1.1 GENERAL INFORMATION ABOUT METAL CORROSION

Corrosion is a natural process where refined materials react with their environment, and revert to a more chemically stable form. Corrosion is a constant force in many industries from Oil and Gas, to highway construction, bridges, and pipeline and underground systems. The rate of corrosion is more dependent on a number of variables, but for corrosion to occur, four basic element are required (Anode, Cathode, corrosion Metallic path and Electrolyte).

Corrosion of a metal in an electrochemical process occurs where metallic atoms are oxidized, normally ending up as oxides or salts. For normal corrosion of steel the iron atoms oxidizes into positive ions (Fe^{2+}) that go into solution in the surrounding water. Here they normally react with other ions and molecules to form oxides and salts.

The locations on the metal surface where the metal ions are oxidized, represent anodic sites where the surplus electrons are left in the metal. For the overall corrosion process, there must be a complementary cathodic reaction (reduction) at cathodic sites, where surplus electrons leaves the metal to take part in the cathodic reaction. For oxygen driven corrosion the cathodic reaction results in the formation of OH- ions involving oxygen, water and electrons from the metal. The OH^- ions will react with the iron ions and oxygen to form Ferrous Oxide (Fe_2O_3).

The overall reaction is: $4Fe + 3O_2 = 2Fe_2O_3$.

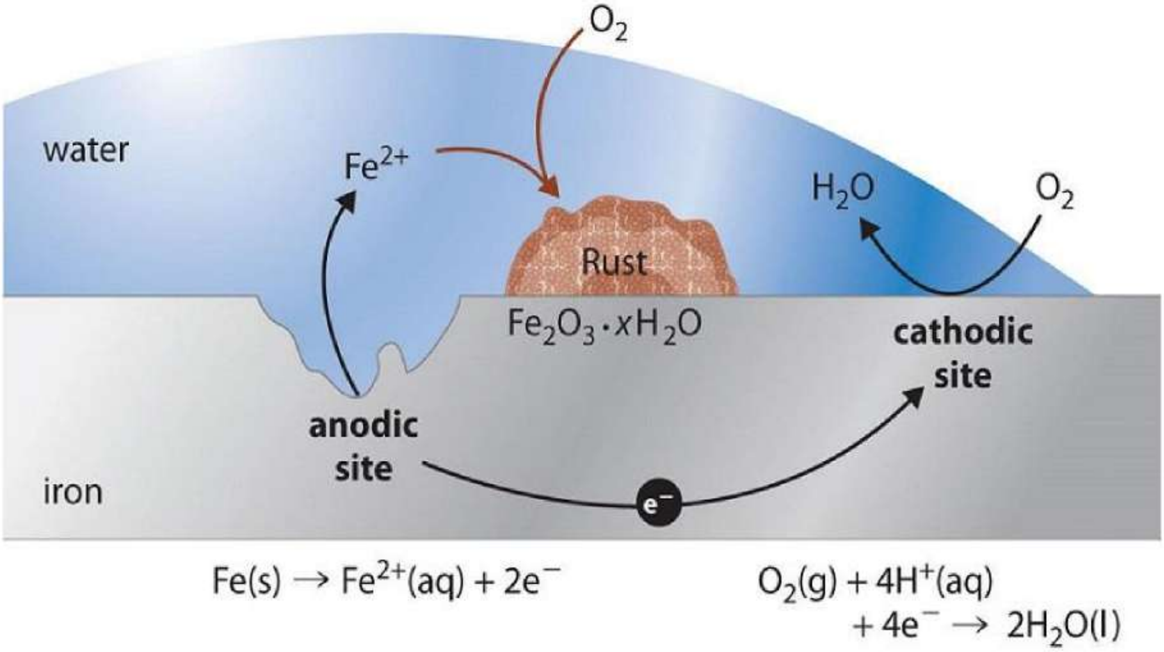


Figure 1.1-Schematic diagram of electrochemical corrosion

Metallic materials are normally exposed to corrosion in the atmospheric and aqueous surroundings. Modern corrosion science began in the early twentieth century with the local cell model proposed by Evans et al and the corrosion potential model proved by Wagner and Traud. The two models have joined into the modern electrochemical theory of corrosion, which describes metallic corrosion as a coupled electrochemical reaction consisting of anodic metal oxidation and cathodic oxidant reduction.

The electrochemical theory is applicable not only to wet corrosion of metals at normal temperature but also to dry oxidation of metals at high temperature. In general, metallic corrosion produces in its initial stage soluble metal ions in water, and then, the metal ions develops into solid corrosion precipitates such as metal oxide and hydroxide.

Corrosion cells are condition on a metal surface in which a flow of electric current occurs between metal surface and an electrolyte with which it is in contact sufficient to cause the metal to deteriorate. The corrosion cells are designed to measure corrosion properties of an object immersed in an electrolyte. It is normally used to test the reaction of metal samples in a corrosive environment.

A corrosion cell consist of the following fundamental component

- Anode (oxidation reaction)
- Cathode (Reduction reaction)
- Electrolyte (Cations an anions)
- Electrical connection between the anode and cathode for the flow of electron current

The driving force behind a corrosive cell is a potential difference between the anode and cathode. These elements of corrosion cells can determine the severity of corrosion. If any of these components is removed, corrosion stops

- Electrochemical Reaction is any process that is either caused or accompanied by the passage of an electric current which involves the transfer of electrons between two substances one a solid and the other a liquid.In a corrosion cell, both oxidation and reduction reactions occurs

Anode (Oxidation reaction)

Oxidation reaction occurs at the anode when electrons are given up by an atom or molecule and when this happens, negative charge decreases. The anode has more negative potential with respect to the cathode and is termed less noble with respect to the cathode.

Oxidation of metal at the anode can be expressed as

$$M \rightarrow M^{n+} + ne^{-} \qquad 1.1$$

Cathode (Reduction reaction)

Reduction occurs at the cathode when electrons are gained by an atom or molecule, charges that are negative increases. The cathode has more positive potential with respect to the anode and is termed more noble with respect to the anode

$1.O_2 + 2H2O + 4e^{-} \rightarrow 4OH$ Aerated neutral to alkaline water 1.2

3. $2H^+ + 2e^- \rightarrow H\uparrow$ Hydrogen evolution (in acids)

4. $M^{n+} + ne^- \rightarrow M$ Metal deposition

5. $M^{n+} + e^- \rightarrow M^{(n-1)+}$ Metal reduction

Electrolyte

Electrolytes are substance that undergoes ionization when dissolved in water or ionizing solvents. It is the electrically conducive medium in which the anode and cathode reside.

Corrosion cells are created when there is an imbalance or non-equilibrium energy balance, causing a movement of energy from high levels to lower levels.

