

Development and Application of Corrosion Control

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The Marine Environment

- World trade has always relied upon the sea
- We have a long history of maritime activity
- Large coastlines have proved good for trade, from fishing to finished goods
- Coastlines also bring problems, due to the aggressive and unforgiving nature of the sea

The Marine Environment

- Water, oxygen and chlorides
 - The perfect recipe for the corrosion of ferrous and other metals
- Living organisms
 - Attach to the metal surface, damage coatings, make inspection difficult
 - Microbial activity can lead to severe corrosion in areas which are normally protected
- Weathering
 - Abrasion and attrition by wave action and sand
 - For concrete, salt damage and chemical attack by sulphates plus corrosion of the reinforcement

The Marine Environment



Steel

- Steels are the backbone of the built environment
- A range of relatively simple iron-carbon alloys
- They offer an excellent combination of properties
 - Relatively inexpensive
 - Easily formed and joined
 - Range of mechanical properties
 - Recyclable and easy to separate (magnetic)

Corrosion

- Whilst steel offers so many advantages, it also has one serious limitation
- If unprotected it reverts to iron oxide (rust)
- As well as losing metal, the corrosion product is greater in volume and may cause damage
- The control and prevention of corrosion is therefore a major industry
 - Originally mainly driven by cost and safety
 - Now also a major contributor to sustainability

Managing Corrosion

- There are many approaches to the management of corrosion
- Each has its own benefits and disadvantages
- In most cases more than one approach is applied to any one situation

Managing Corrosion - Options

- Put up with it
 - Accept it will occur and periodically replace affected elements
- Add a corrosion allowance
 - Increase wall thickness to accommodate anticipated corrosion rate
 - Better with general rather than localised corrosion

Not very sustainable

Managing Corrosion - Options

- Use an inherently corrosion resistant material
 - Stainless steels, nickel alloys, non-metals
 - Expensive or may not have required mechanical properties
- Only the surface needs to be resistant
- Why not use a cheaper material with the required mechanical properties and add a thin protective layer?

Managing Corrosion - Options

- Protective Coatings
 - By far the most widely used method of corrosion protection
 - Easier to inspect and maintain
 - Provides aesthetic benefits
- Performance dependent upon formulation and application
- Susceptible to damage, may not be appropriate where there is high risk of wear or abrasion

