

The webinar will begin at 10:00 a.m. MT

**Corrosion
and
Coatings
School**
TBD

**Corrosion
Website**
[http://www.usbr.gov/pmts/
materials_lab/corrosion](http://www.usbr.gov/pmts/materials_lab/corrosion)

**Corrosion
Webinar
Series**

February
2016
TBD

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Managing Water in the West

Corrosion Webinar Series

Cathodic Protection 101

Presented by:



Jessica Torrey, PhD

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U.S. Department of the Interior
Bureau of Reclamation

What is Corrosion?

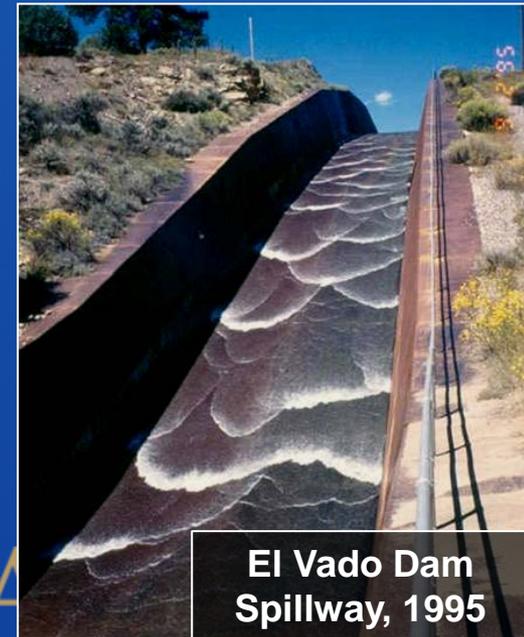
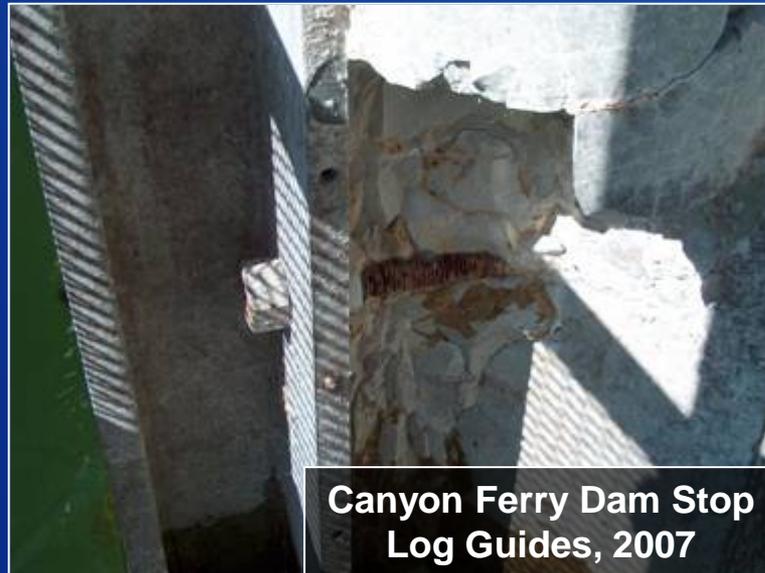
*the deterioration of a material
and/or its properties
caused by a reaction with its environment*

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The Corrosion Reaction

Reaction between
a Metal and an Electrolyte

oxidation (rusting) of steel in water or soil



Corrosion Mitigation Methods

Materials Selection

Protective Coatings

Cathodic Protection

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What is Cathodic Protection?

Cathodic Protection (CP) *is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell*

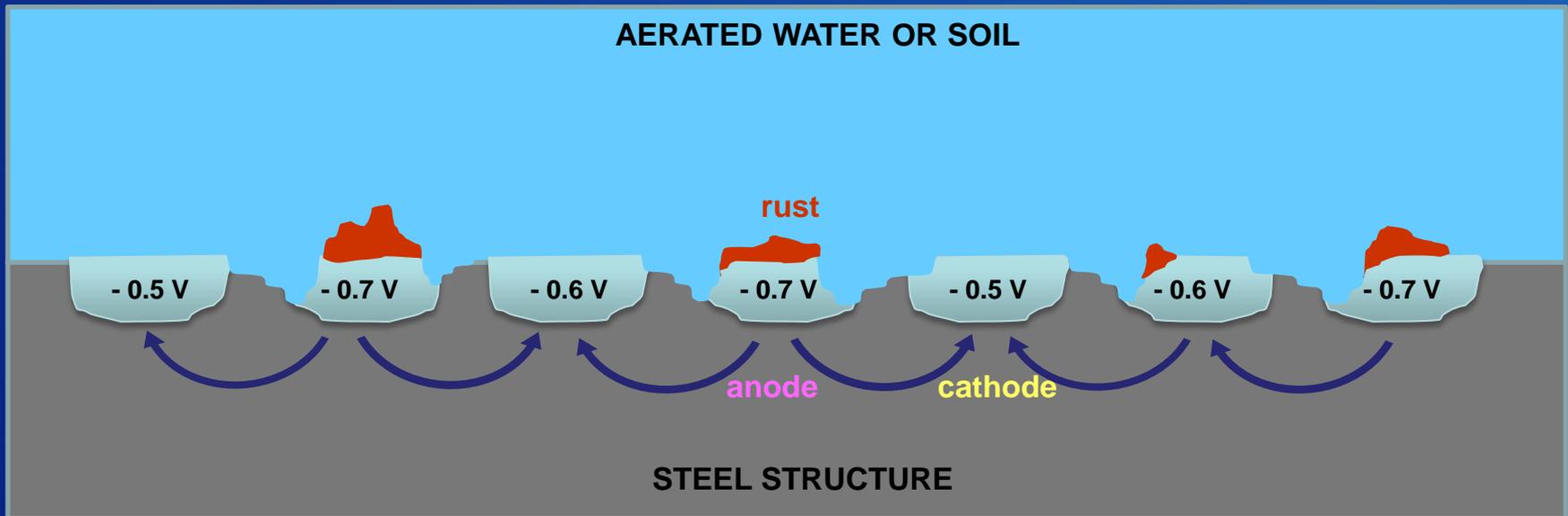
How Cathodic Protection Works

Corrosion

- Anodic and cathodic regions exposed to an electrolyte react with each other resulting in corrosion

Four things needed for corrosion:

- **A**node – the corroding metal
- **C**athode – the metal that doesn't corrode
- **M**etallic Return Path – ex. the steel pipe
- **E**lectrolyte – the soil or water



