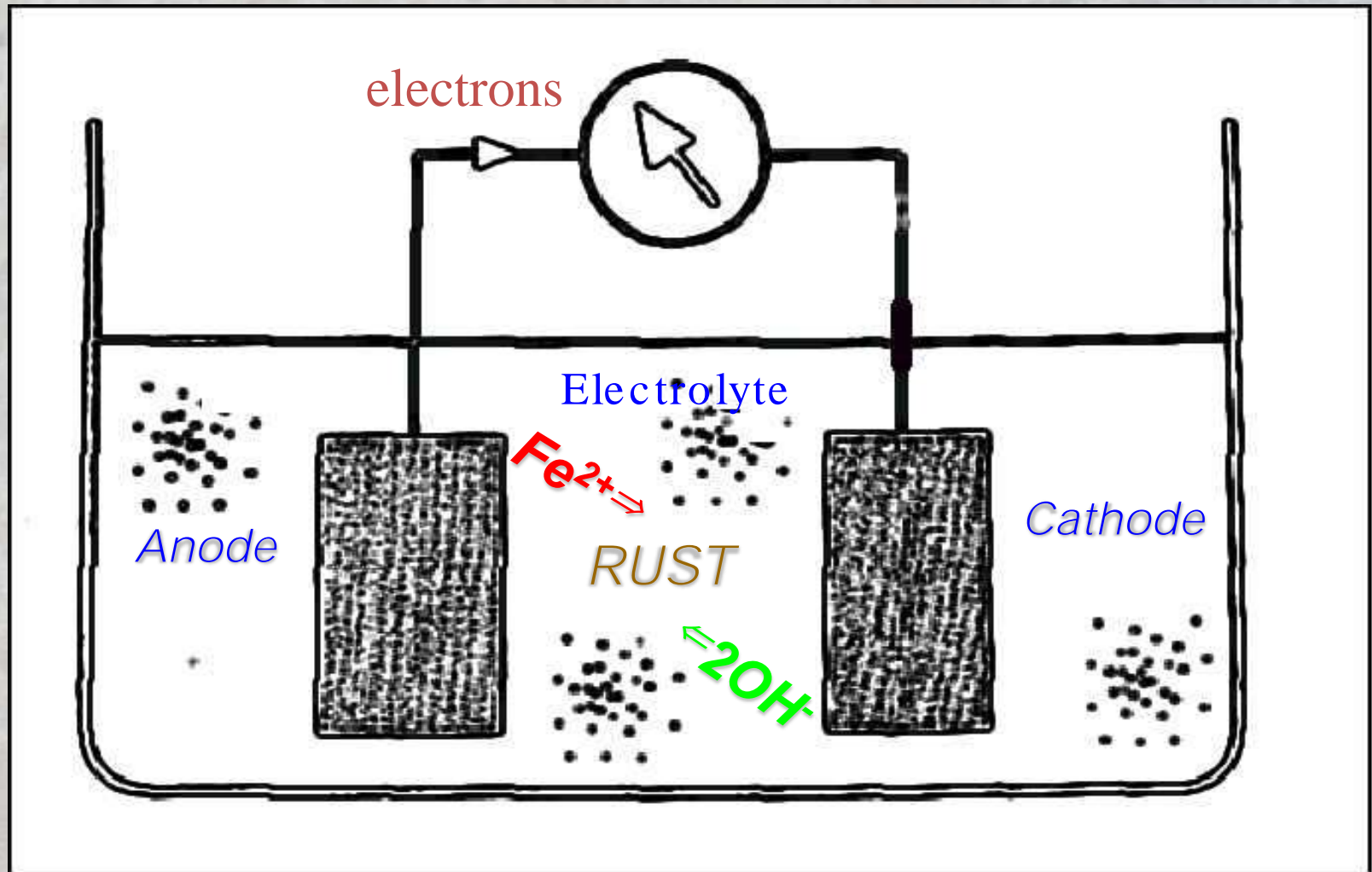


An Introduction to Aqueous Corrosion

Paul Lambert
CEng FIMMM

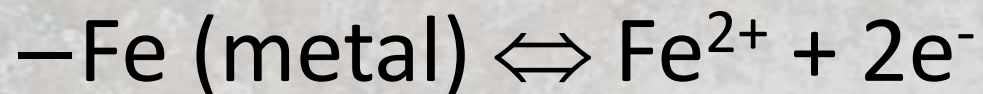
Head of Materials & Corrosion Technology – Mott MacDonald
Visiting Professor, Centre for Infrastructure Management – Sheffield Hallam University
Past President – Institute of Corrosion

