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Managing Water in the West

Corrosion Mitigation of Tanks

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Bureau of Reclamation

Corrosion Mitigation of Tanks

Webinar Objectives

- Review of Corrosion
- Types of Tanks Used by Reclamation
- Coatings Considerations for Tanks
- Cathodic Protection (CP) considerations for Tanks
- CP system Designs for Tanks
- Testing and Inspection

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Review of Corrosion

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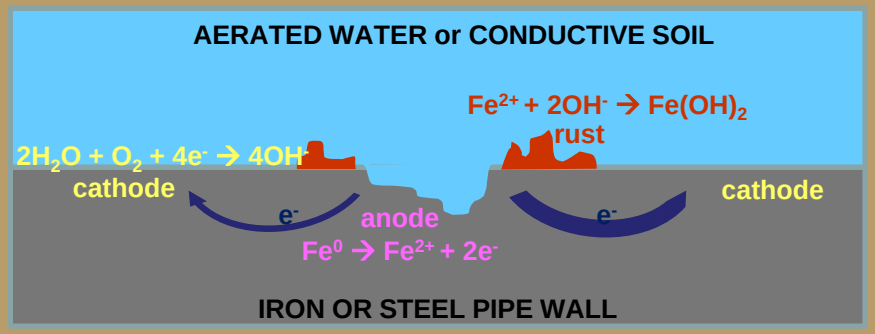
The Corrosion Reaction

ex. oxidation, “rusting,” electroplating, anodizing

Electrochemical Reaction Between a Metal and an Electrolyte

ex. steel, copper, aluminum

ex. soil, water

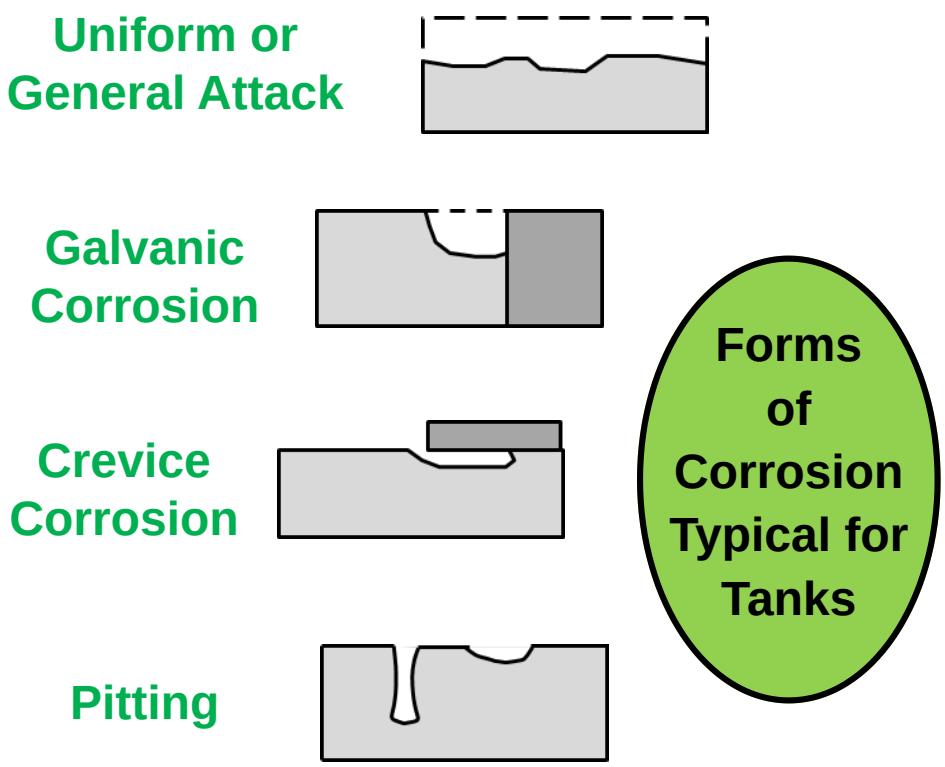


Four Required Components for Corrosion:

1. Anode (Corrodes)
2. Cathode (Protected)
3. Metallic Return Path (ex. Tank)
4. Electrolyte (Usually Soil or Water)

ACME

Forms of Corrosion Typical for Tanks



Dealing with Corrosion:

- Create barrier between metal and electrolyte- Coating
- Eliminate potential differences on a structure's surface- Cathodic Protection
- Avoid use of dissimilar metals
- Avoid oxygen concentration cells by compacting tank base soil properly

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Corrosion Management

The most effective corrosion protection system involves a good bonded coating and cathodic protection.

