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Industrial Water Reuse
A Case History Report

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Background

Typical Cooling Tower

Due to purchase and operating economics evaporative, or "wet", cooling towers are the technology of choice for commercial and industrial cooling systems as water is the best material for both transfer of heat and evaporative cooling. Such installations are many times the largest water use in the facility, often times accounting for over 30% of total water use. Due to fresh water shortages in many areas and increased water and sewer charges, many facilities are now looking to reuse industrial wastewaters as cooling tower makeup.

A chemical manufacturing plant in Arizona desired to reduce their use of fresh water and subsequent discharge of wastewater to the sanitary sewer. Our examination of the plant showed three reverse osmosis systems operating with softened influent water to provide high quality process water with reject (concentrate) discharged to the sanitary sewer. Three process cooling tower systems were also on site using hard city water for makeup with an average thermal load of 482 tons. The average reverse osmosis reject flow rate was determined to be sufficient to supply 100% of the cooling tower makeup needs under most conditions. As the reverse osmosis reject is both soft and concentrated, corrosion in the cooling tower systems was the major concern given the chloride and sulfate levels in the city water which would be concentrated in the reverse osmosis reject water to be reused as cooling tower makeup.

Our patented[i] treatment chemical composition, “Aqua Ionic”, was designed to control corrosion when using softened makeup water with high levels of dissolved solids, chloride, and sulfate. Following an extended review of our technology and proposed equipment package, the chemical plant purchased a design and equipment package to reuse the reverse osmosis reject as cooling tower makeup.

Equipment Package

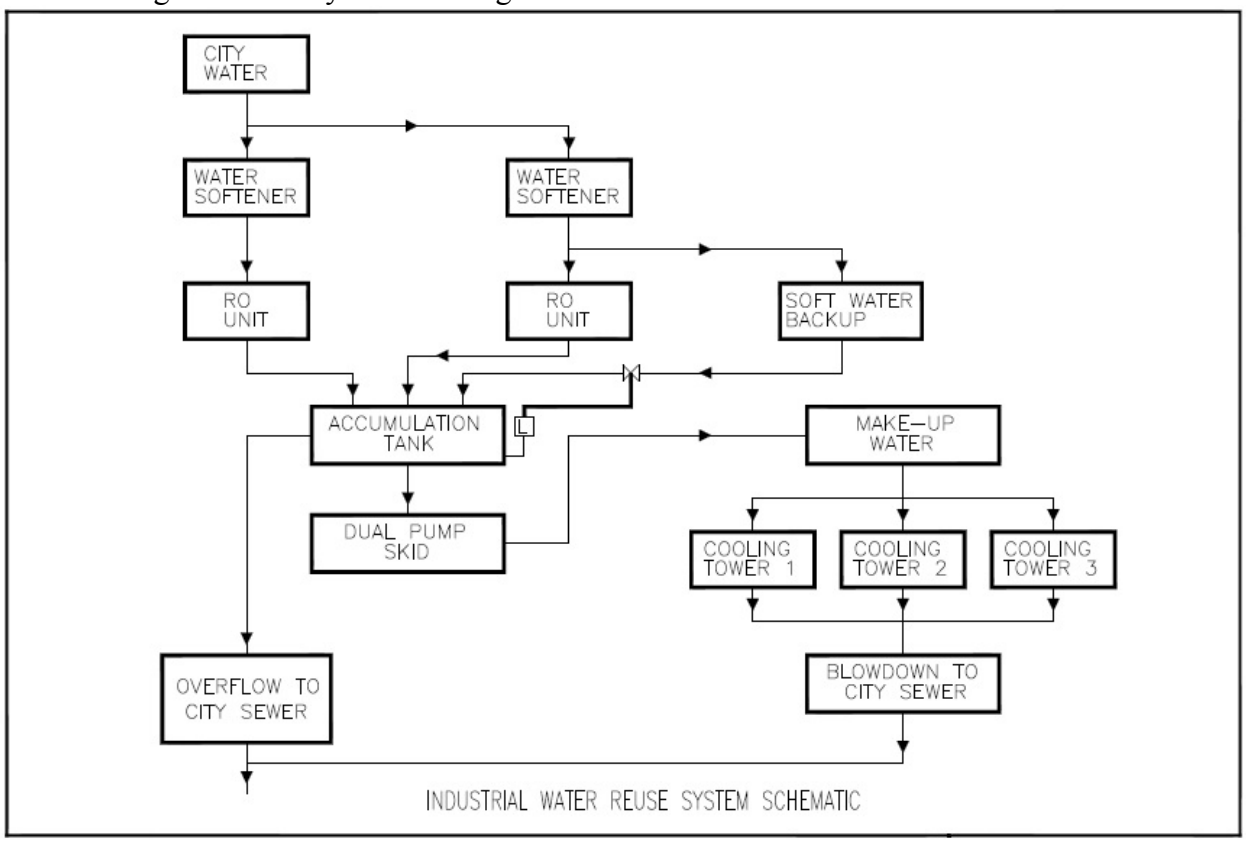
Skid Mounted System Control Panel and Pumps, Tank in Background

