

# CATHODIC PROTECTION FOR SHIPS

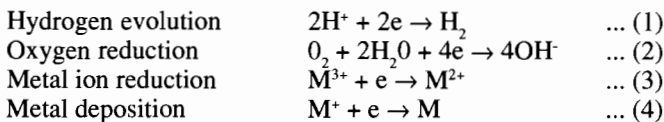
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*Cathodic protection has been in use for longer than most engineers realise. Interestingly enough, cathodic protection was successfully applied even before the science of electrochemistry was developed.*

*It is of particular interest to the shipping industry to note that Humphry Davy first used cathodic protection on British naval ships in 1824.*

A brief chemistry background would not be wasted in establishing the basis of corrosion in general, and then focusing on cathodic protection.

In metallic corrosion several cathodic reactions are encountered, of which the most common are:



Metal ion reduction and metal deposition are less common reactions. All of the above reactions have one thing in common - they consume electrons. In addition, these reactions can largely be used to interpret most corrosion problems.

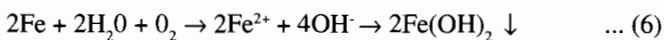
Consider what happens when iron is immersed in seawater that is exposed to the atmosphere - corrosion occurs. The anodic reaction is:



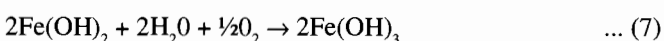
Since the seawater is exposed to the atmosphere it contains dissolved oxygen and is nearly neutral, where the cathodic reaction is:



Keeping in mind that sodium and chloride ions do not participate in the reaction, the overall reaction is obtained by adding (2) and (5):



In an oxygenated environment ferrous hydroxide that precipitates from solution is unstable and further oxidises to the ferritic salt:



The final product is known as rust.

## What is cathodic protection?

Cathodic protection is achieved by supplying electrons to the metal structure to be protected. Equations (1) and (5) indicate that the addition of electrons to the structure will tend to suppress metal dissolution and increase the rate of hydrogen evolution.

In conventional electrical theory current is considered to flow from (+) to (-) and as a result a structure is protected if current enters it from the electrolyte (seawater). Conversely, accelerated corrosion occurs if current passes from the metal to the electrolyte (seawater). Cathodic protection of a structure can be achieved in two ways, namely:

- by application of an external power supply (impressed current)
- by application of an appropriate galvanic system (sacrificial anode)

## Impressed current cathodic protection

The positive and negative terminals of an external dc power supply are connected to an inert anode and the ship's hull respectively. Electric cabling is insulated to avoid current leakage. Figure 1 shows how current passes from the inert anode through the electrolyte (seawater) to the ship's hull.

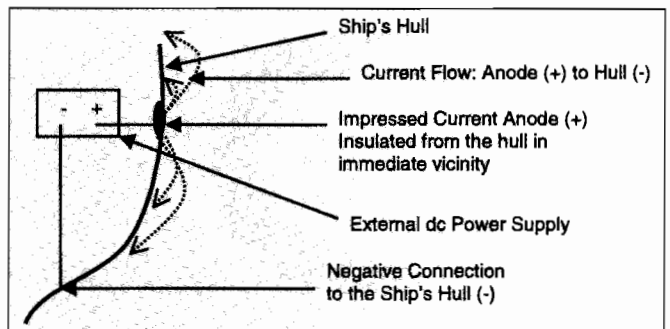


Figure 1: Impressed current cathodic protection applied to a section of a ship's hull

## Sacrificial anode cathodic protection

Figure 2 shows sacrificial anode cathodic protection applied to a ship's hull. Galvanic coupling is shown between the ship's hull and an aluminium strip anode. Aluminium is anodic (+) with respect to steel and corrodes preferentially when coupled with steel.