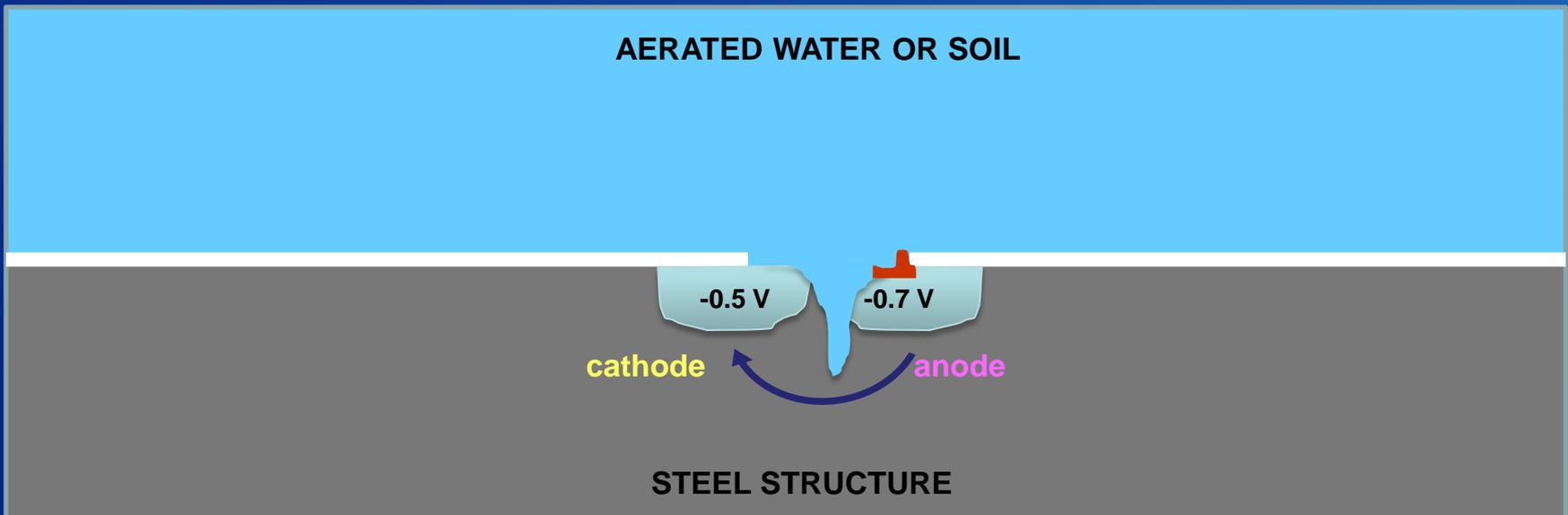
How Cathodic Protection Works

Mitigation- Coating

- Primary defense against corrosion acting as a barrier between metal and electrolyte
- May contain defects where corrosion can occur

Four things needed for corrosion:

- **Anode** – the corroding metal
- **Cathode** – the metal that doesn't corrode
- **Metallic Return Path** – ex. the steel pipe
- **Electrolyte** – the soil or water



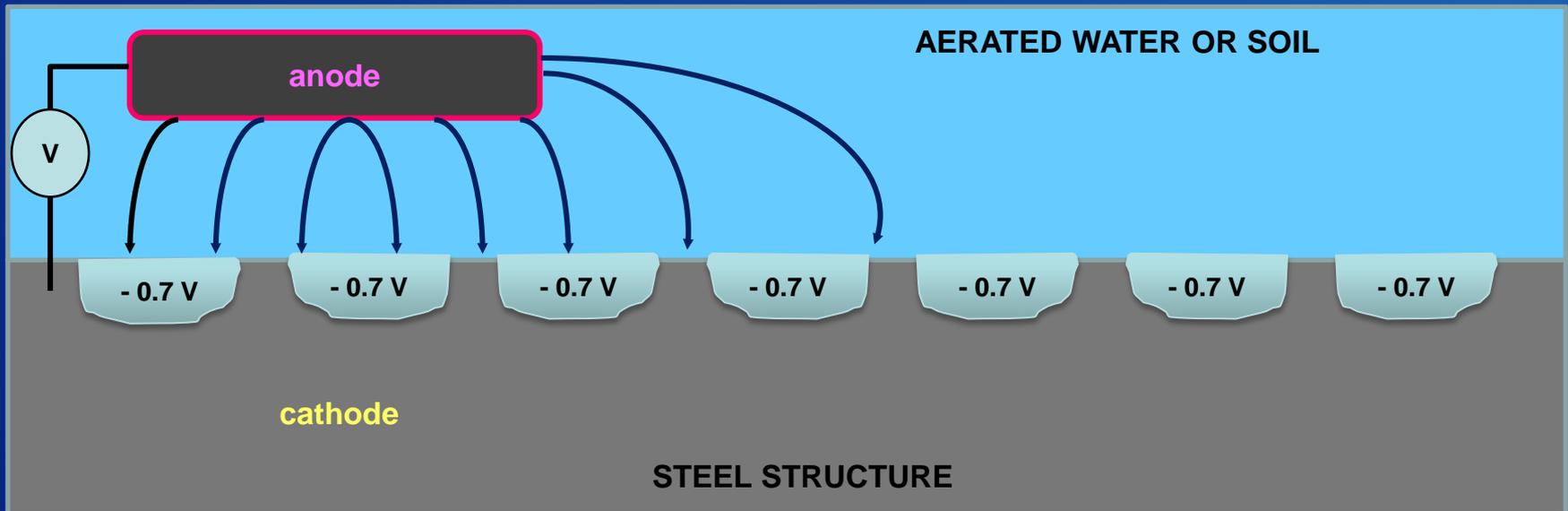
How Cathodic Protection Works

Mitigation- Cathodic Protection

- Control the corrosion by making the structure the cathode
- This takes a huge amount of current for a bare structure- not economical.

Four things needed for corrosion:

- *Anode* – the corroding metal
- *Cathode* – the metal that doesn't corrode
- *Metallic Return Path* – ex. the steel pipe
- *Electrolyte* – the soil or water



