Water Tank Cathodic Protection

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Corrpro Companies, Inc.

"Preserving and Sustaining Global Assets & Infrastructure"

Water Storage Tanks

Corrosion related to infrastructure (O&G Pipelines, Water Systems, Bridges) costs the United States over 400 Billion Dollars per year in Renovation or Replacement Costs!

With Modern Technological Advances such as Cathodic Protection, it is estimated that a large % of these expenditures are preventable

* Congressional Commissioned Study “Corrosion Costs and Preventative Strategies In The United States” 1998 Presented to Congress in September, 2001.

CORROSION THEORY AND CORROSION PREVENTION

- Why Corrosion Happens
- Methods of Corrosion Control
- How Coatings & Cathodic Protection Work
- How Steel & Metallic Structures Are Effectively and Economically Maintained
- The Value of Utilizing Cathodic Protection

The Environmental Protection Agency now mandates corrosion protection for all underground fuel storage tanks in the US

Magnesium anodes pre-packaged on underground fuel storage tanks

The Value of Using Cathodic Protection

- Economical initial cost of installation
- Economical to maintain
- Extends useful life of the coating
- Minimizes the need for coatings maintenance
- Minimizes the need for re-coating
- Minimizes metal repairs
- Minimizes the need for costly downtime
- Significantly lowers total cost of ownership

AWWA Standard D104-04

"Automatically Controlled Impressed-Current Cathodic protection for the Interior of Steel Water Tanks"

"The combination of coatings and cathodic protection may be more economical and effective than using coatings or cathodic protection alone"

NACE Standard Recommended Practice RP0388-95

"Impressed Current Cathodic Protection of Internal Steel Surfaces of Steel Water Storage Tanks"

"If the water is sufficiently corrosive to justify the use of coatings, then cathodic protection is also justified and provides a greater degree of protection than when either method is used alone"

National Fire Protection Association

NFPA Standard 25 "Inspection and Testing Of Water Storage Tanks for Fire Protection"

"The inspection interval for the interior surface areas shall be three (3 Years)"

Exception 1: If corrosion control is utilized

the inspection interval shall be five (5) years"

"Cathodic protection corrosion control system should be inspected annually"

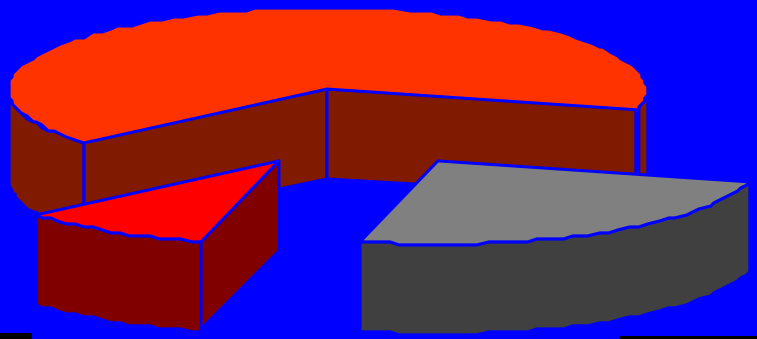
NSF 61
National Sanitation Foundation
Standard 61

Anything that comes in contact with drinking water is tested and certified to be safe for the drinking water supply.

For stand-alone coating systems re-coating is typically recommended at 1-5% failure. A standard AWWA D104 anode system is designed to protect up to 20% bare for a **minimum** of 20 years. Systems can be designed to protect up to 100% bare steel.

Approximate Cost Breakdown
of a Typical Coating Project

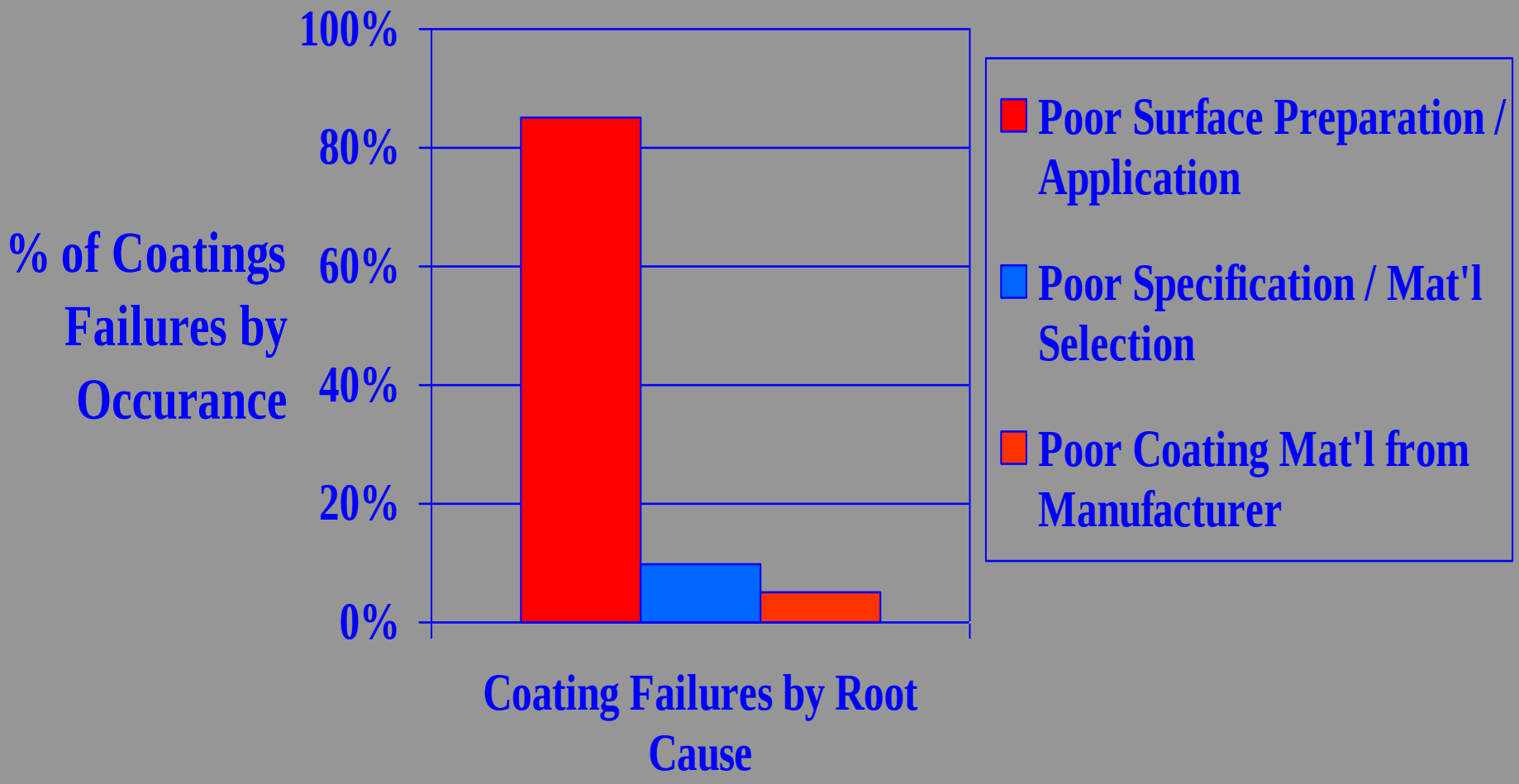
Surface Preparation 65%



Material 10%

Application 25%

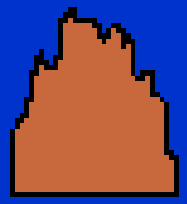
Approximate Percentage of Coating Failure
Occurrences, Grouped by Root Cause



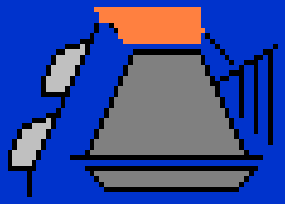
CORROSION IS DEFINED AS:

The deterioration of a substance (usually metal) due to a reaction with its environment

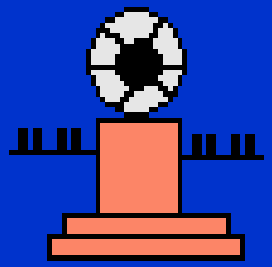
Corrosion - A Natural Process



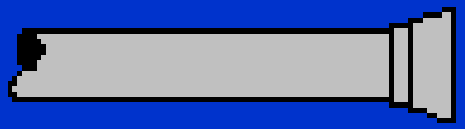
IRON OXIDE



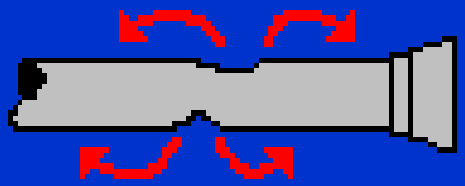
REFINING



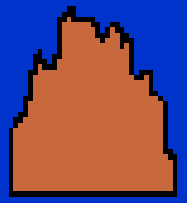
MILLING



IRON



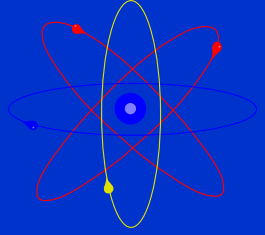
CORROSION



IRON OXIDE

The Galvanic Energy Series

- Each metal requires a certain amount of energy to remain stable
- The metals in higher positions contain higher levels of energy
- When energy is released, metal loss occurs
- Energy release = corrosion



PRACTICAL GALVANIC SERIES

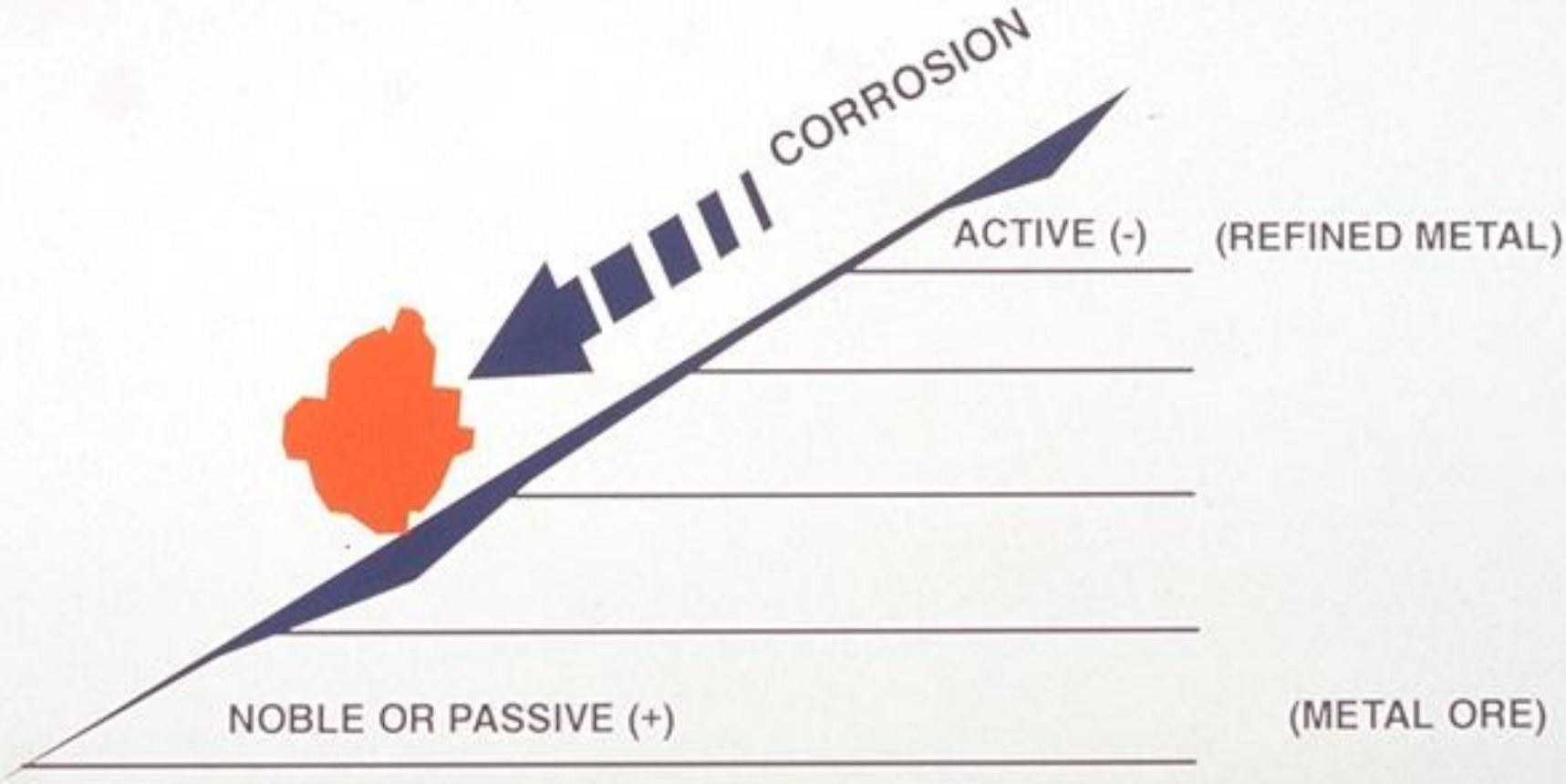
Material	Potential*
Pure Magnesium	-1.75
Magnesium Alloy	-1.60
Zinc	-1.10
Aluminum Alloy	-1.00
Cadmium	-0.80
Mild Steel (New)	-0.70
Mild Steel (Old)	-0.50
Cast Iron	-0.50
Stainless Steel	-0.50 to + 0.10
Copper, Brass, Bronze	-0.20
Titanium	-0.20
Gold	+0.20
Carbon, Graphite, Coke	+0.30

