Water Conservation in Cooling Towers Using Controlled Hydrodynamic Cavitation

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ABSTRACT

This paper describes an alternative, patented non-chemical cooling water treatment system. The system includes a mechanical unit and a separation/filtration unit. The unit works primarily on the principals of Controlled Hydrodynamic Cavitation (CHC). As the cooling water is pumped through the unit, the CHC action destroys microbial cell walls and converts dissolved calcium and bicarbonate ions into calcium carbonate ($CaCO_3$) solids that are separated from the recirculating water by the separation/filtration unit.

Case studies are highlighted in the paper to summarize the application of this new treatment system for cooling water applications. Performance data, such as water savings, scale control, corrosion and bacteria (*Legionella*) reduction, are presented.

Keywords: cooling tower, water conservation, hydrodynamic cavitation, non-chemical treatment

1.0 INTRODUCTION

Cooling towers are a component of some buildings' cooling systems. Where installed, cooling towers can account for up to 30% of the total water used in an average building, a statistic that can be even higher during summer months. Water is lost in cooling towers by evaporation (which provides cooling), bleed (to prevent build-up of dissolved and suspended solids), drift (water droplets entrained in exhaust air), splashes, overflow, and leaks. Cooling tower systems are very dynamic, and treatment of the water is required to control microbial growth, scaling, corrosion and fouling.

Due to more stringent environmental regulations and the escalating cost of water, there is a need in industry to improve the performance of open recirculating cooling water systems. In addition, it is important to minimize the impact of the discharge of cooling water containing chemical treatment additives on the environment (surface water), as well as to economize on energy.

Case studies are highlighted in the paper to summarize the application of this new treatment system for cooling water applications. Performance data, such as scale control, corrosion and bacteria reduction, are also presented. In addition, a 60% – 80% reduction in blowdown and a 20% – 30% reduction in makeup water usage can be achieved. These results indicate that unlike other non-chemical treatment methods, the CHC system offers a complete solution for water related problems that typically occur in circulating cooling water systems. This technology can also provide USGBC LEED credit for new construction (NC) and innovation and design (ID). An additional point may be earned (Water Efficiency 1.2) by utilizing cooling tower blowdown for landscape irrigation purposes.

2.0 TECHNOLOGY DESCRIPTION

The VRTX CHC system is a side-stream treatment system (see Figure 1). It includes two primary components: a CHC unit and a separation/filtration unit in addition to controls and a corrosion coupon rack (see Figure 2). The separation/filtration unit is used to remove the precipitated calcium carbonate (formed by cavitation) and other suspended solids from the recirculating cooling water.

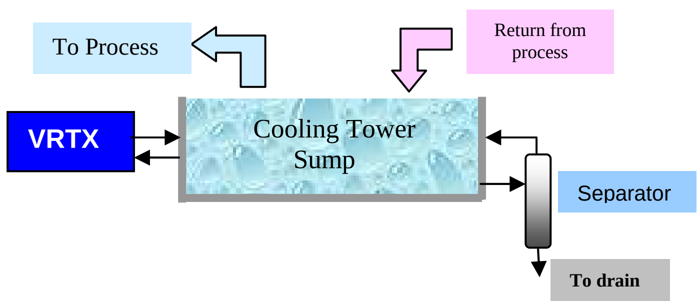

Figure1: Schematic of CHC System Layout

Figure 2. A Standard CHC Unit with a Separator System and Controls

The patented CHC chamber consists of a pressure equalizing chamber, nozzles and a cavitation chamber (Figure 3). Inside the cavitation chamber, two pairs of nozzles are positioned opposite each other at specific distances, lengths and angles.

