New Technology Saves Cooling Water Demands

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Introduction

Water is becoming a scarce resource in many parts of the United States, especially during drought seasons (1). Tracking the flow data of rivers nationwide, the U.S. Geological Survey identified 59 points on 57 rivers that reached record low levels in March 2002 (2). Federal scientists used temperature and precipitation data to calculate that severe or extreme drought has spread over 21% of the country so far this year. (3). Experts predict that the availability of fresh water will be more vulnerable worldwide in the near future, due to the growing population and increasing water consumption per capita (4, 5). Responding to these growing problems, the industry has been challenged to find ways to reduce water use.

One industry with an especially vital interest in the preservation and quality of water is the brewing industry. Not only does its product consist of over 90% water, additionally, 4-7 barrels (each equals 31 US gallons) of water are used during the brewing process for every barrel of finished beer.

The Spoetzl Brewery, Inc. in Shiner, Texas, serves as an example of how this problem can be addressed. The brewery, established in 1909, is Texas' oldest independent brewery. It produces the Shiner brand family of beers with Shiner Bock its most famous brew, enjoyed by many in the Southern half of the United States. The brewery operates a refrigeration system with anhydrous ammonia as the primary coolant. The recompressed ammonia is being cooled down in 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. On average, the makeup water contains 100 ppm (as $CaCO_3$) of total hardness, 60 ppm (as $CaCO_3$) of calcium hardness and 400 ppm (as $CaCO_3$) of total alkalinity. The pH is around 7.7 with a TDS at about 720 ppm. The original chemical water treatment system was designed with a makeup water holding tank into which additives were automatically injected, based on water conductivity. From this holding tank, the cooling water was pumped up to the towers on the roof.

Chemical Treatment

During chemical treatment, three kinds of chemicals were applied to maintain the proper operation of the system. Sulfuric acid was added to prevent calcium carbonate buildup; Chlorine and a non-oxidizing biocide were used to control microorganism growth; and a corrosion inhibitor, based on molybdenum, was applied to reduce corrosion rates. The control range for pH was 8.0 – 8.2; the residual molybdenum and free chlorine were set at 1.5 to 2.5 ppm and 0.3 to 0.5 ppm, respectively.

In conjunction with the chemical treatment, cycles of concentration were kept low with repeated bleed-off to assure water quality. The cycles of concentration were 2 – 2.5 during the summer months and below 2 for the rest of the year, resulting in an average around 2. Despite these efforts, significant calcium carbonate deposit accumulated on and around the condenser tubes and inside the condensers. Considering that the thermal conductivity of calcium carbonate is 50 times less than that of carbon steel (6), the formation of inorganic scale on condenser tubes significantly reduces the heat transfer rate across condenser tubes, and consequently, excess electric energy is required to run the ammonia compressors.

New Treatment

In August 2001, chemical treatment was replaced by the VRTX system, a patented non-chemical technology for cooling water treatment. The VRTX system consists of a VRTX unit and a filtration/separation unit. The VRTX unit is a mechanical device using the principle of kinetic energy to treat fluids. When the cooling water is pumped through the VRTX chamber, dramatic changes in velocity and, consequently, static pressure lead to the destruction of microbial cell walls and the conversion of dissolved calcium and bicarbonate ions into calcium carbonate ($CaCO_3$) colloids:

$$\textit{Dissolved Ca ions} + \textit{Dissolved bicarbonate ions} \xrightarrow{\text{Energy}} \textit{CaCO}_3\ \textit{colloids} + \textit{Carbon dioxide gas} + \textit{Water}$$

$$Ca^{2+} + 2HCO_3^{-} \xrightarrow{\text{Energy}} CaCO_3 + CO_2 + H_2O$$

The $CaCO_3$ colloids formed under this condition are in the form of aragonite, shown by electron scanning microscopy (SEM) analysis. Aragonite has the same chemical composition as calcite, the hard scale $CaCO_3$ form. But their molecular structures and the crystal shapes are different. The rhombohedra calcite crystal has six flat surfaces; these flat surfaces lead to significant adhesion to other surface and form a hard deposit. The shape of aragonite is needle-like. This unique shape substantially reduces the adhesion to other surfaces, but tends to form soft deposits. These deposits are stable upon heating and can be carried throughout a heating or cooling system while causing no apparent damage. This transport property allows the $CaCO_3$ particles to be moved to the filtration unit, where they are separated from the recirculating water.