* Potentials With Respect to Saturated Cu-$CuSO_4$ Electrode

THE ENERGY HILL

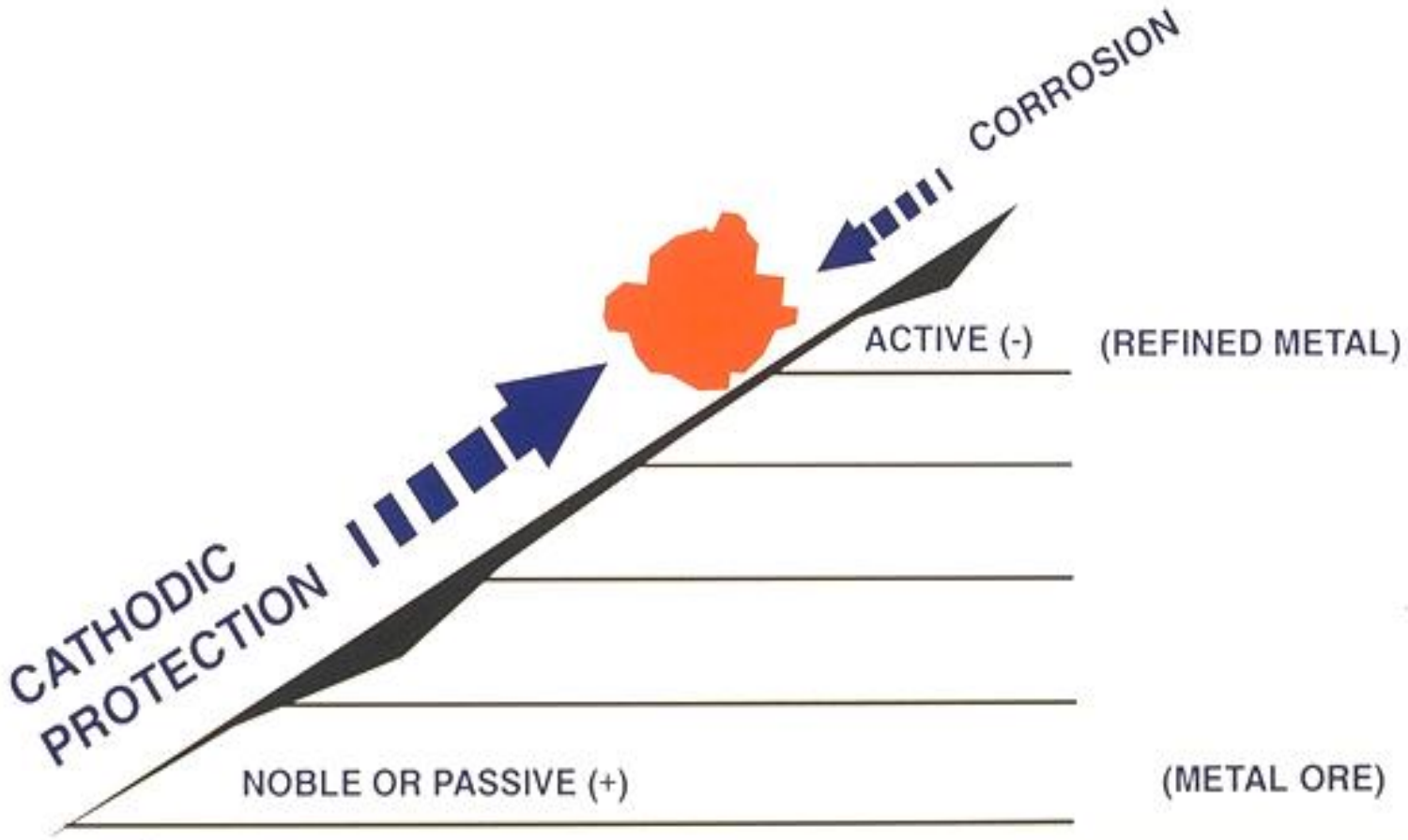
GALVANIC ENERGY SERIES

RELEASE OF ENERGY



Cathodic Protection introduces an external DC current which makes the entire structure a cathode.

MAINTAINING THE ENERGY LEVEL



Four Requirements for a Corrosion Cell

- **Electrolyte**: Ionic current path (moisture)
- **Anode**: Metal in contact with the electrolyte which where corrosion occurs
- **Cathode**: Metal in contact with the electrolyte where no corrosion occurs
- **Conductor**: electronic current path

