AN INDUSTRY PERSPECTIVE ON CATHODIC PROTECTION DESIGN

Alex Delwiche

Deepwater EU Ltd
A subsidiary of Deepwater Corrosion Services Inc. Houston TX

Contents

- Introduction to CP Design
- System Examples
  - Offshore
  - Onshore
  - Other applications

Introduction

- Cathodic Protection can be applied to any steel structures at risk of corrosion.
- Cathodic Protection should be designed into the structure from the beginning.
- If a life extension of an existing structure is required then the CP designer has some extra work to do!

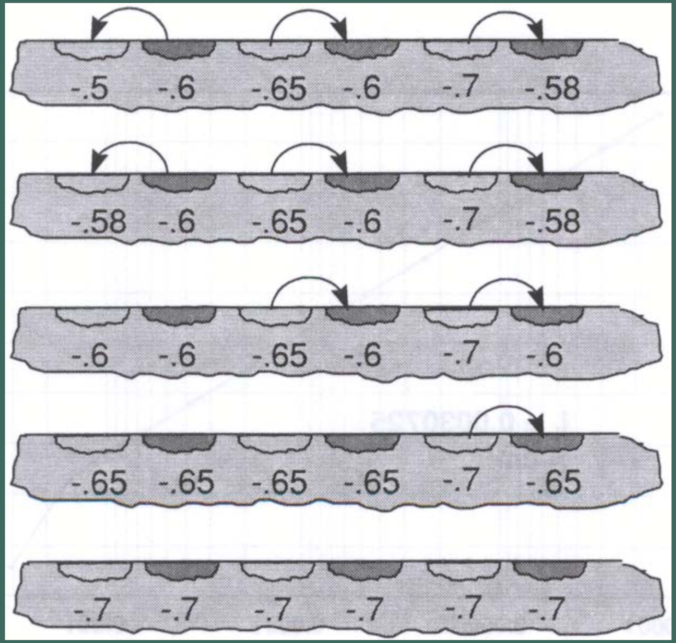
Design Objectives

CP AIMS TO AVOID SITUATIONS LIKE THIS

Design Objectives

One definition of cathodic protection is:

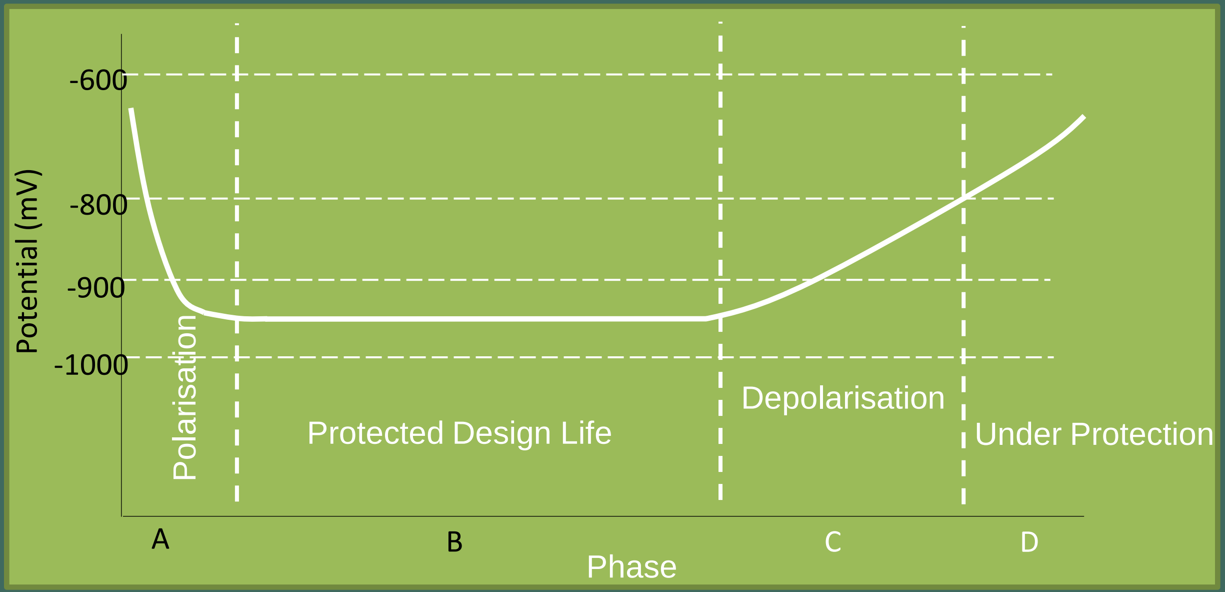
- Turn the whole of the steel structure into the cathode of a larger anode/ cathode electrochemical system.



Design Objectives

The aim of the CP design is to polarise the structure (period A) as quickly as possible and maintain the protection (period B) for the design life.

When depolarisation (period C) starts the CP system has reached its design life and leads to under protection (period D).



Design Considerations – Potential Criteria

This standard gives the basic electrochemical potential criteria for carbon steel.

Material	Minimum negative potential V	Maximum negative potential [a] V
Carbon steel		
Aerobic environment	– 0,80	– 1,10 [b]
Anaerobic environment	– 0,90	– 1,10 [b]
Austenitic stainless steel		
$N_{PRE} \geqslant 40$ [c]	– 0,30 [d]	– 1,10
$N_{PRE} < 40$ [c]	– 0,50 [d]	– 1,10
Duplex stainless steel	– 0,50 [d]	[e]
Martensitic stainless (13 % Cr) steel	– 0,50 [d]	[e]

The potentials given in Table 1 apply to saline mud and normal seawater compositions (salinity 3,2 % to 3,8 %).

The potentials are referenced to an SCE reference electrode, which are equivalent to a silver/silver chloride reference electrode (Ag/AgCl/seawater) in 30 Ω·cm seawater.

[a] These negative limits also ensure negligible impact of CP on pipeline coatings.

[b] Where pipeline systems are fabricated from high strength steel ($\sigma_{SMY} > 550$ MPa), the most negative potential that can be tolerated without causing hydrogen embrittlement shall be ascertained.

