

Cathodic and Anodic Protection

- Introduction
- Electrochemical thermodynamics
- Electrochemical kinetics
- Corrosion rate measurements
- Various forms of corrosion
- Corrosion mitigation
 - cathodic and anodic protection
 - coatings and inhibitors
 - material selection and design

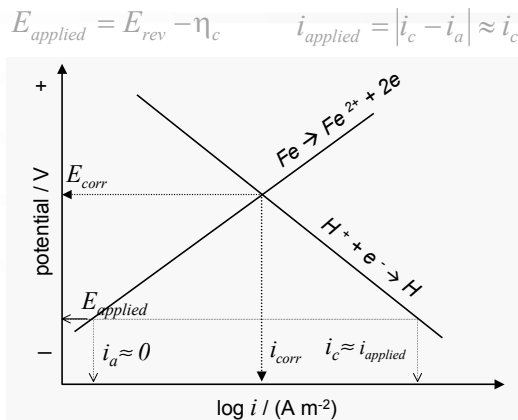
Cathodic protection

- one of the most widely used methods
- works almost all the time on all metals and environments
- first used in 1820s to combat marine corrosion
- now used primarily to coated protect carbon steel in neutral environments
- examples: pipelines, oil and gas wells, offshore structures, seagoing ship hulls, marine pilings, water tanks, some chemical equipment

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Principles of cathodic protection: impressed current method

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Impressed current method

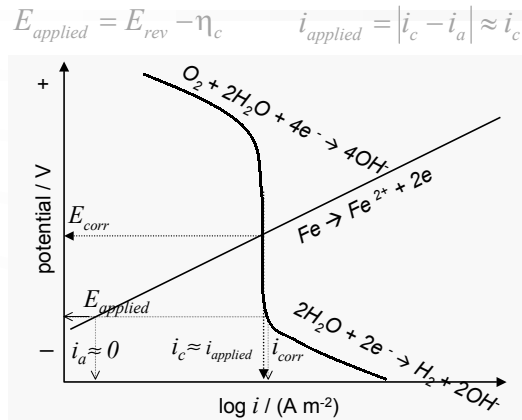
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- example:
 - mild steel in strong acid
 - corrosion current: $i_{corr} \approx 10 \text{ A/m}^2$
 - corrosion rate: $CR \approx 11.5 \text{ mm/y}$
 - apply cathodic polarization: $\eta_c = 120 \text{ mV}$
 - reduces corrosion current to: $i_{corr} \approx 0.1 \text{ A/m}^2$
 - reduces corrosion rate to: $CR \approx 0.1 \text{ mm/y}$
 - impressed current density: $i_{applied} \approx 150 \text{ A/m}^2$
 - impressed current per m^2 : $I_{applied} \approx 150 \text{ A}$
 - not practical
 - need coating
 - hard to find one for strong acids

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Impressed current method: steel in neutral aerated water

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Impressed current method

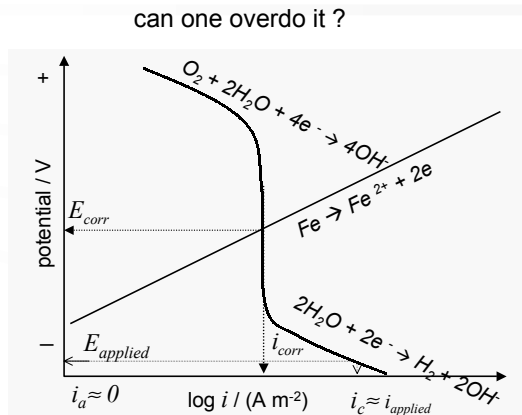
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- example:
 - mild steel in aerated neutral seawater
 - corrosion current: $i_{\text{corr}} \approx 1 \text{ A/m}^2$
 - corrosion rate: $CR \approx 1.1 \text{ mm/y}$
 - apply cathodic polarization: $\eta_c = 120 \text{ mV}$
 - reduces corrosion current to: $i_{\text{corr}} \approx 0.001 \text{ A/m}^2$
 - reduces corrosion rate to: $CR \approx 0.001 \text{ mm/y}$
 - impressed current density: $i_{\text{applied}} \approx 1 \text{ A/m}^2$
 - impressed current per m²: $I_{\text{applied}} \approx 1 \text{ A}$
 - practical
 - works even better with coating
 - alkaline conditions lead to scale precipitation

