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Proper designing and material selection:

- Avoiding the contact of dissimilar metals in the presence of corroding solution.
- When two dissimilar metals are to be in contact, the anodic metal should have large area, whereas the cathodic metal should have as much smaller area as possible.
- If two dissimilar metals are to be used, they should be as close as possible to each other in electrochemical series.
- If it is unavoidable of the direct joining of dissimilar metals, then an insulating fitting may be applied between them to avoid metal to metal electrical contact.
- The anodic metal should not be painted or coated when in contact with a dissimilar cathode metal, because any break in coating may lead to a rapid localized corrosion.

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→ Moisture should be excluded wherever possible.

If moisture & electrolyte solution is present, suitable inhibitors should be used.

→ Corrosion can be controlled by suitably adjusting the acidity or alkalinity of the medium. When the control of pH is not practicable, corrosion can be reduced using inert coatings and inert metals.

→ The equipment should be designed as to avoid sharp corners and lap-joints

→ Free drainage and easy washing should be possible by proper design of baffles, drain nozzles, valves and pumps.

Modifying the corrosive environment:

An environment can be made less corrosive either by the removal of harmful constituents or by the addition of a substance that will

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neutralize the effect of corrosive constituents of the environment.

- * Deaeration or deactivation of water or neutral solution.

- * Dehumidification

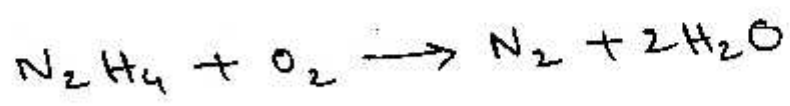
- * Alkaline neutralization

- * The oxygen concentration type of corrosion is dependent on the amount of oxygen available at the cathode area. Consequently, the exclusion of oxygen from aqueous solution will reduce or prevent metal corrosion. This is usually done either by 'deaeration' or 'deactivation'.

Deaeration or mechanical methods depend on the adjustment of temperature and pressure, together with mechanical agitation, so that dissolved gases like O_2 and CO_2 are expelled out, thereby decreasing the corrosion rate.

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Deactivation methods are based on the removal of corrosive gases from water by chemical means. This may involve the use of a large surface of scrap iron or the addition of chemicals capable of combining rapidly with the oxygen in water. Among the chemicals used, sodium sulphite is frequently employed, because the reaction product is soluble. Hydrazine (N_2H_4) is advantageous over sodium sulphite, because the reaction products are nitrogen and water, thereby no solid matter is added to medium.



- * Dehumidification is the process of reducing the moisture content of air to minimize the effect of corrosion. Substances like alumina or silica gels are used, which

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absorbs the moisture on their surface.

* Alkaline neutralization is the prevention of corrosion rate by neutralising the acidic character of corrosive environment (due to the presence of H_2S , HCl , CO_2 , SO_2 etc.). It includes NH_3 , $NaOH$, lime, soap etc. This method has been widely used in controlling the corrosion of refinery equipment.

INHIBITORS

"A corrosion inhibitor is a substance which effectively decreases the corrosion rate of a metal when added in small amounts to corrosion environment."

Inhibitors are organic or inorganic substances that dissolve in the corroding medium, but are capable of forming a protective layer of some kind of either the anodic or cathodic areas.

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Anodic inhibitors: Inhibitors that suppress the anodic reaction or metal dissolution are called 'Anodic Inhibitors'. Oxidizing substances such as chromates, phosphates, silicates, nitrates and hydroxides are used as anodic inhibitors for the protection of iron and steel. These inhibitors seal off the anodic regions by forming oxide films.

Cathodic inhibitors: Most of the organic inhibitors tend to shield the cathodic areas and can be grouped as cathodic inhibitors. E.g. Amines, mercaptans, heterocyclic nitrogen compounds, thioureas, sulphides and heavy metal soaps. Some inorganic inhibitors, such as Zn, Mn and Ca salts and $\text{Ca}(\text{HCO}_3)_2$ present in hard water which are cathodic. These react with OH^- ions at the cathode, forming insoluble hydroxides which are deposited on the

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Cathode forming barriers.

