Marine Corrosion

Revision 1

Corrosion

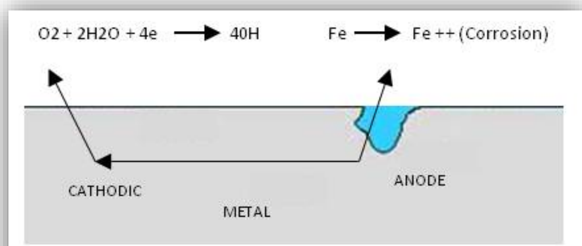
When two dissimilar metals are connected in an electrolyte such as sea-water, a corrosion cell is formed in which one metal becomes an anode and suffers corrosion while the other metal becomes the cathode and is preserved.

Anodic and cathodic areas exist on the surface of all steel structures due to slight variations in materials composition, local stresses, differences in coating condition and availability of oxygen.

On a bare steel plate in sea-water, these areas form on what is apparently a uniform surface. Since corrosion will result in metal loss, roughening and wastage will occur on an uncoated plate.

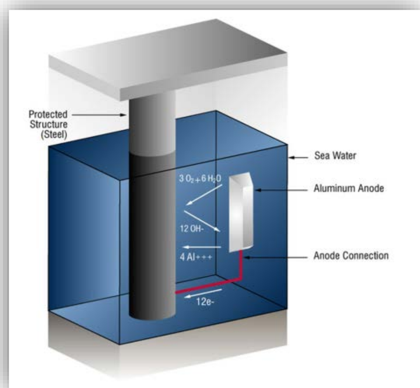
Where an imperfect coating exists, corrosion will take the form of accelerated pitting at the location of the bare spots and eventual breakdown of the coating.

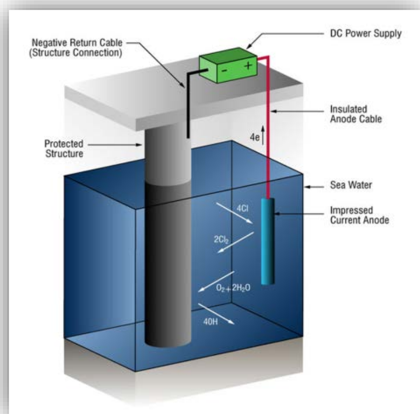
Whatever the circumstances, in the absence of cathodic protection, corrosion will eventually occur.



Differential Corrosion Cell

Cathodic Protection





The principal of cathodic protection involves the introduction into the electrical circuit of a metal that is more electro-negative than the existing anodic and cathodic areas.

This additional metal becomes the anode and will corrode while providing current to the metal it is protecting, thereby overcoming the local anodic areas and making them cathodic.

A cathodic protection solution to a galvanic corrosion problem is to introduce an anode in a suitable alloy of magnesium, aluminium or zinc which will suffer corrosion and so be 'sacrificed' in protecting the cathode. This approach is used in Sacrificial Systems.

As an alternative solution, the protective current needed to make the structure fully cathodic may be obtained by applying low voltage DC derived from normal AC mains supply.

This is achieved by transformer/rectifiers which supply DC to specially designed 'inert' anodes which will dissipate large currents without themselves suffering significant wastage. This approach is used in Impressed Current Systems.

Cathodic Protection Systems, whether of Sacrificial or Impressed Current type, can be either used as the sole method of corrosion control, or in many instances, in conjunction with a coating.

Protection, even with the best and most expensive coatings, alone is seldom adequate. Coatings are always vulnerable to damage and can only be as good as atmospheric and surface conditions permit at the time of their application.

Cathodic Protection is therefore an essential ingredient in an overall corrosion control system for applications on ships as well as on off-shore structures, jetties, storage tanks and pipelines both underground and sub-sea.

Ship Hull Protection

Hulls of ships are prone to corrosion of an aggressive nature in the form of pitting unless they are cathodically protected.

Protection with the best and most expensive coating along is not enough because the coating is vulnerable to mechanical damage at sea or in port and to imperfections at the time of application.

