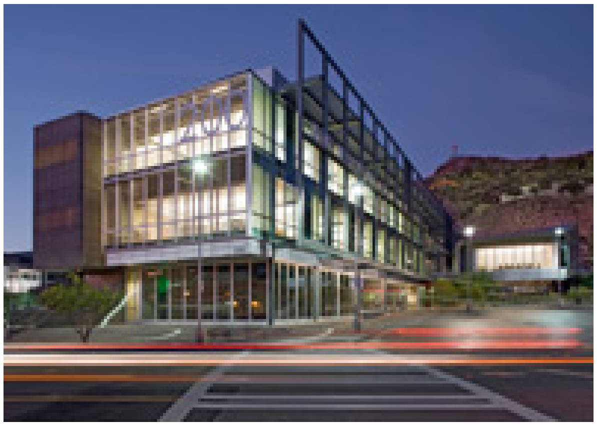
Cooling Tower Zero Blowdown Technology
Tempe Transportation Center, Tempe, Arizona



The Tempe Transportation Center, Tempe, AZ, was designed to be certified by the USGBC LEED green building program to its highest level, “Platinum”. While the building is designed to minimize powered air conditioning by innovative design, due to ambient summer temperatures in Tempe reaching highs exceeding 110 F, an evaporative cooling tower – chiller system of 176 tons capacity was included in the design. Initial thinking by the building designer was to use the typical blowdown from such a system to water the various plantings at the facility.

Following a discussion between the designer and ProChemTech, it was decided that this reuse of cooling tower blowdown was not practical given the high hardness and salinity of the Tempe city water supply. At this point, ProChemTech recommended use of its patented[1] Zero Blowdown Technology (ZBT tm) as a means to reduce building water use via elimination of cooling tower blowdown. ZBT eliminates the need for cooling tower blowdown via removal of scale causing constituents from the makeup water by softening with insoluble material introduced by air flow through the cooling tower removed by side stream filtration. The key to ZBT technology is the treatment product used to control the extreme corrosivity of highly concentrated softened cooling water.

BlueTrak and MiniBrom

After a careful review of our technology, the installation of a ZBT water management program was approved by the building designer. ZBT specific equipment provided by ProChemTech included an appropriate sized water softener and a multimedia side stream filter. Additional water management program equipment provided included a corrosion coupon rack, makeup water meter, BlueTrak tm product control and feed unit, and MiniBrom tm electrolytic bromine biological control unit. This equipment package was installed by ProChemTech technicians with system start-up in April, 2008.

Like most large building projects, this one had its fair share of start-up problems. Several directly affected operation of the ZBT system, the most severe being an air entrainment problem due to insufficient detention time downstream of the cooling towers for effective air-water separation. The resultant air entrainment in the cold cooling water caused numerous problems such as air lock of the chiller condenser, blowing filter media out of the side stream filter, and rendering the on-line spectrophotometer of the BlueTrak product control and feed system inoperative.

Water Softener

A second problem, that was not evident until the air entrainment problem was corrected, involved control of the water level in the cooling tower basin. It was found that the cooling towers were routinely overflowing via the overflow pipe due to the level controls being set to maintain the water level too high. This overflow resulted in inadequate program control for several months. Our technical staff worked with the designer and various consultants, engineers, contractors, and the City of Tempe engineering staff to get all the cooling system problems affecting the ZBT system corrected by mid March, 2009. We have since serviced and monitored the system on a biweekly basis to collect operating data and ensure proper operation of the installed equipment.

Design Comparison

City of Tempe water is variable, but typically has calcium hardness near 115 mg/l with an alkalinity of 140 mg/l, both expressed as $CaCO_3$. Maximum cycles of concentration (COC) would be limited to three (3) using a typical 1:2 ratio phosphonate and polymer blend scale control water treatment program. ZBT eliminates all cooling tower blowdown, but does have some additional water use for regeneration of the water softener and backwash of the side stream multimedia filter. Using a 65% load factor on the design cooling tower capacity of 176 tons gives the following comparison of a standard three (3) COC with a ZBT water management program. Water use given as gallons per year (gpy).

Parameter	Standard Program	ZBT Program
Evaporation, gpy	1,108,500	1,108,500
Blowdown, gpy	554,300	0
Water Softener, gpy	0	57,530
Multimedia filter, gpy	0	19,970
Total fresh water use, gpy	1,662,800	1,186,000
Water use reduction, gpy		**476,800**
Water to sewer, gpy	554,300	77,500
Sewer use reduction, gpy		**476,800**
Salt use, lb/yr	0	12,880
Inhibitor product, lb/yr	463	100

Review of this table shows that replacing a typical water treatment program with ZBT would reduce fresh water use by 28.8% and decrease discharges to the sewer by 86%. A significant decrease in inhibitor product use, 78%, would also be obtained while use of toxic chemical biocides is eliminated by the MiniBrom electrolytic bromine generator, which uses a non-toxic aqueous solution of sodium bromide and chloride for its feed stock. The project qualifies for LEED points on the basis of water use reduction, elimination of toxic chemical use, and use of innovative technologies.

