Customer Advanced Technologies Program

The Interpress Technologies Project

Scale Prevention for Evaporative Coolers

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Energy Efficiency & Customer Research & Development
Sacramento Municipal Utility District

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Contents

About the Customer Advanced Technologies Program

SMUD's Customer Advanced Technologies (C.A.T.) program works with customers to encourage the use and evaluation of new or underutilized technologies. The program provides funding for customers in exchange for monitoring rights. Completed demonstration projects include lighting technologies, light emitting diodes (LEDs), residential building shell construction, geothermal heat pumps, indirect / direct evaporative cooling, non-chemical water treatment systems and a wide variety of other technologies.

For more program information, please visit: http://www.smud.org/education/cat/index.html

Introduction

Preventing or limiting the formation of scale deposits is an important part of maintaining evaporative cooling systems. When calcium scale accumulates on the cooling pads, it dramatically reduces airflow and reduces their effectiveness. To make matters worse, since the water is usually in direct contact with the supply air stream, many operators are reluctant to use any type of water treatment chemicals. Fortunately, customers now have several non-chemical water treatment systems to choose from. The challenge is to identify which technologies work and where to apply them.

This technology report is about a local SMUD customer's experiences with a catalytic water conditioner known as the FRE-FLO.™ A catalytic water conditioner is a device that relies upon a process known as "Epitaxial nucleation" to control scale (more on this later). As you read this report, please keep in mind that the results for using this type of technology may vary widely depending on the quality of the local water supply and system operating characteristics. More research is currently underway for this and other types of water treatment devices.

Technology Description: How Does it Work?

To understand the theory behind this device, we must first briefly discuss the formation of scale.

Water usually contains several dissolved minerals including calcium carbonate ($CaCO_3$) iron and silica. As long as these minerals stay in *suspension* (dissolved) they do not pose a problem to equipment. However, when water evaporates, the minerals are left behind. Eventually, the re-circulated water becomes *supersaturated* and can no longer hold the minerals in suspension. When this happens, the minerals fall out of suspension (precipitate) and form scale. Since calcium carbonate will usually precipitate and form scale sooner than most other minerals, equipment manufacturers usually provide guidelines for maximum $CaCO_3$ levels in their maintenance manuals.

Preventing Scale

There are three basic ways to help prevent scale from forming on water-cooled equipment: chemical treatment, blow-down, and non-chemical water treatment systems. However, since the water in evaporative coolers is in direct contact with the supply air, chemicals are seldom used. Most operators rely exclusively upon blow-down to maintain adequate control.

- **Blow-down:** The concentration of minerals can be controlled through dilution by replacing some of the water in the unit basin with fresh water (aka make-up water). This process is called blow-down. The number of times water is re-circulated in an evaporative cooler before being discharged to the sewer is expressed by the term *cycles of concentration*.

$$\textbf{Cycles of Concentration} = \frac{\text{mineral content of evaporative cooler water}}{\text{mineral content of make-up water}}$$

  Although cycles of concentration set points will vary widely, they usually range from 2 to 3 cycles for most evaporative cooling equipment applications. Operating a unit at over three cycles of concentration may be risky, while operating at lower levels wastes water.

- **Non-chemical methods**

1) **Catalytic Water Conditioners:** Use a catalyst to stimulate the mineral particles to grow micro-crystals within the device. The micro-crystals within the chamber of the device are subsequently carried off in the discharge water stream during blow-down. Since the minerals are used to generate crystals, they are no longer available to form scale.