Based on the water volume in the system, makeup feed rates and water chemistry, a 60 GPM VRTX unit and a 50 GPM disc filter were installed. Both VRTX unit and filter draw and return water to three sumps separately. Globe valves were installed on the intake lines to adjust flow rates for equal treatment of all three sumps.

The disc filter combines the advantages of centrifugal separator and media filter. The spinning incominge water creates a centrifugal cleaning action, spiraling heavier particulate away from the disc stack. This dramatically reduces the backflush frequency. The media comprises injection molded polypropylene disks, which form a three-dimensional filter media. As cooling water passes through the depth of the disks, the disks capture the suspended particulates. As these particulates accumulate, it causes a pressure differential across the filter. When the differential pressure reaches predetermined level, an automatic back-flushing cycle is initiated. The disk caps lift hydraulically to allow the disc stack to open and separate. Backflush nozzles spray filtered water uniformly through the disc stack. When the backflush cycle is complete, the disc caps re-compress the disc stack and normal filtration is resumed. The water required for the backflush is a fraction of the amount used by traditional sand filters. With the reduced backflush frequency and water volume, water consumption and discharge are reduced.

Performance

Since the VRTX installation, water samples were taken weekly for the first month, biweekly for the next 2 months, and once a month ever since for water chemistry and bacteria analysis. Condenser tubes and the inside of the condensers were inspected regularly for scale buildup. The performance of VRTX treatment can be summarized as follows:

- Old scale is gradually removed and no new scale is formed: Two weeks after installation, it was noticed that the hard scale on the condenser tubes started to soften. Most of the scale was removed after 2 months of operation. Recent inspection shows that all the condenser tubes are clean, and scale buildup on the inside walls of the condensers is reduced significantly.

- Very low bacteria counts: Total bacteria counts in cooling water normally ranges from 400 to 2,500 CFU/mL (Chart 1), measured by standard Pour Plate Method (Standard Method 9215 B).

- Excellent corrosion control: Corrosion rates of less than 2.2 mpy for galvanized steel and 2.5 mpy for carbon steel and less than 0.3 mpy for copper alloy (Chart 2).