Corrosion of metallic materials can be categorized into two groups

- i. Wet Corrosion:

Also known as electrochemical corrosion occurs in an environment where liquid solution with dissolved elements such as (Cl^-, H_2S, CO_2 etc) serve as the corrosive media. The liquid is the electrolyte and the process is electrochemical.

For wet corrosion to occur there must be an anode, a cathode, an electrical potential difference between the electrodes, a metallic path electrically connected with both electrode and an electrically conducive medium.

- ii. Dry Corrosion:

Also known as chemical corrosion occurs when oxygen in the air reacts with metals without the presence of a liquid. It is not typically detrimental as wet corrosion, but it is temperature sensitive. When there is no water or moisture to aid corrosion, the metal oxidizes alone.

1.1.2 Types of Corrosion

Corrosion in the oil and gas pipeline and gathering system may occur in several forms and these forms will be properly discussed in details below.

Uniform corrosion: This type of corrosion is also regarded as general corrosion; it electrochemical and chemical reaction which takes place uniformly over the entire exposed surface. The metal becomes slimmer and may eventually crack.

Uniform corrosion is seen as the greatest form of destruction of metal when it occurs. However, this form of corrosion is not a great concerned as it is relatively easy to measure and predict thereby making failures of metals rare.

Figure. 1.2-Diagram of uniform corrosion

Localized Corrosion: This type of corrosion involves the selective removal of metal by corrosion at small areas on a metal surface that is in contact with a corrosive environment. Localized corrosion usually takes place when small areas are attacked at a much higher rate than the rest of the original surface. There are two types of Localized corrosion that is generally known: **Pitting corrosion and Crevice Corrosion.**

Pitting corrosion: Pitting corrosion is a localized form of corrosion which results in the formation of holes or cavities when it attacks materials. Pitting is considered to be dangerous than uniform corrosion because it is slightly more difficult to detect and predict. Theoretically, a local cell that initiates a pit can also be caused by abnormal anodic environment surrounded by normal surface which acts on the cathode. Pitting can be prevented by reducing the exposure to aggressive ions by shielding the part;

reducing the concentration of these ions in the environment surrounding the part, and minimizing the effect of the exposure to corrosive factors on those design elements that must not be worn out by pitting.

Figure. 1.3-Diagram of the pitting on corrosion

- **Crevice Corrosion:** Crevice is another form of localized form of corrosion that takes occurs in a confined space to which the working fluid from the environment is limited. This confined space is known as crevice. Examples of crevices aregaps and contact areas between parts, seals, inside cracks and seams.

  Crevice corrosion occurs in poorly gasketed flanges and under bolt heads and attachment components immersed in liquids. Because the surface attacked by crevice corrosion are partially shielded from exposure to the outer environment by materials adjacent to them, this type of corrosion is difficult control.

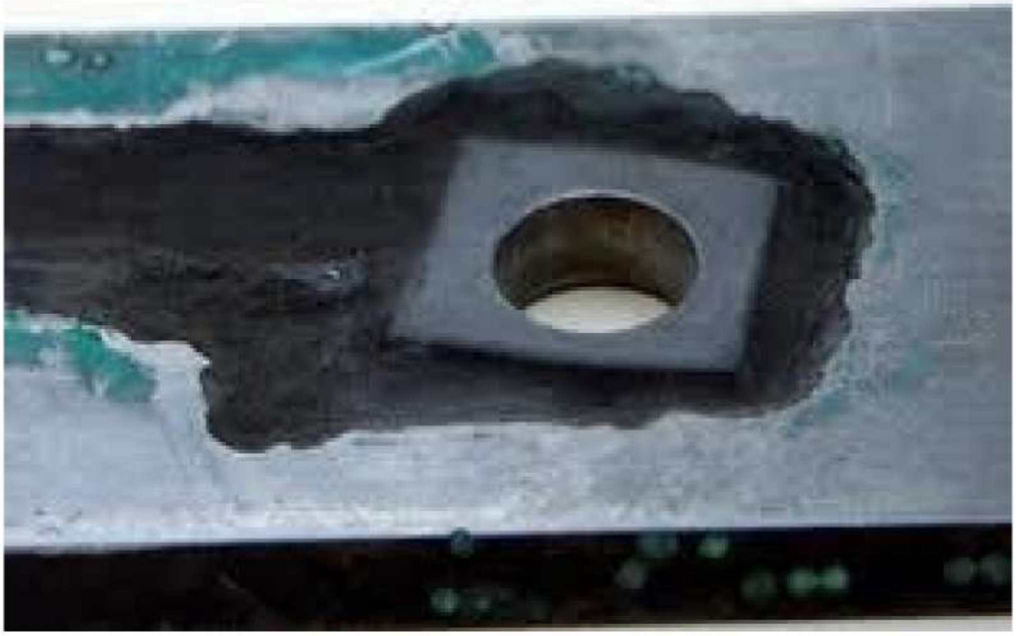


Figure 1.4-Diagram of the crevice corrosion

Galvanic Corrosion: Galvanic corrosion occurs when two different metals have physical or electric contact with each other and are immersed in a common electrolyte or when the same metal is exposed to an electrolyte with different concentrations.

A potential difference usually exists between two dissimilar metals when they are immersed in a corrosive or conductive media. When these metals are placed in contact, the potential difference produces electron flow between them. The less resistant metal is corroded relative to the cathodic metal. Magnesium to steel is one example, with magnesium being the metal that will take all the attack. If a metal mix is unavoidable, the two metals should be electrically insulated so that there is no path for current flow between the two. The use of combinations of metals which have potentials widely separated in galvanic series as well as combinations where the area of anodic metal is small relative to that of the cathode should be avoided. Chemical inhibitors reduces the galvanic effect when metals are being exposed to fluids.