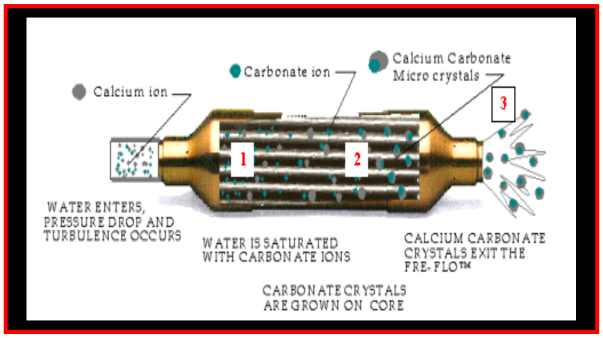
2) **Pulse Power:** Alter the electrical charge of the mineral particles so that they form 'colloidal nucleating powder.' This technique causes minerals to 'clump together' (nucleate) rather than deposit onto the equipment surfaces. The minerals are subsequently carried off in the discharge water stream during blow-down. For more information, please refer to "Pulse Power NCWT Systems" available at http://www.smud.org/education/cat/index.html.

How FRE-FLO™ Works

FRE-FLO™ is designed to convert dissolved minerals within the water into calcium carbonate crystals. According to the manufacturer, this is accomplished by the following sequence of events:

1) The water entering the device experiences a pressure drop and turbulent flow. This causes the dissolved carbon dioxide (CO_2) within the water to become a gas and alters its chemical characteristics. The water is now in a "saturated" condition and is ready to form calcium carbonate crystals.

2) The core of the FRE-FLO™ is designed to promote the growth (nucleation) of calcium carbonate crystals. When the saturated water passes over the core of the device, the dissolved calcium precipitates out in crystalline form.



Source: http://www.crystalgrowthtech.com

3) The calcium carbonate crystals are removed and carried off by the force of the water. The crystals travel within the water (as suspended solids) and are eventually removed through the blow-down process. The minerals used to form the crystals are no longer available to form scale.

Calcium carbonate is a cathodic corrosion inhibitor. Since the scale-causing minerals are kept in suspension, the FRE-FLO™ controls corrosion by allowing the water to cycle up and produce natural corrosion inhibiting alkaline conditions. Additionally it helps deter under-deposit corrosion that can be associated with scale deposits by helping to prevent the formation of these deposits.

Important: According to the manufacturer, FRE-FLO™ is designed only to prevent scale from forming on equipment services – it does not have any effect upon microbial organisms.

Showcase Project

Project: **Interpress Technologies**
930 Stiker Ave
Sacramento, CA 95834

Background: Interpress Technologies, a manufacturer of printed cartons for butter, raisins, cups of soup, and other food products, has a well-deserved reputation for being energy efficient and progressive-minded. Their 50,000 square foot facility features high efficiency lighting systems and is cooled by indirect / direct evaporative cooling systems. Unfortunately, these cooling systems have experienced significant problems with scale build-up and require extensive annual cleaning. Interpress decided to install and test FRE-FLO™ catalytic water conditioners on nine of its cooling units. An independent water treatment company, BWI Solutions Inc., was hired to test, monitor and evaluate the performance of the device. To accomplish this test, two similar units, one with a FRE-FLO™ and one without were tested side by side. A summary of the results are presented below:

> "We clean our evaporative coolers twice every year. In the past, this has been a very labor-intensive process. Since the units equipped with the FRE-FLO™ device produce much less scale, they are easier to clean. It only takes us about half as much time to clean up these units."
>
> - Tom Zakrzewski
> Interpress Technologies

Observations

- The FRE-FLO™ reduced scale formation by approximately 29 percent. This will extend the useful life of the evaporative cooling pads and reduce maintenance costs. According to Tom Zakrzewski, of Interpress Technologies, the units equipped with the FRE-FLO™ are much easier to clean and will need fewer pad replacements.
- Since FRE-FLO™ does not control microbial growth, the bacteria levels were slightly higher in the FRE-FLO™ equipped unit due to operation at higher cycles of concentration. However, the bacteria counts remained within generally accepted levels of control.
- Cost of FRE-FLO™: $750
- Customer Advanced Technologies Grant: $375
- Net Cost of FRE-FLO™: $375
- Estimated annual maintenance and water savings: $60
- Simple Payback: 6.8 years
- BWI's evaluation has been included in its entirety on the following pages of this report. As you read this report, please keep in mind that these tests were conducted in a 'real world application,' where it is virtually impossible to control all of the test parameters. BWI experienced several challenges during the test that affected some of the data. Although these challenges make the results less than

perfect, they are still valuable. In order to account for the different operating modes and equipment malfunctions experienced during the test, BWI based the calculations upon metered water data.