Purification and alloying of metal.

The corrosion resistance of a given metal may be improved by increasing its purity. E.g. High purity aluminium is subject to a lesser pitting corrosion extent. High purity copper does not corrode once the surface film forms after initial exposure to the atmosphere.

It is more common to increase both strength and corrosion resistance by the use of suitable alloying elements. ~~Al, Mg and Pb~~

For maximum corrosion-resistance, alloy should be completely homogeneous. Chromium is the best suitable alloying metal for iron & steel. Its film is self-healing. Thus, steel contains up to 13% Cr & is used in cutlery, surgical

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instruments. Iron alloys containing 13 to 25% Cr called "ferrite ~~steel~~ stainless steels" are used in turbine brackets, heat-resisting parts.

CATHODIC PROTECTION

When electrical current flows between the anodic and cathodic areas on a corroding metal surface, the higher the current, the greater and faster will be the corrosion at the anode. The rate of corrosion can be controlled by imposing additional current on the metal using an external circuit. If an opposing current is applied to nullify corrosion, it is called 'Cathodic Protection'. If the potential of the metal is adjusted that the corrosion is very much suppressed (as the metal becomes passive), then it is called 'Anodic Protection'.

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Cathodic Protection: The principle involved in this method is to force the metal to be protected to behave like a cathode, thereby corrosion does not occur. There are two types of cathodic protection:

- (i) Sacrificial anodic protection method:
- (ii) Impressed current cathodic protection.

(i) In sacrificial anodic protection method, the metallic structure (to be protected) is connected by a wire to a more anodic metal, so that all the corrosion is concentrated at this more active metal. The more active metal itself gets corroded slowly, while the parent structure (cathodic) is protected. The more active metal so employed is called "sacrificial anode". The corroded sacrificial anode block is replaced by a fresh one, when consumed completely. Mg, Zn, Al and

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Their alloys are commonly used as sacrificial anodes.

Important applications of sacrificial anodic method include protection of buried pipelines, underground cables, marine structures, water-tanks, etc.

