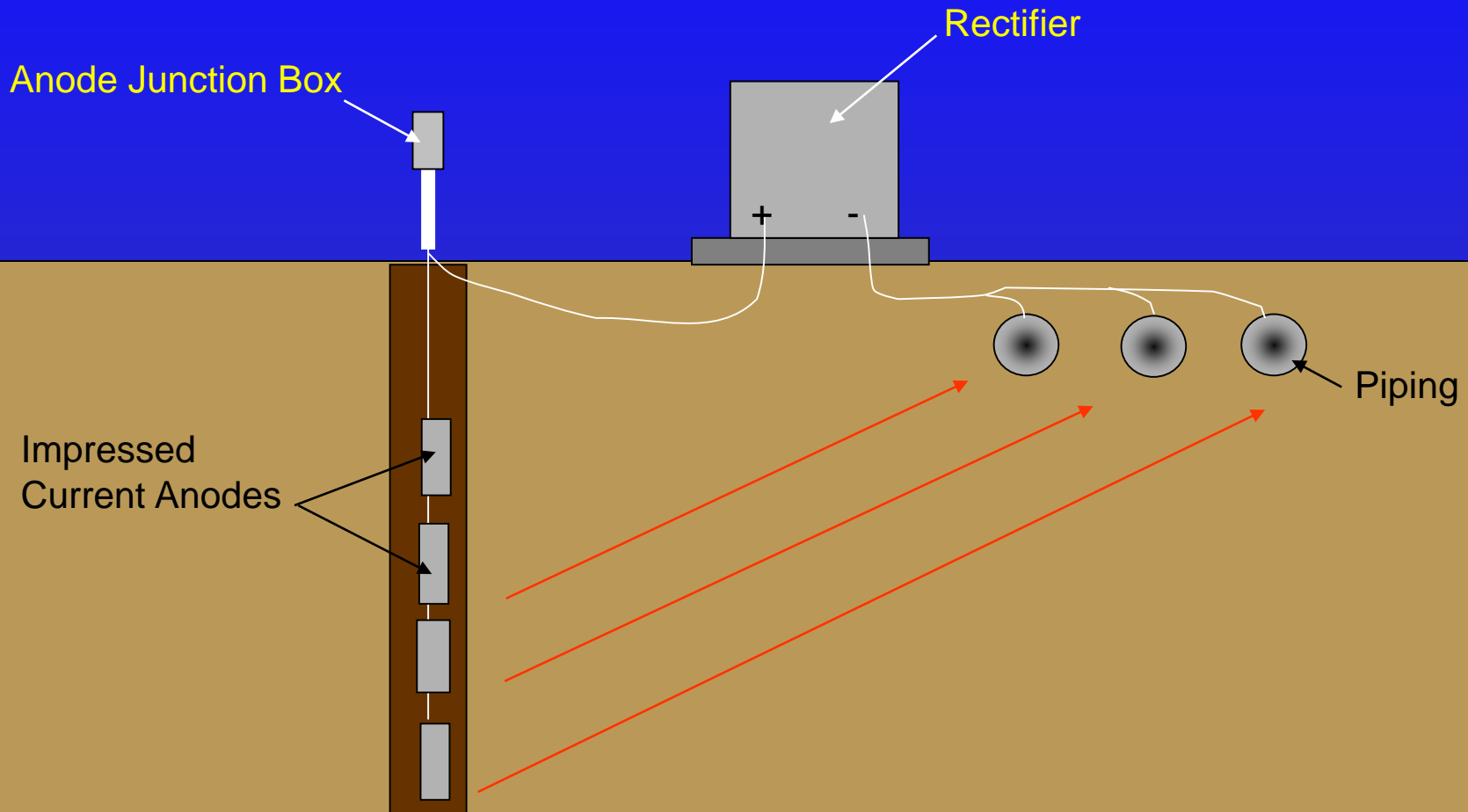
Stress Corrosion



# Insituform



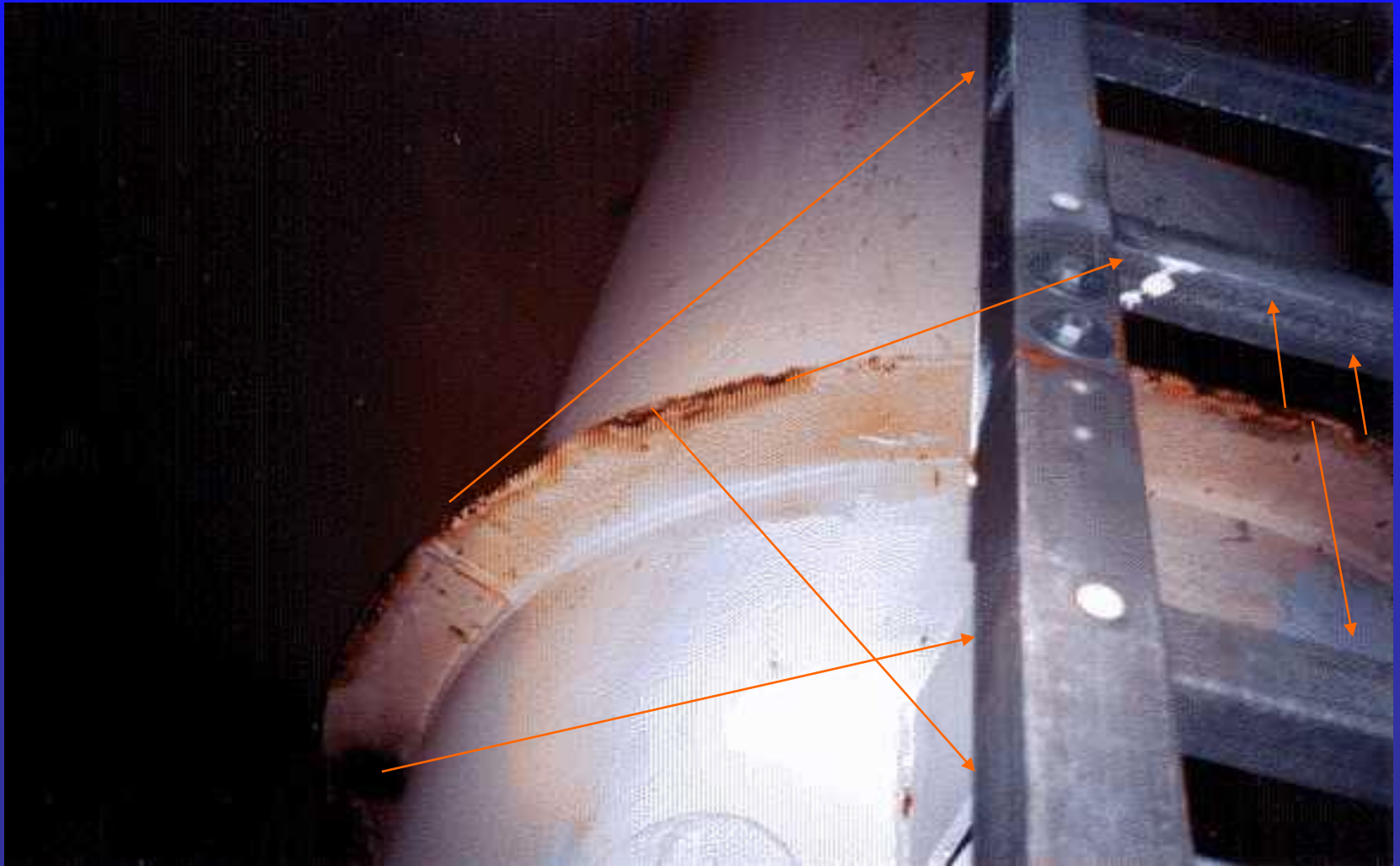
# Yard Piping Deep Anode Groundbed Impressed Current System





**Factory Installed Cathodic Protection Systems**

# Bi-Metallic Corrosion Between Carbon Steel Tank & Stainless Steel Ladder



# ***Corrosion Control for Water System Piping Results in Reduction of Water Loss***

***Presented By:***

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***<http://www.corrpro.com>***



# Repair of Break Should Include Anode Installation



**Incomplete**



**Complete**



**Annual Cathodic Protection Survey**



# ***Corrosion Control for Water & Wastewater Systems***

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**Corrosion** is the leading contributor to cast and ductile iron water system breaks!



