Year One Summary

TVA Energy Project

Zeta Rod Cooling Water Conservation Installation

U.S. Government Data Facility

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Zeta Rod Water Conservation Project Summary:

- **5.8 Million gallons of water saved during the first year**
- **22% less incoming make up water used**
- **65% less waste water sent to the sewer**

Zeta Rod® Water Management Systems were selected to be utilized as the water treatment system of choice for the recirculating open-loop chillers, heat exchangers and cooling towers for the two HVAC Central Plants at a U.S. Government Data Facility in the Southeastern United States. The purpose of the system was to deliver significant water conservation while protecting critical cooling equipment in a manner consistent with a well managed traditional chemical water treatment program. The Zeta Rod system was included as part of an Energy & Water Conservation Project implemented by the Tennessee Valley Authority (TVA).

A Zeta Rod Water Management System (ZWMS) was installed into the Central Cooling Plants February of 2012. This summary highlights the data collected from the first year of operation.

The objective of the program was to achieve a significant reduction in the volume of water used by the chillers and cooling towers for the facility, to eliminate the water treatment chemicals, to reduce maintenance and to prevent scaling, biofouling and corrosion. Key to the success of the conservation objective was the ability of Zeta Rod technology to facilitate increased water re-cycle, without jeopardizing the efficient operation or condition of the chiller/cooling tower system. The increase in water savings was accomplished by retaining water in the cooling loop as measured by highly increased cycles of concentration, a condition not generally advisable or possible with a conventional chemical treatment program.

The success of the program to date has been supported by data indicating that 5.8 million gallons of water were saved during the first year of operation, without any added water treatment chemicals. Additionally, effective control of scale, corrosion and bacteria was fully documented.

The chiller systems equipped and remotely controlled and managed by Zeta used 22% less water and reduced the amount of blow down (waste water to the drain) by 65%.

Facility description and water treatment program prior to implementation of the Zeta Rod Water Management System

The data facility has two central plants to provide heating and cooling. Plants H & K are located in different areas of the campus. Plant H consists of five 900 RT Chillers and Plant K consists of four 900RT chillers with two Plate and Frame heat exchangers used for seasonal energy conservation.

Prior to the implementation of the ZWMS program, the cooling tower blow down flow was set historically to maintain between 2.5 to 3 cycles of concentration, as measured and controlled by conductivity of the recirculating water in the chiller systems of each plant. The blow down controllers were set to open bleed valves when the conductivity in the cooling tower water reached a level of 650 µS as compared to the conductivity of the makeup water of 200 to 250 µS. A chemical treatment program was in place to provide protection against corrosion, scaling and biofouling. A continuous feed of chemicals into the cooling tower water was required.

Zeta Water Management System Technology

The picture above illustrates a typical insertion point of the Zeta Rod into the piping of each condenser water supply and return line for one of the chillers in Plant H.

The Zeta Rod system is an integrated water treatment and water conservation program for open recirculating evaporative cooling systems. Its design was refined to meet requirements for remote monitoring and control set by the U.S. Army Corps of Engineers Research Laboratory, and demonstrated over a four-year field evaluation period at four U.S. Military bases.

The ZWMS consists of Zeta Rod® electrodes energized by high voltage self-monitoring power supplies; along with water meters, flow-meters and controllers to collect digitally metered data and calculate the bleed rate adjustment.

Zeta Rod technology uses a strong capacitive field to produce particle dispersion and deliver protection against scale, corrosion and biofouling. By altering the surface tension of the recirculating water and by altering the surface charge on microscopic particles, components of deposits are prevented from aggregating into harmful deposits. The more highly concentrated water resulting from higher reuse in circulation raises the pH and alkalinity of the water to reduce inherent corrosion potential.

Cooling towers and chillers under a ZWMS program are protected from deterioration and energy loss without the use of chemical additives. Operation at high cycles of concentration provides significant levels of water conservation. With no chemical additives in the cooling water, the bleed water can be reclaimed for landscape irrigation, injection wells, or other uses. The Zeta program eliminates the need to store, handle and dispose of chemical containers in the facility.