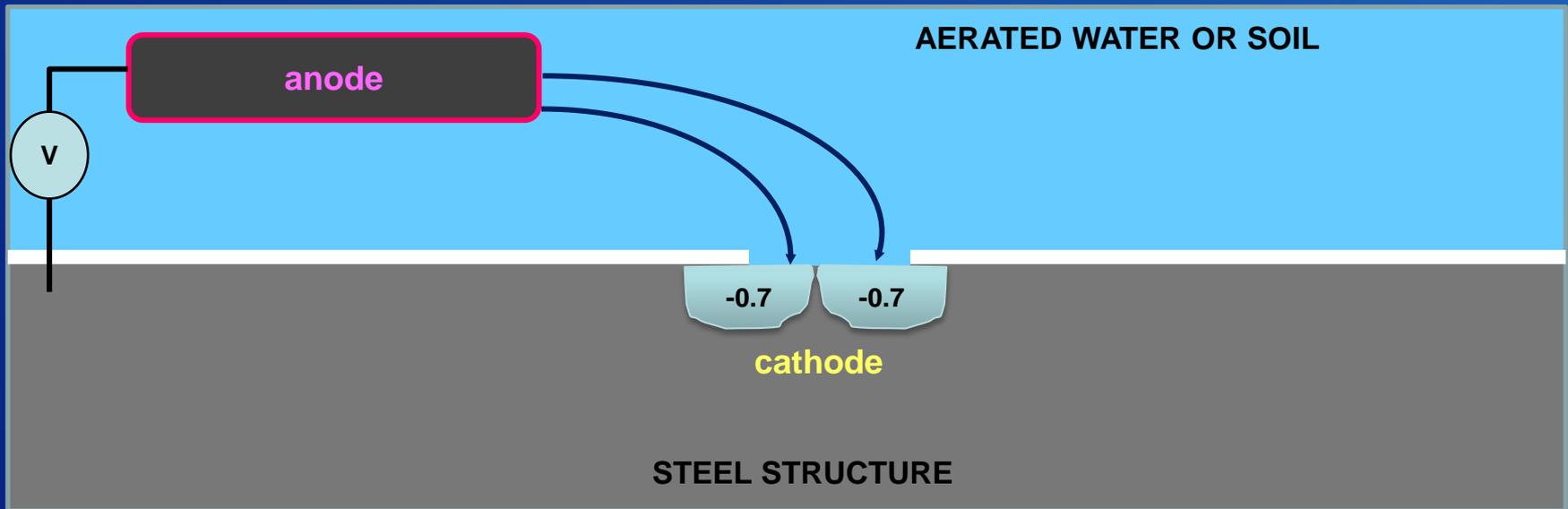
How Cathodic Protection Works

Mitigation- Coating with CP

- Coating- provides barrier and limits amount of bare steel
- CP- protects exposed steel only at defects in the coating

Four things needed for corrosion:

- *Anode* – the corroding metal
- *Cathode* – the metal that doesn't corrode
- *Metallic Return Path* – ex. the steel pipe
- *Electrolyte* – the soil or water



Corrosion Protection

A **coating** is the primary defense against corrosion.

Cathodic protection works with the coating to protect the structure at defects in the coating.

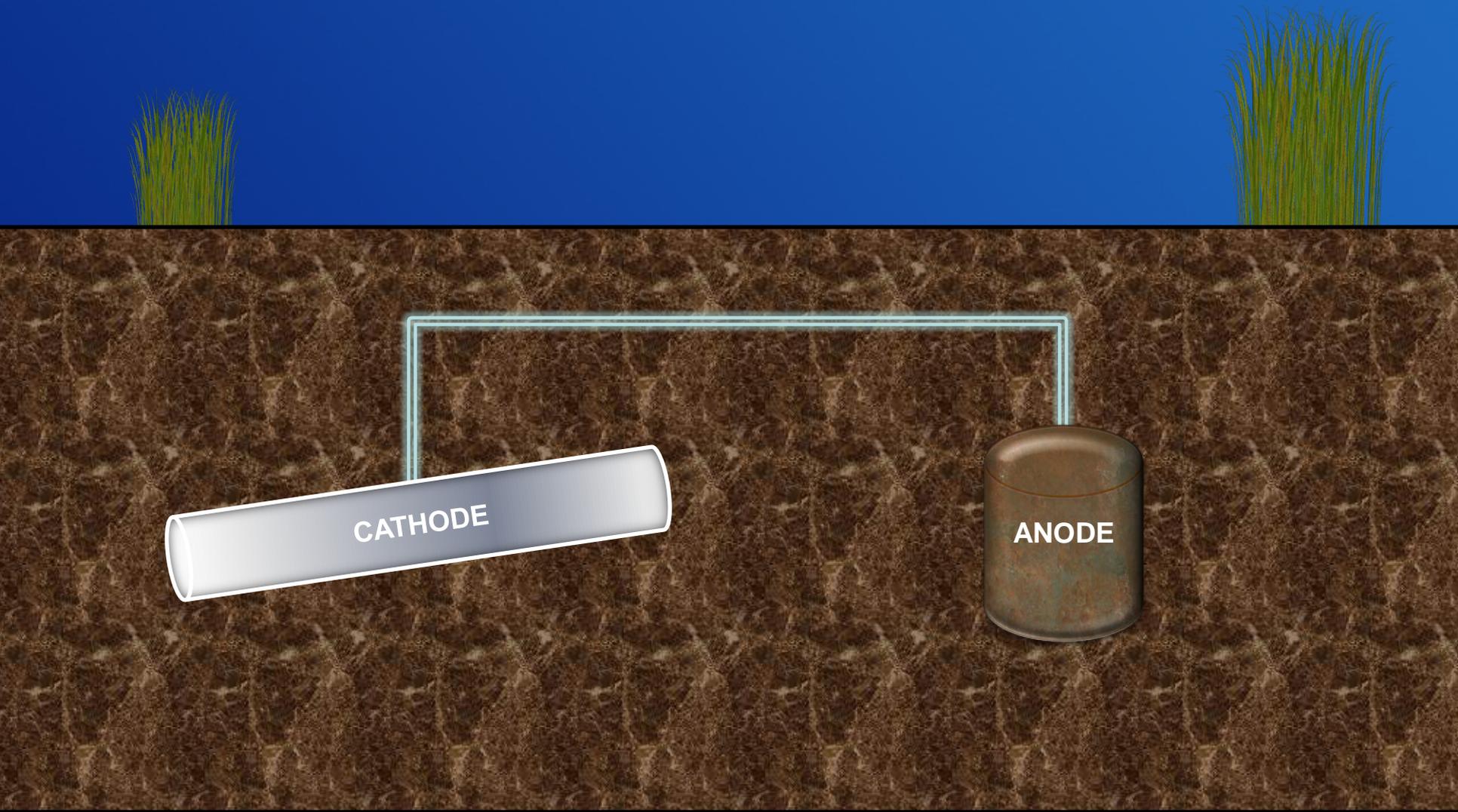
The most effective corrosion protection system for buried and submerged structures involves a good coating and cathodic protection.