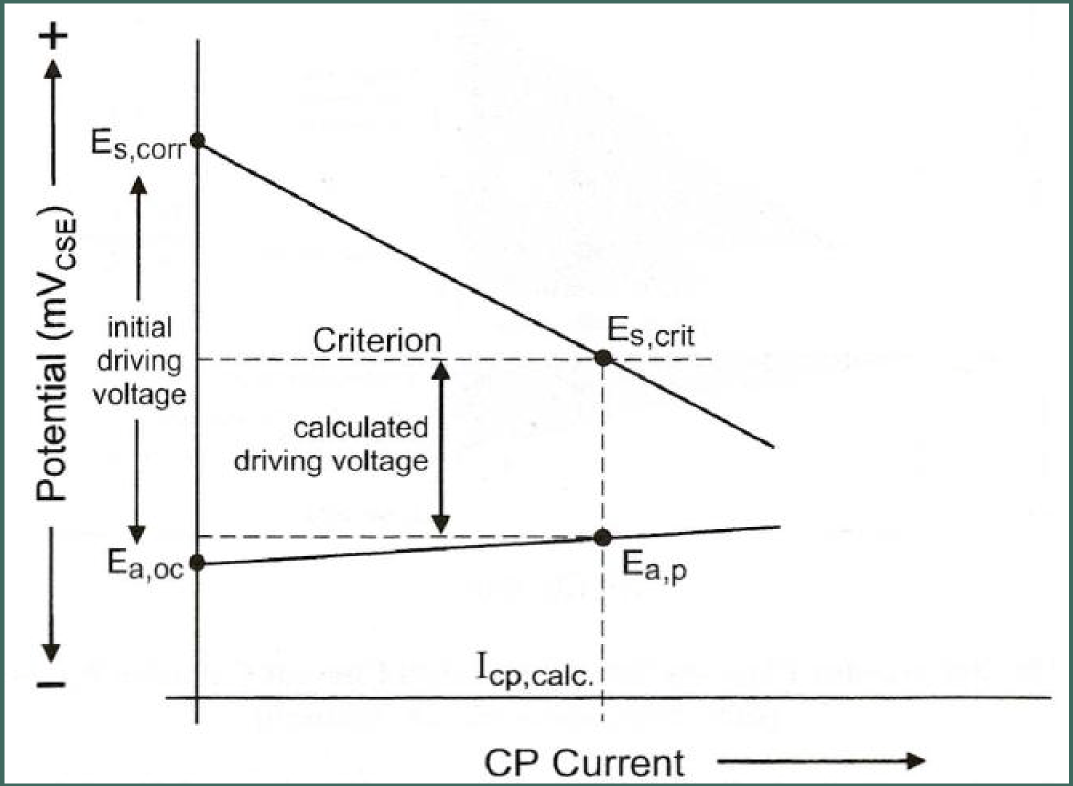
[c] N_{PRE} = %Cr + 3,3 %(Mo+0,5W) + 16 %N.

[d] For stainless steels, the minimum negative potentials apply for aerobic and anaerobic conditions.

[e] Depending on strength, specific metallurgical condition and stress level encountered in service, these alloys can be susceptible to hydrogen embrittlement and cracking. If a risk of hydrogen embrittlement exists, then potentials more negative than –0,8 V should be avoided.

Design Considerations – Current Demand

Basically, for a CP design, the cathode current required to achieve the necessary potential shift must be calculated.



Design Considerations – Current Demand

AGAIN, THE CODES AND STANDARDS PROVIDE GUIDANCE BASED ON EXPERIMENTAL AND OPERATIONAL DATA.

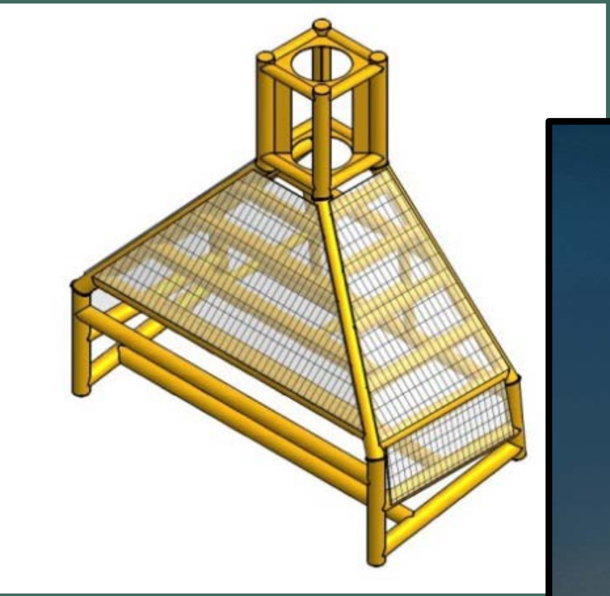
Depth (m)	Design Current Densities (initial/final) in A/m²			
	Tropical (>20°C)	Sub-Tropical (12-20°C)	Temperate (7-12°C)	Arctic (<7°C)
0 - 30	0.150 / 0.090	0.170 / 0.110	0.200 / 0.130	0.250 / 0.170
> 30	0.130 / 0.080	0.150 / 0.090	0.180 / 0.110	0.220 / 0.130

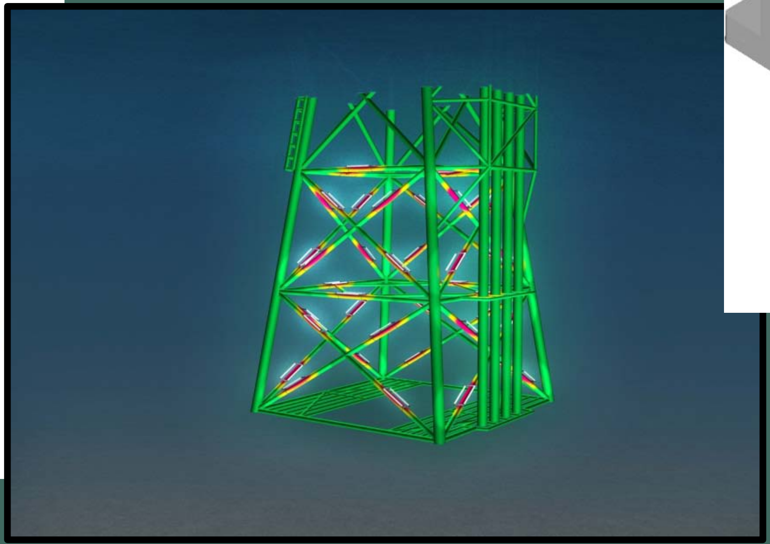
NOTE THAT THE VALUES, FOR STEEL, ARE QUOTED AS CURRENT DENSITIES. WE NEED TO APPLY THESE TO THE BARE SURFACE AREA.