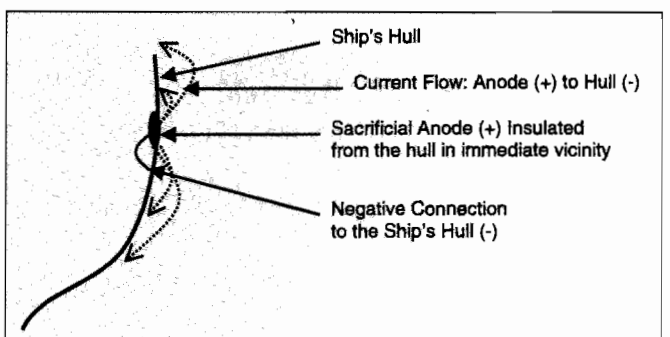


Figure 2: Sacrificial anode cathodic protection applied to a ship's hull

## Protection criteria and design principles

Corrosion takes place all over submerged bare steel. But, if the steel has been coated, the corrosion attack is concentrated at points of paint breakdown and takes the form of deep pits or even complete penetration of the plate.

### External corrosion

Corrosion on hulls means metal loss, consequent surface roughening, increased drag and excessive fuel consumption. Weld grooving may occur, which is highly dangerous if not repaired, time consuming and costly to repair in dry-dock. Similarly, structural members on tanks can seriously weaken the structural integrity of a ship.

As a measuring standard, steel structures exposed to seawater are protected if polarised to a potential of -0,85V dc versus a copper/copper sulphate reference electrode. Often, reference electrode potential mapping is carried out to determine the uniformity of applied currents.

Anode selection and positioning is based on engineering and economic considerations.

Table 1 details the information that is required to design a suitable cathodic protection system for a ship.

Actual Wetted Surface Area (WSA) which can be calculated from	
Ships' hulls	Ships' tanks
Dimensions: length between perpendiculars, breadth moulded and maximum draft	Owners' drawings (mid-ship section and GA or capacity plan, steelwork/structural drawings for peak tanks)
Block coefficient	Type and extent of coatings with estimate of percentage breakdown
Type of coatings	Desired system life and percentage time in ballast
Desired system life	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 the propeller bonded with a slip ring?	Classification Society Approval required
Number of propellers, rudders, thrusters, seachests	
Any special factors?	

Table 1: Information required to design a suitable cathodic protection system for a ship

Numbers and types of anodes required to protect the external hull of a vessel are calculated by taking into account several factors - size, type of vessel, service conditions and the condition of the hull - whether new or in service. Current density requirements vary for each vessel. However, Table 2 provides general guidelines for a wide range of vessels.

	New building mA/m <sup>2</sup>	In service mA/m <sup>2</sup>
Ocean-going ships (SPC coated)	10	15
Other ocean-going ships	12	15
Coasters	14	20
Ro-Ro ferries	14	20
Trawlers	22	24
Kort nozzle tugs	22	24
Dredgers	24	27
Ice breakers	25	30
Tugs	18	22

Table 2: Current density requirements for a range of vessels

The placement of anodes, particularly in tanks carrying crude oil, petroleum or other inflammable products, will most likely require the approval of Classification Societies to avoid creating an environment conducive to spark formation. Lloyds Register of shipping, for example, rules that the potential energy of aluminium or related alloys should be greater than 275J.

To determine the type and number of anodes required, the wetted hull area must be estimated. An approximation of the wetted hull surface area is calculated using a suitable formula, such as the one below:

$$\text{Wetted Surface Area} = (1,8 \times \text{LBP} \times \text{D}) + (\text{LBP} \times \text{BC} \times \text{B})$$

Where:

- LBP = length between perpendiculars
- D = draft
- BC = block coefficient
- B = breadth

Typical block coefficients for different vessels are given in Table 3.

Vessel type	Block coefficient
Passenger vessel	0,6
Cargo vessel	0,75
Trawler	0,55
Coasters	0,75
Yachts	0,4 - 0,5
Tankers	0,8 - 0,9
Tugs	0,6
Naval vessels	0,55
Dredgers	0,8
Launches	0,4

Table 3: Typical block coefficients for different vessels

The total current required to protect the vessel is calculated as follows:

$$\text{Current (amperes)} = \frac{\text{protected area (m}^2\text{)} \times \text{current density (mA/m}^2\text{)}}{1\,000}$$

Total weight or anode material (sacrificial anode approach) required is calculated as follows:

$$\text{Weight (kg)} = \frac{\text{current (amperes)} \times \text{design life (years)} \times 8\,760}{\text{capacity of material (amp.hrs/kg)}}$$

where 8 760 = number of hours in a year

When selecting the number and type of anodes, both the total current and total weight requirements must be met. The following formulae achieve these criteria:

$$\text{Number of anodes} = \frac{\text{total weight required}}{\text{individual net weight}}$$

$$\text{Number of anodes} = \frac{\text{total current required}}{\text{individual current output}}$$

Having determined the number and type of anodes required it is important to ensure that the current distribution achieved by installing the anodes in certain positions is maximised and effective. Propellers are mounted at the stern of most vessels and this area is subject to major turbulence, necessitating the installation of a higher proportion of the anodes in the after part of the vessel, in particular near the propeller.

