Closed Once-Through Systems

In equipment where light is excluded, slime formations are due to fungi. Usually, they predominate on the heat exchange surfaces. Bacteria form thick, soft slime. Yeast and molds form tough rubbery slimes. Chlorine and hypochlorite solutions, fed intermittently, are usual preventatives.

UNDERWATER CORROSION

When deleterious substances are present in water, the corrosivity of the solution is increased in proportion to the amount of deleterious substances present, the temperature, and usually the rate of flow of the solution over the metal surfaces. There are other relevant factors, but their influence in general is subordinate to those mentioned. Dissolved oxygen, acid gases, and chloride salts are the corrosion accelerators most frequently encountered.

Neutral and slightly alkaline waters saturated with air, corrode iron at a rate about triple that for the same water free of air. Hot water containing oxygen will corrode iron at a rate three to four times that for the same water when cold.

Corrosion of iron decreases as the *pH* of water solutions increases, and practically ceases at a *pH* of 11. Film-forming agents such as chromium, nickel, and silicon, can be added in the manufacturing of metals to provide increased corrosion resistance. In some processes, inhibitors, such as chromates, can be added to the water to minimize corrosion.

Soft water, as for example the effluent from zeolite softeners, is likely to be several times more corrosive to iron than hard waters. In small installations, the use of copper or brass pipe usually is a practical expedient. Cement-lined pipe and tanks suitably resist attack.

Where the water contains slime-forming organisms, especially those bacteria that thrive on iron, chlorination of the water is imperative to inhibit tuberculation and subsequent pitting.

Bitumastic paints, applied at *regular* intervals upon *well cleaned* surfaces, will measurably prolong the life of equipment handling cold waters.

It is generally agreed that the rate at which oxygen reaches the surface determines the rate of corrosion of ferrous metals. Underwater, the oxygen diffusion to a surface is often restricted by films and scale that form on the surface, and consequently the rate of corrosion differs from that of surfaces exposed to the atmosphere or to alternately wet and dry conditions.

All ferrous metals will not corrode at the same rate. A thorough knowledge of the conditions to be encountered and experience gained from tests of the materials in service are required when attempting to predict performance or life in a given service.

Copper, aluminum, and other non-ferrous metals and their alloys have been found effective in resisting many types of underwater corrosion. Corrosion of ferrous metals with which these metals are in contact, may be accelerated in water of good conductivity.

The environmental conditions are responsible for length of service of any metal. No single material is suitable for all types of service.

Once-Through Systems

Where corrosion can be expected in once-through systems, it may be minimized through the use of one of the following methods:[12]

1. Forming a protective film of calcium carbonate on the metal surfaces.
2. Providing mechanical or chemical deaeration, or both, of the water.
3. Using organic or inorganic corrosion inhibitors, or both, in low concentrations.

Formation of a thin protective calcium carbonate film is accomplished by adjustment of the water until the Langelier Index has a value greater than +0.5. This is rather difficult in systems which have a wide variation in temperature. Since the Langelier Index is dependent on temperature, when a water is adjusted to form a protective film on those surfaces of higher temperature, no film will form on colder surfaces. Therefore, this method of corrosion control is more applicable to large municipal distribution systems. Where heat transfer is involved, the method is usually impractical except under unusual circumstances. When this method is used, *pH* is increased by using an inexpensive alkali such as lime, caustic soda, or soda ash. Lime is usually used for waters of low calcium content. Caustic soda or soda ash are used for waters of high calcium content.

Mechanical[17] and chemical deaeration are not often used in once-through systems because of relatively high operating costs. Mechanical deaeration also requires the use of costly equipment. Chemical deaeration is usually accomplished by raising *pH* with caustic soda and by continuously feeding catalyzed sodium sulfite in proportion to water flow. The use of catalyzed sulfite is not permitted in water to be used for potable purposes.

There are several corrosion inhibitors such as chromate, polyphosphates, and silicates which are effective in once-through systems.[18] Polyphosphate at a concentration of 2 to 5 ppm has been found useful in controlling tuberculation of iron pipe and in reducing overall corrosion. Usually, more effective treatment is to use chromate-polyphosphate at concentrations of less than 60 ppm.

Sodium silicate is often used in relatively soft waters by increasing the silica content about 8 ppm. It is used primarily to reduce corrosion in potable water supply systems.

Open Recirculating Systems

Corrosion in open recirculating systems, such as air washers and cooling towers, is usually controlled by use of corrosion inhibitors such as chromates polyphosphates, a combination of chromate and polyphosphate, and nitrites.[19, 20] Mechanical or chemical deaeration is not practicable in open systems because of the high rate of aeration. It is not practicable to use high *pH* values of 11 or more in systems containing wood. High *pH* will cause serious delignification of wood. High *pH* values also prevent control of scale. Corrosion control is usually carried out in the *pH* range of 6.5–8.

Chromates are by far the most effective corrosion inhibitors. It is extremely important, however, to maintain an adequate concentration of 300–500 ppm, which is effective for most systems. If for economic reasons substantially lower concentrations are used, serious pitting corrosion may occur.

Polyphosphates are most effective in reducing tuberculation. It is not usually possible to reduce overall corrosion to anywhere near the degree possible with chromate.

Where economy of treatment is of primary importance, a substantial reduction of pitting and overall corrosion can be obtained by using as