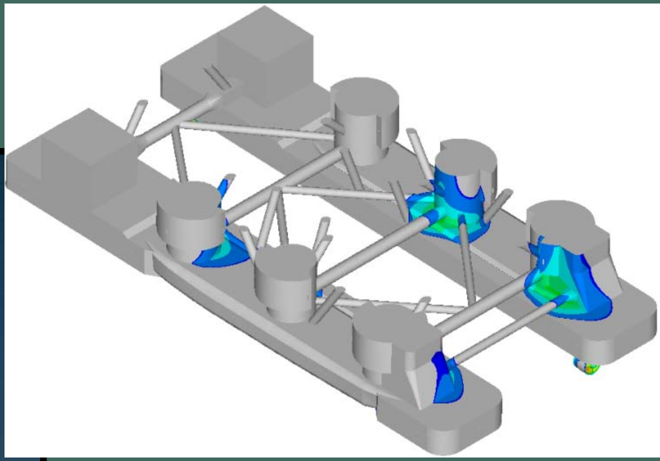
Design Considerations – Surface Area

THE BARE SURFACE AREA OF THE STRUCTURE, *AND ALL ASSOCIATED COMPONENTS*, EXPOSED TO THE ENVIRONMENT NEED TO BE CALCULATED.

THIS IS RELATIVELY EASY FOR SIMPLE GEOMETRIES BUT MODELLING TOOLS CAN BE USEFUL.







Design Considerations – Coatings

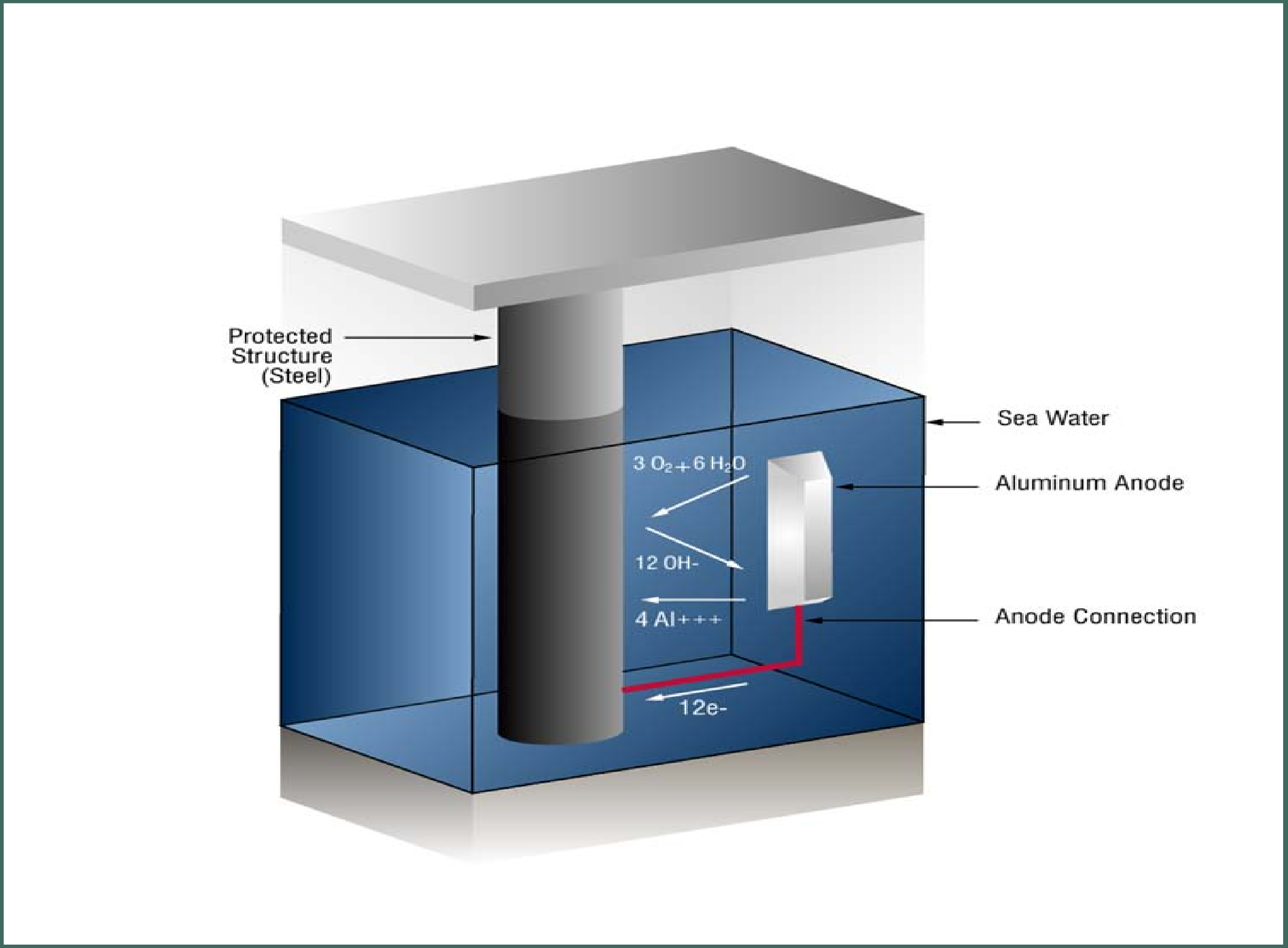
Structure	Coated	
	Yes	No
Pipeline	✓	
Wellhead	✓	
FPSO	✓	
Ship ballast tank		✓
Caisson internal		✓
Semisub	✓	✓
Jacket	✓	✓