Above: Chemical treatment equipment (left) replaced by Zeta Rod system panel (right)

Water Conservation Documentation

The metered make up and blow down volumes are displayed below for the period between February 2012 and January 2013.

	Plant H Under ZWMS					Plant K Under ZWMS			
Month	Make Up	Blow Down	Evap.	Cycles		Make Up	Blow Down	Evap.	Cycles
Feb-12	48,700	5,750	42,950	8.5		390,300	109,510	280,790	3.6
Mar-12	416,500	73,670	342,830	5.7		774,000	116,840	657,160	6.6
Apr-12	424,100	68,060	356,040	6.2		668,800	105,700	563,100	6.3
May-12	429,300	71,930	357,370	6.0		716,800	91,790	625,010	7.8
Jun-12	835,000	141,060	693,940	5.9		782,000	113,870	668,130	6.9
Jul-12	1,170,700	199,170	971,530	5.9		842,700	108,640	734,060	7.8
Aug-12	969,000	122,420	846,580	7.9		850,200	105,640	744,560	8.0
Sep-12	856,329	83,320	773,009	10.3		787,400	81,870	705,530	9.6
Oct-12	314,600	66,140	248,460	4.8		745,400	159,910	585,490	4.7
Nov-12	113,500	25,610	87,890	4.4		648,600	101,150	547,450	6.4
Dec-12	122,800	11,900	110,900	10.3		584,100	76,920	507,180	7.6
Jan-13	57,200	10,310	46,890	5.5		505,100	51,180	453,920	9.9
Total	**5,757,729**	**879,340**	4,878,389	6.5		**8,295,400**	**1,223,020**	7,072,380	6.8

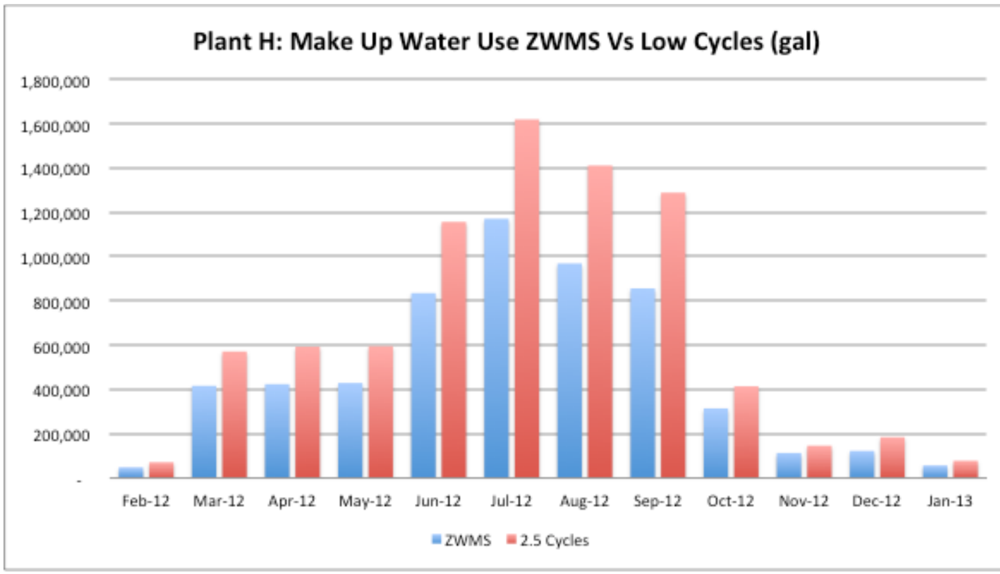
The following table shows the estimated water use and discharge for Plants H & K during those same months had they been operating at 2.5 cycles of concentration of the previous chemical treatment program.[i]