Chart 1. Bacteria Test Results Since VRTX Treatment

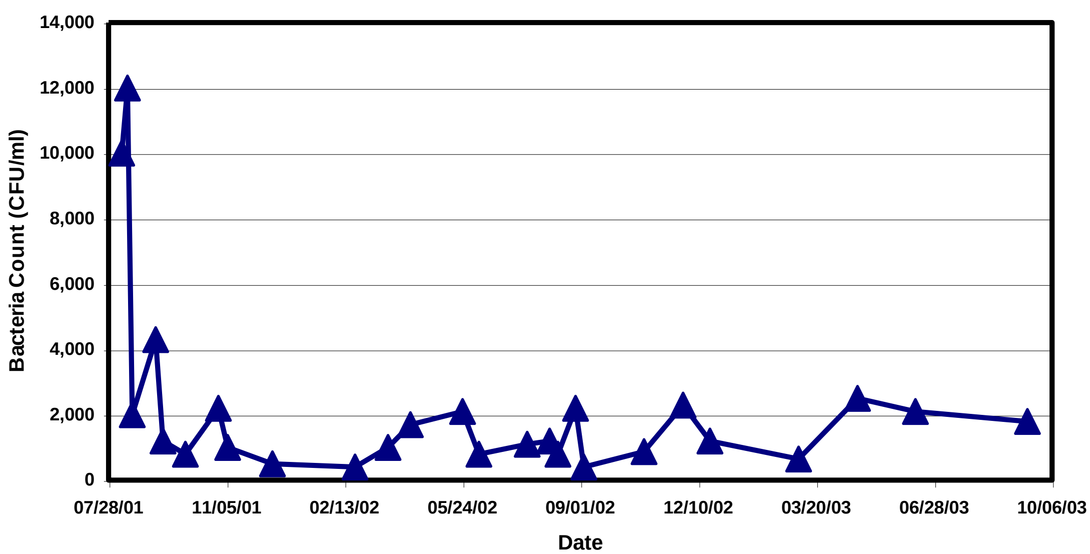
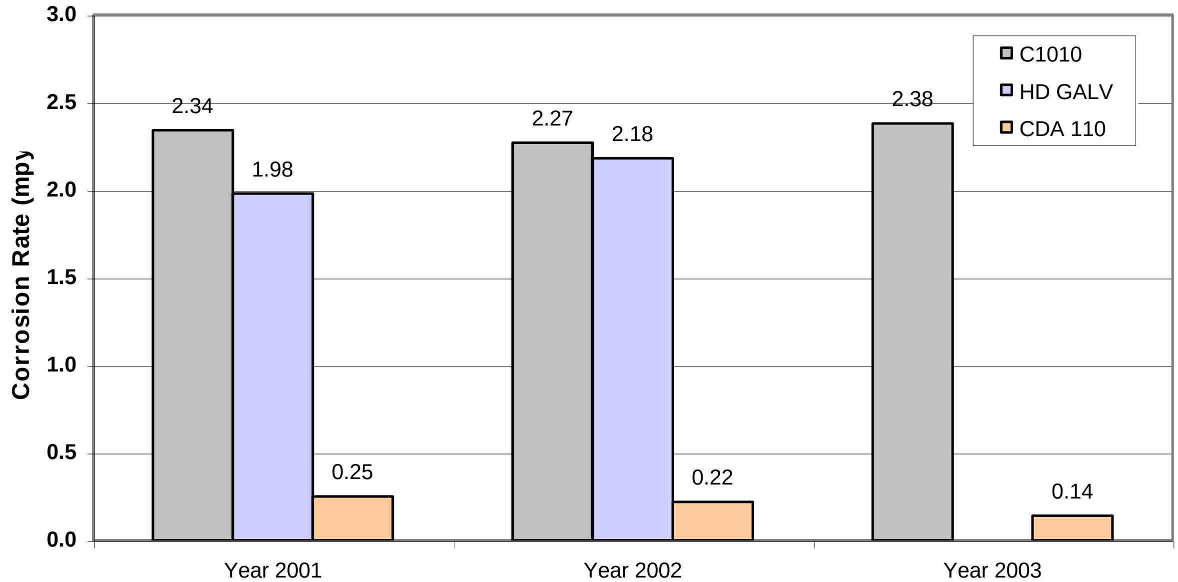


Chart 2. Corrosion Coupon Test Results Since VRTX Treatment



Water Savings

The brewery installed water meters on both makeup and blowdown lines 47 days prior to the installation of the VRTX system. Readings from both meters have been recorded regularly since. Chart 3 summarizes the results. During the 47-days prior to VRTX treatment, the blowdown was 395,600 gallons and makeup consumption was 901,600 gallons. Since the installation of VRTX system, the blowdown volume was only 441,000 gallons and makeup consumption was 3,253,300 gallons over last 12 months.

Based on the above data, the makeup and blowdown rates were calculated, as shown in Chart 4. During the last 12 month of VRTX treatment, the average blowdown rate was 1210 gal. per day and makeup rate was 8929 gal. per day. Both makeup and blowdown rates change with seasons, due to the changes in the evaporation rate of cooling water. Evaporation rates are affected by the heat load of the system, which are directly related to plant production rates and weather conditions. Consequently, the evaporation rate is higher during summer season and lower during winter season.