Two Forms of Cathodic Protection

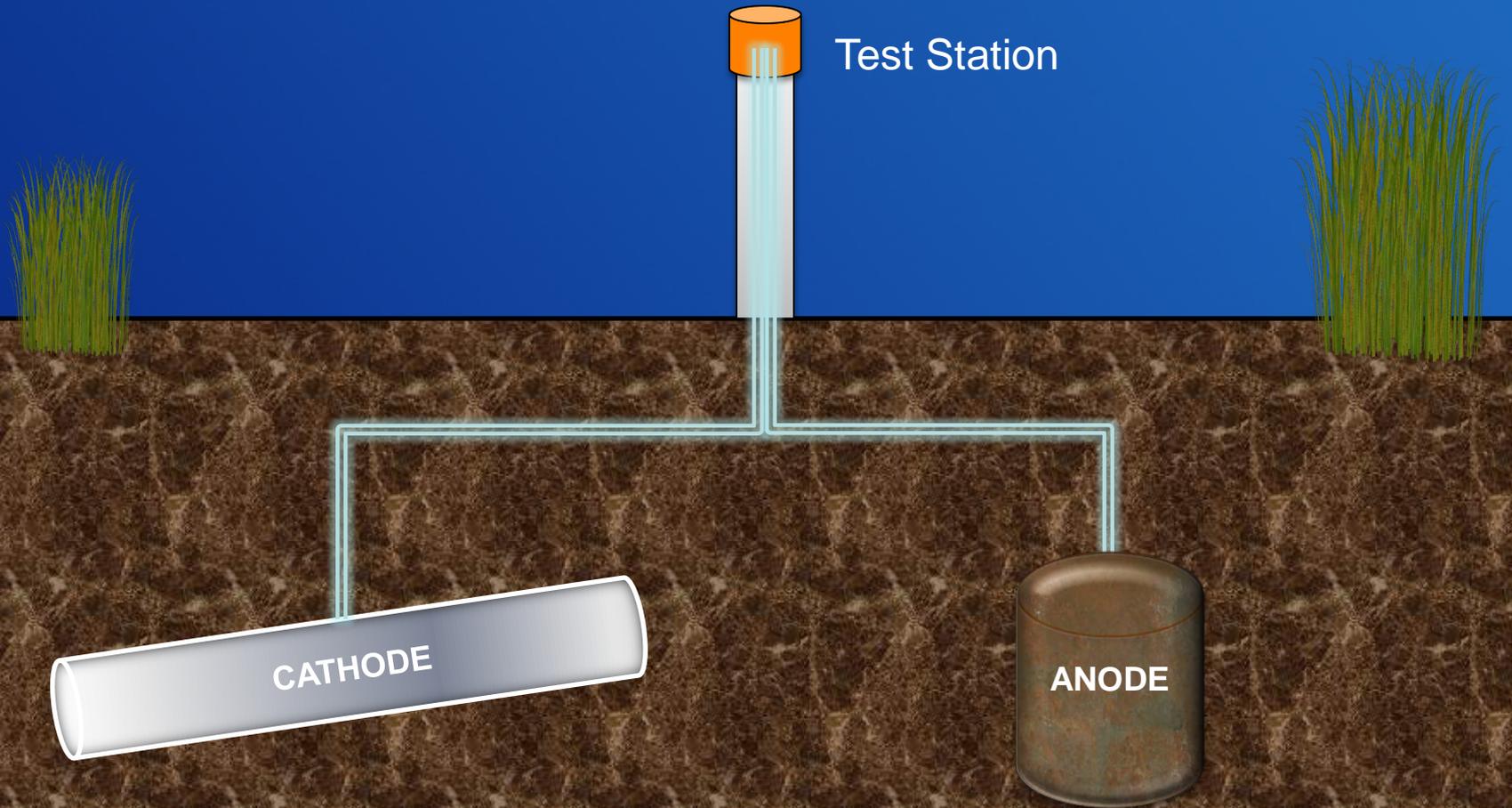
- **Galvanic Anode**
 - Structure directly connected to a sacrificial anode
 - Current provided by natural voltage difference between metals (galvanic corrosion)

- **Impressed Current**
 - Structure connected to anodes through rectifier
 - Current supplied by rectifier

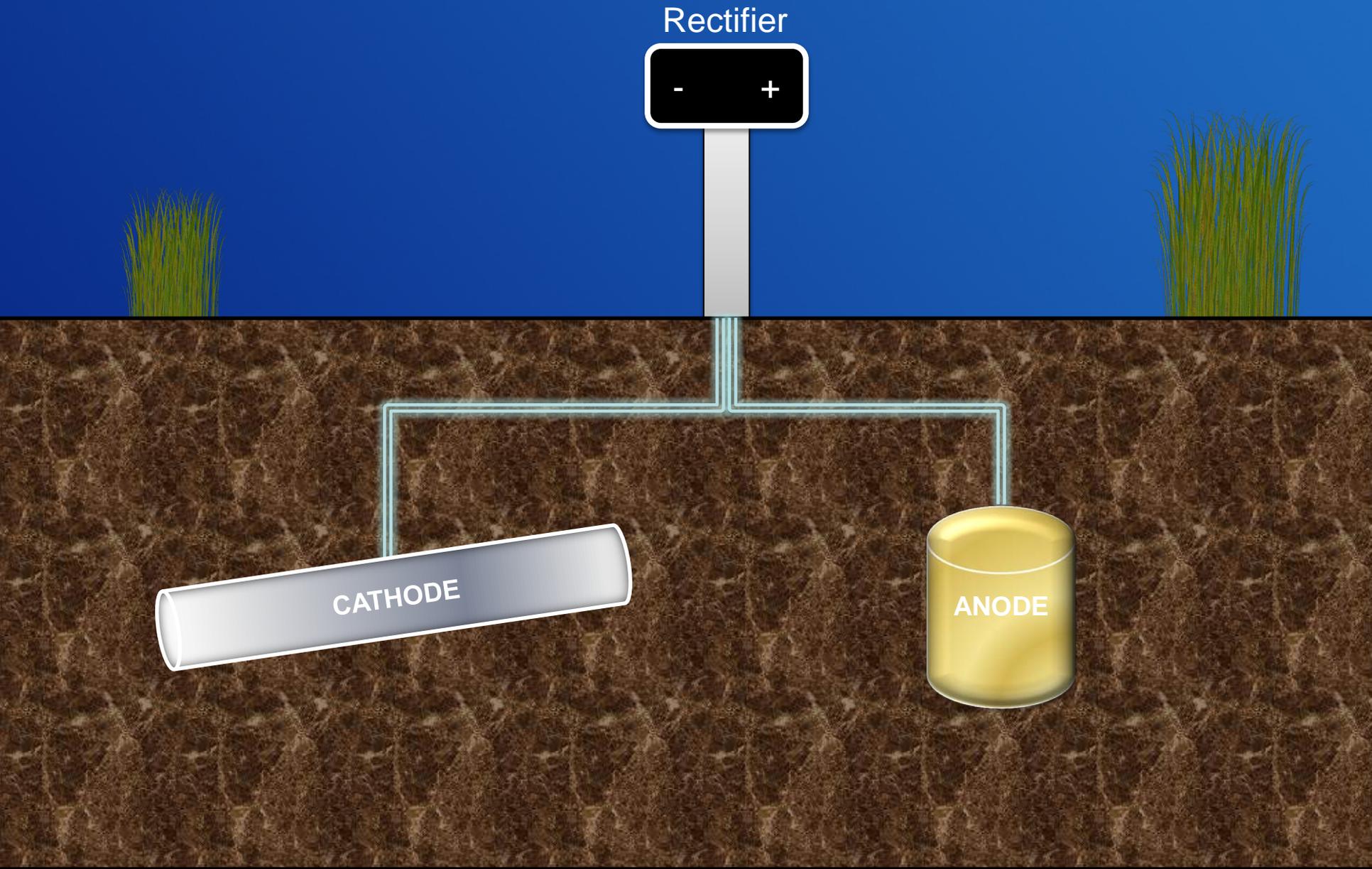
Galvanic Anode CP System



Galvanic Anode CP System



Impressed Current CP System



CP System Components

- **Anodes**
- **Metallurgical Bonds**
- **Test Stations**
- **Junction Boxes**
- **Rectifiers**
- **Cable**