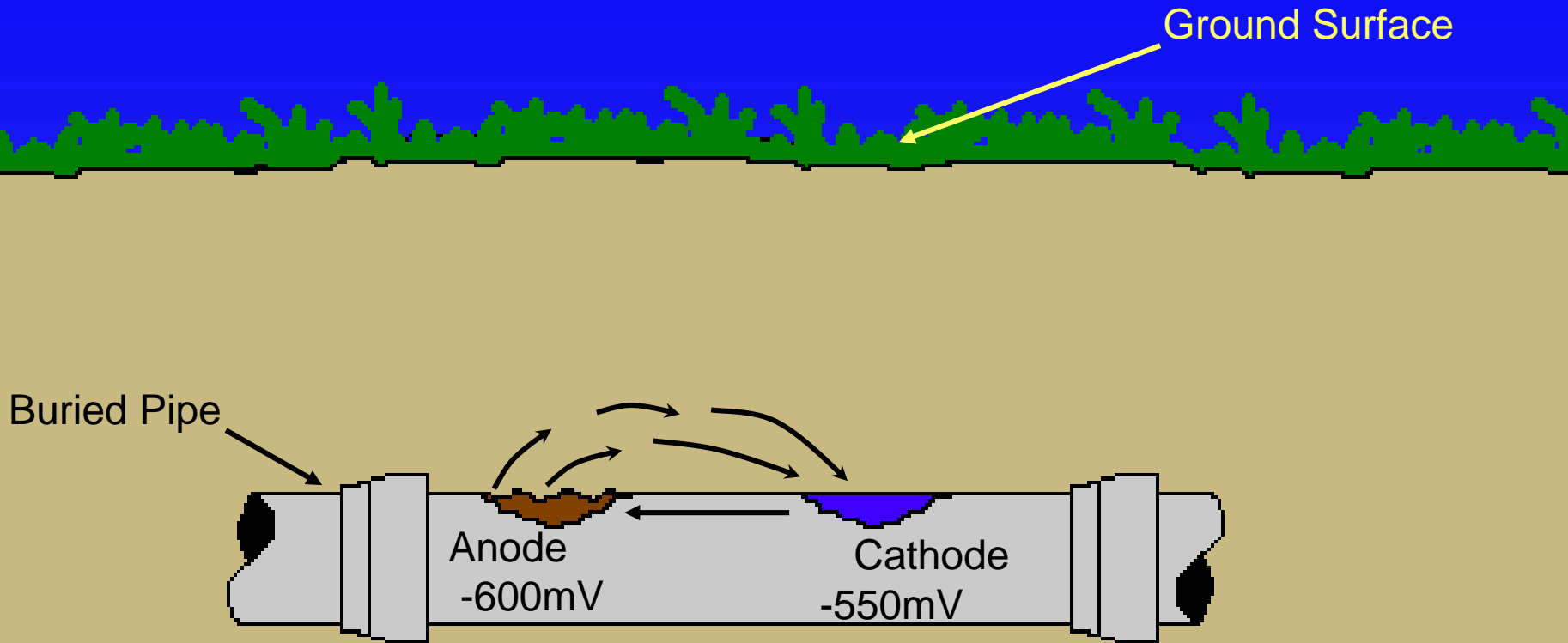
**Bolt & Nut Corrosion**



# Inspection of CP System



# Basic Corrosion Cell



- 1) Anode
- 2) Cathode
- 3) Electrolyte
- 4) Electrical Connection

# ***Structures***

- ***Piping (Distribution/Transmission)***
- ***Metallic Fittings***
- ***Water Storage Tanks***
- ***Clarifier Units***
- ***Lift Stations***

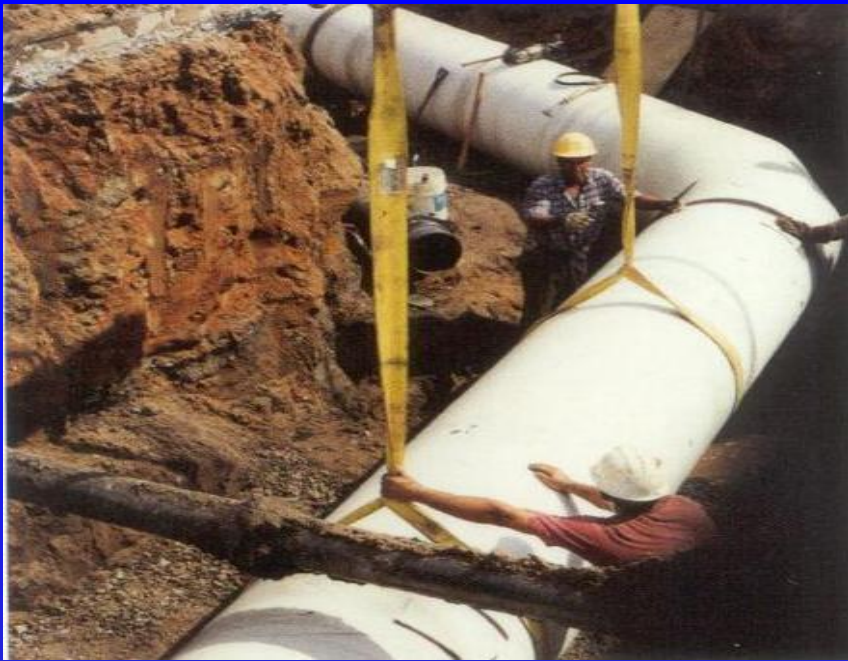
# Corrosion Can be Defined as Either:

## ▶ Practical

Tendency of a Metal to Revert  
to its Native State

## ▶ Scientific

Electrochemical Degradation  
of Metal as a Result of a Reaction  
with its Environment



# Copper Service Connections





# Anode Installation Prevents Corrosion on Copper Service Line

Non metallic or  
Polyethylene Encased  
Ductile Iron Main

Anode Connection to Line

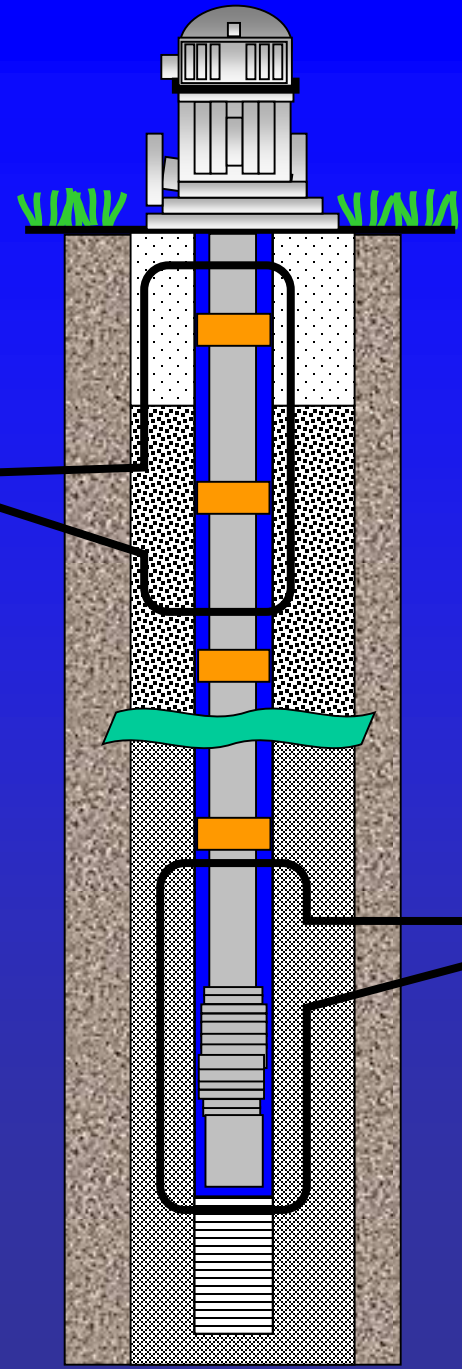
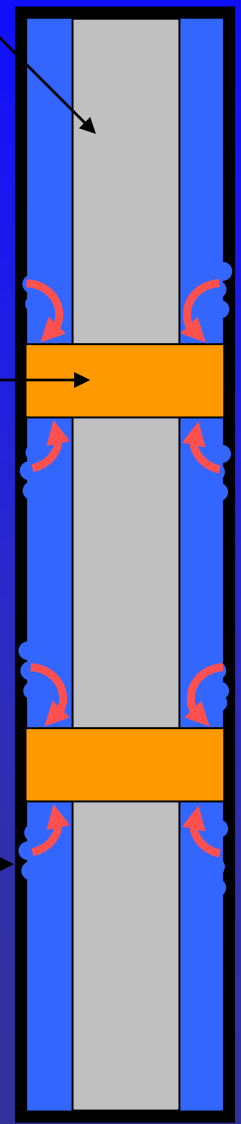
Anode