Chart 5 summarizes the calculated cycles of concentration. The cycles of concentration can be thought of as an indicator of the number of times water is used in the cooling tower before it is discharged. The low cycles of concentration represent high makeup usage and a high blowdown rate.

Chart 3. Recorded Makeup Water Consumption and Blowdown Data

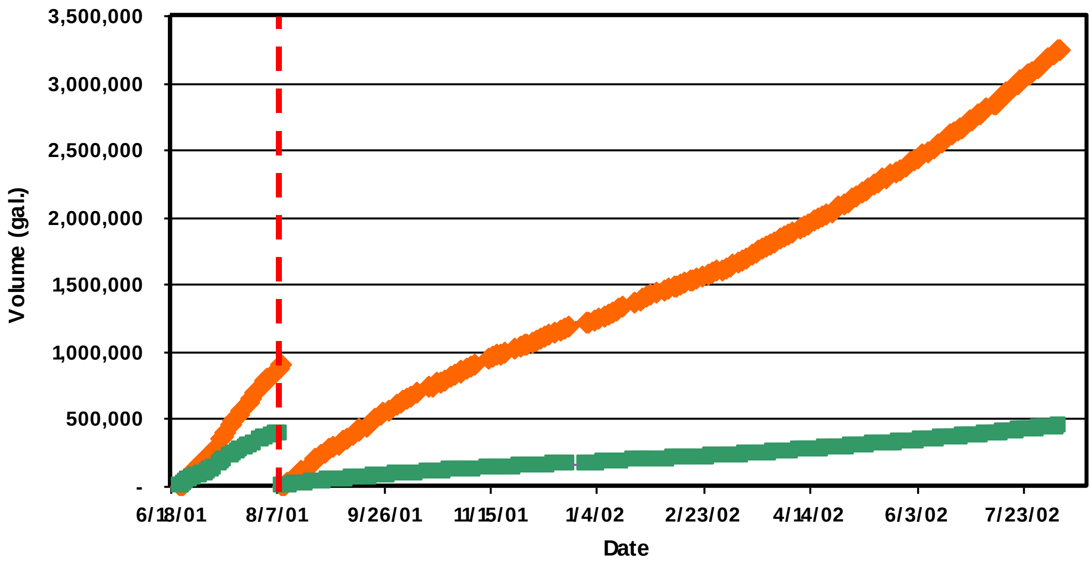
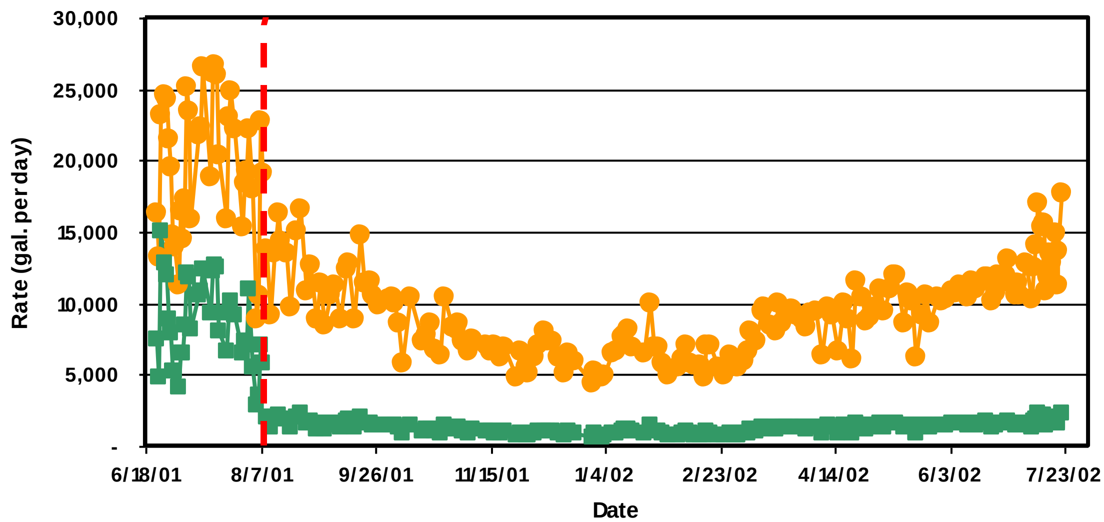


