The Importance of Cycles in Cooling Tower Treatment

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Cooling Systems

Introduction
The concept of “cycles of concentration” can be difficult to understand but is one of the most important parameters in managing a cooling water treatment program. Failure to maintain the proper cycles can result in corrosion and/or scale formation as well as greatly increase water and treatment costs.

Evaporation and Why Bleed is Needed
Cooling towers primarily reject heat by evaporating a small portion of recirculating water to the air. The dissolved minerals that were in the evaporated water are left behind and will concentrate in the bulk tower water as fresh makeup water is added to replace the evaporated water. As water continues to evaporate from the tower, the concentration of minerals will eventually reach a point where their solubility is exceeded and scale deposits occur.

To control the dissolved solids level, a portion of the tower water must be discharged to drain as bleed or blowdown. Since the makeup water contains a lower concentration of dissolved minerals, bleed reduces the overall mineral concentration in the tower water.

One purpose of water treatment chemicals is to extend the solubility of these mineral salts so higher concentrations can be maintained without scale formation. This allows the tower system to operate with less bleed and greatly reduces the makeup water requirements. Also, most corrosion inhibitor programs are designed to provide effective control only if the specified cycles are maintained. Consequently, failure to maintain recommended cycles for the inhibitor being used can result in severe corrosion and scale.

Unless a portion of the tower water is discharged as bleed, scaling and/or corrosion will eventually occur regardless of what treatment chemicals are used.

Defining Cycles of Concentration
The term used in calculating and determining the amount of bleed is called cycles of concentration. Cycles can be defined as the number of times the dissolved minerals in the system cooling water are concentrated versus the level in the raw makeup water.

Cycles are NOT the number of times a given volume of water flows over the tower in a given time frame, and are NOT related to cycling the tower on and off in a given time frame.

Cycles and Water Usage
Maintaining recommended cycles is critical to conserving water and treatment cost, as well as scale and corrosion control. The table on the next page gives the impact on water and treatment usage as a function of cycles on a 500-ton chiller system running at full load for 24 hours per day (evaporation rate = 21,600 gpd).

The table shows a dramatic decrease in water and inhibitor cost by increasing cycles from one and a half to three. It also shows that increasing cycles follows the law of diminishing returns. As the cycles are increased past five, the increased savings becomes negligible.

The optimum cycles for any system is a function of makeup water quality, system temperatures, and, sometimes, system design. If makeup water hardness is high enough, you may be limited to low cycles, unless pretreatment or acid feed is used.
### Cycles vs. Water and Inhibitor Costs

*Based on water cost of $3.00 per 1,000 gallons

<table>
<thead>
<tr>
<th>Cycles (gpd)</th>
<th>Bleed (gpd)</th>
<th>Makeup (gpd)</th>
<th>Annual Water Cost*</th>
<th>% Reduction Water Cost</th>
<th>% Reduction Inhibitor Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>43,200</td>
<td>64,800</td>
<td>$70,956</td>
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<td>00.0</td>
</tr>
<tr>
<td>2.0</td>
<td>21,600</td>
<td>43,200</td>
<td>$47,304</td>
<td>33.3</td>
<td>50.0</td>
</tr>
<tr>
<td>3.0</td>
<td>10,800</td>
<td>32,400</td>
<td>$35,478</td>
<td>50.0</td>
<td>75.0</td>
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<tr>
<td>4.0</td>
<td>7,200</td>
<td>28,800</td>
<td>$31,536</td>
<td>55.6</td>
<td>83.3</td>
</tr>
<tr>
<td>5.0</td>
<td>5,400</td>
<td>27,000</td>
<td>$29,565</td>
<td>58.3</td>
<td>87.5</td>
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<tr>
<td>6.0</td>
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<td>25,920</td>
<td>$28,382</td>
<td>60.0</td>
<td>90.0</td>
</tr>
<tr>
<td>8.0</td>
<td>3,086</td>
<td>24,686</td>
<td>$27,031</td>
<td>61.9</td>
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</tr>
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<td>10.0</td>
<td>2,400</td>
<td>24,000</td>
<td>$26,280</td>
<td>62.9</td>
<td>94.4</td>
</tr>
</tbody>
</table>

### Determining Tower Water Cycles

Determining the cycles can be done using system flow rate measurements or by chemical means. If there are water meters on the makeup and bleed lines, and water flows can be recorded in each, then mass balances can provide an accurate measurement of the average cycles over a given time period.

The formula used to calculate the cycles of concentration by mass balance is:

\[
\text{Cycles} = \frac{\text{Makeup}}{\text{Bleed}}
\]

This formula is derived from the overall mass balances of the cooling system involving evaporation, makeup, and bleed:

\[
\text{Bleed} = \frac{\text{Evaporation}}{(\text{Cycles} - 1)} \\
\text{Makeup} = \text{Evaporation} + \text{Bleed}
\]

If the makeup or bleed flow rate cannot be measured, there are chemical means commonly used to calculate the cycles at the specific time the water is sampled. The water characteristic chosen should reflect the dissolved solids or a very soluble ion. The ones usually used are conductivity, chlorides, or silica, depending on makeup water quality, ease of performing an accurate test, and other variables.

Determining the cycles involves performing a test for this same water characteristic on both tower and makeup water samples and calculating the ratio of “Tower Water Impurity” divided by “Makeup Water Impurity.”

For example:

\[
\text{Cycles} = \frac{\text{Tower Water Conductivity (or Chlorides)}}{\text{Makeup Water Conductivity (or Chlorides)}}
\]

It is desirable to periodically perform additional testing and compare the calculated cycles with cycles based on hardness to ensure scaling is being controlled.

### Controlled and Uncontrolled Bleed Losses

Bleed is the removal of ANY water from the system other than evaporation. It can be intentional, by opening a bleed valve, or unintentional, such as water loss from a pump seal, leaks in the system, overflow down the tower drain, or windage and drift loss. Both intentional and unintentional bleed control the cycles of concentration.

If the unintentional losses are high enough, your cycles may be lower than ideal. Excessive water use and treatment cost will be the result.