- **Coatings are the primary corrosion protection for tanks.**
- **Cathodic protection will help extend the life of the coating and maximize time between recoats**
- **Cathodic Protection will protect tanks at coating defects.**
- **The right corrosion mitigation system is a up-front investment that will reduce long-term O&M costs.**

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For further review of corrosion please see our previous webinars.

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Types of Tanks

Types of Tanks

- AST (above ground storage tanks)
  - More commonly used in Reclamation
- UST (underground storage tanks)
  - Reclamation does not commonly use these types
  - Typically do not directly bury steel tanks.

This Webinar will focus on Above Ground Steel Storage Tanks

<500,000 gal – use steel
>500,000 gal – use concrete (construction more expensive but cheaper to maintain)

*concrete tanks do have corrosion issues related to chemistry that need to be considered.

Types of Tanks

Air Chamber

- Pressurized
- Always welded steel due to pressure
- Pill like shape (ideal for pressure vessels)

Surge Tank

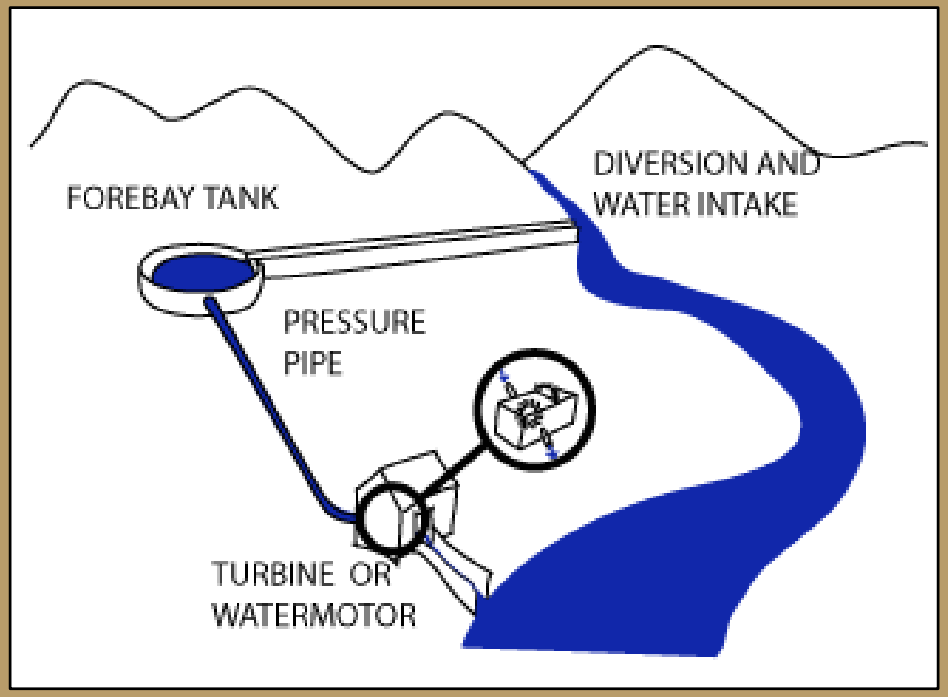
- Mitigates pressure surges in system.
- Must be high point of the line
- Open to atmosphere or covered

Types of Tanks

Forebay Tank –
Pond like tank at the top of a penstock. Allows particle settling before entering a penstock.

Regulating Tank-
Bulk storage reservoir

Distribution Tank-
Storage



http://en.howtopedia.org/wiki/How_to_Build_a_%22Water_Motor%22

These tanks are all similar in design (steel, closed/open top, short/tall) but are named based on function.

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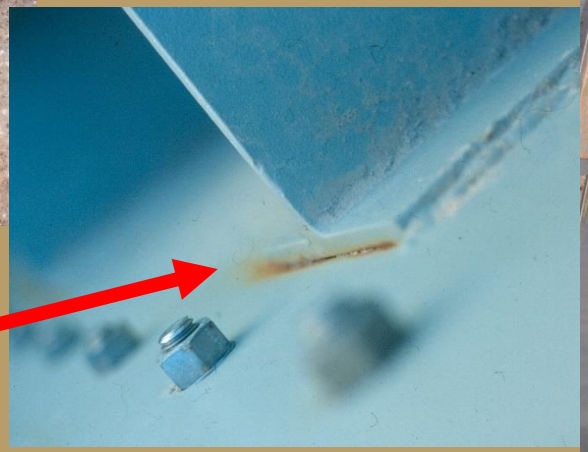
Tank Construction

Bolted

Welded



Composite

Concrete

Concrete
Wire-wrapped

Coatings Considerations for Tanks

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Protective Coatings

Protective coatings (including paint) are the primary means employed by Reclamation to control corrosion.

