4.4 Control Methods-Electrochemical protection

Electrochemical protection, also known as cathodic protection (CP), is a technique used to prevent or reduce the corrosion of metals by making them the cathode in an electrochemical cell. This method is particularly useful for protecting structures like pipelines, tanks, and underground or underwater metal structures.

CATHODIC PROTECTION:

The reduction or prevention of corrosion by making metallic structure as cathode in the electrolytic cell is called cathodic protection. Since there will not be any anodic area on the metal, corrosion does not occur. There are two methods of applying cathodic protection to metallic structures.

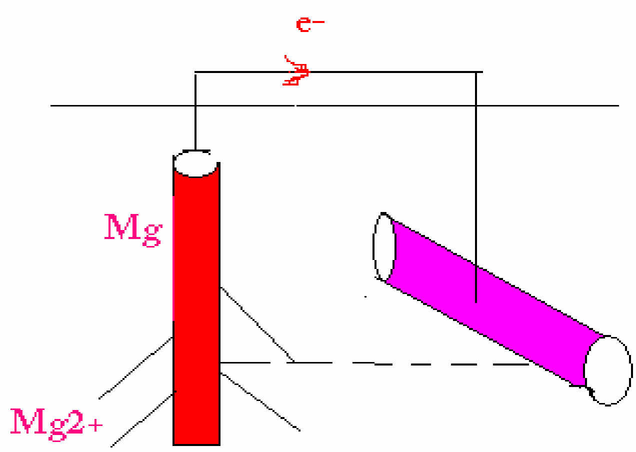
a) Sacrificial anodic protection (galvanic protection) SAP
b) Impressed current cathodic protection ICCP

SACRIFICIAL ANODIC PROTECTION METHOD

In this method, the metallic structure to be protected is made cathode by connection it with more active metal (anodic metal). Hence, all the corrosion will concentrate only on the active metal. The parent structure is thus protected. The more active metal so employed is called sacrificial anode. The corroded sacrificial anode block is replaced by a fresh one. Metals commonly employed as sacrificial anodes are magnesium, zinc, aluminium and their alloys. Magnesium has the most negative potential and can provide highest current output and hence is widely used in high resistivity electrolytes like soil.

Applications:

1. Protection as buried pipelines, underground cables from soil corrosion.
2. Protection from marine corrosion of cables, ship hulls, piers etc.
3. Insertion of magnesium sheets into the domestic water boilers to prevent the formation of rust.
4. Calcium metal is employed to minimize engine corrosion.



In cathodic protection, an anode of a more strongly reducing metal is sacrificed to maintain the integrity of the protected object (eg., a pipeline, bridge, ship hull or boat).

Advantages:

1. Low installation and operating cost.
2. Capacity to protect complex structures.
3. Applied to wide range of severe corrodents.

Limitations:

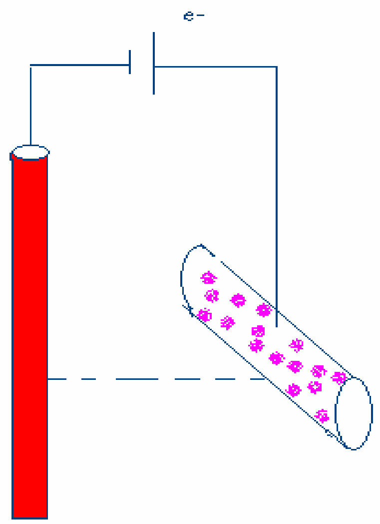
1. High starting current is required.
2. Uncoated parts cannot be protected.
3. Limited driving potential, hence , not applicable for large objects.

IMPRESSED CURRENT CATHODIC PROTECTION METHOD

In this method, an impressed current is applied in opposite direction to nullify the corrosion current and convert the corroding metal from anode to cathode. Usually the impressed current is derived from a direct current sources (like battery or rectifier on AC line) with an insoluble, inert anode (like graphite, scrap iron, stainless steel, platinum orhigh silica iron).

A sufficient DC current is applied to an inert anode, buried in the soil (or immersed in the corroding medium) and connected to the metallic structure to be protected. The anode is, usually, a back fill, composed of coke breeze or gypsum, so as to increase the electrical contact with the surrounding soil.

Impressed current cathodic protection has been applied to open water box coolers, water tanks, buried oil or water pipes, condensers, transmission line towers, marine piers, laid up ships etc. This kind of protection technique is particularly useful for large structures for long term operations.



In Impressed-current cathodic protection, electrons are supplied from an external cell so that the object itself becomes cathodic and is not oxidized.