Buried/Submerged Components

Sacrificial Anodes: Mg, Zn, Al



Metallurgical Bond

Impressed Current Anodes: Graphite

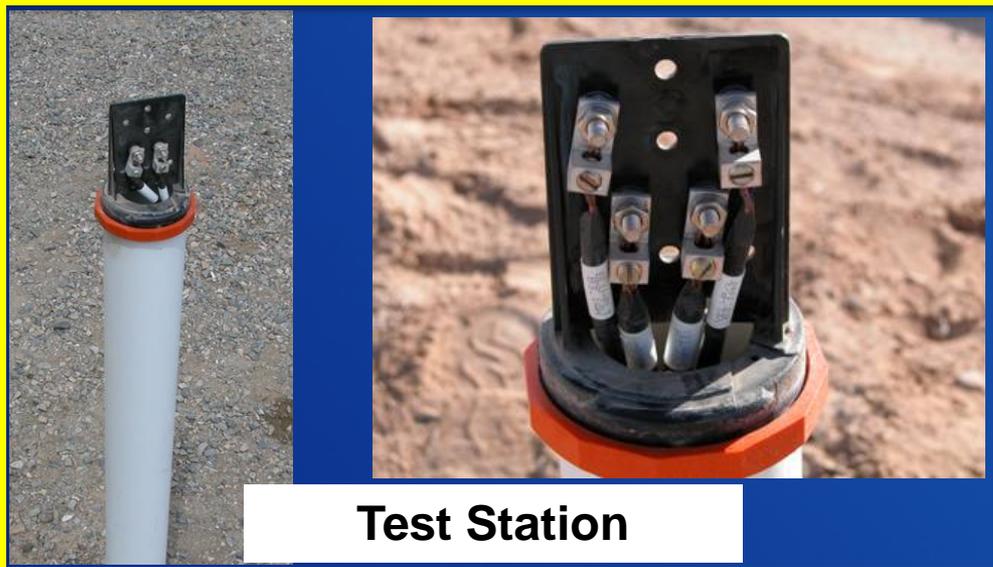


IC: High-Silicon Cast Iron anodes

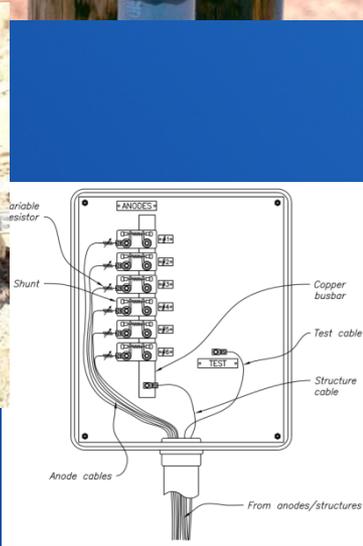
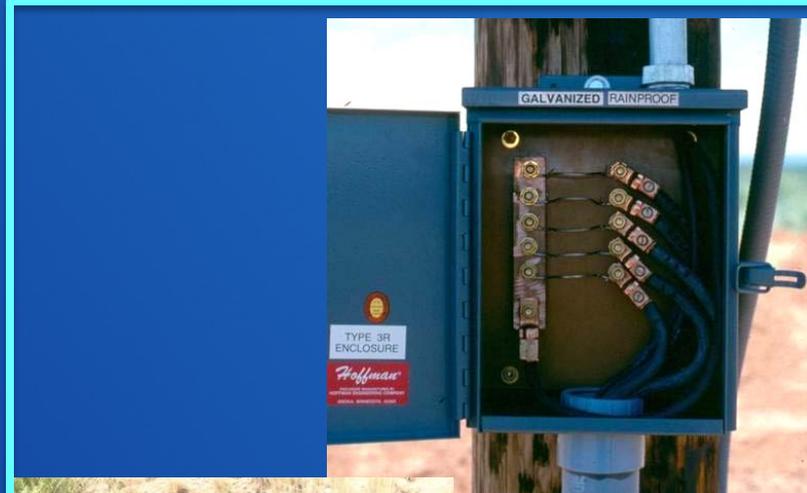