System Design Specifications

- Cooling Tower – Two Baltimore Aircoil Model VOT 88-L cooling towers operated in parallel to obtain a combined flow of 432 gpm, inlet 95, outlet 85, with a wet bulb of 78 F. To correct the air entrainment problem, a PCT designed cold well was installed downstream of the cooling tower basin discharge.
- Recirculation pumps: Two units provided rated each at 450 gpm at 50 ft total head.
- Water softener: PCT Model DT 9000 M 60 dual pressure tank, alternating service automatic water use controlled regeneration with 3 cu ft of 30,000 grain/cu ft high capacity resin in each tank. This unit is rated 12 gpm average, 30 gpm maximum, soft water flow with a capacity of 90,000 grains per tank. Unit design provides for a maximum regeneration frequency of once per day.
- Sidestream filter: PCT Model MMST 2850-30 single pressure tank timer controlled backwash multimedia (anthracite, sand, and garnet) filter with three (3) cu ft total media. This unit is rated at an average flow rate of 16 gpm. Unit design provides for a minimum cooling system turnover every 12 hours with a backwash rate variable from once a day to once a week.
- BlueTrak Chemical Controller: Advantage 2-EZ unit equipped with patent pending BlueTrak spectrophotometer cell, controls feed pump for dosing of inhibitor product based on actual concentration in the cooling water. Control limits set at absorption readings of 0.08 to 0.12.
- MiniBrom Model MB 2.5: Patent pending electrolytic bromine unit that produces bromine from a harmless aqueous sodium bromide and chloride solution (PCT 3024, USEPA registered product #58616-6). Unit rated to produce a maximum of 2.5 lbs/day as bromine with dosage control by an Advantage Model LFB timer set to dose three times a week for 1.5 hours each. Bromine feed initially set-up to provide 1.0 to 1.5 mg/l bromine in the cooling water one (1) hour after end of dose. Service monitoring control set at a maximum ATP reading of 500 rlu.
- Cooling water treatment product: PCT 6453 B, a polysilicate base product that incorporates ZincGard tm for control of white rust and yellow metal corrosion and BlueTrace for testing and control purposes. Product dosage controlled automatically by installed BlueTrak unit, final field control test limits of 0.08 to 0.12 absorption at 620 nm, product dosage target 500 to 750 mg/l.

Results

Water Use Reduction

For the operating time period of March 17, 2009, to May 4, 2010, annualized makeup (MU) water use was found to be 562,830 gallons with an **average COC of 16.3.** Calculation of windage (W) and sidestream filter backwash (BW) water loss gives a result of 34,529 gpy using the equation W + BW = MU/COC. Using this value, we determined the evaporation (E) for the system as E = MU – (W+BW) = 528,301 gpy.

The blowdown required for a standard water management program operating at three (3) COC is calculated by B = E/COC-1, giving 264,151 gpy.

Subtracting the 34,529 gpy lost to windage and backwash in the ZBT system, the **Tempe Transportation cooling tower system operated for the time period March, 2009, to May, 2010, with an annualized water use reduction of 229,622 gpy as compared to a standard program.** Note that the average thermal load during this time period calculates to 54.6 tons, 31% of total cooling capacity, as the building was not fully occupied.

Water Chemistry

The following table summarizes the results from two samplings of the ZBT water management program makeup and cooling water, August 4, 2009, and April 19, 2010.

Parameter	Softened Makeup Water		Cooling Tower Water	
Sample dates	08/04/09	04/19/10	08/04/09	04/19/10
pH	8.1	7.6	9.4	9.2
total alkalinity mg/ $CaCO_3$	110	105	2,125	2,850
conductivity mmhos	1,100	947	17,690	17,180
calcium mg/l	0.10	0.18	6.10	3.06
magnesium mg/l	0.047	0.059	1.90	2.28
iron mg/l	<0.03	<0.03	0.46	0.57
copper mg/l	<0.02	<0.02	0.13	0.23
zinc mg/l	0.032	0.013	0.704	1.06
silicon mg/l	3.4	4.1	43.5	62.6
chloride mg/l	280	191	5,100	3,690
sulfate mg/l	63	66.1	1,470	1,780
total phosphate mg/l as PO_4	0.06	<0.15	12.3	81.8
ortho phosphate mg/l as PO_4	<0.15	<0.15	10.3	45.2
suspended solids mg/l			7	3
cycles on conductivity			16.1	18.1