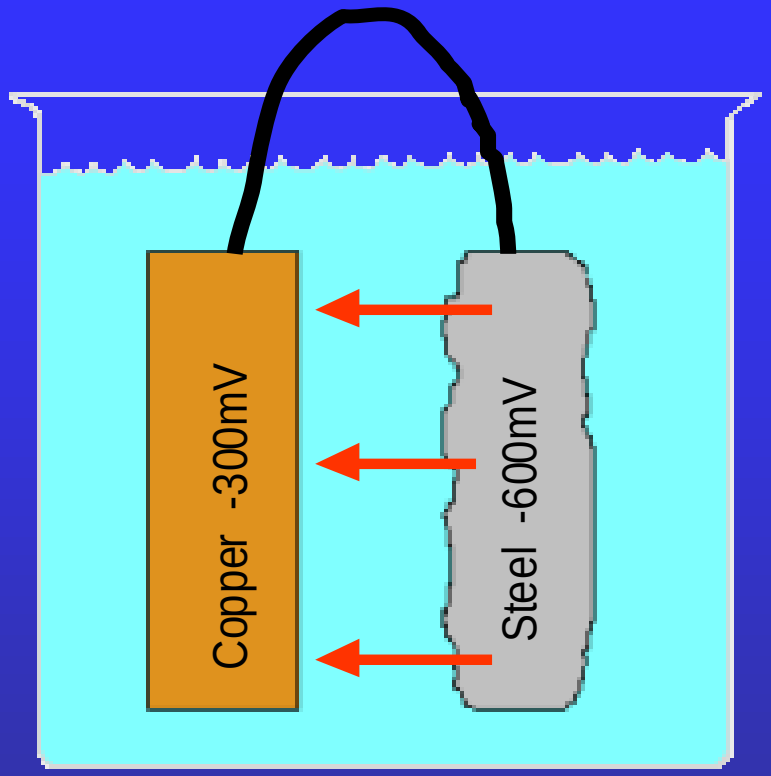
Corrosion

1) ANODE

2) CATHODE

3) ELECTROLYTE

4) METAL PATH



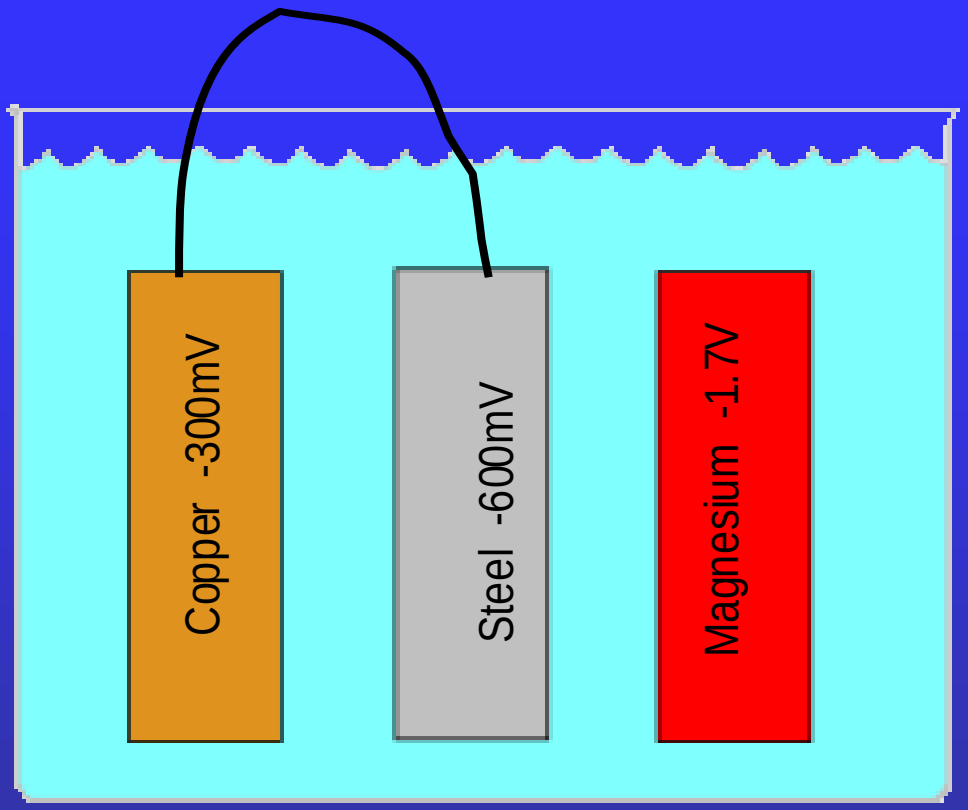
Corrosion

1) ANODE

2) CATHODE

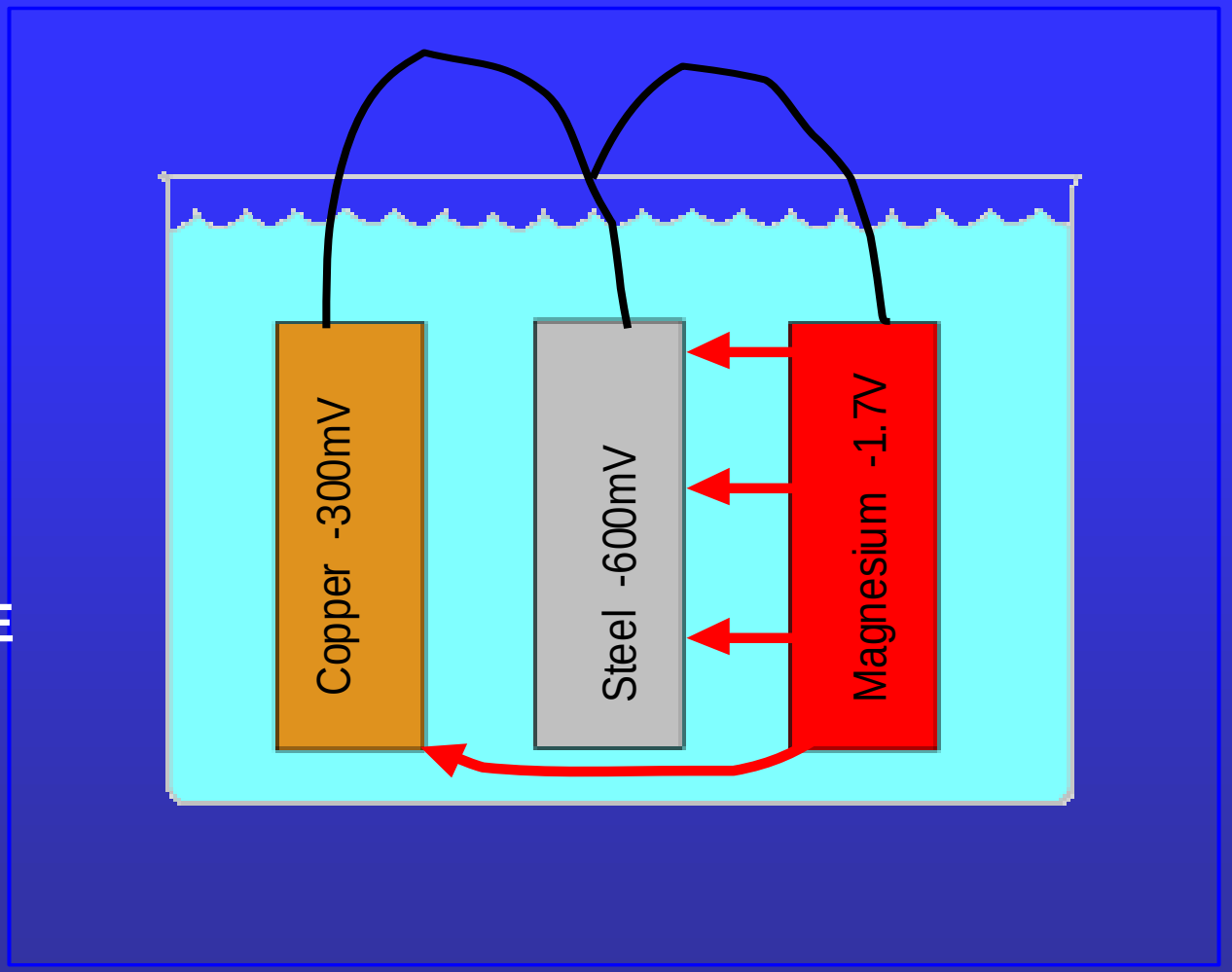
3) ELECTROLYTE

4) METAL PATH



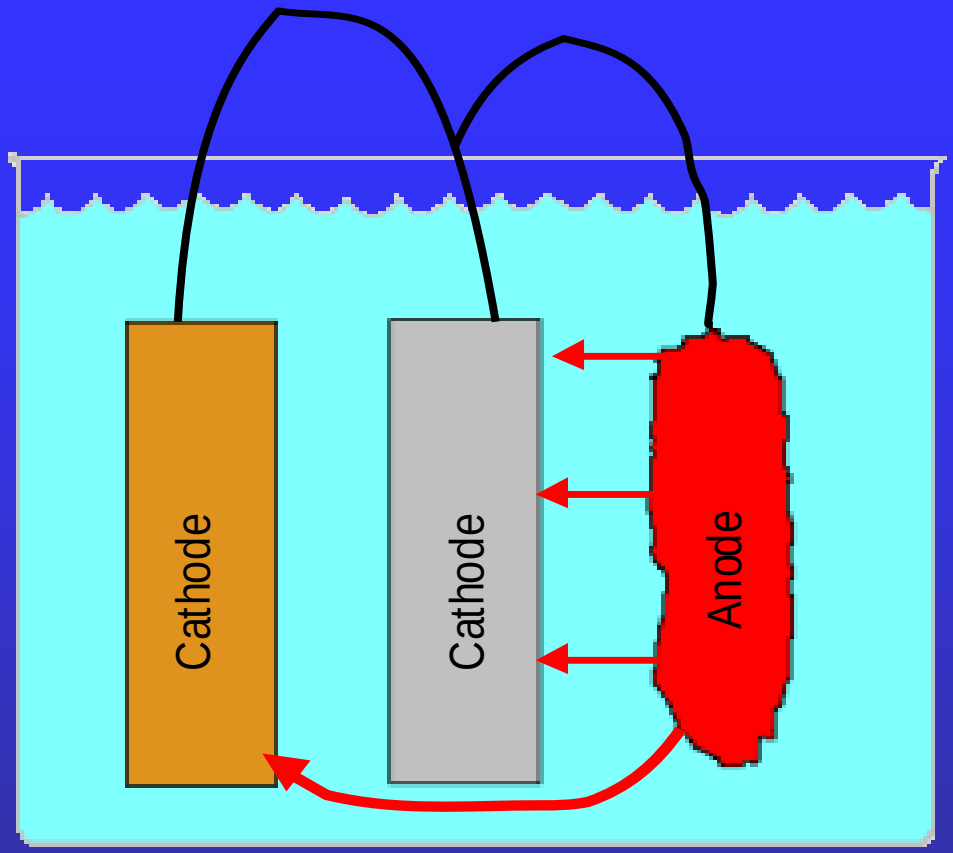
Cathodic Protection

1) ANODE
2) CATHODE
3) ELECTROLYTE
4) METAL PATH



Cathodic Protection

1) ANODE
2) CATHODE
3) ELECTROLYTE
4) METAL PATH



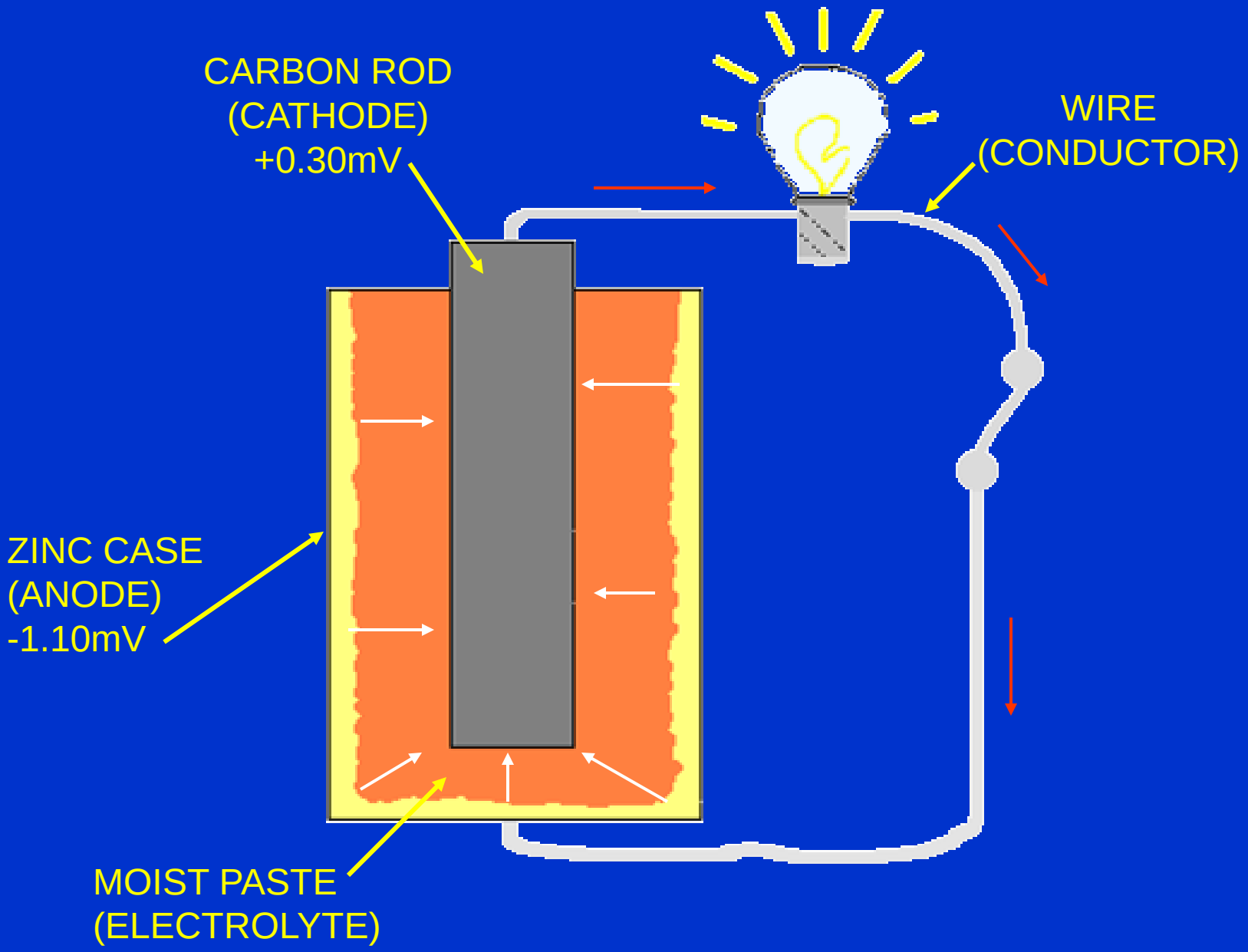
Water Storage Tanks and Treatment Facilities Possess the Four Requirements for Corrosion Cells to Form

- Electrolyte: Water and/or Wastewater
- Conductor: Steel Tank or Equipment
- Anode: Metal in contact with the electrolyte
- Cathode: Metal in contact with the electrolyte

A Battery is an Example of a Corrosion Cell

- Electrolyte: chemical paste
- Anode: zinc container
- Cathode: Carbon electrode
- Conductor: metal connection

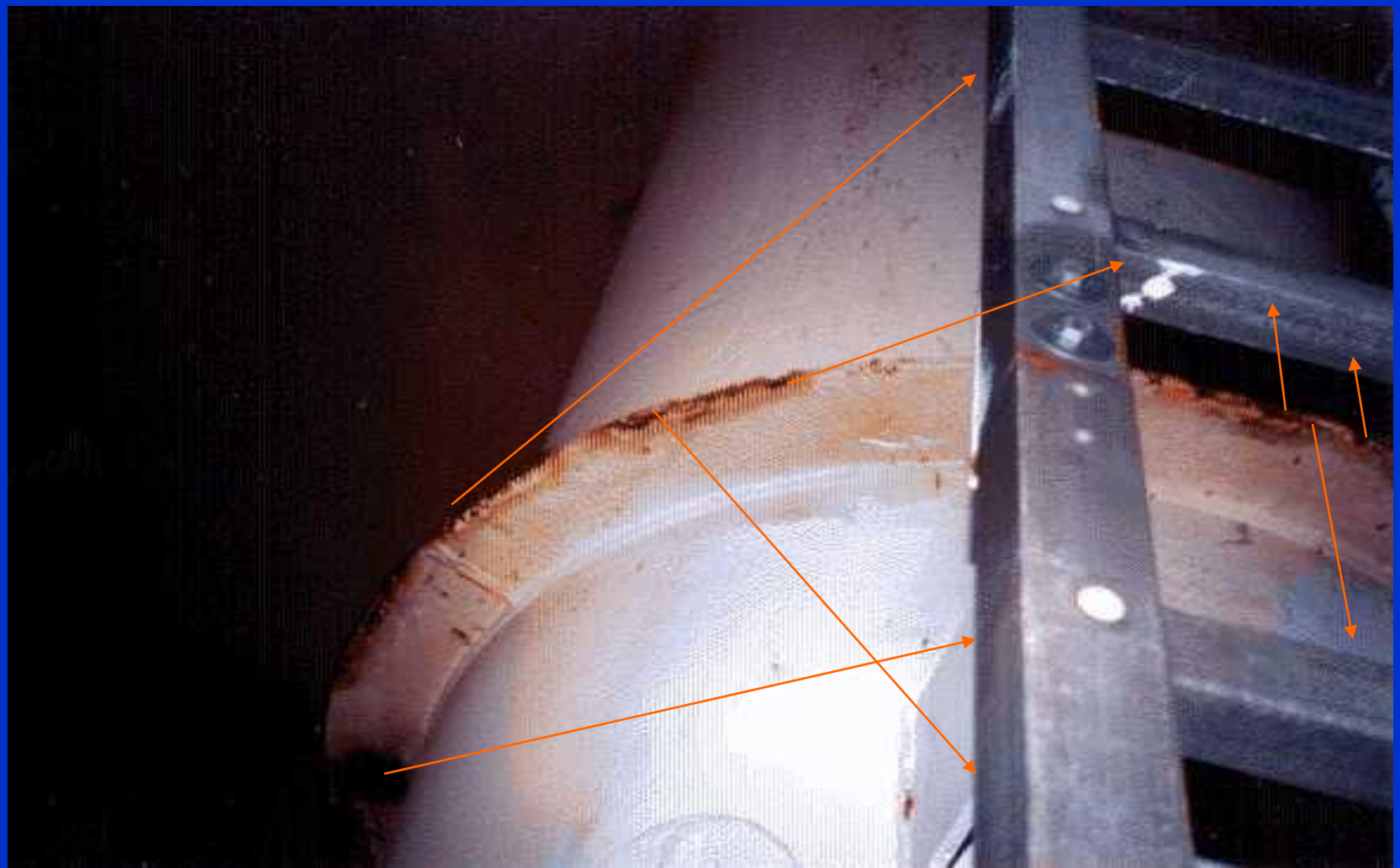
The electrical energy of the corrosion process is measurable in the form of light


CARBON ROD
(CATHODE)
+0.30mV
WIRE
(CONDUCTOR)
ZINC CASE
(ANODE)
-1.10mV
MOIST PASTE
(ELECTROLYTE)

Metals Connected together can form a Corrosion cell

ANODE (corrodes)		CATHODE (protected)
• New Steel	to	• Old Steel
• Steel	to	• Copper
• Galvanized Steel (ladders & safety climbs)	to	• Steel
• Steel	to	• Stainless Steel (ladders & safety climbs)
• Magnesium	to	• Steel
• Steel	to	• Reinforcing Steel

Galvanic Corrosion Induced by a Stainless Steel Ladder

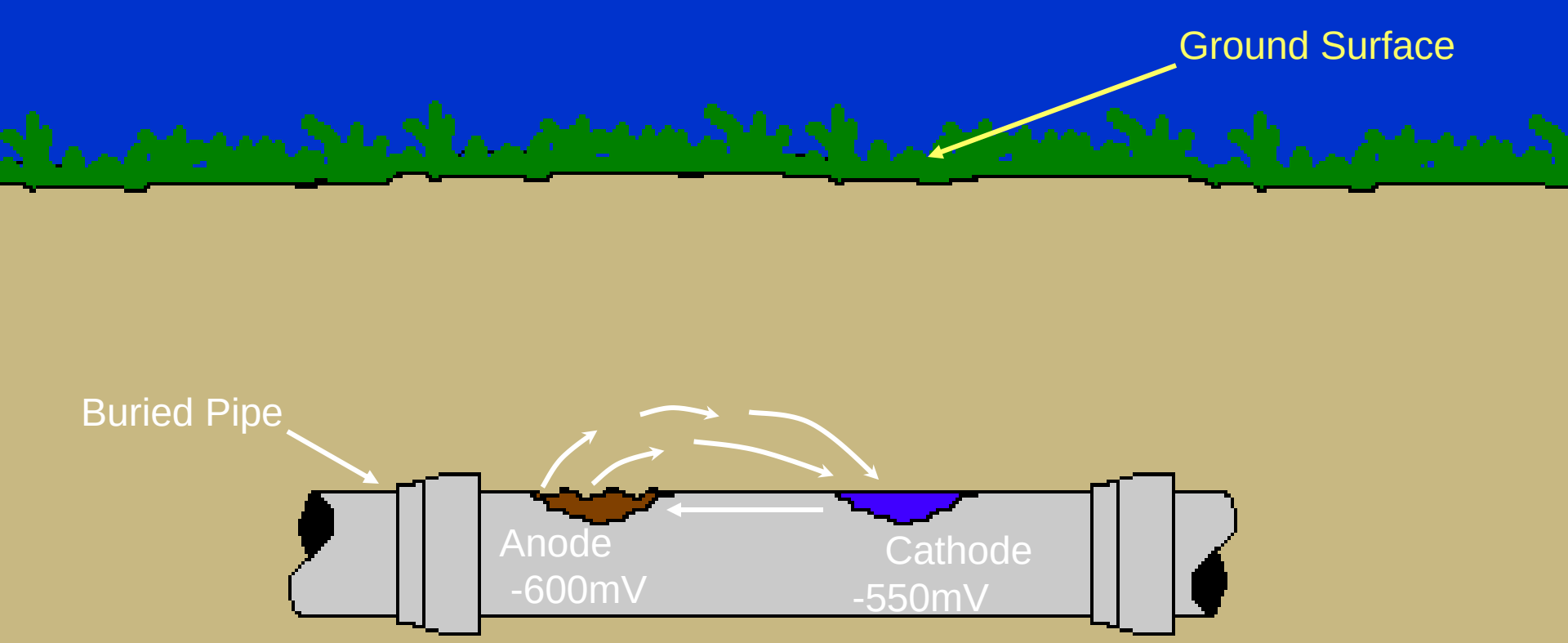


Galvanic Corrosion reaction between steel and rebar in a treatment facility

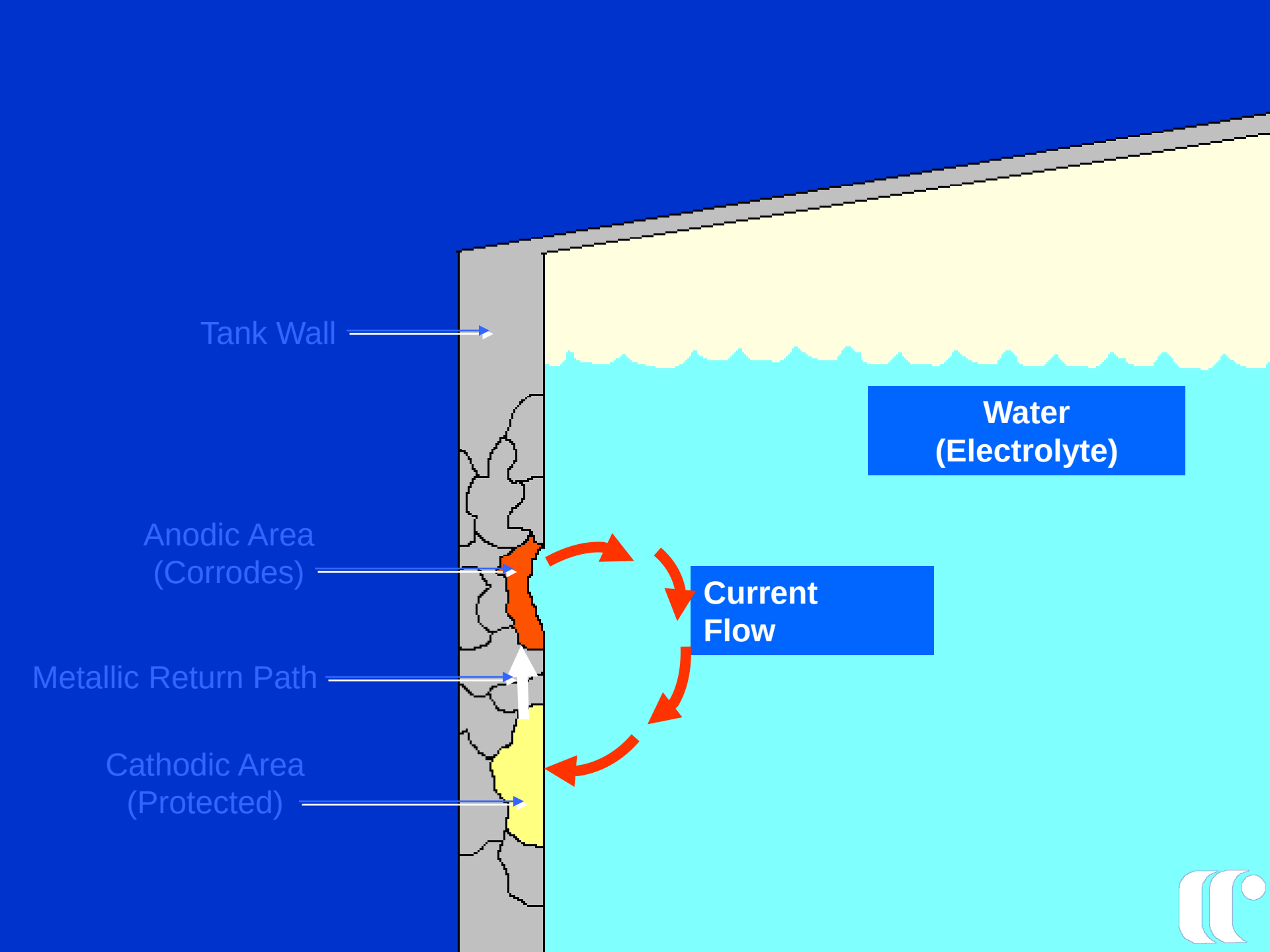
Homogeneous Metal Corrosion Example: Steel Plate or Iron Pipe

