

piece of equipment and the method of its operation, such separation may be promoted by one or more than one, of several factors:

- The concentration of solids may be increased by the evaporation of water.
- The dissolved solids may be rendered less soluble in the water by changes in temperature.
- Conditions may favor the decomposition of unstable compounds with the formation of less soluble compounds.

Figs. 2 and 3 show that the solubilities of both calcium carbonate and calcium sulphate decrease with the rising temperature within a moderate range of temperatures. Surfaces transferring heat into water, such as

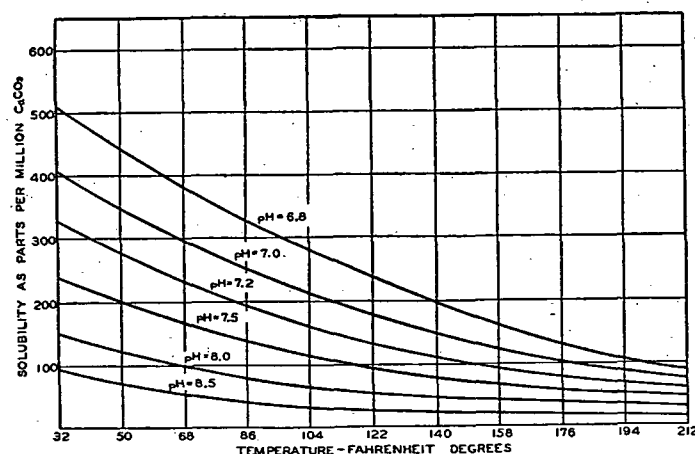


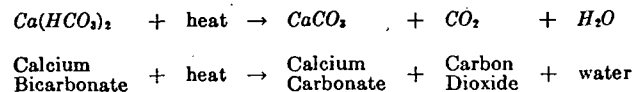
FIG. 2. SOLUBILITY OF CALCIUM CARBONATE IN DISTILLED WATER, CONTAINING CARBON DIOXIDE

(pH Values at Approximately 73 F)

Fig. 2 Adapted from (1) *Ind. & Eng. Chem.*, 20 (1928) 1197—by Baylis. (2) *J.A.C.S.* 50 (1928) 2086—Frear & Johnson.

condensers and coolers, are more susceptible to scale and sludge formation than are the cold parts of the same system using the same water.

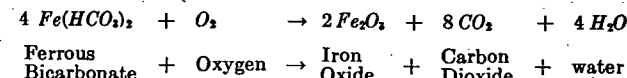
The most common of the unstable soluble salts are the bicarbonates of calcium, magnesium, and occasionally iron. Under conditions favoring the removal of carbon dioxide, as when the water is strongly aerated or when it is boiled, the bicarbonates are readily converted to the relatively insoluble carbonates. The type of scale most usually encountered is calcium carbonate (often called alkalinity) from the decomposition of calcium bicarbonate according to the following chemical reaction:



Conversely, carbonates are readily converted to the more soluble bicarbonate by the addition of carbon dioxide or other acidic materials. This explains the increase in the apparent solubility of calcium carbonate

at decreasing pH values (increasing concentration of hydrogen ion) shown in Fig. 2, the carbonate really going into solution largely as bicarbonate.

In special cases, primarily with well waters possessing a high natural iron content, deposition of iron oxide from the decomposition of ferrous bicarbonate takes place according to the following reaction:



Low water velocity in heat transfer equipment often causes sludges to settle out in the tubes. This has the same effect on heat transfer as scale

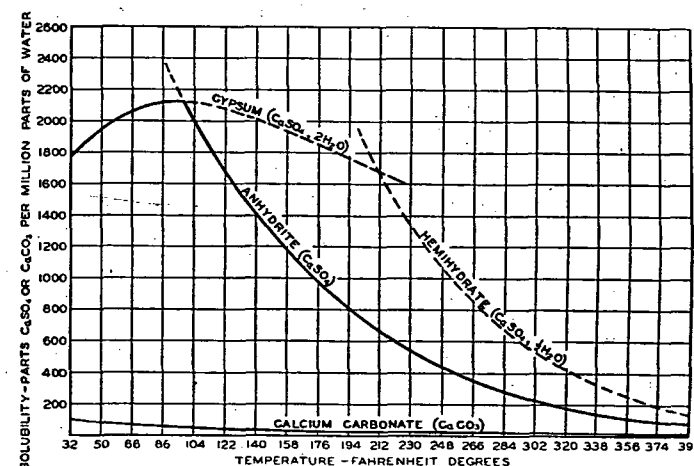


FIG. 3. SOLUBILITY OF CALCIUM SULFATE AND OF CALCIUM CARBONATE FOR COMPARISON

(CaCO_3 in Equilibrium with Normal CO_2 Content of the Atmosphere)

Fig. 3 Adapted from Bull. No. 15, *Univ. of Mich.* Formation and Properties of Boiler Scales by P. E. Partridge.

formation. When this occurs, increasing the water velocity often cures the condition.

It is sometimes desired to evaluate the tendency in a particular water toward the separation of calcium carbonate, which may be desirable as a means of establishing a corrosion-resistant film on metal surfaces, or in other circumstances may be undesirable because of the impedence of the calcium carbonate film to heat transfer. This tendency is indicated approximately by the Langelier Index,⁹ which is obtained by subtracting the actual pH of a particular water from the pH at which it is estimated precipitation of calcium carbonate would just begin. This estimate may be made by the use of Fig. 4.

There are various expedients which may be employed for avoiding or mitigating difficulties due to scales:

- The water may be treated before use to remove elements such as calcium, magnesium, and iron, which form relatively insoluble compounds. In the various softening processes this removal of these elements is accompanied by the addition of other elements, particularly sodium, the compounds of which are relatively soluble.
- The water may be treated within the equipment to promote the separation of