2019 Association of Water Technologies
Annual Conference and Exposition

September 11 – 14, 2019

Palm Springs Convention Center
Palm Springs, CA

Reuse of Reverse Osmosis Concentrate as Cooling Tower Makeup

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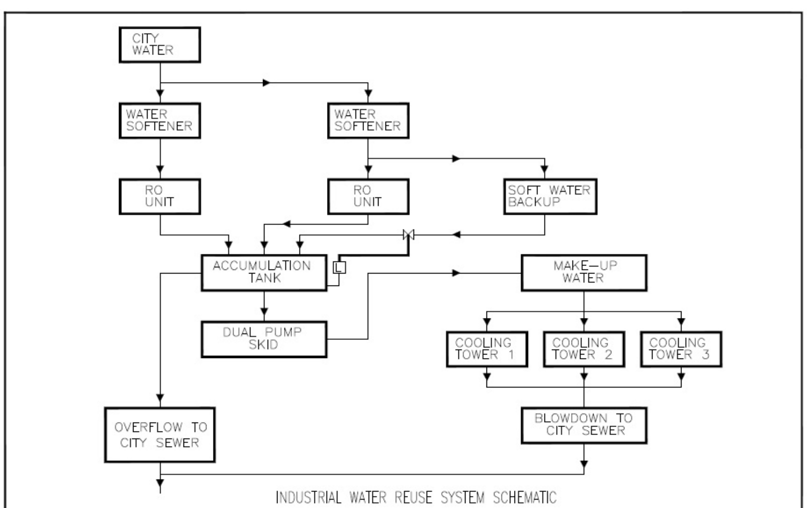
Background

Cooling Tower #3

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. Often facilities that have cooling towers also have reverse osmosis (RO) units to purify incoming water for process use or boiler makeup. A typical RO unit operates at a recovery of 75%, thus for a produced high purity, permeate, water flow of 100 gpm, the influent flow would be 133 gpm with a brine (concentrate) flow of 33 gpm. For a cooling tower operating at 5 cycles of concentration (COC), a brine flow of 33 gpm (47,520 gpd) would be sufficient to operate a cooling tower with a thermal capacity of 1,342 tons. Currently the majority of RO installations simply discharge the brine to sanitary sewer.

If the RO influent is softened as pretreatment, the RO brine will also be low hardness with high levels of rejected ions such as sodium, chloride, and sulfate. Looking at the brine as cooling tower blowdown, at 75% recovery it is at a COC of 4. While RO brine would be extremely corrosive when operated at 5, or more, COC in a cooling tower, we have invented and patented[i] specific chemistry which is suitable for operation of cooling towers using RO brine as makeup.



Schematic of 2017 installed system, RO brine discharge to accumulation tank

As cooling tower loads change and operation of RO systems is often on an intermittent basis, a hydraulic equalization and soft water backup system must be devised if RO brine is to be reliably reused as cooling tower makeup. A typical system would consist of a RO brine accumulation tank, level controls to add soft water when the tank level falls to a predetermined level, appropriate level alarms, and a dual pump skid to provide cooling tower makeup water.

The economics typically justify the cost of an equalization and backup system given current water and sewer rates. Using the rates from Tucson, AZ, water at $5.88/1000 gallons and sewer at $4.85/1000 gallons with a 100 gpm RO system operating on a 12 hr/day 360 day/yr basis, we see that reuse of the brine would reduce the water and sewer costs due to RO operation by:

water – 23,760 gpd reduction = $139.71/day

sewer – 23,760 gpd reduction = $115.24/day

total cost reduction of $254.95/day or $91,782/yr

A daily brine flow of 23,760 gpd would be sufficient to operate a 671 ton thermal load on a 24/7 basis 360 days/yr operating at 5 COC.

Considering the cost of the single equalization and backup system installed to date with capacity for a 500 ton thermal load, we estimate that a 671 ton system would cost no more than $64,000, giving a simple ROI of well less than a year.