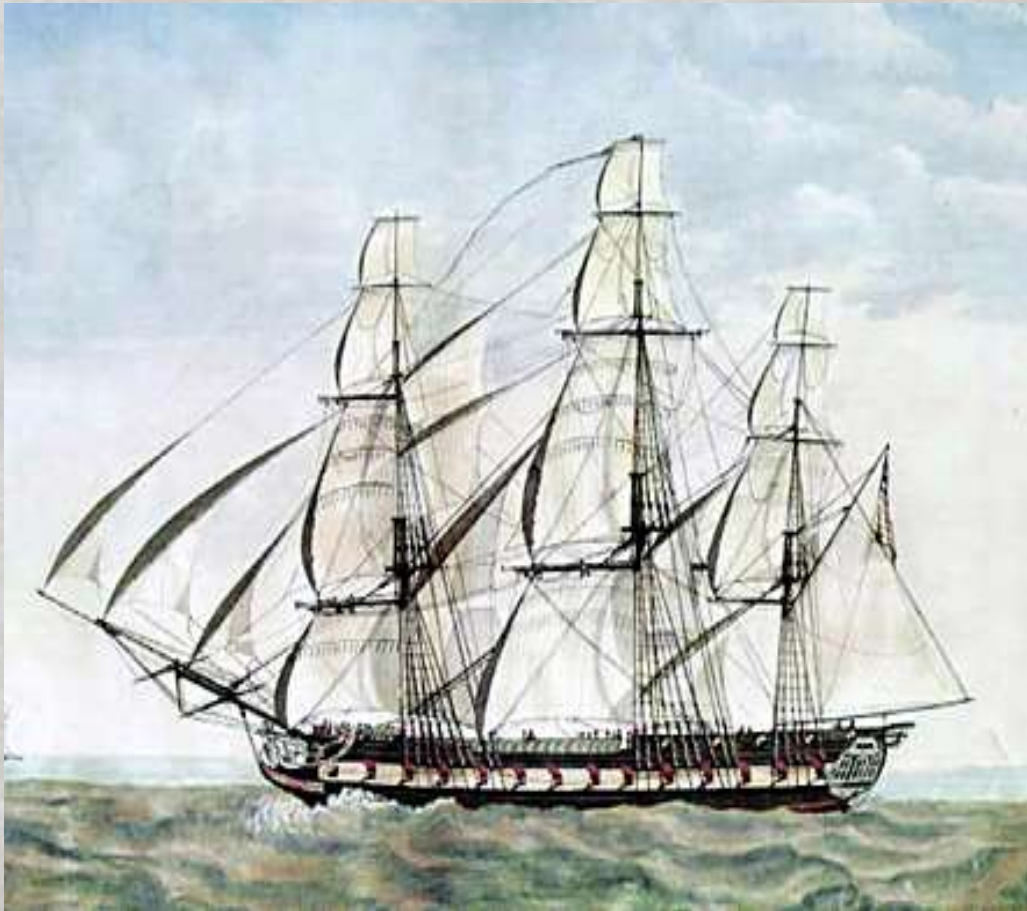
Managing Corrosion - Options

- Interfere with the corrosion process so it stops or occurs more slowly
 - Use corrosion inhibitors in enclosed systems
 - Add corrosion inhibitors to coatings to enhance their performance
 - Employ cathodic protection to limit or prevent the anodic reaction that leads to loss of metal

History of Corrosion and its Prevention

- The majority of the techniques we employ to explain and control corrosion go back a long way
 - 1675: Erosion Corrosion (Boyle)
 - 1763: Bimetallic Corrosion (British Navy)
 - 1824: Cathodic Protection (Davy)
 - 1919: Inhibitive Pigments (Cushman & Gardner)
 - 1920: Intergranular Corrosion of Brass (Moore et al)
 - 1938: Mechanism of Inhibitors (Evans)
- The use of coatings goes back into pre-history

Bimetallic Corrosion in Seawater



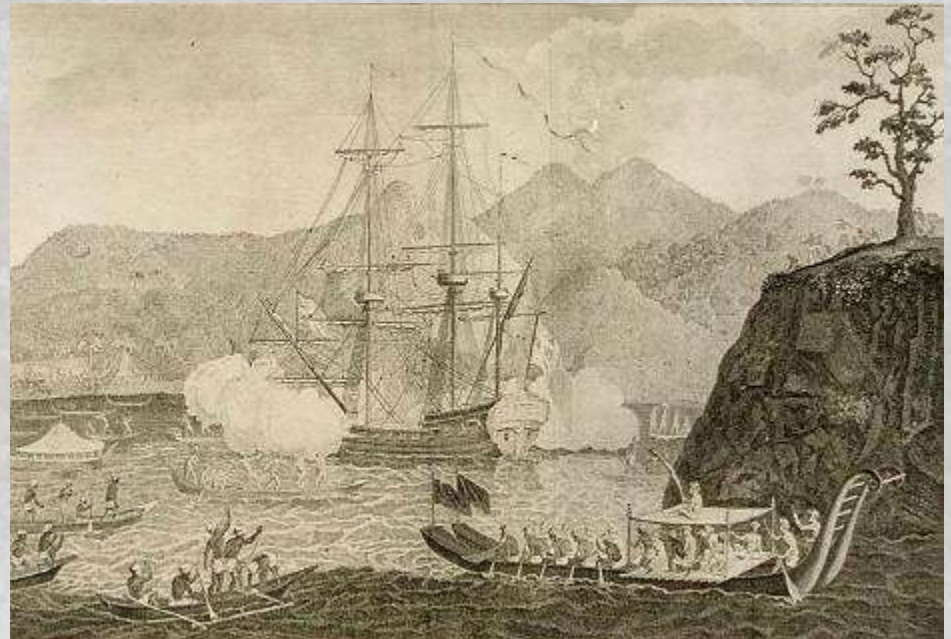
- HMS Alarm, 1763
- Trials with copper sheets nailed to hull
- Effective as antifouling but fails as iron nails corrode preferentially