- Corrosion cells are created by different electrical levels in each grain of steel
- When in contact with an electrolyte (moisture) energy transfers between grains of steel
- Grains discharging energy corrode
- Grains accepting energy do not corrode

Basic Corrosion Cell



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


Tank Wall
Water
(Electrolyte)
Anodic Area
(Corrodes)
Current
Flow
Metallic Return Path
Cathodic Area
(Protected)

To Prevent Corrosion, one or more of the four requirements of a corrosion cell must be eliminated or minimized

- Not practical to eliminate the electrolyte

WATER

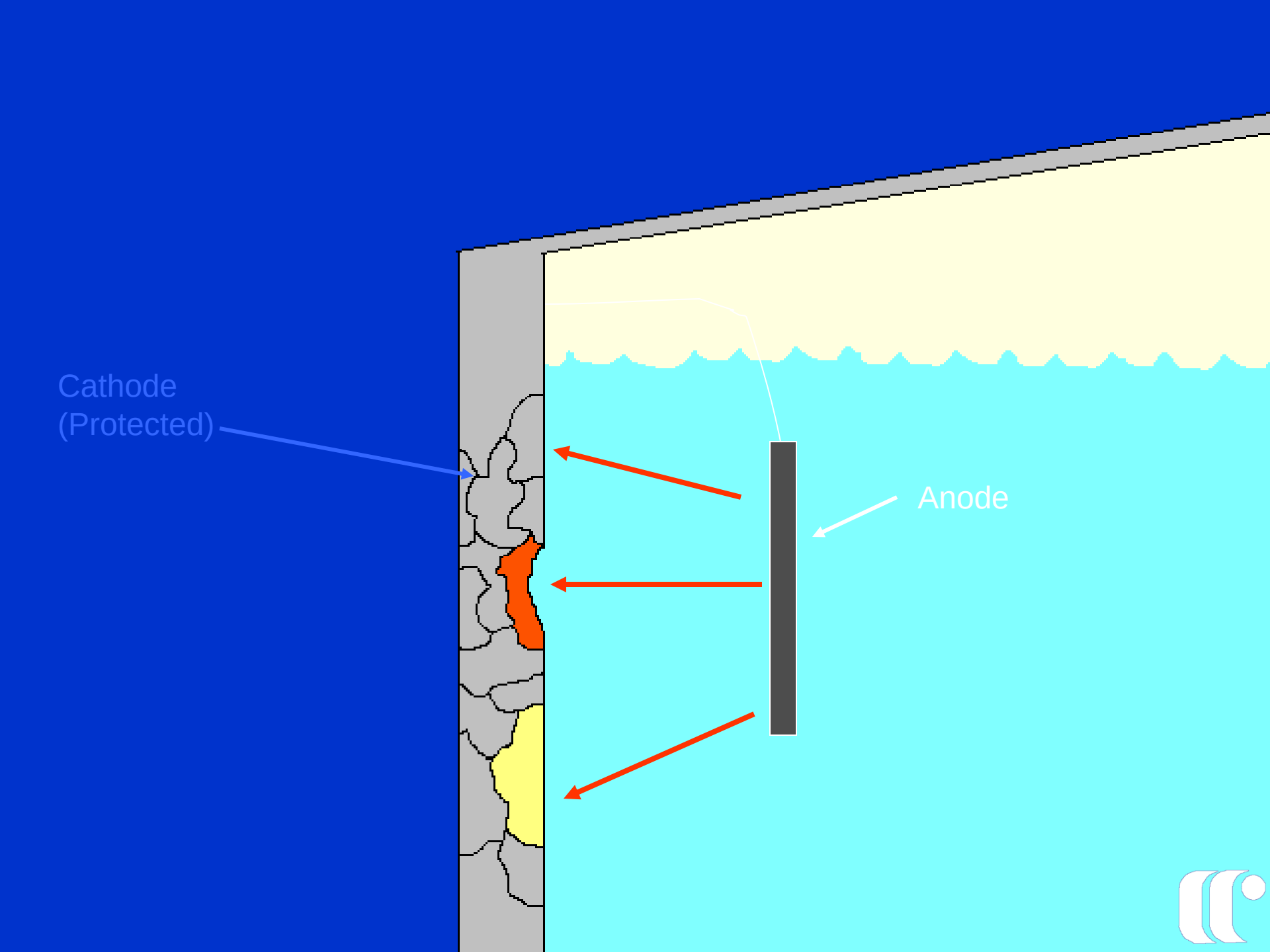
- Not practical to eliminate the conductor

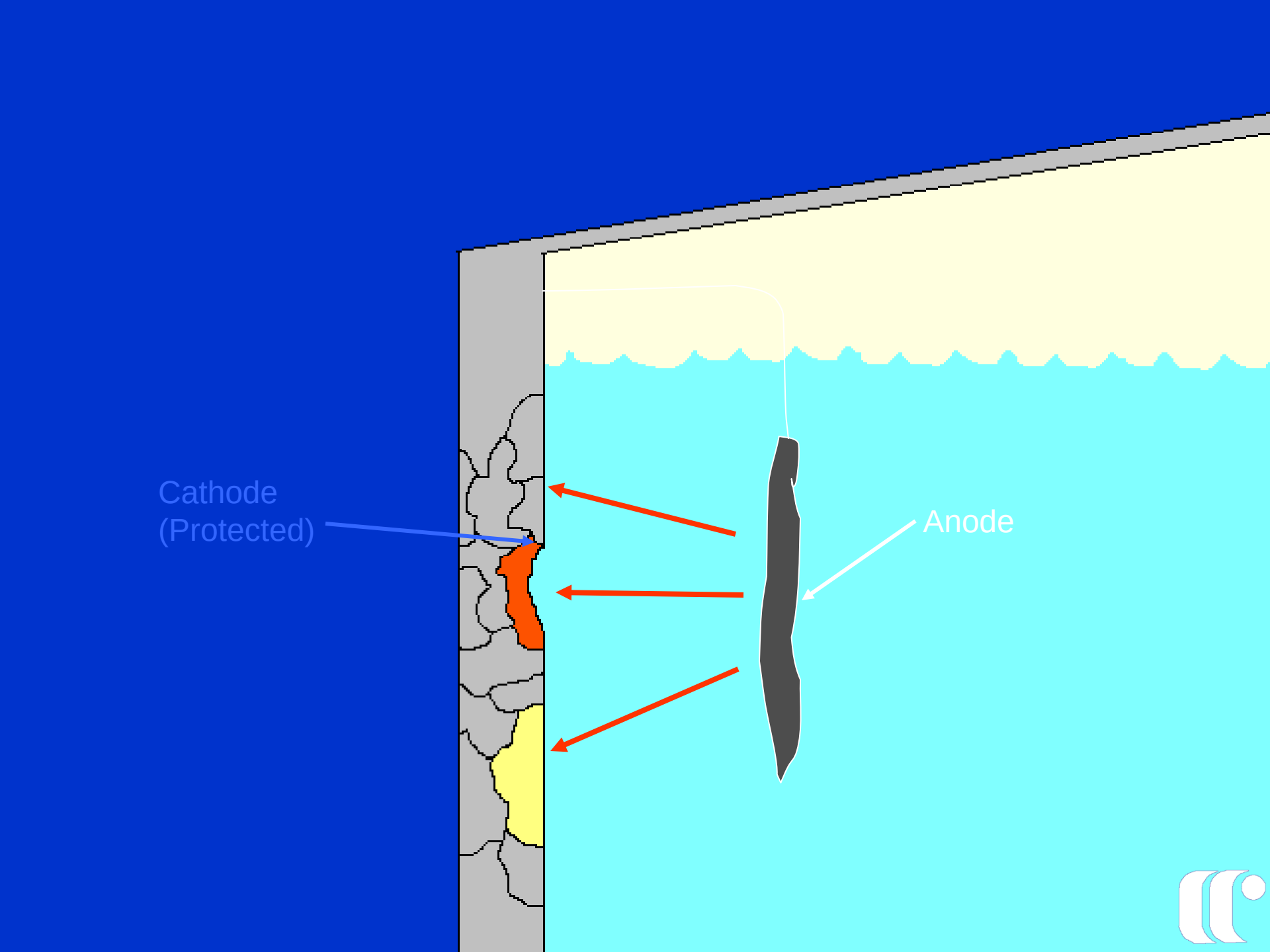
TANK OR EQUIPMENT

For Corrosion Control it is Practical to eliminate or minimize

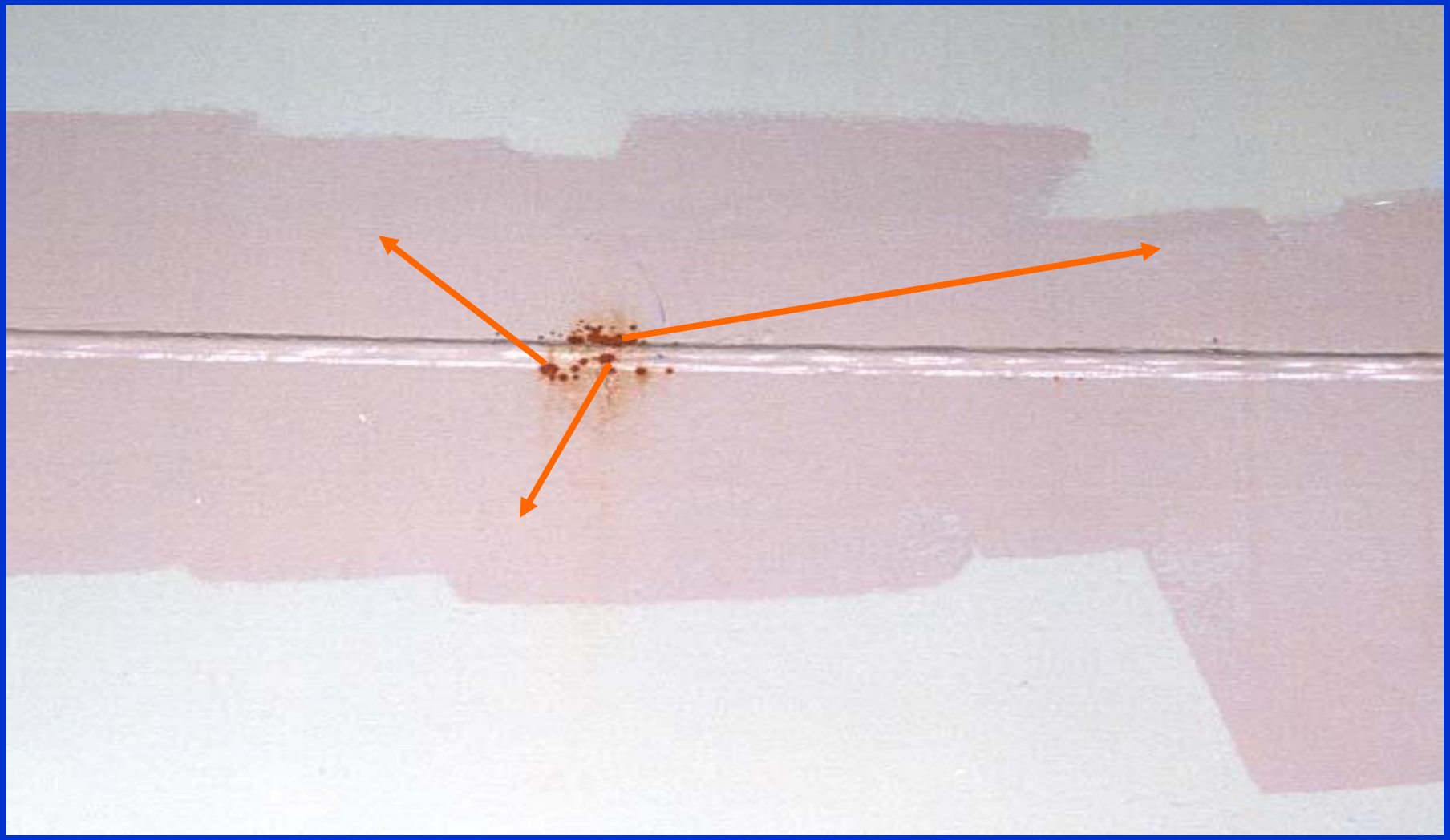
- Exposed metals (anodes and cathodes) in contact with the electrolyte: **Protective Coating**

- Change all anodic metal areas (where corrosion occurs) to cathodic metal areas (where no corrosion occurs): **Cathodic Protection**