- **Coating acts as a barrier between the steel tank and the water to electrically isolate the tank**

- **Examples of Coatings for tanks:**
  - waterborne epoxies, acrylics, mastics and high-solids epoxies and urethanes

Protective Coatings

Is the coating suitable for the storage application in mind?

1. **Is it ok to use a particular coating in potable water situations?**

   National Sanitation Foundation (NSF) International standard ANSI/NSF 61 for use in potable water tanks. Ex. epoxies

2. **Will a harsh environment be present?**

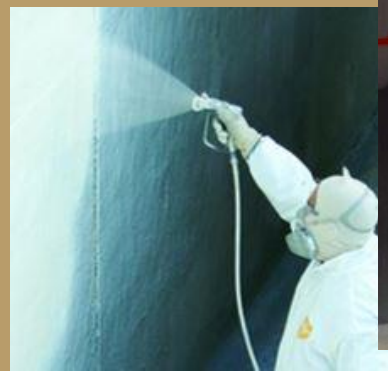
   Water may vary in pH, temperature, dissolved solids and hardness - creating an aggressive environment in the area below the waterline

3. **Are we dealing with sludge or other abrasive particulates?**

Surface Preparation

Proper surface preparation is key to successful coating performance.

- **Definition** – The cleaning of metal to ensure the best possible bond between a coating and the surface.
- Coatings service life is directly related to surface preparation.
- Surface prep includes removal of oils and soluble salts from the surface.
- Building a surface profile is important (ex. abrasive blasting).



WATCH OUT

Beware of dark colored logos on the side of a tank.

Under solar exposure the dark logo can heat up and cause blistering on the inside of the tank.

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Cathodic Protection Considerations for Tanks

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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*

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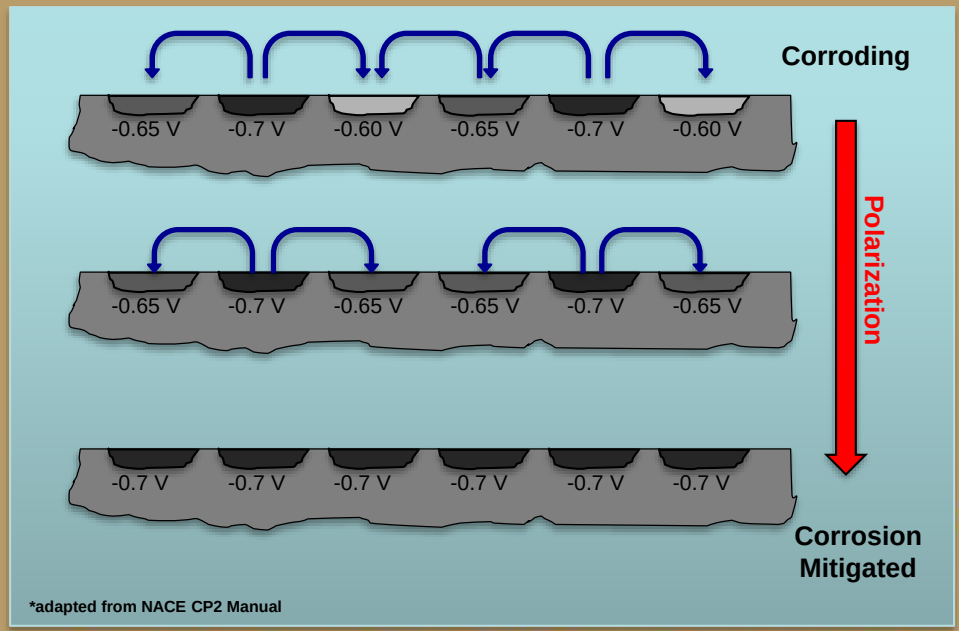
Cathodic Protection

- **Current flows through Electrolyte from Anode to Tank**
  - **Polarizes tank to eliminate potential differences between anodic and cathodic areas on the surface**
  - **Corrosion rate ceases or is greatly reduced**

- **Electrons are provided from a source to the tank**
  - **Via a more active metal to be sacrificed- galvanic anode CP**
  - **Via a rectifier- impressed current CP**