Conclusions

Potential Benefits

- **Improved cooling efficiency:** scale formations significantly reduce cooling efficiency. Consequently, units with scale formations will run longer and consume more energy than clean units.

- **Reduced maintenance costs:** units equipped with the FRE-FLO™ are easier to clean and will need fewer cooling pad and pump replacements. Although the pads for direct evaporative cooling units are relatively inexpensive, the labor costs associated with replacing the pads, de-scaling and cleaning the evaporative cooling systems may be significant.

Challenges

- **Relatively long payback**: the installed cost of FRE-FLO™ is relatively high ($750 per unit). Consequently, the simple financial payback for some locations may be too long (over ten years) for some customers. Of course, the payback period for customers with high water and labor rates will be considerably shorter.

- **Lack of biological control:** as mentioned earlier in this report, catalytic water conditioners are designed only to prevent the formation of scale – they have no effect upon microorganisms. Customers may still need to periodically clean and disinfect their cooling units.

- **Silica:** To our knowledge, catalytic water conditioners do not have any effect upon silica. Because of this, customers who receive water with high levels of silica will be limited to operating their units at lower cycles of concentration. This may severely limit potential water savings.

Recommendations

Based upon the test results, catalytic water conditioners such as FRE-FLO™ appear to be a viable option for reducing scale build-up in evaporative cooling systems. Manufacturers of evaporative cooling units may want to consider providing catalytic water conditioners on an O.E.M. basis.

Interpress Technologies, Inc.
Evaporative Cooler Water Study Report

<u>Prepared for</u>
Interpress Technologies, Inc.
and
The Sacramento Municipal Utility District
Customer Advanced Technologies Program
October 3, 2003

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Interpress Technologies, Inc.

Evaporative Cooler Water Study Report

Interpress Technologies, a printing business located in Sacramento, California, uses AdobeAir MasterCool Industrial Fan Coolers and AdobeAir Indirect Cooler Modules with MasterCool Plus Units to cool their print processing areas. These roof-mounted evaporative coolers have experienced significant scale buildup in the past. The Sacramento Municipal Utility District (SMUD) funded a study to determine if FRE-FLO™ non-chemical treatment units can help prevent scaling in these evaporative units. FRE-FLO™ devices are manufactured by Best Technology Company of Santa Monica, CA and utilize a non-powered, non-chemical catalytic conditioner to precipitate calcium carbonate from the water.

FRE-FLO™ Unit Disassembled Showing Catalytic Casting

<u>Approach:</u> Two identical AdobeAir MasterCool Industrial Evaporative Coolers (EC) were studied over a six-week period during the summer cooling season to determine if the FRE-FLO™ fitted catalytic water treatment system provided any observable benefits when compared to a control evaporative cooler without the FRE-FLO™ unit. The FRE-FLO™ unit was mounted in the circulation line of the sump pump. The EC units cool separate production areas at Interpress Technologies, Inc. Manually operated switches in the production areas control the units. Hour meters were mounted on each unit's master circuit. The coolers are roof mounted with the same North-South orientation within approximately 20 feet of each other. The two evaporative pads on the west side of each unit were replaced at the start of the study with new pads that had been weighed. At the end of the study, the pads were removed, dried for one week and reweighed. The pad weight gain was used to compare the impacted salts of evaporation (scale) build-up on the pads for each unit.

Two new evaporative pads in both the test and control unit were weighed before and after the study period to determine weight gain from salts of evaporation (scale)

Evaporative cooler sump showing circulation pump and blow down water meter. Water meters were also installed on the make-up line to each unit.

Each unit was equipped with make-up and bleed line water meters (SaMeCo WFU 10.110) to track water usage. Bleed rates were manually adjusted using the original equipment plastic bleed valves to provide nearly identical fixed bleed rates of 7 gallons per hour at the start of week three of the study. Bleed rates were not adjusted thereafter during the study.