Cathode
(Protected)
Anode


Cathode
(Protected)
Anode

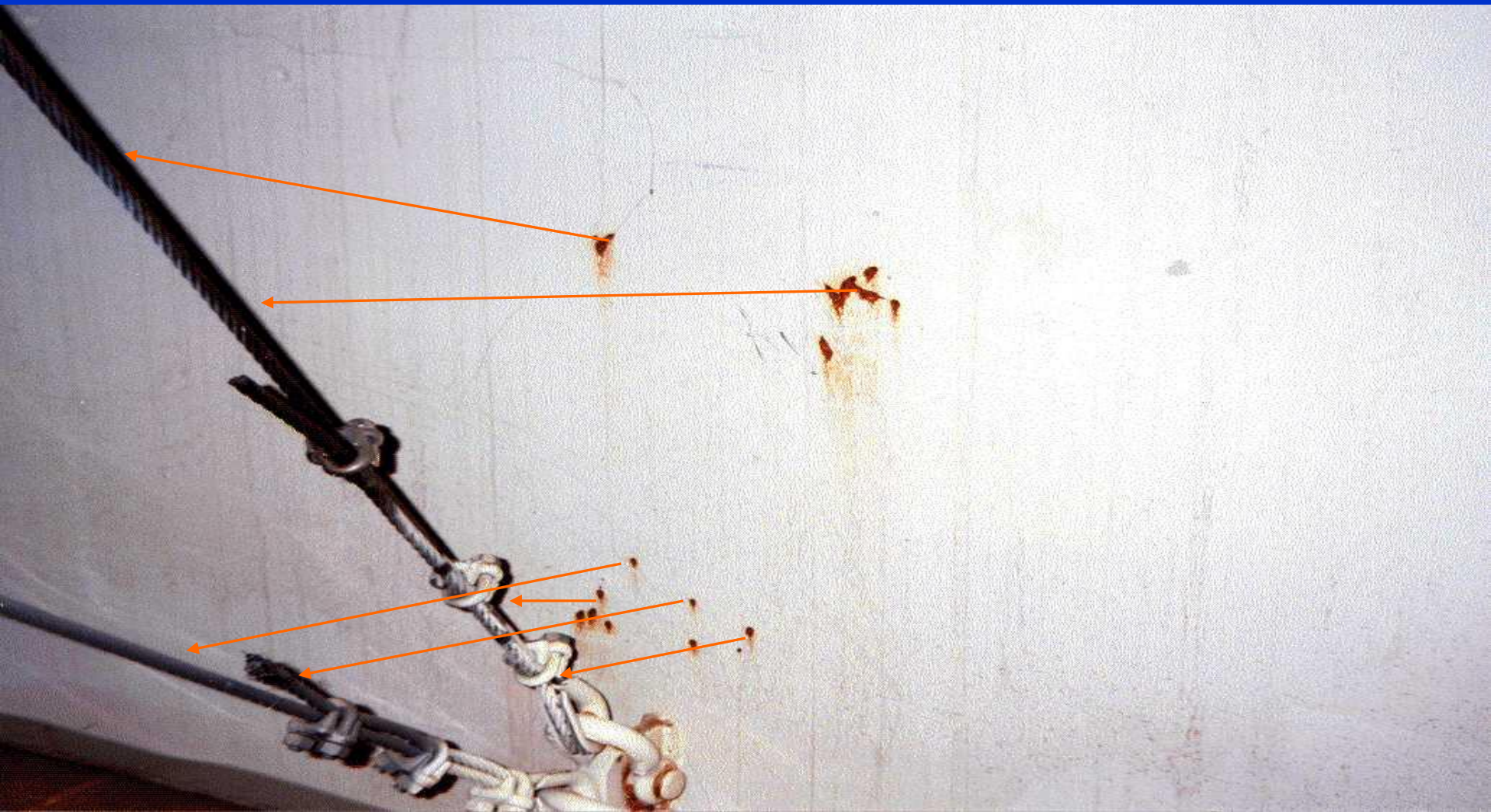
Continued active corrosion on a weld seam after two years in service and one attempted touch-up



Q. Why are small areas of corrosion activity NOT small problems?? A. Area effect concentration cells

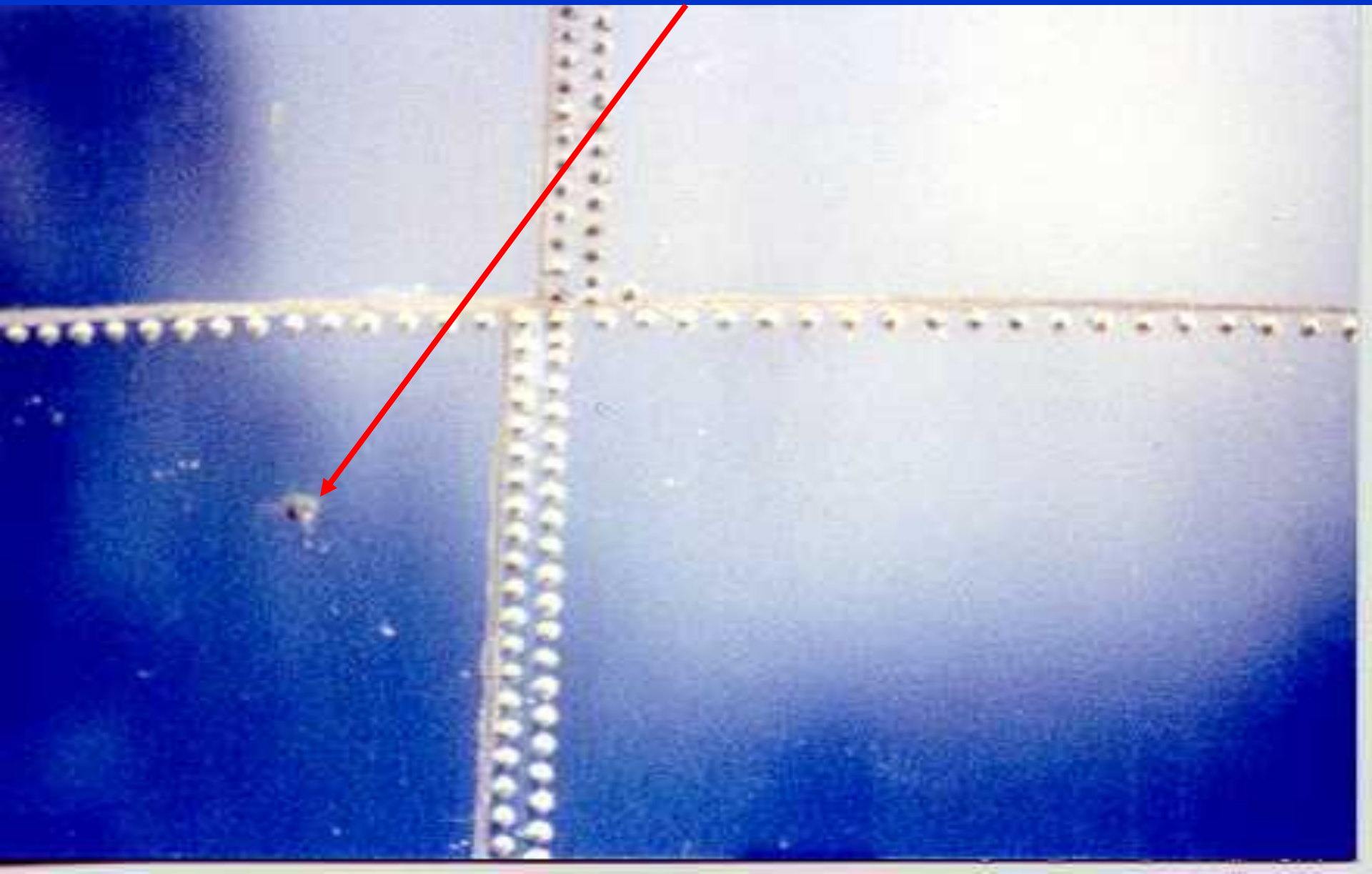
Area effect: “Corrosion of the anodic area may be 100 - 1000 times greater than if the anodic and cathodic areas were equal in size”

Corrosion Engineering Fontana & Greene 1978



Pitting Corrosion can lead to costly welding repairs or the use of “pit fillers” or even.....

A Corrosion Penetration Failure



A Cathodic Protection System will send a D.C. electrical “charge” through the water to both the metallic structures arresting galvanic corrosion

Calcareous deposits often form over “holidays”

Protection of holidays in coating along the edges of the support column

Exposed “holiday” with no active corrosion

AWWA Standard D104-97

- “Automatically controlled impressed current cathodic protection for the interior of steel water storage tanks”

Cathodic Protection is Effective When:

- Current distribution from anode to cathode meets “criteria for protection”
- Criteria is defined as a structure to water potential of -.850V to -1.050V relative to a copper-copper sulfate reference electrode
- Protective current is distributed over the entire submerged surface area
- Protective current is maintained continuously

In Reference to AWWA D104-97 the Major Components of a Cathodic Protection System Are:

- Automatically controlled rectifier
- Reference electrodes
- Anode
- Anode suspension system
- Hardware and wiring

Automatic Rectifiers

The purpose of an automatically controlled rectifier is to adjust the current output as conditions in the electrolyte change due to:

- Water Level
- Temperature
- Water Chemistry
- Water Turbulence
- Polarization

Properly Calibrated Automatic Potential Control Rectifier

This rectifier has achieved it's protective potential level and has stopped applying current. The unit will *automatically* start up again when the potential drops below its "set point"

10 year old Automatic Rectifier with analog meters still in near perfect condition & operating properly to provide corrosion control within criteria for protection

Reference Electrodes

The purpose of long life reference electrodes is:

- To constantly monitor the protection levels in the system
- Transmits a signal to the automatic controller to adjust the current output as required

Copper-Copper Sulfate Reference Electrode

Waterworks Anodes

Long life anodes should have an average design life of ten to twenty (10 - 20) years.

Anode Materials Typically Include:

- Titanium with precious metal oxide coating
- Platinized Niobium with a copper core

DESIGN
by a corrosion engineer

- Certified by N.A.C.E.
  (National Association of Corrosion Engineers)
- Experienced in Cathodic Protection
- Experienced in Cathodic Protection of Waterworks Structures

The Corrosion Engineer Determines

1. Total submerged surface area
2. Percentage bare
3. Current density
4. Resistivity of water
5. Consumption rate of anode material
6. Anode size, length and layout
7. Anode suspension system
8. Rectifier unit output
9. Number and location of reference cells
10. Number and type of electrical connections
11. Location of rectifier
12. A.C. requirements
13. National and local codes

Anode Suspension Systems Vary Depending Upon Icing or Non-icing Conditions

- For icing conditions the standard design is a horizontally suspended anode system supported from the side wall or interior dry access column
- For non-icing conditions the standard design is a vertically suspended system from the roof of the tank

Vertically Suspended Mixed Metal Oxide Anodes


8 13 '96

Advantages of the Vertical System

- Systems are easily installed without the need to drain the tank
- Systems can be completely serviced, upgraded, repaired and replaced without the need to drain the tank

Horizontally submerged anode system

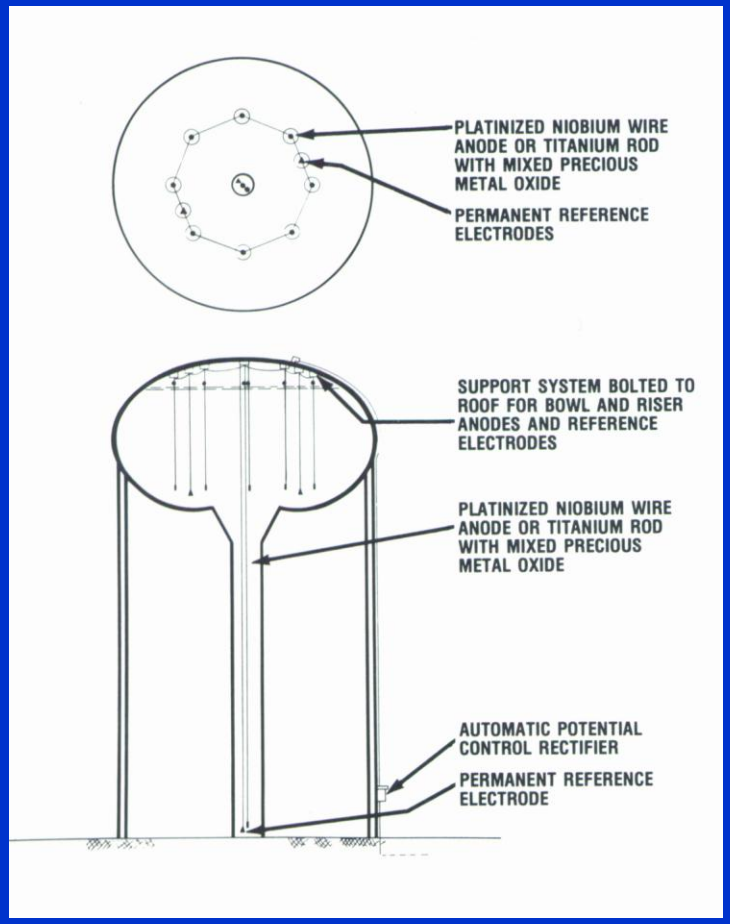
Advantages of the Horizontal System

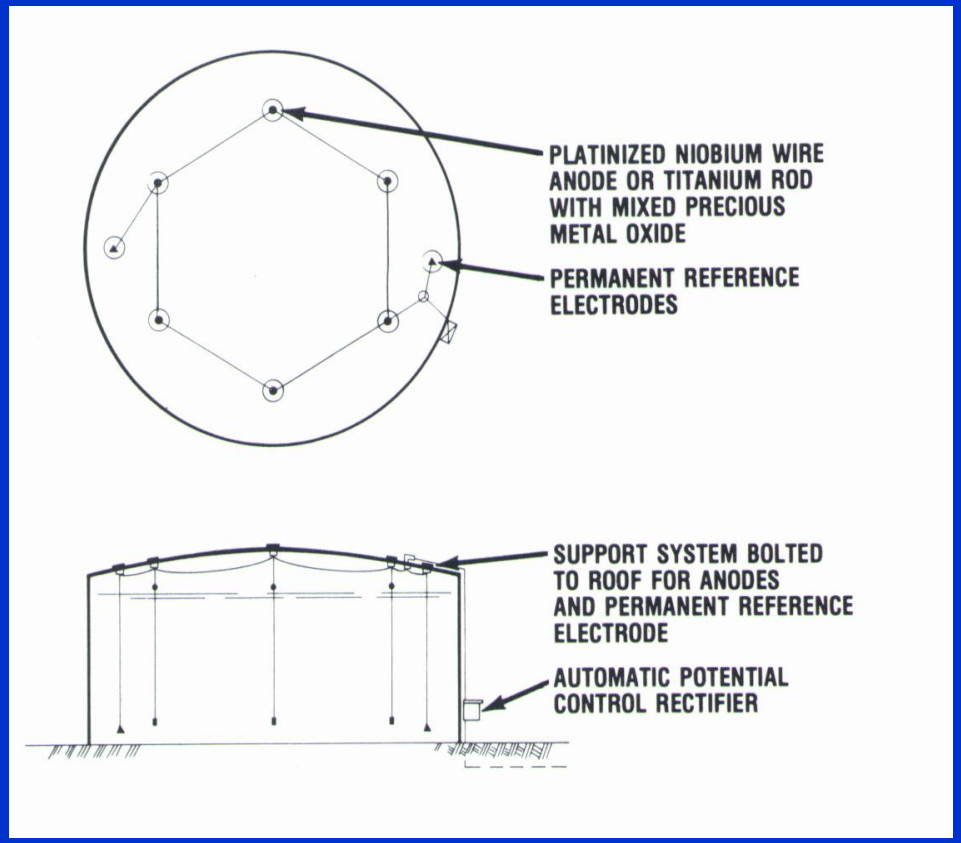
- Supported in the lower portion of the tank to avoid contact with ice
- Eliminates the need for seasonal anode replacement
- Eliminates build up of old anodes in the bottom of the tank

