

Water Tank Cathodic Protection



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"Preserving and Sustaining Global Assets & Infrastructure"

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Water Storage Tanks



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

Corrosion related to infrastructure (O&G Pipelines, Water Systems, Bridges) costs the United States over 300 Billion Dollars per year!

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”.

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



AWWA Standard D104-97

“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”

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.

NSF 61 Compliance Certificate

• **UNDERWRITERS LABORATORIES INC.**

• An independent, not-for-profit organization testing for public safety

• _____ MANUFACTURE REFERENCE No. MH17837

• **COMPANY NAME**

• _____ CERTIFICATE No. M230-76778

• **ADDRESS**

• _____
• **CITY, STATE, ZIP CODE**

• The above company is qualified under the Classification and Follow-up Service of Underwriters Laboratories Inc. to furnish Drinking Water Treatment Components Classified with respect to Standard ANSI/NSF 61.

• The above mentioned company is therefore authorized to issue this Certificate for the bulk shipment of material described below as it's representation that such material is manufactured in compliance with requirements established by Underwriters Laboratories Inc. for this class of product. This Certificate does not indicate proper application or use of the material and does not apply to other material, which may be used at the location specified.

• -- SEE U L PLUMBING AND ASSOCIATED PRODUCTS DIRECTORY --

• TRADE DESIGNATION: ACIC 1-2-4-7-8-9-10-14-16 CATEGORY Mechanical Devices

• USE LEVEL: 25,000 Gallon Tanks or Larger

• **DRINKING WATER SYSTEM COMPONENTS**

• **ANSI / NSF 61**

• **7N53**

• Date of Issuance of Certificate: _____

• Date Material Supplied: _____

• Carrier: _____ City/State _____

• Description of Container: _____

• Bill of Lading No. _____

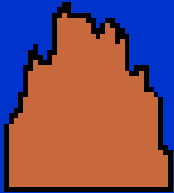
• Shipped To: _____ . City/State _____

• Signature of Authorized Person : _____

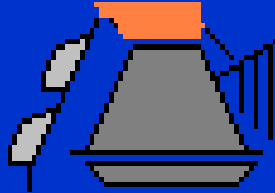
CORROSION IS DEFINED AS:

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

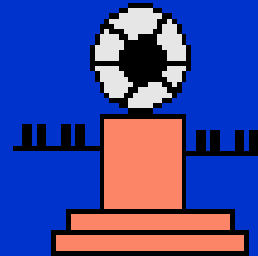
Corrosion - A Natural Process



IRON OXIDE



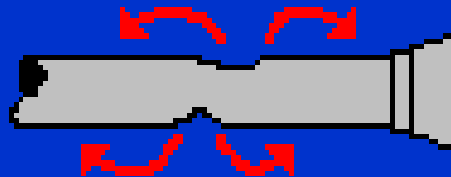
REFINING



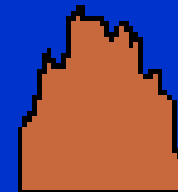
MILLING



IRON



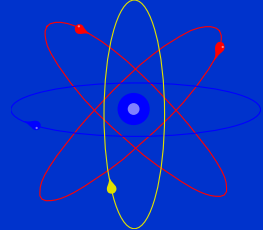
CORROSION



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-CuSO₄ Electrode

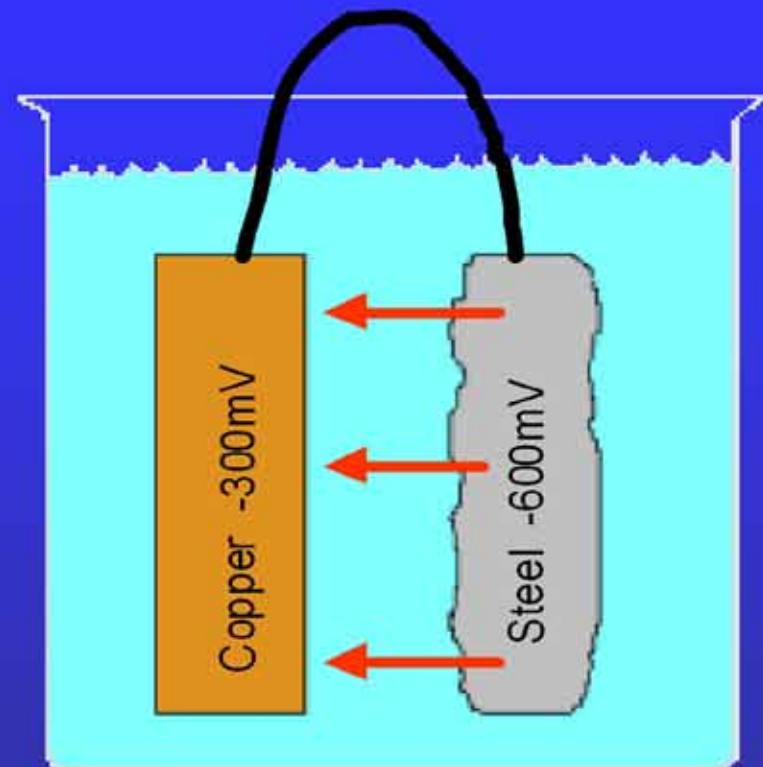
Cathodic Protection
introduces an external DC
current which makes the
entire structure a cathode.

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

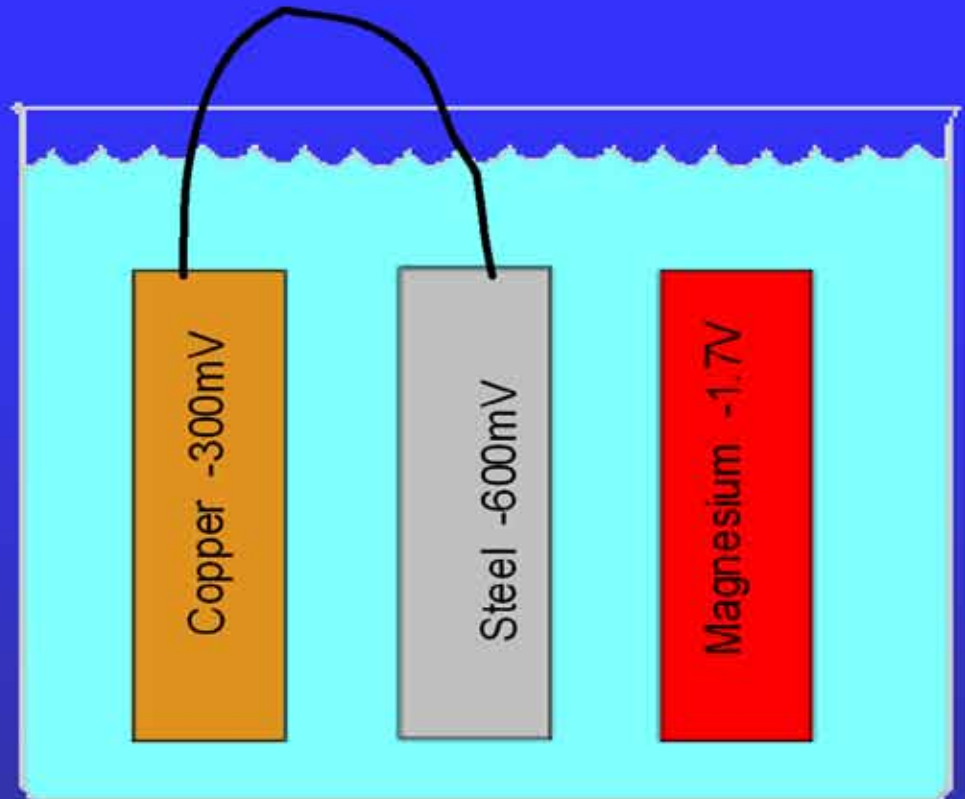
Corrosion

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



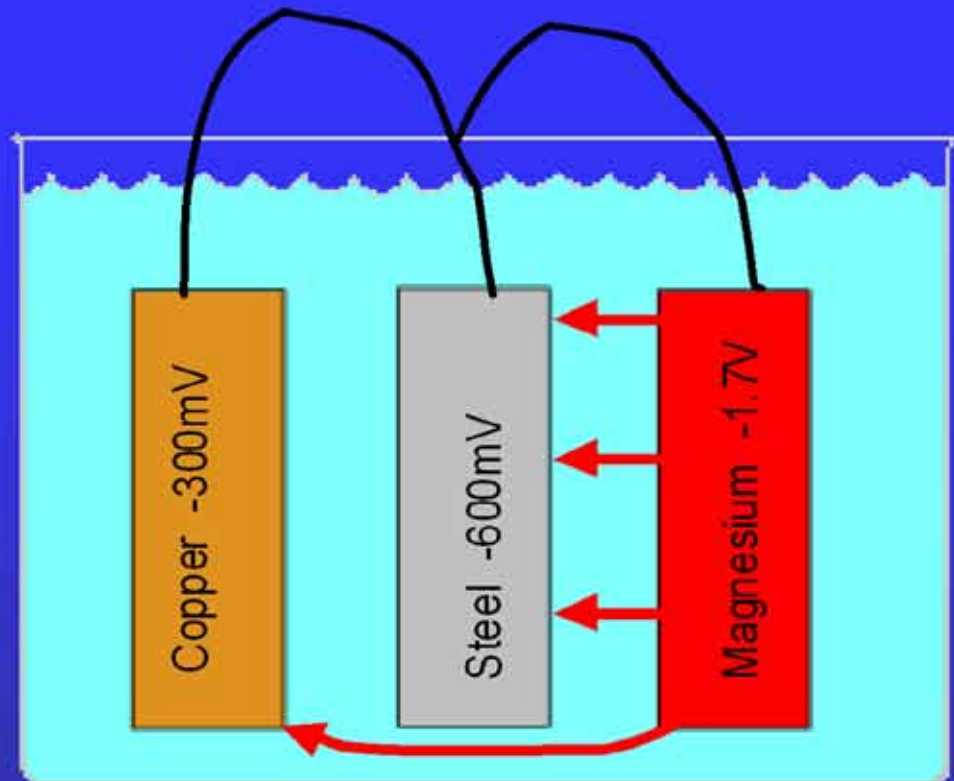
Corrosion

- 1) ANODE
- 2) CATHODE
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- 4) METAL PATH