**Stainless Steel Bowl Shaft**

**Bronze Shaft Spacers (Cathode)**

**Mild Steel Column Pipe (Anode - Corrodes)**



**Bowl Shaft (Stainless Steel) Cathode**

**Crown (Steel) Anode**

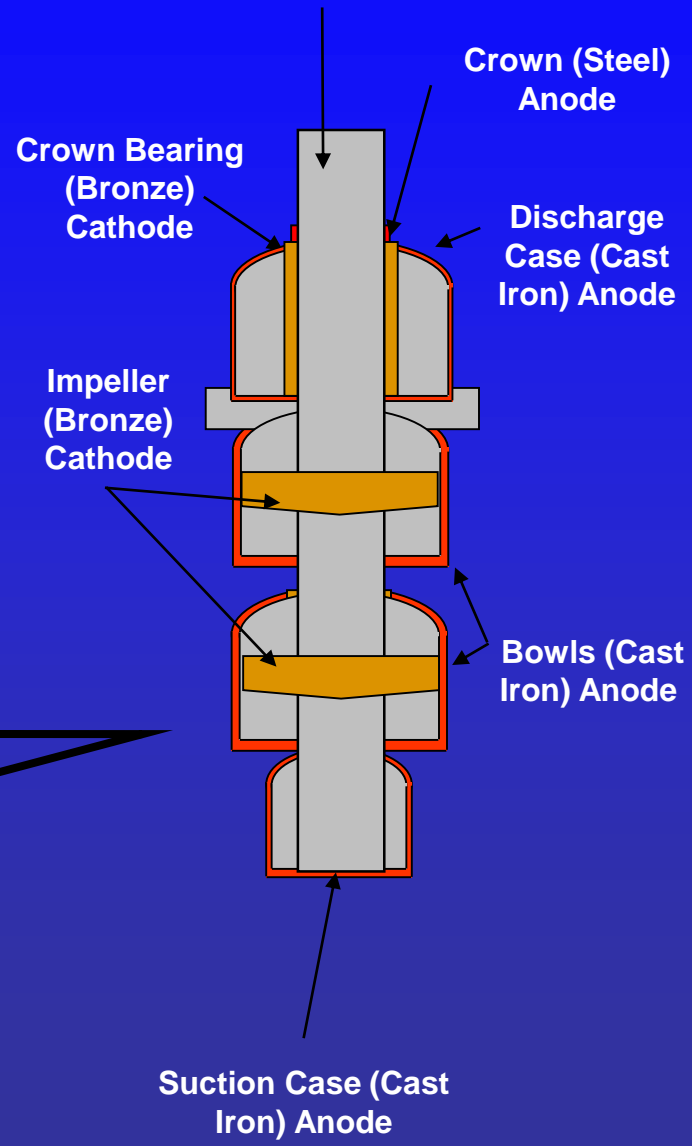
**Crown Bearing (Bronze) Cathode**

**Discharge Case (Cast Iron) Anode**

**Impeller (Bronze) Cathode**

**Bowls (Cast Iron) Anode**

**Suction Case (Cast Iron) Anode**



# Water Wells



# Stainless Steel Corrosion







# History of Iron Pipe

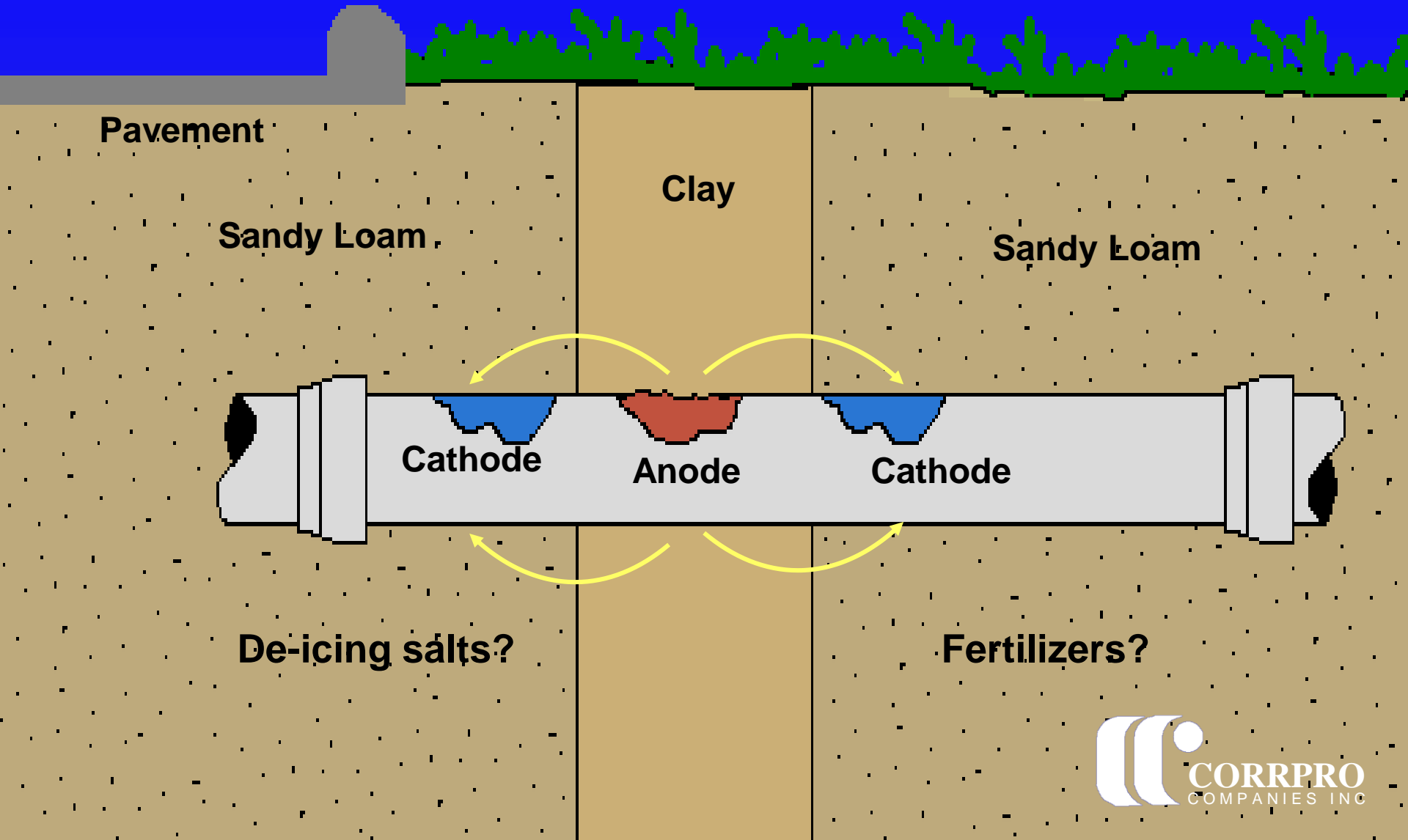
## Cast Iron

- Introduced to North America during the 1800's and installed till the 1970's.
- Early on, statically cast process produced a thick walled, heavy pipe.
- No longer produced in North America.