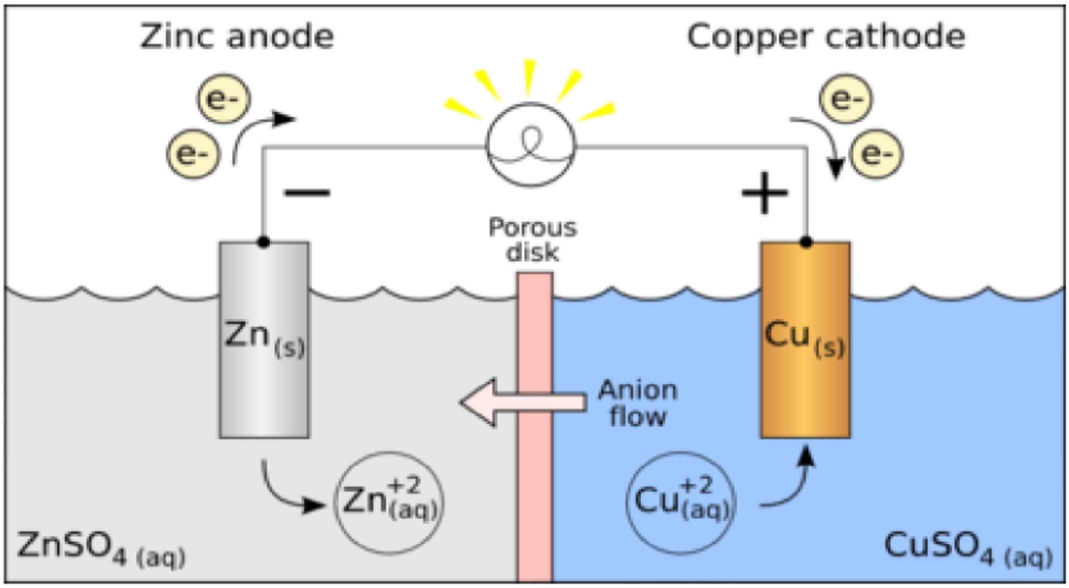


Figure 1.5-Diagram of the galvanic corrosion

Erosion Corrosion: Erosion corrosion is the accelerated rate of deterioration on metal because of relative movement between a corrosive fluid and the metal surface. The movement is rapid and mechanical wear effects or abrasion is involved. Metal is removed from the surface as dissolved ions or it forms solid corrosion products which are mechanically swept from the metal surface. Often times, the movement of the environment reduces corrosion, especially when localized attack occurs under stagnant conditions, but this is not erosion because deterioration in not increased.

Erosion corrosion is categorized in appearance by gullies, rounded holes and valleys which usually exhibit a directional pattern. In many aspects, failures caused by erosion occur in a relatively short time and they are unexpected because erosion effects were not considered.

Failure of pipes and material at an accelerated rate that is caused by relative movement between a corrosive fluid and a metal surface is called erosion corrosion. The fluid velocity is generally high. Mechanical wear may include abrasion when the fluid contains suspended solids. Erosion destroys protective surface films and enhances chemical attack. Erosion corrosion may occur in two forms such as cavitation and fretting.

Cavitation is a special kind of erosion corrosion which arises from the formation and collapse of water bubbles near the surface of metals. Rapid bubble collapse can produce shock waves that cause local deformation of the metal surface. Materials that have a good resistance to cavitations have tenacious passive films, high strength and hardness.

Fretting is another form of erosion corrosion which is often referred to as wear or rubbing corrosion. It takes place between two surfaces under load that are subjected to cycles of relative motion of small amplitude. Fretting creates a breakdown of the surface into oxide debris and results in surface pits and cracks. Examples of fretting include press fits, bolted and riveted connections and machine components that experience vibration.

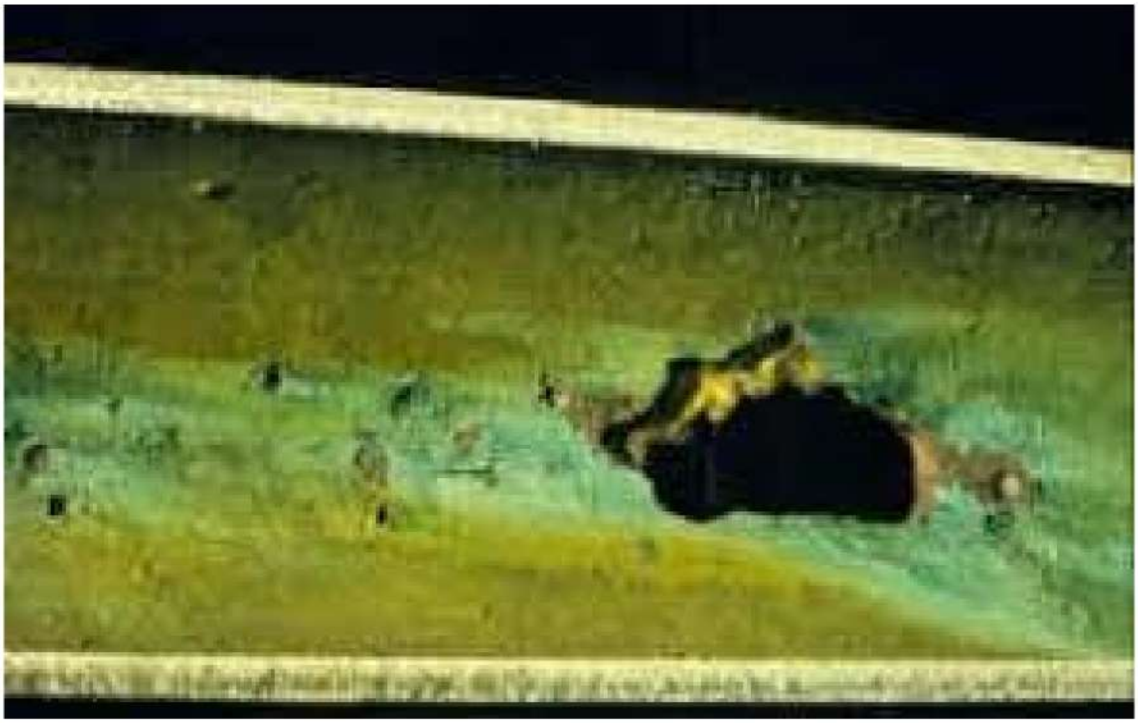


Figure 1.6-Diagram of the erosion corrosion

Other forms of erosion-corrosion are:

Liquid impingement is another form of erosion corrosion in which material removal is caused by an action of an impinging stream of fluid. The mechanism of attack involves the removal of protective films, which leads to an accelerated corrosion.

Liquid Erosion is similar to impingement however the difference is that the fluid flow is parallel to the surface. The mechanism involves the removal of metals or films by mechanical action plus corrosion of the active metal.

Slurry Erosion involves metal removal due to the combine action of wear and corrosion. The source of wear and an acceleration of corrosion are abrasive particles dispersed in the slurry. The best system to control slurry erosion is through ceramics and elastomers.

Microbial Influenced corrosion: This form of corrosion refers to corrosion affected by the presence or activity or both, of microorganism. There are hundreds of bacteria known to cause microbiologically influenced corrosion of carbon steel, stainless steel, aluminum and copper alloy in water and soils. Microbiologically influenced corrosion is caused by a specific general of bacteria which feed on nutrients and other element found in water and soils. The biological activities modify the local chemistry and render it more corrosive to the metals.