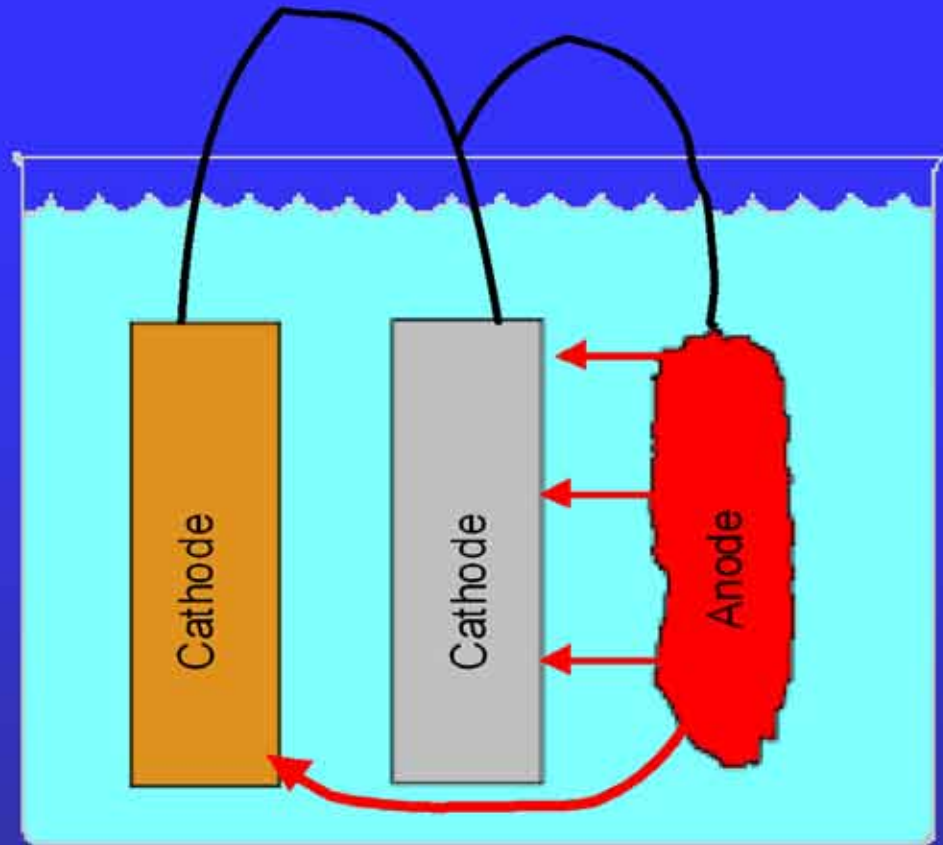
Cathodic Protection

- 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

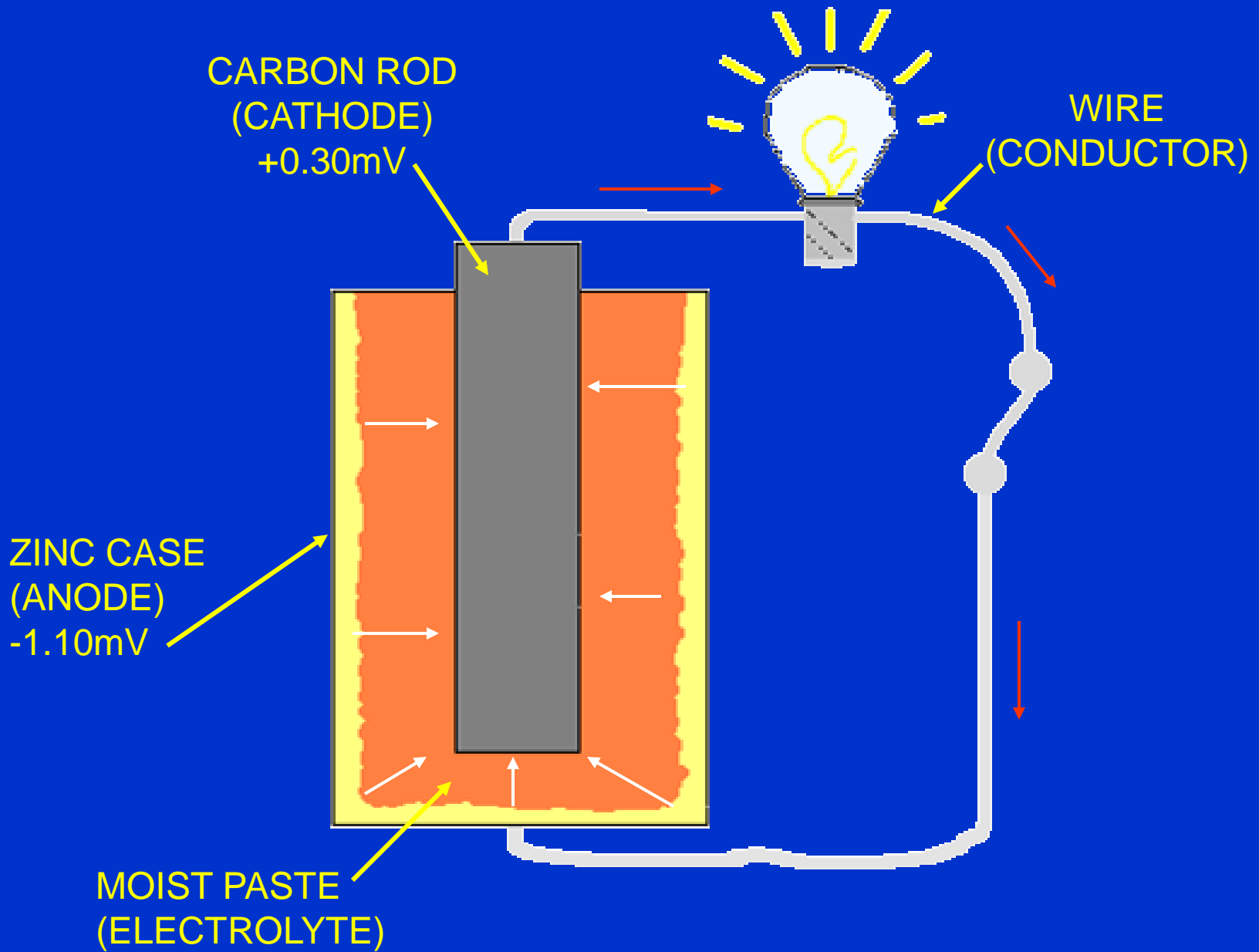
- Electrolyte: Water and/or Wastewater
- Conductor: Steel Tank or Equipment
- Anode: Metal in contact with the electrolyte
- Cathode: Metal in contact with the electrolyte

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



Metals Connected together can form a Corrosion cell

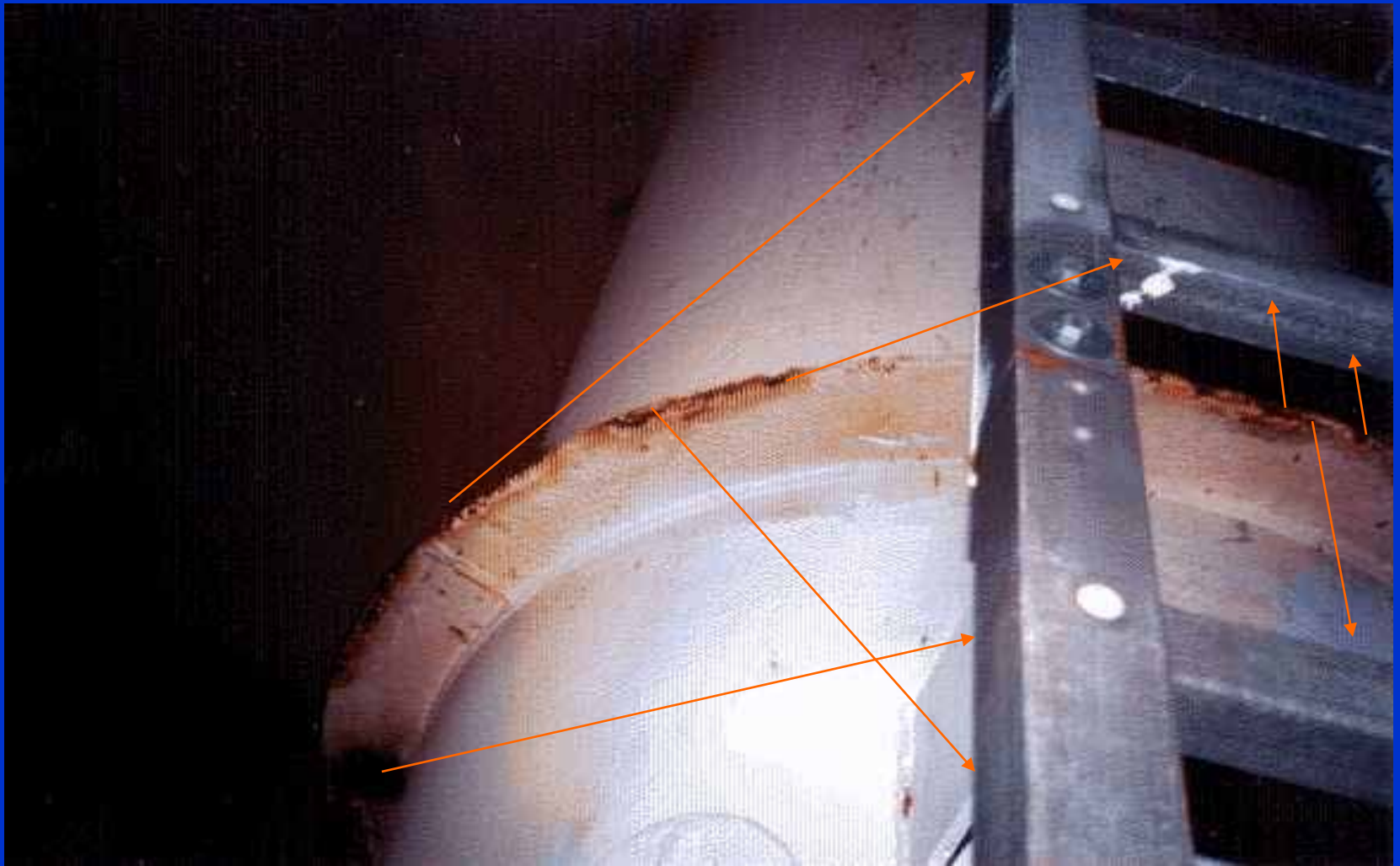
ANODE (corrodes)

- **New Steel** to
- **Steel** to
- **Galvanized Steel** to
(ladders & safety climbs)
- **Steel** to
- **Magnesium** to
- **Steel** to

CATHODE (protected)

- **Old Steel**
- **Copper**
- **Steel**
- **Stainless Steel**
(ladders & safety climbs)
- **Steel**
- **Reinforcing Steel**