The equipment package consisted of a 5,000 gallon black polyethylene tank to receive the reverse osmosis reject, manufactured dual pump skid to provide water to the cooling towers, PLC based control panel, makeup and blowdown meters, soft water backup valve and water meter, and retrofit of the three cooling tower systems with new control and chemical feed units. The pump skid and system control panel were manufactured by ProChemTech while Advantage MegaTron XS controllers were used for cooling tower control and chemical feed. This equipment package was installed by a combination of chemical plant personnel and an outside plumbing contractor.

Installation and start-up was completed in March, 2017.

Schematic of System

This drawing shows the system as designed and installed.



Cooling System Information

The cooling tower systems are equipped with four counter flow units, PVC fill, one with galvanized steel and three with stainless steel construction (two connected and operated as one system) giving a total of three cooling tower systems. The total rated thermal capacity of the cooling tower systems was given as 500 tons typically operating 24 hours per day, seven days a week providing cooling water to plant chillers and air compressors. Using hard city water makeup, these cooling towers were being operated at three (3) cycles of concentration (COC) with conductivity controlled blowdown, timed biocide addition, and makeup proportional chemical feed.

The major reason for replacement of the cooling tower controllers was that the cooling towers were to be operated at over five (5) COC with the reuse water as makeup, resulting in a cooling water conductivity exceeding the maximum 10,000 mmhos range on the existing controllers.

The Aqua Ionic water management program implemented during reuse system start-up uses a single polysilicate base inhibitor product and a single oxidizing biocide, n,n, dibromosulfamate, for biological control. A colorimetric control tracer is used for routine manual control testing since discharge of the commonly used cooling water molybdate tracer to the sanitary sewer in the blowdown is not permitted. Cycles of concentration are maintained between five (5) and six (6) based on cooling water conductivity. Note that chloride testing, oftentimes used for cycles of concentration control testing, cannot be used due to variations in the reverse osmosis concentrate chloride levels and use of a high chloride content biocide.

Start-up Problems
Two major problems became evident during system start-up.

Routine testing of the water in the accumulation tank showed total hardness values from 85 to 170 mg/l. Going upstream; we found total hardness values of 68 to 136 mg/l in the reverse osmosis feed water. Obviously, the facility had some major problems with operation, or damage to, the two water softeners providing influent water to the reverse osmosis units. The problem was corrected by the two outside contractors responsible for maintenance and operation of the reverse osmosis systems.

A second problem became evident when we attempted to increase the cycles of concentration in two of the three cooling towers systems from three (3) to our target of five (5). Investigation showed that the two cooling tower systems that were unable to increase cycles of concentration were equipped with sidestream hydrocyclone units which purged on a time basis. The hydrocyclone units were shut down and the cooling towers increased cycles of concentration to the desired level. The amount of water discharged during the purge was sufficient to limit cycles of concentration. We also note that sidestream hydrocyclones are of little value on cooling tower systems[ii].

Results
The following operational information covers the time period June 19 to July 19, 2017.

Metered Total Cooling Tower Makeup – 446,500 gallons
Metered Soft Water Backup Amount– 5,000 gallons
Metered Cooling Tower Blowdown – 62,500 gallons
Calculated Evaporation – 384,000 gallons
Calculated Thermal Load – 482 tons

As a basis for comparison, the following results were calculated using the thermal load and operating the cooling systems at three (3) COC.

Total Cooling Tower Makeup – 576,000 gallons
Cooling Tower Blowdown – 192,000 gallons

Fresh Water Use Reduction = 576,000 gallons – 5,000 gallons = 571,000 gallons

Sanitary Sewer Discharge Reduction = 638,500 gallons – 62,500 gallons = 576,000 gallons

Water Quality Data
This table compares makeup and cooling tower analysis results for samples taken on July 17, 2017.

