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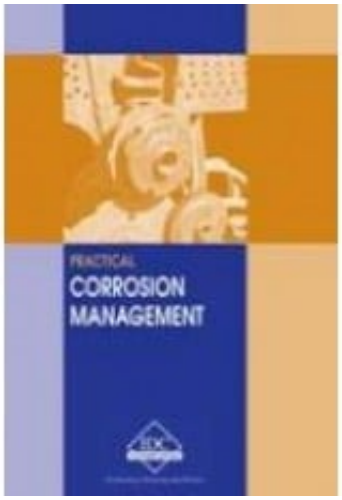
# MY-E - Practical Corrosion Management

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### Short Description

This manual covers the fundamental principles and concepts related to corrosion, the metallurgical and environmental factors that influence it, and the various methods employed for corrosion control and failure prevention.

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### First Chapter

**Chapter 1: Introduction to Corrosion**

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**Introduction to Corrosion**

*Estimates of total cost of corrosion all over the world are very high. Production of metals used for corrosion resistance and replacement of corroded parts require large amounts of energy, compounding the nation's energy problem. Therefore, it becomes imperative to understand the process of corrosion and to prevent and control the damage due to corrosion economically and safely.*

**Learning objectives**

- To understand the two types of corrosion and the mechanism involved
- To learn the definition and the cost of corrosion
- To understand the basic concepts of corrosion.

## 1.1 Introduction

With the exception of noble metals such as Gold and Platinum, most metals exist in nature in combined forms as oxides, hydroxyl carbonates, carbonates, chlorides, sulphides, and silicates. These are known as metal ores and minerals. During the process of extraction, these minerals or metal ores are reduced to their metallic states. As soon as metals are extracted from their ores, the process of reversal begins. In other words, the metals have a natural tendency to revert to their previous combined state.

During this process, mostly oxides are formed, but depending upon the presence of impurities, sulphides, carbonates, sulphates, etc. may also be formed. This process by which the metals have a tendency to go back to their original combined state is known as corrosion. Corrosion is also known as weeping of metals.

The term 'corrosion', which causes the wastage or deterioration of metals, may be applied to gradual transformation of metals in the compound state or combined state, weathering of timbers and concrete, the leading of glass, and cracking of plastics.

Some examples of corrosion are:

- rusting of iron, during which a reddish brown scale and powder of $Fe_3O_4$is

formed on the surface of iron in the presence of moisture and air
- reaction of chlorine gas with magnesium or tin
- formation of green layer of basic carbonate, $CuCO_3$+ $Cu(OH)_2$ on the surface of copper when exposed to moist air containing $CO_2$.

## 1.2 Definition of corrosion

When metals are used in various forms, they are exposed to the environment. The exposed metal surfaces start decaying by converting into more stable metal compounds fairly rapidly. Destruction or decay of metal or deterioration in its properties by chemical or electro reaction with the environment is called corrosion.

Corrosion can also be defined as ‘the destructive attack on metals by reaction with the environment’ (Mars G. Fontana), but this excludes non-metals. Some reactions with the environment are helpful, for example:,

- Dry Cell
- Aluminum oxide – Anodizing
- Cathodic Protection.

However, metals corrode the most. The environment could be of any type such as atmosphere, water, sea water, acids, alkalis, steam, gases, soils, and liquid metals.

## 1.3 Types of corrosion

Corrosion is of two types: dry corrosion or wet corrosion

### 1.3.1 Dry corrosion

Dry corrosion, also known as direct chemical corrosion, refers to high temperature oxidation that occurs at the gas-metal interface. In dry corrosion, the metal chemically reacts with an oxidizing component of its environment.

In dry corrosion, the metal is exposed to gases such as oxygen, halogens, sulphur dioxide, hydrogen sulphide, and nitrogen in the surrounding environment; as a result, corrosion occurs on metal surfaces in immediate proximity through

the direct chemical interaction of the environment or atmospheric gases. This type of corrosion affects the metals in two ways:

- the metal is consumed
- properties of metals change..

The effect of dry corrosion depends on:

- the chemical affinity between the corrosive environment and solid metals
- the capacity of the reactive layer on the metal surface to form the protective film.

Dry corrosion is generally of three types: oxidation, corrosion caused by other gases, and liquid metal corrosion.

**Oxidation corrosion**

Oxidation corrosion is a result of direct chemical action of oxygen at low or high temperatures on metals, usually in the presence of moisture. At ordinary temperature, the attack on the metals is slight, but alkali and alkaline earth metals are more oxidized at low temperatures. At high temperatures, all metals with the exception of Silver (Ag), Gold (Au) and Platinum (Pt) are oxidized. Alkali metals (Lithium (Li), Sodium (Na), Potassium (K), Rubidium (Rb), Cesium (Cs), Francium (Fr), etc.) and alkaline earth metals (Beryllium (Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), etc.) get less oxidized. Hence the oxide formed on the surface is porous, and this porosity of the oxide film does not offer any resistance to oxidation by the environment. It easily allows oxygen to diffuse into the metal leading to corrosion even at low temperature. Heavy metals form more voluminous oxides than the metals from which they are formed. In such cases, the oxide film formed on the surface is continuous and does not allow the atmospheric oxygen to diffuse into the metal easily, thus resisting the process of corrosion.

