

MARINE STRUCTURES CORROSION AND METHODS OF PREVENTION

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INTRODUCTION

- **Corrosion & Accelerated Low Water Corrosion (ALWC)**
- **Introduction to Cathodic Protection (CP)**
- **Galvanic Anodes versus Impressed Current**
- **CP of Steel in Concrete**
- **Project Examples and Case Study**
- **Conclusions**

CORROSION

- **All metals, except Gold, will corrode with time, to try and form a stable oxide compound**
- **Corrosion rate depends on the metal and its environment.**
- **Guidance on corrosion rates given in BS6349-1:2000 Maritime Structures – Part 1: Code of practice for general criteria.**

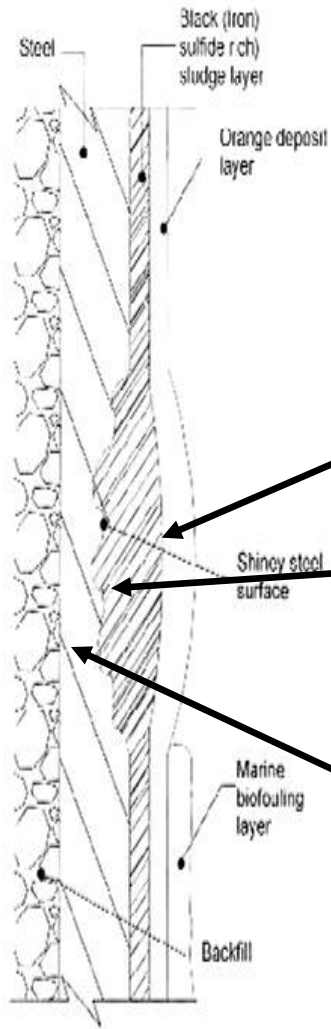
ACCELERATED LOW WATER CORROSION



ALWC: Background

- Many established forms of localised corrosion, including microbial corrosion
- Since early 1980s increasing reports in UK of corrosion just above LAT
- Quoted range of corrosion rates of 0.3-4.0 mm/side/year
- Is it new?
- Influencing Factors?
- 2005 CIRIA report

Identification



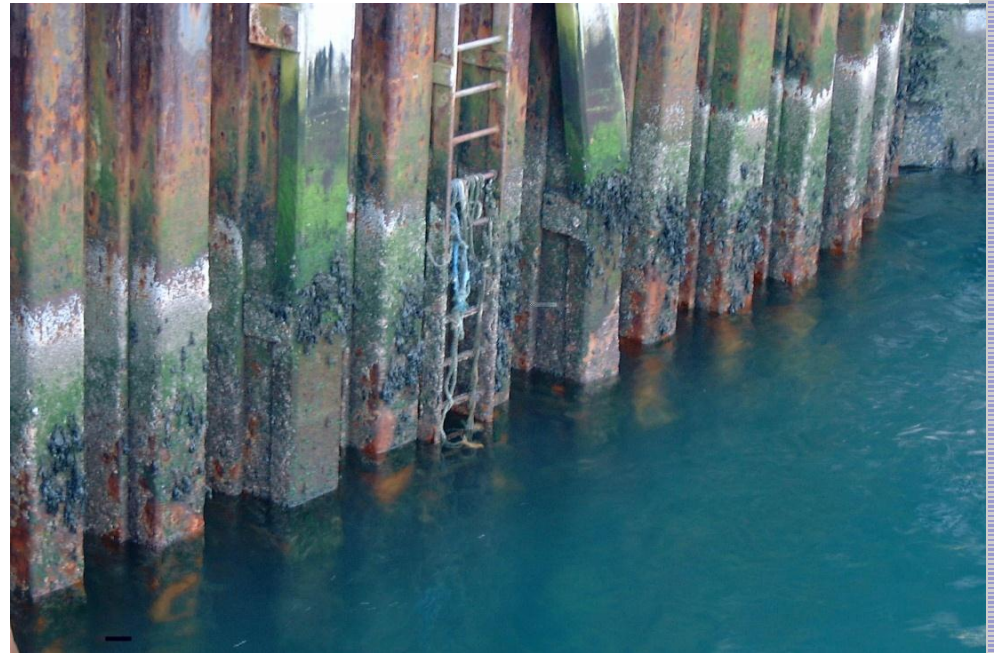
Section through ALWC patch on steel substrate