Corrosion Control Engineering has two main types of sacrificial anodes: high purity zinc and aluminium.

For hull protection, zinc anodes with their high electrical efficiency, are of particular value when the aim is to restrict current output and so achieve a long system life from anodes of small bulk.

Aluminium anodes combine high electrical capability with light weight and offer a lower cost per ampere hour of available current and the need of fewer anodes. As an added benefit, few anodes mean a reduced frictional resistance eon the hull of the ship.

Ship Tank Protection

The corrosion pattern in cargo tanks of crude oil carriers is very different from that on the ship's hull but can prove even more damaging and expensive. The cargo tanks are alternated with sea-water and in this environment the corrosion problem takes the form of pitting on horizontal surfaces such as the inner bottom shell plating, the upper surfaces of stringer platforms and the face plates of longitudinal and transverse members. Uniform wastage of vertical surfaces is inevitable.

Pitting may also occur in lower areas where water may be present beneath oil cargoes and where residual ballast water is present in tanks which are supposed to be empty.

The wastage of internal surfaces of 'permanent' ballast tanks is usually uniform in nature and can be inhibited by the installation of anodes distributed evenly throughout the internal structure.

Corrosion of these types can be controlled simply and economically with either Zincalloy or Alalloy anodes or a combination of both, depending on the particular environmental conditions of each installation.

Zincalloy can be invaluable in tank applications, particularly in the upper areas where the installation of aluminium anodes (Alalloy) is restricted, however it provides the most effective and economical solution to the corrosion problem.

Flexible Alalloy, an extruded aluminium alloy anode, can be manipulated through complex double bottom tanks structures and fixed by clamps. Welding is eliminated and labour costs are reduced. Whatever the galvanic corrosion problem on a ship, Corrosion Control Engineering have the experience in both design and protection to offer the optimum solution backed by the latest technological developments and worldwide service capability.

System Design

Cathodic Protection Systems can be designed either by experienced Corrosion Control Engineering service engineers visiting a vessel or in the company's design and estimating offices. When necessary, Classifications Society approval can be obtained on an owner's behalf.

In order to design cathodic protection systems, Corrosion Control Engineering requires the following information:

Actual Wetted Surface Area (WSA) which can be calculated from	
Ship's Hull	**Ship's Tank**
Principal dimensions i.e. length between perpendiculars, breadth moulded and maximum draught (if protection is required to stern frame and rubber system only the maximum draght and/or dwt tonnage are required)	Owner's drawings i.e. midship section and GA or capacity plan, steelwork/structural drawings for peak tanks.
Desired system life	Desired system life and percentage time in ballast
Type of coatings	Type and extent of coating with estimate of percentage breakdown
Block coefficient	Cargoes to be carried, type of tank (ballast only or cargo/ballast)
Nature of Service	Any heating coils, their material and whether they are insulated from the structure
Is propeller bonded with slip-ring?	Classification Society approval required
Number of propellers, rudders, thrusters, seachests	
Any special factors?	

Marine Corrosion

Anode Requirements for Full Hull Protection

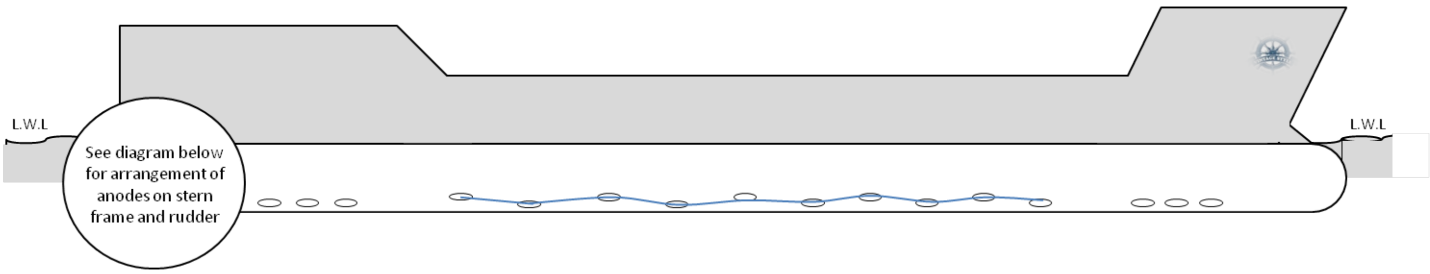
The number and type of sacrificial anodes required to protect the external hull of a specific vessel are calculated by taking into account several factors - size, the type of vessel, service conditions and the condition of the hull - whether it is new or in service.