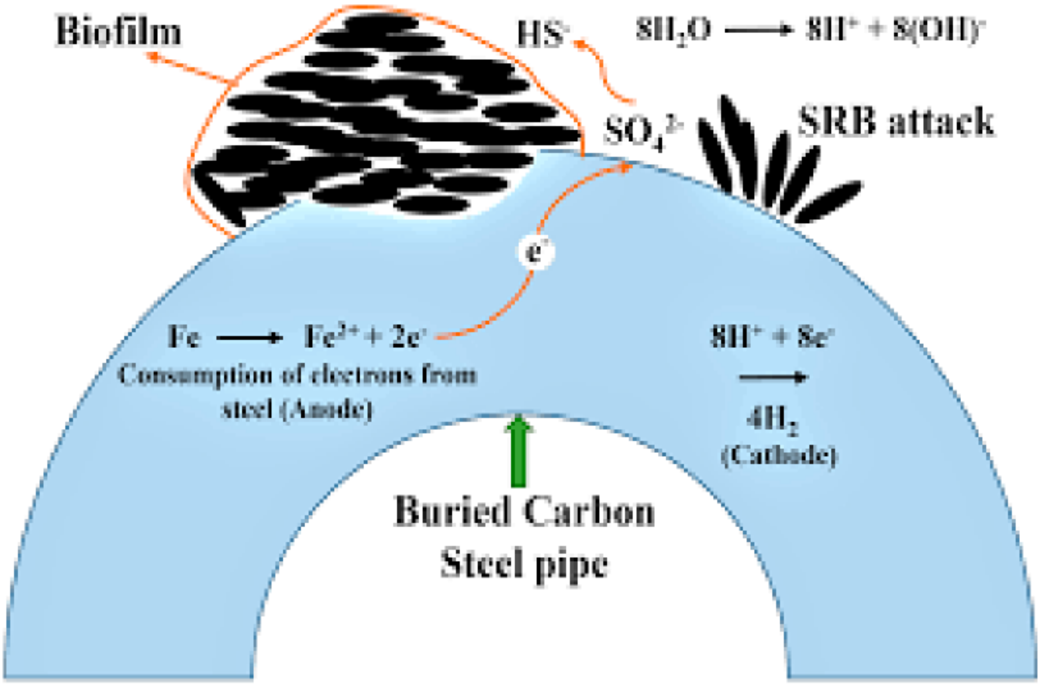


Figure 1.7-Diagram of the microbial influenced corrosion

Environmentally Assisted Cracking:

occurs due to the adverse effect of the environment which is predominantly from corrosive environments. It can take place when the following factors stress, materials and environment are aligned. This type of cracking can be identified by pits around the crack.

1. Environment: a corrosive environment is the main reason for environment-assisted cracking. When there are high levels of impurities, dissolved oxygen and wetness in the stream, a high corrosive environment is created

2. Material: when the strength and impurities of materials are increased, environmental assisted cracking is easier.

3. Stress: Environment assisted cracking occurs preferentially where the local stress is high

Stress- corrosion cracking: in this kind of corrosion, material deterioration is due not to significant material removal but to crack. Cracking caused by the simultaneous action of a tensile stress and a specific corrosive medium is known as stress-corrosion. This type of corrosion is time dependent that is, it may sometimes take minutes or several months. The mechanism of stress corrosion cracking is a very complex phenomenon not yet fully understood.

It can occur in many plastics, aluminum, copper, magnesium and other alloys as well as titanium and carbon steels. An example of a special kind of corrosion cracking is exfoliation, or scaling of a surface in flakes /layers as a result of corrosion. Rolled or extruded steel and some aluminum alloys with elongated or flattened grains as well as many plastic materials can manifest exfoliation.

Figure 1.8-Diagram of Stress- corrosion cracking

1.1.3 Types of corrosion in pipeline

In a pipeline or gathering system, there are two types of corrosion that occurs when CO_2 and H_2S are present in crude oil: sweet and sour corrosion.

Sweet Corrosion: Carbon Dioxides

CO_2 consist of one atom of carbon with two atoms of oxygen. It is a corrosive compound found in natural gas, crude oil, and condensate. It is one of the most common environments in the oil field industry where corrosion occurs.

Carbon dioxide is a weak acidic gas and becomes corrosive when dissolved in water. CO_2 corrosion is most common in areas of flowing wells, gas condensate wells, areas where water condenses, tanks filled with CO2, saturated produced water, and pipelines, which are generally corroded at a slower rate because of lower temperatures and pressures. CO2 corrosion is enhanced in the presence of both oxygen and organic acids, which can act to dissolve iron carbonate scale and prevent further scaling.

The most common forms of corrosion when CO2 is present include uniform corrosion, pitting corrosion, wormhole attack, galvanic corrosion, heat-affected corrosion, mesa attack, raindrop corrosion, erosion corrosion, and corrosion fatigue. Corrosion rates in a CO2 system can reach very high levels (thousands of mils per year), but it can be effectively inhibited.

Sour Corrosion: Hydrogen Sulfide

Hydrogen sulfide is a flammable and poisonous gas that is formed from decomposing underground deposits of organic matter such as decaying plant material. It is often present in wells drilled in shale or sandstone, or near coal or peat deposits or oil fields. Hydrogen sulfide gas produces an offensive "rotten egg" or "sulfur water" odor and taste in water.

Wells with large amounts of H2S or wells with only 10 ppm or above are usually labeled sour and this gas occurs in approximately 40% of all wells. Partial pressures above 0.05 psi H2S are considered corrosive. The amount of H2S increases as the well ages and when this gas combines with water it forms a strong corrosive sulfuric acid (H_2SO_4).

A nuisance associated with hydrogen sulfide includes its corrosiveness to metals such as iron, steel, copper, and brass. It can tarnish silverware and discolor copper and brass utensils.

1.2 Internal pipeline corrosion and the influence of various factors of corrosion.

When hydrocarbon containing CO_2, H_2S and water are flowing through a pipeline, certain parameters will influence the rate of internal pipeline corrosion and these parameters will be explained

1.2.1 Nature of the metal: Metal with more potential are relatively stable and those with more negative potential are unstable according to electrochemical series. Corrosion of metal can be predicted if the electrode potential of the metals in some electrolyte is known. The electromotive force is the difference between the electric potentials of the cathodic and anodic reactions.

1.2.2 Surface of the metal: The surface state of a metal can determine the rate of corrosion. Highly polished surface resists corrosion while a rough surface containing various types of imperfections like dislocations, point defect are liable to severe attack.

1.2.3 Environment: Moisture is the most important factor that causes corrosion. Moisture present in the air often contains contaminants such as chlorides, sulfates, nitrates and other chemicals which accelerate corrosion. Sealed compartments can expand and contract with temperature variations, allowing moisture to enter. Temperature variations also cause condensation on equipment. Accumulation of dirt and debris can hold moisture against equipment, accelerating the corrosion process.

