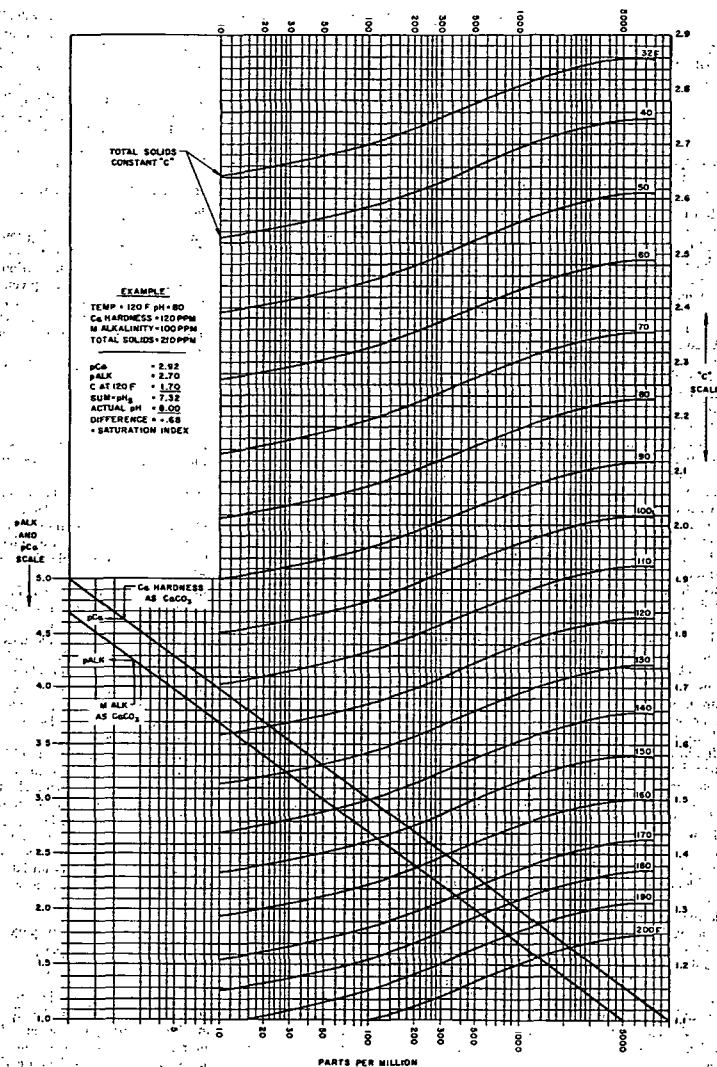




Adapted from S. T. Powell, *Industrial and Engineering Chemistry*, Vol. 37, September 1945, p. 842.

Fig. 2 Langelier Saturation Index Nomograph

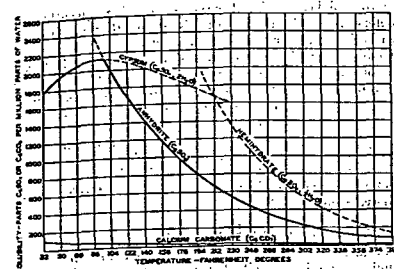
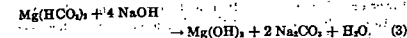
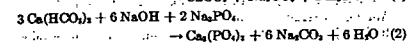


Fig. 3 Adapted from Bull. No. 14, Univ. of Mich. *Formation and Properties of Boiler Scales* by P. R. Partidge.

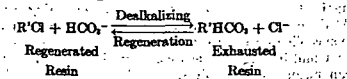
Fig. 3 Solubility of Calcium Sulfate and Calcium Carbonate for Comparison
 (CaCO₃ in Equilibrium with Normal CO₂ Content of the Atmosphere)

ity of calcium phosphate, as shown in Equation 2. Magnesium is most commonly precipitated as the hydroxide, as shown in Equation 3.



There are situations in which it is economically or otherwise impossible to remove the hardness from water. In these cases other measures can be taken to control scale formation. One common method is to reduce the alkalinity of the water. This very substantially reduces scale formation because the solubility of calcium carbonate is much less than that of other calcium salts.