CP works with coatings to protect tanks at holidays and prevent undercutting of coating



Galvanic Anode CP System

Sacrificial String Anodes

CTS presentation “Internal Cathodic Protection of Tanks and Vessels” Clive Hakins

New Mg Anode

Old Mg Anodes

- 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 tank.
- Both the tank and the anode must be in contact with the electrolyte (water)

Features:

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

Zinc Anode

Anodes:

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

Impressed Current CP System

Features:

- High current requirements
- Can handle large or poorly coated structures
- If hanging anode weights are an issue use ICCP to obtain current

Graphite Anodes

Mixed Metal Oxide Disk Anode

Platinized wire anode in slotted PVC tube for submersion

- 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

Anodes:

- Graphite, High-Si Cast Iron, Mixed Metal Oxide, Platinum
- Anodes Normally Connected Through Calibrated Shunts in Junction Box

CP System Design for Tanks

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General Design Considerations

- Cathodic Protection systems are designed for a minimum 20 year service life if possible
- Ease of maintenance and replacement of anodes- for example we try to use GACP where possible
- Try to provide even current distribution throughout tank
- Treat outside and inside of tank separately

- Factors affecting design:
  - Size of tank- anodes must distribute current to entire submerged portion, or the portion in contact with soil
  - Holes, openings, valves
  - Pressure (Is it a pressure vessel?)
  - Material, geometry, and weight of anode
  - Liquid type in tank (acid, base, potable water, water with heavy metals)
  - Resistivity of liquid inside or soil outside
  - Temperature

General Design: Exterior

Tank CP protection exterior and interiors are treated separately

Exterior Tank Base

- Oiled sand or clean sand with crushed limestone (high resistivity, higher pH)
  - Issues: MUST be evenly compacted or concentration cell corrosion may develop
- Typically we don't need to protect the tank base with CP

If using CP:

- Protect underneath the tank base
- Anode rings are a potential configuration
- Use of permanent reference electrodes installed under the tank base.
- AWWA D100- reference for tank foundations

Anode rings prior to backfill

Waterworld.com article Vol. 25 Issue 3 "Cathodic Protection for Above Ground Storage tanks"