Galvanic Corrosion Induced by a Stainless Steel Ladder



Galvanic Corrosion reaction between steel and rebar in a treatment facility

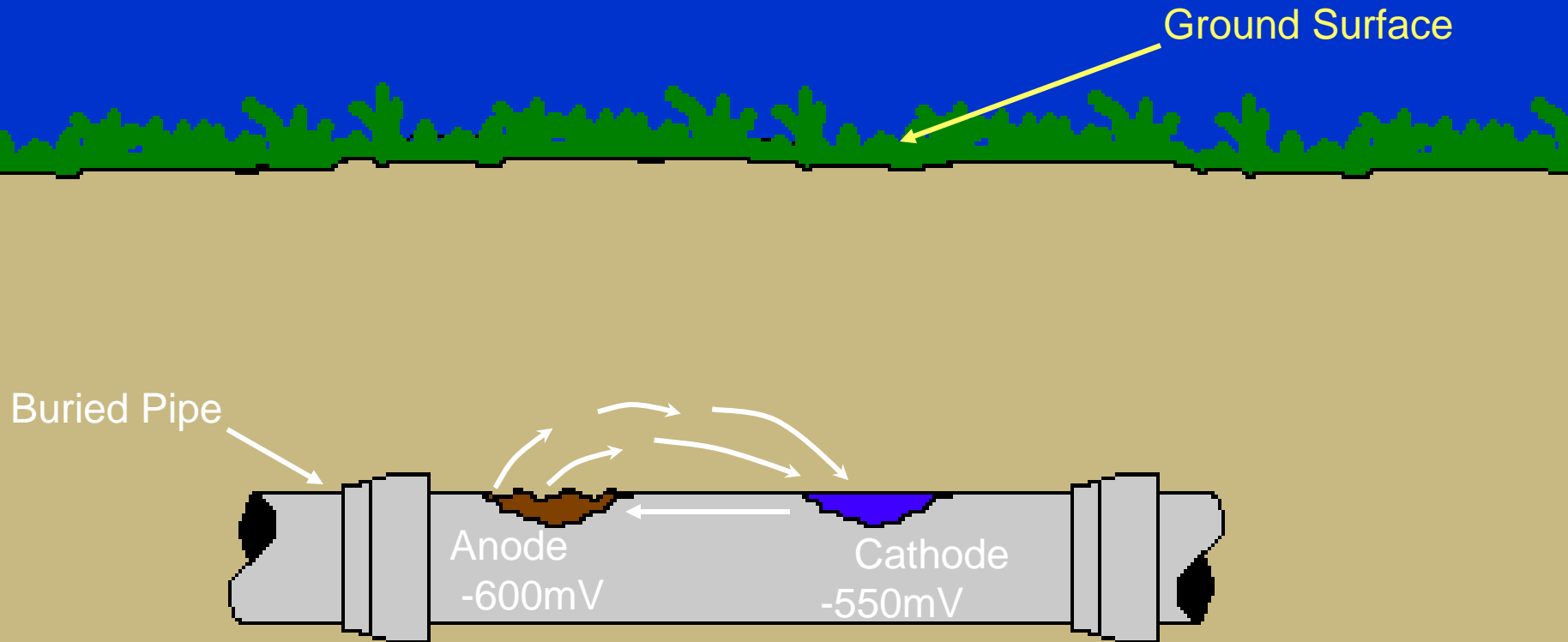


Homogeneous Metal Corrosion

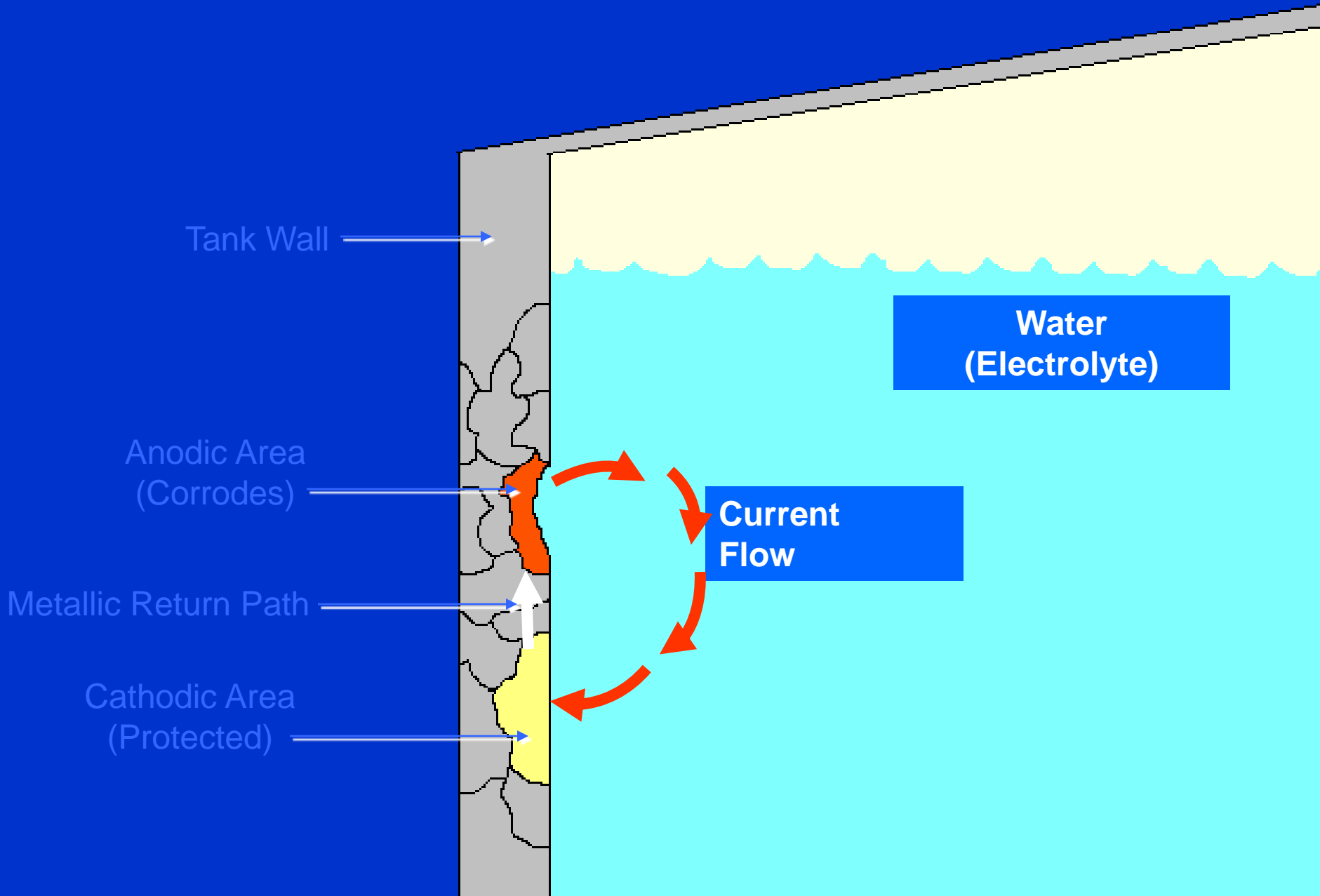
Example: Steel Plate or Iron Pipe

- 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





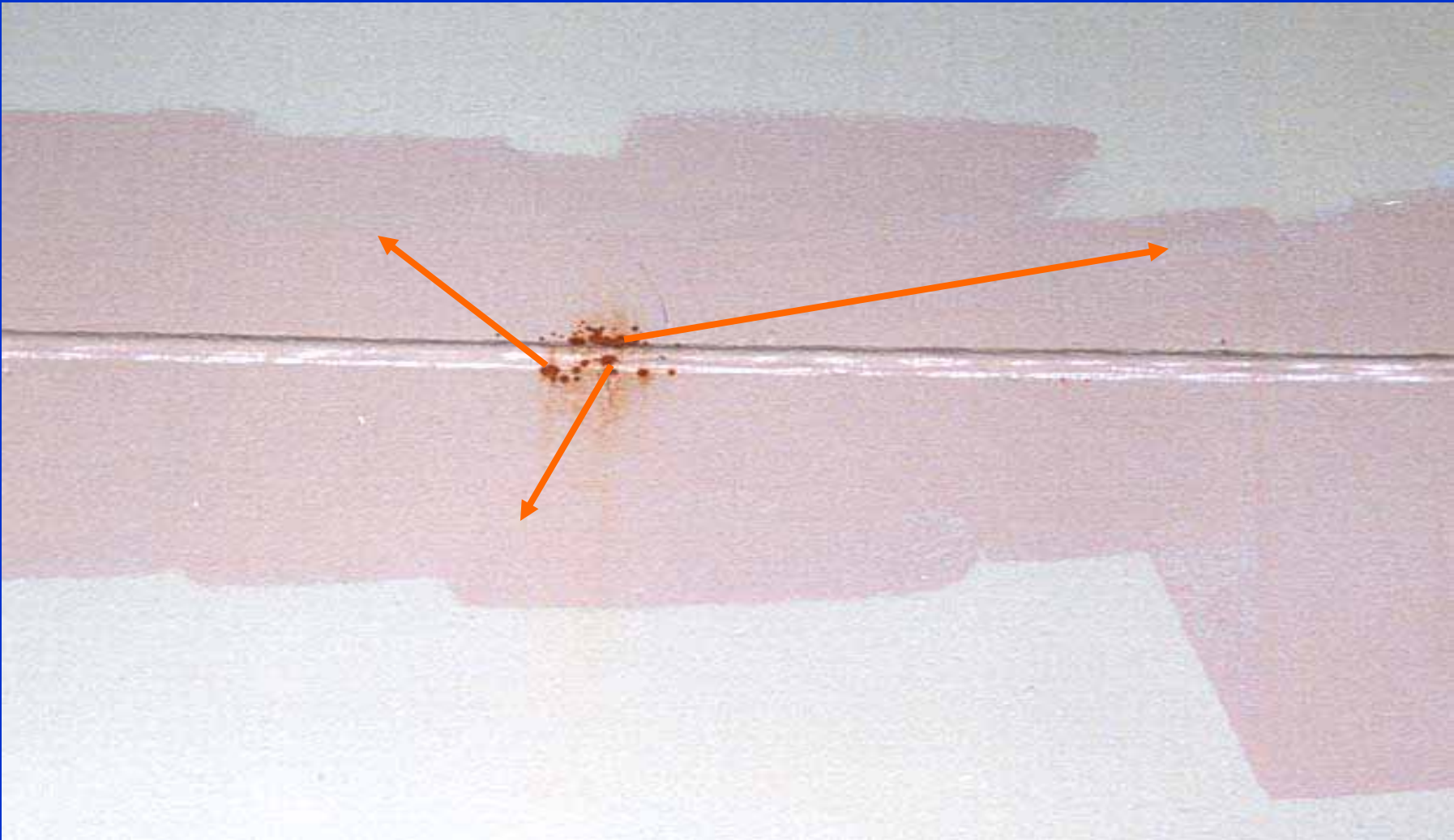
To Prevent Corrosion, one or more of the four requirements of a corrosion cell must be eliminated or minimized

- 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

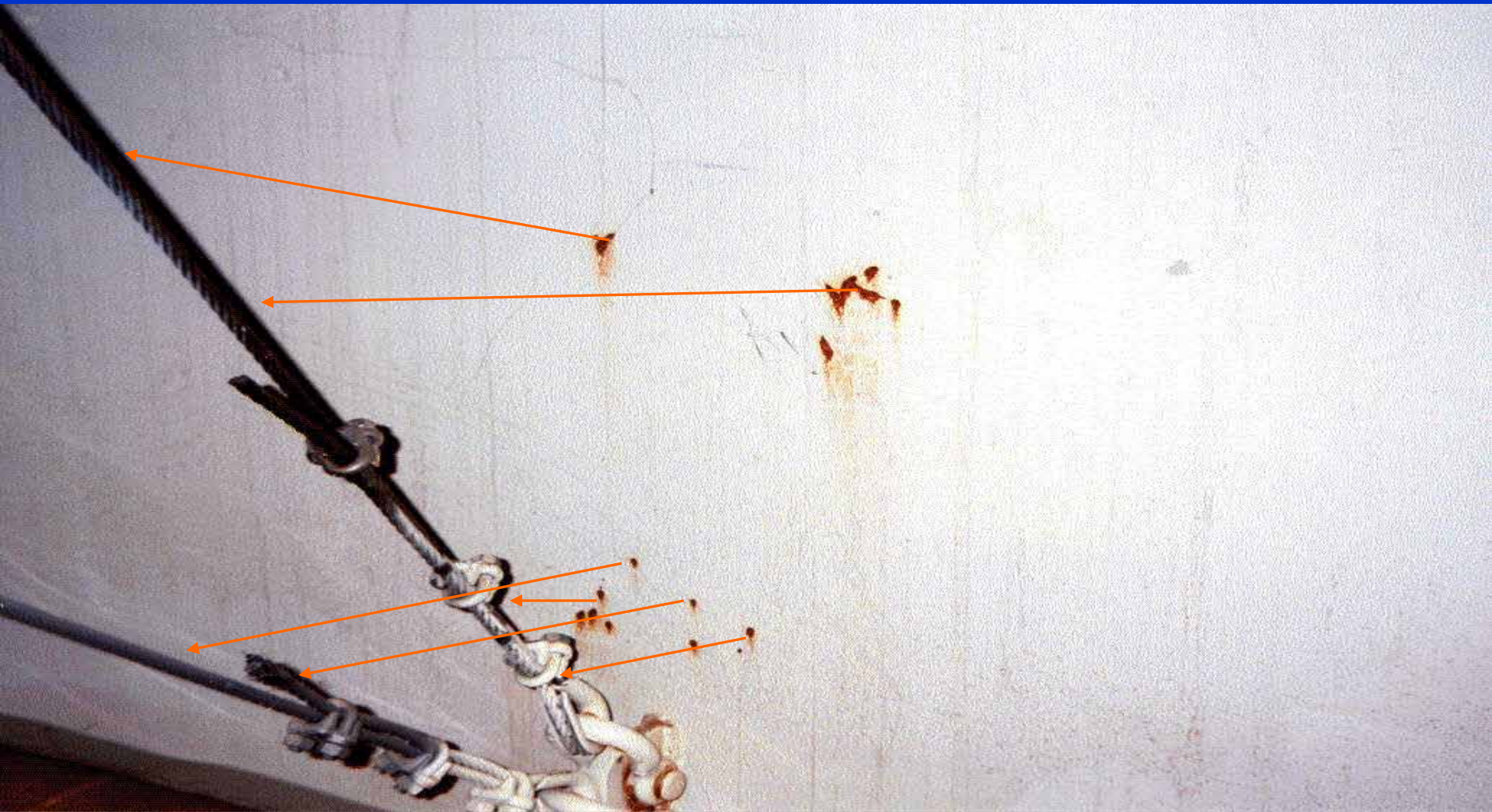
Continued active corrosion on a weld seam after two years in service and one attempted touch-up



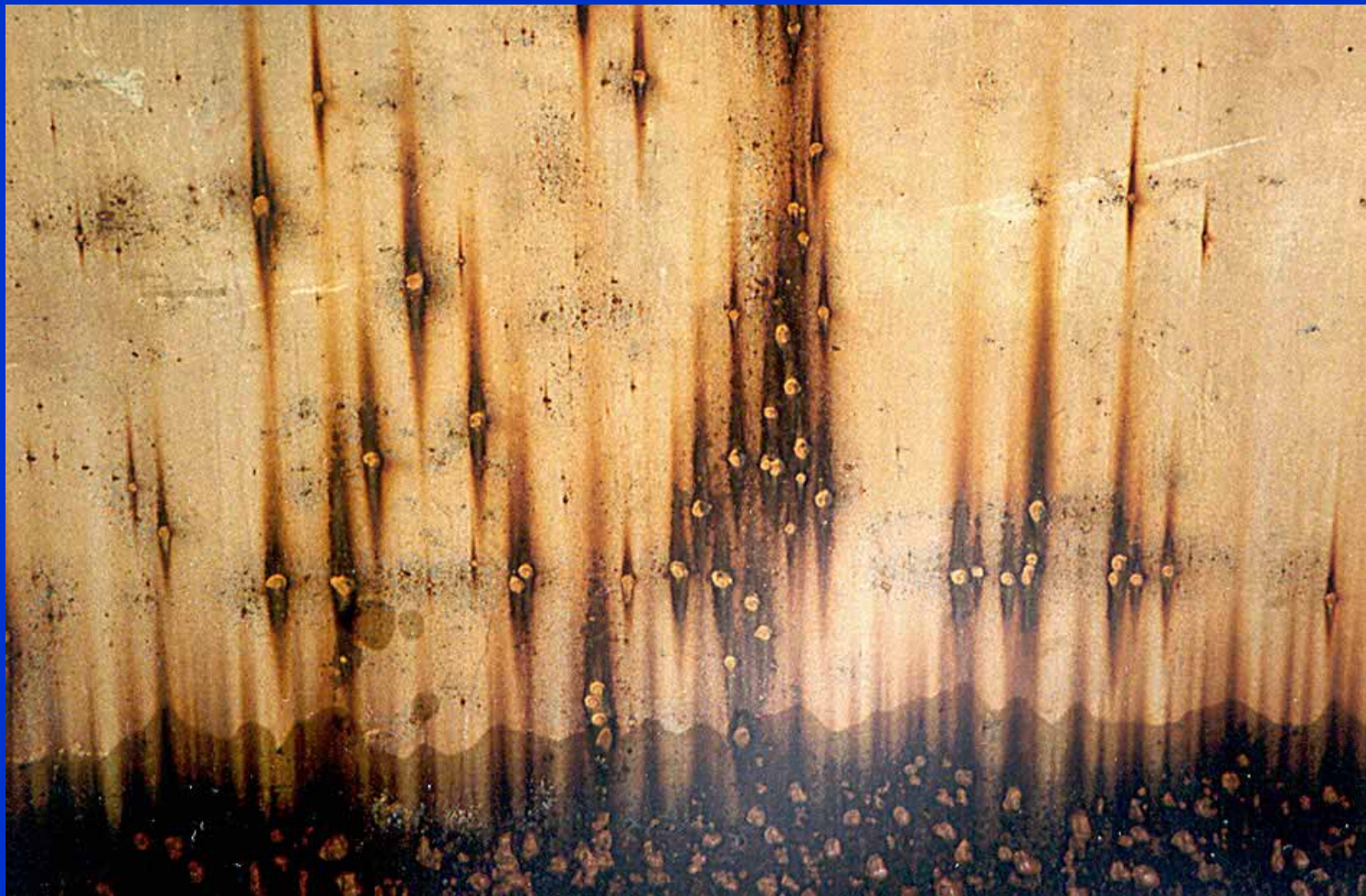
Q. Why are small areas of corrosion activity NOT small problems?? A. Area effect concentration cells



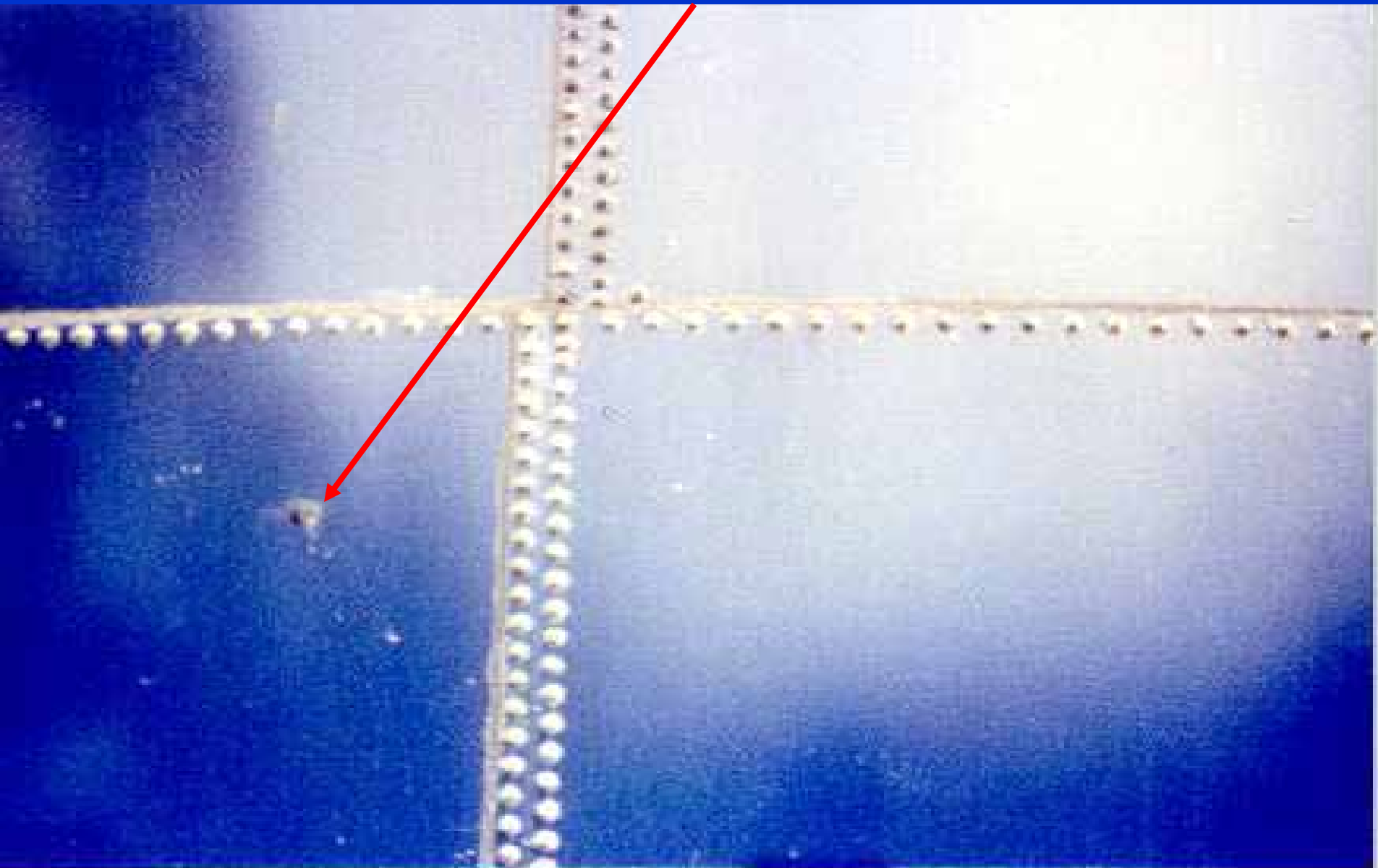
Area effect: “Corrosion of the anodic area may be 100 - 1000 times greater than if the anodic and cathodic areas were equal in size”
Corrosion Engineering Fontana & Greene 1978



