An Introduction to Aqueous Corrosion

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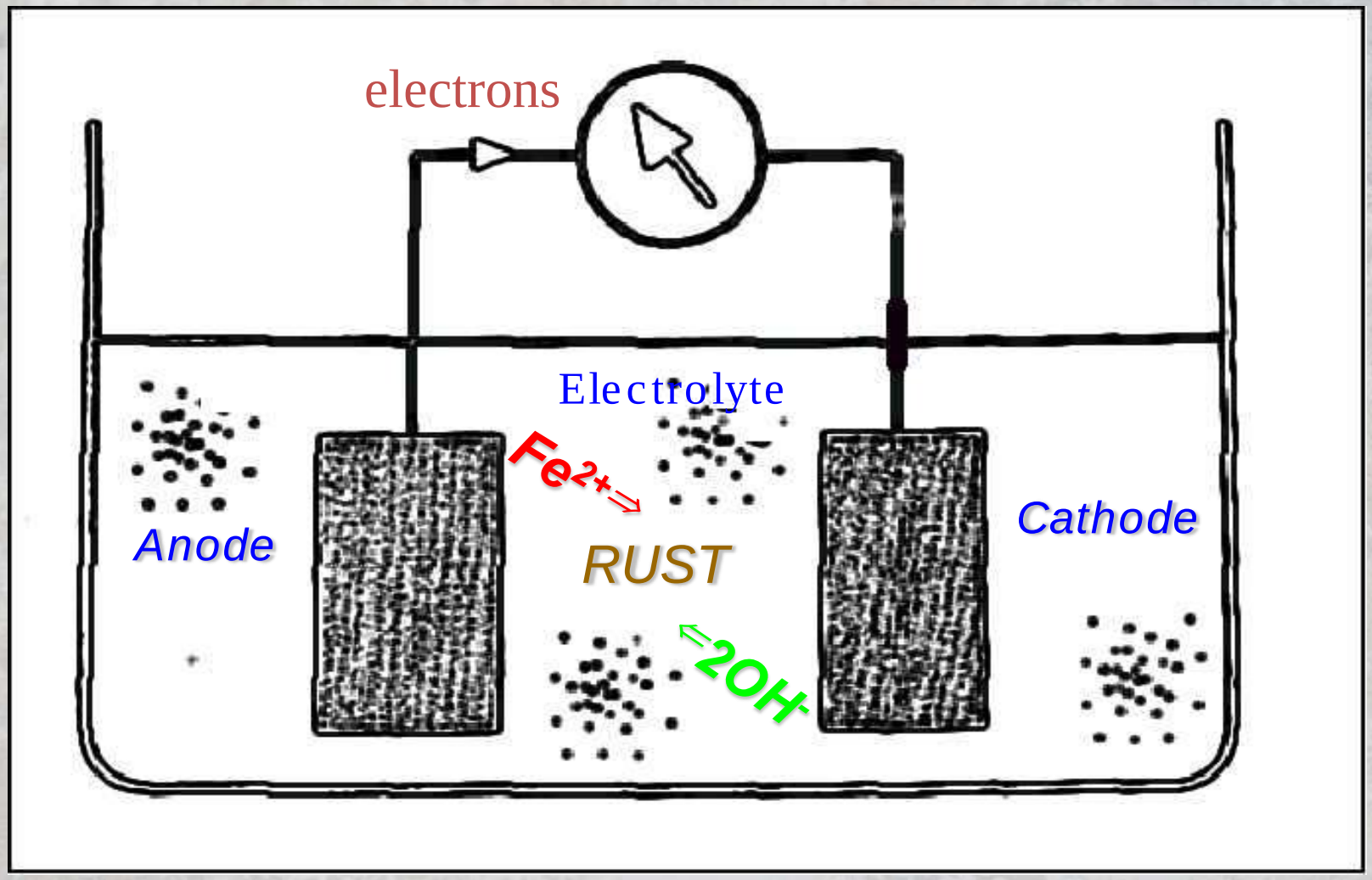
A Simple Corrosion Cell



Why does steel corrode ? (1)

- Differences in electrical potential on the surface form ANODIC and CATHODIC sites

- At anodic sites the metal oxidises:

  – $Fe\ (metal) \Leftrightarrow Fe^{2+} + 2e^{-}$

Why does steel corrode ? (2)

- Simultaneously, reduction occurs at cathodic sites, typically:

  – $\frac{1}{2}O_2 + H_2O + 2e^-$ (metal) $\Leftrightarrow 2OH^-$ (aq.) or

  – $2H^+$ (aq.) + $2e^-$ (metal) $\Leftrightarrow H_2$ (gas)

- 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

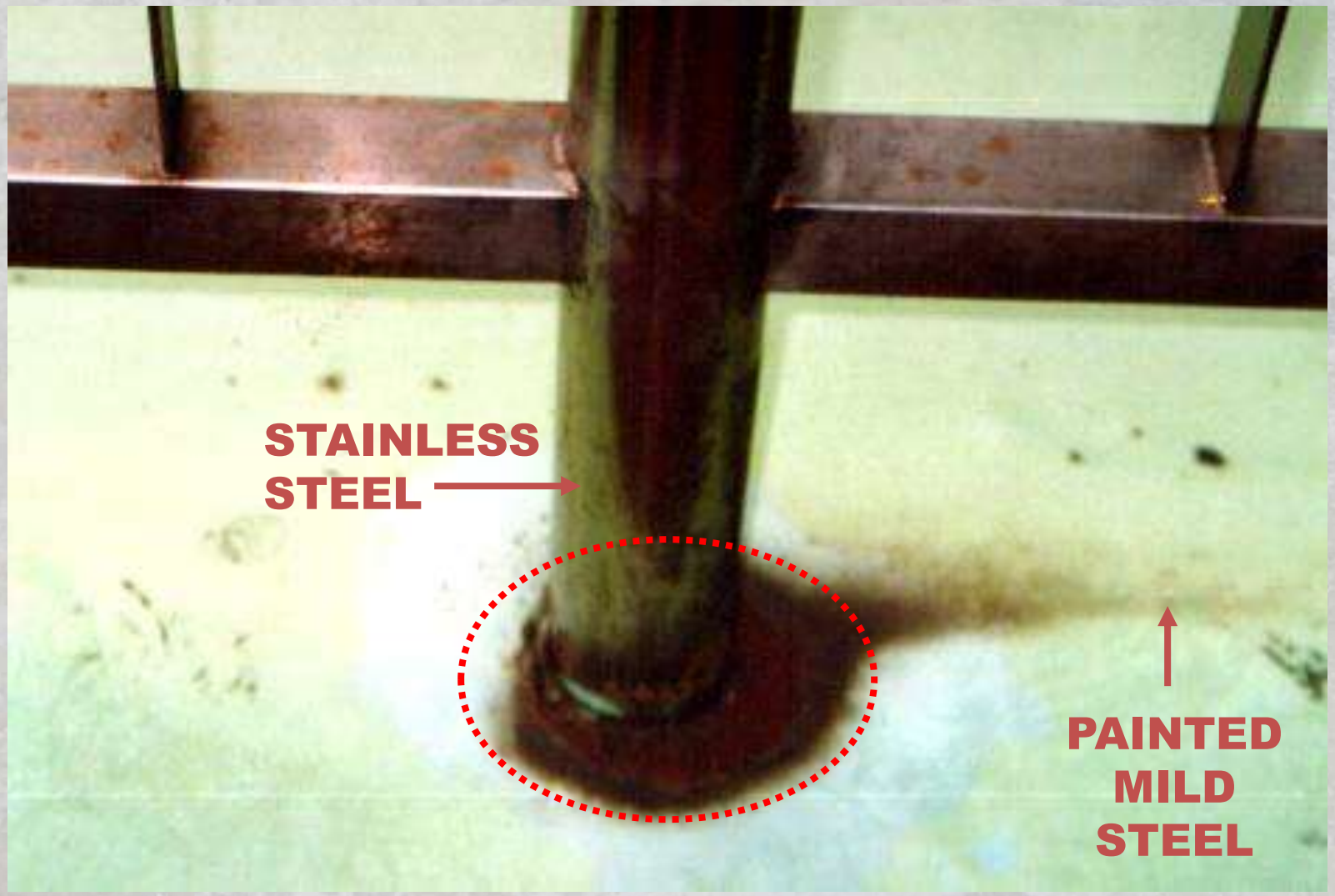
- Typically occurs in gaps between two surfaces
- Only one surface needs to be metal
- Surface deposits can also produce crevices
- Corrosion cell caused by differential oxidation
- The smaller the crevice, the more intense the corrosion
- Must be designed-out or filled-in