Design Considerations – System Type

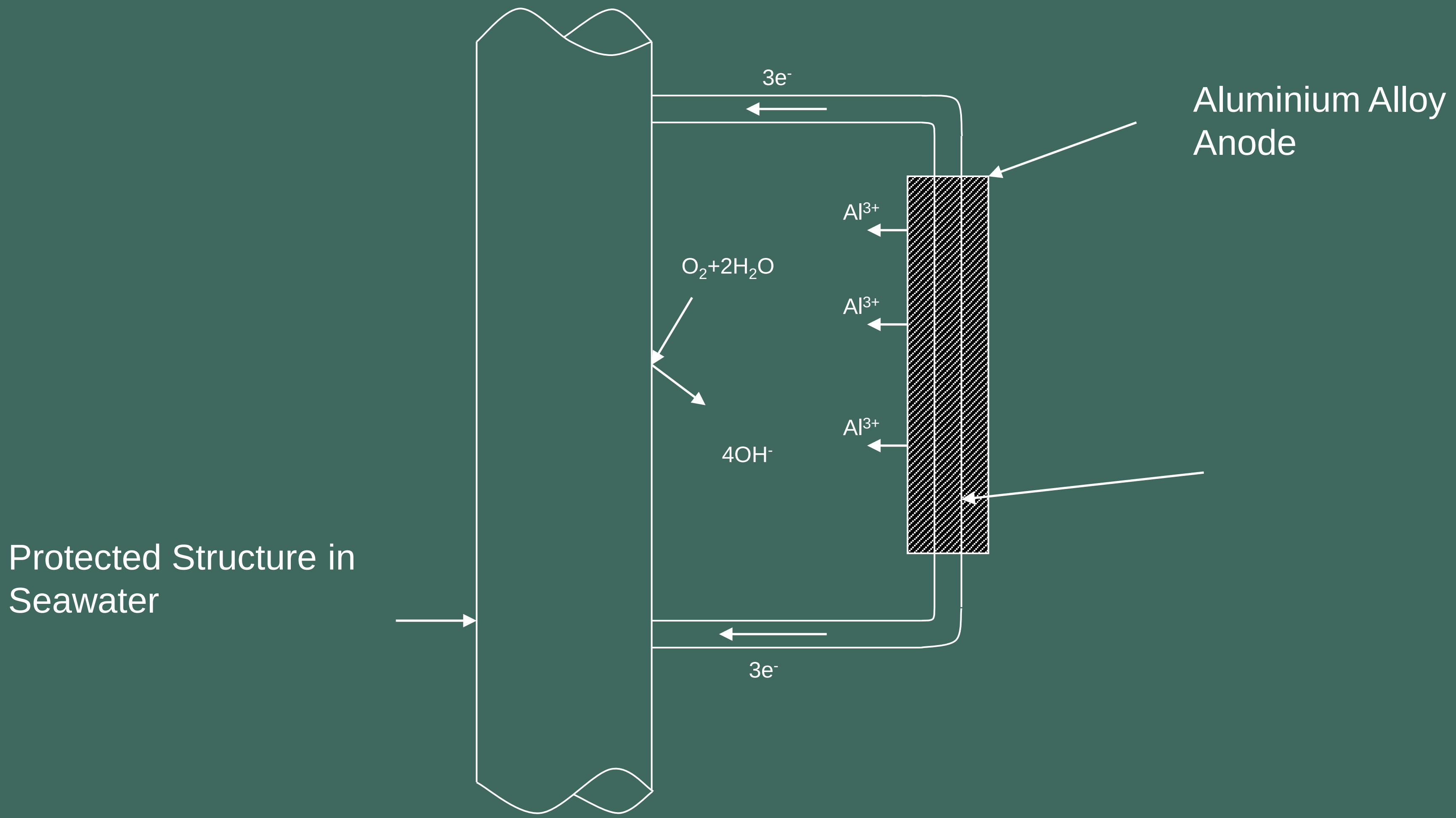
There are three system choices:

- Sacrificial – normally zinc or aluminium anodes which are more electronegative than the steel
- Impressed current – inert anodes powered by an external power source
- Hybrid – a mixture of sacrificial and impressed current