IC: Pt/Nb wire anode in slotted PVC tube for submersion

Above-Ground Components



Test Station



Junction Box



Rectifier



Test Station/Junction Box Components



Hardware



Busbar



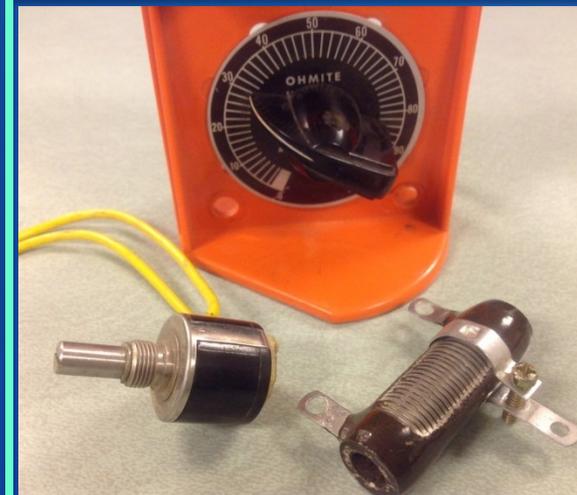
Bond Bar



HMWPE Cu Cable



Shunt



Variable Resistor

Rectifier Components

Coarse Tap

Fine Tap

AC Primary Breaker

AC Secondary Breaker

Shunt

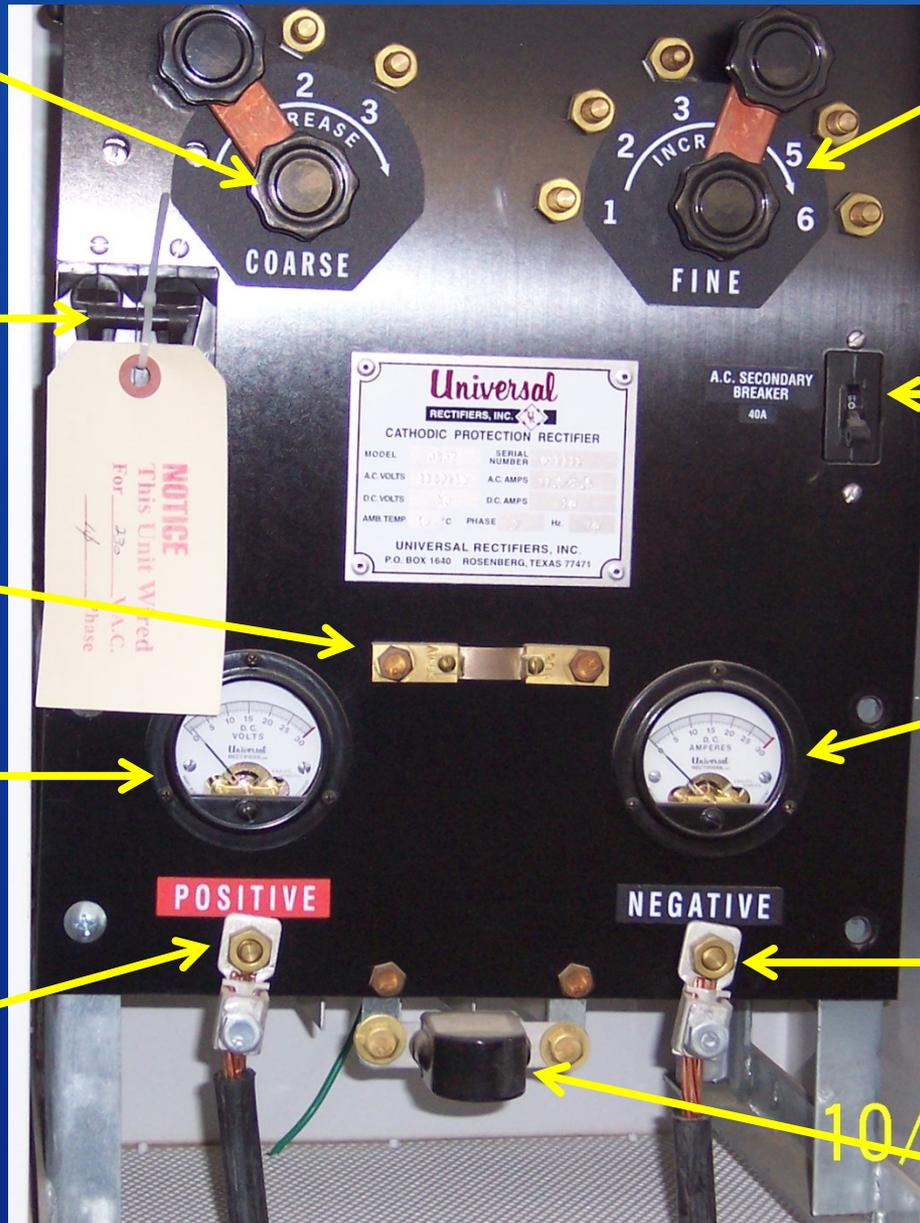
Ammeter

Voltmeter

Positive DC Output - to anode

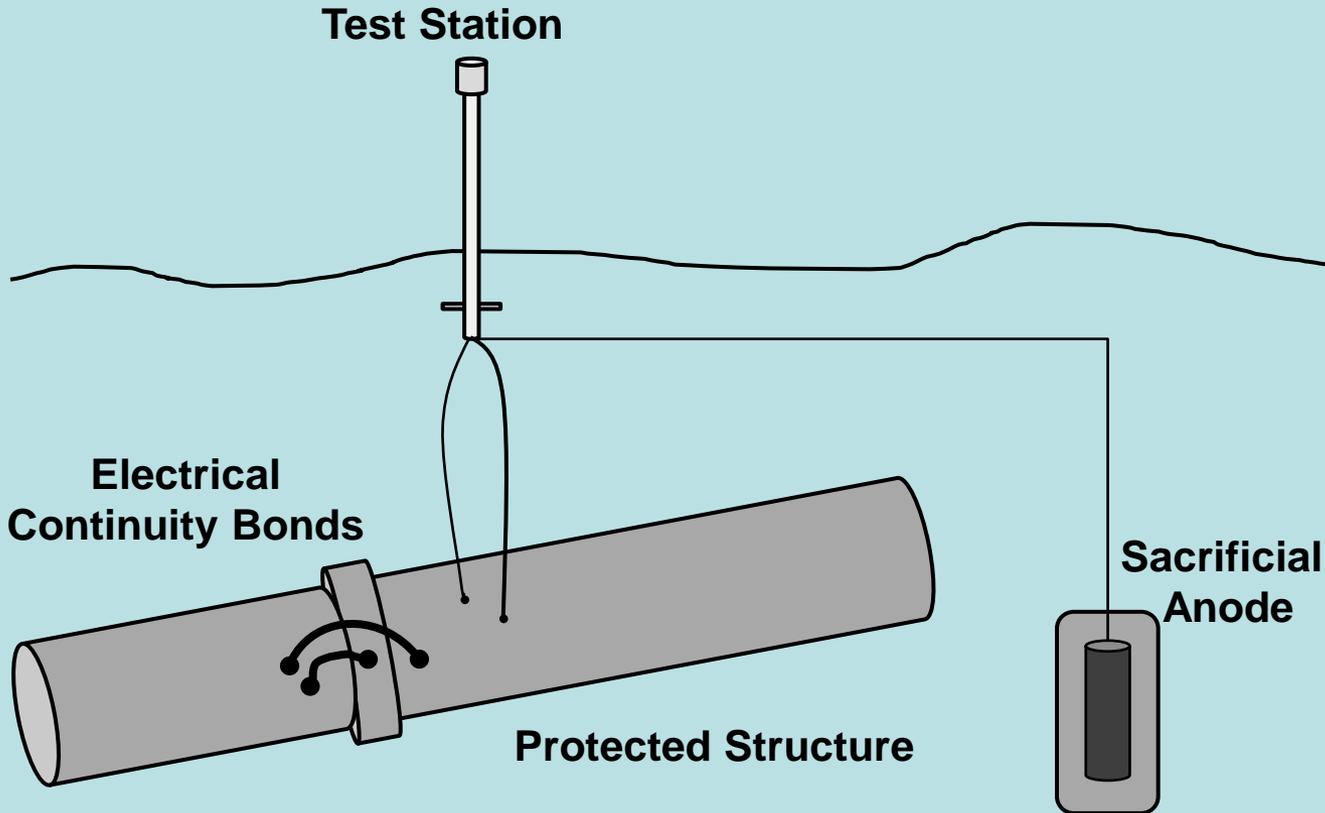
Negative DC Output - to structure

Lightning Arrestor



Galvanic CP System

San Xavier Farm Rehabilitation,
July 2007



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Galvanic Anode CP System

Palo Verde Diversion Dam Radial Gate, January 2013



- Also known as **Sacrificial Anode Cathodic Protection**
- This system provides a cathodic protection current by **galvanic corrosion** or by **sacrificing one material to prevent corrosion of the other material**

Features:

- Low current requirements
- Typically protect smaller surface areas
- No external power needed
- Low maintenance