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

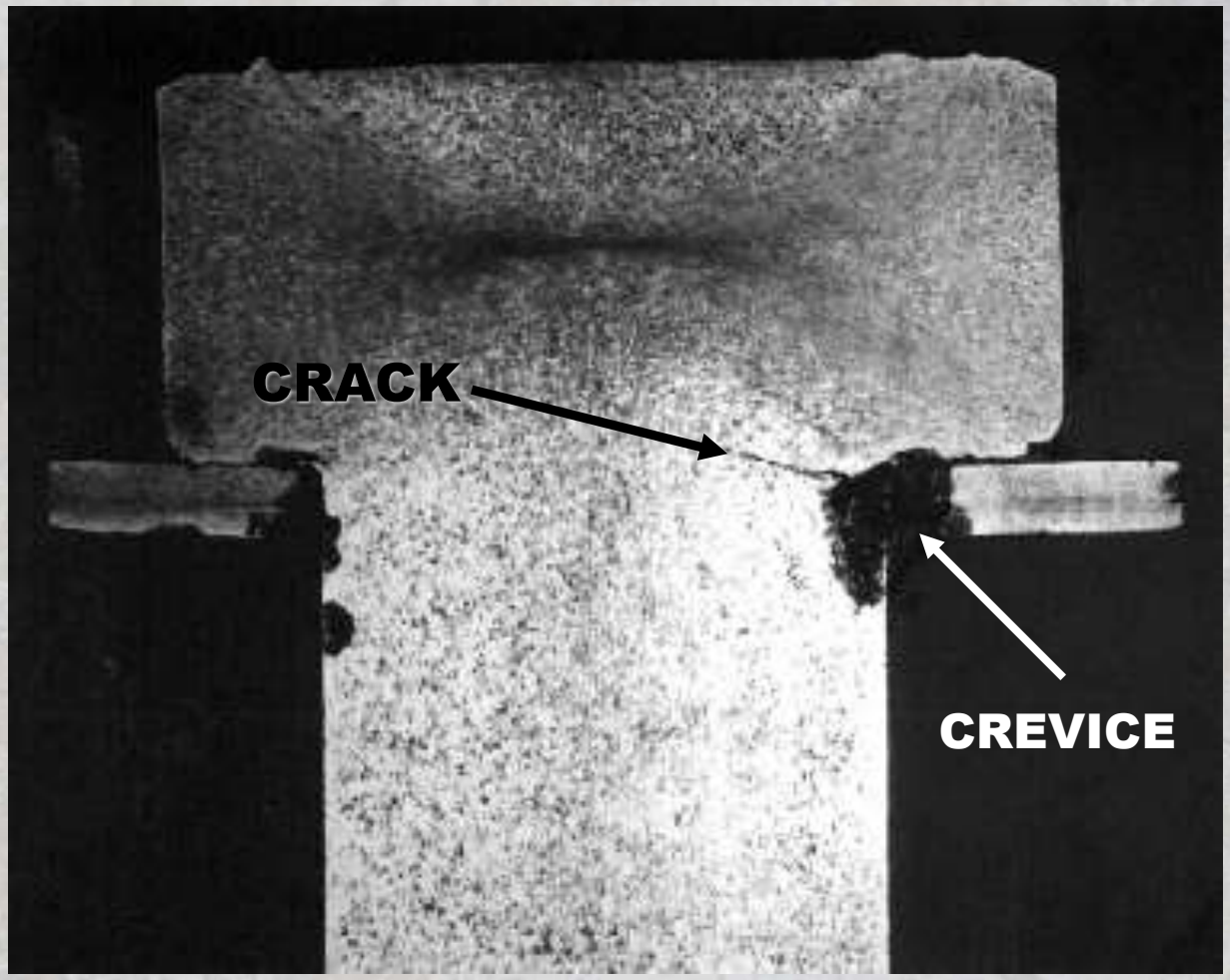
Bimetallic Corrosion



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