Current density requirements vary for each vessel but the following table gives a general indication of recommendations for a broad range of vessel types.

	New Building mA/m^2	In Service mA/m^2
Ice vessels	25	30
Dredgers	24	27
Kort nozzle tugs	22	24
Trawlers	22	24
Tugs	18	22
Ro-Ro ferries	14	20
Coasters	14	20
Other ocean-going ships	12	15
Ocean-going ships (SPC Coated)	10	15

Having determined the number of anodes required, it is important to ensure that the current distribution is effective and with the propeller located at the stern of the vessel - an area of major turbulence - it is necessary to fit a higher proportion of the anodes in the after part of the vessel, particularly close to the propeller.

The diagram below shows a typical anode distribution for a large vessel.



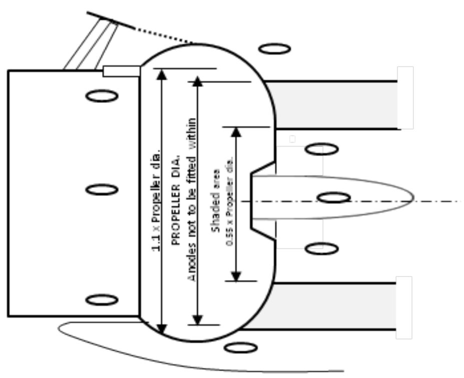
Typical External Hull Anode Arrangement

As a guide, it is recommended that 60% of the anodes are mounted in the after half and the balance in the forward section. Due to the possibility of the anchor cable abrading the forward quarters and removing the paint, more anodes should be fitted in this part than at midships but positions where the anchor cable actually contacts the full should be avoided.

Anode Requirements for Stern Frame Protection

For stern frame and rudder protection, Corrosion Control Engineering has devised the following table of typical quantities and types of anodes required for various sizes of vessel.

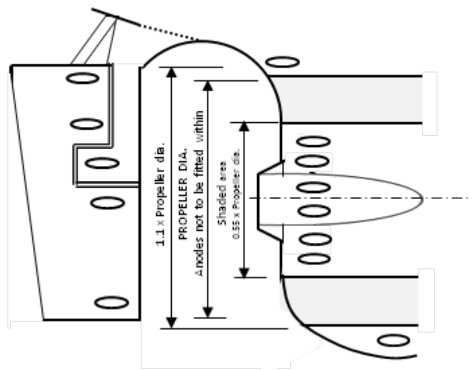
Draft (metres)	DWT (tonnes)			Number of anodes CCE117 or CCE124 or CCE14Z		
4.5 - 7	2,000	-	5,000	12		14
7 - 8	5,000	-	8,000	14		18
8 - 9	8,000	-	10,000	16		20
9 - 10	10,000	-	20,000	18		22
10 - 11	20,000	-	30,000	20		26
11 - 12	30,000	-	40,000	24		30
12 -13	40,000	-	60,000	30		38
13 - 14	60,000	-	80,000	36		44
14 - 15	80,000	-	115,000	40	24	50
15 - 17	115,000	-	200,000	52	30	64
17 - 19	200,000	-		66	38	82



Once the quality of anodes required has been assessed, distribution, particularly in this area, is critical. For vessels of 40,000 dwt or more, the distance between anodes on the rudder should not exceed 4m.

The diagrams shows typical systems.