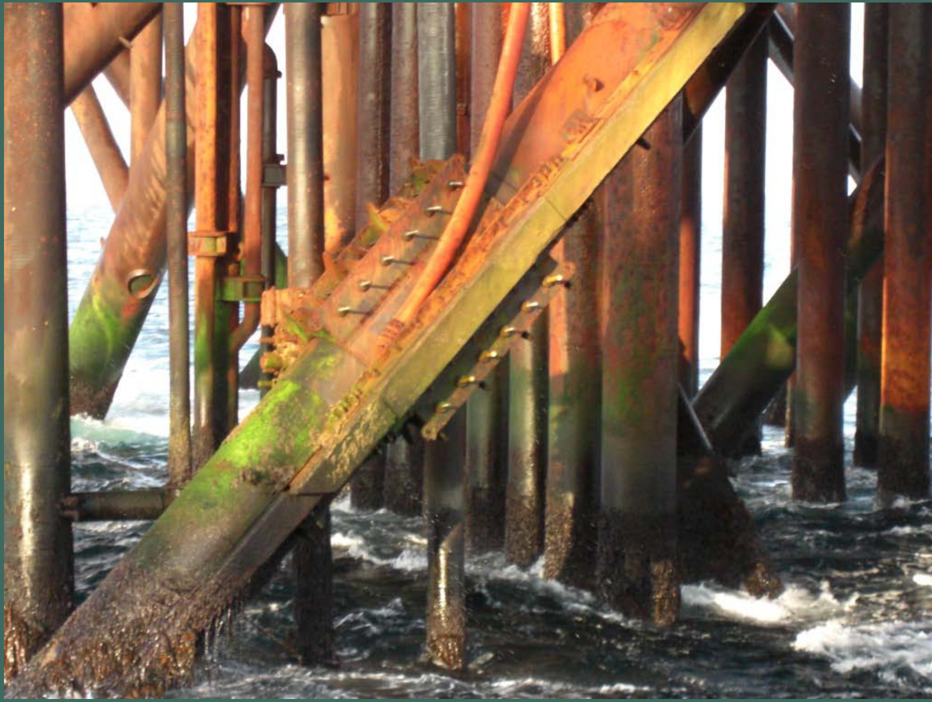
Sacrificial System



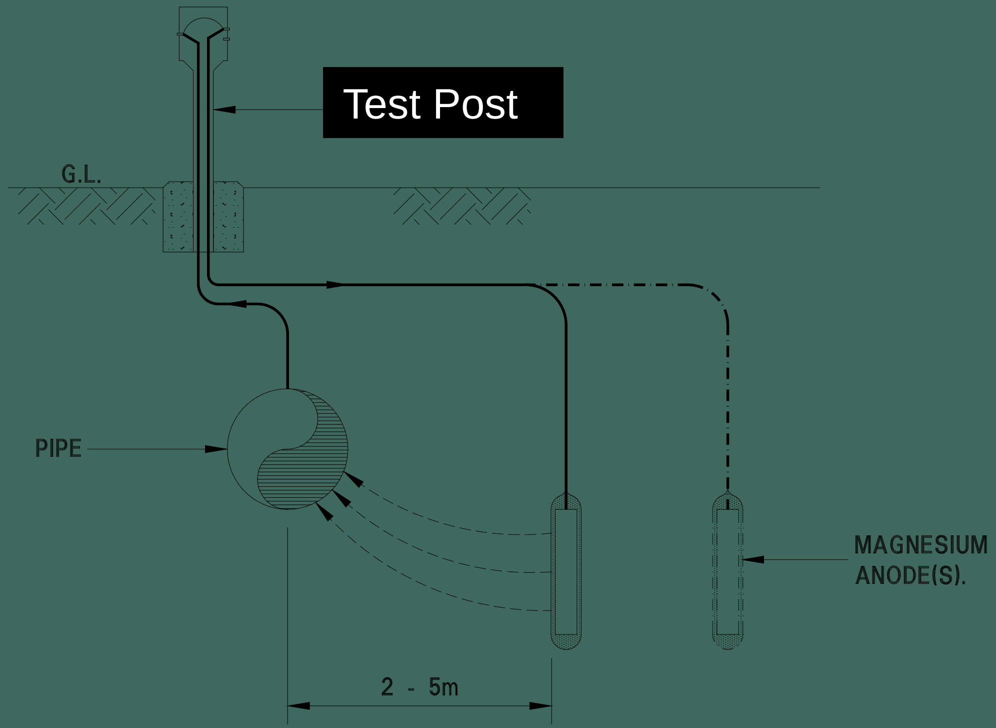
Sacrificial Anode Cathodic Protection



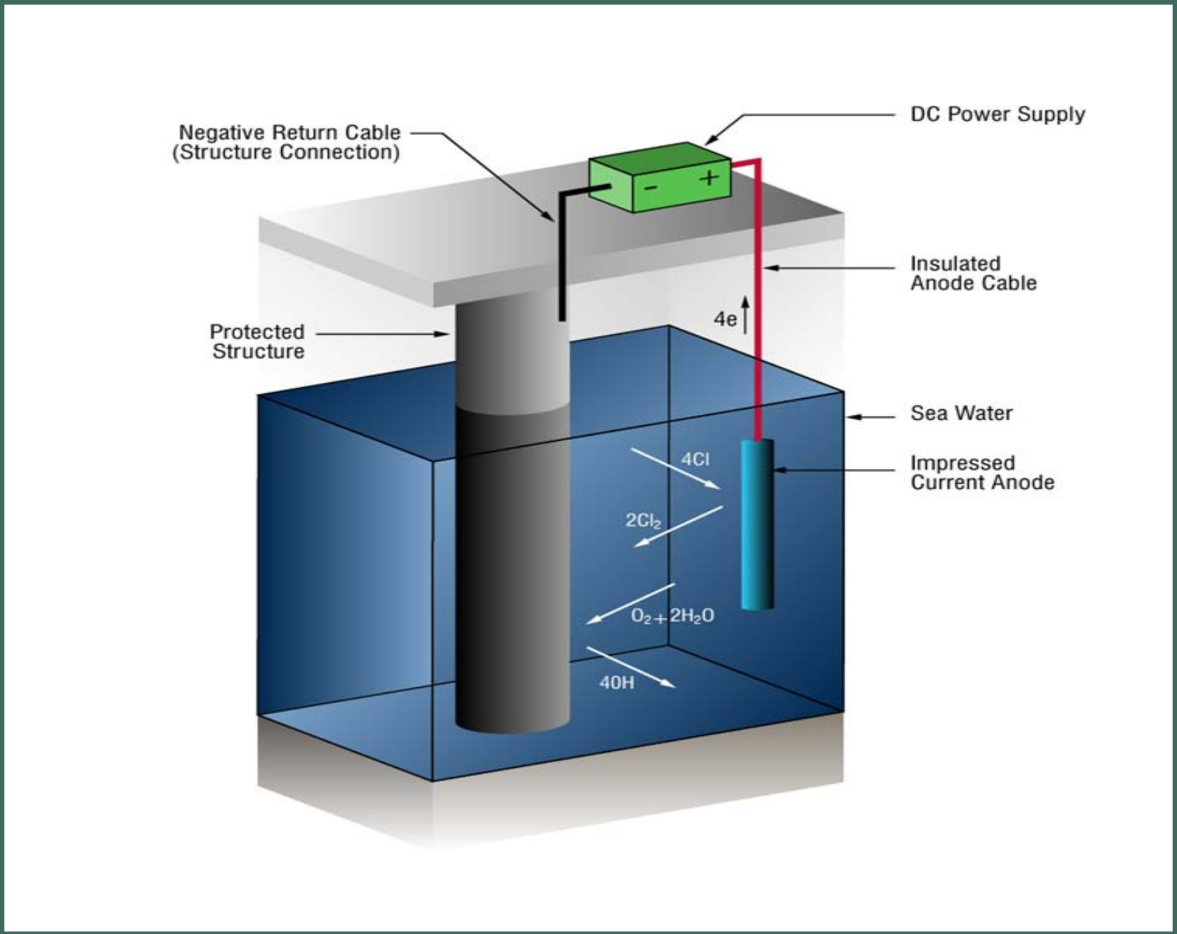
Detailed Design and Engineering – Practicalities