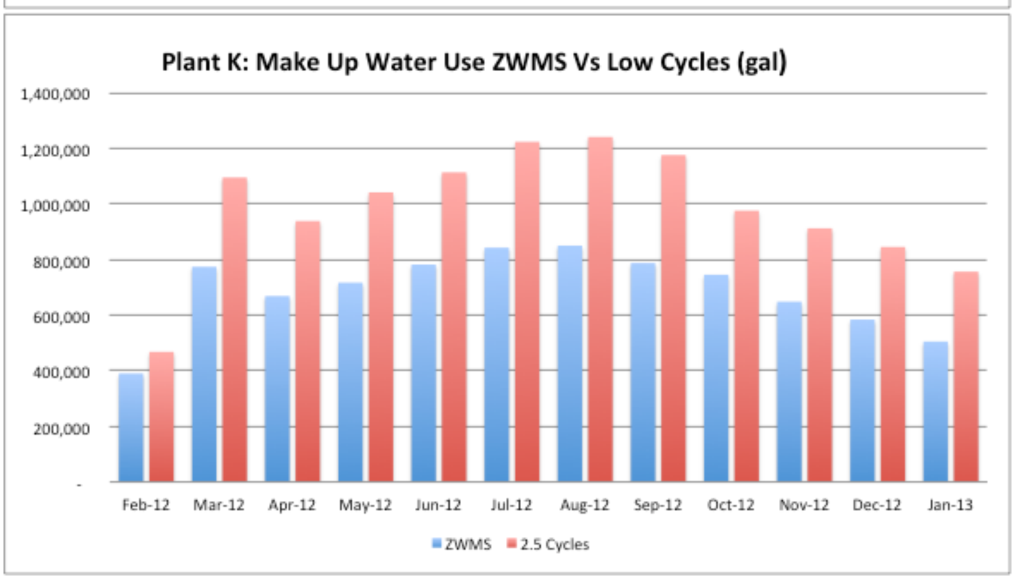
	Plant H @ 2.5 cycles of concentration				Plant K @ 2.5 cycles of concentration		
Month	Make Up	Blow Down	Evap.		Make Up	Blow Down	Evap.
Feb-12	71,583	28,633	42,950		467,983	187,193	280,790
Mar-12	571,383	228,553	342,830		1,095,267	438,107	657,160
Apr-12	593,400	237,360	356,040		938,500	375,400	563,100
May-12	595,617	238,247	357,370		1,041,683	416,673	625,010
Jun-12	1,156,567	462,627	693,940		1,113,550	445,420	668,130
Jul-12	1,619,217	647,687	971,530		1,223,433	489,373	734,060
Aug-12	1,410,967	564,387	846,580		1,240,933	496,373	744,560
Sep-12	1,288,348	515,339	773,009		1,175,883	470,353	705,530
Oct-12	414,100	165,640	248,460		975,817	390,327	585,490
Nov-12	146,483	58,593	87,890		912,417	364,967	547,450
Dec-12	184,833	73,933	110,900		845,300	338,120	507,180
Jan-13	78,150	31,260	46,890		756,533	302,613	453,920
Total	8,130,648	3,252,259	4,878,389		11,787,300	4,714,920	7,072,380

