Corrosion Basics

Understanding the basic principles and causes of corrosion

Water Constituents

The concentrations of various substances in water in dissolved, colloidal, or suspended form are typically low but can vary considerably. A hardness value of up to 400 ppm of calcium carbonate (CaCO₃), for example, is sometimes tolerated in public supplies, whereas 1 ppm of dissolved iron would be unacceptable. In treated water for high-pressure boilers or where radiation effects are important, as in some nuclear reactors, impurities are measured in very small units such as parts per billion (ppb). Water analysis for drinking water supplies is concerned mainly with pollution and bacteriological tests, though other factors may be important for anticipating corrosion activity. For industrial supplies a mineral analysis is often of more interest. The important constituents can be classified as follows:

- Mineral constituents, including hardness salts, sodium salts (chloride, sulfate, nitrate, bicarbonate, etc.), salts of heavy metals, and silica
- Organic matter (including that of both animal and vegetable origin), oil, trade waste (including agricultural) constituents, and synthetic detergents
- Microbiological forms, including various types of algae and slime-forming bacteria

The pH of natural waters is rarely outside the fairly narrow range of 4.5 to 8.5. High values, at which corrosion of steel may be suppressed, and low values, at which gaseous hydrogen evolution may occur, are not often found in natural waters. The role of copper is affected to a marked extent by pH value. In acidic waters, slight corrosion occurs; and the small amount of copper in solution causes green staining of fabrics and porcelain fixtures. In addition, redeposition of copper on aluminum, galvanized, or even steel surfaces can set up corrosion cells, resulting in severe pitting of the more active metals. Scavengers, such as steel wool, are often used to remove copper from solution.

From a corrosion standpoint, the most significant contaminant is dissolved oxygen (DO) from ambient air. Oxygen is a cathodic depolarizer that reacts with and removes hydrogen from the cathode during electrochemical corrosion, thereby permitting corrosion attack to continue. In a closed vessel, corrosion continues to increase with temperature, hence the requirement for removing DO from hot water systems and boilers.

Other constituents that contribute to corrosion are chlorides, CO₂, sulfides, or NH₃ from industrial or natural sources. Of course, many other manmade contaminants can be found in local areas if industries are permitted to discharge their waste products into water resources. As with other chemical reactions, corrosion increases with elevated temperature, unless stifled by insoluble scales, the removal of corrosive gases, or the addition of corrosion inhibitors.

The importance of protective scale formation has led to the development of analytical tools, such as the Langelier Saturation Index and Ryznar Stability Index, that calculate the tendency to form these scales based on concentrations of CaCO₃, hardness, total dissolved solids, alkalinity, temperature, and pH. Scales precipitated onto metal surfaces can provide excellent protection of the substrate when uniform but may accentuate pitting at pores, cracks, or other voids in the film. If the film attains any significant thickness, the loss of heat transfer through the metal and deposited scale can be a problem in certain applications. Thus, the development of scales on metal surfaces is an important consideration when using metals in waters.

In a broad range of about pH 5 to 9, the corrosion rate can be expressed simply in terms of the amount of DO present (e.g., µm/y per mL, DO per L of water). At about pH 4.5, acid corrosion is initiated, overwhelming the oxygen control. At about pH 9.5 and above, deposition of insoluble ferric hydroxide [Fe(OH)₃] tends to stifle the corrosion attack.

This article is adapted by MP Editorial Advisory Board Member Norm Moriber from Corrosion Basics—An Introduction, Second Edition, Pierre R. Roberge, ed. (Houston, TX: NACE International, 2006), pp. 127-128. MP