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Impressed current method: steel in neutral aerated water

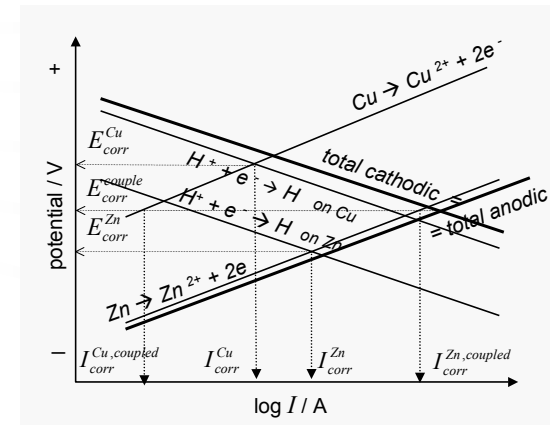
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Principles of cathodic protection: sacrificial anode method

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Sacrificial anode method

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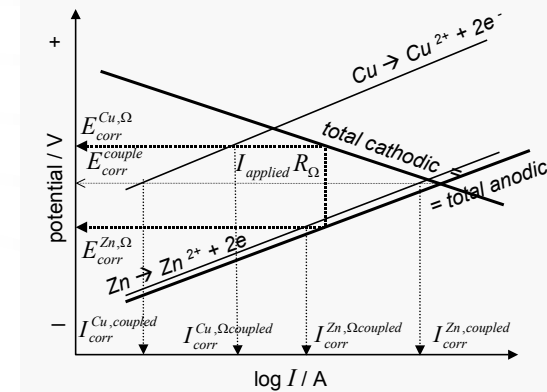
- sacrificial anode continuously “consumed” by corrosion and needs replacement
- good candidates:
 - **zinc**: used broadly, e.g. galvanized zinc coating is a common distributed sacrificial anode for steel
 - **magnesium**: used for underground pipeline protection, i.e. in soil and other low conductivity environments
 - **aluminium**: improved life in seawater and other high conductivity environments because it polarizes less than zinc and magnesium

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Solution resistance problem

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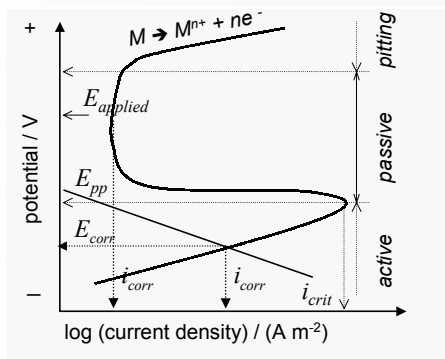


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Anodic protection by impressed current

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Anodic protection

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- suitable for active-passive alloys (e.g. stainless steel, nickel alloys, titanium)
- requires a broad potential range for passivity
- need sizable/expensive electrical equipment
- risky if potential “slips” into the active/pitting region
- used often for very aggressive solutions when other methods fail, e.g. for protection of tanks storing of strong acids (e.g. sulphuric, phosphoric, nitric)

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Common issues

Introduction

Electrochemical
thermodynamics
Electrochemical

kinetics

Corrosion rate
measurements

Various forms of
corrosion

Corrosion mitigation

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anodic protection

▸ coatings and
inhibitors

▸ material selection
and design

- potentiostatic vs. galvanostatic control
- reference electrodes
- current distribution and throwing power
- complex geometry, crevices
- stray currents
- rectifiers
- cost