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Monitoring and Adjustment of Cooling Water Treatment Operating Parameters

Foreword

The efficient and safe operation of a cooling tower system typically involves a substantial amount of routine monitoring of chemical, physical, and microbiological phenomena. This technical committee report is intended for personnel directly responsible for daily operation and control of cooling tower systems, facility engineering and maintenance personnel, and water treatment company sales and technical staff personnel. The purpose of this report is to provide a concise compilation of what are considered common practices in this area. Monitoring and control of cooling systems generally occurs in three phases:

- Initial system surveys, conducted after assuming responsibility for the management or operation of a new or unfamiliar cooling system;
- Monitoring and adjustment of cooling tower operating parameters during a campaign of operation; and
- Inspections and measurements of the condition of a cooling tower system during off-line periods such as outages or turnarounds.

This report is specifically concerned with the second topic—monitoring and adjustment of cooling tower operation on a day-to-day basis during periods of routine operation.

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Introduction

Monitoring of cooling tower operation falls into two major categories. The first deals with the monitoring and control that is directed at maintaining cooling water chemistry within defined specifications. This includes both the components introduced by the supply of make-up water and those added to control scale, corrosion, and microbiological activity. The second monitoring activity includes measurements that assess the severity of scaling, corrosion, or microbiological processes during a campaign of operation. The data obtained from the second category of measurements are used to refine the specifications that form the basis for the water treatment strategy.

Monitoring and Control of Water Chemistry

Concentration Factor and Blowdown Rate

A cooling tower is a device that removes process heat from a stream of water through evaporation (see Figure 1). Water that is evaporated is replaced by fresh water (make-up) from some source. Typically, water used as make-up to cooling systems is taken "as-is" from the supply and contains dissolved mineral components. Because water leaving as a result of evaporation doesn't remove any dissolved solids, these materials concentrate in the recirculating water.

If the concentration of these impurities is not controlled, scale formation and corrosion problems often result. To limit the concentration of these impurities, a portion of the cooling tower water is frequently discharged. This wastage is referred to as *blowdown. Concentration factor* is the term that is frequently used to quantify the degree of concentration that has occurred in a cooling tower. It is defined as the ratio of the concentration of an impurity in the cooling tower water divided by the concentration of the same impurity in the make-up water. For example, if the concentration of sodium ions in the cooling tower water is 500 mg/L and the concentration of these ions in the make-up water is 100 mg/L, then the *concentration factor* would be 5.

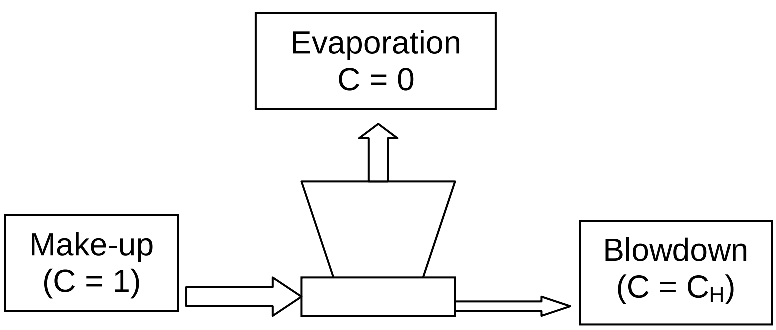

FIGURE 1: Streams in Cooling Tower Operation

<u>Hydraulic Concentration Factors</u>

The *concentration factor* is typically calculated (see Equations [1] and [2]) when the flow rates of both the make-up water and the blowdown are known. Leaks and water lost to airborne entrainment (drift) are considered part of the blowdown for purposes of this analysis.

$$C_H = \frac{MU}{BD} \qquad (1)$$

or equivalently,

$$C_H = \frac{MU}{MU - E} \qquad (2)$$

where:

C_H = hydraulic concentration factor (dimensionless)[1]
MU = make-up flow rate
BD = blowdown flow rate
E = evaporation rate

MU, E, and BD are always in the same units.

If make-up and blowdown flow rates are not available, it is possible to estimate evaporation (see Equations [3] and [4]) from a cooling tower. In metric units using a typical evaporation efficiency of 80%:

$$E = 0.132R \times \Delta T \quad (3)$$

where:

R = recirculation rate (m^3/min)
ΔT = hot return water temperature (°C) - cold supply water temperature (°C)
E = evaporation (m^3/min)

Or in English units:

$$E = 0.0008R \times \Delta T \quad (4)$$

where:

R = recirculation rate (gallons per minute [gpm])
ΔT = hot return water temperature (°F) - cold supply water temperature (°F)
E = evaporation (gpm)

Although the application of Equation (1) appears to be simple, it is often not very useful because the true blowdown flow rate is seldom known with sufficient accuracy. This is because the blowdown rate includes the cooling tower misting rate (drift) and all unintentional water losses such as pump seal leaks, splashing from the cooling tower, etc. However, in the case of cooling towers employing high-efficiency drift eliminators and little or no unintentional leakage, Equations (1) or (2) are often employed to estimate C_H.

Chemical Species Concentration Factors

The concentration factor of an individual species (C_s) is typically determined by measuring the concentration of a species in both the make-up water and the cooling tower water (or blowdown), and then determining the ratio. See Equation (5):

$$C_S = \frac{C_B}{C_M} \quad (5)$$

where:

C_B = concentration of a species in the blowdown or tower water
C_M = concentration of the same species in the make-up water

Care is typically used in selecting the species to measure. Problems can arise if anything alters the concentration of the selected species other than concentration due to evaporation. Examples of potential problems include the loss of calcium and carbonate caused by the precipitation of calcite ($CaCO_3$), the loss of carbonate (CO_3^{-2}) and/or bicarbonate (HCO_3^-) by acid addition and degassing of carbon dioxide (CO_2), and the addition of sulfate (SO_4^{-2}) by the use of sulfuric acid (H_2SO_4) for pH control. For these reasons, the species that are most often used to determine the C_s are magnesium, chloride (when halogen is not being used for pH control, or chloride-producing biocides are not added), and sulfate (when H_2SO_4 is not being used for pH control).

The conductivity of water is approximately proportional to the total dissolved solids concentration of the water. Conductivity is also one of the simplest and cheapest water assays. A method that is commonly used to estimate C_s is to determine the ratio of the conductivity of the blowdown (or tower water) divided by the conductivity of the make-up water.

Scalant Mass Balance Calculations

One method that is frequently used to estimate whether mineral deposits are forming or not is to first calculate the expected concentration (see Equation [6]) of a potential scale-forming species (such as calcium), then compare the expected value to the actual value. If the expected concentration is significantly greater than the actual concentration, mineral deposit formation is likely. The expected concentration for a species such as calcium is often determined by first determining a value for C_H, then multiplying by the concentration of the species in the make-up water.

$$C_{Exp} = C_H \times C_M \quad (6)$$

where:

C_{Exp} = expected concentration of a potential scale-forming species
C_M = concentration of species in the make-up water

C_H is typically estimated by either the chemical concentration factor (C_s) of a nonprecipitating species such as Mg (Equation [5]) or, if the data are available, from the flow rates of the make-up and blowdown streams (Equation

[1] Hydraulic concentration factor and cycles of concentration are synonymous.