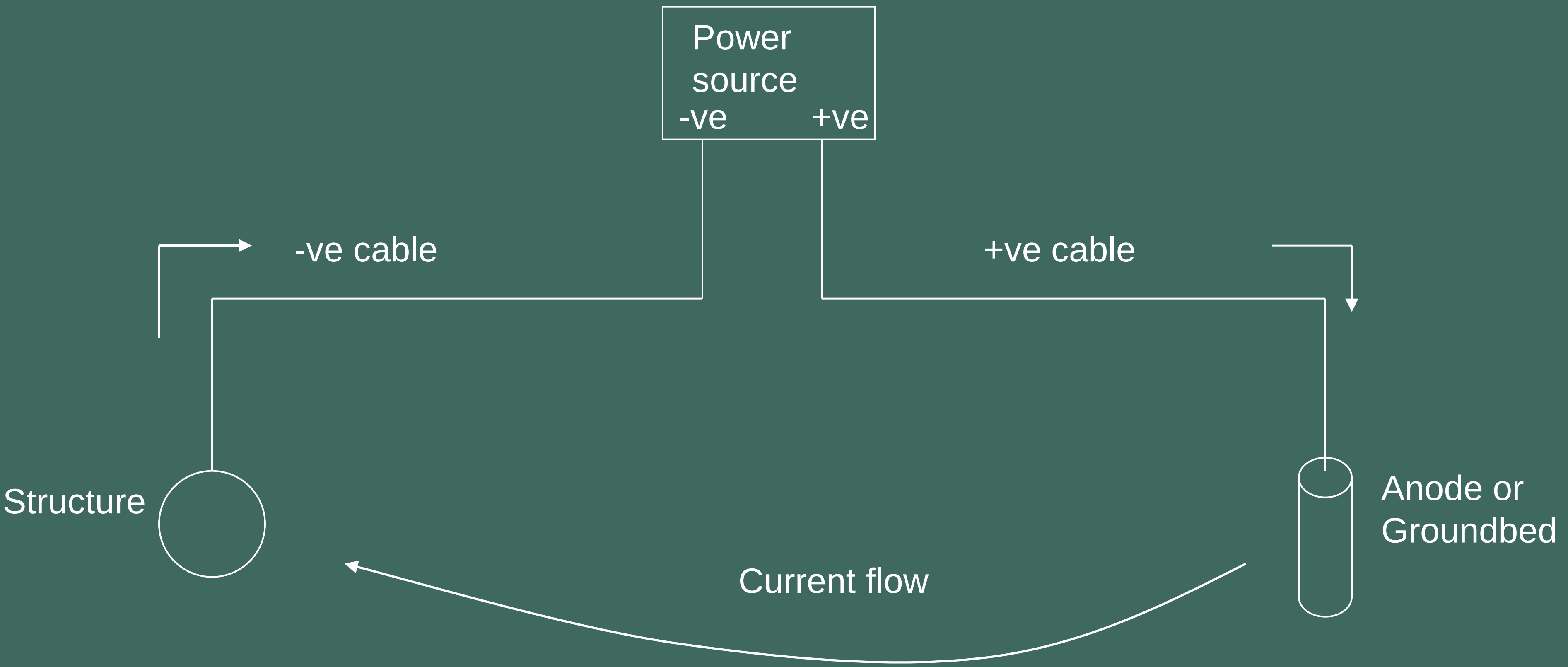
Typical Onshore Sacrificial Anode Installation



Impressed Current System

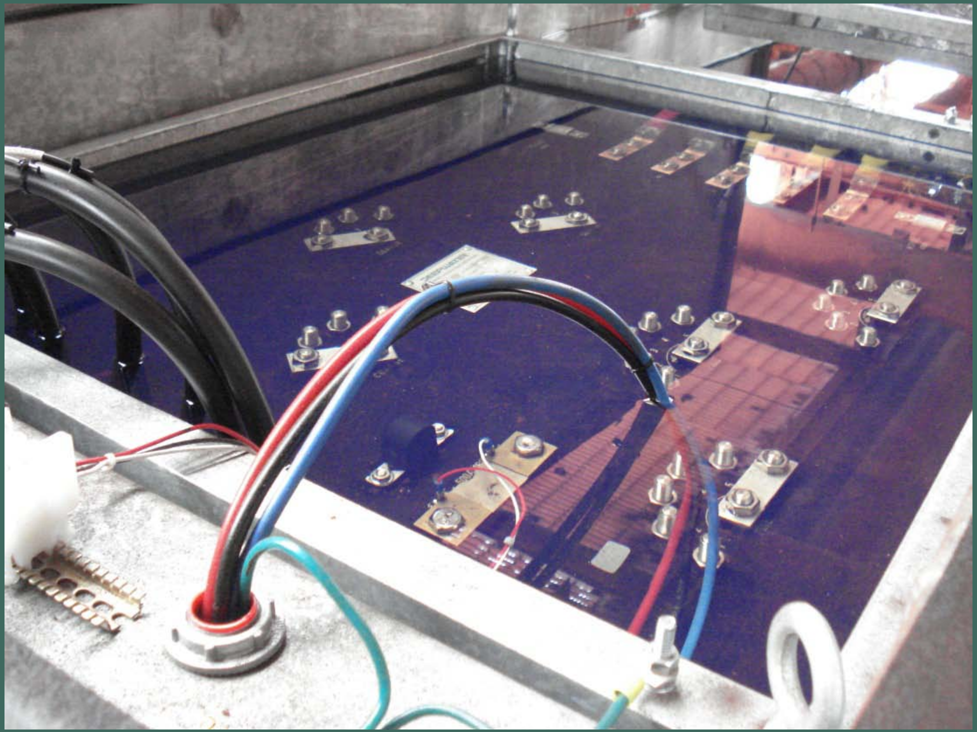


Basic Features of an Impressed Current CP System



Power Supplies

- DC current required
- From AC to DC – Transformer Rectifiers
- From Solar Energy



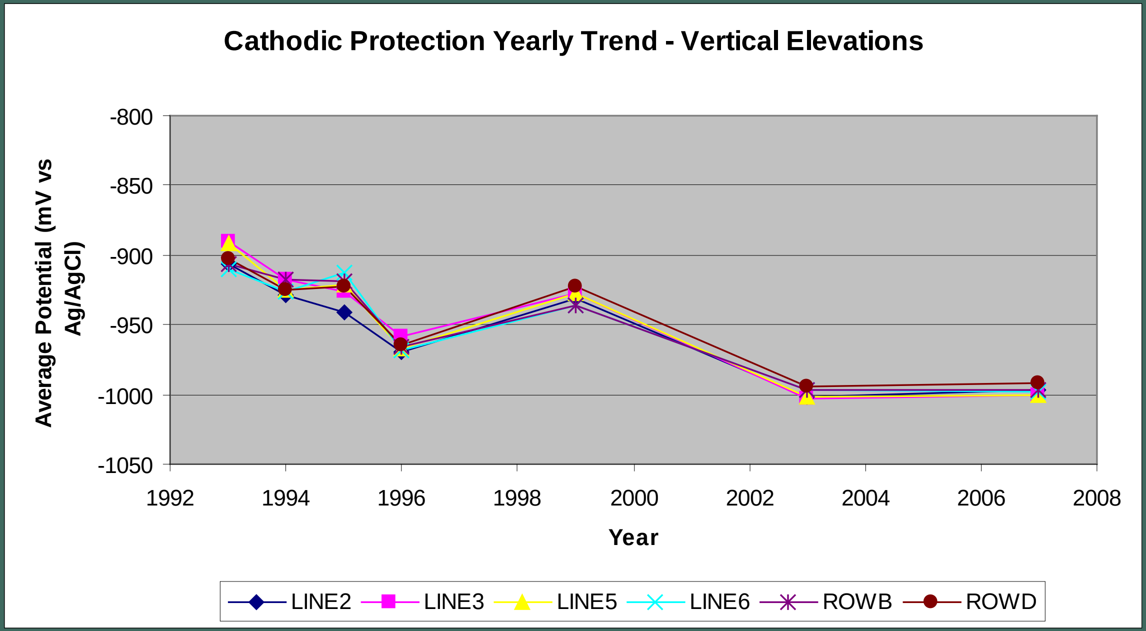
Detailed Design and Engineering – Practicalities