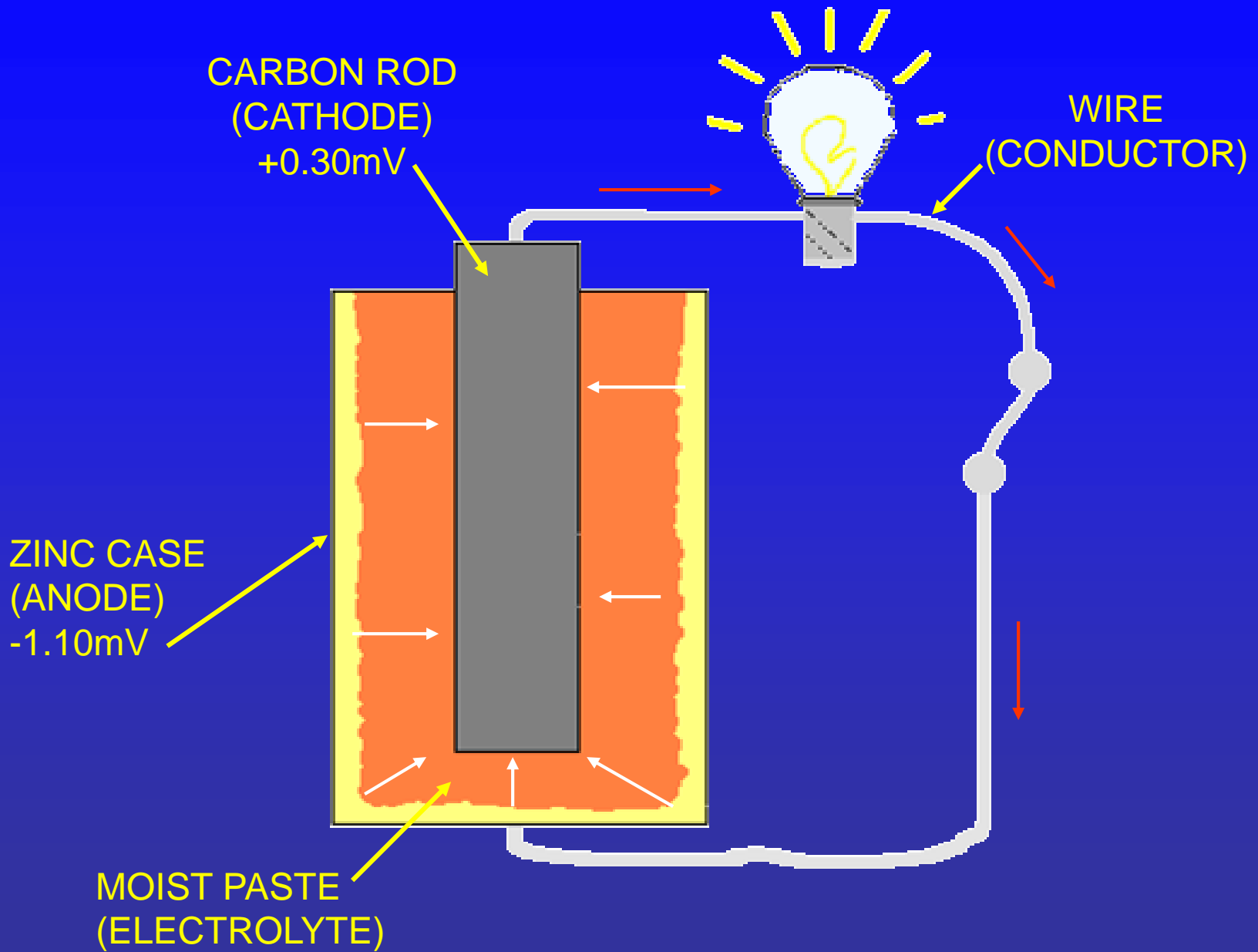
## Ductile Iron

- Introduced in 1955 as an improvement to cast iron.
- Centrifugal casting process produces a thinner walled, lighter pipe which is stronger and more ductile than cast iron.

# Dissimilar Soils







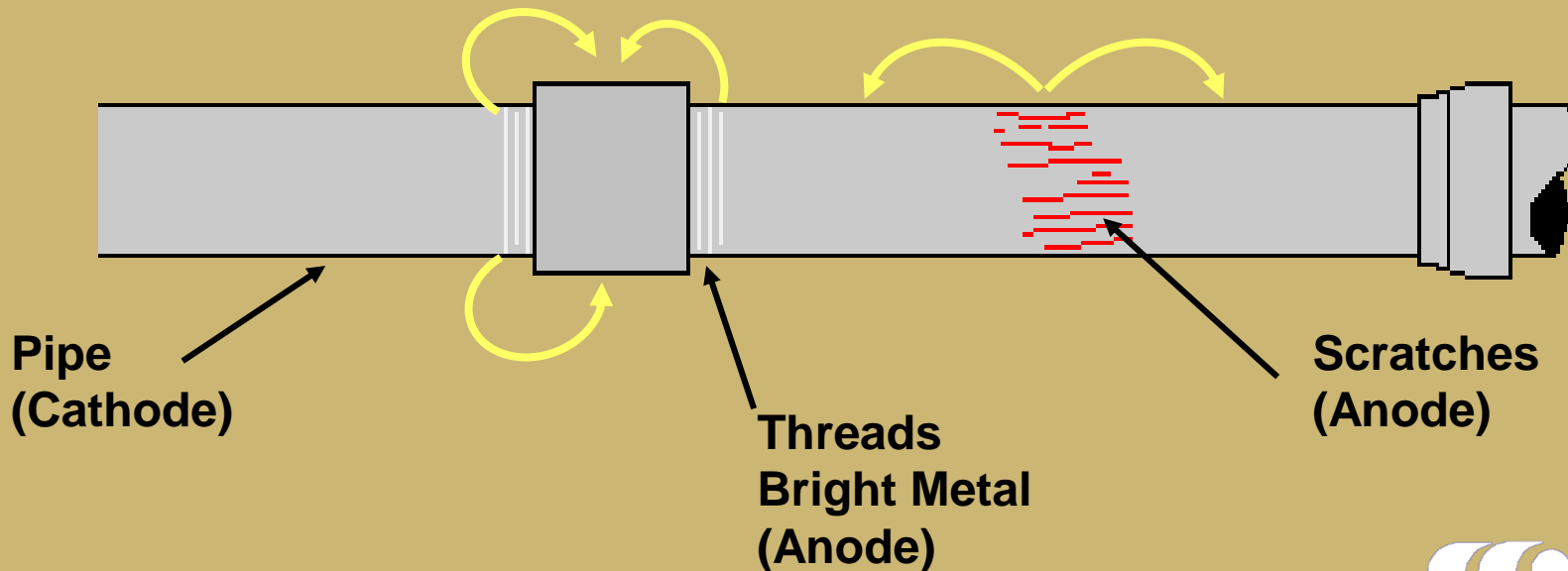


Corrosion of iron when coupled to copper service line.