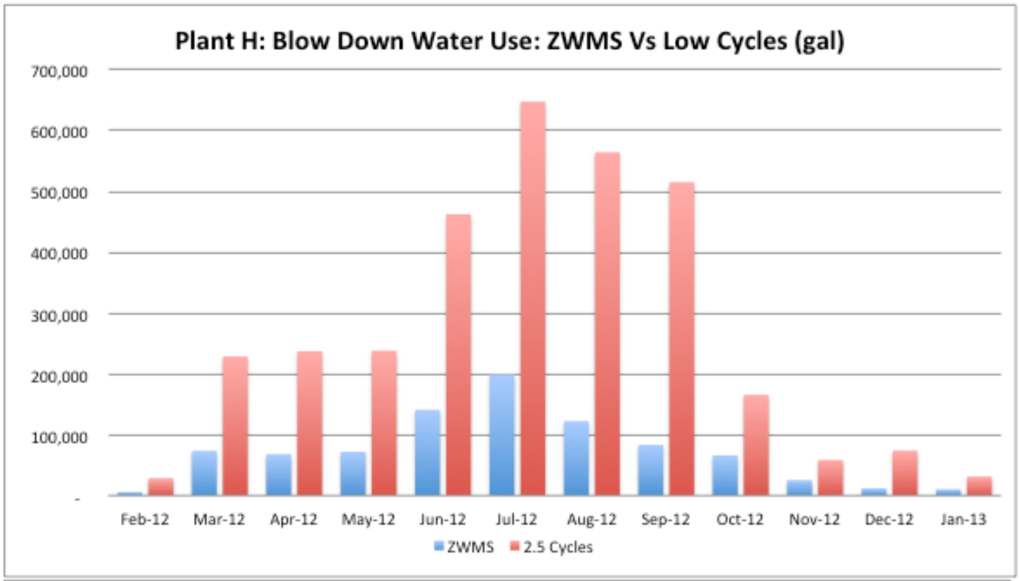
The following table shows a summary of the water savings obtained at each plant when the actual metered flow is compared with the calculated water use calculated at lower cycles of concentration.

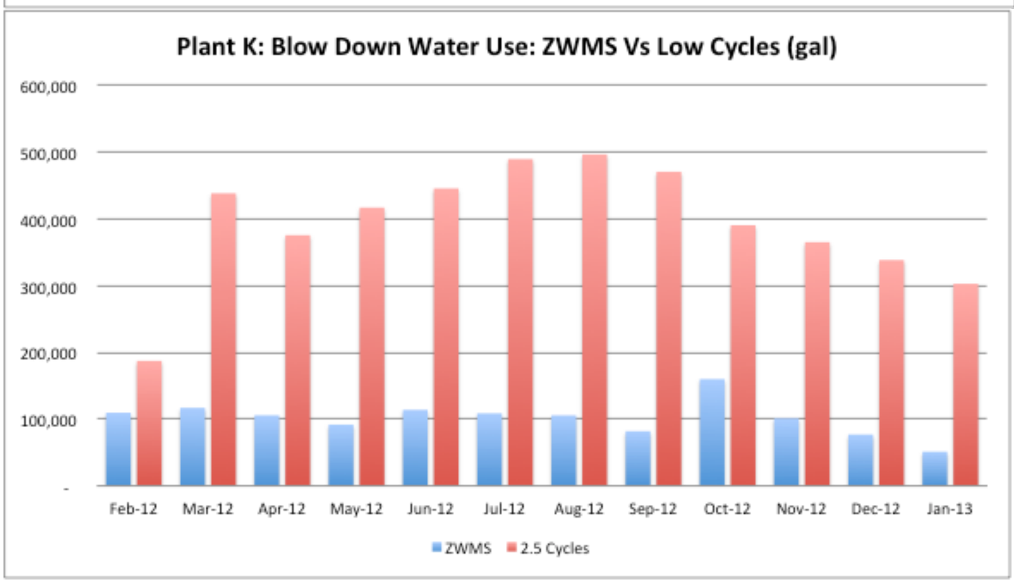
Water Savings Obtained From Feb 2012 - Jan 2013				
	Plant H		Plant K	
	Make Up	Blow Down	Make Up	Blow Down
2.5 Cycles	8,130,648	3,252,259	11,787,300	4,714,920
ZWMS	5,757,729	879,340	8,295,400	1,223,020
Difference (gal)	2,372,919	2,372,919	3,491,900	3,491,900
Zeta Savings (%)	29%	73%	30%	74%

The following graphs show the comparison of water that would be consumed at low cycles (red) versus the lower consumption at high cycles of concentration under the ZWMS (blue).









Measurement of Corrosion, Scaling & Biofouling Protection

Water conservation was the primary target of this project, but scale, corrosion and biofouling control was of high importance. These three primary parameters, in addition to water conservation must be addressed with treatment of any open recirculating evaporative cooling system.