Location

•Sheet Piles

- In-pans & out-pans
- Increasingly identified in the band LAT-Mid tide
- U Piles: More prevalent on out-pans?
- Geographic Location



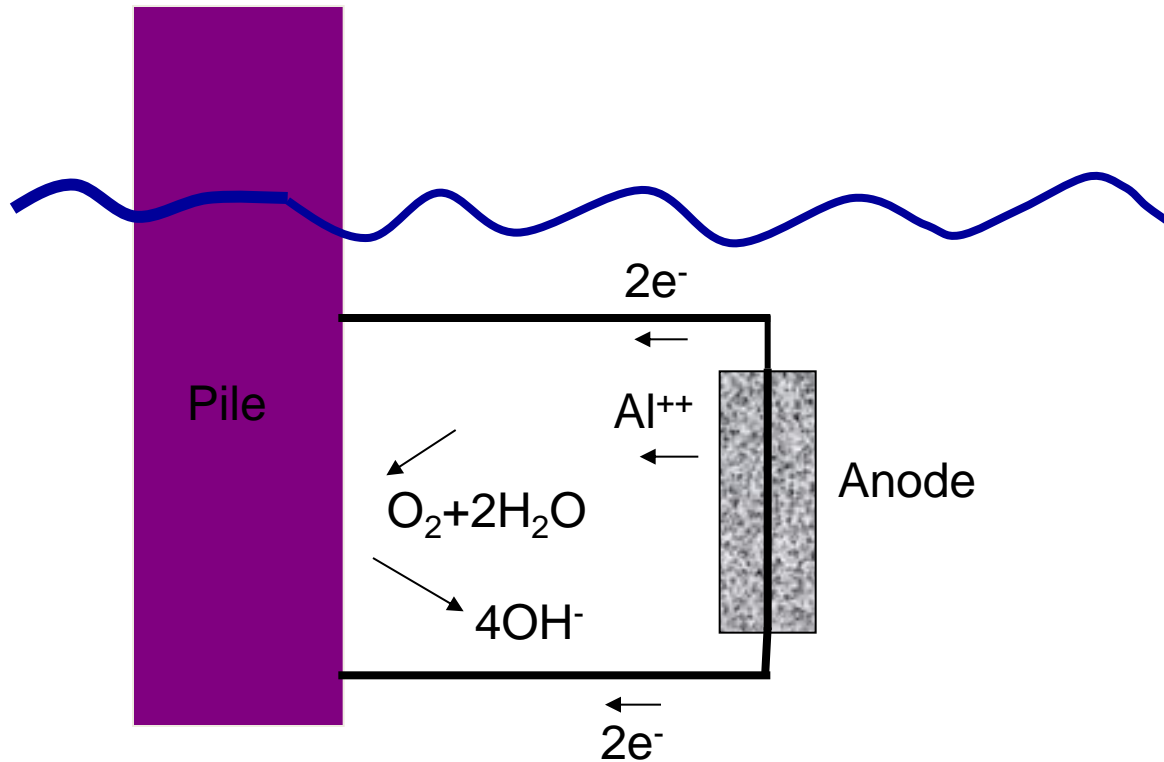
INTRODUCTION

- **Humphrey Davy used galvanic anodes in 1824**
- **Thomas Edison used impressed current in 1890**
- **Established standards**
 - **BS 7361: Part 1 : 1991**
 - **BS EN ISO 13174: 2012 (previously 2001)**
 - **DNV RP 401 : 2010**
- **CP well established & proven for steel in sea water**
- **Mandated for Offshore Installations and Pipelines**
- **CP of Reinforced Concrete Marine Structures**