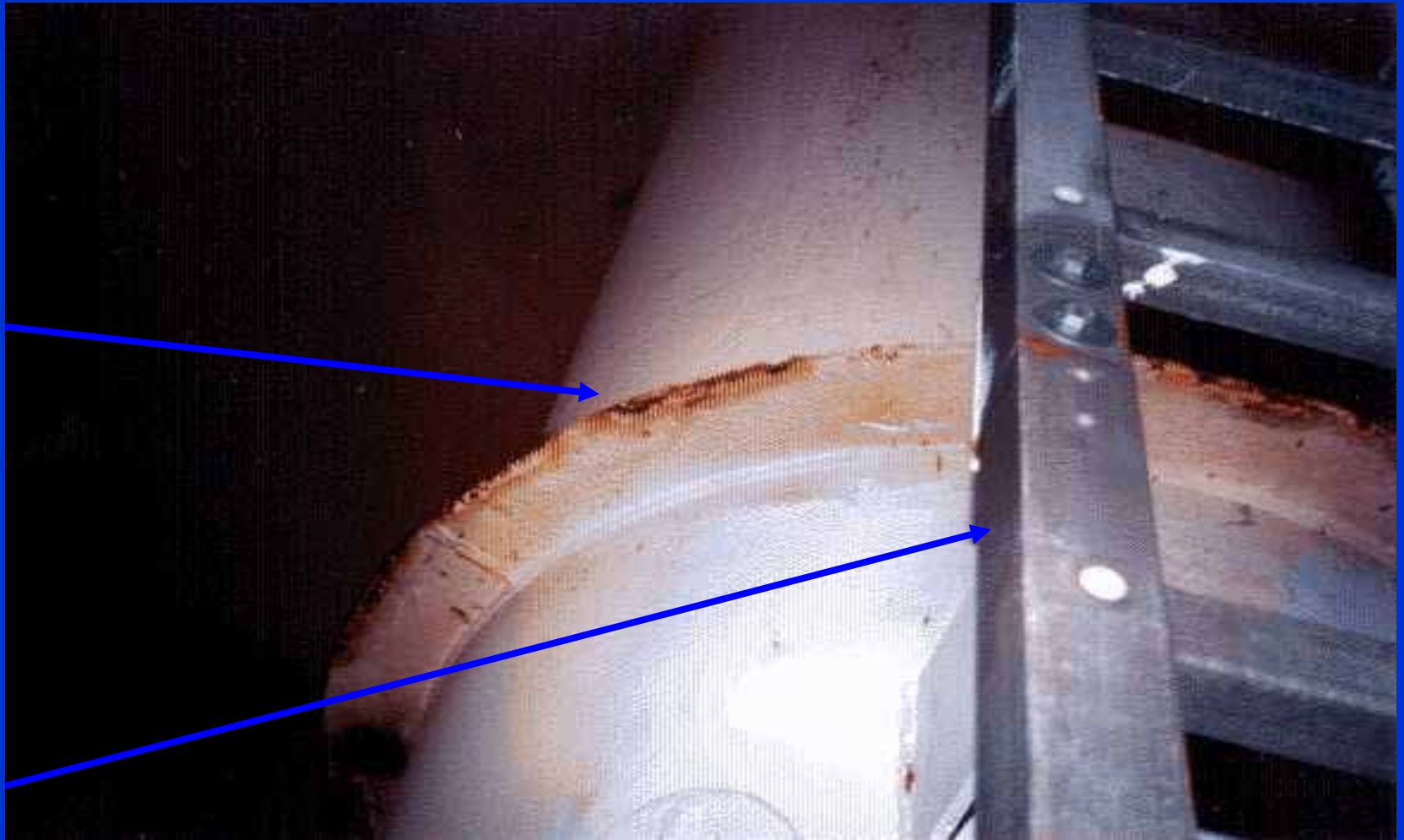
Pitting Corrosion can lead to costly welding repairs or the use of “pit fillers” or even.....



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



The same principal applies to Treatment Equipment



Calcareous deposits often form over “holidays”



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



Exposed “holiday” with no active corrosion



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

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.



AWWA Standard D104-04

- “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 -0.850V 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 D104-04 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 its 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





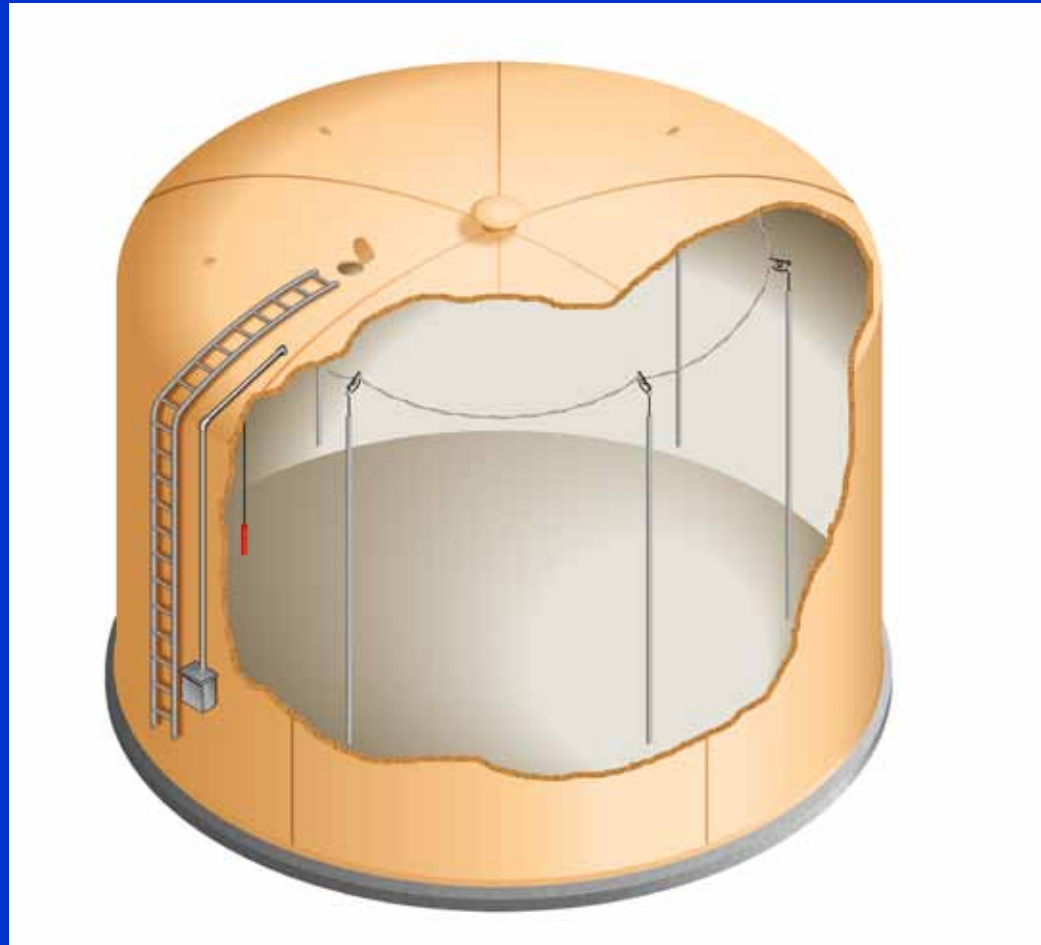
Advantages of the Vertical System

- 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

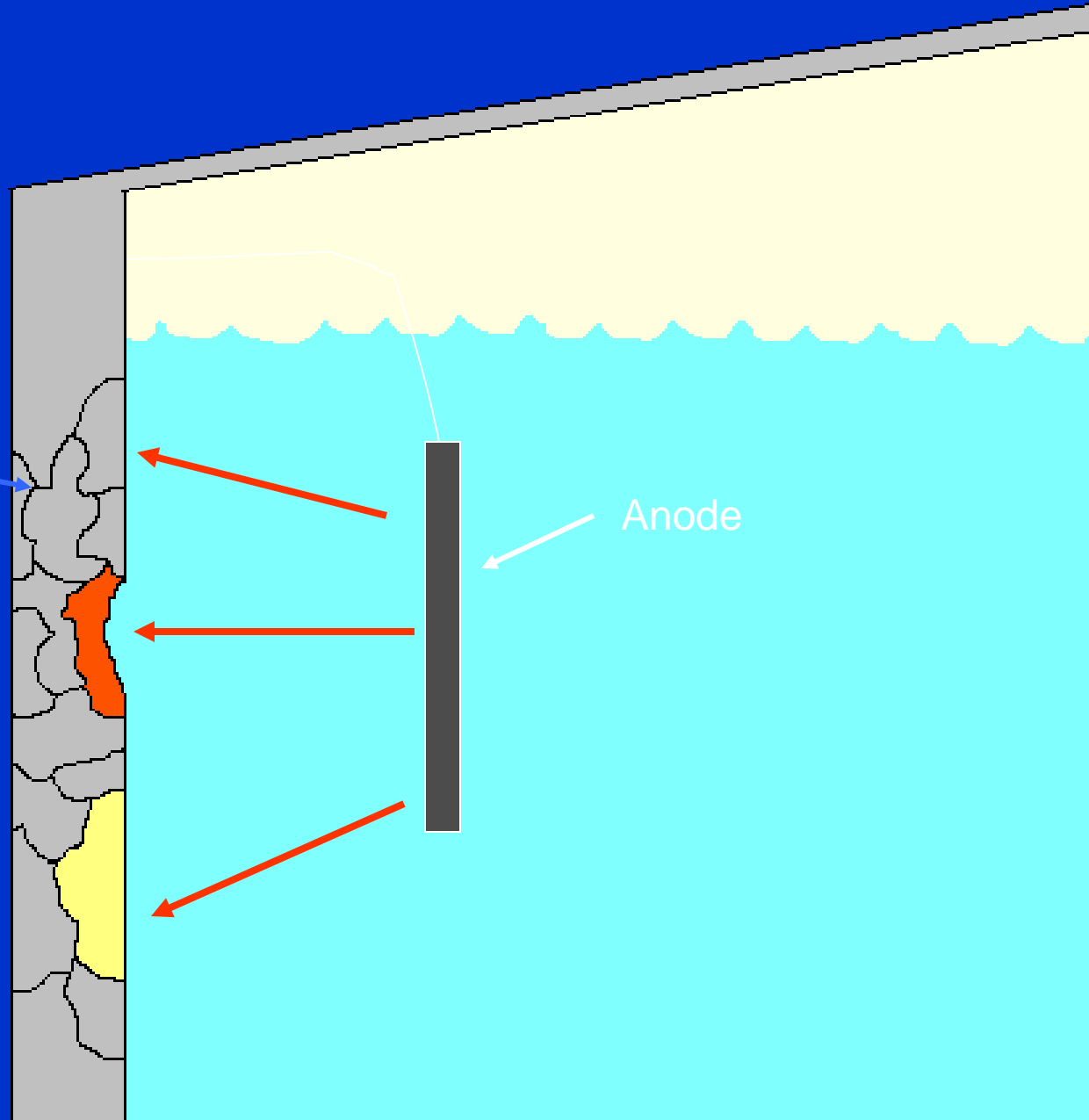
Horizontally submerged anode system



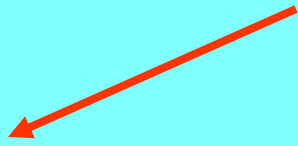
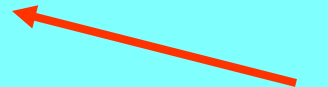
Sacrificial anode system: Proposed new AWWA standard



Cathode
(Protected)