Chart 4. Makeup and Blowdown Rates Calculated from The Metered Data



The definition of cycles of concentration is the concentration ratio of dissolved solids in blowdown water to makeup water. Using dissolved chlorides:

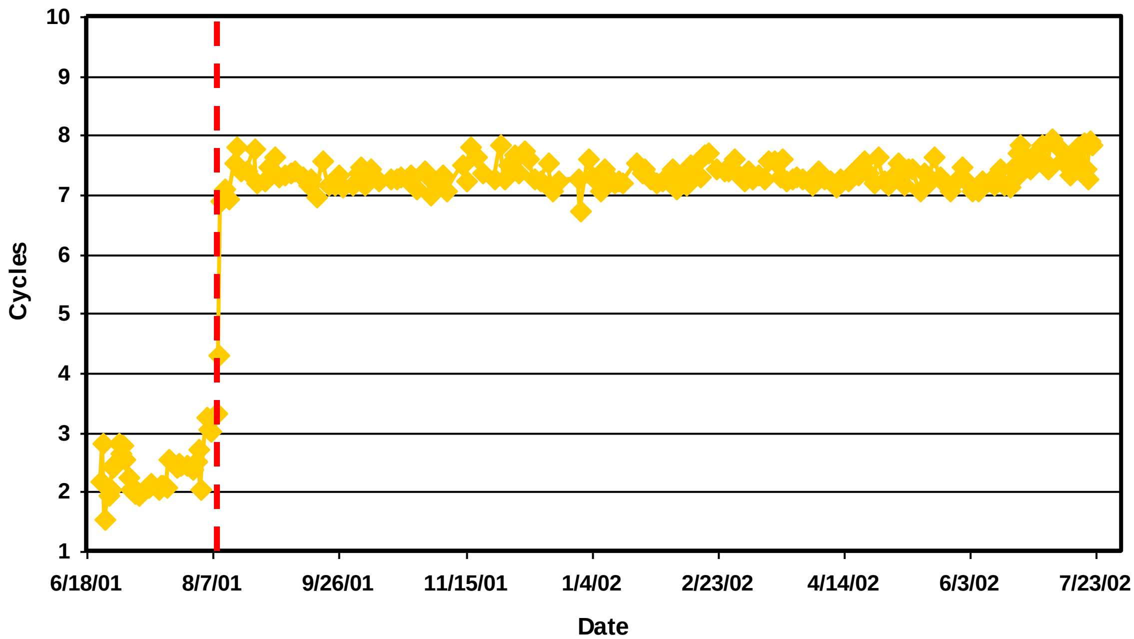
$$\text{Cycles of concentration} = \frac{\text{Chloride concentration in sump}}{\text{Chloride concentration in makeup}} \quad (1)$$

Cycles of concentration can also be expressed as follow, based on mass balance:

$$\text{Cycles of concentration} = \frac{\text{Makeup rate}}{\text{Blowdown rate}} \tag{2}$$

The average cycles of concentration were 2.3 during chemical treatment period. With VRTX treatment, the cycles were kept between 7 to 8 during last 12 month, with an average of 7.4.

Chart 5. Calculated Cycles of Concentration



To eliminate the effect of different seasons on evaporation, makeup rates, blowdown rates, and cycles of concentrations are charted to provide a direct comparison of water consumption during the same period (June 22 – Aug. 8) with chemical treatment for the Year 2001 and VRTX treatment for the Year 2002 (see Charts 6 – 8). The results can be summarized as:

- 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 7.6.

- 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 refrigeration system.