A Simple Corrosion Cell



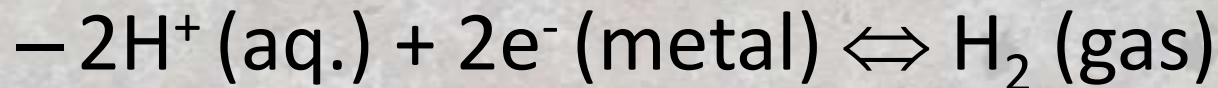
Why does steel corrode ? (1)

- Differences in electrical potential on the surface form ANODIC and CATHODIC sites
- At anodic sites the metal oxidises:



Why does steel corrode ? (2)

- Simultaneously, reduction occurs at cathodic sites, typically:



- Electrons are conducted through metal while ions travel through electrolyte

General Corrosion

- Uniform attack of the metal surface
- Low rate of penetration
- Potentially greater degree of contamination
- 'Typical' rates are available for most metal/environment combinations
- Difficult to design against
- May require protection - e.g. coatings

General Corrosion



Pitting Corrosion

- Highly localised, high rate corrosion
- Rapid perforation of sections
- Several causes, including chloride ions
- Once initiated, pits can be self perpetuating
- Often associated with stagnant conditions
- Coatings can provide barrier but any defects can become active anodic sites

Pitting Corrosion



Crevice Corrosion

- Typically occurs in gaps between two surfaces
- Only one surface needs to be metal
- Surface deposits can also produce crevices
- Corrosion cell caused by differential oxidation
- The smaller the crevice, the more intense the corrosion
- Must be designed-out or filled-in