Engineering of the CP system involves converting the theory into a practical working system

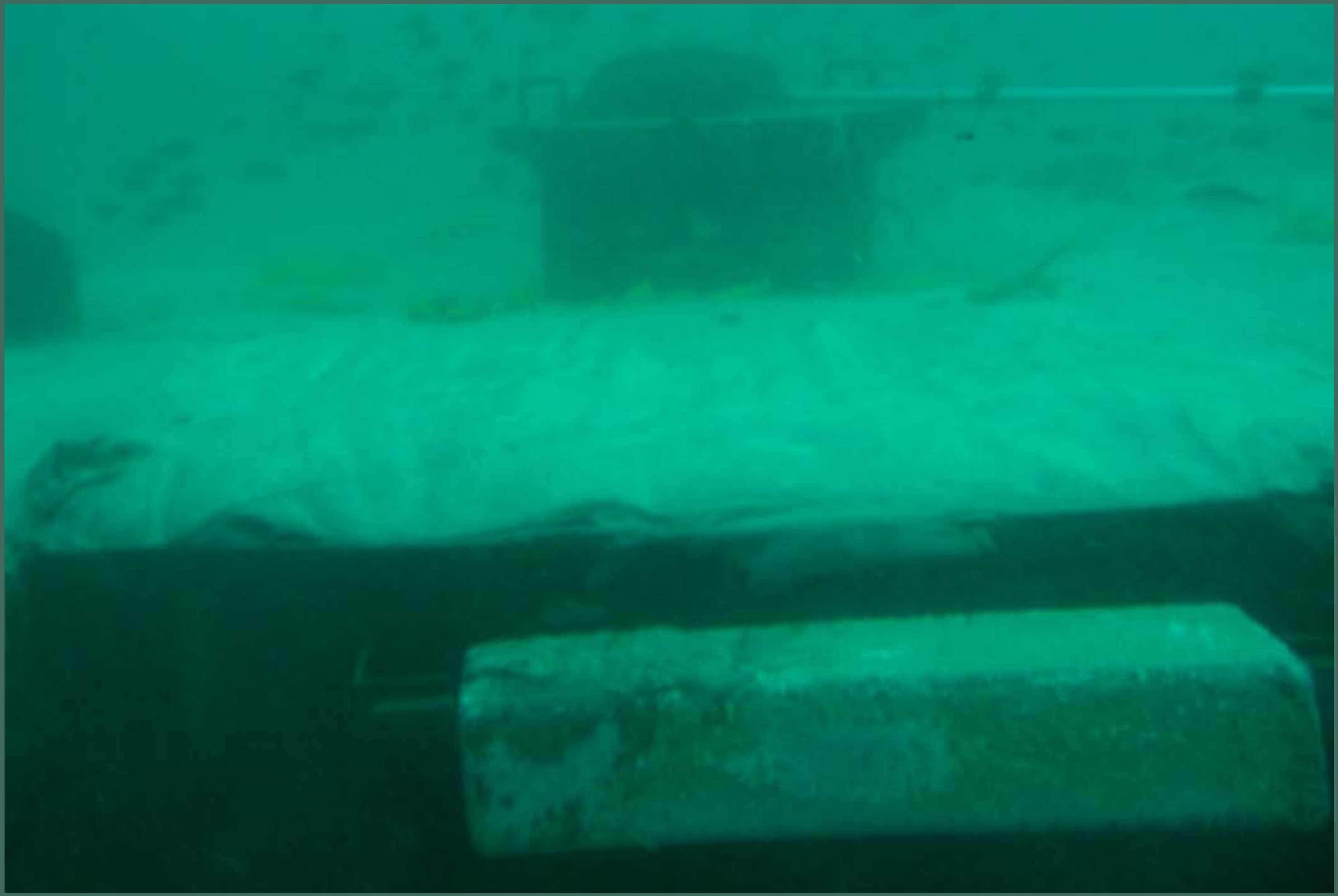
Detailed Design and Engineering - Operation

Once the system is installed it needs to be operated and monitored:

- Operations and Maintenance Manual
- Fault finding procedures



Offshore CP Example (Sacrificial)



Offshore CP Example (Sacrificial)

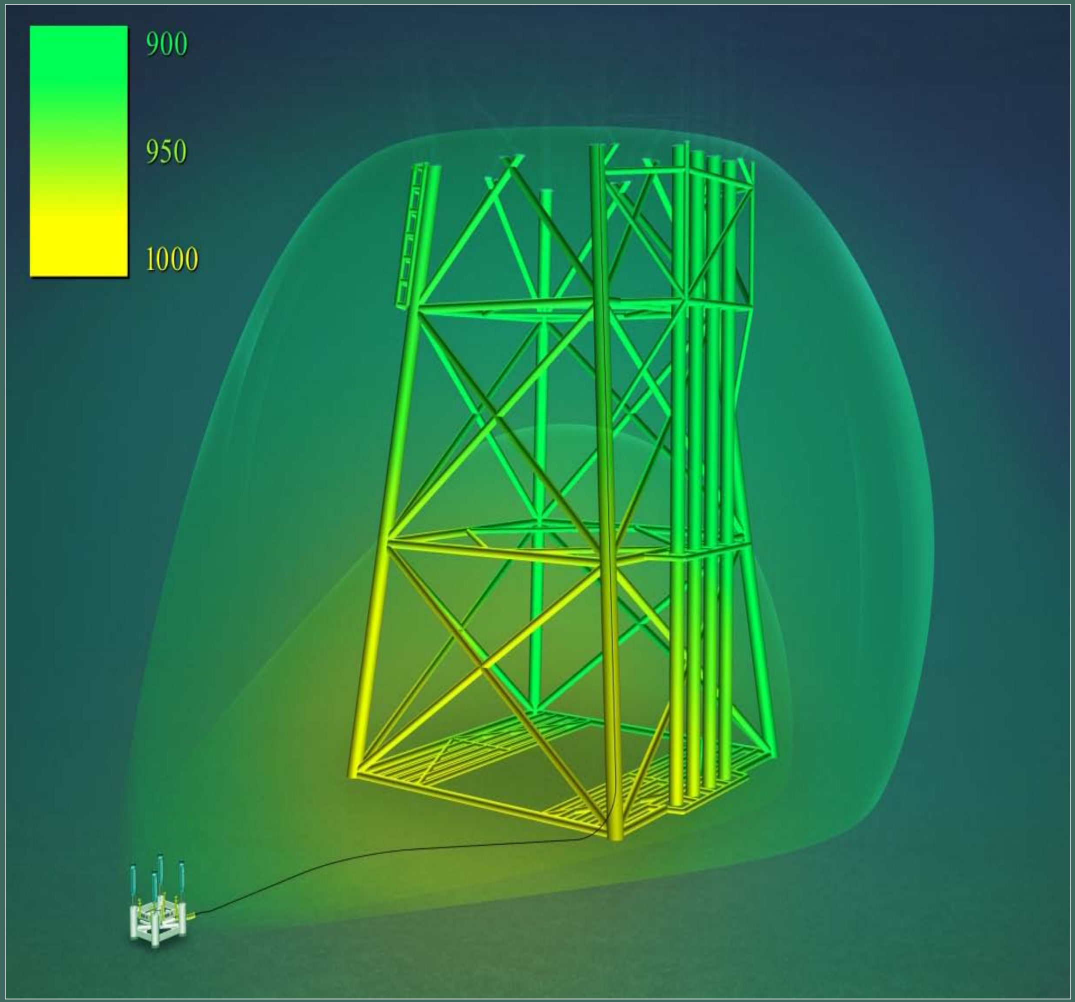
Offshore CP Example (Sacrificial)