General Design: Interior

Interior of Tank

- Water quality (may not require CP)
- Water level changes
- Accessibility

Potable Water considerations

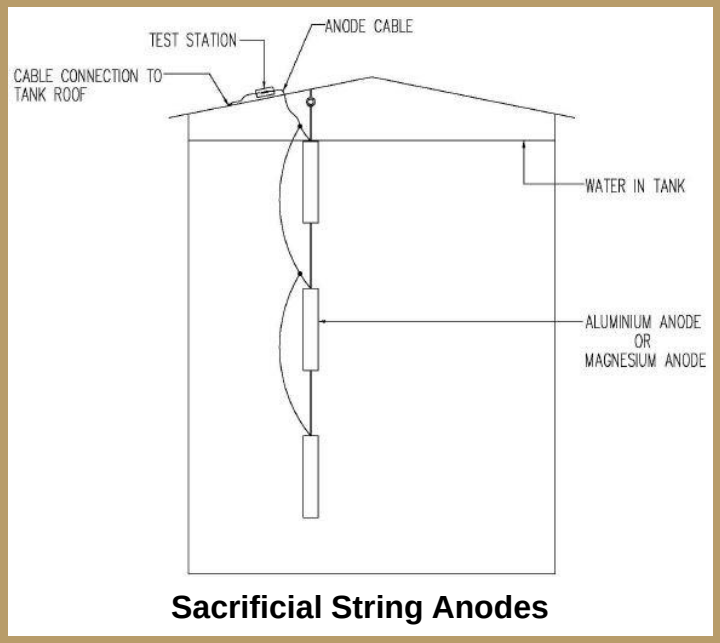
- No zinc anodes

We Often Protect the Interiors

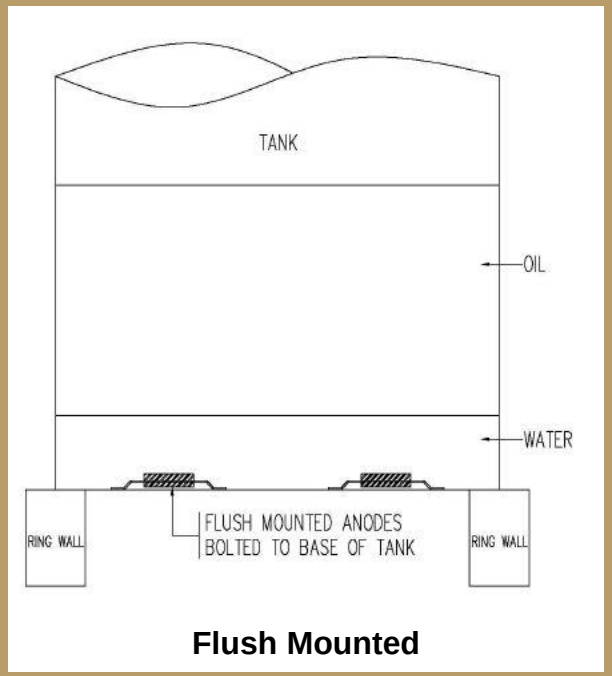
General Design: Interior

Types of anode configurations:

- **Flush mounted**
- **Flotation Buoys**
- **Ring mounting**



Sacrificial String Anodes



Flush Mounted

Flotation Buoy

Anode Systems Company "Cathodic Protection for 100,000 Gallon Water Tank"

CTS presentation "Internal Cathodic Protection of Tanks and Vessels" Clive Hawkins

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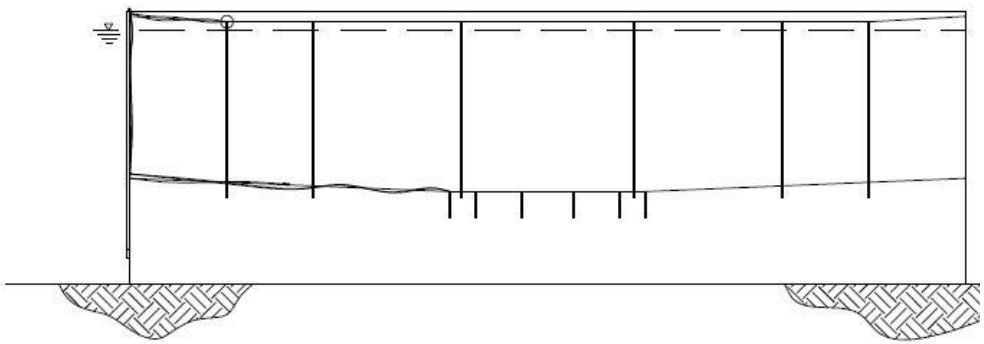
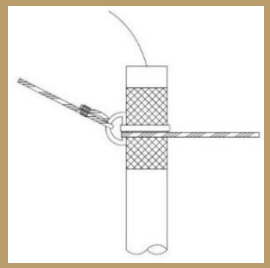
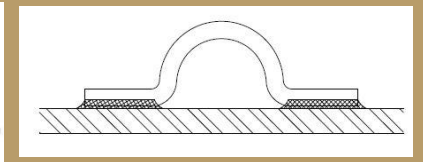
Ring Configuration