New Mg Anode



Old Mg Anodes



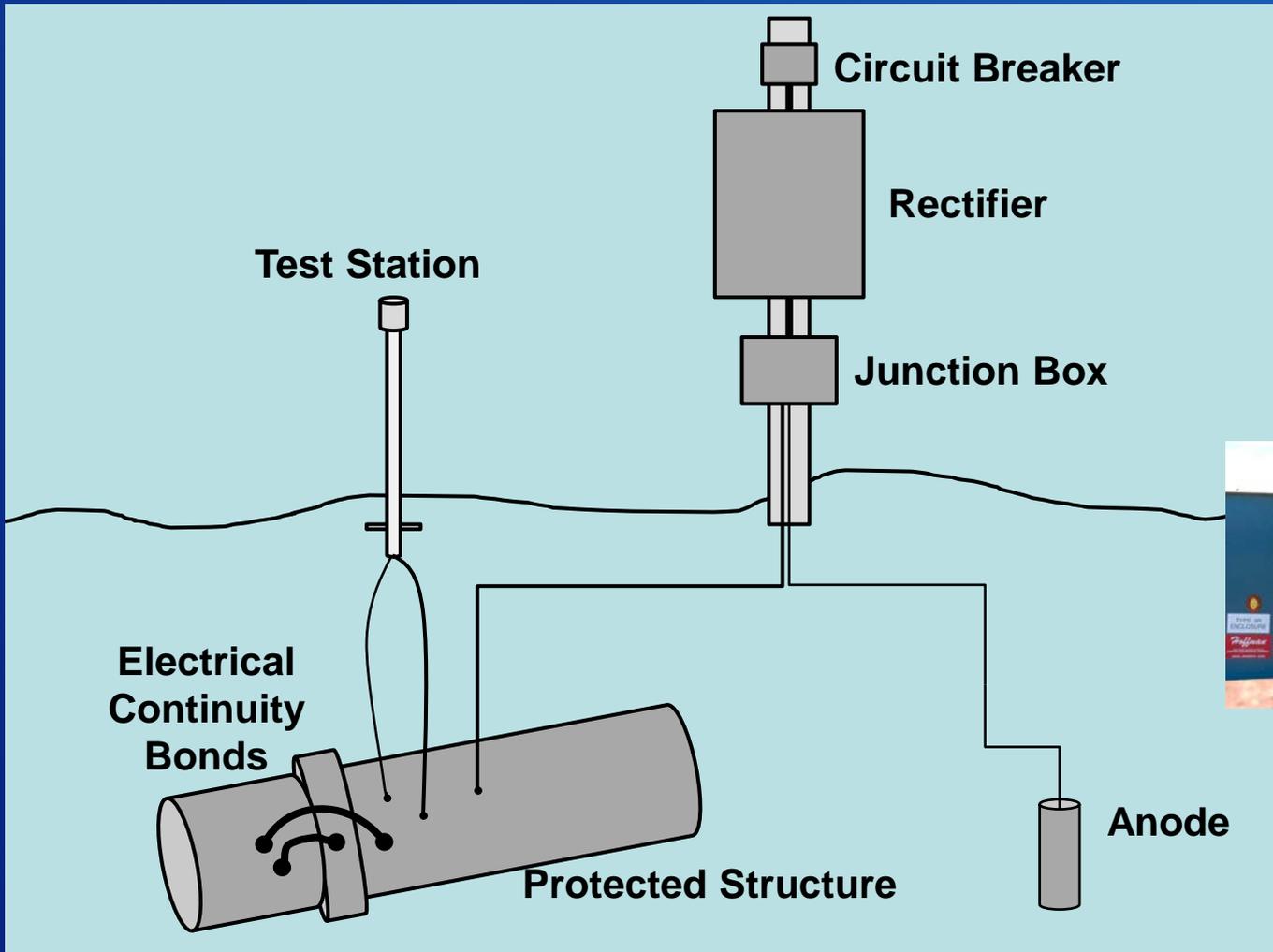
- Both the structure and the anode must be in contact with the electrolyte (water or soil)

Anodes:

- Soil and Fresh Water- Magnesium (and Zinc)
- Brackish Water- Aluminum and Zinc

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Impressed Current CP System



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Impressed Current CP System



- This system provides a cathodic protection current from an **external power source**
- A direct current power source forces current to discharge from anodes, through the electrolyte, and onto the structure to be protected
- Both the structure and the anode must be in contact with the electrolyte

Features:

- High flow of water
- High current requirements
- Can handle large or poorly coated structures

Mixed Metal Oxide Disk Anode



Graphite Anodes



Anodes:

- Graphite, High-Si Cast Iron, Mixed Metal Oxide, Platinum

Where will you find CP?

Burial:

- Pipelines
- Tanks/ Tank Bottoms
- Metallic Fittings



Navajo Nation Municipal Pipeline, 2009



GACP, Mesa Verde National Park, 2013

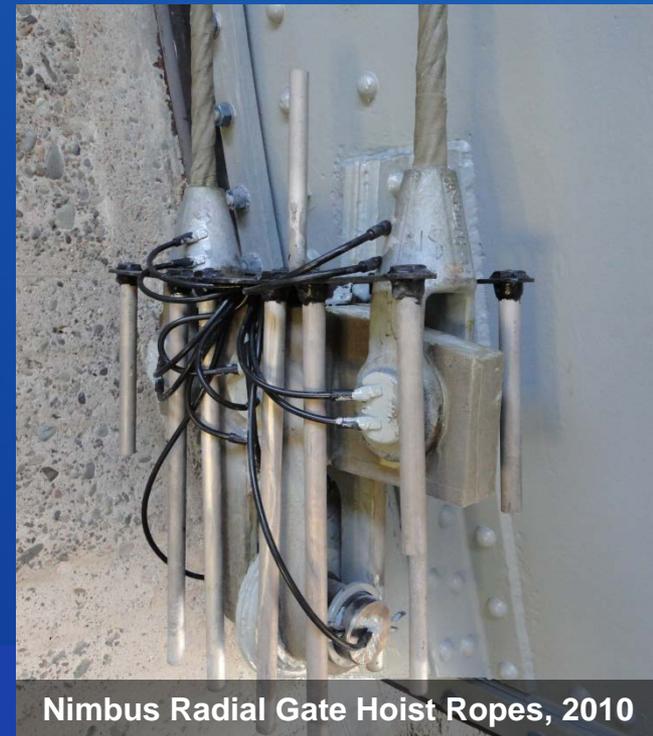


Where will you find CP?

Immersion:

- Gates
- Tank Interiors
- Air Chambers
- Pipe Interiors
- Trash Racks
- Fish Screens
- Pumps

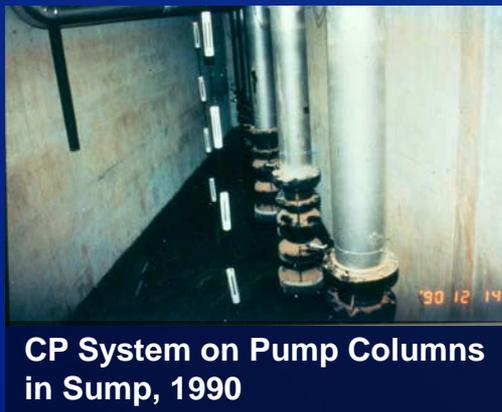
Delta-Mendota Canal, February 2013



Nimbus Radial Gate Hoist Ropes, 2010



Angostura Dam Radial Gates, May 2011



CP System on Pump Columns
in Sump, 1990

Operation & Maintenance

TSC typically designs cathodic protection systems for a minimum 20-year lifetime.