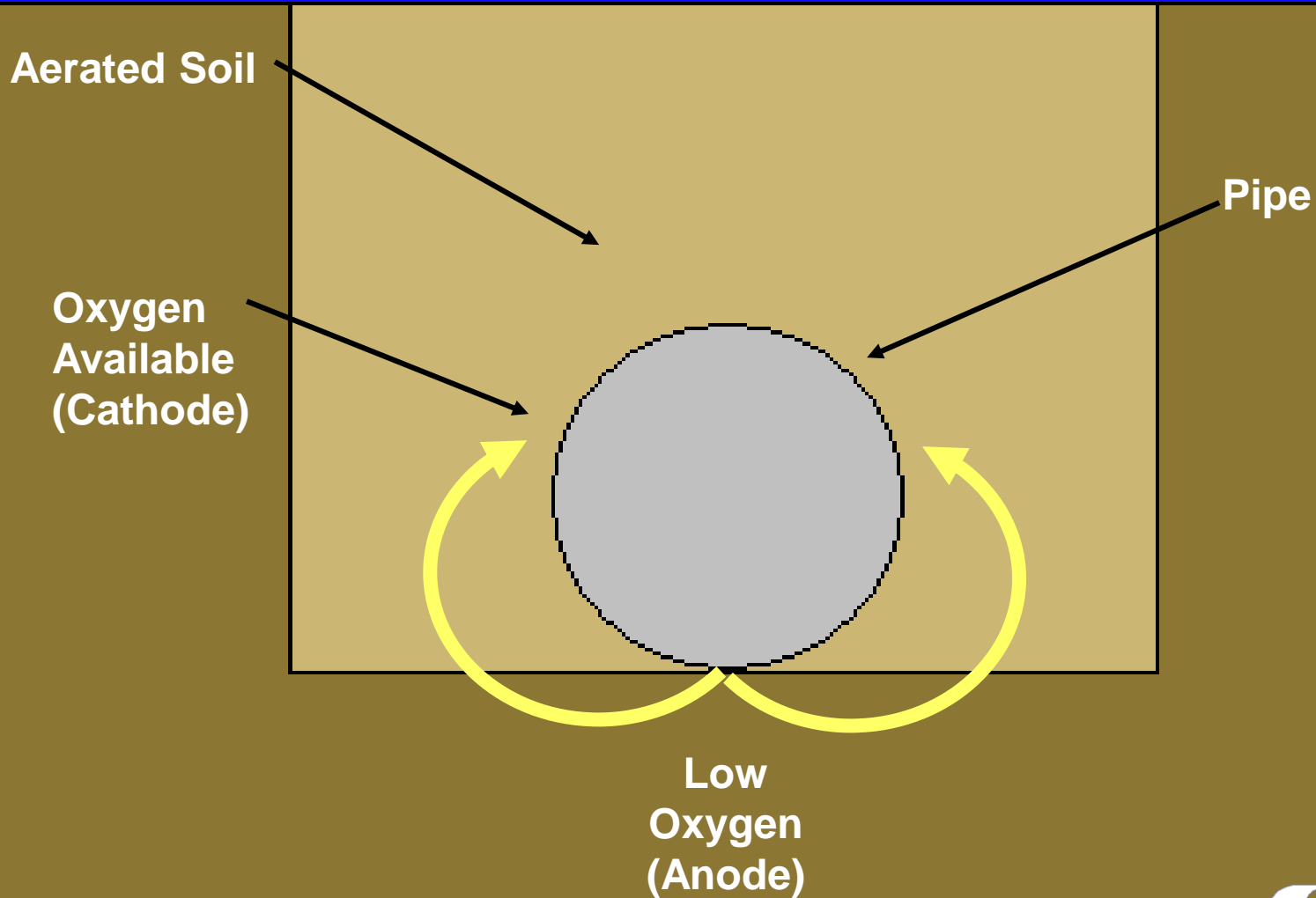
# Corrosion Pitting



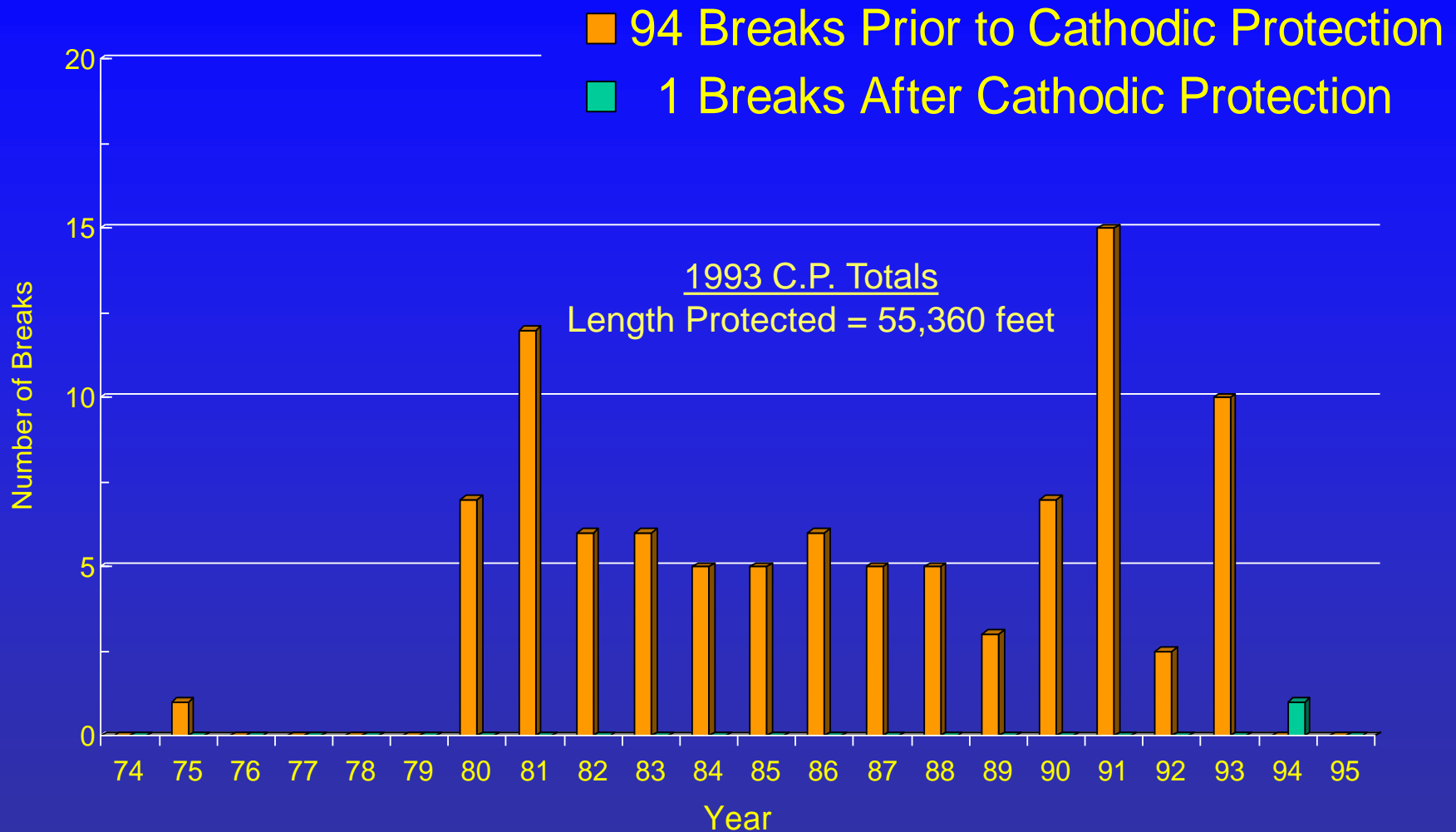
# Dissimilar Surface Conditions



# Corrosion Caused by Differential Aeration







## Break Records for Water Mains Cathodically Protected in 1993

**Traffic  
Disruptions**



**Water Loss**



**Fire  
Protection**



**Legal &  
Environmental  
Claims**

**Damages**





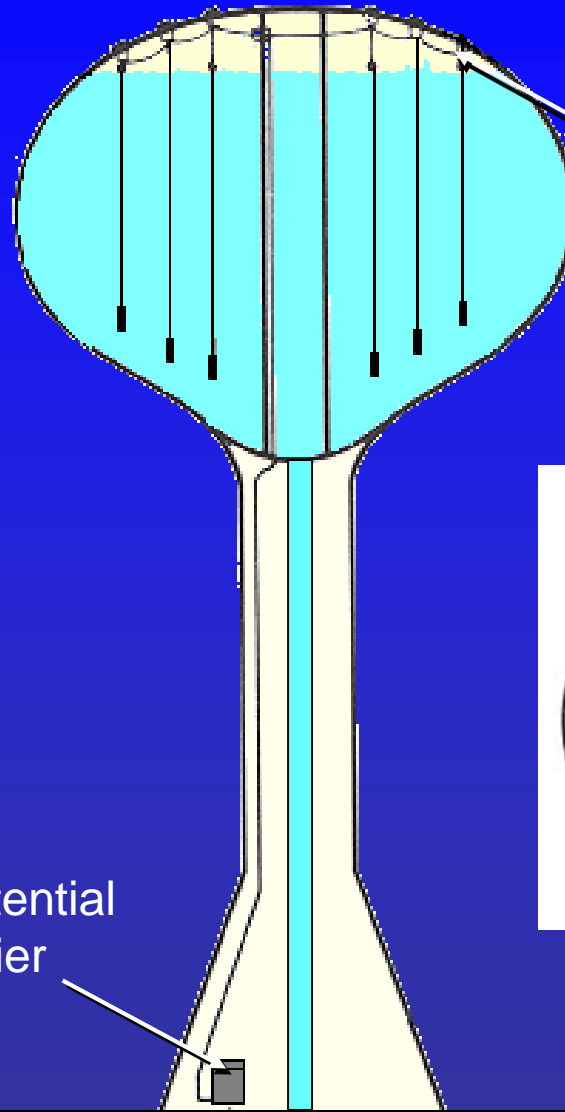


Corrosion on damaged polyethylene encased pipe.