Case History

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 RO systems operating with softened influent water to provide high quality process water with brine discharged to the sanitary sewer. Three process cooling tower systems were also on site using hard city water for makeup with a design thermal load of 500 tons. The average RO brine flow rate was determined to be sufficient to supply over 100% of the cooling tower makeup needs under most conditions. As RO brine is concentrated soft water, corrosion in the cooling tower systems was the major concern given the high chloride and sulfate levels in the city water supply.

Equalization and Backup Equipment

The equipment package consisted of a 5,000 gallon black polyethylene tank to receive the reverse osmosis brine, 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, overflow 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, and the system has been in continuous operation to the current date.

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 – Cooling tower #3) 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) 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 5 COC with the brine water as makeup, resulting in a cooling water conductivity exceeding the maximum 10,000 mmhos range of the existing controllers.

The water management program implemented for the reuse system uses a single polysilicate base corrosion and deposition inhibitor product and a single oxidizing biocide, n,n,dibromosulfamate (stabilized bromine), 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. COC are maintained between 5 and 6 based on cooling water conductivity. Note that chloride testing, oftentimes used for COC control testing, cannot be used due to variations in the RO brine 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 RO influent. Obviously, the facility had some major problems with operation, or damage to, the two water softeners providing influent water to the RO units. The problem was corrected by the two outside contractors responsible for maintenance and operation of the RO systems.

A second problem became evident when we attempted to increase COC in two of the three cooling towers systems from 3 to the target of 5. Investigation showed that the two cooling tower systems that were unable to increase to the desired COC were equipped with sidestream hydrocyclone units which purged on a time basis. The hydrocyclone units were shut down and the cooling towers COC immediately increased to the desired level. Water discharged during the hydrocyclone purge was sufficient to limit COC. We also note that sidestream hydrocyclones are of little value on cooling tower systems due to inability to remove particles smaller than 25 microns.

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 Brine	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
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 a rule of thumb[ii] 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. As shown in the analysis results, cooling water chloride levels obtained are over twice the maximum industry rule of thumb along with a substantial amount of sulfate also present.

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 two corrosion coupon studies between June and December, 2017. Cooling water parameters of conductivity, chloride, and sulfate were within the ranges noted during the entire corrosion coupon study period. Coupon material selection was by the third party with no input from us. The results as reported are summarized in the following table.

Coupon Material	CT #1	CT #2	CT #3
mild steel average	1.5 mils/yr	0.35 mils/yr	0.3 mils/yr
copper average	0.1 mils/yr	<0.1 mils/yr	0.1 mil/yr

Minimal pitting corrosion was reported. These are excellent results per the Association of Water Technologists guidelines[iii] for industrial cooling tower systems.

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Technology History

The technology to use soft water makeup chemistry, trademarked "Aqua Ionic", had its beginnings in 1984, when softened makeup water was first used to address severe scale problems in cooling tower systems providing cooling water to large, very high temperature glass melting furnaces, a two furnace plant is shown. While use of softened makeup water eliminated the scale problem, severe corrosion problems became evident within six (6) months.

Initial work discovered that a high molybdate – polysilicate – polydiol formulation provided acceptable corrosion control at moderate COC using 100% softened makeup water. Later addition of zinc to the formulation provided additional corrosion control.

With the substantial increase in the cost of molybdate and imposition of effluent limits on discharge of molybdate in some jurisdictions, additional R&D was conducted to eliminate molybdate from the formulation. This work was successful in the discovery that addition of polyphosphate and ortho phosphate, replacing molybdate, to the formulation provided acceptable corrosion rates at an economical dosage. Azole and a white rust inhibitor compound are also included in formulations for cooling systems where yellow metals and galvanized components are present.

Our research on corrosion control technology to resolve this initial problem lead directly to the advanced corrosion control technology demonstrated in reuse of RO brine as cooling tower makeup.

References

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

[ii] Cooling Water Treatment Principles and Practice, Colin Frayne, Chemical Publishing Company, Inc, New York NY.

[iii] 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 of ProChemTech International, Inc. He is a Certified Water Technologist, Fellow of the American Institute of Chemists, Emeritus Member of the American Institute of Chemical Engineers, and member of WateRuse Association, American Chemical Society, Cooling Technology Institute, and Water Environment Association. 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 water treatment technology patents. Contact information: E-mail tek@prochemtech.com, phone number 814-265-0959.