complished by the addition of polyphosphate in low concentrations.[11] The use of polyphosphate in the ratio of two parts by weight to one part by weight of iron is usually most effective. The polyphosphate must be added to the water before exposure of the water to air or chlorine if effective stabilization of the iron is to occur.

Closed Recirculating Systems

The closed recirculating system is one in which water circulates through one heat exchanger where it absorbs heat, has its temperature elevated, and circulates through another heat exchanger in which its temperature is lowered. In cold water or chilled water systems scaling is seldom a problem. In hot water systems scaling is seldom a problem unless there is a large amount of makeup water.[12] In this case surface-active agents such as polyphosphate are used.

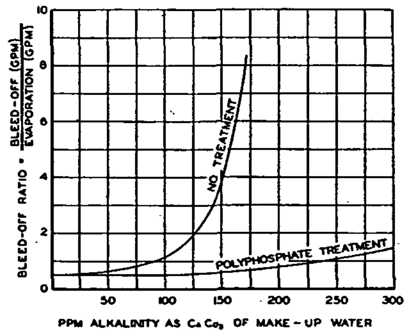

FIG. 5. RELATION OF BLEED-OFF REQUIREMENT TO $CaCO_3$ IN MAKE-UP WATER

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.

The corrosive properties of the water can also be increased through the absorption of acid gases such as sulfur dioxide (SO_2), from the air.[13] The absorption of gases from the air being processed and the concentration of solids due to evaporation are factors in air washer operation when the air is humidified.

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

$$(\text{Make Up})\,[Ca(HCO_3)_2 \text{ conc.}] = (\text{Evap.})\,[Ca(HCO_3)_2 \text{ conc.}] + (\text{Drift})[Ca(HCO_3)_2 \text{ conc.}]$$

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

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.