Water Test Procedures: Water tests were preformed weekly from August 6, 2003 through September 24, 2003. Make-up water samples were drawn from make-up water float valves. Pan water samples were drawn directly from the pans. All sample bottles were dedicated to each sample location and rinsed three times with the sample water prior to filling. Dip slide samples were taken when the sample was drawn. The dip slides were incubated at room temperature for 48 hours prior to reading. Other water analysis was conducted within 24 hours of the samples being drawn. The following analysis methods were used:

- Conductivity and pH: Myron L Company, 6P Ultrameter. Conductivity resolution 0.01 µS through the 0-100 µS range, 0.1 µS through the 100-1000 µS range. 0-14 pH measurement with 0.01 pH resolution.
- LaMotte Company 2020 Turbidimeter
- Solar-Cult® Bacteria, Yeast and Fungi Dip Slide
- LaMotte Company Single Parameter Tests:
  - Alkalinity 7240-01, 25 ppm/drop
  - Chloride 7172, 10 ppm/drop
  - Hardness 7246, 5 ppm/drop
  - Iron 4447, Visual Color Comparator, 0.5-10 ppm
  - Silica 4463, 0.5-10 ppm, 5-100 ppm (diluted, 10 ppm resolution), 50-1000 ppm (diluted, 100 ppm resolution)

Study Challenges

During the study, several events occurred that were considered in the study analysis:

- Unknown to us at the beginning of the study, the units are equipped with both fan and pump switches in the production area. If additional cooling isn't required, the production staff can operate the fan without running the pump. The hour-meters are on the master power disconnect on the roof, recording all fan operation regardless if the pump is running. The pumps must operate to generate evaporation in the pads. Only the FRE-FLO™ equipped unit was observed running in "fan only" mode. The control unit always had both the pump and fan running, or

Hour meter on evaporative cooler main disconnect used to determine unit run times.

neither running, when observed during our weekly visits. Therefore, hour-meter readings may be higher than actual pump operation hours for the FRE-FLO™ equipped unit.

- During the second week of the study, the bleed water meter on the control unit became tilted, preventing it from recording bleed water during that week. To compensate, we calculated blow-down values based on the prior week's bleed rate (gallons per hour) and the units' hours of operation. During that visit, we fixed the meter and adjusted the bleed rates to be approximately 7 gallons per hour as recommended by AdobeAir by timing flow into a container of known volume.

- During the third visit, the FRE-FLO™ unit's sump was dry and the make-up water valve was shut off. We suspect that the float valve had stuck open, flooding the unit and causing a production person to shut off the water. There was a telltale stain on the roof. We adjusted the float and restored make-up water flow during our visit. Make-up water meter readings were unusually high during the week consistent with the overflow theory. Since the sump was dry, evaporation did not occur in the pads. In our analysis, we removed week three's water use data since it encountered this overflow event.

- The FRE-FLO™ equipped evaporative cooler operated significantly more than the control coolers. To normalize the results, we looked at pad weight gain per 1,000 gallons of evaporation (make-up water minus blow-down) thus adjusting for the different operating tempos.

<u>Results and Analysis:</u>

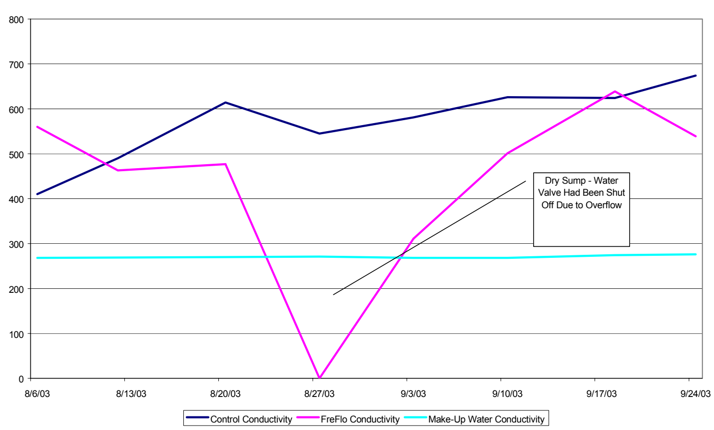
<u>Scale Formation:</u> Pad weight gain (ounces of scale formed per 1,000 gallons of evaporation) on both the two control pads and the two FRE-FLO™ pads provided the following results:

Control: 1.24 and 1.52 oz scale weight gain/1,000 gallons of evaporation
FRE-FLO™: 1.05 and 0.91 oz scale weight gain/1,000 gallons of evaporation.