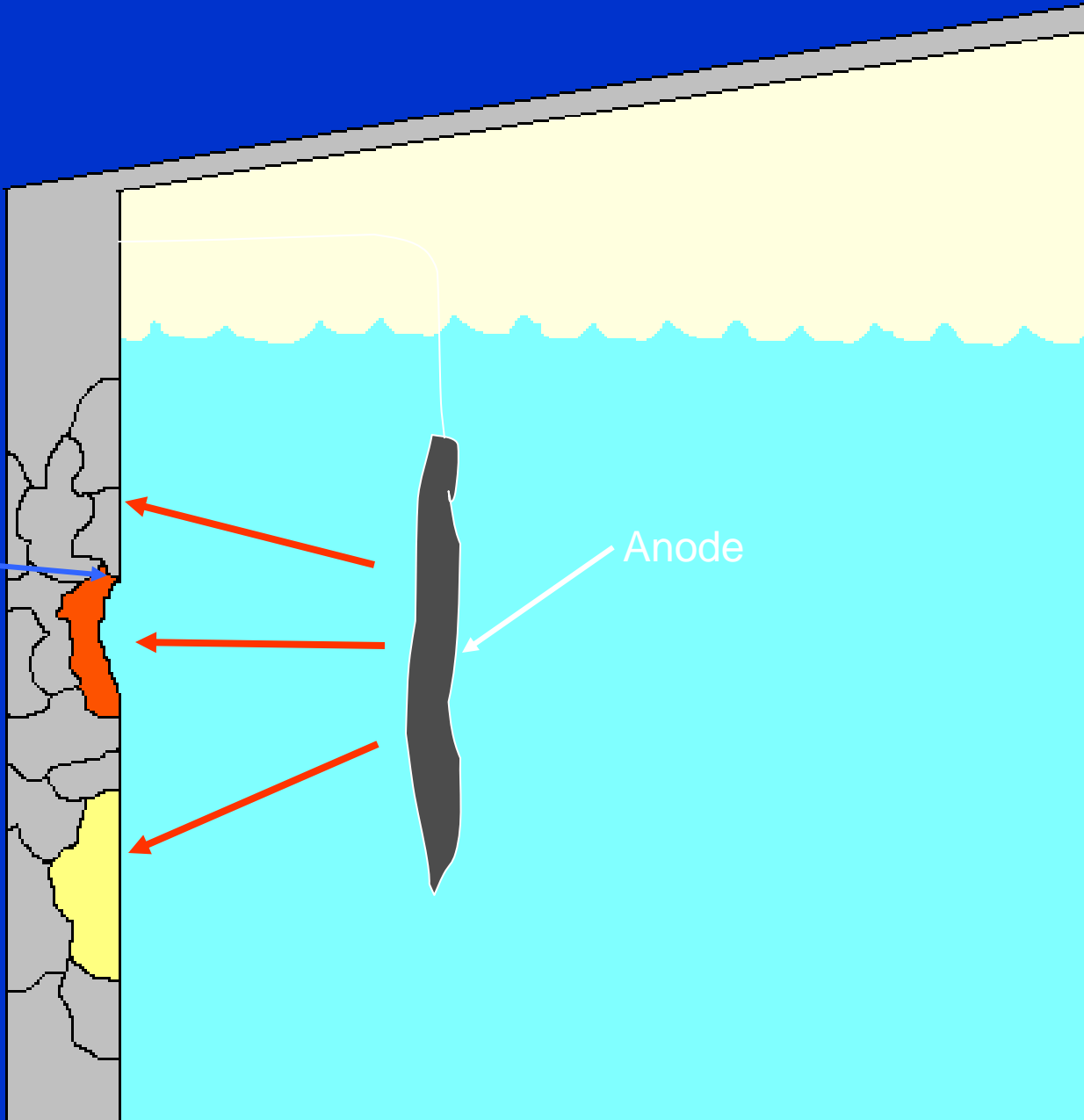


Anode



Cathode
(Protected)

Anode



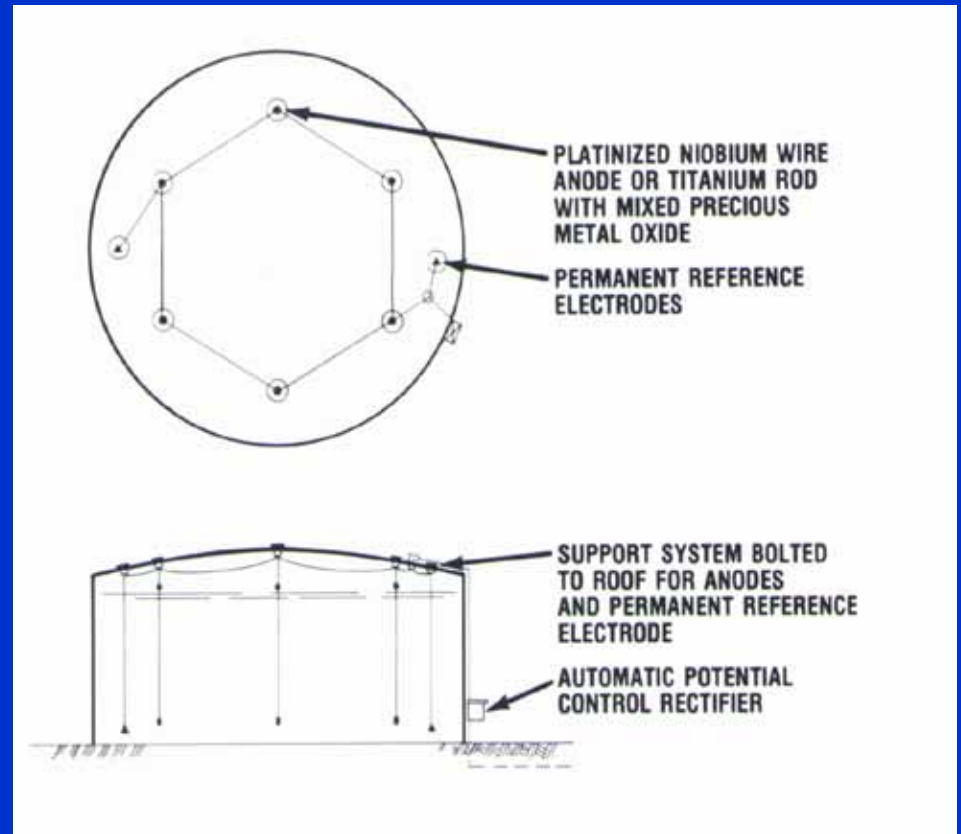
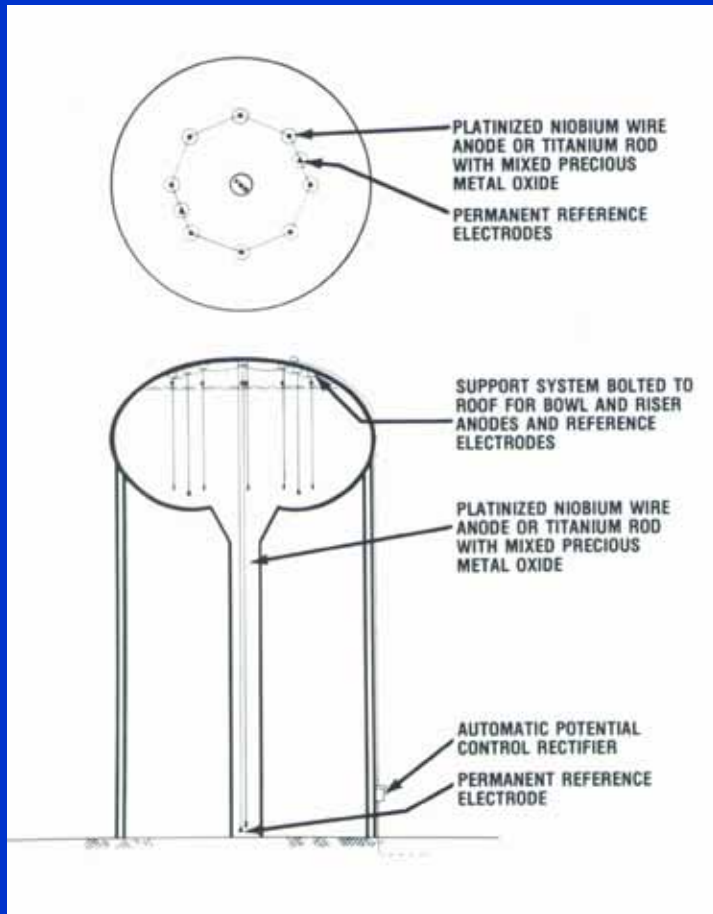
Examples of System Designs

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

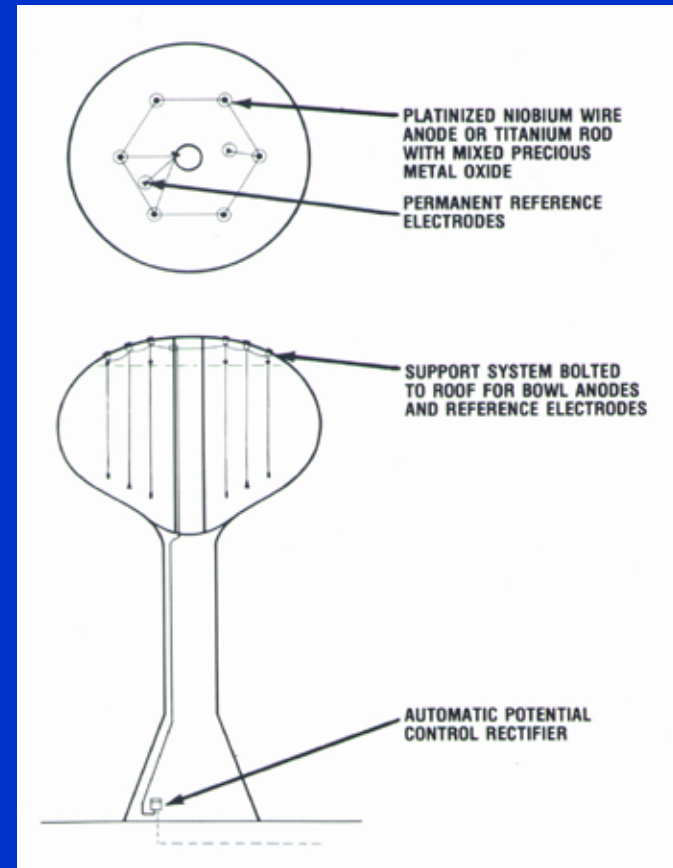
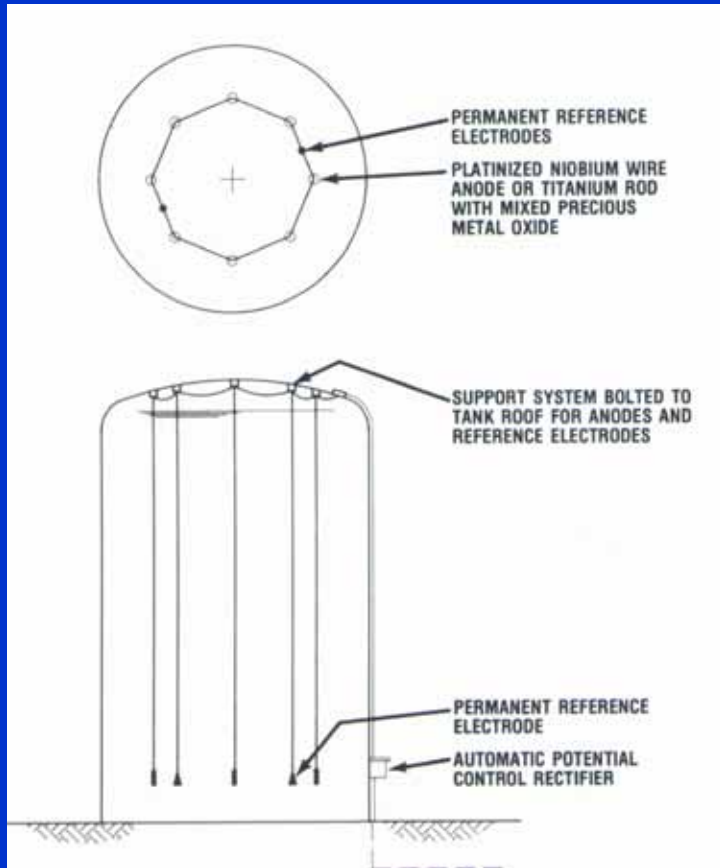
Advantages of the Horizontal System

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

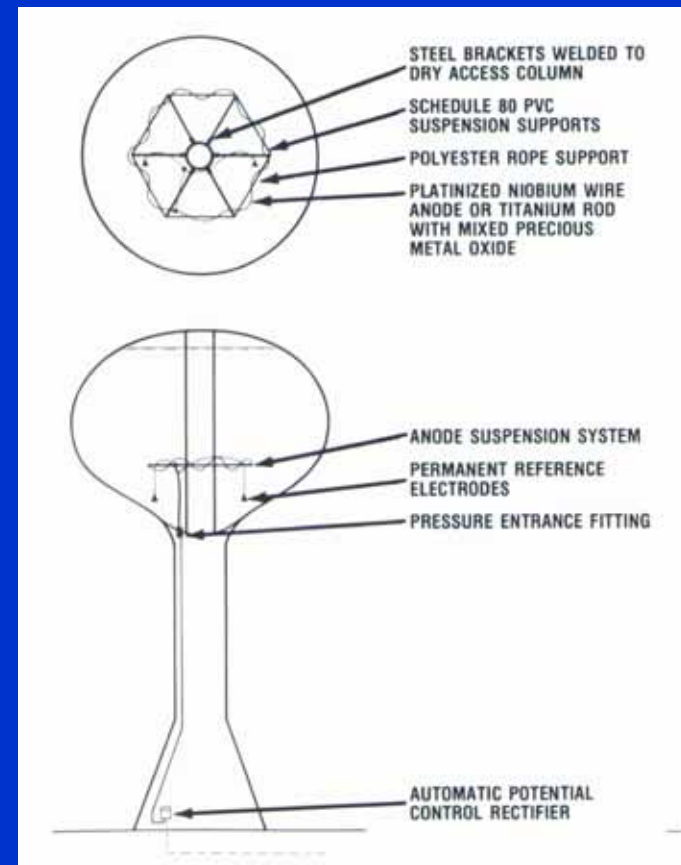
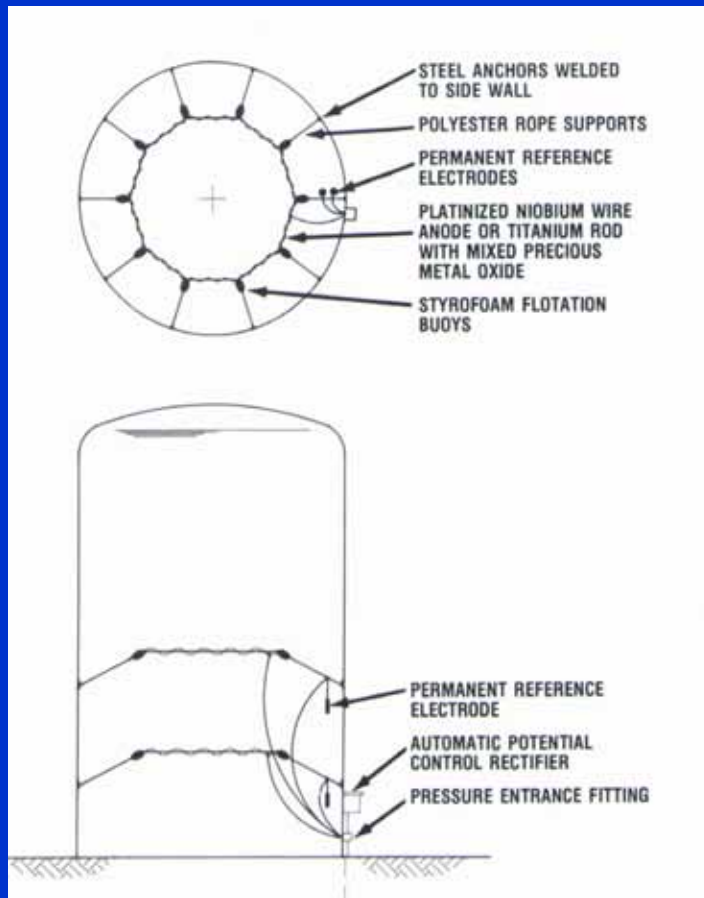
Typical Vertically Suspended Anode Systems