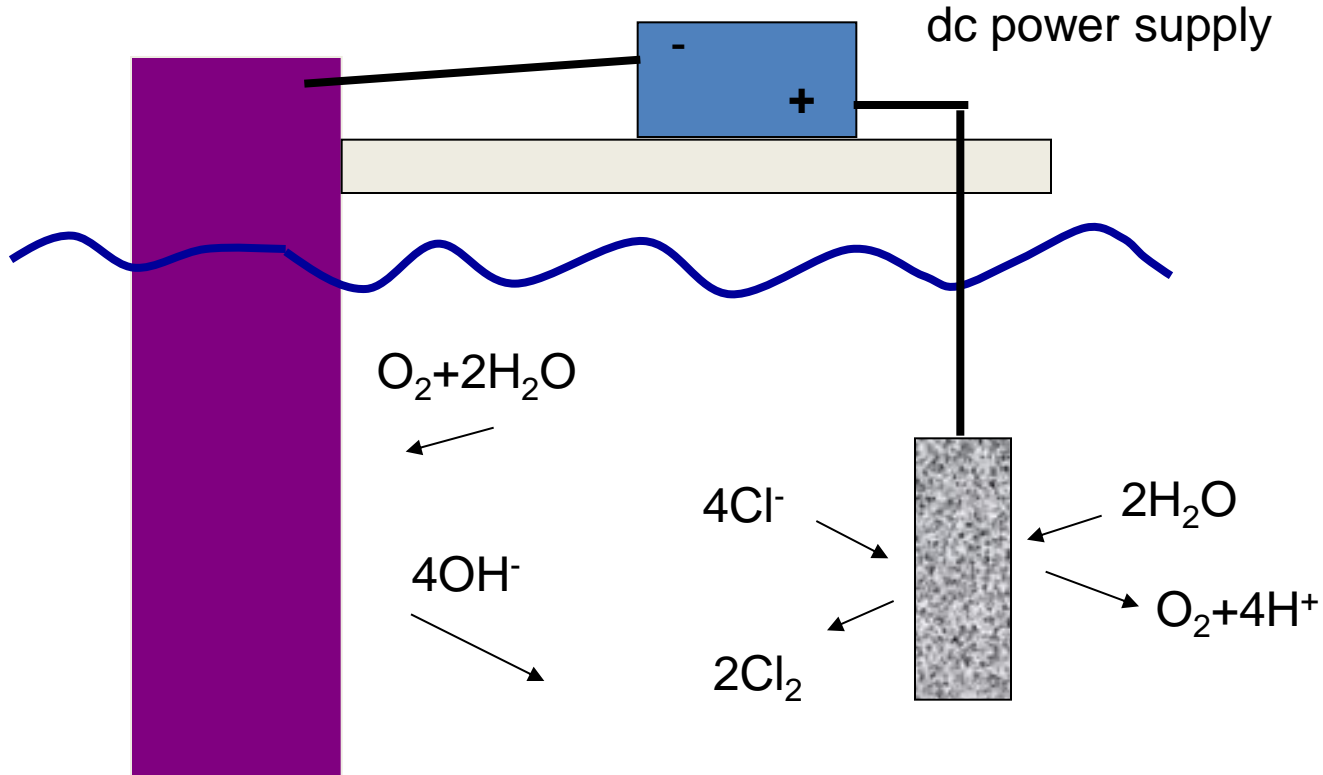
Common

Corrosion Prevention Association

INTRODUCTION: GALVANIC



INTRODUCTION : IMPRESSED



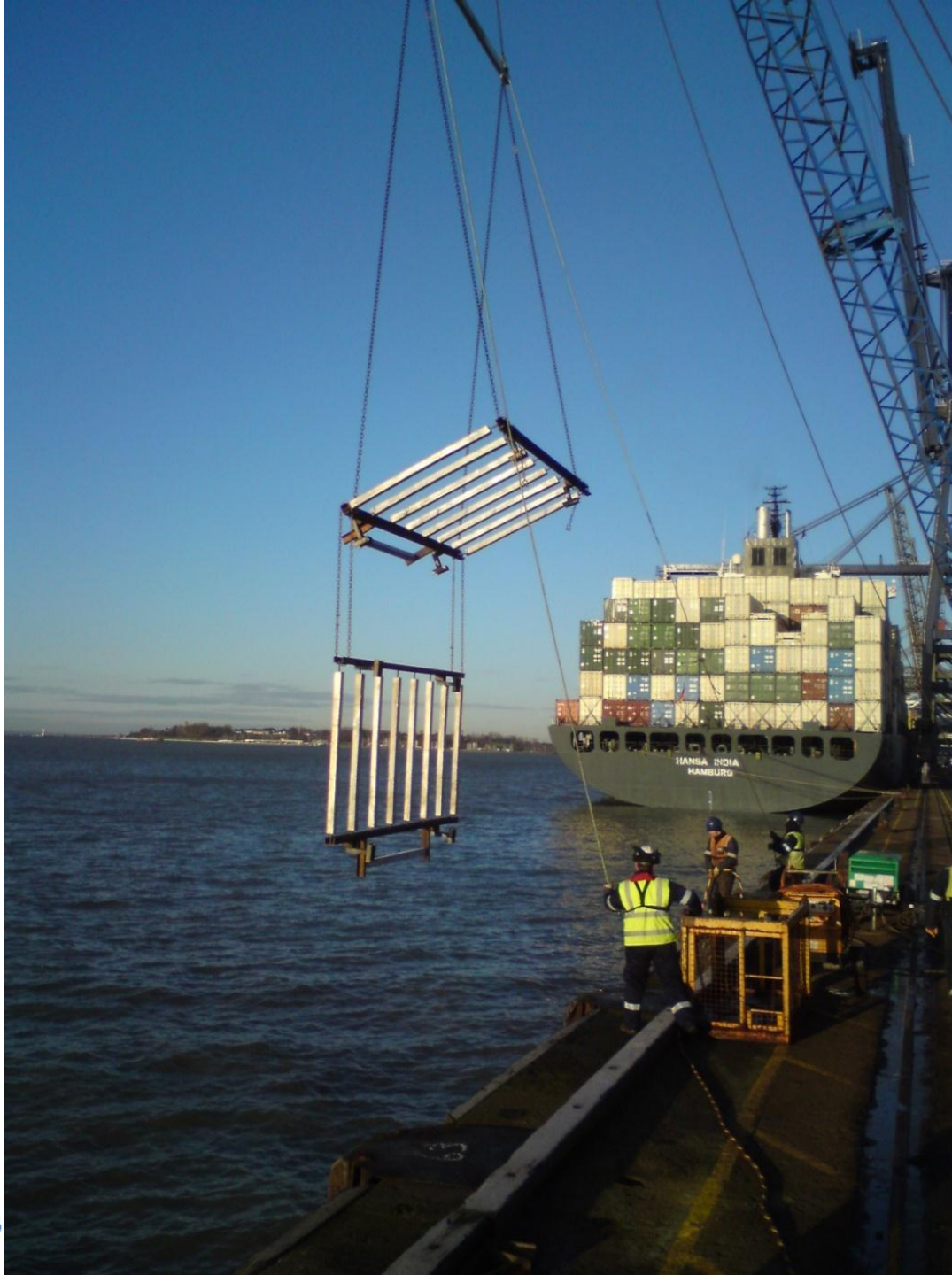
GALVANIC OR IMPRESSED CURRENT? – THE CASE FOR GALVANIC ANODES

- **No power supplies**
- **No electricity bill**
- **No cabling**
- **Less to go wrong**
- **Less frequent inspection & monitoring**



