

# Corrosion: Causes and Prevention

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Corrosion is fundamentally an electro-chemical reaction which takes place between cations or positively charged ions of the metal and anions or negatively charged ions of environment. Under conditions of corrosion the metal undergoes a chemical change and becomes less mechanically resistant under stress. It also becomes more susceptible to continued chemical attack resulting in the oxidation of the metal and the formation of corrosion product. An electro-chemical reaction requires an electrolyte to carry the current. The electrolyte may be any solution from moist air to a strong acid. Corrosion will not occur in a totally dry environment unless high temperatures are involved. In the latter case, the temperature increases ion activity to a point where ion exchange can occur without an electrolyte.

## FACTORS RESPONSIBLE FOR CORROSION

When two different metals are placed in an electrolyte each metal will exert a characteristic electro-chemical potential relative to the electrolyte. The difference in these potentials is the emf of the overall reaction and this determines the driving force of the reaction. The metal with higher negative potential relative to electrolyte is termed as Anode and the metal with lower potential is the Cathode. The anodic metal undergoes corrosion because it is here the metal is oxidised while the cathodic metal is protected. Establishing corrosion resistance is nothing more than reducing the flow of electrons between the anode and cathode. Corrosion will not occur if the flow is zero. This is possible by choosing materials that are at equal potentials in a given environment. The purity of the metal, the composition and interrelation of all the substances with which it comes in contact, the presence of bacteria, the possibility of minute

*Corrosion is one of the most serious problems confronting the Engineers of Paper Industry. The article covers the factors responsible for corrosion and various types of corrosion and its prevention. The author has also reviewed about Stainless Steel and the Corrosion in an integrated Pulp & Paper Industry*

externally produced electric currents being present, may also affect corrosion.

Before dealing with various types of corrosion and its prevention it is highly essential for the Engineers of Pulp & Paper Industry to have a thorough knowledge about the properties of various metals and alloys particularly the versatile alloy "Stainless Steel".

## STAINLESS STEEL

Use of Stainless Steel is well-established for the production of quality papers. Cleanliness and freedom from rust or iron pick up is specially important for the production of high grade papers. Corrosion is one of the most serious problems confronting the Engineer in Paper Industry. Wide range of Stainless Steels offer excellent resistance to corrosion.

The Stainless Steel is commonly specified by AISI Standards. AISI stands for American Iron & Steel Institute. These numbers have three digits ranging from 300 series to 500 series. The Steels in 300 series are the Iron-Chromium-Nickel alloys. They are austenitic, non-magnetic and not hardenable by conventional heat treatment. Those in 400 series are ferritic or martensitic and are either hardenable or not hardenable by heat treatment, depending on composition. They are mostly the straight Iron-Chromium types. The 500 series are relatively low alloy steels.

Stainless Steels comprise a group of modern alloys which are by definition a wide range of alloy steels containing a minimum of 11.5% Chromium with or without the addition of other elements. Chromium provides basic corrosion resistance and supplies fundamental passivity by forming an inert layer of Chromium oxide on the surface of steel which resists further corrosion and

makes the steel stainless. The Chromium content varies from 12% to 28% according to end use. Nickel, the second important alloying element also increases corrosion resistance and its principle value lies in facilitating fabrication of the alloy. A necessary alloying element is carbon which is useful in producing hardness. Carbon consumes seventeen times its weight in Chromium to form Chromium Carbide and so carbon must be carefully balanced in composition to achieve desired properties of the alloy.

## VARIOUS TYPES OF CORROSION AND ITS PREVENTION

1. **Intergranular Corrosion** is a selective attack on the grain boundaries of metal or closely adjacent material without appreciable attack on the grains themselves. The attack destroys the metal to the depth it has progressed and makes the metallic grain to fall out of a piece of steel. In austenitic stainless steel, this type of corrosion is the result of carbide precipitation along grain boundaries which causes depletion of Chromium around these areas. This takes place at temperatures in the neighbourhood of 1200°F. Since much fabrication works such as forging welding and flanging is done around these temperatures, it is obvious that after such treatment the alloy will not be in the best state of corrosion resistance. A heat treatment consisting of heating the alloy piece to a temperature of 1900-2100°F followed by rapid cooling will readjust the chromium to its corrosion resistant state. When such treatment is not possible, a titanium content of about five times the carbon or niobium content of ten times the carbon gives virtual immunity from intergranular corrosion. Carbide formation can

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also be prevented by maintaining the lowest possible carbon content i.e. 0.03 per cent carbon.

2. **Galvanic Corrosion** occur when dissimilar metals are in electrical contact when immersed in an electrolyte. It is some times possible to reduce this corrosion by creating conditions under which an electric current, opposite in direction to the small current, is formed in the corroding metal. This method called "Cathodic Protection" is illustrated by galvanising or zinc coating of mild steel. The zinc corrodes in preference to the steel, the positive current flowing from the steel to the zinc. The zinc coating slowly disappears but it has delayed the rusting of steel. This effect is described as "Sacrificial protection".
3. **Pitting Corrosion** takes place when two areas of the same metal are subjected to different ion concentration. Such a condition can occur within a simple rotary pump handling water at high velocities, a differential concentration of ions occurring between the centre and the circumference of the Impeller. Due to higher circumferential velocity, ions are removed from the vicinity of the Impeller rim faster than at the region near the shaft. Resulting from this, the rim of the Impeller may become anodic to the centre and consequently series of corrosion cells are set up rapidly producing familiar pitting corrosion on the disc and at the tip of the Impeller. A flaw in the surface or a crevice will contain a stagnant electrolyte so that ion concentration can build up. If the crevice is deep as between the flange and a gasket, failure will occur long before ion equilibrium can take place. The above corrosion can be minimised by careful design and fabricating to eliminate crevices by polishing the exposed surface of equipment. The addition of Molybdenum in 18-8 type alloys is beneficial. Silicon addition is also beneficial but carbon, selenium and titanium are detrimental.
4. **Internal Stresses** due to such operations as cold working and quen-