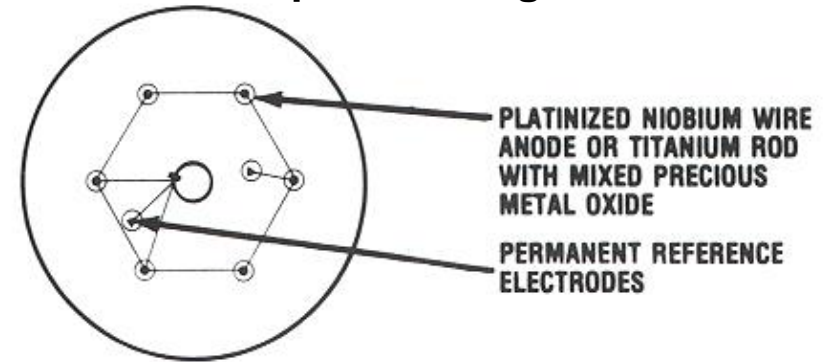
Corrosion of pre-stressed concrete cylinder pipe (P.C.C.P.).

# Suspended Vertical Anode System



Support System Bolted to Roof for Bowl Anodes and Reference Electrodes

Top View Diagram



Automatic Potential Control Rectifier







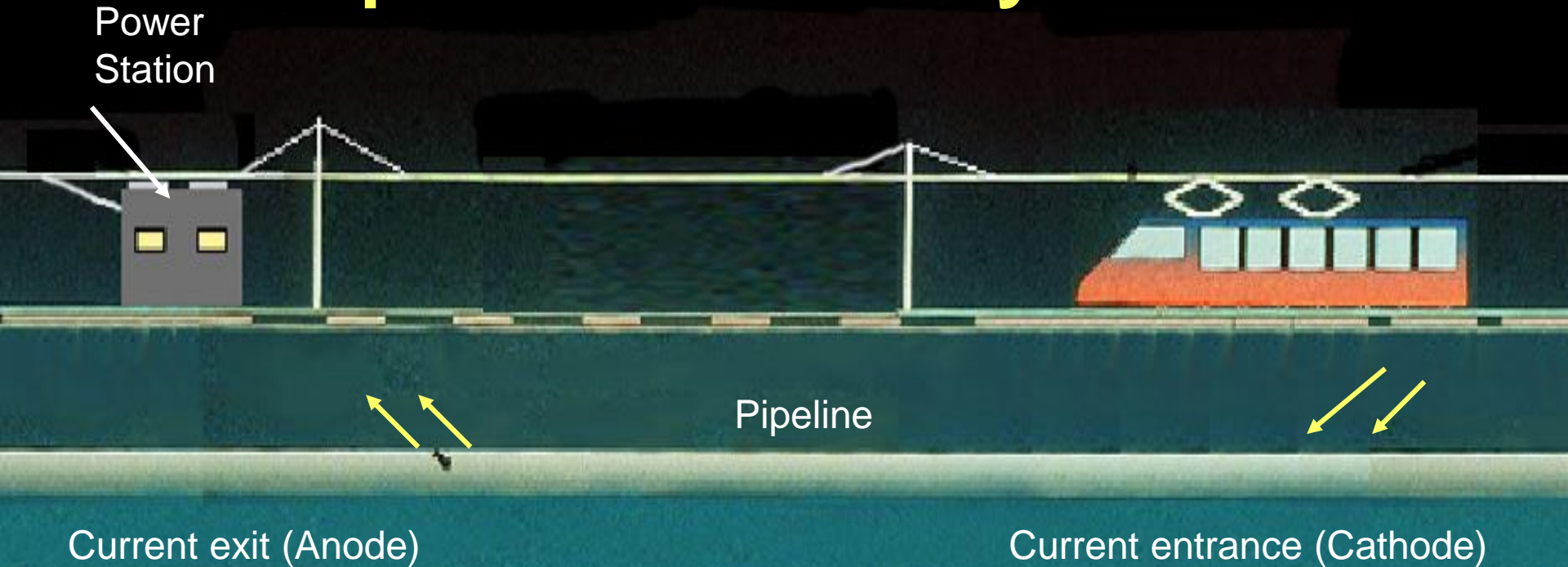
# Corrosion



# PCCP Failure

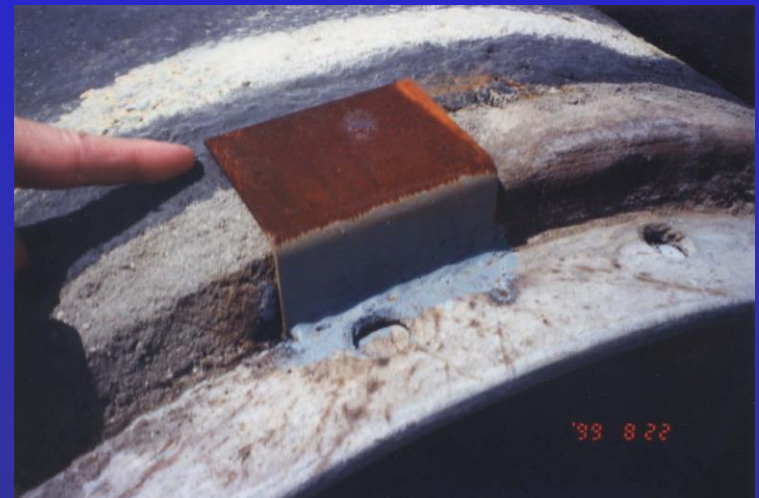


# Stray Current by DC Operated Transit Systems





**Pre-stressed Concrete Cylinder Pipe (PCCP)**





# ***Give Me a Break Fundamentals of Pipeline Corrosion***



***Presented By:  
James T Lary  
Corrpro***

***1090 Enterprise Dr.  
Medina, OH 44256  
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email: [jlary@corrpro.com](mailto:jlary@corrpro.com)  
<http://www.corrpro.com>***

***corrpro®***

# ***Corrosion Control & Cathodic Protection of Water & Wastewater Systems***



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# Coating Flaws (Holidays)



# Pipeline Inspection Report

Inspector name \_\_\_\_\_ Date \_\_\_\_\_ Address of pipeline inspection \_\_\_\_\_ Leak? Yes \_\_\_\_\_ No \_\_\_\_\_ File Number: \_\_\_\_\_

- 1) Type of Pipe: cast iron \_\_\_\_\_ ductile iron \_\_\_\_\_ carbon steel \_\_\_\_\_ copper \_\_\_\_\_ carbon steel \_\_\_\_\_ non metallic \_\_\_\_\_ other \_\_\_\_\_
- 2) Diameter of pipe \_\_\_\_\_" Pipeline Name \_\_\_\_\_ Service Type: Water \_\_\_\_\_ Wastewater \_\_\_\_\_ Estimated date of pipe installation \_\_\_\_\_ Depth of pipe \_\_\_\_\_'
- 3) Type of Pipe: Distribution \_\_\_\_\_ Transmission \_\_\_\_\_ Service \_\_\_\_\_ Hydrant \_\_\_\_\_ Mechanical joint \_\_\_\_\_ Fasteners \_\_\_\_\_ Other \_\_\_\_\_ Unknown \_\_\_\_\_
- 4) Type of Coating: Polyethylene Encased \_\_\_\_\_ Shop applied coating \_\_\_\_\_ No Coating \_\_\_\_\_ Tape Wrap \_\_\_\_\_ Unable to determine \_\_\_\_\_
- 5) External Pipe Condition: Very Good \_\_\_\_\_ Good \_\_\_\_\_ Poor \_\_\_\_\_ comments: \_\_\_\_\_

6) Is corrosion pitting evident? \_\_\_\_\_ Yes \_\_\_\_\_ No Number of Pits \_\_\_\_\_ Typical Size of Pits \_\_\_\_\_ Quantity of pits: \_\_\_\_\_

7) Is graphitization evident (longitudinal or circumferential breaks) \_\_\_\_\_ Yes \_\_\_\_\_ No

8) Is the pipe installed in (check off appropriate items): Industrial area \_\_\_\_\_ Residential area \_\_\_\_\_ Rural area \_\_\_\_\_ Near street or road \_\_\_\_\_  
Near creek or waterway \_\_\_\_\_ In reclaimed land \_\_\_\_\_ Near oil or gas pipelines \_\_\_\_\_ Near high voltage lines \_\_\_\_\_.