- Based on the recorded data, the annual water saving is over 2.0 million gallons

Chart 6. A Direct Comparison of Makeup Rates During The Same Period

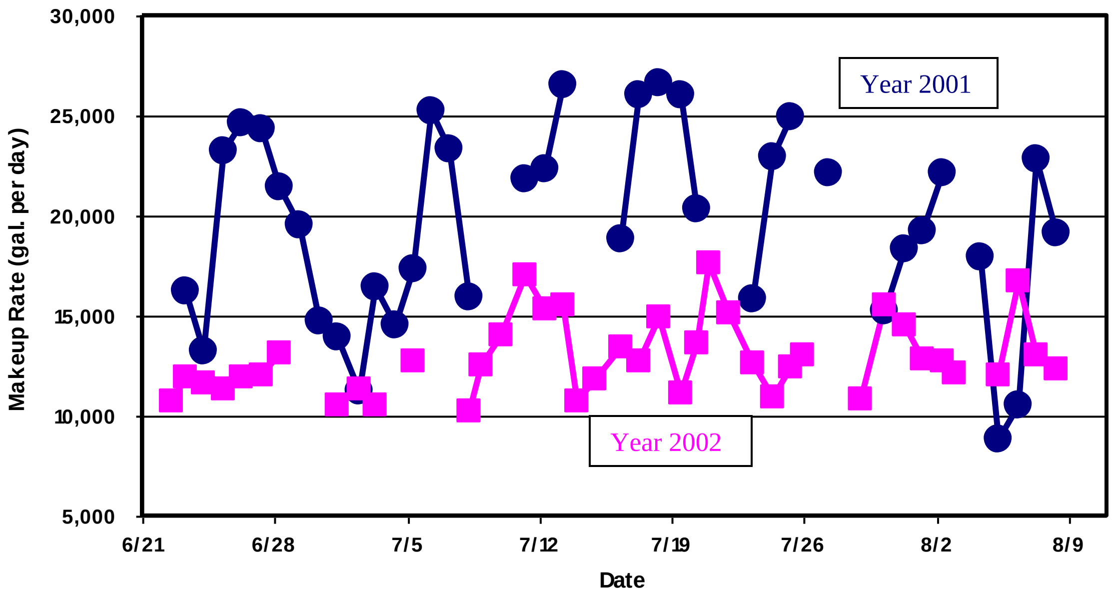


Chart 7. A Direct Comparison of Blowdown Rates During The Same Period

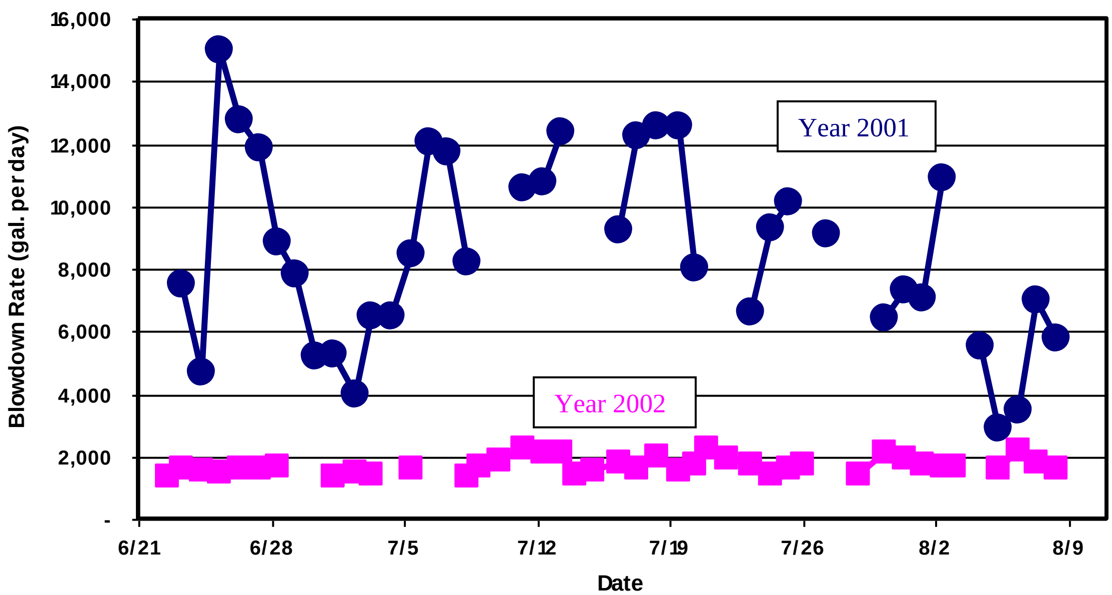
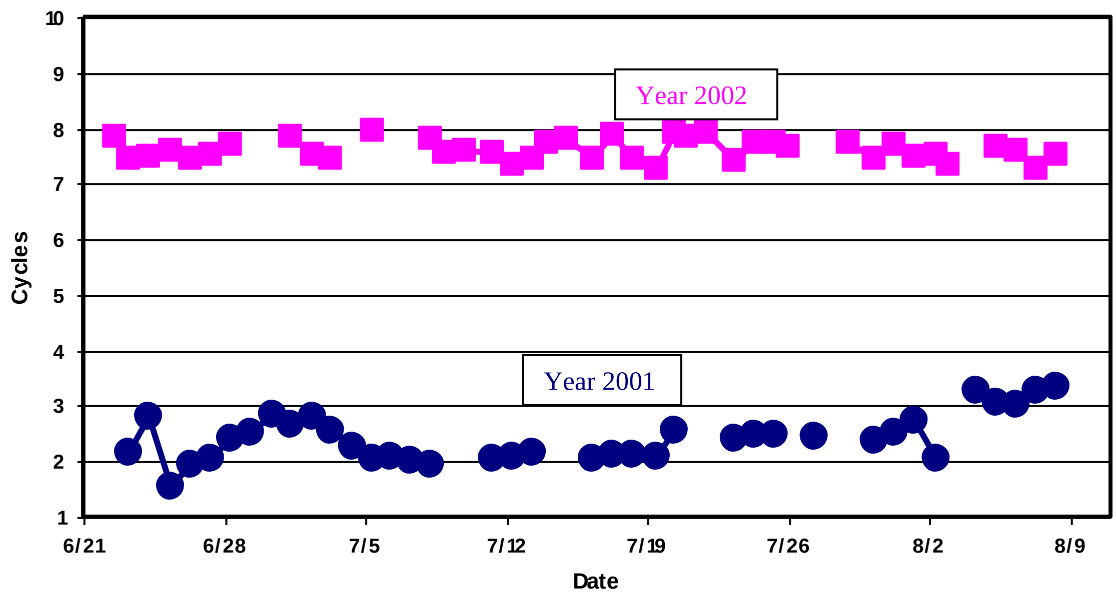


Chart 8. A Direct Comparison of Cycles of Concentration During The Same Period



Conclusion

Increased demand for water combined with tighter restrictions on environmental pollution has dictated the need for improvement in water treatment. The VRTX system provides an effective chemical-free solution for cooling water systems.

With the installation of the VRTX system, discharge from this cooling system has been reduced significantly, up to 80%. Consequently, the makeup water consumption also decreased substantially. In addition, the discharge water now contains no hazardous chemicals.

Besides the water savings, field observations and laboratory tests indicate that the VRTX system is superior in controlling problems, such as scale, corrosion and bacterial activities, to the previous chemical treatment.

Acknowledgements

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References

1. R. Doyle, "In a dry land" Scientific America. July 2001
2. Visit website http://water.usgs.gov/waterwatch/ for real-time stream-flow data, and maps and graphs of current water resources conditions
3. T. Watson and P. Overberg, "Rivers down to barest of levels". USA TODAY. March 28, 2002
4. P. Gleick, "The World's Water 2000 – 2001". Island Press. Washington DC. 2000
5. P. Simon, "Thirsty World" Environmental Protection. November 2001
6. J. McCoy, "Chemical Analysis of Industrial Water". Chemical Publishing Company, New York. 1969