Inhibitors:

Inhibitors are organic or inorganic substances which decrease the r ate of corrosion. Usually the inhibitors are added in small quantities to the corrosive medium. Inhibitors are classified into

1) Anodic inhibitors (chemical passivators)
2) Cathodic inhibitors (adsorption inhibitors)
3) Vapour phase inhibitors (volatile corrosion inhibitors)

Anodic Inhibitors:

Inhibitors which retard the corrosion of metals by forming a sparingly soluble compound with a newly produced metal cations. This compound will then adsorb on the corroding metal surface forming a passive film or barrier. Anodic inhibitors are used to repair

a) the crack of the oxide film over the metal surface
b) the pitting corrosion
c) the porous oxide film formed on

Cathodic Inhibitors:

Depending on the nature of the cathodic reaction in an electrochemical corrosion, cathodic inhibitors are classified into

a) **In an acidic solution:** the main cathodic reaction is the liberation of hydrogen gas, the corrosion can be controlled by slowing down the diffusion of H+ ions through the cathode. Eg., Amines, Mercaptans, Thiourea etc.

$$2H^+ + 2e^- \rightarrow H_2 \uparrow$$

b) **In a neutral solution:** in a neutral solution, the cathodic reaction is the adsorption of oxygen or formation of hydroxyl ions.

The corrosion is therefore controlled either by eliminating oxygen from the corroding medium or by retarding its diffusion to the cathodic area.
The dissolved oxygen can be eliminated by adding reducing agents like Na_2SO_3.
The diffusion of oxygen can be controlled by adding inhibitors like Mg, Zn or Ni salts. Eg., Na_2SO_3, N_2H_4, Salts of Mg, Zn or Ni.

$$\frac{1}{2} O_2 + H_2O + 2e^- \longrightarrow 2OH^-$$

Vapour phase inhibitors:

These are organic inhibitors which are readily vapourised and form a protective layer on the metal surface. These are conveniently used to prevent corrosion in closed spaces, storage containers, packing materials, sophisticated equipments etc. Examples are Dicyclohexylammonium nitrate, dicyclohexyl ammonium chromate, benzotriazole, phenylthiourea etc

ANODIC PROTECTION

This is an electrochemical method of corrosion control in which an external potential control system, called potentiostat, is used to produce and maintain a thin non corroding, passive film on a metal or an alloy. The use of potentiostatis to shift corrosion potential into passive potential so that the corrosion of the metal is stopped.

The potential of the object (say acid storage tank) to be protected is controlled by potential controller (potentiostat) so that under certain potential range, the object becomes passive and prevents further corrosion. This potential range depends upon the relationship between the metal and the environment.

Applications:

1. Used in acid coolers in dilute sulphuric acid plants
2. used in storage tanks for sulphuric acid
3. used in chromium in contact with hydrofluoric acid

Limitations:

1. This method cannot be applied in the case of corrosive medium containing aggressive chloride.
2. This cannot be applied if protection breaks down at any point, it is difficult to reestablish.

Bio corrosion Protective Coatings

Bio corrosion, also known as microbiologically influenced corrosion (MIC), is a form of corrosion accelerated by the presence of microorganisms. These microorganisms can produce corrosive substances or create conditions that lead to corrosion. Protective coatings are an essential method for mitigating bio corrosion and prolonging the lifespan of metal and concrete structures.

1. Anti-Microbial Coatings:

These coatings contain biocides or antimicrobial agents designed to inhibit the growth of microorganisms on the surface.

- **Biocidal Agents:** Commonly used agents include silver, copper, and zinc compounds, which are known for their antimicrobial properties.

  Applications: Useful in environments where microbial growth is prevalent, such as in water treatment facilities, cooling systems, and marine environments.

  Advantages: Directly targets and inhibits the growth of microorganisms, reducing the risk of biocorrosion.

  Disadvantages: Potential for biocides to leach into the environment, which may require careful consideration of environmental impact.

2. Barrier Coatings:

Barrier coatings provide a physical barrier between the metal or concrete and the corrosive environment, preventing direct contact with moisture and microorganisms.

- **Epoxy Coatings:** Epoxy-based coatings are commonly used for their strong adhesion, chemical resistance, and barrier properties.
- **Polyurethane Coatings:** Known for their flexibility and resistance to UV degradation, polyurethane coatings are suitable for environments with varying temperatures and conditions.

  Applications: Suitable for pipelines, tanks, marine structures, and reinforced concrete.

  Advantages: Effective at preventing moisture and contaminants from reaching the underlying material.

Disadvantages: Requires proper surface preparation and application to ensure effectiveness.

3. Zinc-Rich Coatings:

Zinc-rich coatings offer galvanic protection by providing a sacrificial layer of zinc that corrodes preferentially, protecting the underlying metal.

- **Types:** Zinc-rich primers or coatings contain a high percentage of zinc dust or flakes.

  Applications: Commonly used on steel structures, such as bridges and pipelines, to provide cathodic protection.

  Advantages: Provides sacrificial protection and enhances overall corrosion resistance.

  Disadvantages: Zinc-rich coatings typically require a topcoat for additional protection and durability.

4. Concrete Sealers:

For concrete structures, sealers are applied to prevent the ingress of moisture and corrosive agents, which can lead to biocorrosion of embedded steel reinforcement.

- **Saline and Siloxane Sealers:** These sealers penetrate the concrete and form a hydrophobic layer that repels water.
- **Acrylic Sealers:** Provide a protective film on the surface, preventing moisture and contaminants from entering.

  Applications: Used on concrete slabs, walls, and reinforced concrete structures.

  Advantages: Helps in maintaining the integrity of concrete and protecting embedded steel.

  Disadvantages: Sealers need to be reapplied periodically as they wear off over time.