Biofouling

Total Aerobic Bacteria counts in circulating water are the standard method to evaluate biological control success. The desired control target for bacteria populations is a maximum of $1x10^5$ colony forming units per milliliter (cfu/ml).

Bacteria counts in both cooling towers remained under the accepted levels during the period reported in this report, and continue to show low levels to date. The following table shows the results from the samples collected.

Month	Plant H (cfu/ml)	Plant K (cfu/ml)
Jun 2012	1 $x10^2$	< 1 x10
Aug 2012	<1 x10	1 $x10^2$
Oct 2012	1 $x10^4$	1 $x10^3$
Nov 2012	1 $x10^2$	<1 x10
Dec 2012	<1 x10	1 $x10^2$
June 2013	1 $x10^3$	1 $x10^2$

Corrosion

Corrosion rates are monitored with the use of pre-weighed corrosion coupons, which are exposed to the cooling water for 90 days. After exposure, the coupons are sent to a certified lab where they are cleaned and weighed again. The corrosion rates are then calculated from the weight loss of the coupons.

Mild Steel and Copper coupons were installed at Plants H & K to monitor corrosion rates for these metals. The accepted target rates were:

- Mild Steel: Less than 5mpy (mils per year)
- Copper: Less than 1mpy

Corrosion rates were maintained well below the accepted desirable levels throughout the period, and continue to remain under control to date. The following table shows the corrosion rates from Plants H & K.

Corrosion Coupons						
			Mild Steel		Copper	
Date in	Date Out	Days Exposed	Plant H	Plant K	Plant H	Plant K
2/14/12	6/26/12	133	1.5520	5.4924	0.1558	0.2517
6/26/12	9/24/12	90	1.1301	3.6741	0.3591	0.3144
9/24/12	12/9/12	76	1.7416	3.8756	0.3584	0.5281

The initial Mild Steel corrosion rate (Feb 2012 – June 2012) for Plant K was higher than the recommended target of 5mpy, however, corrosion rates are similar to bacteria counts in the sense that the trend is the important metric. The corrosion rate for Mild Steel for Plant K dropped to accepted levels after the initial sample.

Scaling

Condenser approach temperature is a good indicator of the condition of the tubes in a condenser. As scale starts to form on the surface of the tubes, the approach temperatures begin to increase. Approach temperatures have remained stable since the implementation of the ZWMS at Plants H & K indicating that no fouling is taking place in the condenser tubes.

[i] The following equations are used in cooling towers for water balance calculations:

$$MU = BD + EV \quad [1]$$

Equation [1] states that the water added to a cooling tower (MU) should be equal to the amount of water evaporated (EV) plus the water discharged through blow down (BD).

Cycles of concentration (cc) are the ratio of water added to the tower (MU) to water discharged from the tower through blow down (BD).

$$cc = MU/BD \quad [2]$$

Dividing equation [1] by BD one can obtain equation [3]

$$cc = 1 + EV/BD \quad [3]$$

Equation [3] can then be rearranged to make the blow down a function of the evaporation & cycles of concentration.

$$BD = EV/(cc-1) \quad [4]$$

ZWMS system meters the make up and blow down volume used by the towers. With these values known, the amount of water evaporated, as well as the cycles of concentration can be calculated.

Evaporation is only affected by the environmental conditions and thermal load of the system and does not depend upon how many cycles of concentration are being maintained in a cooling tower. Therefore, the amount of water evaporated by a cooling tower on any given day will be the same, regardless of the cycles of concentration.

Since the amount of water evaporated for each month was known, calculating the amount of blow down that would have been required at lower cycles of concentration (2.5 in this case) was accomplished by using equation [4].

At that point, the amount of blow down and evaporation at 2.5 cycles is known the make up volume is calculated using equation [1].

This procedure was utilized in this summary to make comparative calculation relative to the quantity of water consumption in Plants H & K had they been operating at the 2.5 cycles of concentration.