Corrosion Studies

Three corrosion coupon studies using National Association of Corrosion Engineers specification corrosion coupon racks and coupons were undertaken on this system between start-up and the last reported sampling. The first, coupons removed on September 8, 2008, was completed before proper chemical control was established and documents the high corrosion rates resulting from use of softened makeup water and inadequate corrosion inhibitor level, results as follows:

Date of Removal	Material	Corrosion Rate – mil/yr
09/08/08	steel	6.85
09/08/08	copper	0.16
09/08/08	zinc	4.86

The second corrosion study coupons were removed in November 3, 2009. During the time period of this study, product feed and control in the cooling system was much better than during the first study period. The results from this second corrosion coupon study are as follows:

Date of Removal	Material	Corrosion Rate – mil/yr
11/03/09	steel	3.97
11/03/09	copper	0.21
11/03/09	zinc	4.76

The results of the last corrosion study, during which time period much better system control was obtained and the corrosion inhibitor maintained at 500 to 750 mg/l, are as follows:

Date of Removal	Material	Corrosion Rate – mil/yr
04/19/10	steel	1.02
04/19/10	steel	1.06
04/19/10	copper	0.06
04/19/10	zinc	3.42

Biological Control

Biological control of the system was monitored using on site ATP testing with the results logged on the service reports. The maximum ATP test result recorded was 187 rlu, minimum 7 rlu, with an average of 60.7 rlu. Given that our biological control specification was to maintain the ATP rlu level below 2000, biological control via the MiniBrom electrolytic bromine generator was excellent.

Product control

The BlueTrak unit maintained the set product control limits approximately 95% of the time during the period it was operational. The one time that the product level was outside of the established control limits it was found that the unit was slightly off calibration. In comparison to other product control methods, which are generally outside of established control limits 25% or more, the BlueTrak unit has provided excellent product dosage control.

Problems

The only significant problem experienced during operation of the ZBT program was formation of an iron based deposit on the condenser tubes during the start-up period, when steel corrosion rates were very high. This scale has required two acid solvent cleanings to date on the condenser tubes and still has not been completely removed.

Discussion
The ZBT cooling system achieved a 29% reduction in total system water use during the evaluation period, at an average 31% thermal load, as compared to a standard water management program. This matches well with the 28.8% water use reduction as projected in our Design Comparison. If the system was operated at the expected annual design load of 65%, the annual water use reduction will be 481,465 gallons.

The steel corrosion rate of 6.85 mil/yr obtained during the first study is considered to be "poor"[2] corrosion control and proves that operation of a softened makeup cooling system with an inadequate level of corrosion inhibitor results in unacceptably high corrosion rates.

During the second corrosion coupon study, an improved rate of 3.97 mil/yr was obtained, which is considered to be "acceptable" corrosion control. This level of corrosion, however, is much too high for a highly cycled zero blowdown system as iron corrosion products can form deposits, such as encountered during the system start-up. Based on these results, the level of inhibitor in the cooling water was increased from the original 250 to 500 mg/l control limits to 500 to 750 mg/l.

The increase in inhibitor concentration was very successful in reducing the steel corrosion rates, the average dropping to just 1.04 mil/yr, which is considered to be "excellent" corrosion control. This excellent corrosion rate is especially significant in view of the very high chloride, sulfate, and dissolved solids levels present in the cooling water, which makes for a very corrosive environment.

High pH and alkalinity, such as obtained in the cycled cooling water, would normally result in a very high corrosion rate for zinc (galvanized steel). The rate found in the final study, 3.42 mil/yr, is considered "good"[3] by at least one industry source. Our own studies show that in the absence of the ZincGard white rust inhibitor, which is a component of the treatment product used in the ZBT water management program, that zinc corrosion rates can easily exceed 20 mil/yr at the pH and alkalinity levels obtained in the Tempe Transportation cooling tower system.

ProChemTech International, Inc.

"Innovation in Water Management"

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1 US Patent 7,595,000, "Operation of Evaporative Cooling Towers with Minimal or No Blowdown"
2 Cooling Water Treatment Principals and Practice, Colin Frayne, Chemical Publishing Company, Inc., NY, NY, 1999.
3 Corrosion and Fouling Monitoring of Water Systems, Dr. Bennett Boffardi, The Analyst, Technology Supplement, Spring 2010.

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