Bimetallic Corrosion in Seawater

- Bimetallic (Galvanic) Corrosion
- Where the paper that covered the delivered copper sheet was trapped beneath the nail head, little or no corrosion occurred
- The Navy concluded that iron should not be used in direct contact with seawater

Military Intelligence

- Despite the report on HMS Alarm, in 1763 Commodore 'Foul Weather Jack' Byron began a circumnavigation of the globe in his copper bottomed ship, HMS Dolphin
- As well as the banging of the loose copper sheets, the rudder would periodically drop off as the iron pintles corroded through

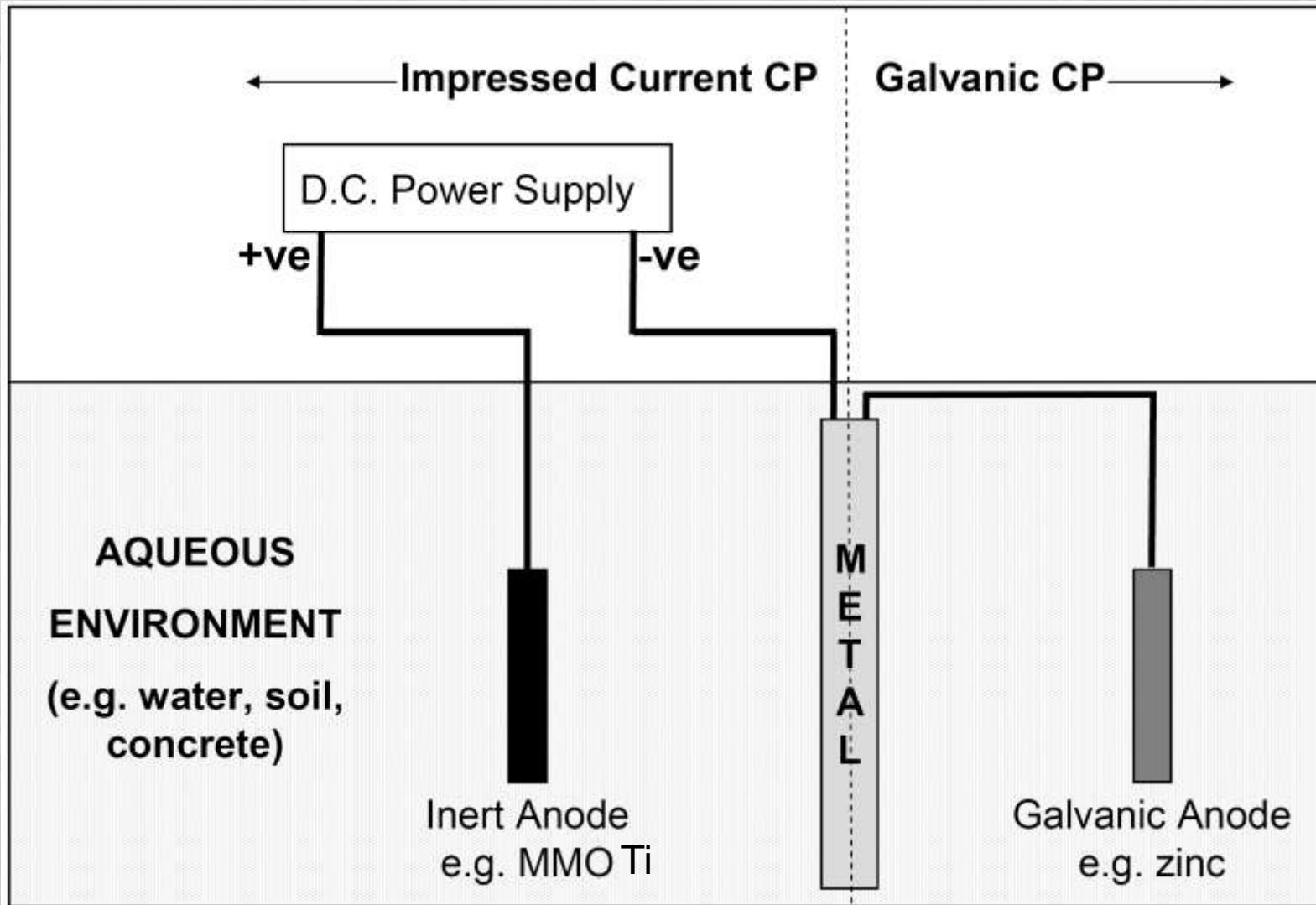


Cathodic Protection

- Sir Humphry Davy FRS
 - *"On the corrosion of copper sheeting by seawater, and on methods of preventing this effect, and on their application to ships of war and other ships". Proceedings of the Royal Society, 114 (1824), pp 151-246 and 115 (1825), pp 328-346.*
- Developed galvanic and impressed CP with Faraday



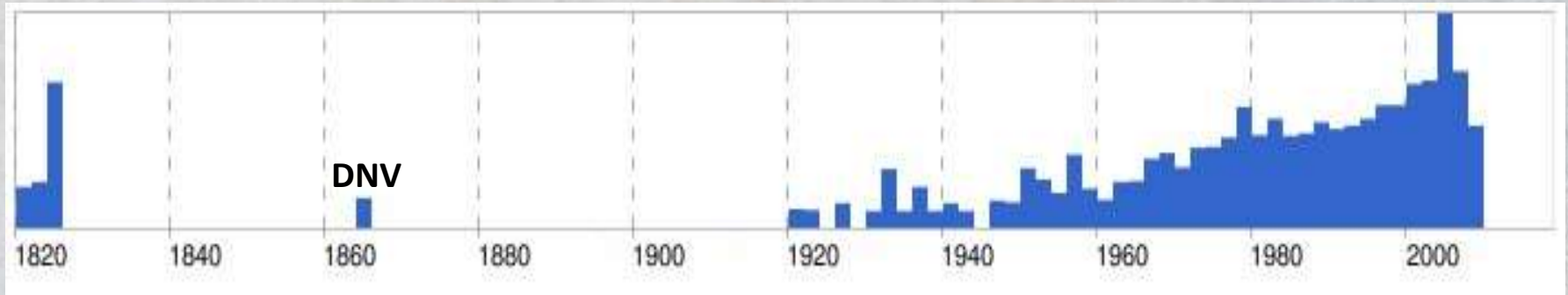
Cathodic Protection



First CP Application

- HMS Samarang
- Able to prevent corrosion of the iron nails by using zinc or iron 'protectors'
- Effective at preventing the corrosion of the iron, but also stops the copper from corroding
- The first trial was deemed 'successful' but the hull was covered in shells and weed
- The 'protectors' were removed – and did not return for 100 years

CP Timeline



- After the ‘failure’ of CP, Davy was ridiculed by the Fleet Street press
