Mitigation of corrosion by cathodic protection

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Agenda

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• General CP Description
• CP Design Criterion
• Types of CP system
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• Impressed Current (ICCP) System
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Objective

The objective of this presentation is to provide an introduction to the principles of corrosion mitigation by way of cathodic protection (CP) within a bias towards an offshore environment. The presentation will provide an overview of ‘Sacrificial Anode’ (SA) and ‘Impressed Current’ (ICCP) based systems.
Question

What is cathodic protection (CP)?
Answer

Electrochemical protection by decreasing the corrosion potential to a level at which the corrosion rate of the metal is significantly reduced” (ISO 8044)
What is Corrosion/Cathodic Protection

![Diagram of Corrosion and Cathodic Protection]

- **Cathode**
- **Anode**
- **Electrolyte**
- **Direction of Conventional Current**
- **Metallic Connection**
- **OH⁻**
- **Fe²⁺**
Applications of CP
General Corrosion Description

• Corrosion is a process that occurs naturally to metal and alloys.

• When a metal is immersed in any electrolyte (such as seawater), an electrical potential cell is set up at the metal/electrolyte interface.

• Within the cell:
  • Metallic atoms give up one or more electrons to become positively charged ions (anodic reaction)
    \[2Fe \rightarrow 2Fe^{2+} + 4e^-\]
  • Oxygen, water and the released electrons combine to form negatively charged hydroxyl ions (cathodic reaction)
    \[O_2 + 2H_2O + 4e^- \rightarrow 4OH^-\]

• Cathodic protection controls the location of the anodic reaction
Where it all Began

• “The first practical use of cathodic protection is generally credited to Sir Humphrey Davy in the 1820s. Davy’s advice was sought by the Royal Navy in investigating the corrosion of copper sheeting used for cladding the hulls of naval vessels. Davy found that he could preserve copper in sea water by the attachment of small quantities of iron or zinc; the copper became, as Davy put it, “cathodically protected” (Francis, 1981).

The principle has not really changed!!!

CP Description

- Cathodic polarisation of all noble sites (cathodes) to the most active (anode) site on the metal surface.
The Galvanic Series of metals illustrates the difference in potential between differing metals.
CP Description

• Polarisation is achieved by the application of CP.

• Generally accepted potential range for ‘cathodically protected’ carbon steel -800mV to -1100mV vs. Ag/AgCl.

• Sacrificial Anodes:
  • Al, Zn, Mg

• Impressed Current Anodes:
  • Platinised Titanium, Mixed Metal Oxide, Silicon Iron,
Types of CP

- Sacrificial Anode (Zinc)
- Impressed Current Anode

ELECTROLYTE (Seawater)

Current Flow

Electrical Connection

dc Power Supply

Electrical Cable
CP Description

Lifecycle of CP System
CP Description

Lifecycle of CP System
## CP Design Criteria

<table>
<thead>
<tr>
<th>Material</th>
<th>Minimum Protective Potential (V)*</th>
<th>Maximum Protective Potential (V)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Steels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immersed in seawater</td>
<td>-0.80</td>
<td>-1.10</td>
</tr>
<tr>
<td>Buried in sediment</td>
<td>-0.90</td>
<td>-1.10</td>
</tr>
<tr>
<td>Duplex Stainless Steel</td>
<td>-0.50</td>
<td>-0.80</td>
</tr>
<tr>
<td>Martensitic Stainless Steel</td>
<td>-0.50</td>
<td>-0.80</td>
</tr>
</tbody>
</table>

* The potentials are referenced to a Ag/AgCl reference electrode
Galvanic Anodes
Impressed Current (ICCP) Anodes
## Impressed Current (ICCP) System

<table>
<thead>
<tr>
<th><strong>Power Unit</strong></th>
<th>Converts from AC to DC and steps down the voltage typically in the range of 18V to 30V</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electronics</strong></td>
<td>Constant Potential, Constant Voltage, Constant Current; Data logger; Remote Monitoring</td>
</tr>
<tr>
<td><strong>Cables</strong></td>
<td>Minimal voltage drop required. Need to be durable for long term subsea use. Structure/Power Unit -ve Connection Anode/Power Unit +ve Connection</td>
</tr>
<tr>
<td><strong>Anode</strong></td>
<td>A noble material (Generally MMO – Mixed Metal Oxide). Should be installed at ‘remote earth’. Different Strategy for vessels</td>
</tr>
</tbody>
</table>
## CP System Type Comparison

<table>
<thead>
<tr>
<th>Galvanic Anode System</th>
<th>ICCP System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low OPEX (reduced maintenance required).</td>
<td>High OPEX (maintenance required).</td>
</tr>
<tr>
<td>Interference problems are limited to non-existent.</td>
<td>CP interference issues are likely.</td>
</tr>
<tr>
<td>Considered more suitable for confined spaces due to gas evolution.</td>
<td>Considered less suitable for confined space due to gas evolution.</td>
</tr>
<tr>
<td>Uncontrollable Output.</td>
<td>Controllable Output.</td>
</tr>
<tr>
<td>Based on the potential difference between the anode and the structure (driving force).</td>
<td>External power supply is needed.</td>
</tr>
<tr>
<td>Mainly used for offshore pipelines, subsea structures and new platform structures.</td>
<td>Generally Used for aged platform structures and retro fit.</td>
</tr>
</tbody>
</table>
CP System Monitoring
**Common CP Design Standards**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Onshore/Offshore</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNV RP B-401</td>
<td>Offshore</td>
<td>Cathodic Protection Design</td>
</tr>
<tr>
<td>Norsok M-503, 1997</td>
<td>Offshore</td>
<td>Cathodic Protection, Common Requirements</td>
</tr>
<tr>
<td>AWWA D106-10</td>
<td>Onshore</td>
<td>Sacrificial Anode Cathodic Protection Systems For The Interior Submerged Surfaces Of Steel Water Tanks</td>
</tr>
<tr>
<td>NACE SP0169:2007</td>
<td>Onshore</td>
<td>Control of External Corrosion on Underground or Submerged Metallic Piping Systems</td>
</tr>
<tr>
<td>API Recommended Practice 651</td>
<td>Onshore</td>
<td>Cathodic Protection of Above ground Petroleum Storage Tanks, 1997</td>
</tr>
<tr>
<td>API Recommended Practice 2A</td>
<td>Offshore</td>
<td>Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms, Section 14.0</td>
</tr>
<tr>
<td>BS EN 12954</td>
<td>Both</td>
<td>Cathodic Protection of Buried and Immersed Metallic Structures – General Principles and Application for Pipelines”</td>
</tr>
<tr>
<td>BS EN 13509</td>
<td>Both</td>
<td>Cathodic Protection Measurement Techniques</td>
</tr>
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</table>
Further viewing for CP

http://www.youtube.com/watch?v=RAlC75xG4qU

http://www.youtube.com/watch?v=QYd9ENn1nP0&list=PLTBnXCO7ptxMdjbUqBqnOONpmmxNmY4Am

http://www.youtube.com/watch?v=JweyK4rs6TE

https://www.google.co.uk/search?q=cathodic+protection+anodes&tbm=isch&tbo=u&source=univ&sa=X&ei=PKi3U8CjDJHB7AbzpYDwBQ&ved=0CEMQsAQ&biw=1587&bih=1012
Anode Material Types
Any Questions

• Any Questions?