Examples of System Designs

- System designs which are typically utilized for various styles of water storage tanks

Typical Vertically Suspended Anode Systems





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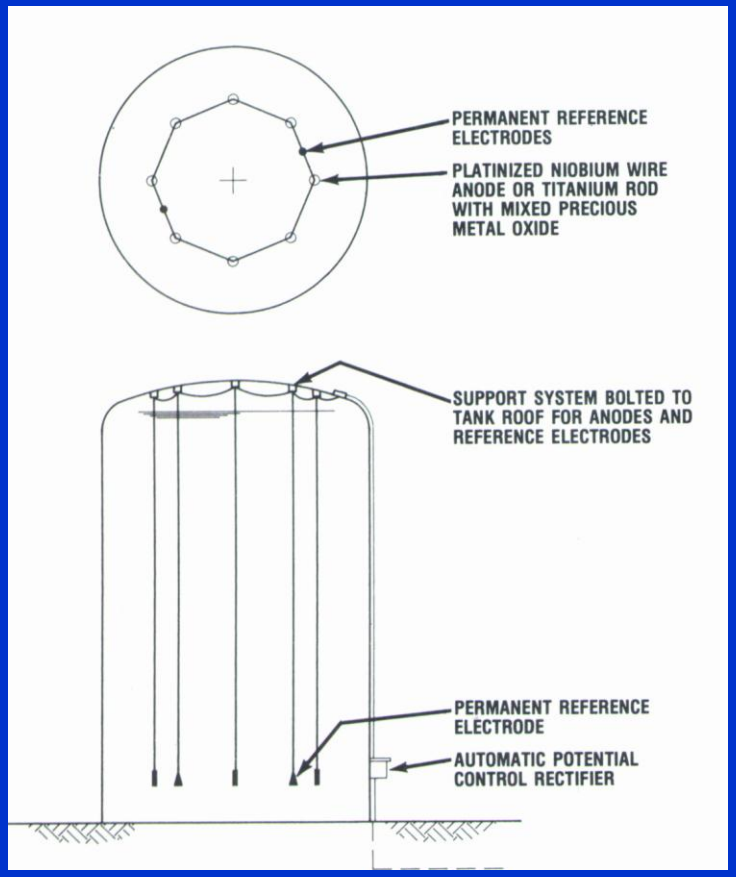
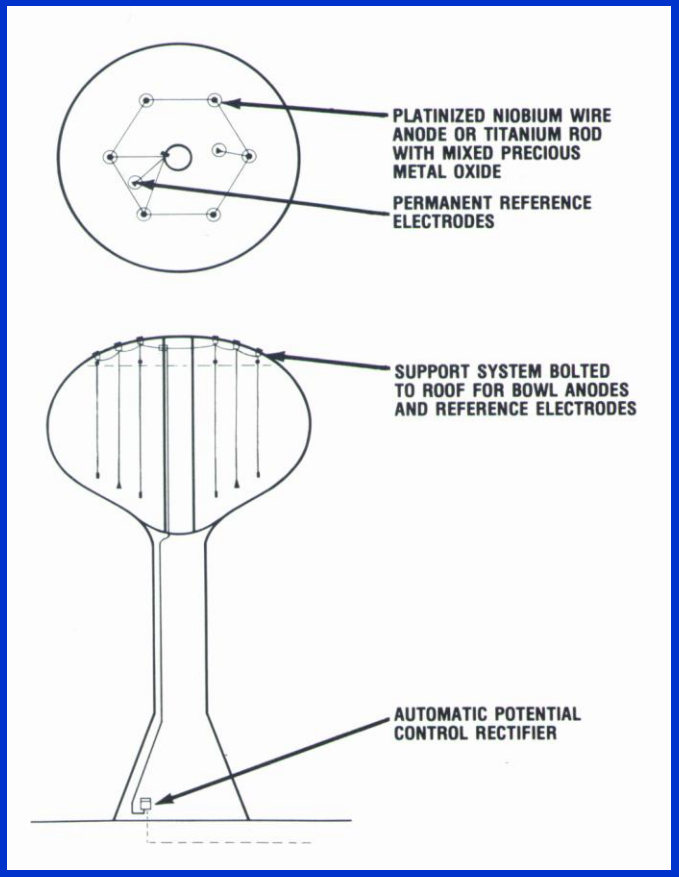
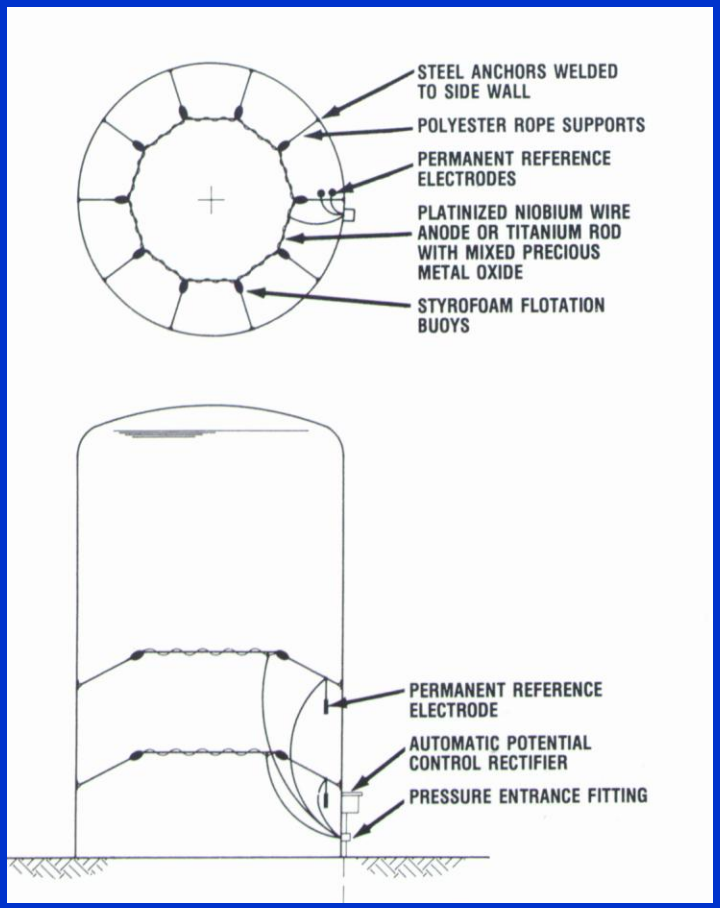
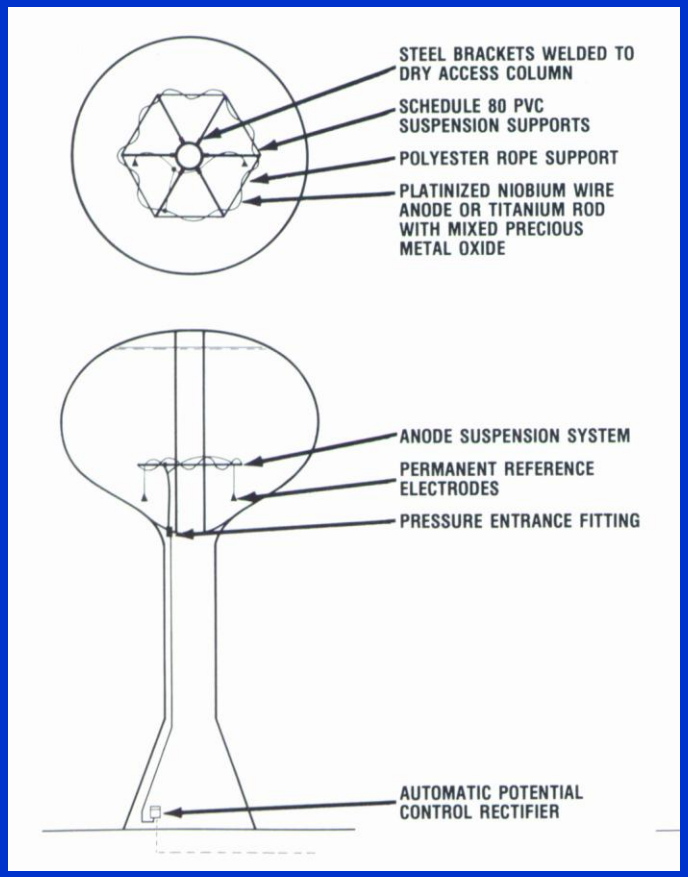




Typical Horizontally Suspended Anode Systems





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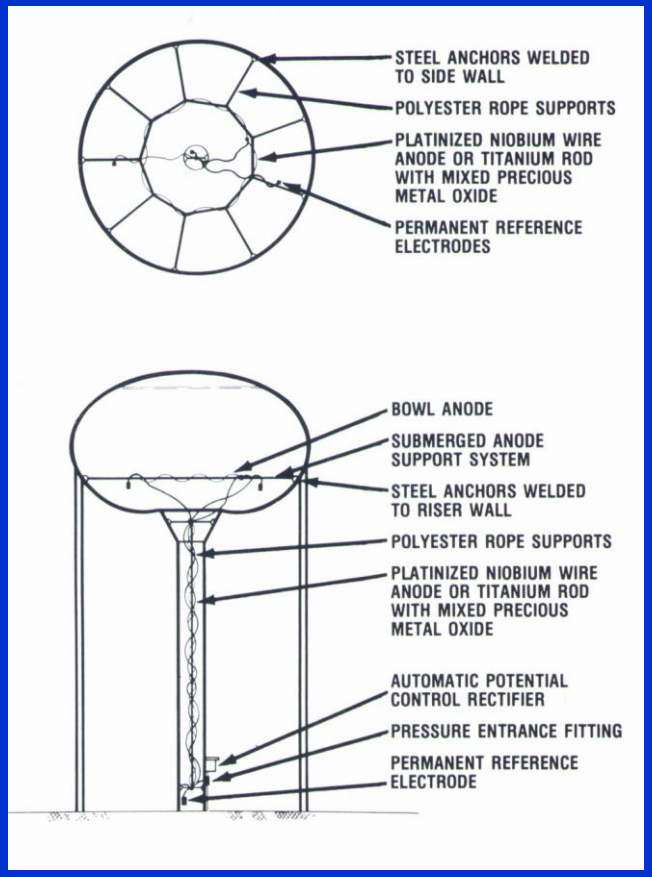
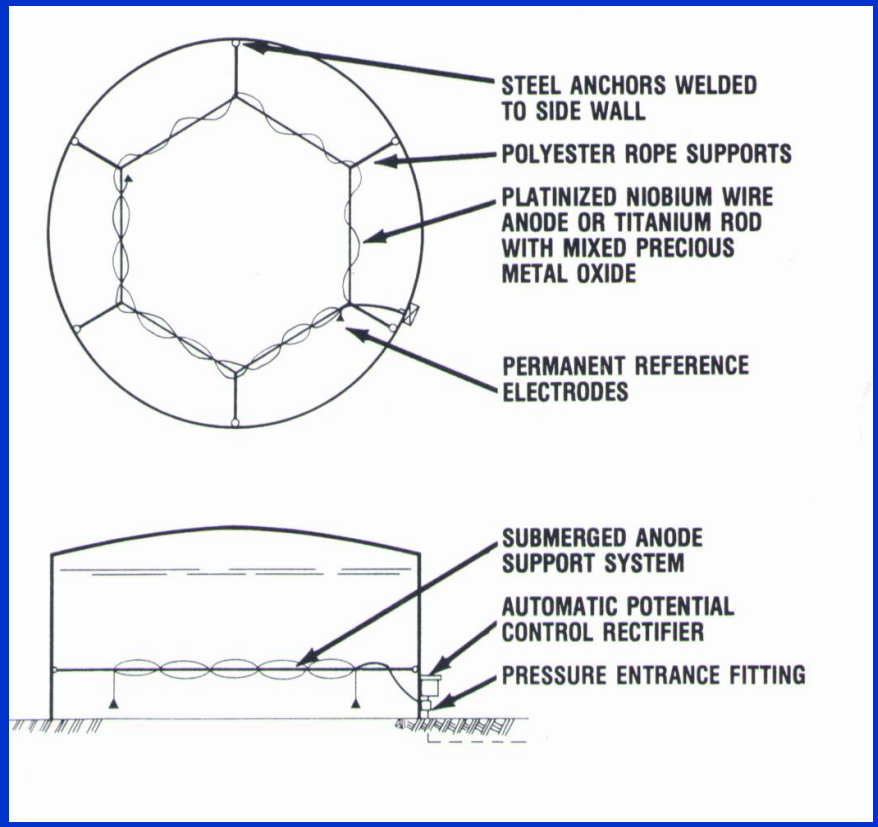