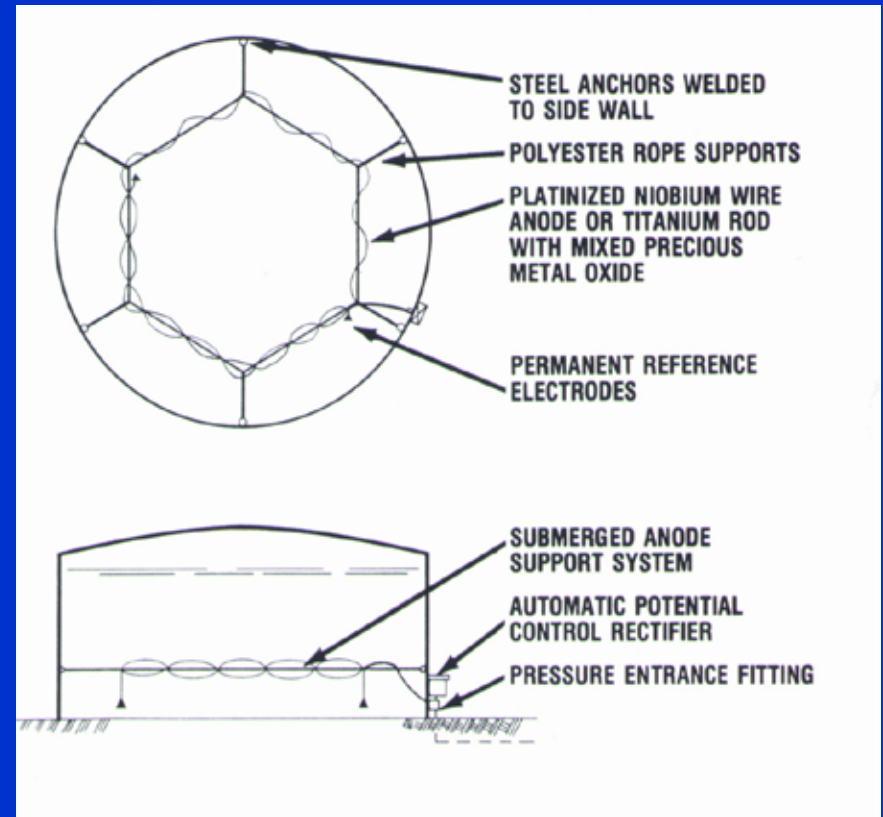
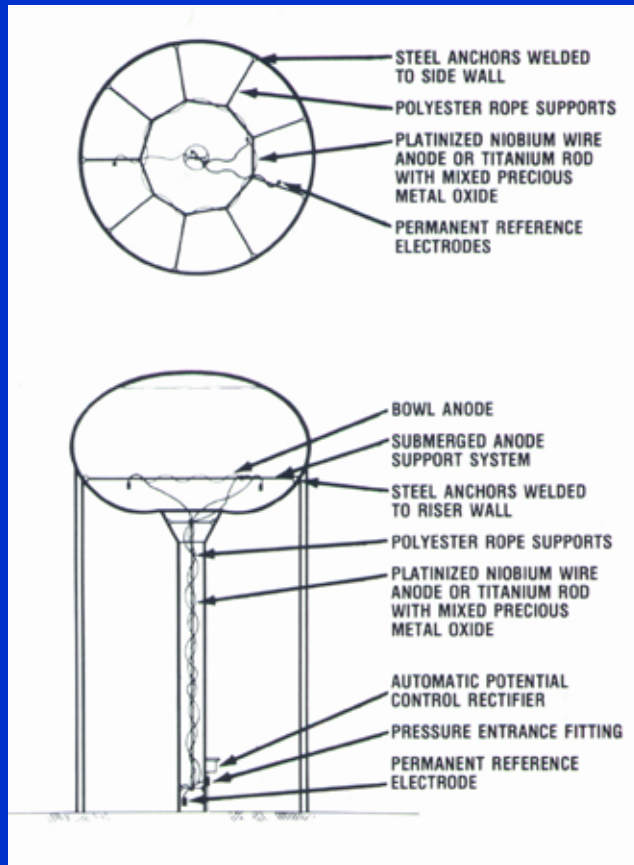
Typical Vertically Suspended Anode Systems



Typical Horizontally Suspended Anode Systems



Typical Horizontally Suspended Anode Systems

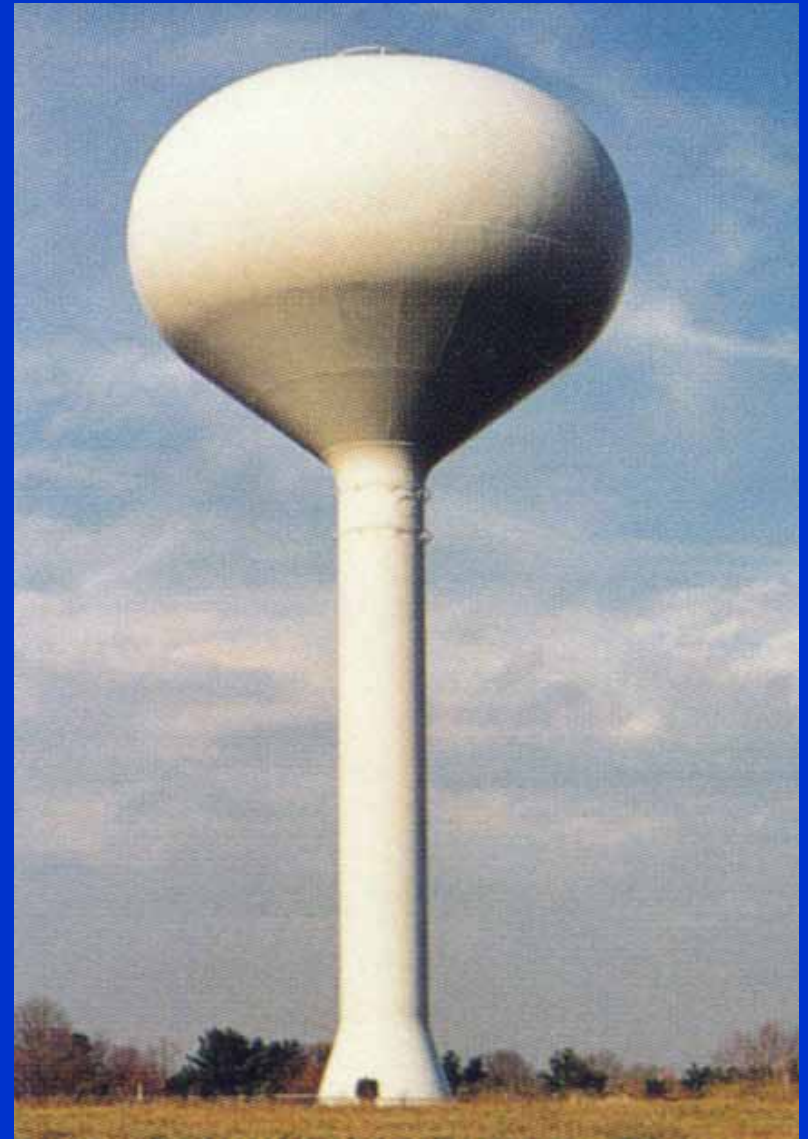


Start-up and Calibration

- 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 the 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

FIELD SERVICES WORK ORDER

corrpro

CUSTOMER: _____ Ship To: _____

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

NOTES: _____

Measurements for testing, evaluation and adjustment: "Settle-Off" _____ "On" _____ Does Tank "Ice Over" Y N _____ Other _____

FOUND: a) Rectifier Tap Setting at: Course _____ Fine _____ Auto _____ Manual _____ Water Level _____
 b) Rectifier Operating at:
 Bowl: Volts _____ Amps _____ Pot. Set _____ Pot. Level _____
 Floor: Volts _____ Amps _____ Pot. Set _____ Pot. Level _____
 c) Resistance: Anode - Bowl _____ Floor _____ Aux. No. _____
 Readings: Reference Cell - Bowl _____ Floor _____ Aux. No. _____

LEFT: d) Independent Tank-to-Water Potential Profile Within Tank
 Tank Bottom: On _____ Instant Off _____ Cell To Cell Test Portable Test Cell Neg.
 Permanent Cell #1 _____ #2 _____
 Is Testing Isolated: Y N
 Is Cell #2 in Floor: Y N
 If "NO" Where _____

e) Rectifier Operation Adjusted To: Tap Setting: Course _____ Fine _____ Auto _____ Manual _____
 Bowl: Volts _____ Amps _____ Pot. Set _____ Pot. Level _____
 Floor: Volts _____ Amps _____ Pot. Set _____ Pot. Level _____

EVALUATIONS:
 Electrical: _____
 Anode: _____
 Rectifier: _____
 Overall System Performance: _____
 Recommendations: _____

OPERATOR INSTRUCTIONS PROVIDED TO:
 Do NOT adjust rectifier in automatically controlled mode of operation. Record meter readings at intervals not to exceed sixty (60) days.

CREW TIME IN: _____ CREW TIME OUT: _____ FOLLOW-UP REQUIRED: _____

If you have any questions please call the office noted above. We appreciate the opportunity of being of service.