Stern Frame Anode Layout



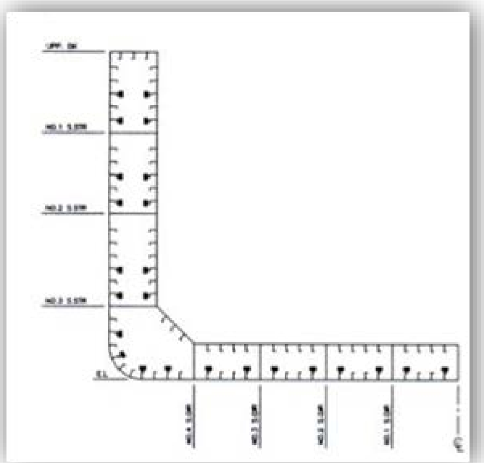
With all stern frame systems, anodes should be positioned to avoid areas of the hull lying directly ahead of the propeller blade tips and in the area within the outer half of the propeller radius. Anodes placed in these positions can cause cavitations and a consequent reduction in the efficiency of the propeller.

If the propeller is bonded to the hull by a slip ring, the number of anodes required, as shown in the anode quantity table, will increase by 30%.

Anode Requirements for Cargo and Ballast Tank Protection

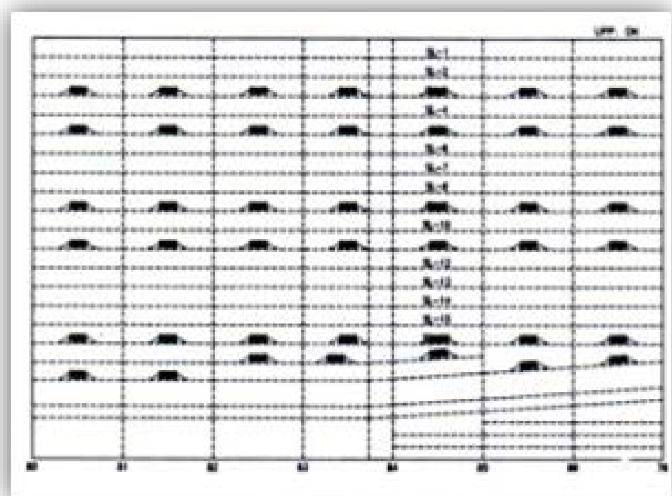
The type of cargo to be carried and the time that the tank is in ballast affect the current density which must be made available for protection.

However, the following table gives general recommended current densities for various types of tanks with bare steel.



Typical Sect.

Type of Tank	Cargo to be Carried	Recommended Current Density
• Upper wing tanks • Peak tanks	Salt water	130mA/m^2 (12mA/ft^2)
• Segregated ballast tanks • Deep tanks • Cargo ballast tanks • (Spirit tankers)	Salt water (Petroleum products/ salt water)	110mA/m^2 (10mA/ft^2)
• Double bottom tanks • Cargo ballast	Salt water Crude oil/salt water	90mA/m^2 (8mA/ft^2)



Where tanks are painted, additional protection should be provided against paint breakdown. An initial current density of 5mA^2 should be considered, then 10mAm^2 should be added for every 10% of anticipated breakdown over the life of the cathodic protection system. Therefore, for a system with 20% paint breakdown the current density should be 25mA/m^2.

Once the number of anodes required has been calculated, their distribution in the tanks must be determined. The following table gives the rules which should be observed for effective protection against corrosion.

Long BHD

Type of Tank	Current Requirement	Recommended Anode Material
Centre tanks	⅔ in the bottom of the tank ⅓ in the upper areas	Aluminium and /or zinc
Wing tanks	½ in the bottom of the tank ½ throughout the remainder	Aluminium and /or zinc
Anode Distribution		
Permanent ballast tanks	even distribution over surface area	Aluminium and /or zinc
Double bottom tanks	at least one anode in each membrane box	Aluminium and /or zinc

Special note should be taken of the positioning of aluminium anodes in tanks carrying crude oil or petroleum, or other inflammable products. Certain Classification Societies have restrictions on the height at which these may be placed because of the potential for a spark to be produced should an anode fall from a defined height. The Lloyds Register of Shipping, for example, rules that the potential energy of an aluminium or aluminium alloy anode should not exceed 275J (29kg fm).