ching and stresses due to applied loads will make a metal or alloy more anodic and tend to increase the rate of corrosion. Since the stresses may be highly concentrated about the point of attack, the material fail by cracking. It can be minimised by (a) treatments to relieve internal stresses (b) adjusting compositions, including the elimination of certain impurities. **Stress Corrosion** in Brass takes place in presence of Ammonia, for Stainless Steel in presence of chlorides and for Mild Steel in presence of strong Caustic Soda. The addition of titanium is beneficial for austenitic stainless steel.

5. **Erosion — Corrosion** is caused by the high velocity streams of solutions or vapours particularly when the high velocity stream contains suspended solids or is turbulent or impinges on the surface. It has been found that the flow of liquid can be quite critical according to whether it is streamlined or turbulent. In the latter case, a phenomenon as cavitation corrosion can develop, whereby small vacuum cavities are formed which on collapsing have the property of peeling the protective film away from the surface of the metal, thus exposing it to more corrosion. Erosion very effectively removes even the passive chromium oxide layer from Stainless Steel. The best cure for Erosion is proper design and the use of precipitation hardening steel.

#### CORROSION IN PAPER MACHINE

The very high level of humidity in the Machine House is the cause of corrosion in Machine Structures and Frame Work. Epoxy resins have a very useful application to such items which suffer from severe rusting.

Corrosion in Stock Pipe Lines may be frequent source of trouble particularly where low pH specification is obtained by addition of Aluminium Sulphate. Serious corrosion has been experienced at pH value less than 5.0.

The Corrosion of Dryers particularly M. G. Cylinder can be serious embarrassment and is severe at low pH values. Surface roughening and numerous

pitted areas are caused in the Paper making area of the Cylinder. It is assumed that the sheet moisture acts as an electrolytic medium and the corrosion current under the acidic conditions will be much higher when the medium is neutral or slightly alkaline. The possibility of Cylinder corrosion is certainly increased by the presence of certain anions in the sheet moisture and the chloride ions have a particularly serious effect on ferritic cast iron under acidic conditions. Hence, sulphuric acid should always be used in preference in Hydrochloric acid if it is necessary to adjust the pH value. Still, if, the machine water has high chloride content, (100 ppm as Chloride ion) it would encourage corrosion attack. Under such conditions the use of superior grade of austenitic cast Iron with much higher Nickel content is recommended. Further, due to corrosion and erosion of Machine wire under acidic conditions, the particles of copper are subsequently carried forward to the Dryer Section where, particularly with an M. G. Cylinder corrosion cells are set up with distributed copper particles acting as cathode and the cylinder surface as anode in acidic conditions and higher surface temperature of the Cylinder. Principle of cathodic protection is applied by means of specially designed doctor blades making the surface of the cylinder uniformly cathodic and thus preventing the occurrence of anodic areas on the surface. A continuous current is applied in opposition to the current set up by surface corrosion cells.

Acidity, high chloride ion concentration and free residual chlorine in water will contribute positively to corrosion of machine wire. Sulphate reducing bacteria producing hydrogen sulphide is responsible for the attack on copper alloys causing rapid loss of tensile strength due to intergranular corrosion. Addition of certain organic inhibitors to machine system is recommended. It protects the machine wire by forming a strong elastic film. This film acts as a barrier to the corrosive action of machine stock at low pH value in the region of 4.0. Wire cleaning also should normally be done with inhibited sulphuric acid or sulfamic acid.

## CORROSION IN PULP AND RECOVERY UNIT

Corrosion is not a problem in Soda Mill. So the sulphide content of sulphate mill liquors is clearly the cause of corrosion. Corrosion is most severe with strong white liquor and it is aggravated by high local velocities by the presence of lime sludge. The presence of chloride in the liquor circuit may aggravate the rate of corrosion. Very rapid corrosion occur in the Lime Slaker, Classifier, Causticizers, White Liquor Clarifier and other inter-connecting pipes.

In presence of moisture, chlorine is extremely corrosive. In dry state it is inactive and Iron, Brass, Nickel, Monel metal as well as most acid resisting

alloys can be used for storing or conveying it. At elevated temperatures, however, these metals are attacked. For chlorine in contact with water satisfactory service is given by lead, silver and Hastelloy C. Teflon and other plastic material may be found suitable.

The iron structures above Pulp Washing Section get heavily corroded due to alkaline vapours and also due to chlorine attack from nearby Bleaching Section.

## CONCLUSION

The successful outcome of this costly battle can only result from proper selection of material of construction taking into account the corrosive conditions that are likely to be encountered.

Further, the layout and design of the Plant should be based on Standard principles of corrosion prevention. In fact, it has been truly said that the "fight against corrosion starts in the Drawing Board."

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