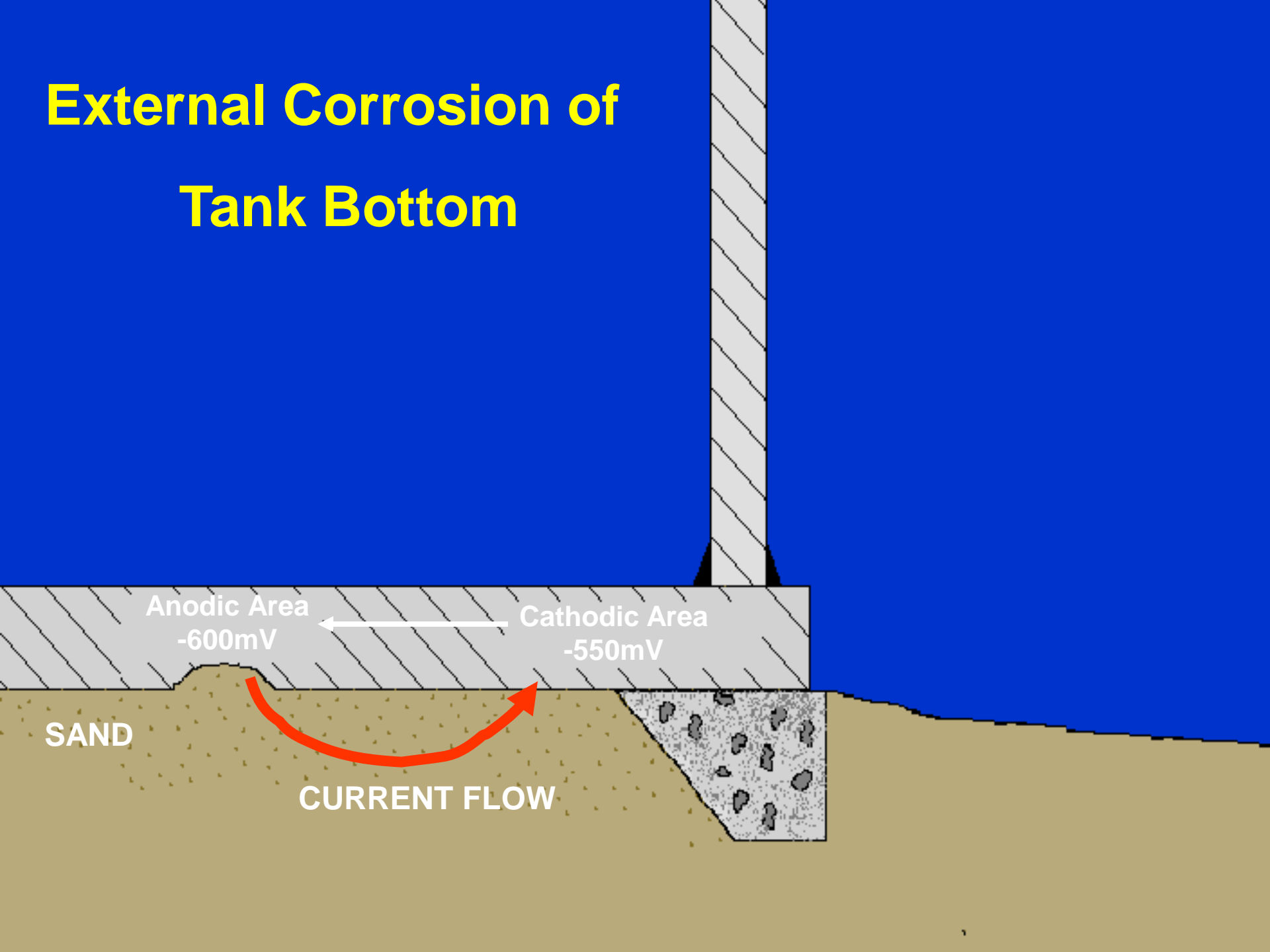
CORRPRO SUBSCRIBER'S ACCEPTANCE

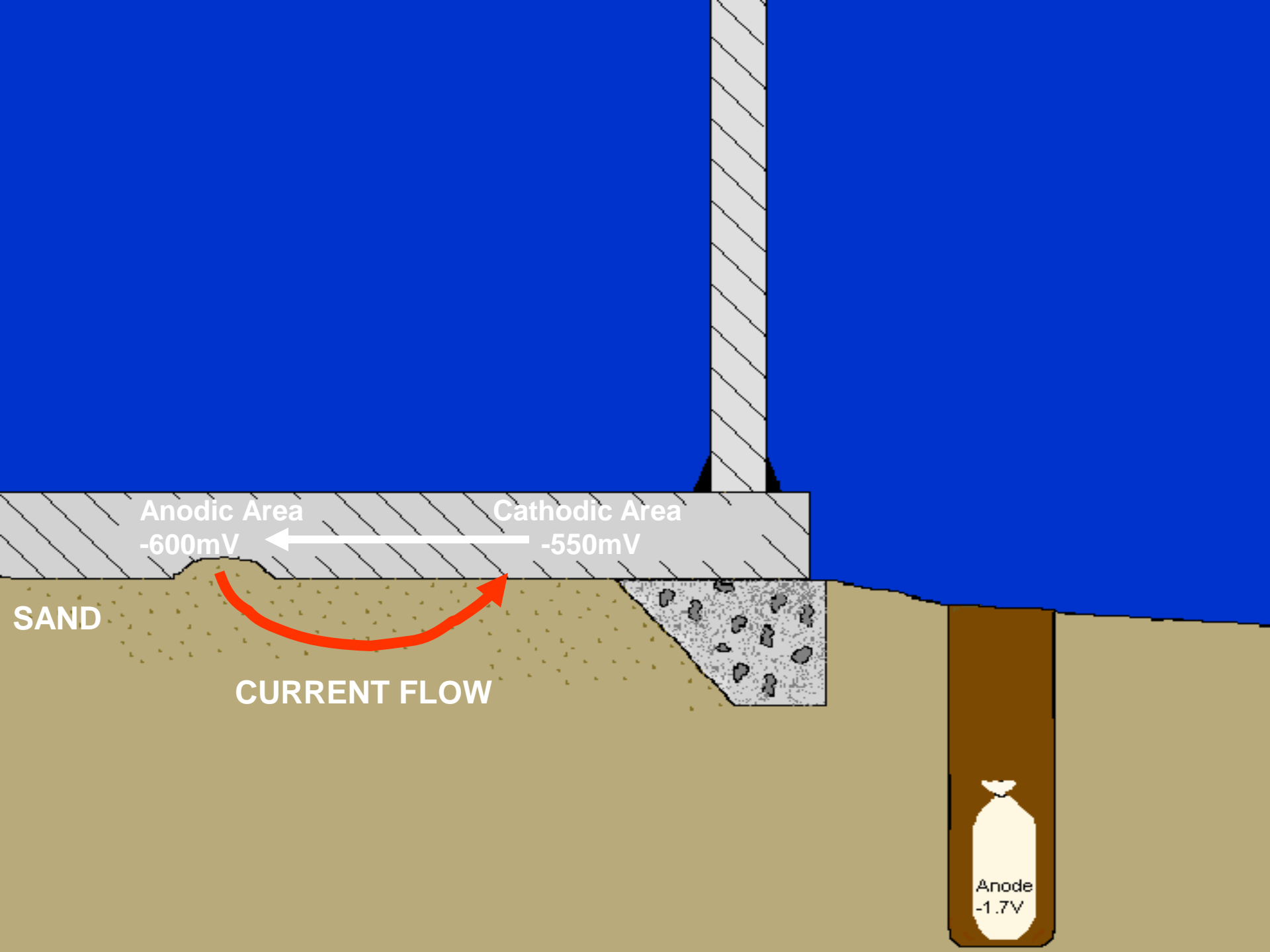
By: _____ Date: _____ By: _____ Date: _____

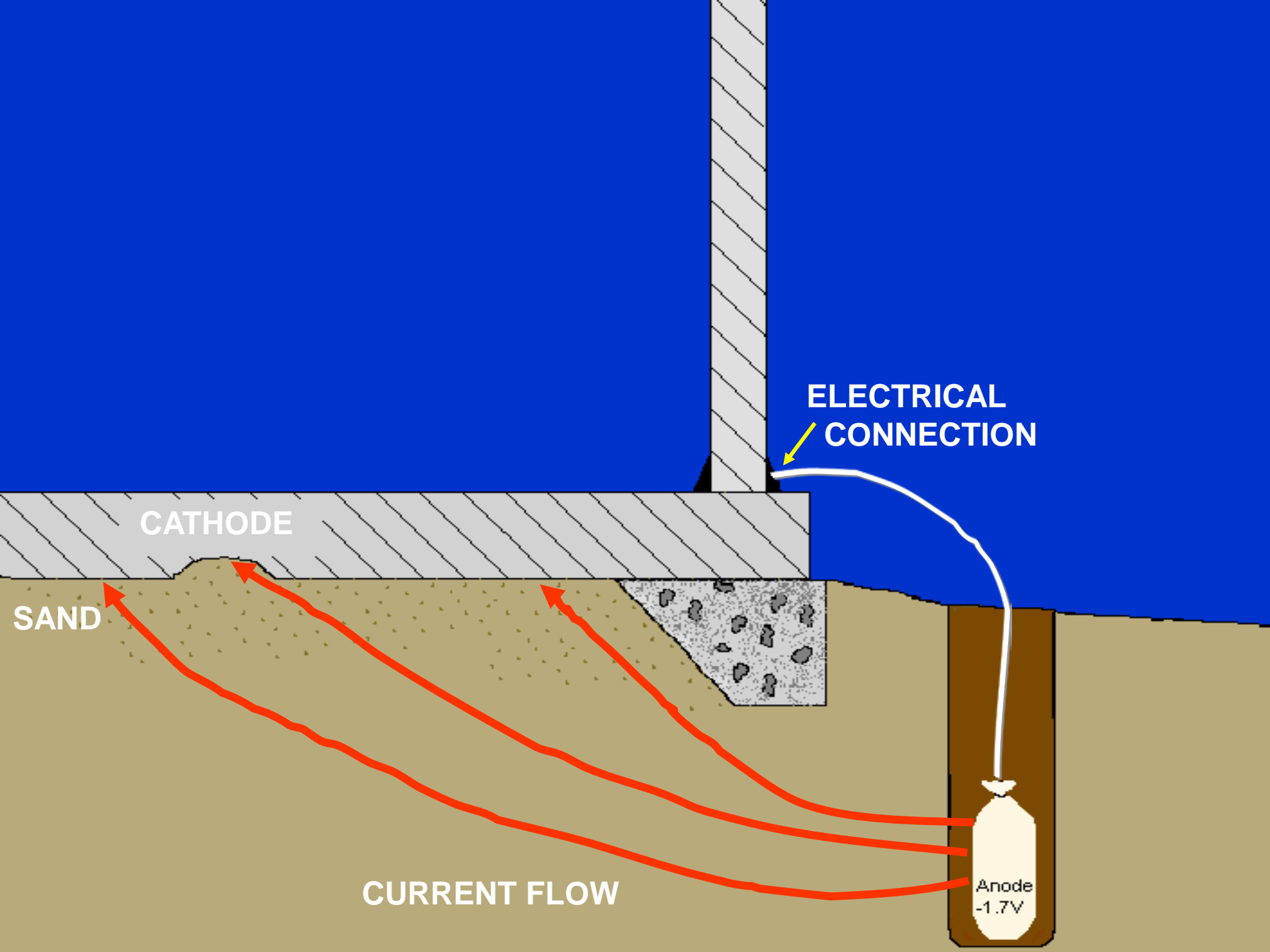
Continuing Maintenance

- Owner should check the meters on the rectifier at intervals not to exceed 30 days
- Compare the volts, amps and potential readings to set point and previous readings
- If monthly 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