As a rule of thumb, it is recommended that approximately 60% of the anodes be mounted in the after half, with the balance in the forward section.

In a similar fashion, more anodes will be required in the forward quarters in the vicinity of anchor cables abrading the hull surface, thus removing paint. Direct points of anchor contact on the hull should be avoided as installation sites for obvious reasons.

### Internal corrosion

Cargo and the time internal tanks are in ballast affect the required current density for protection to be achieved. Recommended current densities are shown in *Table 4*.

Type of tank	Cargo carried	Recommended current density
Upper wing tanks Peak tanks	Salt water	130mA/m <sup>2</sup>
Segregated ballast tanks Deep tanks Cargo ballast tanks (Spirit tankers)	Salt water (Petroleum products/salt water)	110mA/m <sup>2</sup>
Double bottom tanks Cargo ballast	Salt water Crude oil/salt water	90mA/m <sup>2</sup>

*Table 4: Recommended current densities for protection to be achieved*

Type of tank	Current requirement	Recommended anode material
Centre tanks	$\frac{2}{3}$ in the bottom of the tank $\frac{1}{3}$ in the upper areas	Aluminium and/or zinc
Wing tanks	$\frac{1}{2}$ in the bottom of the tank $\frac{1}{2}$ throughout the remainder of the tank	Aluminium and/or zinc
<b>Anode distribution</b>		
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

*Table 5: Rules to observe for the effective application of internal cathodic protection*

Painted tanks require adequate provision for anticipated paint breakdown over the life of the cathodic protection system. As a rule of thumb the initial design current density will be approximately 5mA/m<sup>2</sup> with the addition of 10mA/m<sup>2</sup> for every 10% of the anticipated breakdown over the life of the cathodic protection system.

As an example, a cathodic protection system that is designed for an anticipated 20% breakdown in tank paint will require a current density of approximately 25mA/m<sup>2</sup>.

The number and type of anodes is determined in a similar fashion to the external cathodic protection system. Some rules to observe for the effective application of internal cathodic protection are given in *Table 5*.

An anode is most often welded or clamped into position using the steel core that is part of the anode when it is cast. A low resistance path is highly desirable, making welding the preferred method of attachment. However, exceptions to this rule exist and bolted or clamped anode installations take place.

During the operation of tank cathodic protection systems the following factors should be considered to maximise system effectiveness:

- clean salt water being used as ballast in tanks
- it is essential that ballast time be maintained at an optimum level
- after deballasting tanks it is important to ensure that all the ballast has been removed as residual ballast can cause severe corrosion in areas not under cathodic protection
- unless a vessel has a defined haulage level, tanks should be operated at a ballast level that offers the most cathodic protection to internal structural steel
- regular inspections of tanks and the anode attachments will soon reveal any irregularities. Future anode maintenance can be planned and the extent of internal corrosion monitored
- check anode functionality by looking for a white hydroxide adhering to the anode surface, which may be scraped off quite easily. Hard anode surfaces indicate that the anodes are not operating correctly
- oil tankers carrying crude oil should have washing procedures delayed as long as possible as the wax deposits assist with the cathodic protection of the internal steelwork
- operations demanding cleaning immediately after leaving discharge ports must be taken into consideration when designing the internal cathodic protection system

### Conclusion

Despite the availability of cathodic protection solutions for corrosion in marine environments, the routine maintenance and understanding of the application thereof leaves much to be desired.

Advice to prudent ship owners is to protect their assets while there is adequate steel to protect, thereby reducing dry-dock time for plate replacement and costly repair.

In future cathodic protection techniques will continue to improve and the invaluable benefits derived from cathodic protection will be realised by those who have applied it.