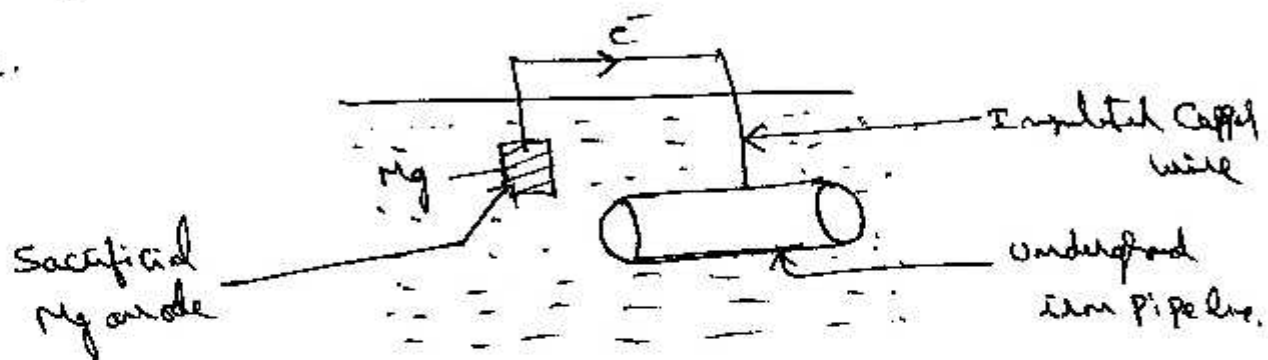
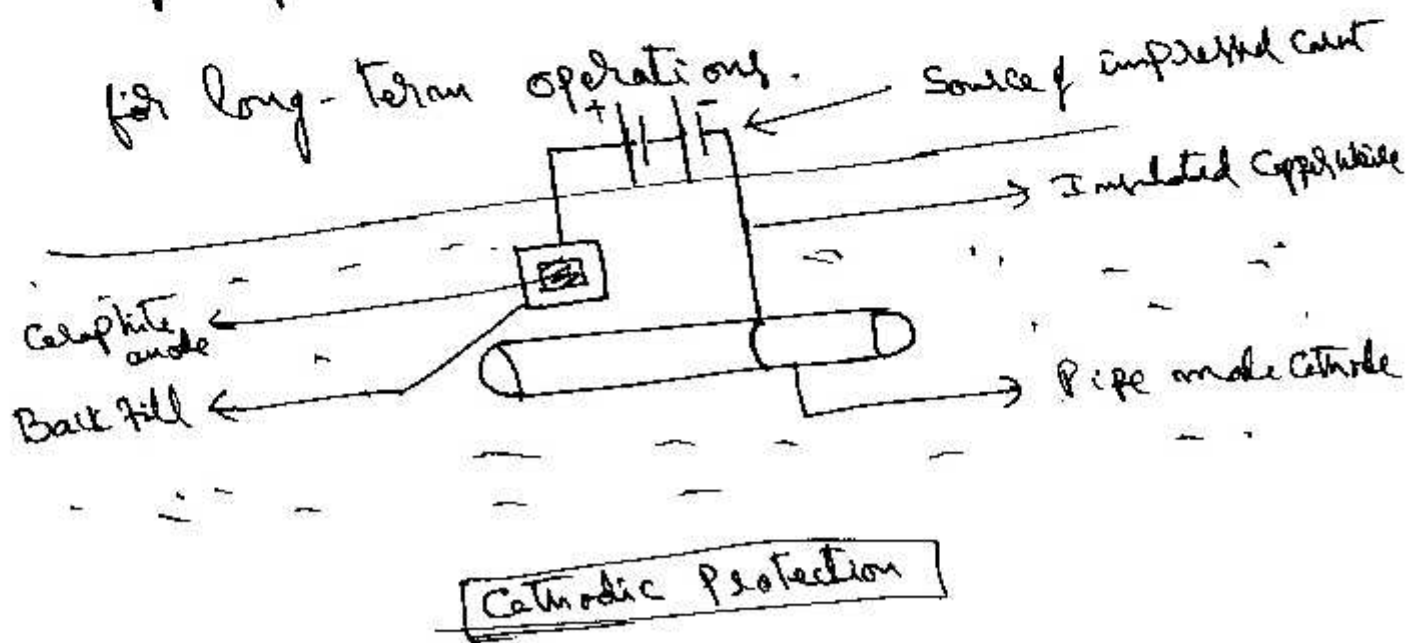


Fig. Sacrificial anodic protection

(ii) In impressed current cathodic protection, an impressed current is applied in opposite direction to nullify the corrosion rate, and collect the corroding metal from anode to cathode. The impressed current is derived from D.C. source (like battery, rectifier), with an insoluble anode (like graphite, platinum, high silica iron). Usually

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a Sufficient d.c. current is applied to an insoluble anode, buried in the soil (or immersed in corroding environment) and connected to the metallic structure to be protected. The anode is, usually, in a backfill (composed of coke breeze or gypsum) so as to increase the electrical contact with the surrounding soil. This type of protection has been applied to open water-box coolers. This type of protection is useful for large structures for long-term operations.



Anodic Protection:

Anodic protection is a form of corrosion control in which metal is polarized by applying current in a direction that renders it more anodic.

This type of technique is only applicable to such metals and alloys which exhibit active-passivity.

The potential range over which the metal is passive should be wider (e.g. 50 mV is satisfactory for commercial use). The current density should be as low as possible. The lower the passive current needed to maintain the protection, the lesser will be operating costs. Anodic protection system has a large throwing power and hence quite complex structures can be protected.