1.2.4 Concentration of Electrolyte: Concentration cells occur when the concentration of electrolyte in contact with the metal is different in two contact locations. The extent of this corrosion reaction is proportional to the difference in concentration at contact point. It also varies with the type of electrolyte. If an area of the electrolyte close to the metal shows a lowered concentration of metal ions, the region turns anodic in comparism to different portion of the metal surface. Therefore, this part of the metal corrodes faster, so as to increase the local ion concentration in the electrolyte.

1.2.5 Temperature of the medium: Corrosion is an actively controlled chemical reaction in which the rate is greatly affected by temperature. Increase in temperature directly leads to a higher corrosion rate because electrochemical reactions generally occur faster at higher temperatures. Temperature also has an effect on the formation of protective film. At lower temperatures the corrosion product can be easily removed by flowing liquid. At higher temperatures the film becomes more protective and less easily washed away. Further increases in temperature result in a lower corrosion rate and the corrosion rate goes through a maximum.

1.2.6 Diffusion of Oxygen: In most cases, the rates of corrosion in metals are controlled by the diffusion of reactants to and from the metal surface. Freshly exposed bare steel surfaces will corrode at a higher rate than those covered with a compact layer of rust. The corrosion rate is also heavily controlled by the diffusion of oxygen through the water to the steel surface. In areas where oxygen diffusion is prevalent, corrosion appears to occur at faster rates.

1.2.7 Conductivity of Metals: Corrosion will occur when there is a conductive medium between two parts of the corrosion reaction. Corrosion will not take place in distilled water and the rate of corrosion will increase as the conductivity increases due to the presence of more ions in the solution. The corrosion rate of metals (steel) reaches a maximum close to the normal ionic content of water.

1.2.8 Acidity and alkalinity of the Solution: pH is a measure of the acidity and alkalinity on a scale of 1 to 14. The pH value is a measure of the hydrogen ion concentration in a solution. A Ph value of 7 is neutral. The values of pH lower than 7 are acidic and values higher than 7 are alkaline. For metals like zinc, iron, magnesium etc, hydrogen evolution will thermodynamically favored cathodic reaction. Corrosion of each metal in acidic medium is therefore high.

1.2.9 Inhibitors and Chemical Additives: Inhibitors can reduce the corrosion rate by presenting a protective film. The presence of the proper inhibitors with optimum dosage can maintain the corrosion rate at 0.1 mm/year. Inhibitor usage can greatly decrease corrosion rates and, hence, increase pipeline life. The impingement of sand particles can destroy the inhibitor film and, therefore, reduce inhibitor efficiency.

1.3 Method for protecting pipeline from corrosion

The growing need of metal in every walk of life and loss of it by corrosion has put a big question before humanity regarding how to avoid corrosion so that it can be used to its maximum extent. The following methods are considered as the procedures for protecting pipeline from corrosion.

1.3.1 Selection and Design of appropriate materials

Once it is detected that the materials of construction are prone to corrosive attack, it is normally certain to change the materials of construction and select alternate materials to suit the specific need. Stainless steels cover a wide range of alloys, each with a particular combination of corrosion resistance and mechanical properties. In oil and gas applications, many of these stainless steel grades are used, depending on the demands of the particular service environment.

Metallic corrosion can be prevented by either changing the metal or altering the environment, or by separating the metal from the environment or changing the electrode potential of the metal. A large number of corrosion failures are due to improper design of equipment and the corrosion control can therefore be warranted at the design stage itself.

1.3.2 Use of inhibitors

Corrosion inhibitors are chemicals that are added in small quantities to a corrosive environment to effectively decrease the corrosion rate of the metal. They normally work by adsorbing themselves to form a film on the metallic surface. Inhibitors are normally distributed from a solution or by dispersion. They reduce the corrosion process by either:

- Increasing the anodic or cathodic polarization behavior;
- Reducing the movement or diffusion of ions to the metallic surface;
- Increasing the electrical resistance of the metallic surface.

Classification of Inhibitors

- **Anodic inhibitors (Passivating inhibitors);** acts by a reducing anodic reaction, that is, it blocks the anode reaction and supports the natural reaction of passivation metal surface due to the forming of a film adsorbed on the metal. There are two types of anodic inhibitors: oxidizing anions such as chromate, nitrite, and nitrate, that can passivate steel in the absence of oxygen and the nonoxidizing ions, such as phosphate, tungstate, and molybdate, that require the presence of oxygen to passivate steel. These inhibitors are the most effective and consequently the most widely used.