Most of the alkalinity can be removed by means of an anion exchange resin, in a process analogous to softening. In this case the alkalinity (bicarbonate) is retained by the resin, which gives up to the water an equivalent amount of chloride. When the resin begins to pass larger amounts of alkalinity than desired, it is backwashed and regenerated by means of a salt solution, as described above. Usually, this salt solution contains a small percentage of alkali:



Inasmuch as the hardness of the water remains unchanged but the alkalinity is reduced, this process is called dealkalizing, rather than softening.

More commonly, and particularly in large cooling towers, sulfuric acid is used to eliminate most of the alkalinity. The solubility of calcium sulfate is about 1200 ppm, in contrast to 35 ppm for calcium carbonate, thus permitting a much higher hardness to be present in the circulating water before scale can form. The acid feeding procedure involves a considerable risk unless careful controls are employed. The alkalinity of the circulating water is reduced to such a low figure that a slight overdose of acid produces a very low pH and cor-

spondingly corrosive circulating water. Accordingly, good practice dictates that acid feed be restricted to systems which operate under constant conditions of makeup water composition, and evaporation, or that automatic pH control equipment be employed.

For cooling waters in which the above measures cannot be used, two other measures are used in conjunction in order to minimize scale formation in cooling systems. First, the total solids in the circulating water are limited by use of a continuous bleed or bleed-off to a maximum value calculated from the Langelier Saturation Index or the Ryznar Stability Index. Second, scale control adjuncts are added to the water in order to increase the apparent solubility of the calcium carbonate. Most commonly low concentrations (2-5 ppm) of sodium polyphosphates are used, and are frequently supplemented by other materials, including organic dispersing agents, such as the various lignin derivatives. These measures are also used with acid feeding.

Biological Growth. Algae, bacterial slimes, and fungi are important bacterial growths because of their ability to interfere with the functioning of cooling systems. Generally speaking, heating systems do not suffer from the effects of biological growths, because their operating temperatures are sufficient to kill the organisms involved.

Algae, which require light for carrying on their life processes, are likely to cause difficulty in cooling tower head pans; spray ponds, and other areas where sunlight is abundant. Algae growths can become copious enough in a short time to cause blocking of water distribution piping, nozzles, and troughs. In smaller equipment, blocking off sunlight by the use of opaque head pan covers can be a very effective algae control measure. Where this is not possible, biocidal chemicals can be used.

Most waters contain slime-producing organisms, but significant amounts of slime are produced only when the conditions are such that their life processes are favored. These conditions include sufficient food material from the water or from airborne material, combined with optimum temperature conditions, such as often exist on cooling surfaces and in air washers. Equipment near sources of nutrients are particularly susceptible to slime formation. Two common examples are air washers in printing plants which have fine paper dust in the air, and refrigeration cooling towers located in food storage areas of markets. Slimes can be formed from bacteria, yeasts, or moulds. Generally, the former form thick, soft slimes, and the latter two tend to form tough, rubbery slimes. In either case, the use of biocidal materials is indicated.

In very large systems, particularly once-through cooling systems utilizing river, estuarine, or sea water, macroorganisms such as barnacles and mussels may form. Although antifouling paints can be used on large diameter pipe surfaces to minimize the growth of such macroorganisms, they must be renewed at frequent intervals and are not applicable to inaccessible areas such as the insides of smaller diameter piping. Generally speaking, chlorine is the only chemical used to destroy such organisms. In once-through systems intermittent feeding of chlorine in the form of chlorine gas or hypochlorite solutions provides the most effective, economically feasible method for controlling the growth of microorganisms and slimes.

In other systems, the effective control of slime and algae frequently requires a combination of mechanical and chemical measures. For example, when a system already contains a considerable accumulation of slime, a preliminary mechanical or detergent cleaning will make the subsequent application of a biocidal chemical more effective in killing the growths and more enduring in the prevention of further