**Corrosion by other gases**

In addition to oxygen, there are certain other dry gases such as $CO_2$, $SO_2$, $Cl_2$, $H_2S$, and $F_2$ that corrode metals. The extent of corrosion in such cases depends upon the chemical affinity between the metal and the gas responsible for the

corrosive effect. The degree of attack in such cases also depends upon the formation of porous and non-porous films on the surface of metals as in the case of oxidation corrosion by oxygen or air.

**Liquid Metal Corrosion**

Liquid metal corrosion is a result of chemical action of flowing liquid metal at high temperatures on solid metals or alloys. This type of corrosion is common in devices used for nuclear power. The corrosion may be due to dissolution of a solid metal by a liquid metal or due to internal penetration of the liquid metal into the solid metal. In both cases solid metal becomes weak.

### 1.3.2 Wet corrosion

Wet corrosion, also known as immersed or electrochemical corrosion, occurs at metal solution interfaces. This type of corrosion is the result of electrochemical or chemical reaction between a metal and its surroundings. In both cases, a basic reaction is the electrochemical oxidation caused by the removal of one or more electrons from the metal with the formation of passive ions. These reactions take place at the interfaces and the rate of reaction is modified by the properties of the corrosion products. The metallic compounds that are formed as a result of corrosion of metals may or may not act as a barrier for further attack. The formation, destruction, or removal and reformation of naturally occurring film on the surface of metals at the site of corrosion reaction largely affect the corrosion and corrosion control.

The corrosion occurs mostly under wet or moist conditions through the electrochemical reaction by the formation of the short circuited galvanic cells. The modern electrochemical theory of corrosion is based on Nernst theory.

When metal is placed in a solution, a current is set up in the system, and it is carried by the electrodes of corroding metal and ions in the solution. At the anodic area, oxidation reaction i.e. free electrons are liberated. Anodic metal is destroyed by either dissolving or forming the oxide. Therefore, corrosion always occurs at the anodic area. The anodic reaction involves dissolution of metal to form corresponding metallic ion with liberation of free electrons. The electrons set free at the anode flow through metal and are finally consumed in a cathodic reaction. Thus wet corrosion involves flow of electrons between the anodic and

cathodic areas.

This is different from a cathodic reaction where the acceptance of electrons takes place by means of either evolution of hydrogen or absorption of oxygen (see Figure 1.1).

**Figure 1.1**

*Electrochemical process*

Wet corrosion is of three types: chemical, underwater and underground.

### Chemical corrosion

This type of corrosion is a result of electrochemical or chemical reaction between a metal and its surroundings.

### Underwater corrosion

This type of corrosion includes corrosion in water pipes of all types, heating systems, steam boilers, etc. The water is in sufficient amounts underground, whereas the air in such a corrosion is limited.

### Underground or soil corrosion

This type of corrosion takes place in pipes and underground structures, and in ferrous metals in concrete. This type of corrosion becomes complicated because of various salts present in the soil.

## 1.4 Cost of corrosion

Corrosion is recognized as one of the most serious problems in modern society resulting in losses as much as hundreds of billions of dollars each year. Cost of corrosion studies have been undertaken by several countries including the United States of America, the United Kingdom, Japan, Australia, Kuwait, Germany, Finland, Sweden, India, and China. The studies have ranged from formal and extensive efforts to informal and modest efforts. The common finding of these studies was that the annual corrosion costs ranges from approximately 1 to 5 percent of the Gross National Product (GNP) of each nation.

Much can be done to reduce corrosion and the consequent economic loss. Corrosion costs more than the total annual cost of floods, hurricanes, tornadoes, fire, lightening, and earthquakes. The cost of corrosion can be defined in different ways depending upon the industry. The production of metals used for corrosion resistance and to replace corroded parts require a large amount of energy, thus compounding a nation's energy dearth. In the oil and gas industry, the cost of corrosion is increasing because of deeper wells and more hostile environments such as higher temperature and corrosive sulfur gases. Corrosion of bridge is a major problem as they age faster and require replacement. The collapse of silver bridge into the Ohio river cost 40 lives and million of dollars. The paper industry estimates that corrosion increases the cost of paper $6 to $7 per ton.

The factors contributing to the increase in cost due to corrosion is analyzed in each sector and preventive measures to reduce the cost and damage are taken. The annual cost of corrosion comprises both direct costs and indirect costs. The direct costs related to corrosion have two main components:

1. The cost of design, manufacturing, and construction
2. The cost of management

## 1.5 Summary

'Corrosion' causes deterioration and wastage of metals. It ranges from gradual transformation of metals in the compound state or combined state due to weathering of timbers and concrete, the leading of glass to the cracking of plastics. Corrosion can be defined as the destructive attack of metal by reaction with the environment. Corrosion as a chemical reaction is of two types: dry corrosion and wet corrosion.

Dry corrosion, also known as direct chemical corrosion, refers to high temperature oxidation and occurs at the gas-metal interface. In dry corrosion, the

reaction is a chemical interaction between the metal and an oxidizing component of its environment.

Wet corrosion, also known as immersed or electrochemical corrosion, occurs at metal solution interfaces. This type of corrosion is the result of electrochemical or chemical reaction between a metal and its surrounds. Corrosion has a tremendous economic impact and much can be done to reduce it.