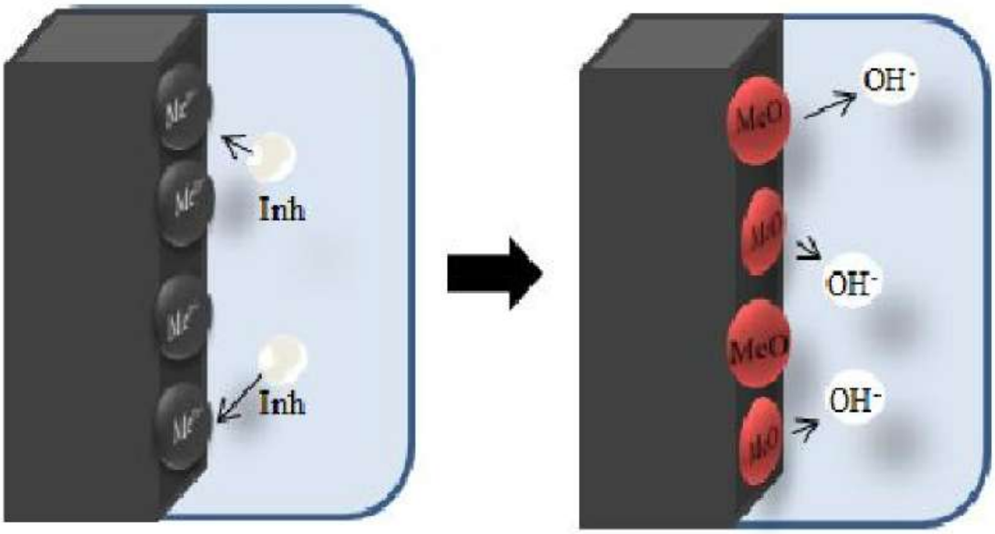


Figure 1.9-Illustration of anodic inhibitor

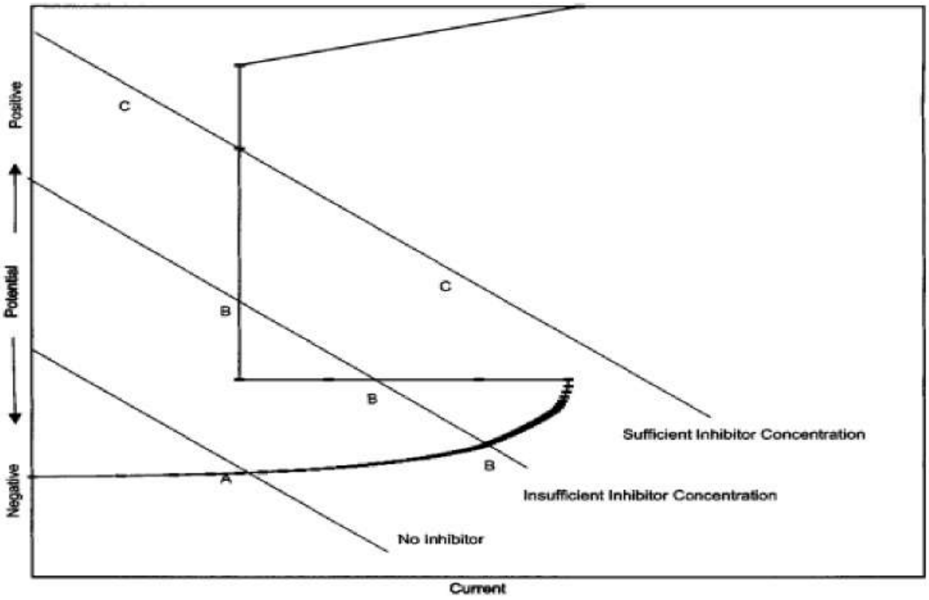


Figure 1.10-polarization diagram of an active passive metal showing the dependence of current on passivate inhibitors

- **Cathodic inhibitors;** Cathodic inhibitors either slow or prevent the occurrence of cathodic reaction of the metals or selectively precipitate on cathodic sites to increase the surface impedance and limit the diffusion of reducible species to these sites. Cathodic inhibitors can provide inhibition by three different mechanisms:

(1) as cathodic poisons,

(2) as cathodic precipitates, and

(3) as oxygen scavengers.

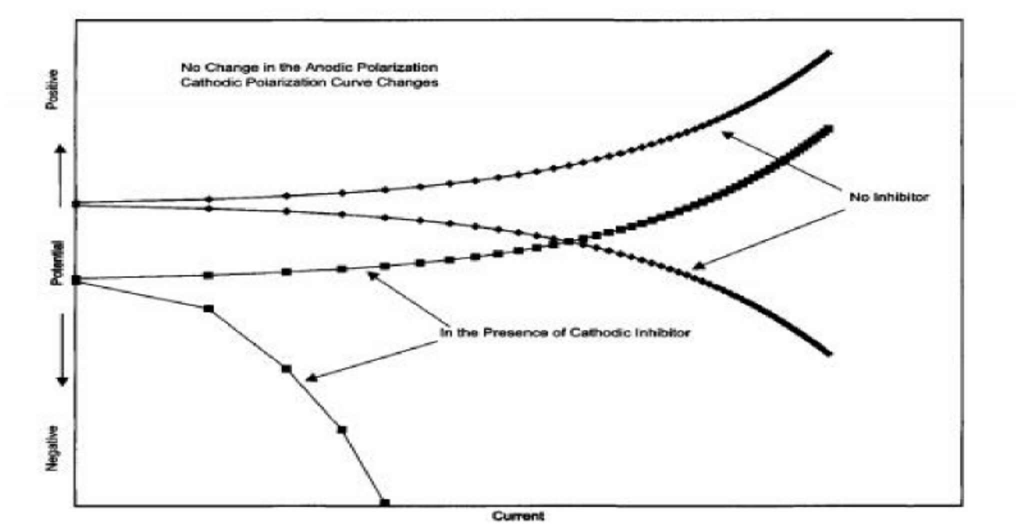


Figure 1.11-polarization curve in the presence of cathodic inhibitors

Some cathodic inhibitors, such as compounds of arsenic and antimony, work by making the recombination and discharge of hydrogen more difficult. Other cathodic inhibitors, ions such as calcium, zinc, or magnesium, may be precipitated as oxides to form a protective layer on the metal. Oxygen scavengers help to inhibit corrosion by preventing the cathodic depolarization caused by oxygen

- **Precipitation inhibitors;** Precipitation-inducing inhibitors are film-forming substance that blocks both anodic and cathodic sites indirectly and have a general action over the metal surface. Precipitation inhibitors are compounds that cause the formation of precipitates on the surface of the metal, thereby providing a protective film. Hard water that is high in calcium and magnesium is less corrosive than soft water because of the tendency of the salts in the hard water to precipitate on the surface of the metal and form a protective film. The most common precipitation inhibitors are the silicates and the phosphates.
- **Organic inhibitors:** Organic inhibitors affect the entire surface of a corroding metal when present in sufficient concentration. It protects the metal by forming a hydrophobic film on the metal surface. Their effectiveness depends on the

chemical composition, their molecular structure, and their affinities for the metal surface.

Organic inhibitors will be adsorbed according to the ionic charge of the inhibitor and the charge on the surface. The strength of the adsorption bond is the dominant factor for soluble organic inhibitors. These materials build up a protective film of adsorbed molecules on the metal surface, which provides a barrier to the dissolution of the metal in the electrolyte. Because the metal surface covered is proportional to the inhibitor concentrates, the concentration of the inhibitor in the medium is critical. For any specific inhibitor in any given medium there is an optimal concentration. Both anodic and cathodic effects may be observed in the presence of organic inhibitors.

- **Volatile corrosion inhibitors.** Volatile corrosion inhibitors also called vapor phase inhibitors are compounds transported in a closed environment to the site of corrosion by volatilization from a source.

Volatile corrosion inhibitors. are used to protect ferrous materials and non-ferroumetals against corrosion or oxidation where it is impractical to apply surface treatments. In closed vapor spaces, such as shipping containers, volatile solids such as salts of dicyclohexylamine, cyclohexylamine, and hexamethylene-amine are used.