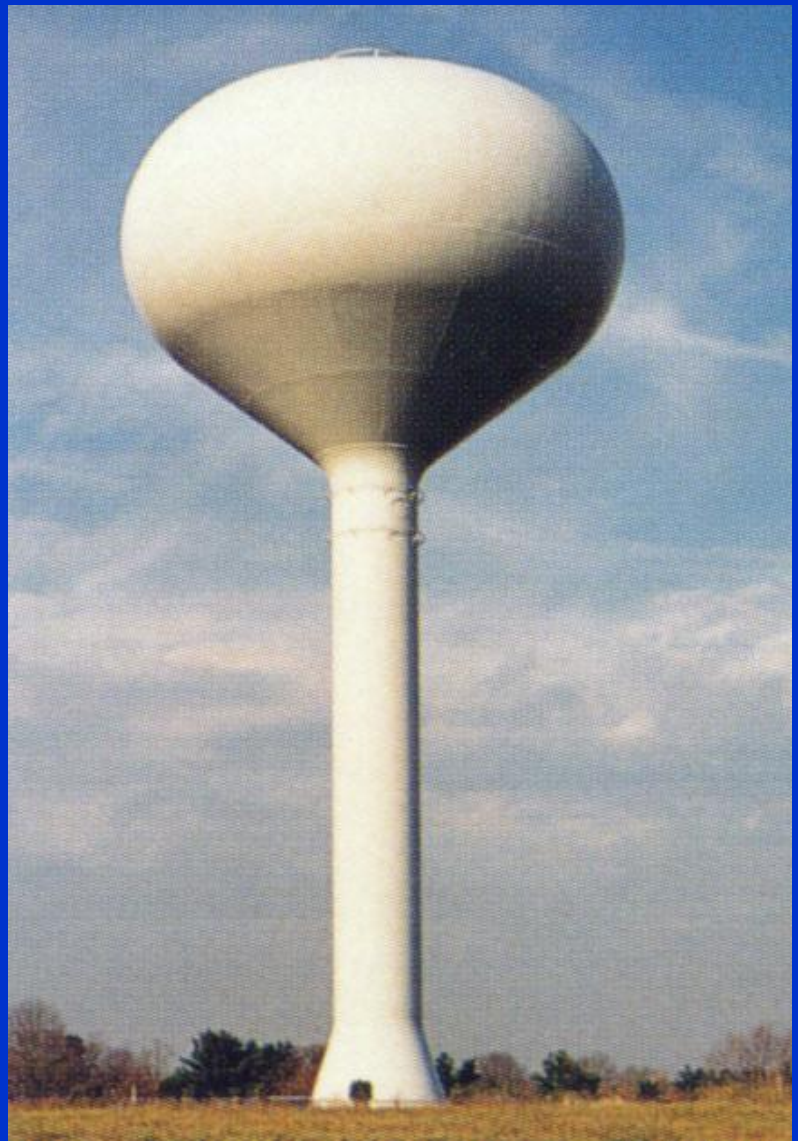


Start-up and Calibration

- Start-up service verifies the system is operating at optimum performance levels
- Calibration adjusts the system to perform within “Criteria for Protection”
- Independent tank-to-water potential profile verifies the systems output levels
- Complete written report with data and evaluation furnished to the owner

Annual Maintenance Services

- Complete system evaluation
- Potential testing to verify system performance
- Calibration to maintain corrosion control per AWWA & NACE criteria
- Written report with recommendations



Annual Service Inspection by a Qualified Technician is Recommended by AWWA D104

The annual service visit includes:

- Complete electrical system check for continuity of anode and reference cell circuits
- Independent reference cell potential test to verify system performance
- Calibration and adjustment of the system to maintain corrosion control within “criteria”
- Written evaluation and recommendations

Service Visit

- Electrical measurements shall be conducted with a portable high impedance voltmeter and a calibrated copper-copper sulfate reference electrode
- Adjustments shall be made in accordance with "criteria for protection" for optimum corrosion control
- Data shall provide sufficient information to evaluate to evaluate the performance of he system relating to "Criteria for protection"
- If additional work is required a written report will be furnished with recommendations

Resistance readings verify electrical system continuity

Technician Recording the Readings During the Independent Cell Test

Technician Performing Visual Inspection of Vertical Anodes

Independent cell tests verify the operating cells performance

Field Services Work Report

HARCO CPS WATERWORKS
a corrpro company
www.corrpro.com

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1055 W. Smith Road	581 Sigman Rd., Ste. 300	2421 Iorio Street	5643 N. 52nd Ave.
Medina, OH 44256	Conyers, GA 30013	Union, NJ 07083	Glendale, AZ 85301
330/725-6681	770/761-5400	908/686-1770	602/269-7641
Fax 330/723-6065	Fax 770/761-5410	Fax 908/686-1704	Fax 602/842-9697

CUSTOMER: **Ship To:**

Customer Contact Name and Number: _____ Schedule _____
Customer P.O. _____ Customer No. _____ Job No. _____ Region _____
Tank Capacity and Type _____ Type of System _____ Type of Service _____
Tank Address: _____ County _____
Rectifier Mfg. _____ No. _____ System No. _____ Rating _____
Anode Configuration _____

Measurements prior to testing, evaluation and adjustments "OFF" _____ "ON" _____

a) Rectifier Tap Setting at: _____ Auto ☐ Manual ☐ Water Level _____
b) Rectifier Operating at:
Bowl Volts _____ Amps _____ Pot. Set _____ Potential Level _____
Riser Volts _____ Amps _____ Pot. Set _____ Potential Level _____
c) Resistance Readings | Anode - Bowl _____ Riser _____ Aux. No. _____
Reference Cell - Bowl _____ Riser _____ Aux. No. _____
d) Independent Tank-to-Water Potential Profile Within Tank:

Tank Bottom	ON	Instant OFF
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

e) Rectifier Operation Adjusted To: _____ Tap Setting: _____ Auto ☐ Manual ☐
Bowl Volts _____ Amps _____ Pot. Set _____ Potential Level _____
Riser Volts _____ Amps _____ Pot. Set _____ Potential Level _____

WORK ORDER

	☐ Installation	☐ Startup	☐ Service	☐ Other
1) Electrical				
2) Anode System				
3) Rectifier				

Evaluation - Overall System Performance for Corrosion Control: _____
Recommendations: _____

Operator Instructions provided to: _____ Do **NOT** adjust rectifier in automatically controlled mode of operation. Record voltage, current and potential meter readings at intervals not to exceed sixty (60) days.

HARCO/CPS WATERWORKS
a corrpro company

By: _____ Date: _____

SUBSCRIBER'S ACCEPTANCE

By: _____ Date: _____

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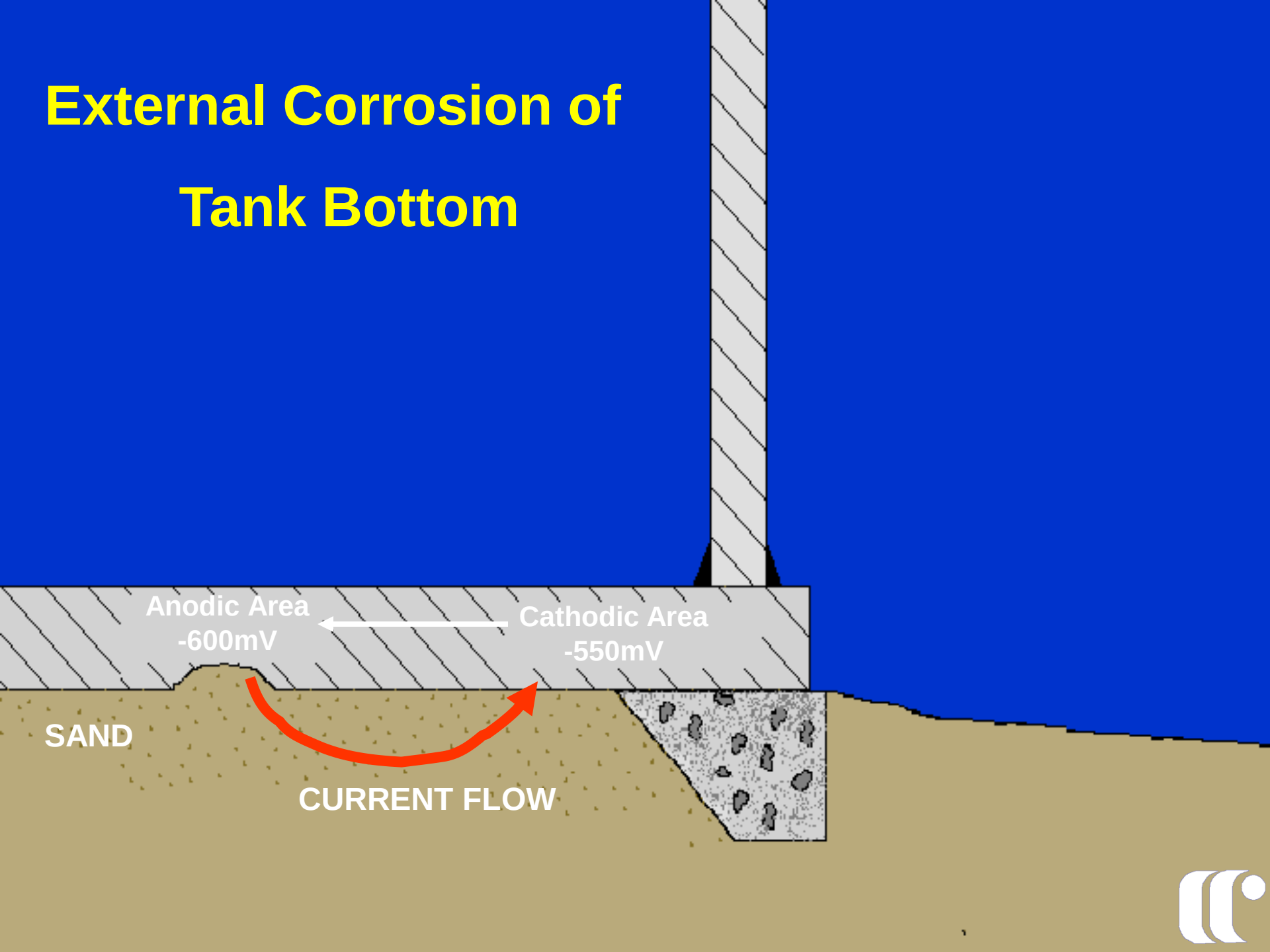
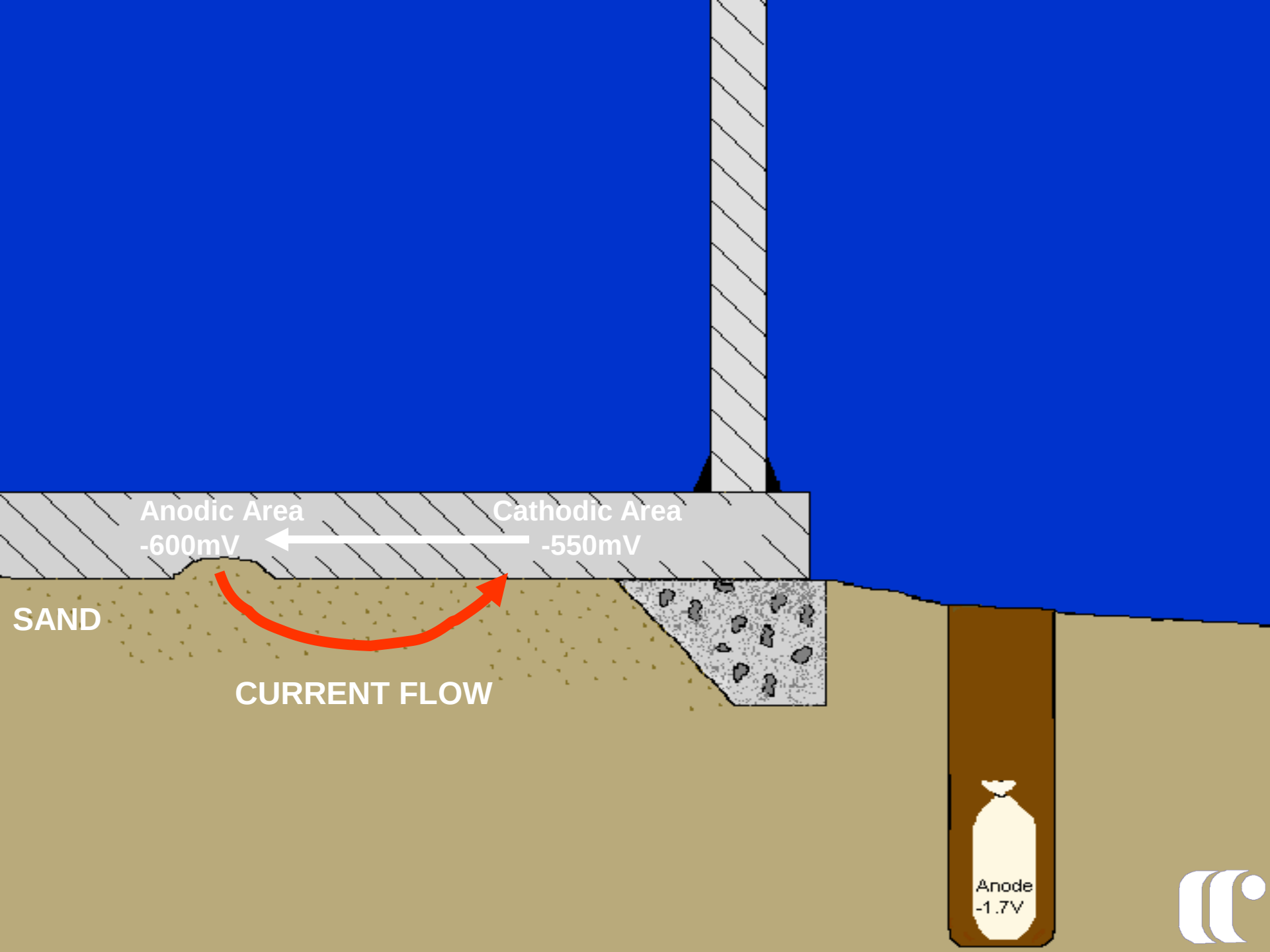
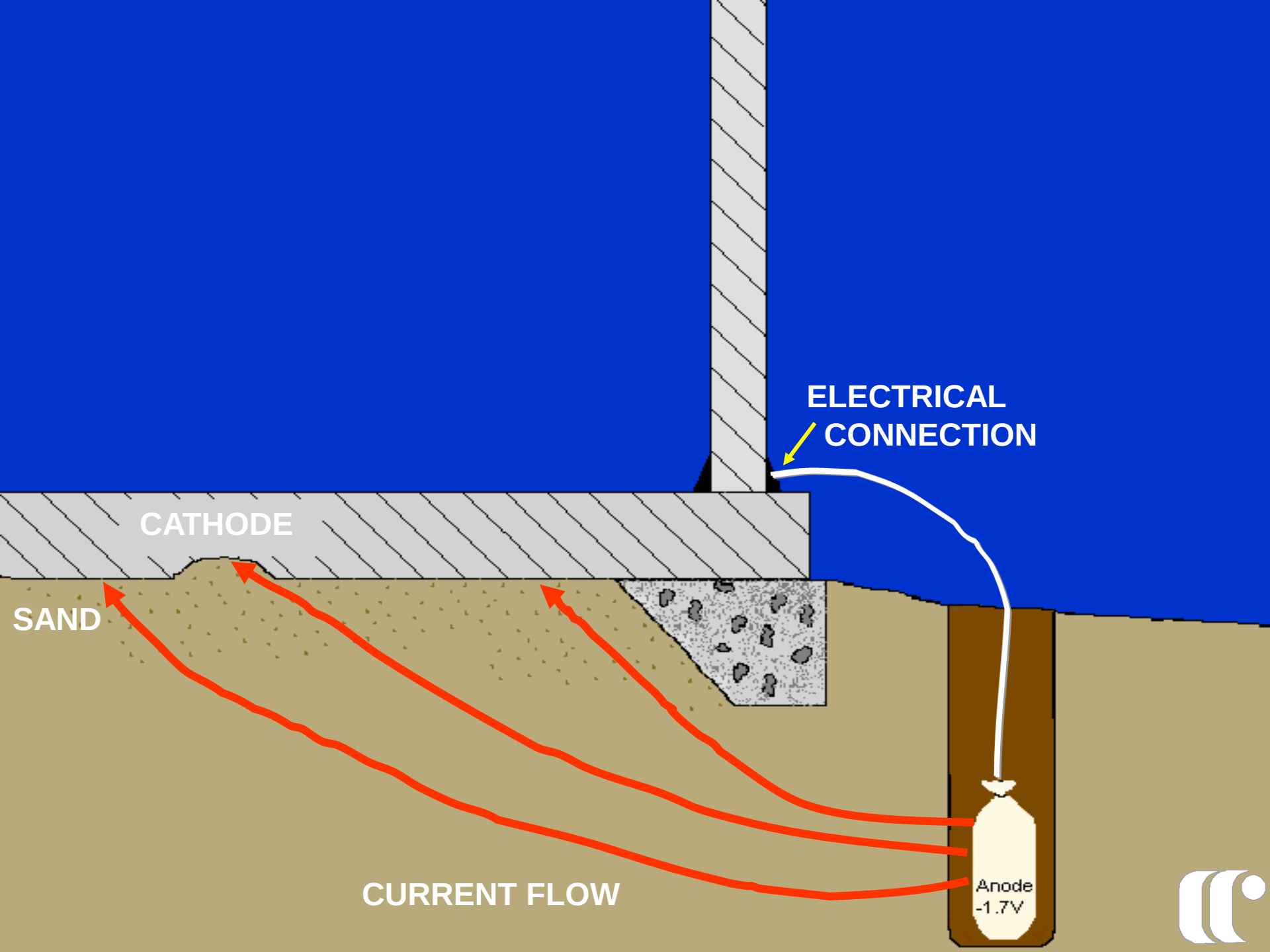
Continuing Maintenance