Parameter	City Water	RO Reject	CT #1	CT #2	CT #3
pH	7.8	8.2	9.5	9.5	9.5
total alkalinity	120	338	2,185	2,163	2,125
conductivity	991	2,210	11,650	11,690	11,500
calcium	76.5	0.07	0.56	0.53	0.40
magnesium	25.4	0.068	0.375	0.304	0.339
iron	<0.05	-	<0.03	<0.03	<0.03
copper	<0.05	-	0.04	0.02	0.03
zinc	<0.012	-	0.040	0.031	0.069

Parameter	City Water	RO Reject	CT #1	CT #2	CT #3
silicon	3.1	32.0	105	101	100
chloride	145	255	3,350	3,380	3,352
sulfate	237	418	3,170	3,160	3,316
total hardness	296	0.5	2.9	2.6	2.4
COC on Conductivity			5.3	5.3	5.2

It is generally accepted in the cooling water industry that a maximum chloride level to prevent excessive corrosion is 1,200 mg/l while high levels of sulfate also increase corrosion rates.[iii] As shown in the analysis results, cooling water chloride levels obtained are over twice the accepted maximum along with a substantial level of sulfate.

Corrosion Test Results

As corrosion is the major concern when operating with a cycled soft water having high levels of chloride and sulfate, the customer engaged a third party to undertake a corrosion coupon study between September 9 and December 13, 2017. Cooling water parameters of conductivity, chloride, and sulfate were within the ranges noted during the entire corrosion coupon study period. The results as reported are summarized in the following table.

Coupon Material	CT #1	CT #2	CT #3
mild steel	0.1 mils/yr	0.3 mils/yr	0.2 mils/yr
copper	< 0.1 mils/yr	<0.1 mils/yr	0.1 mil/yr

No pitting corrosion was reported. These are excellent results per the Association of Water Technologists guidelines[iv] for industrial cooling tower systems.

Economics

The previous water treatment program and Aqua Ionic program operating costs are the same so there was no increased cost involved with the new water treatment program.

Fresh water use was reduced by 571,000 gallons in the studied month which at the $2.65/1000 gallons charged in Mesa reduced the chemical plant water cost by $1,513.

Sewerage discharge was reduced by 576,000 gallons in the studied month which at the $3.63/1000 gallons charged in Mesa reduced the chemical plant sewer cost by $2,091.

Annual cost savings given the constant thermal load are estimated at $43,248. As the equipment package cost was $47,878 with installation costs estimated at $10,000 for a project cost of about $58,000, the project has a simple payback of 16 months.

Technology

ProChemTech Aqua Ionic water chemistry had its beginnings in 1984, when softened makeup water was first used to address severe scale problems on cooling tower systems providing cooling water to large, very high temperature glass melting furnaces. While use of softened makeup water eliminated the scale problem, severe corrosion problems became evident within six (6) months.

Our continuing research on corrosion control technology to resolve this problem lead directly to the advanced corrosion control technology used today in Aqua Ionic soft makeup water management programs which allow reuse of reverse osmosis reject as cooling tower makeup water.

References

[i] Aqua Ionic patents US 7,595,000 and 8,128,841

[ii] Cooling Tower Sidestream Filtration, T. Keister, Association of Water Technologies, Spring 2012, The Analyst, Volume 19, Number 2

[iii] Cooling Water Treatment Principals and Practice, C. Frayne, Chemical Publishing Company, 1999

[iv] AWT Recommendations and Guidelines for Corrosion Coupons in Cooling Systems, Association of Water Technologies, Technical Committee, 2016

About the Author

Timothy Keister has a B.Sc. in Ceramic Science from Penn State and is the Chief Chemist/President of ProChemTech International, Inc. He is a Certified Water Technologist, Fellow of the American Institute of Chemists, Senior Member of the American Institute of Chemical Engineers, and member of ASHRAE, ACS, CTI, and WEF. After 13 years in the glass industry as the water/wastewater manager responsible for 38 plants, he founded ProChemTech in 1987 as a water management and technology development firm. Tim currently has 11 US patents in water treatment technology. Contact information: E-mail tek@prochemtech.com, phone number 814-265-0959.