Galvanic Anodes For Installation to Sheet Piles: Al/Zn/In Alloy Most Common





GALVANIC OR IMPRESSED CURRENT? – THE CASE FOR IMPRESSED CURRENT

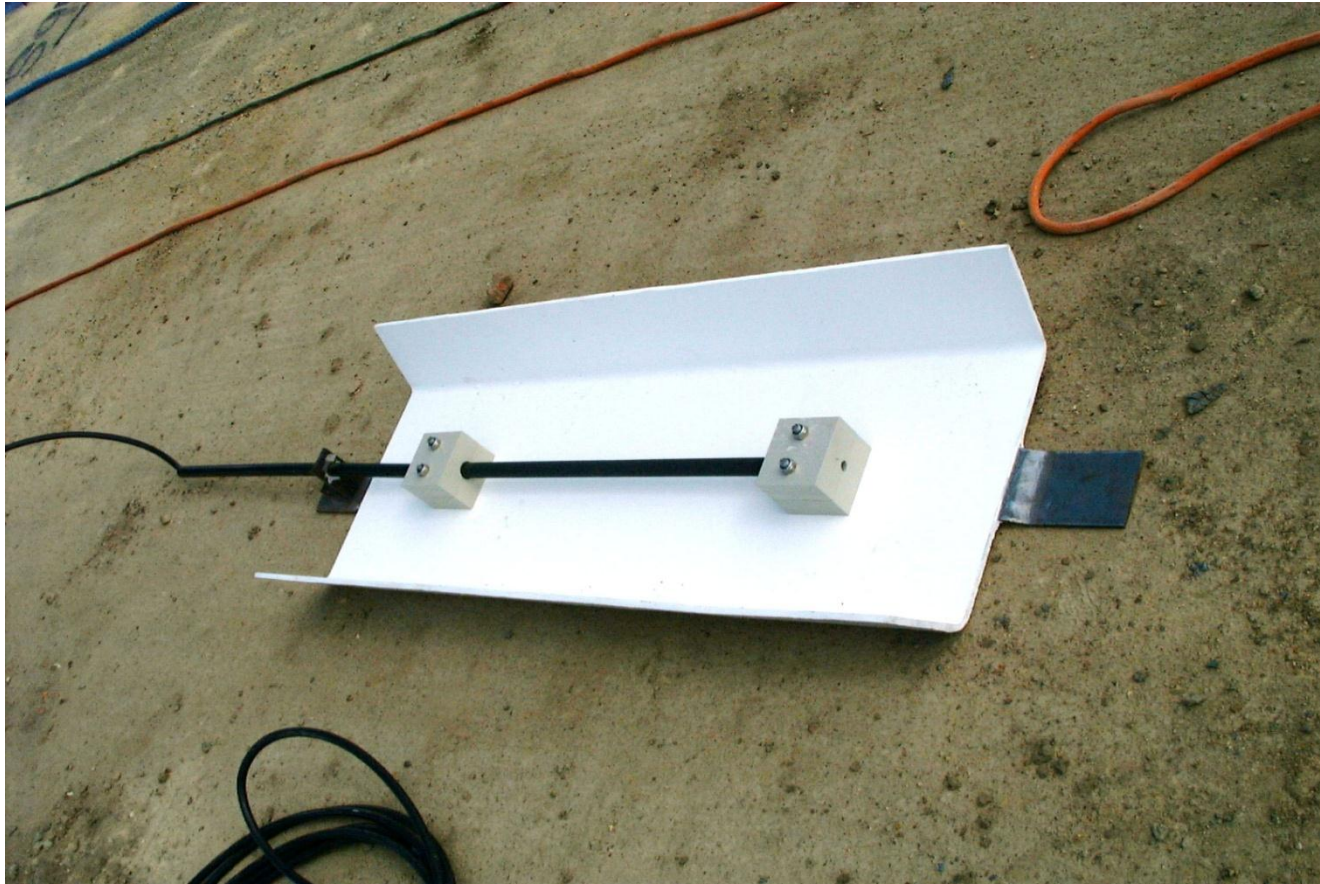
- **Longer anode life**
- **For new build 50% less capital cost**
- **Accurate “Instant Off” potentials**
- **Less anodes to install**
- **OK if high seawater resistivity**
- **OK if high bed level (close to mid tide)**

GALVANIC OR IMPRESSED CURRENT? – THE CASE FOR IMPRESSED CURRENT





Anodes Durable but Lightweight



MMO Coated Ti Anode on GRP shield with steel insert



MMO Coated Ti Anode for Tubular Piles



Cabling must run from anodes to T-R



Typical Transformer-Rectifier

DOES IT WORK?