On contact with the metal surface, the vapor of these salts condenses and is hydrolyzed by any moisture to liberate protective ions. It is desirable, for an efficient Volatile corrosion inhibitors, to provide inhibition rapidly and to last for long periods. Both qualities depend on the volatility of these compounds, fast action wanting high volatility, whereas enduring protection requires low volatility

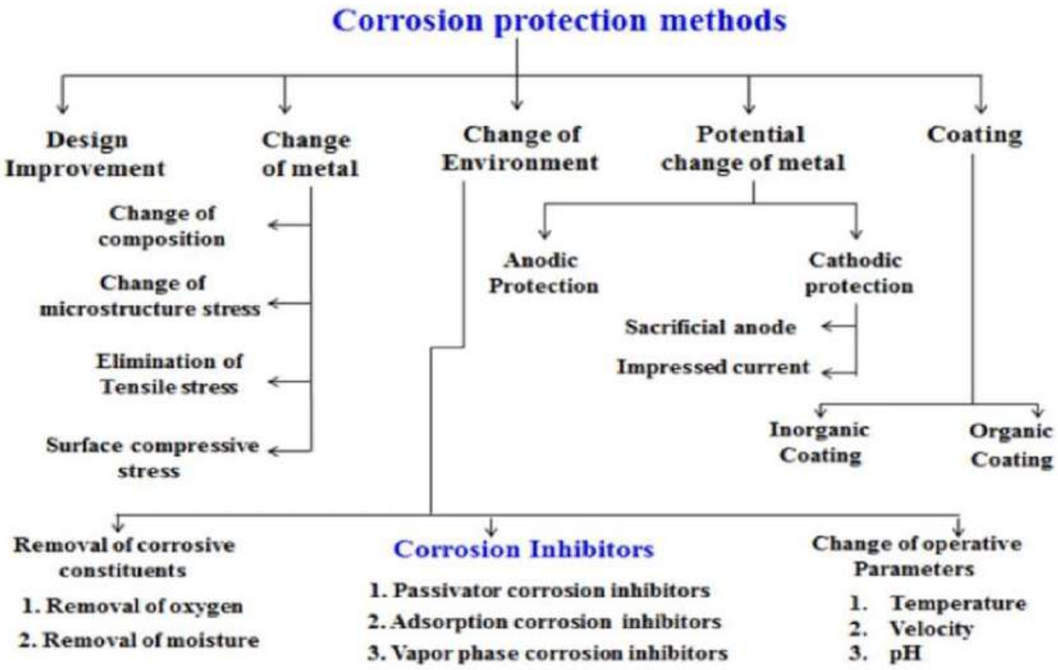


Figure 1.12-Illustration of corrosion protection method

1.3.3 Use of protective coatings:

A protective coating is a layer of material applied to the surface of another material with the intent of inhibiting or preventing corrosion. A protective coating may be metallic or non-metallic. Protective coatings are applied using a variety of methods and can be used for many other purposes besides corrosion prevention.

Commonly used materials in non-metallic protective coatings include polymers, epoxies and polyurethanes and materials used for metallic protective coatings include zinc, aluminum and chromium. A zinc coating over steel is an example of a reactive protective coating. The zinc reacts with the atmosphere more readily than the steel, thus preventing the oxidation of the steel.

A protective coating can be painted on, sprayed on, plated on or even welded onto a material. Polymer coatings are commonly sprayed on. Zinc protective coatings are typically applied by the electroplating or hot dipping galvanizing method.

I. Hot dip Galvanizing

Hot dip galvanizing is a process of coating fabricated steel by immersing it in a bath of molten zinc. There are three steps in hot- dip galvanizing process: surface preparation, galvanizing and inspection.

Surface preparation includes cleaning, degreasing, pickling and fluxing. Degreasing removes dirt, oil and organic residues, while the acidic picking bath will remove mill scale of iron oxide. Fluxing is done to remove any remaining oxides and coat the steel with a protective layer to prevent any further oxide formation prior to galvanizing.

Galvanizing is done after surface preparation. The steel is dipped in the molten bath of at least 98% zinc. The steel is lowered into an angle that allows air to escape from other pockets. While immersed in the kettle, the iron in the steel metallurgical reacts with the zinc to form a series of zinc-iron intermetallic layers and an out layer of pure zinc.

Inspection is the final step of the coating. Determination of accurate quality of coating can be achieved by a visual inspection. Magnetic thickness gauge can also be used to verify the thickness of coating that complies with specification requirements.

2. Electroplating

This is the application of electrolytic cells in which thin layer of metals are deposited onto an electrically conductive surface. A cell consists of two electrodes usually metal, which is held apart from each other.

Positive ions in the electrolyte move to the negatively charged ion when an electric current is turned on, this charge is called cathode. At the same time negatively charged ions move to the positive electrode called anode.

1.3.4 Cathodic protection technique:

Cathodic protection is an electrical method used to reduce corrosion rates of metallic structures in electrolytes such as water. The first application of cathodic protection was credited to Sir Humphrey Davy in 1824, long before its theoretical foundation. Cathodic protection is a method used to reduce corrosion by minimizing the potential difference between anode and cathode.

This is achieved by applying a current to the pipeline from some outside source. When enough current is applied, the whole structure will be at one potential; thus, anode and cathode sites will not exist. It is normally used in combination with coatings and can be considered as a secondary corrosion control technique.

The cathodic protection system can be designed to prevent both oxygen-controlled and microbiologically controlled corrosion. The two methods of applying cathodic are:

-Galvanic anode cathodic protection (GACP)

-Impressed current cathodic protection (ICCP)

The main difference between the two is that impressed current cathodic protection uses an external power source with inert anodes and galvanic anode cathodic protection uses the naturally occurring electrochemical potential difference between different metallic elements to provide protection.

- Galvanic anode cathodic protection

In this type of application, the naturally occurring electrochemical potentials of different metals are used to provide protection. Galvanic anode are coupled to the structure under protection and conventional current flows from the anode to the structure as long as the anode is more active than the structure. As the current flows, all the corrosions occur on the anode which sacrifices itself in order to offer protection from corrosion to the structure.

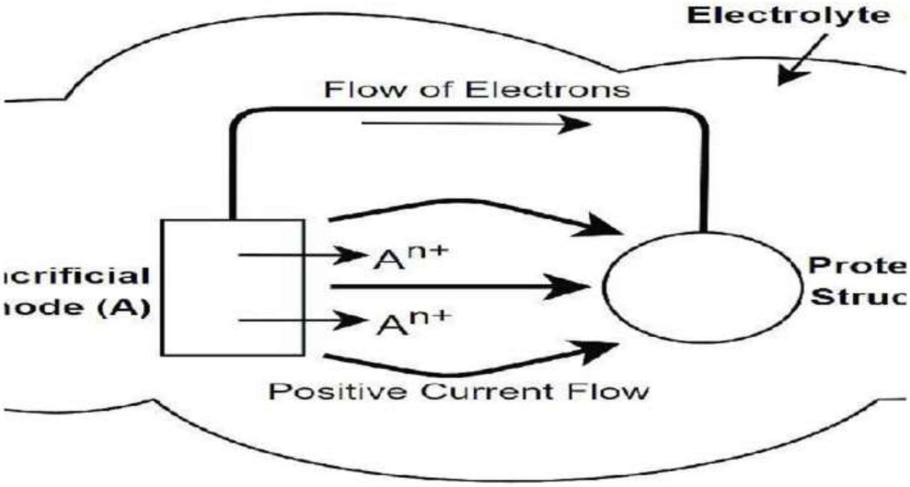


Figure 1.13-Schematic of sacrificial anode cathode protection

- Impressed Current Cathodic Protection (ICCP)