- Coating and corrosion visual inspection: preferably annually or when structure is available due to dewatering, etc.
- Check rectifiers: every 1-2 months; adjust when advised
- Pipeline survey at test stations: annually
- Repair/replace test stations and other components as needed
- Replace anodes: when there is insufficient current

NACE CP Protection Criteria

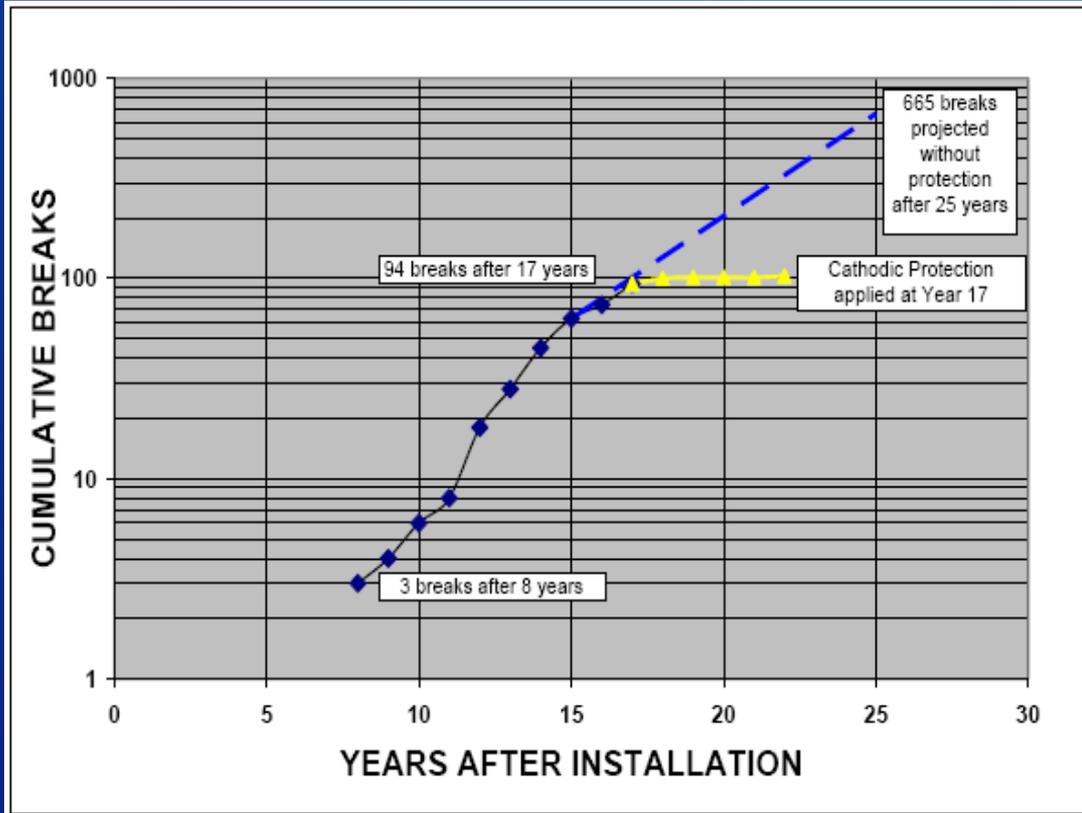
- A polarized potential of **-850 mV_{CSE}** or more negative (a.k.a. Instant OFF structure-to-electrolyte potential)
- A minimum of **100 mV_{CSE} shift** cathodic polarization, i.e. 100 mV more negative than the native potential of the structure
- In addition to the above criteria, Reclamation recommends that the polarized potential of the structure shall not be more negative than **-1100 mV_{CSE}**

** mV_{CSE} means millivolts as measured with a copper-copper sulfate reference electrode



Corrosion Management Programs

Effectiveness of Well Designed Program



Durham Region, Ontario, Canada, Implemented in 1983

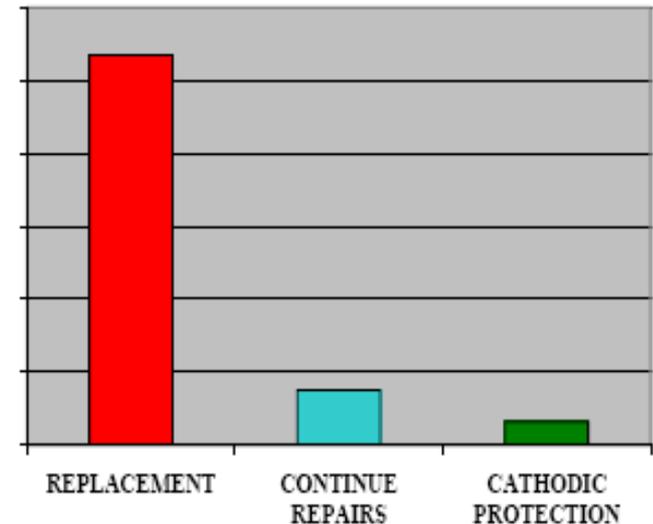
- 193 kilometers of ductile and cast iron water main cathodically protected,
- 17,032 anodes and 1,330 test stations
- ~100 know breaks/yr before CP down to 28 corrosive breaks in 2005
- \$5m to install CP, less than 4% of estimated cost to replace of \$135.4m

Ontario Centre for Municipal Best Practices, "Best Practices Summary Report, Water Loss Management- Cathodic Protection," February 2008.

Economic Benefits

Annualized Costs – 20 Yr. Cycle

Life Extension Cathodic Protection 58% less expensive than continuing with repairs



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Corrosion Protection

The most cost effective corrosion protection system for buried and submerged structures involves a **good coating and cathodic protection.**

Coatings and Corrosion Manuals

RECLAMATION Managing Water in the West

Technical Memorandum No. MERL-2012-40

Guidelines for Field Installation of Corrosion Monitoring and Cathodic Protection Systems



December 2012

U.S. Department of the Interior
Bureau of Reclamation

RECLAMATION Managing Water in the West

Technical Memorandum No. MERL-20xx-xx

Field Guide for Testing and Troubleshooting Cathodic Protection Systems



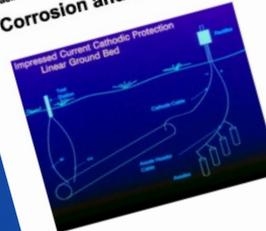
December 2012

U.S. Department of the Interior
Bureau of Reclamation

RECLAMATION Managing Water in the West

Facilities Instructions, Standards, and Techniques Volume 4-5

Corrosion and Cathodic Protection



September 2013

U.S. Department of the Interior
Bureau of Reclamation
Denver, Colorado

RECLAMATION Managing Water in the West

Technical Guide

Guide to Protective Coatings, Inspection, and Maintenance Second Edition



April 2012

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

http://www.usbr.gov/pmts/materials_lab/publications/

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Questions/ Comments?



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