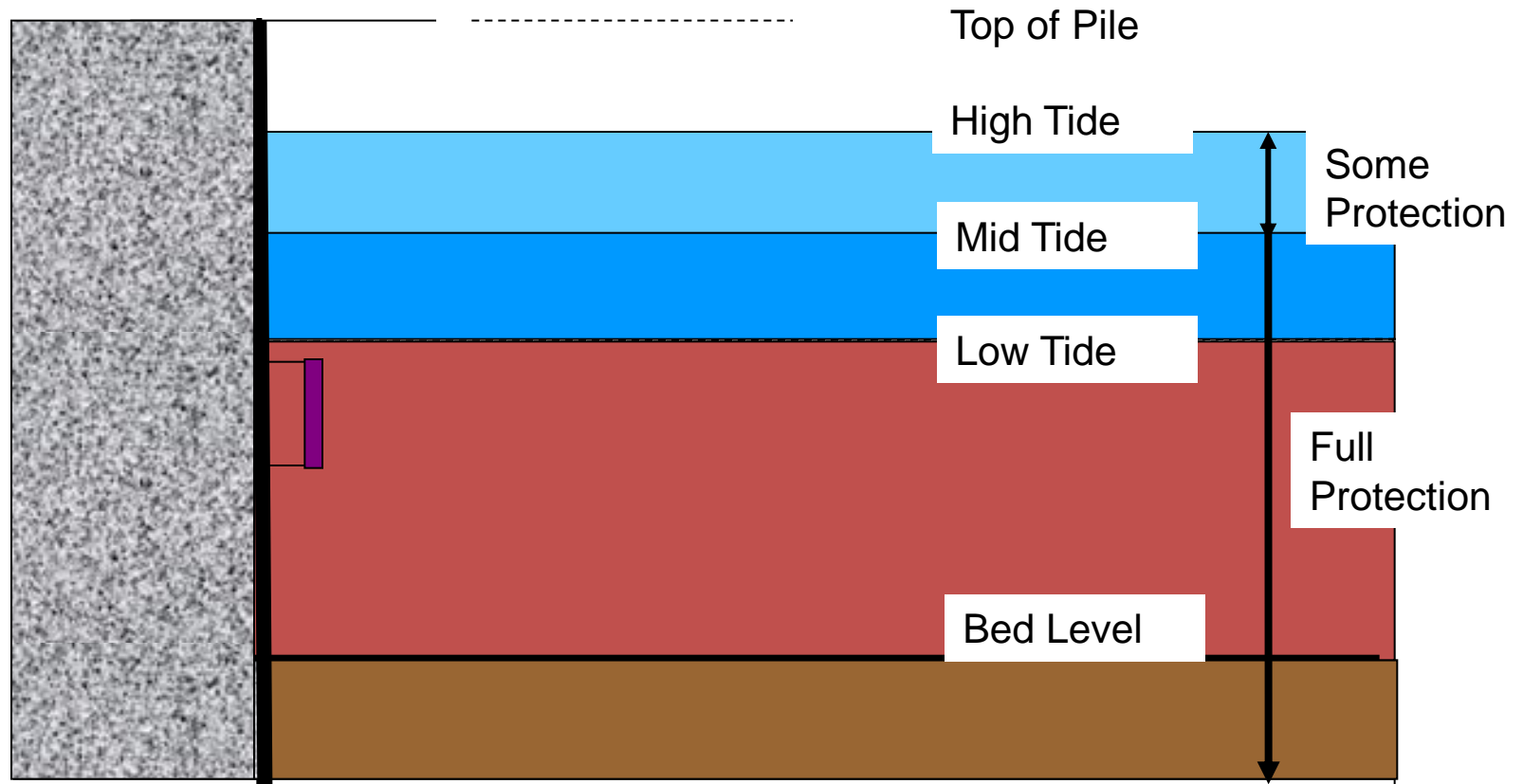


DOES IT WORK?



Visual condition of pile after 3 months

LIMITATIONS











GALVANIC OR IMPRESSED CURRENT? – SUMMARY

- **Most UK ports retro-fitting CP use galvanic anodes**
- **Impressed current used for new ports or extensive upgrading**
- **Impressed current used in estuarine ports with high water resistivity or shallow water depths**

CP OF STEEL IN CONCRETE

- **Exposure to seawater, spray will result in chloride ingress, frequently structures are exposed to chloride levels way beyond safe limits.**
- **Mid-tide to top of splash zone is the best environment for corrosion (Cl^- & O_2 present).**
- **Cathodic Protection systems to stop corrosion of steel in concrete: to prevent this:-**





Example of 'Incipient Anode' Effect

CP OF STEEL IN CONCRETE

Impressed Current Systems

Anode types can be:

- Conductive coatings (not suitable for marine conditions)
- Conductive Cementitious Coatings
- Ti Mesh / Sprayed Concrete Overlay
- Discrete Anodes
- Ribbon Anodes