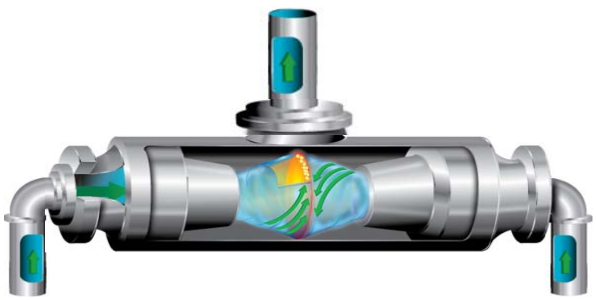

Figure 3. Diagram of the Hydrodynamic Cavitation Equipment

Sump water is first pumped into the pressure equalizing chamber at a pump pressure of ~70 PSI. From the equalizing chamber, water is channeled into the cavitation nozzle, where it is forced to rotate at high velocities. The rotation of the water creates a high vacuum, typically greater than -27.5 in of Hg. This high vacuum condition causes micro-sized bubbles to form in the water resulting in the first cavitation event. These bubbles are filled with a mixture of vapor and dissolved gases, most commonly carbon dioxide and oxygen. The water in the two nozzles are rotating in opposite directions as they travel forward at accelerating speeds. Upon exiting the nozzle, the opposing water streams collide at the mid-point of cavitation chamber. At this point, pressure increases spontaneously, causing the sudden implosion of micro-sized bubbles resulting in the second cavitation event. At the moment of collapse, hydrodynamic cavitation can generate intensive shock waves and extremely high temperatures (12-150,000 psi, 10-17,000° F). Under these conditions, chemical reactions can occur (e.g. oxidation, calcite formation, etc.) and bacteria are ruptured by both mechanical and physical forces.

3.0 CASE HISTORY 1

The citrus facility located in the south east, is a state-of-the-art facility designed to keep citrus & juice products refrigerated. The facility's state-of-the-art North Condenser System (NCS) has the capacity to handle 15,000 tons of ammonia refrigeration (18 evaporative condensers). It is the one of the largest refrigeration systems in North America.

The objectives of this study were to: (a) provide scale, corrosion and microbiological control, (b) improve condenser operating efficiency (c) conserve water by minimizing condenser make up, (d) produce a reduced quantity of condenser bleed that possessed minimal pollution and (e) implement environmental improvements and worker safety wherever possible.

3.1 Results

Figure 4 summarizes meaningful and significant water conservation. The annual water savings was determined to be over 5.4 million gallons of water. Moreover, the use of the CHC system has allowed over 5 million gallons of non-potable water to be available for reused on an annual basis.

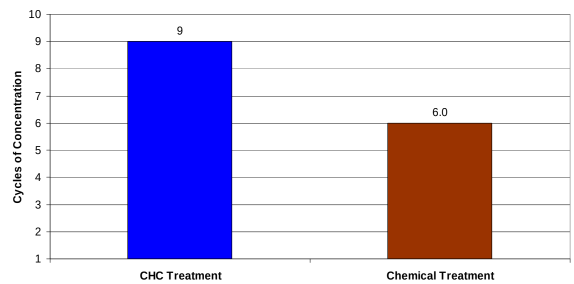

Figure 4. Comparison of Cycles of Concentration: CHC vs. Chemical Treatment

3.2 Summary

- CHC system performance met or exceeded what would be accomplished by using conventional chemical water treatment methods.

- Shortly after startup on the NCS, the CHC system eliminated the use of hazardous chemicals (biocides, algaecides and corrosion inhibitors) in the NCS condenser water. Worker safety was improved, training requirements were reduced, and storage of onsite water treatment chemicals were eliminated for this system. The work environment was also improved for employees and environmental compliance associated with this benefit.

- Annual water savings exceed 5 million gallons.

- Corrosion rate test results were within the Cooling Tower Institute (CTI) Limits.

- Since startup there has been no evidence of scale buildup.

- Microbiological control in the NCS has averaged less than the CTI maximum of 100,000 CFU's per/ml.

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4.0 Case Study 2

A brewery located in the southern United States operates a refrigeration system and averaged 2.0 cycles of concentration on chemical treatment. The site uses three evaporative condensers with a total cooling capacity of 1,244 tons and a water volume of 2,500 gallons. Municipal water is used as makeup for this cooling system. Significant scale deposits accumulated around the condenser tubes and inside the condensers. The facility was looking for a treatment approach that would conserve water while maintaining effective scale and bacteria control.

4.1 Results

The results of the study are presented in Figures 5-7. As seen in Figure 5, with the addition of CHC treatment, blowdown was significantly reduced. Daily blowdown declined from an average of 8,417 gallons/day to 1,657 gallons/day, representing an 80.3% reduction.

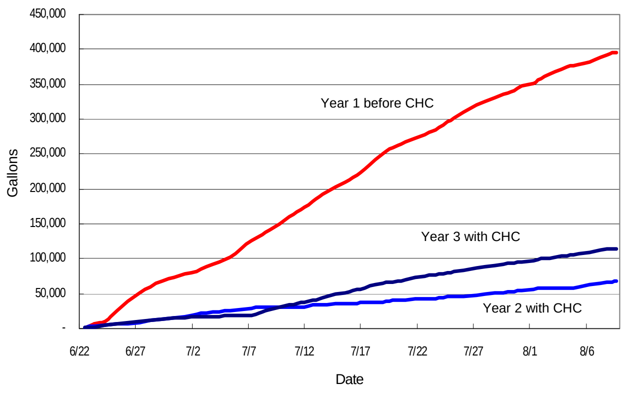

Figure 5. Comparison of Blowdown

Figure 6 illustrates the reduction in make-up water over the trial period. Daily make-up water declined from an average of 19,251 gallons/day to 12,619 gallons/day, representing a 34.5% reduction.