Retrofit Installation Methods

Offshore CP Example (Impressed)

Offshore CP Example (Impressed)

Offshore CP Example (Impressed)



Other Marine Applications

Other Marine Applications

Operational Monitoring

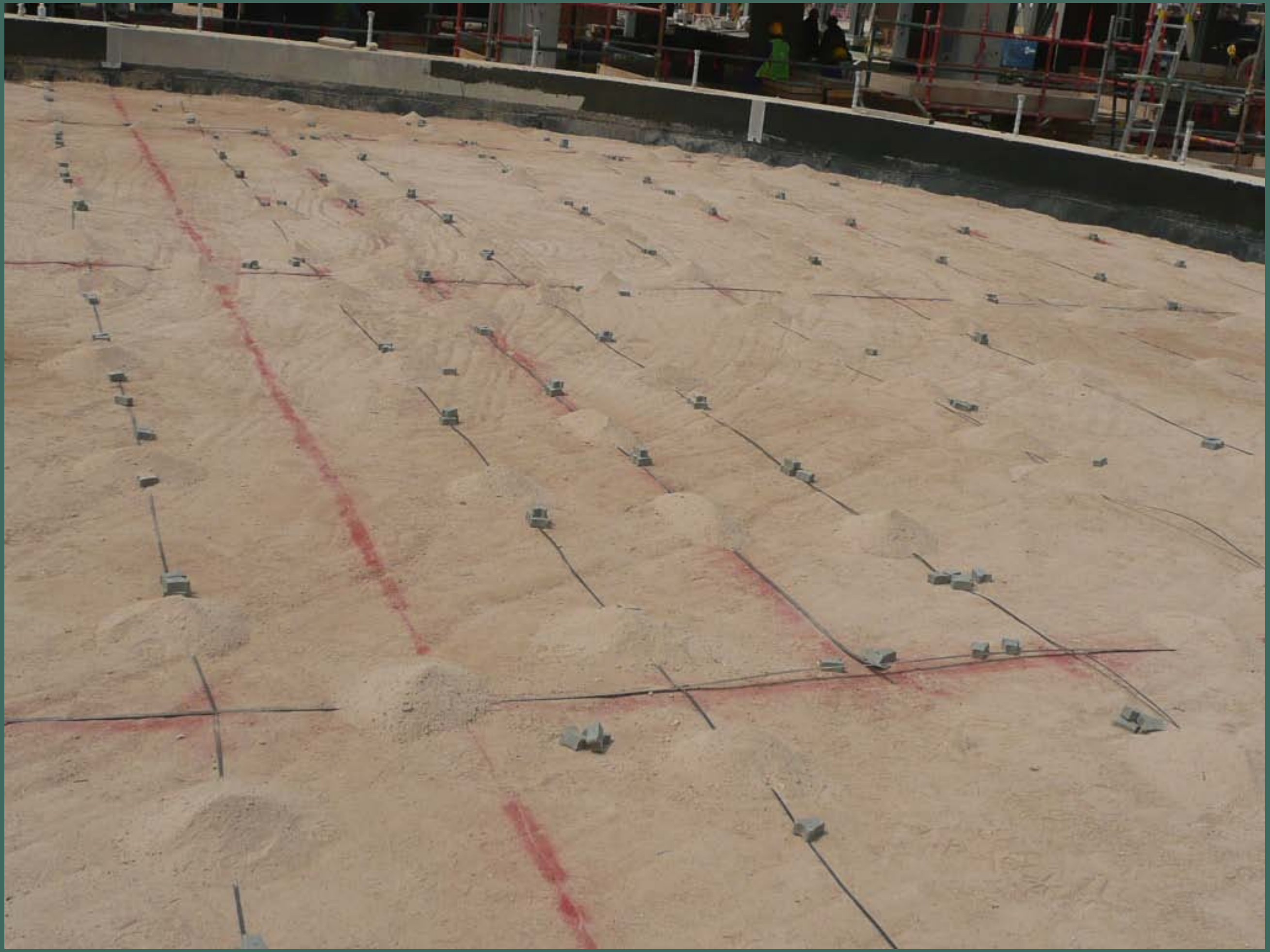
Onshore CP

Onshore CP Example

Onshore CP Example

Onshore CP Example

Onshore CP Example



Specialist Surveys

Close Interval Potential Survey (CIPS)

Potential Monitoring

Specialist Surveys
DCVG – Direct Current Voltage Gradient

Other Applications: Concrete

Recommended further reading

- DNV RP B401 2005 – Cathodic Protection Design
- DNV RP F103 2003 – Cathodic Protection of Submarine Pipelines by Galvanic Anodes
- Cathodic Protection (Second Edition) by John Morgan, National Association of Corrosion Engineers
- DNV RP B401 2005 – Cathodic Protection Design

Recommended further reading

- BS 7361-1- Code of practice for land and marine applications
- NACE SP0169 -
- NACE SP0176 – Corrosion Control of Steel Fixed Structures Associated with Petroleum Production
- NACE RP0187- Design Considerations for Corrosion Control of Reinforcing Steel in Concrete
- EN12474 2001 – Cathodic Protection of Submarine Pipelines
- EN13509 2003 – Cathodic Protection Monitoring Techniques