ELECTRICAL CONNECTION

CATHODE

SAND

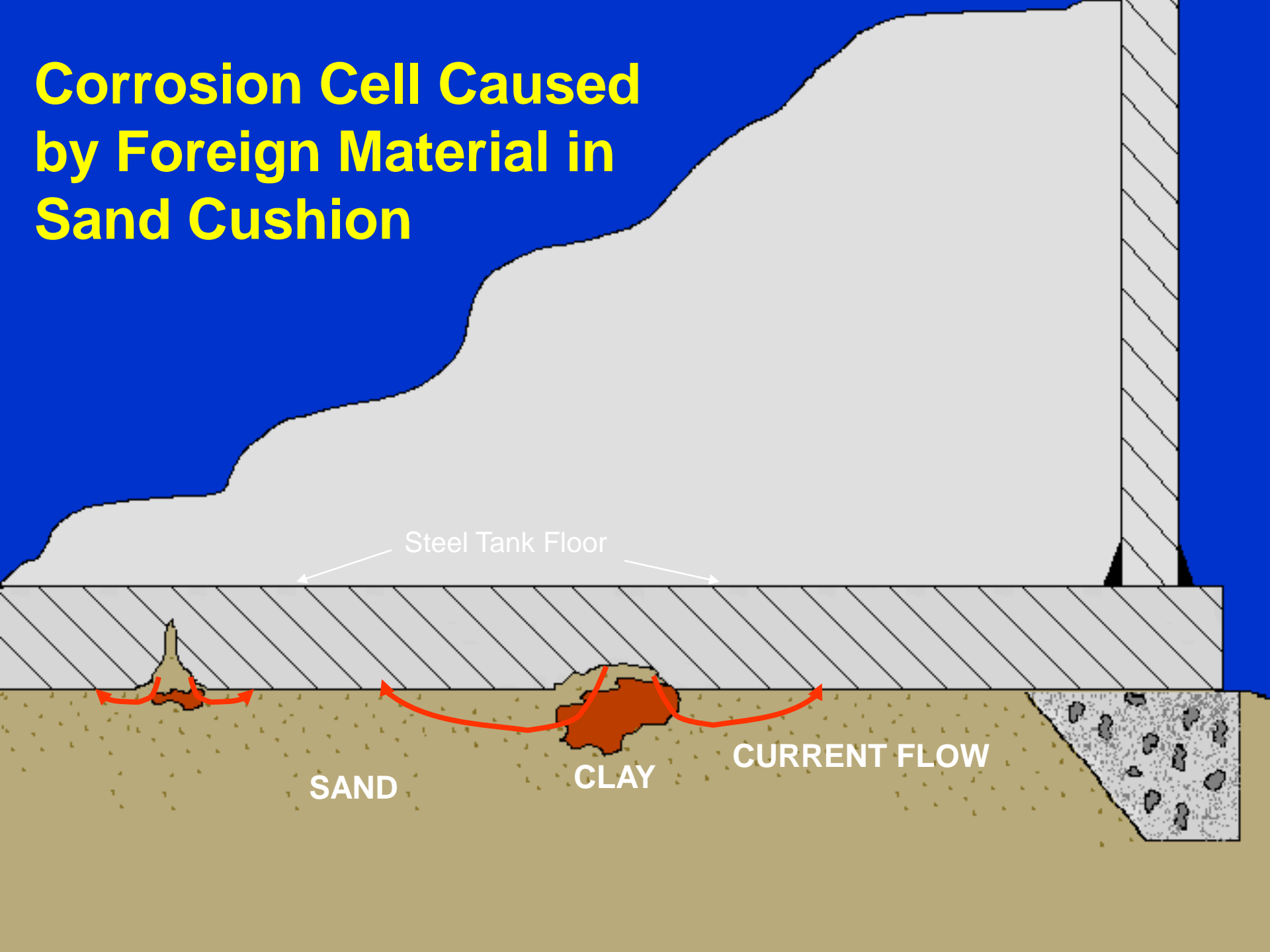
CURRENT FLOW

Anode
-1.7V

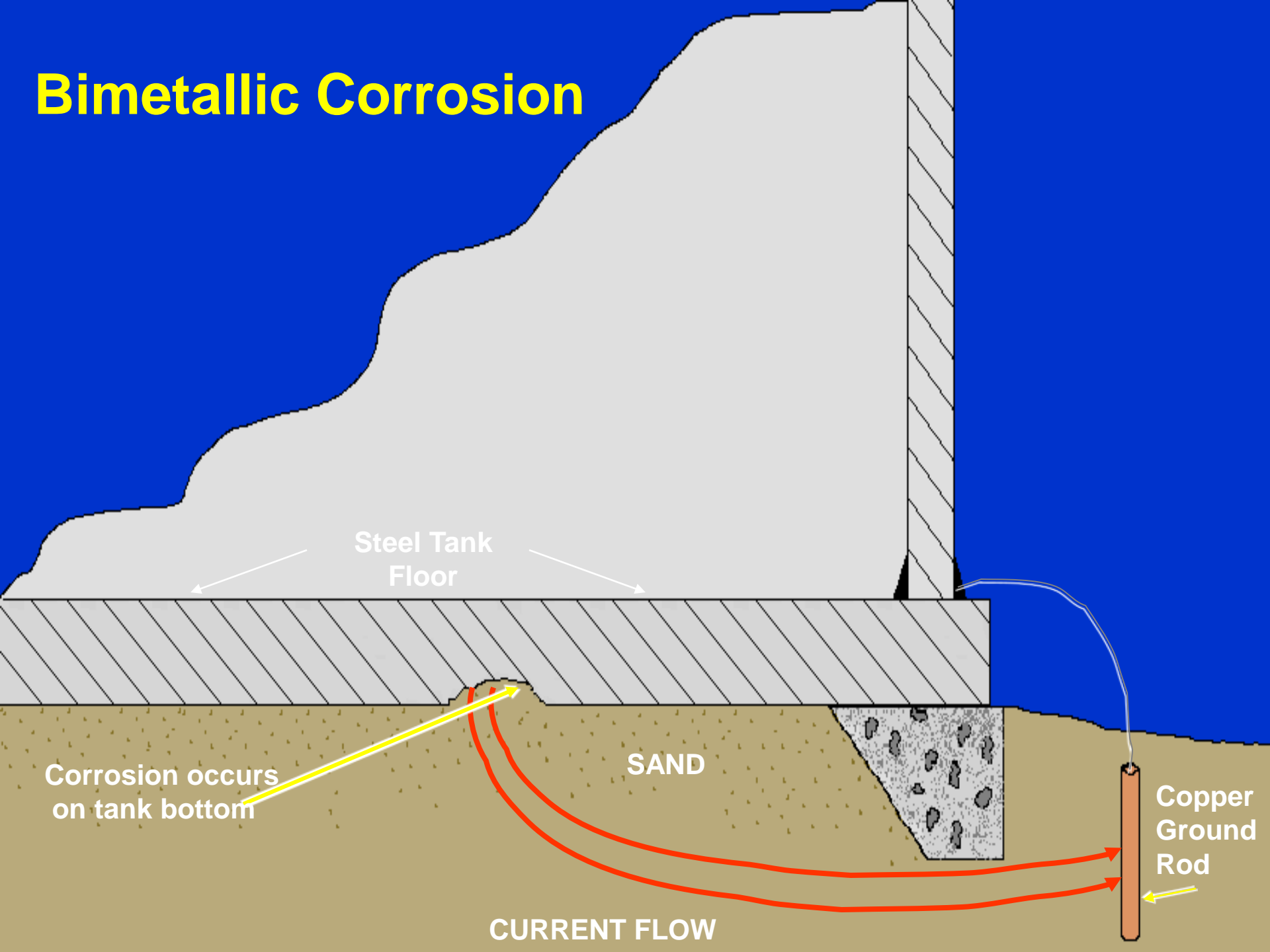


Tank to Soil Potential Measurements

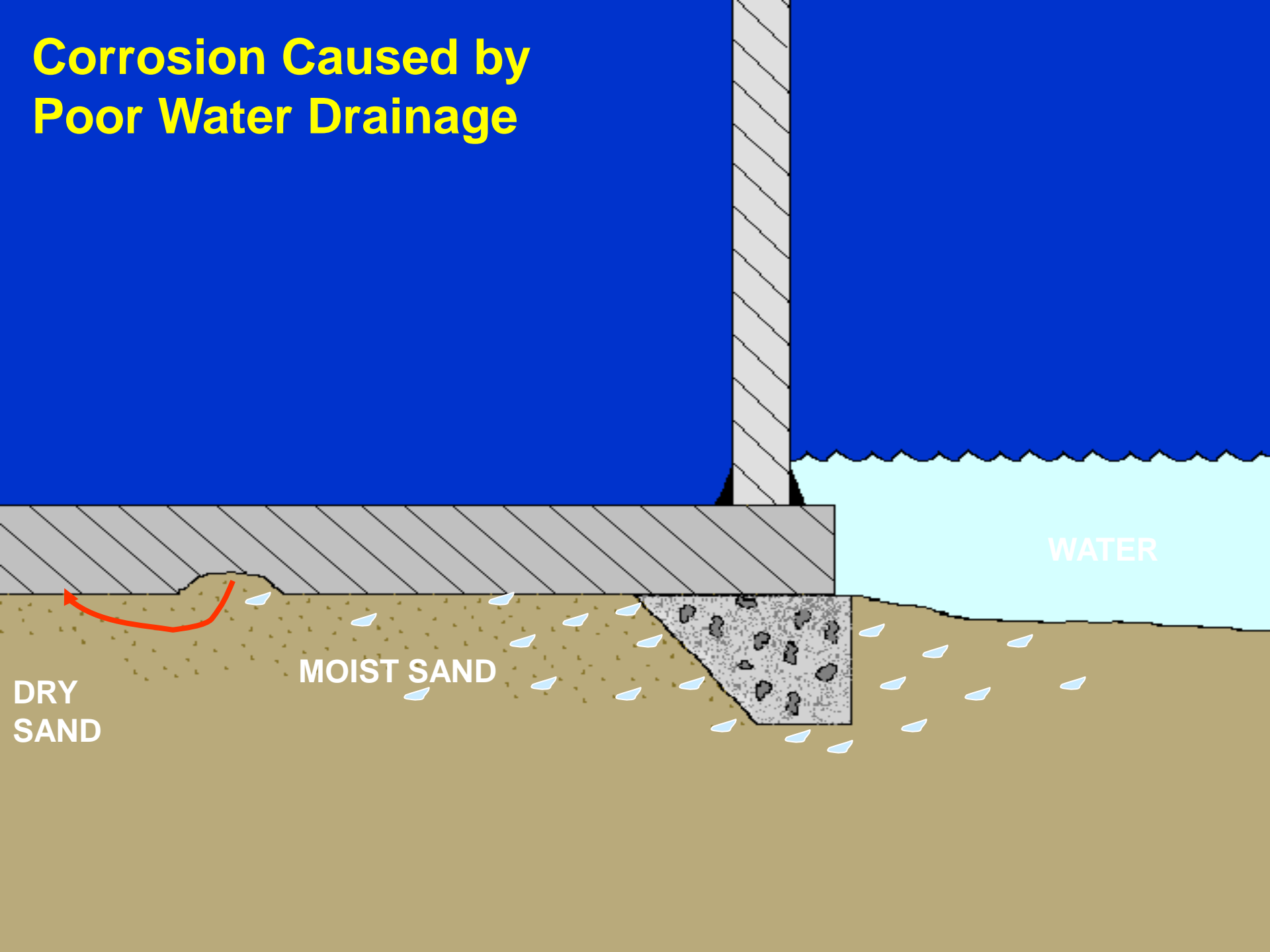
Corrosion Cell Caused by Foreign Material in Sand Cushion



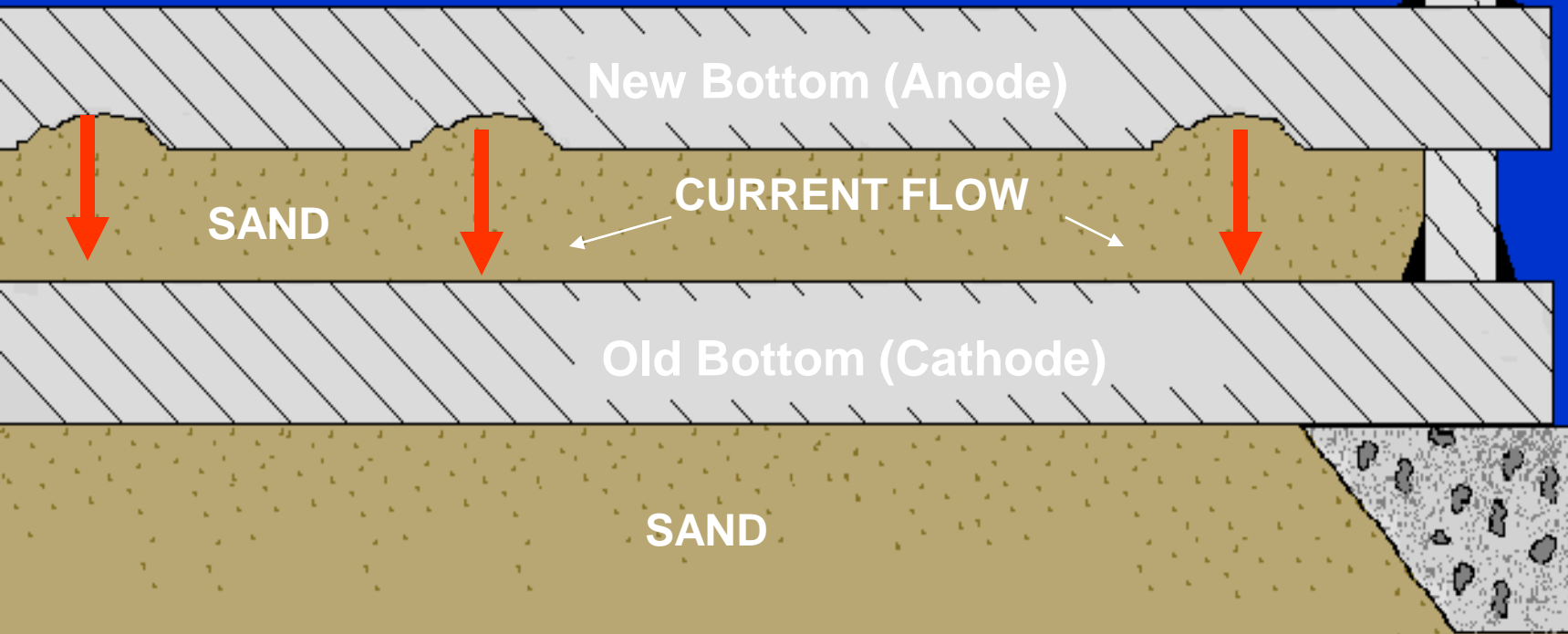
Bimetallic Corrosion



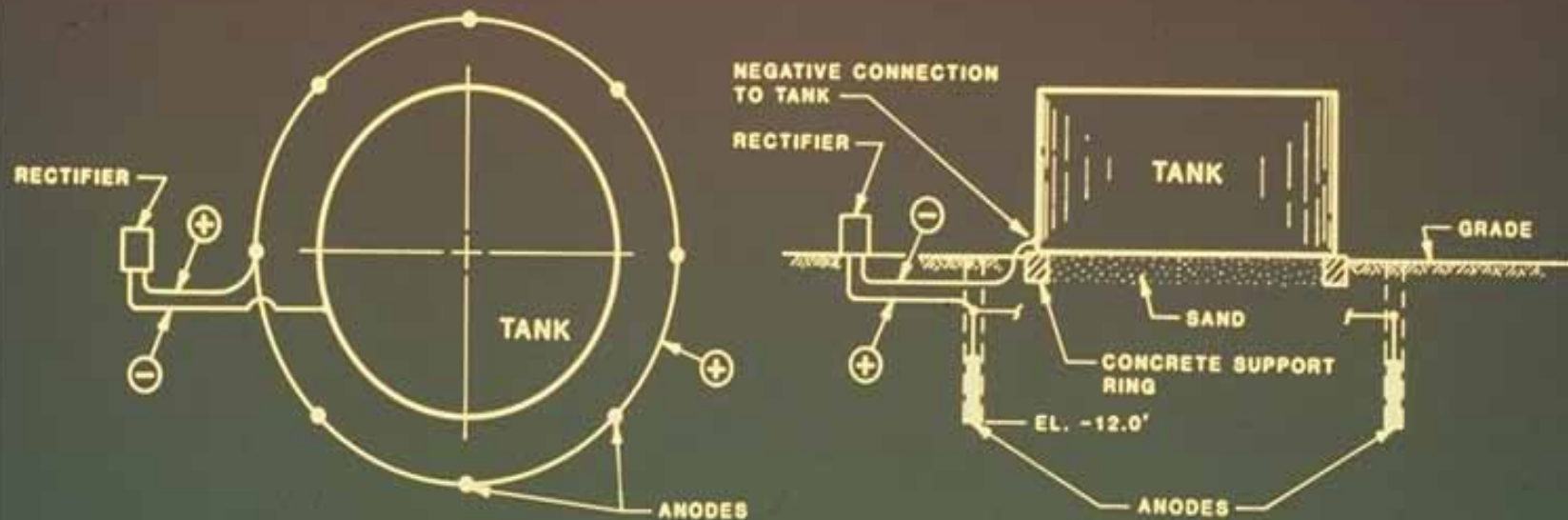
Corrosion Caused by Poor Water Drainage

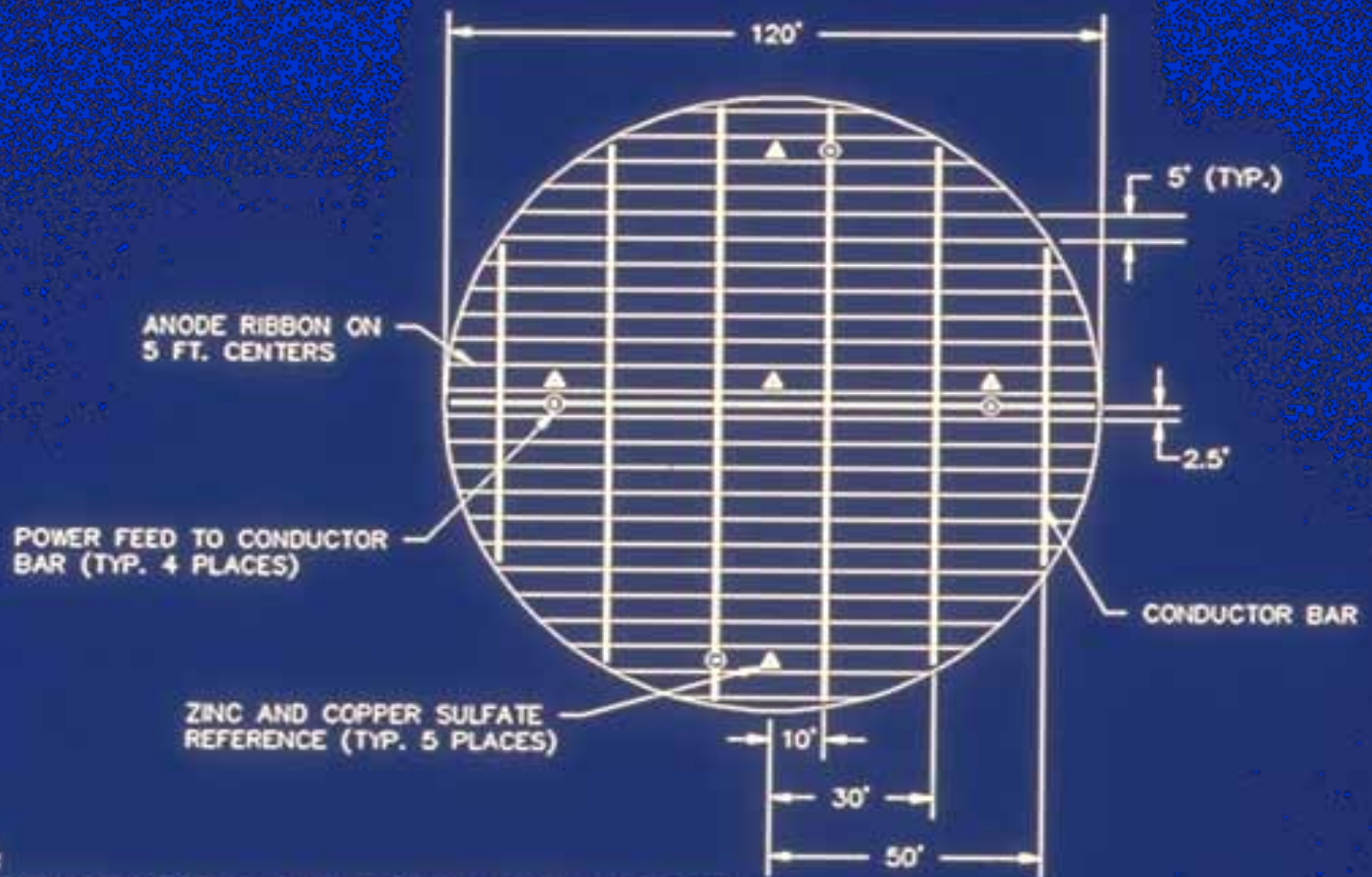


New Steel Coupled to Old Steel



Common Installation Of Vertical Impressed Current Anodes





NOTE:

ROUTE REFERENCE CELL LEAD WIRES AND POWER FEEDS THRU 3 INCH CONDUIT PENETRATION TO JUNCTION BOX.