- Owner should check the meters on the rectifier at intervals not to exceed 60 days
- Compare the volts, amps and potential readings to set point and previous readings
- If report cards are furnished by the cathodic protection constructor, fill them out and mail them to the constructor for review
- Remote Monitoring Technology is quickly evolving as an economical means of monitoring system performance

External Corrosion of Tank Bottom

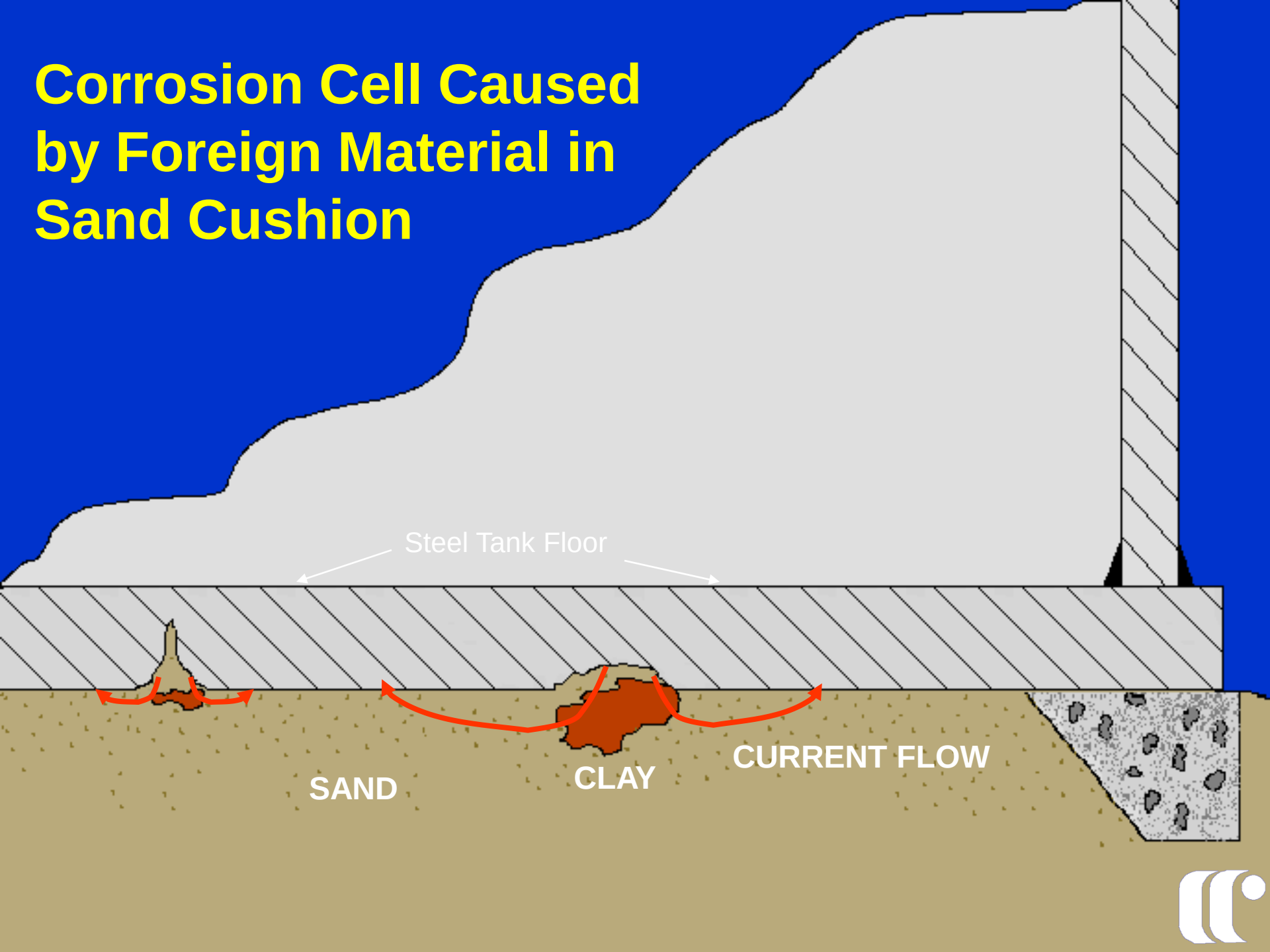



Anodic Area
-600mV
Cathodic Area
-550mV
SAND
CURRENT FLOW
Anode
-1.7V

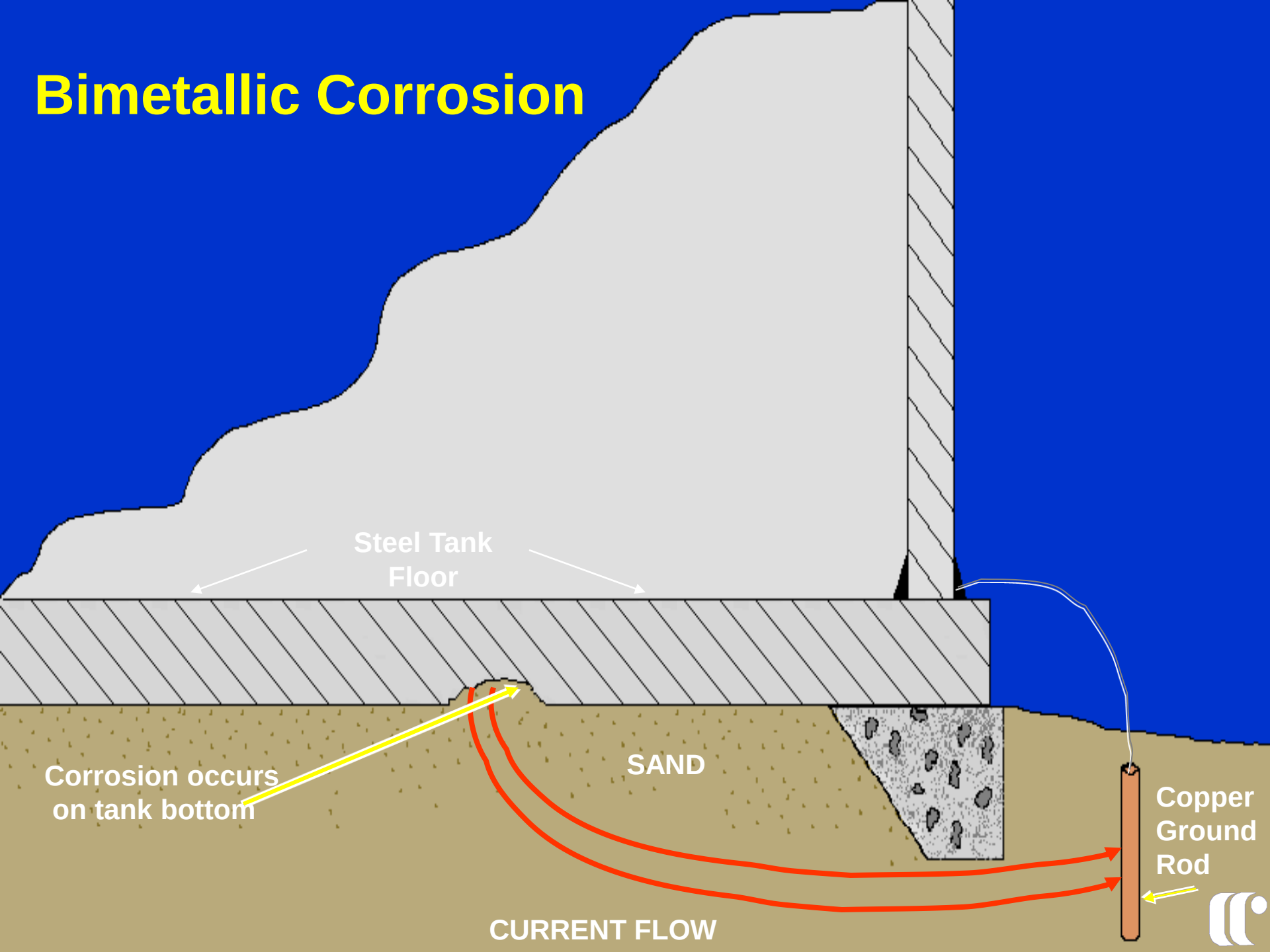

ELECTRICAL
CONNECTION
CATHODE
SAND
CURRENT FLOW
Anode
-1.7V

Tank to Soil Potential Measurements

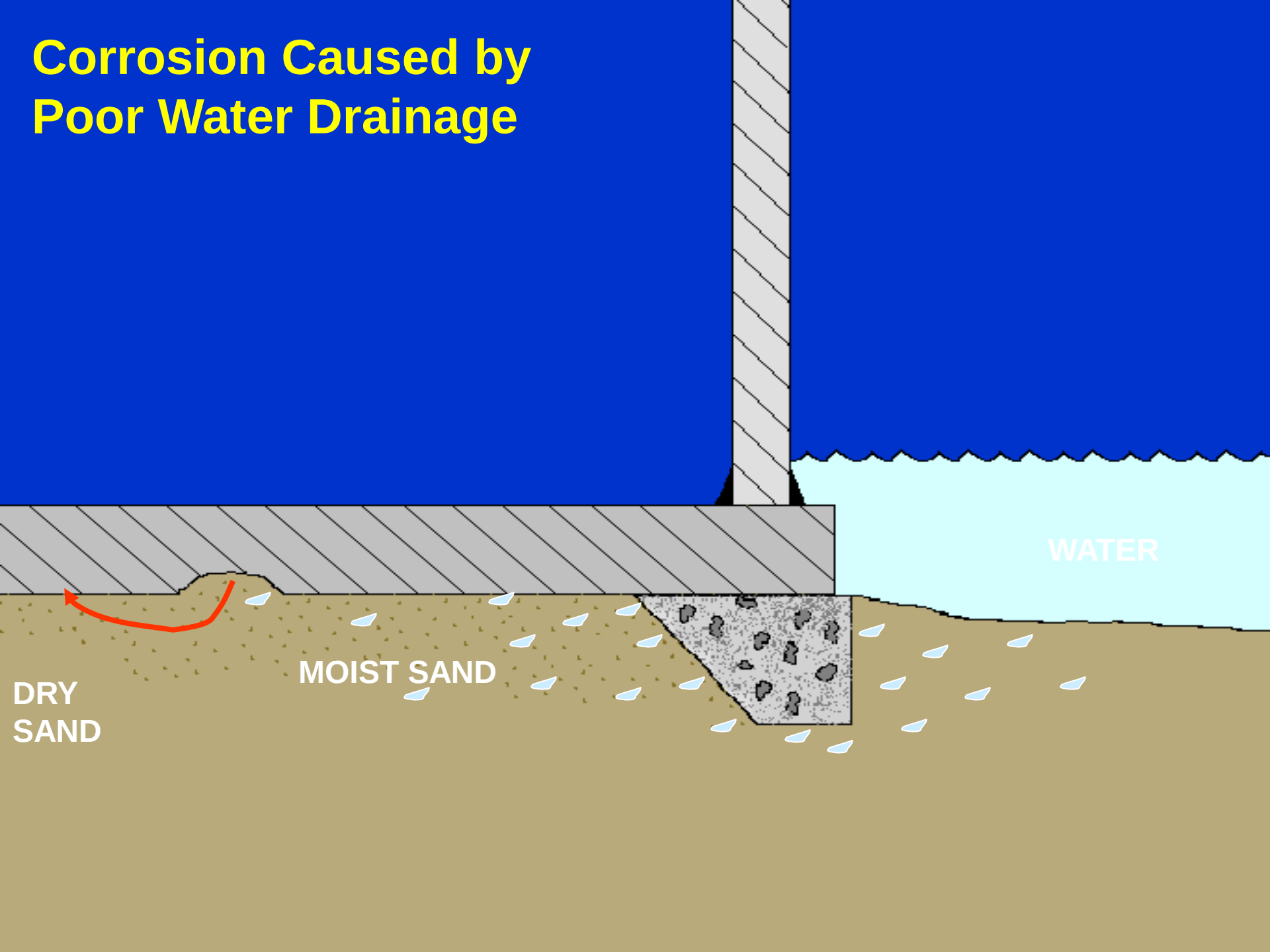
Corrosion Cell Caused by Foreign Material in Sand Cushion



Bimetallic Corrosion



Corrosion Caused by Poor Water Drainage



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 ans storage tank installations.


Traffic Disruptions
Water Loss
Fire Protection
Damages
Legal & Environmental Claims

QUESTIONS ?

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