Side View

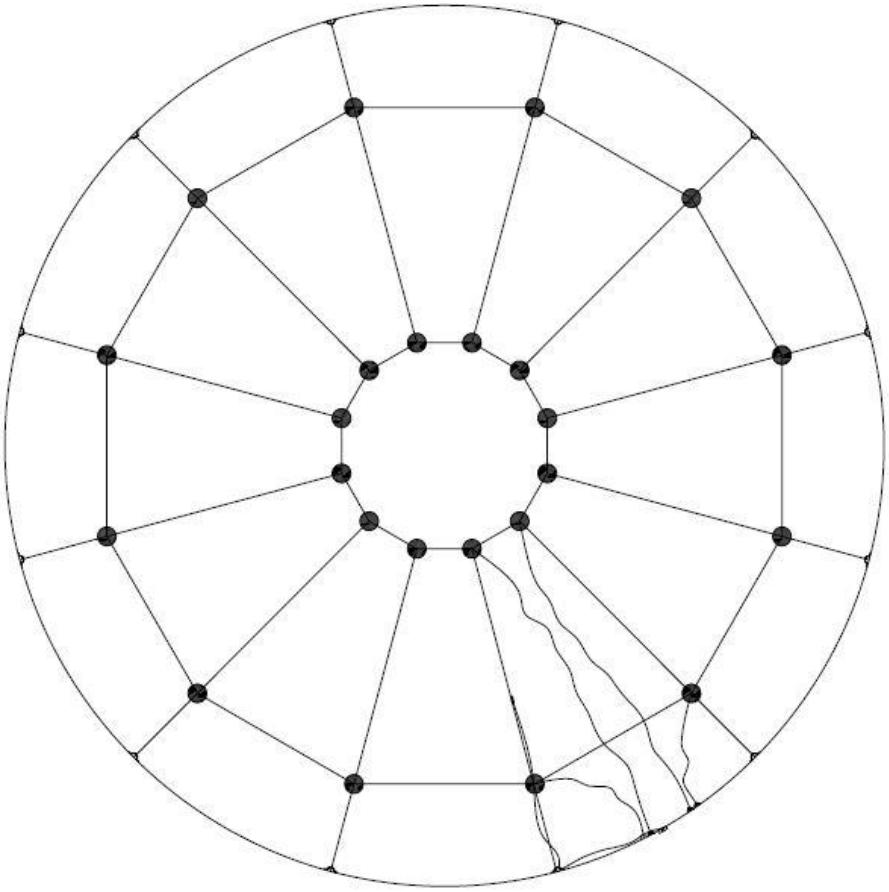






Wire Rope Supports

Top View



Sample system:
2 rings: inner and outer
12 long anodes (outer)
12 shorter anodes (inner)

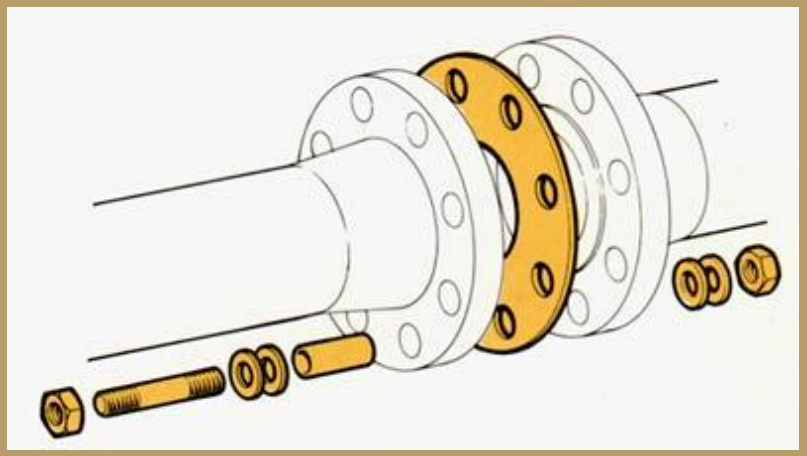
Center anodes allowed for concentrated current distribution along tank bottom, whereas long outer anodes protected along the tank sides.

Other Features that Need Consideration:

Isolation

Typically performed across a joint or flange on a pipeline leaving or entering the tank.

- Reduces CP current requirements (less to protect)
- Disconnects dissimilar metals
- Avoid interference between CP systems (yard piping, exterior tank bottoms, interior tanks are separate systems)



- Yard Piping
- Ladders
- Stairs/railings
- Risers
- Ropes/cables for anode attachments

Guidelines and Specifications

- NACE SP0388 “Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks”
- NACE RP0196 “Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks”
- NACE RP0285 “Corrosion Control of Underground Storage Tank Systems by Cathodic Protection”

Testing and Inspection

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Testing Tank Interior CP Systems

- **Tanks with a submerged CP system should be inspected at regular intervals or during downtime.**
  - **Check polarized potential to NACE criteria**
  - **Test current at each anode in junction box and balance output using variable resistor**
  - **Check rectifier (if ICCP)**
  - **What is the condition of the coating?**
  - **What is condition of anodes?**
  - **Are brackets still providing sufficient mechanical support?**
  - **Is rope support still functioning?**
  - **Are metallurgical bonds still intact?**
  - **Is cable between tank and anode still electrically connected?**

ROV inspection of magnesium anode on tank floor

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}**
- **Refer to CP Testing Webinar for further information on testing.**

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

Inspection Frequency

Standard/ Guideline	Corrosion Inspection Frequency	Polarized Potentials & Current Output	Rectifier Inspection Frequency	CP System Data Analysis by TSC
NACE Standards		Annually	2-month intervals	
USBR Corrosion Staff	When structure is available due to dewatering, maintenance.	Annually	2-month intervals	Every 3-5 years

Based on NACE standards RP0196, SP0388, RP0285

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Questions? Comments?

De Sitter's "Law of Fives"

**$1 spent in getting the structure designed and built correctly
is as effective as spending
$5 when the structure has been constructed but corrosion has yet to start,
$25 when corrosion has started at some points, and
$125 when corrosion has become widespread.**

Thank you to everyone who provided photos and information for this webinar!

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