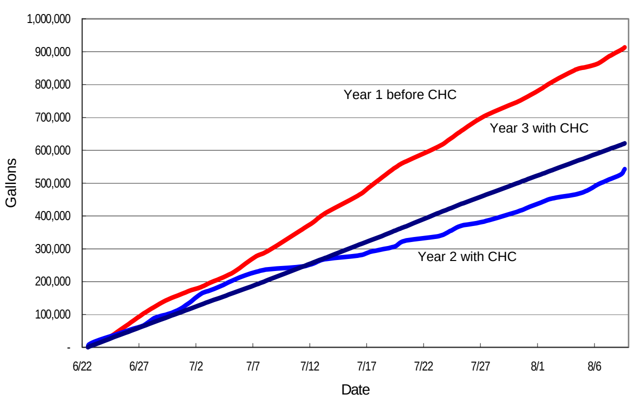

Figure 6. Comparison of Make-up Consumption

Through use of the CHC technology, this site was able to increase their cycles of concentration from an average of 2 to near 7 (Figure 7).

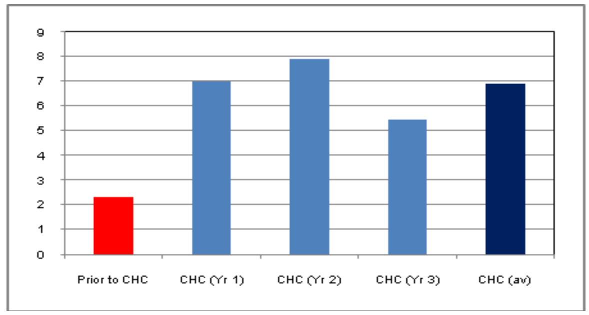

Figure 7. Comparison of Cycles of Concentration

4.2 Summary

- Daily make-up water declined from an average of 19,251 gallons/day to 12,619 gallons/day, representing a 34.5% reduction.
- Daily blowdown declined from an average of 8,417 gallons/day to 1,657 gallons/day, representing an 80.3% reduction.
- Average Cycles of Concentration increased from 2.3 to 6.9.
- During the same period, daily evaporation changed from 10,834 gallons/day to 10,962 gallons/day. This increase is a result of cleaner evaporative tubes and better heat transfer across evaporative tubes. Better heat transfer reduces the consumption of electrical energy required for a refrigeration system.
- Based on the recorded data, the annual water saving is over 2.0 million gallons.

5.0 Case Study 3

A facility located in southern Nevada was investigating alternative to chemical treatment of their cooling tower. After review of a number of options, the CHC system was chosen. A summary of the system and a comparison to the previous chemical treatment is given in Table 1 and 2. As shown, significant water savings and cost were obtained with CHC.

Location	Southern NV
Unit size	350 ton
Flow rate	1050 gpm
System volume	1462 gal
Usage	3720 hr/yr

Table 1. Case Study 3 Background

Treatment	Cycles	Make-up gal	Savings gal	Savings $
Chemical	2	2,355,318	na	na
CHC	3	1,769,418	585,900	1,529* 4,688** 2,925***

* $1.46-3.46/1000 gal make-up water (per yr)
* $1.71/100 gal sewer charge (per yr)
** $8.00 water rebate (one time)
*** $25.00/1000 gal reuse credit, assume 1/5 recycle volume (per yr)

Table 2. Case Study 2: Water and Cost Savings

6.0 CONCLUSIONS

Increased demand for water combined with tighter restrictions on environmental pollution has dictated the need for improvement in water treatment. The CHC system provides an effective chemical-free solution for cooling water systems. The benefits of this technology are:

- Effective at Controlling: Scale, Corrosion and Bacteria
- Saves Water By Running Higher Cycles
- Reduces Energy Consumption By
- Operating a Cleaner System (bullet)
- “Green” Technology
- Zero Chemicals in System
- CHC Eligible for Utility Water Rebates in Some Areas (California, Nevada, etc.)
- CHC Qualifies for USGBC LEED-NC (New Construction) Innovation and Design (ID) Credit 1.1. An additional point may be earned (Water Efficiency 1.2) by utilizing cooling tower blowdown for landscape irrigation purpose.