insoluble carbonates (or, in the case of iron in the presence of oxygen, ferric hydroxide or oxide may be formed). 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.

It is sometimes desired to evaluate the tendency in a particular water toward the separation of calcium carbonate, which may be desirable as a

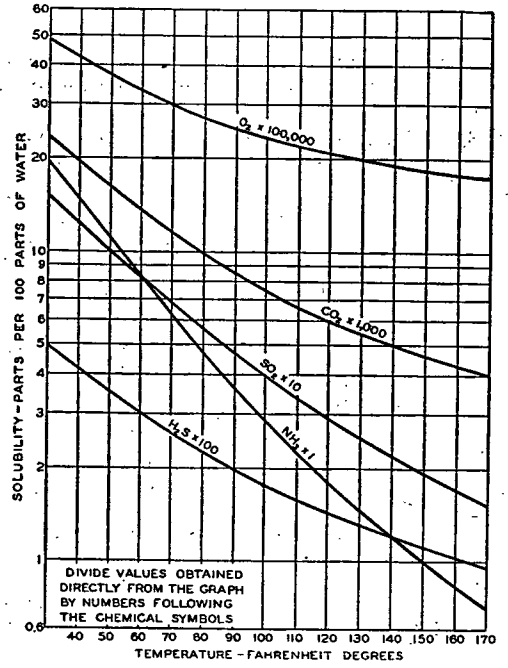

FIG. 1. SOLUBILITY OF GASES AT PARTIAL PRESSURE OF 1 PSI

means of establishing a corrosion-resistant film on metal surfaces, or in other circumstances may be undesirable because of the impedance 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:

a. 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.

b. The water may be treated within the equipment to promote the separation of dissolved solids as sludges, rather than as scale which is, in most cases, more objectionable.

c. The increase in total solids, due to the evaporation of water, may be controlled by the displacement, continuously or intermittently, of some of the used water by fresh supply.

d. Substances, such as the polyphosphates, having the property of inhibiting the precipitation of calcium carbonate from solutions supersaturated with it, may be added.

e. The pH of the water may be lowered (hydrogen ion concentration raised) to reduce the tendency for precipitation of carbonate. This is permissible only to such an extent as will not cause a serious increase in rate of corrosion.

The choice of the best expedient must be made for each type of equipment, and will be affected by local considerations.

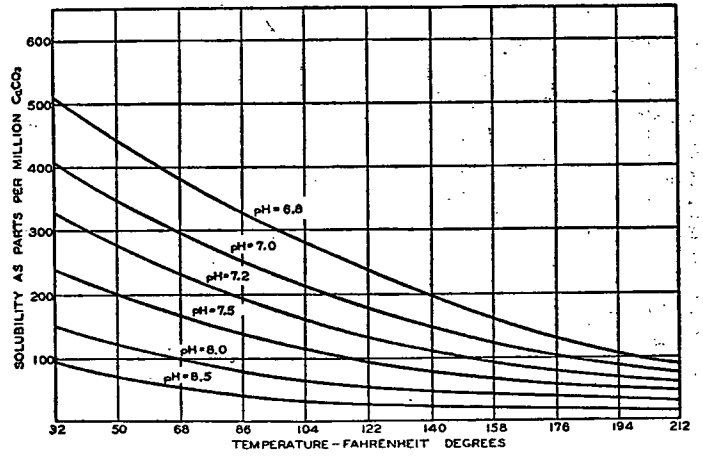

FIG. 2. SOLUBILITY OF CALCIUM CARBONATE IN DISTILLED WATER CONTAINING CARBON DIOXIDE

(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 (1929) 2086—Frear & Johnson.

Once-Through Equipment and Closed Recirculating Systems

Where abundant supplies of water are available at low cost, the cooling water may pass through the equipment once, undergoing a slight rise in temperature. Little difficulty from scale should be experienced in this case unless the carbonate hardness is more than 200 ppm, or the water has been treated to induce incipient calcium carbonate precipitation. Closed recirculating systems in which the water is cooled indirectly, as in radiators, and returned to the equipment, should usually be subject to little trouble with scale. However, in both once-through and closed recirculating systems, slimes may cause trouble.

If there is some tendency for scaling, it may usually be prevented by the addition of small amounts, about 5 ppm or less, of polyphosphate.[10] Alternately, a minor lowering of pH by the addition of carbon dioxide or sulphuric acid may be effective if permissible from corrosion standpoint.