problem. In hot water systems scaling is seldom a problem unless there is a large amount of makeup water.[12] In these cases the use of surface-active agents such as polyphosphate are used.

Open Recirculating Systems

Where water from condensers and similar equipment is passed through a spray pond or cooling tower and then returned to the equipment, there is an increase in the concentration of solids because of the evaporation of some of the water into the cooling air, and, moreover, the aeration removes carbon dioxide. Both factors promote the tendency to deposit scale.

This condition is also true for air washers during periods of operation when air is humidified. Evaporation of recirculated water occurs, causing concentrations of scale forming minerals. (There are cases, such as in New York City, where water supplies have extremely low solids content. Aeration in air washers and cooling towers causes absorption of acid gases

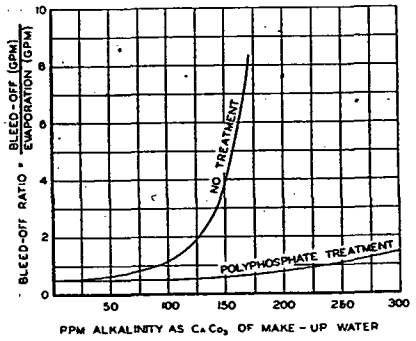

FIG. 5. RELATION OF BLEED-OFF REQUIREMENT TO $CaCO_3$ IN MAKE-UP WATER

such as sulfur dioxide, SO_2, from the air. Serious corrosion rather than scale occurs.)[13]

The concentration of scale-forming minerals in open recirculated cooling water is limited by natural drift or windage loss. This is the loss of water droplets from the system. Windage losses from typical systems may be classified as follows, based on recirculating rates:

	Percent of Recirculating Rate
Evaporative Condensers and Air Washers	0 to 0.1
Mechanical Draft Cooling Towers	0.1 to 0.3
Atmospheric Cooling Towers	0.3 to 1.0
Spray Ponds	1.0 to 5.0

To show the effect of concentration in a typical mechanical draft system assume:

1. Recirculating Rate = 100 gpm.
2. Drift loss = 0.2 percent of recirculating rate = 0.2 gpm.
3. Evaporation Rate = 1 percent of recirculating rate = 1.0 gpm.
4. Calcium bicarbonate in make-up water = 100 ppm.
5. Calcium bicarbonate in evaporated water = 0 ppm.

Let K = concentration of calcium bicarbonate in recirculating water = concentration of calcium bicarbonate in drift loss.

The process of concentration in the system may be represented diagrammatically as follows:

Evap. = 1 gpm
$Ca(HCO_3)_2$ = 0 ppm
↑
Make up = 1.2 gpm
$Ca(HCO_3)_2$ = 100 ppm → [Recirculating Water System, $K = Ca(HCO_3)_2$ conc.] → Drift 0.2 gpm
$Ca(HCO_3)_2 = K$ ppm

The concentration may be obtained from the equation

$$\text{(Make Up) [Ca(HCO}_3\text{)}_2 \text{ conc.]} = \text{(Evap.) [Ca(HCO}_3\text{)}_2 \text{ conc.]} + \text{(Drift)[Ca(HCO}_3\text{)}_2 \text{ conc.]}$$

$$(1.2)\ (100) = (1)(0) + (0.2)(K)$$

substituting,

$$120 = 0 + 0.2\,K$$

whence,

$$K = 600 \text{ ppm}$$

Therefore the concentration of calcium bicarbonate in the recirculating water equals 600 ppm. This far exceeds the allowable concentration of 170 ppm at which scaling will occur.

To correct this situation, it is imperative to provide a continuous bleed-off or blow down from the recirculating water circuit. Typical bleed-off requirements are shown in Fig. 5. Reference to the No Treatment curve shows that a bleed-off rate of 1.2 times the evaporation rate is required when a make-up water contains 100 ppm calcium bicarbonate (or alkalinity) if scale is to be prevented. Calculation by a material balance will show that the bleed-off plus drift loss will limit the calcium bicarbonate to 171 ppm.

It can be seen from Fig. 5 that very large amounts of bleed-off are required as a make-up water approaches or exceeds 150 ppm of alkalinity. When alkalinity exceeds 175 ppm, bleed-off alone is no longer effective. The use of 5 ppm or less of polyphosphate is extremely effective in reducing the required bleed-off and making possible the use of make-up waters which will not respond to bleed-off alone.

Occasionally, waters are encountered which have exceptionally high alkalinities or which develop high pH values when recirculated. The use of sulfuric acid is common in these cases to maintain pH values between 7 and 8. Polyphosphates are most always used when acid is required.

It is very important to control acid feeding carefully to avoid serious corrosion. Automatic pH controllers are often employed for such purpose.

Heating System

In hot water heating systems or in steam heating boilers where all condensate is returned, troubles from scaling should not be severe. If necessary, sodium phosphate or sodium carbonate may be added to the water to prevent the formation of adherent calcium sulphate scale.