8) Describe soil conditions where inspection occurred: wet \_\_\_\_\_ dry \_\_\_\_\_ clay soil \_\_\_\_\_ rocky soil \_\_\_\_\_ cinders \_\_\_\_\_ other \_\_\_\_\_

9) Where soil samples obtained, sealed and analyzed for chlorides, moisture content, pH, sulfides, resistivity? If yes results were: \_\_\_\_\_

10) Were previous repairs made on the pipeline (leak clamps, etc) Yes \_\_\_\_\_ No \_\_\_\_\_. Was new pipe installed \_\_\_\_\_ Yes \_\_\_\_\_ No.

11) Was a repair clamp installed on the pipe during inspection \_\_\_\_\_ Yes \_\_\_\_\_ No

12) Was a galvanic anode installed as part of the inspection process? \_\_\_\_\_ Yes \_\_\_\_\_ No, if yes size and quantity

13) Please relay additional comments: \_\_\_\_\_

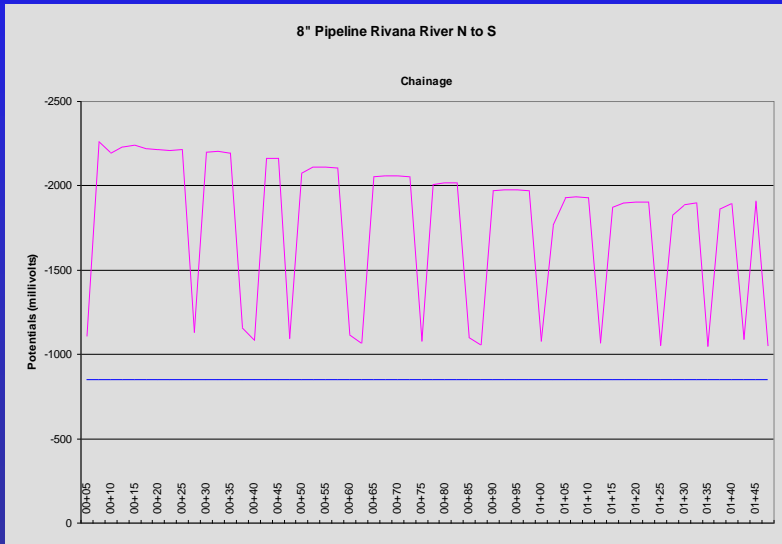
14) Plan of Action \_\_\_\_\_

15) Insert digital photos below:

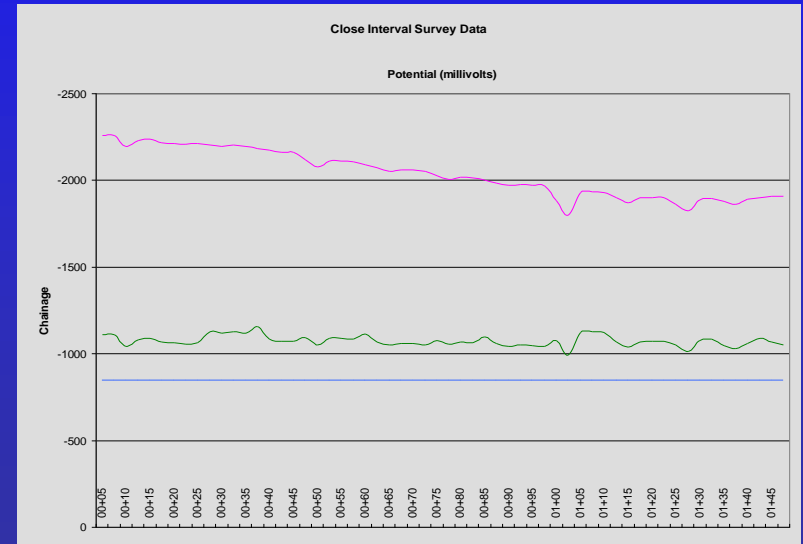




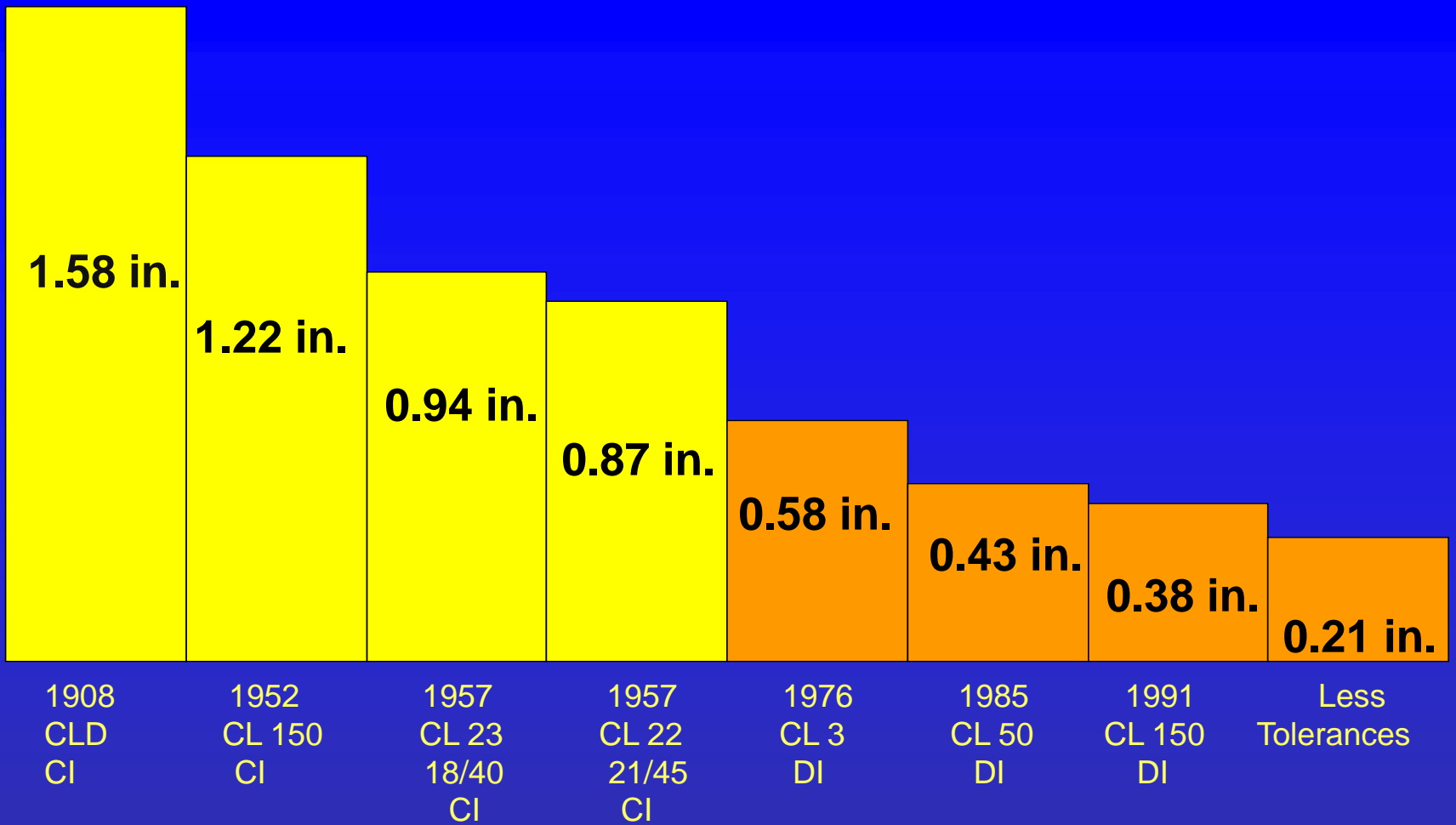
# CIS Survey



Close Interval Data  
Interrupted Survey

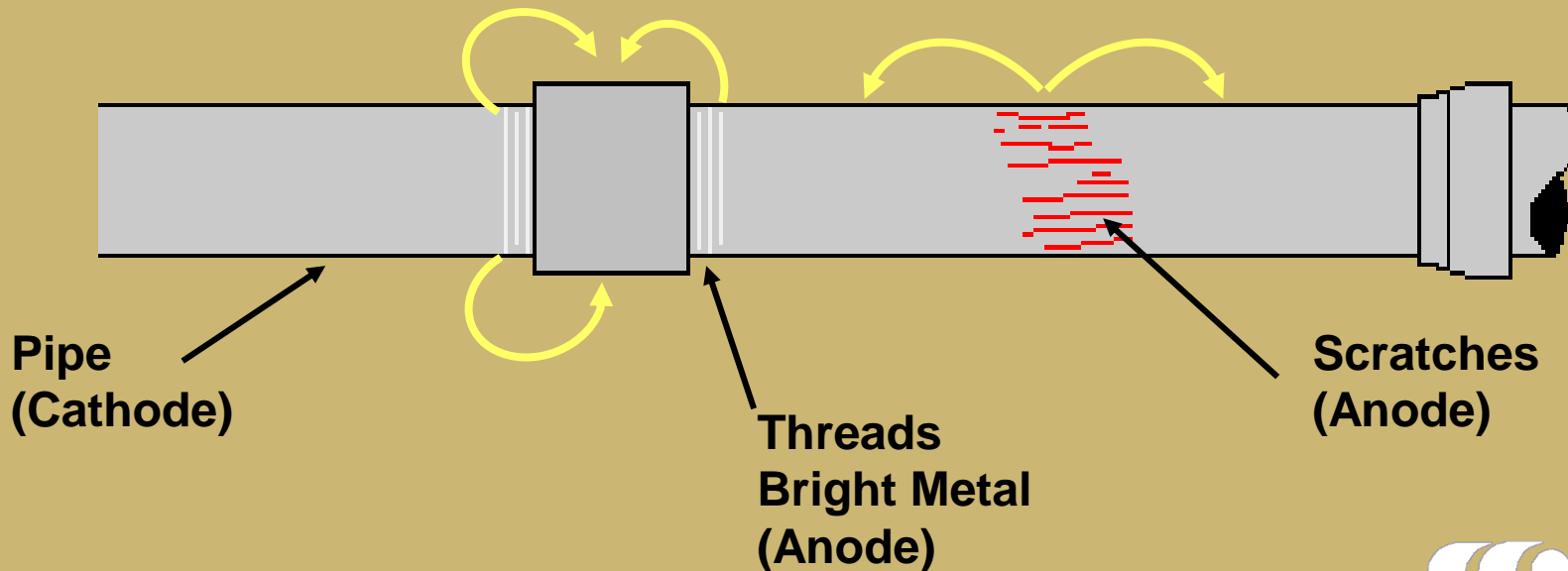


Close Interval Data  
PG/WFA Survey

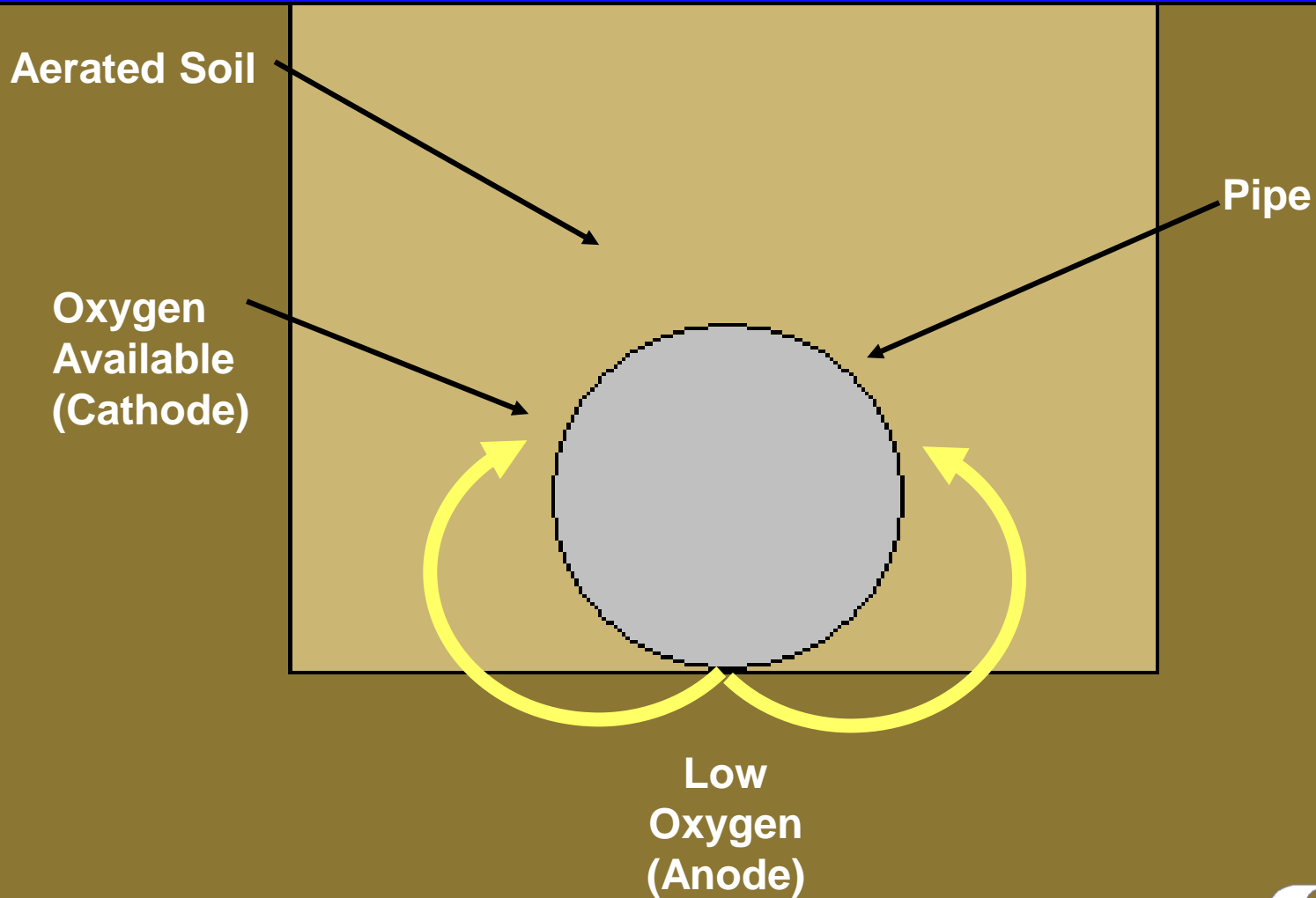


Actual size of AWWA Specification Thickness Reductions for 36-inch Diameter Cast and Ductile Iron Pipe - 1908 to Present (150 PSI Operating pressure)

# Dissimilar Surface Conditions



# Corrosion Caused by Differential Aeration





# Coating Flaws (Holidays)



# Meter Vaults



*(Keep dry if possible)*

# Water Wells



# Galvanic Anode on Polyethylene Encased Ductile Iron Pipe

