



## Corrosion of Metals

Corrosion denotes destruction of metal by chemical or electrochemical action. A gradual attack on the metal by its surroundings results in the conversion of the metal into an oxide, salt or some other compound. Two basic mechanisms of corrosion are recognized; direct chemical attack and electrochemical attack.

**DIRECT CHEMICAL ATTACK** includes all corrosion in which there is no appreciable flow of induced electric current through the metal. The reaction is relatively uniform over the entire exposed surface and usually produces a scale or deposit of uniform thickness on the metal surface. Examples of direct chemical attack are rusting of iron and steel, the patina on copper roofs and the tarnishing of silver.

**ELECTROCHEMICAL ATTACK** is characterized by the establishment of small electric cell areas. The two poles of a cell are connected through the metal and through the corroding solution thus allowing an induced electric current to flow. The attack is localized as opposed to the uniformity of direct chemical attack. Depending upon the circumstances, electrochemical attack can be by either galvanic or concentration cells.

A galvanic cell is found when two dissimilar metals are electrically connected and immersed in an electrolytic solution. The metal having the larger single electrode potential or being higher in the Electromotive Series (see table) is attacked while the other is protected. The intensity of the attack gradually decreases due to polarization, in other words the collection of certain products of electrolysis on the electrodes. Also the rate of attack depends upon the respective areas of the metals acting as the positive and negative terminals. Thus there is a rapid rate of attack on steel nails or screws when used with copper flashings but negligible corrosion when copper nails are used with steel flashings.

A concentration cell occurs when two areas of a single type of metal are exposed to different concentrations of dissolved oxygen or of electrolyte. Attack occurs at the surface in the regions of low oxygen or low electrolyte concentration. Thus a lapped metal joint either submerged or exposed to rainfall in an industrial or sea-coast area will corrode at the lap where the solution moves over it thus preventing build-up in concentration.

**PASSIVATION** occurs when the corroding medium reacts with the metal to form an adhering protective coating. The chemical activity of the metal is altered, thus altering its apparent position in the electromotive force series. A good example is aluminum. Although it is relatively high in the electromotive force series, it does not corrode as readily as iron or steel. The formation of a dense and very adherent film of aluminum oxide protects the metal beneath. With iron and steel, however, the oxide film does not adhere tightly thus allowing corrosion to continue.

**PITTING** is a localized form of corrosion. It is an electrochemical form of attack in which galvanic or concentration cells or both are involved. The galvanic cells are caused by local composition differences at the metal surface either inherent in the manufacture or caused by the breaking of the passive or protective layer. Concentration cells occur at the bottoms of surface imperfections.

**EXPOSURE TO ATMOSPHERIC CONDITIONS ALUMINUM BASE ALLOYS** as a class are highly resistant to normal outdoor exposure conditions. The alloys containing copper as a major alloying constituent (over about 1%) are somewhat less resistant than the others whereas aluminum clad alloys are generally the most resistant. Periodic exposure to rain is beneficial probably because the rain washes off the corrosive products that settle out of the air while the gases ordinarily found in industrial atmospheres have little effect.

In moist locations, aluminum base alloys in contact with dissimilar metals are likely subject to galvanic attack of the aluminum surface adjacent to the other metal. This action is much more pronounced in sea-coast atmospheres than in rural or industrial locations. Contact with copper or copper base alloys causes more pronounced galvanic attack on the aluminum than contact with most other metals. Steel generally does not cause a pronounced acceleration in the rate of attack on aluminum except possibly in sea-coast locations, and stainless steel is even less harmful. Due to their proximity in the activity series zinc (e.g. galvanizing on steel) will protect most adjacent aluminum base alloys under most conditions.

**IRON AND STEEL ALLOYS.** There are two common methods of decreasing the atmospheric attack on ferrous metals when the alloy content is below that of the stainless grades. The first is to cover the metal with a protective coating either metallic (e.g. zinc, tin, lead, nickel, chromium) or non-metallic such as paint. The second is to add alloying metals to iron which, by promoting the formation of a more dense, adherent and hence protective rust, cause a much slower attack.

**COPPER.** The patina or thin protective coating develops slowly and is accelerated by industrial and sea-coast atmospheres. After a long period of exposure, the composition of the patina becomes stable or mineralized and no further change occurs unless it is damaged. The lack of proper provision for expansion and contraction for example, in conjunction with mild atmospheric corrosion can lead to corrosion fatigue failure.

Although copper will not normally fail from corrosion, complicating conditions can lead to active corrosive attack. For example, corrosion can occur where water is retained by a heavy bead of solder or by capillarity along a shingle line. An overhanging structure causing dripping on a copper surface may result in a combination of erosion and corrosion, particularly in industrial areas where the dripping water is probably contaminated with products of combustion.

**ZINC.** The rate of corrosion is worst under conditions of frequent wetting and drying in an industrial atmosphere where the moisture is distinctly acid. In such cases the formation of the basic protective film is hampered. Nearly all metals receive substantial to complete protection when in contact with zinc. Small zinc areas in contact with large areas of more electropositive metals should be avoided. Small areas of other metals in contact with large areas of zinc are relatively safe. Galvanized will be attacked in the presence of copper. Exposed junctions of galvanized and copper should be avoided because of corrosive attack on the zinc at the junction where there could be water (electrolyte) bridge to complete a galvanic cell circuit.

**LEAD.** Sheltering or coating of lead with other materials is not required for atmospheric exposures because of the protective film. Due to the electric insulating nature of this protective film, lead does not usually cause galvanic corrosion of troublesome magnitude when in contact with other metals.