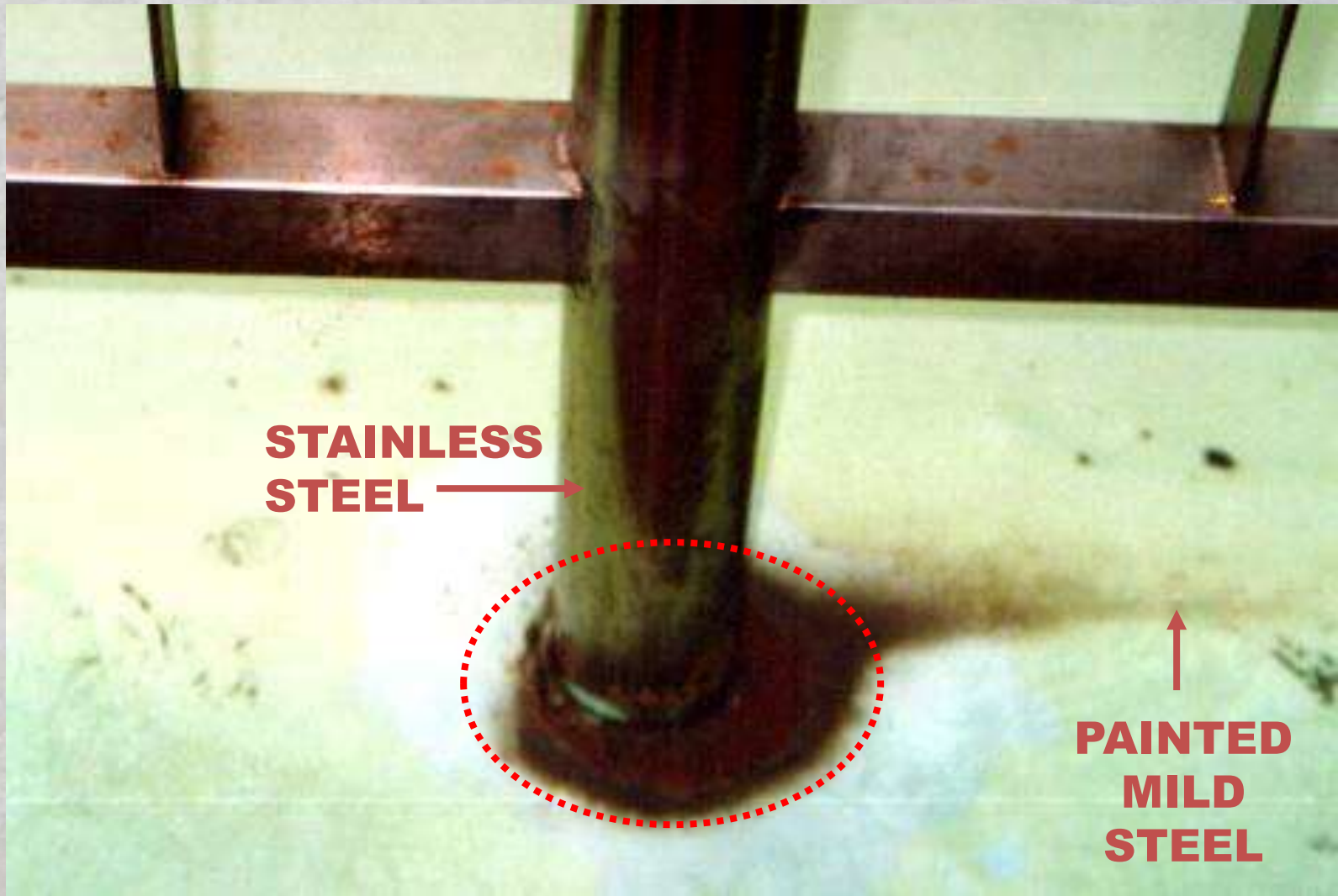
Crevice Corrosion



Bimetallic Corrosion

- Five conditions must be satisfied:
 - an environment in which the ‘anode’ can corrode
 - an electrolytic path
 - an electronic path
 - a large potential difference
 - no restriction of the reactions at the ‘cathode’
- Control involves preventing or interfering with one of these requirements