Advantages:

- Low operating cost
- Applicable to wide range of corroding environment
- Ability to protect complex structures
- Needs few auxiliary or sacrificial electrodes
- Feasibility of the process can be predicted by laboratory experiments.
- Protection current gives an indication of corrosion rate.

Disadvantages:

- * Suitable for only those metals and alloys, which show ~~active~~ active-passive behaviour.
- * High installation cost requiring potentiostat, reference electrode and ~~auxiliary~~ auxiliary electrode.
- * High starting current is required
- * If the system goes out of control, high corrosion rate may occur.

Protective Coatings.

Protective materials provide a continuous physical barrier between the protected surface and its environment. The protective coatings are:

- (i) Metallic Coatings
- (ii) Non-metallic Coatings
- (iii) Organic Coatings

Metallic coatings: The metal to be protected is called the 'base metal', whereas the metal used for protection is called the 'coating metal'.

→ Anodic coatings are produced from metals which are anodic to the base metal. Eg. Zn, Al and Cd coatings are anodic on steel, ~~because~~ ~~their electrode potentials~~ Zinc, being anodic to iron will dissolve and the iron being cathodic is protected. Thus, no attack on iron occurs until practically all the Zinc first corroded. Hence, Zinc coating protect iron' sacrificially.

The process of covering iron or steel sheets with a thin coat of zinc to ~~protect~~ prevent from rusting is called as Galvanizing.

→ Cathodic coatings are obtained by the application of coating of more noble metals than the base metal. Metals used as cathodic coatings are Cu, Sn, Ni, Cr, Ag and to a smaller extent, gold and platinum. Cathodic coatings give effective protection to the base metal till the coatings are completely continuous and free from pores. If such coatings are broken a much more damage can be done to a base metal than to metal without protection.

The process of covering steel or iron with a coat of tin is called as Tinning. Tin is extensively used for coating over mild steel plates required in food industry.

(DOWNLOADED FROM WEB SOURCES)

S. No.	Galvanizing	Tinning
1	Process of covering iron or steel, with a thin coat of ZINC to, prevent it from rusting.	Process of coating steel with a, thin coat of TIN to prevent it, from corrosion.
2	Zinc protects iron sacrificially., Since it is more electro-positive, than iron and does not permit iron to pass into the solution.	Tin protects the base metal iron, from corrosion due to its noble, nature and higher corrosion, resistance.
3	In galvanized articles, zinc continues to protect the underlying iron by galvanic cell action, even if the coating of zinc, is broken at any place	Tin protects underlying iron till the coat is intact. Any break in coating causes rapid corrosion of, iron.
4	Galvanized containers cannot be used for storing acidic foodstuffs as zinc reacts with food acid forming poisonous compounds	Tin coated containers and utensils can be used for storing any food stuff as tin is non-toxic and protects metal from corrosion
5	Ideal temperature is around 450° C	Ideal temperature is around 250°C.
6	Ammonium chloride is used as flux	Zinc chloride is used as flux

Comparison of cathodic and anodic protection

Factors	Cathodic protection	Anodic protection
Suitability	To all metals in general.	Only to those exhibiting active-passive behavior
Environment	Only for moderate corrosion environment.	Even aggressive chemical corrosives.
Cost benefit	Low investment, but higher operative costs..	Higher investment, but low operative costs.
Operation	Protective currents to be established through initial design and field trials	More precise electrochemical estimation of protection range possible.

Anodic coating vs. cathodic coating

S. No.	Anodic Coating	Cathodic Coating
1	It protects base metal, sacrificially	It protects base metal due to high corrosion resist. & noble behaviour.
2	Coating metal is at lower, potential than base metal	Coating metal is at higher potential than base metal.
3	Corrosion of base metal does not increase even on breaking as it heals its film	Corrosion of base metal increases, if there is a break in coating
4	e.g. galvanizing i.e. Zn coating on iron/steel.	Tin coated containers and utensils can be used for storing any food stuff as tin is non-toxic and protects metal from corrosion