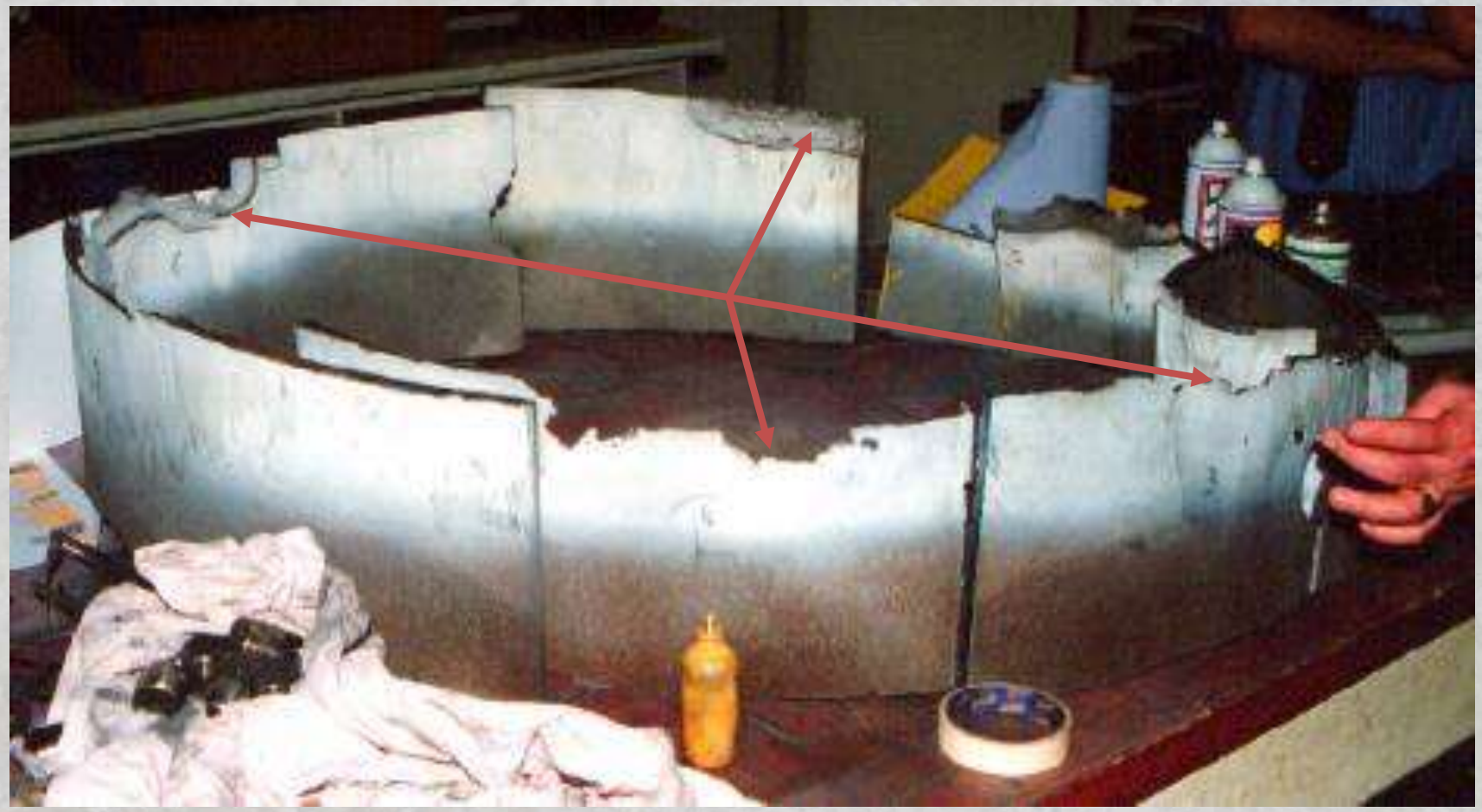


Fall down – go bang

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

Reinforcement Corrosion & Repair

Reinforcement Corrosion & Repair