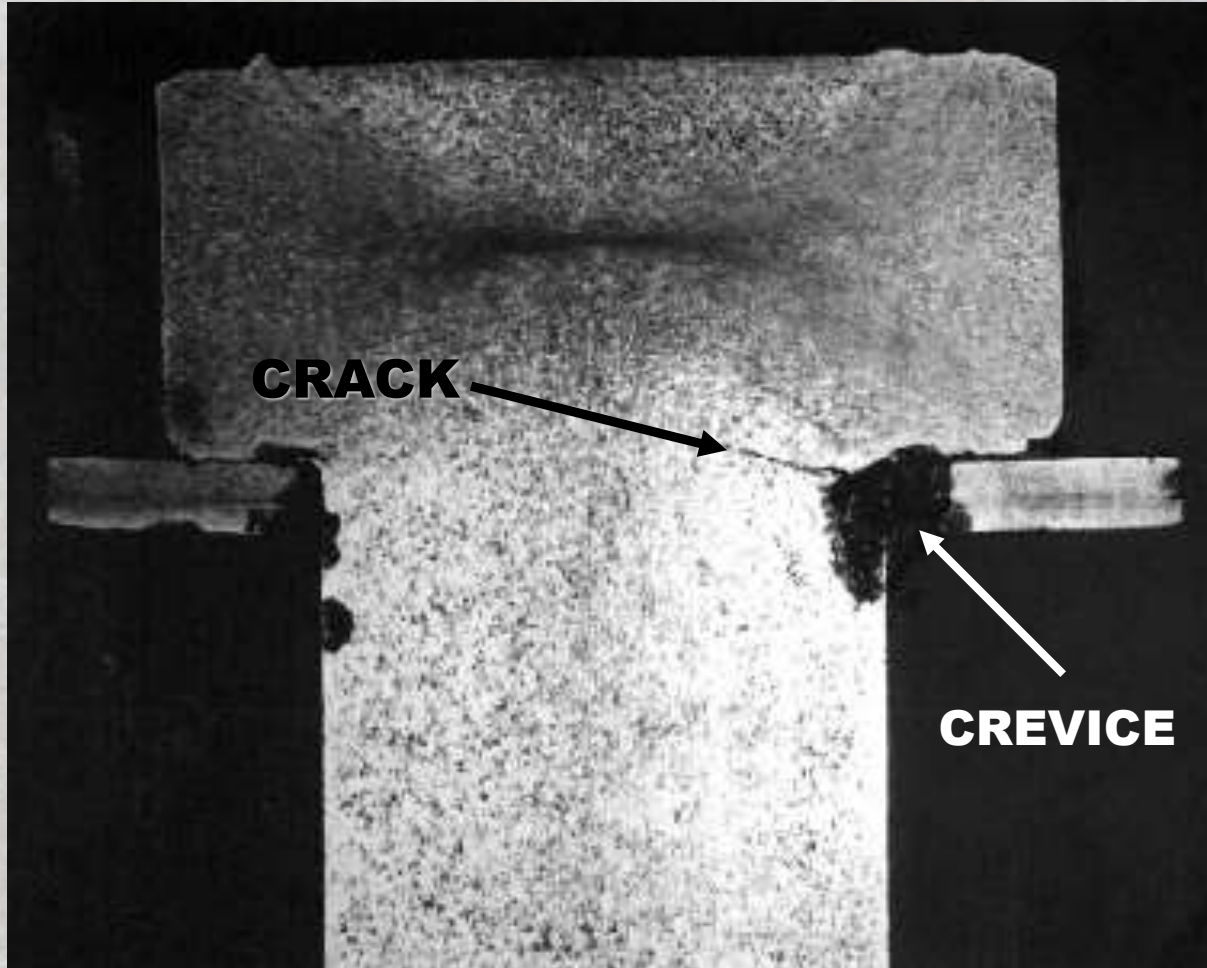
Bimetallic Corrosion



Stress Corrosion Cracking

- Requires both tensile stress and a specific corrosive medium
- Highly specific to alloy, environment and exposure conditions
- Stresses may be due to fabrication or service
- Coatings can exclude the environment

Stress Corrosion Cracking



Fall down – go bang



Corrosion Fatigue

- Caused by a combination of cyclic stress and a corrosive environment
- Hard to distinguish from plain fatigue
- Coatings can exclude the environment
- Techniques that improve plain fatigue resistance can also help with corrosion fatigue - e.g. carburising, nitriding, shot peening

Corrosion Fatigue



Other Forms of 'Corrosion'

- **EROSION-CORROSION**
 - synergy of erosive and corrosive decay
- **CAVITATION**
 - collapsing air bubbles erode surface
- **GRAPHITIC CORROSION**
 - preferential attack in grey cast iron
- **GALLING**
 - local cold welding and tearing (stainless steels)
- **FRETTING**
 - small movements generating fine debris

Corrosion in the Oil & Gas Industry

- As well as exposure to sea water and high temperatures, there are other problems:
 - Carbon Dioxide Corrosion - *'Sweet Corrosion'*
 - Dry carbon dioxide in the presence of moisture produces carbonic acid, resulting in significant damage by a number of mechanisms.
 - Hydrogen Sulphide Corrosion - *'Sour Corrosion'*
 - Hydrogen sulphide dissolved in water can result in severe loss rates in ferrous and other materials and can lead to hydrogen embrittlement and cracking.

Reinforced concrete also suffers from CO_2 (e.g. from the atmosphere) and H_2S (e.g. from sewage) as well as chloride induced corrosion.

Reinforcement Corrosion



Steel in Concrete

Chlorides

Carbon dioxide



Concrete

Chlorides

RUST

Steel

Corrodes

Reinforcement Corrosion & Repair



Reinforcement Corrosion & Repair