CP FOR NEW STRUCTURES



CASE STUDY : PROTECTION OF REINFORCED CONCRETE & STEEL

Existing 1960s jetty

- Combination of existing reinforced concrete pile and pre-stressed concrete piles
- Existing steel piles
- New steel piles
- 30-year life extension required









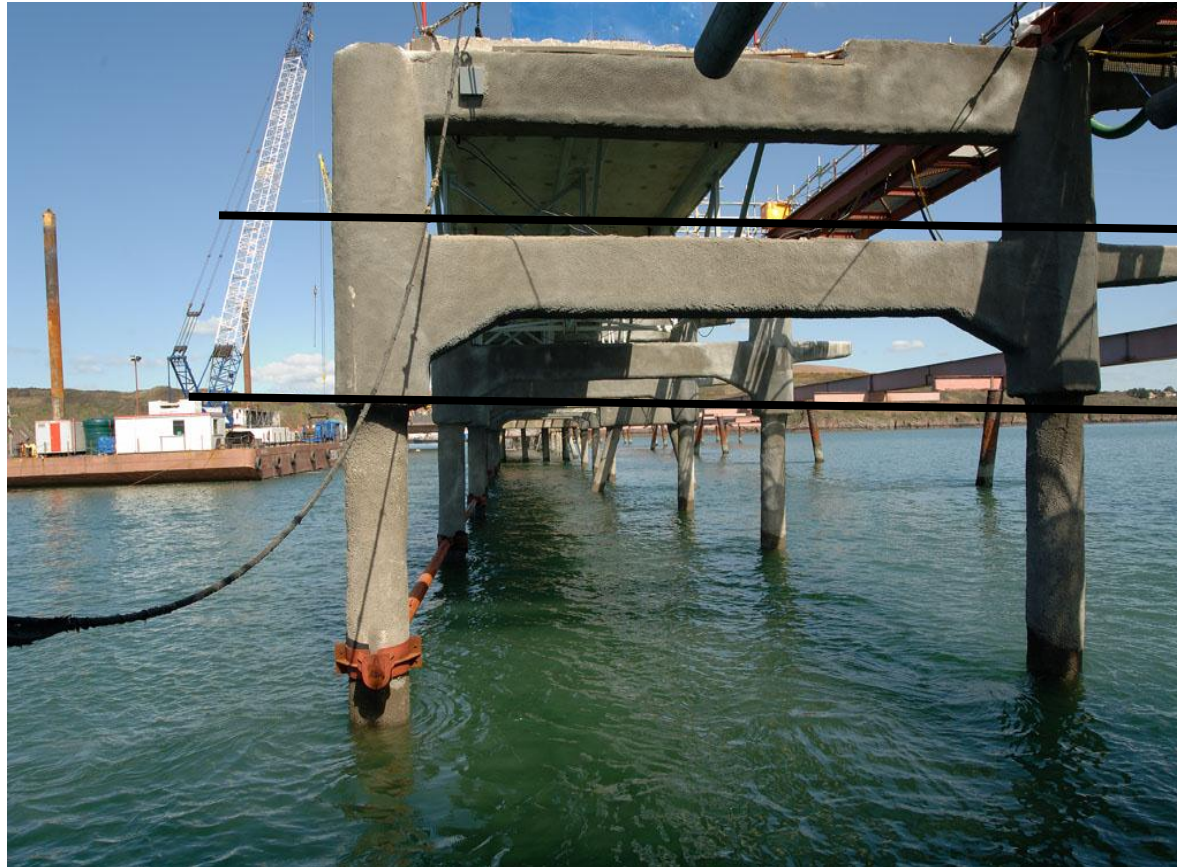








JETTY CASE STUDY



ZONE 1

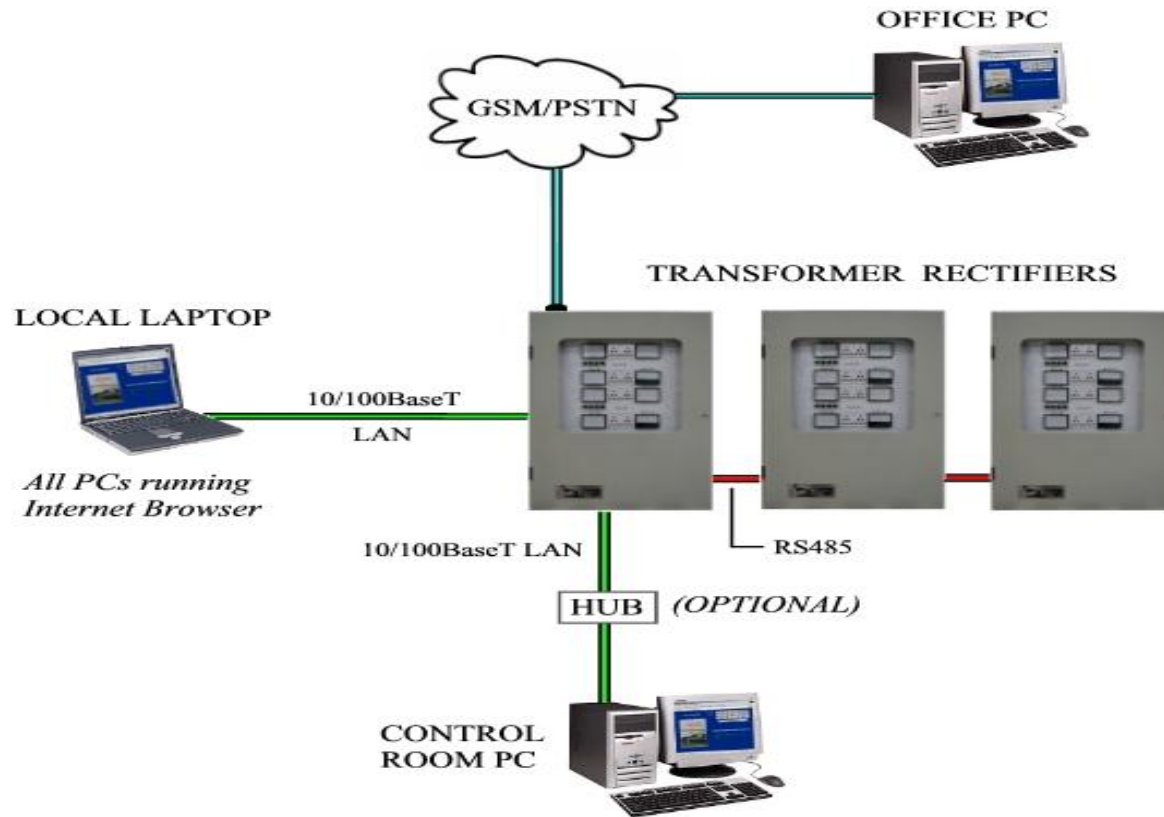
ZONE 2

ZONE 3



JETTY CASE STUDY

Power supply & Monitoring equipment







JETTY CASE STUDY

South Hook LNG Terminal CP SYSTEM

GROUP1 TR1/2/3 <input type="button" value="Enter"/>	GROUP2 TR4/5 <input type="button" value="Enter"/>	GROUP3 TR6/7 <input type="button" value="Enter"/>
GROUP4 TR8/9 <input type="button" value="Enter"/>	GROUP5 TR10/16/17/18 <input type="button" value="Enter"/>	GROUP6 TR11-15 <input type="button" value="Enter"/>

Performance Verification WINDOW

Main	Fn Ck	Settings
Monitor	P.V. Ck	Alarms
	Norm Ck	Alarms Hst

On Demand

No. Data Lines

3

Download Data

PVck Time Pts

1st	1	hrs
2nd	2	hrs
3rd	4	hrs
4th	8	hrs
5th	12	hrs
6th	24	hrs
7th	32	hrs
8th	47	hrs
9th	48	hrs

Scheduled

	Jan	Feb	Mar	Apr
	May	Jun	Jul	Aug
	Sep	Oct	Nov	Dec

(Red=Selected)

Day (1-31)

Hour (0-23)

PVck Time Elapsed hrs mins



CONCLUSIONS

- **CP is a useful tool in providing corrosion prevention in marine environments**
- **There is an extensive track record of using CP to prevent corrosion by ALWC, primarily using galvanic anodes**
- **Impressed current is used for new build steel piling or for ports in brackish waters**
- **CP is widely used to prevent reinforcement corrosion, often using impressed current systems, but galvanic system are increasingly being used**