- He left England for self imposed exile in Switzerland where he died aged 50
- Coleridge, about Davy - *“chemistry tends to turn its Priests into Sacrifices”*

Growth of Oil & Gas Exploration

- The US oil and gas boom resulted in thousands of miles of iron and steel pipes
- By the 1920's corrosion problems started to be identified
- From the early 1930's corrosion control measures including coatings and CP were adopted
- In 1936 the Mid-Continent Cathodic Protection Association was formed (later became NACE)

Avoiding Corrosion – Non-Metallics

- There is increasing interest in using non-metallics, notably FRPs and engineering ceramics, to avoid corrosion problems
- Fibre reinforced polymers using glass, carbon or aramid fibres in a polymer matrix are widely used for pipework and for strengthening
- Many components in pumps and valves can be replaced with high performance ceramic alternatives

Avoiding Corrosion – Non-Metallics

- Sustainable provided they give longer service lives, but not generally recyclable
- Cost is a major limitation, although may also lose toughness and ductility (for safety)
- Will always have niche applications but unlikely to reduce dependency on steel



In Conclusion

- Without the sea, there would be no international trade and commerce
- Without steel, we would not be able to utilise the benefits of the sea
- Without effective corrosion control, we would not be able to use steel
- Without corrosion scientist and engineers, we would not have the tools to understand and control corrosion