In impressed current cathodic protection, the current is forced by a power supply. The power source must be able to deliver direct current, and examples are transformer rectifier units, solar generating units, or thermoelectric generators. The anodes are either inert or have low consumption rates and can be surrounded by carbonaceous backfill to increase efficiency and decrease costs. Typical anodes are titanium coated with mixed metal oxide or platinum, silicon iron, graphite, and magnetite

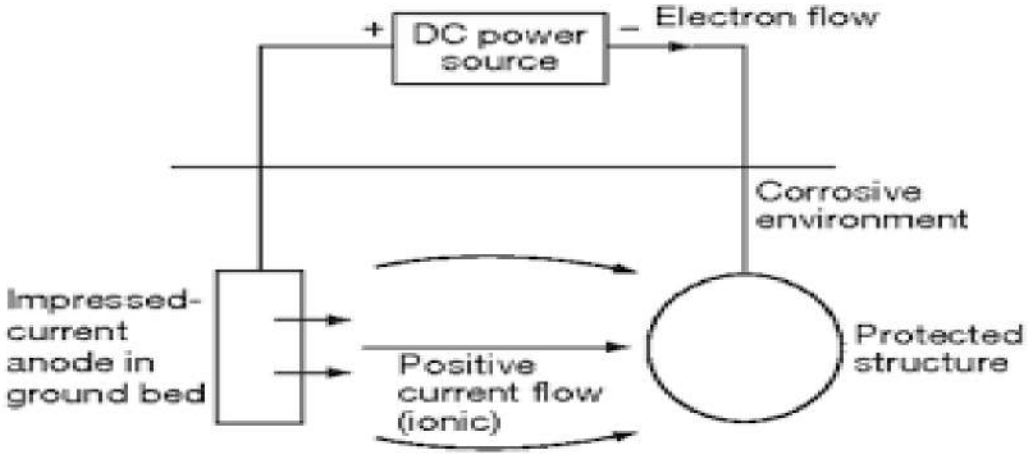


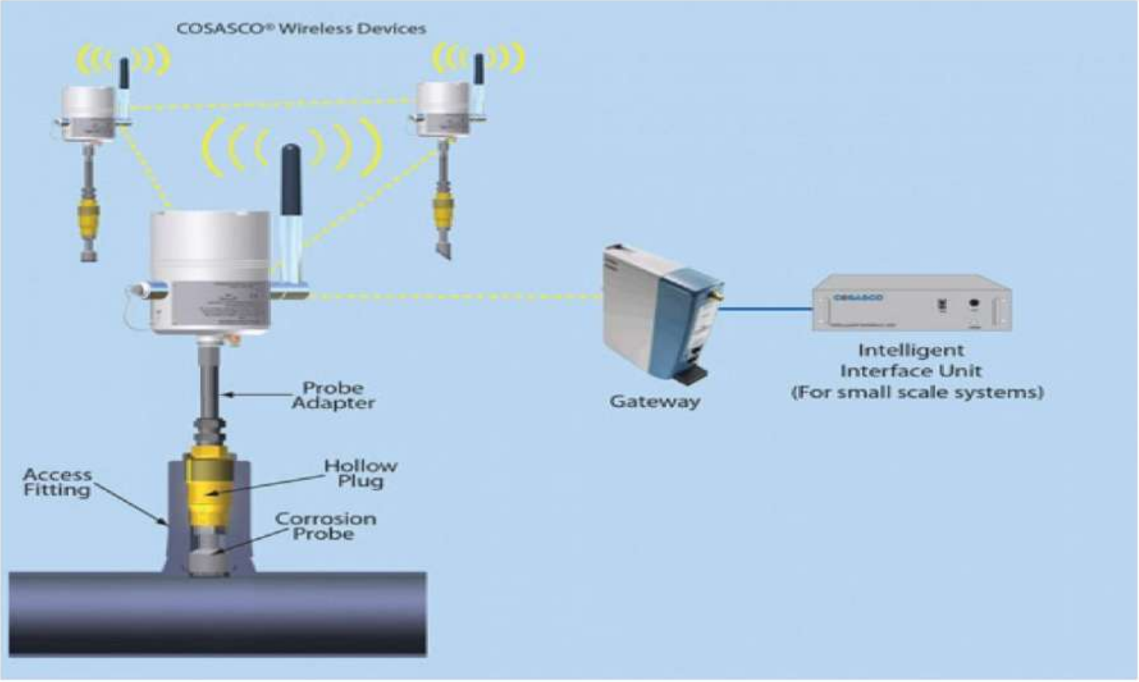
Figure 1.14-Schematic of Impressed Current Cathodic Protection

1.2.5 Adequate corrosion monitoring and inspection:

Corrosion monitoring and inspection is the practice of measuring the corrosivity of process stream (like pipelines) conditions by the use of mechanical, electrical or electrochemical devices known as probes which are inserted into the process stream and constantly exposed to the process stream condition.

Monitoring techniques can provide direct and online measurement of metal loss or corrosion rate in oil and gas process systems. One of the methods is to carry out on-stream inspection by doing the wall thickness measurements periodically on fixed and vulnerable locations of the equipment, piping, and pipelines to assess the material conditions and corrosion rate. Also corrosion is monitored by placing electronic probes in the pipelines and measuring the change in the electric resistance in the probe coil.

The cross-country pipelines are normally checked with intelligent pigging operations like magnetic flux or ultrasonic pigs. These pigs will detect the internal conditions of the pipeline and corrosion conditions on the pipe wall thickness and also indicate the wall thickness available on the pipe wall.



1.16-Corrosion monitoring device

1.4 Conclusion to this section

This chapter has highlighted the general information about metal corrosion, the influence of various and physical, chemical and environmental factors that causes corrosion in oil and gas pipelines. It further explains the characteristics of the different types of corrosion, and the methods of protecting oil gathering pipelines from the danger of corrosion to human, their environmental and the economy.

The effects of corrosion have proven to be a threat to the sustainability and efficiency of pipelines in the distribution of oil and gas from the production sites to the end users. The effect of corrosion has led to mechanical reduction of the strength of oil and gas pipes, which leads to leakages. Leakages are dangerous because they expose the populations to the risk of explosions and fires, as well as damaging the surrounding environment.

Ways to manage corrosion as discussed includes planned actions for determination of corrosion risk, material designs, and correct selection of materials which involves choosing the right materials which should have the following properties of high mechanical strength, high corrosion resistance and low in cost. Corrosion protection with the aid of surface coating materials should be able to resist direct attack from the environment, and should not be very hard.

Cathodic inhibitors absorbs on metals to form protective film which is used to protect the metal surface and also monitoring methods with the aid of probes to measure the corrosiveness in pipeline. This methods should be considered at the stage of design and then their realization in practice under inspection, control, and monitoring