Based on pad weight gain, it appears the FRE-FLO™ does provide scale-reducing benefit. Results indicate approximately 29% reduction in weight gain, which would result in a longer pad life. On October 2, 2003 we reinstalled the FRE-FLO™ and control test pads. We will pull and reweigh the pads next summer to determine the long-term impacts of the FRE-FLO™ unit.

<u>Conductivity Values and Cycles</u>:

The water conductivity values in the FRE-FLO™ equipped EC were generally lower than the control while achieving higher cycles of concentration (cycles) based on the water meter data. The data indicates that the FRE-FLO™ unit reduced the system water conductivity and achieved higher cycles while not generating additional scale.



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Comparing cycles based on water meter values and cycles based on conductivity (system water conductivity/make-up water conductivity) in the control was on average within 17% of each other. However, the same data for the FRE-FLO™ equipped EC indicated the meter based cycles values were on average 58% higher than the conductivity and hardness (as calcium carbonate) derived cycle values. The removal of some of the water's calcium carbonate through precipitation in the FRE-FLO™ unit would lower conductivity and allow higher cycling as supported by the water data. It is reasonable to surmise that a reduction in conductivity will generally lead to less scale for those minerals that contribute to conductivity such as calcium.

	8/12/03	8/20/03	8/27/03	9/3/03	9/10/03	9/18/03	9/24/03	Average
Control Cycles (Meter)	1.76	Meter Failure	2.17	2.43	3.79	2.45	3.29	2.7
Control Cycles (Conductivity)	1.82	2.27	2.01	2.17	2.34	2.28	2.44	2.2
Control Cycles (Hardness)	1.75	2.14	2.00	1.80	2.46	1.81	2.38	2.05
FRE-FLO™ Cycles (Meter)	2.2	2.3	Overflow Event	3.1	3.9	8.3	5.7	4.2
FRE-FLO™ Cycles (Conductivity)	1.7	1.8	Overflow Event	1.2	1.9	2.3	2.0	1.8
FRE-FLO™ Cycles (Hardness)	1.58	1.79	Overflow Event	1.13	2.31	2.13	1.63	1.76

Silica: During the study neither the control nor the FRE-FLO™ equipped EC reached silica levels at or above the saturation point (180 ppm).

Bacteria and Fungi: The FRE-FLO™ equipped EC had similar fungi and bacteria levels to the control EC. In two cases the FRE-FLO™ unit had bacteria level slightly higher than the control. This could be caused by higher cycles, concentrating bacteria in the water. In all cases the bacteria levels were well within generally accepted levels of control, 100,000 colony forming units/milliliter (CFU/ml) or less.

Comments and Recommendations:

- Providing adequate bleed rates is critical for evaporative cooler applications to prevent minerals in the water from reaching saturation and causing scale, and to prevent the amplification of bacteria in the water. Even with adequate bleed rates and treatment technologies such as the FRE-FLO™, salts of evaporation will buildup in the pads, causing pad weight gain and loss of cooling effectiveness; therefore, we recommend that evaporative cooler pads be replaced at least every other year.

- The FRE-FLO™ unit appears to provide benefit in evaporative cooler applications when combined with proper bleed systems. We recommend that in areas with high silica water, bleed rates be set to keep silica under approximately 120-150 ppm based on conductivity derived cycles.

For example: Given: - 150 ppm recommended maximum silica level in the system
- 70 ppm measured silica in the make-up water
Then: 150 ppm / 70 ppm = 2.1 maximum cycles of concentration

Water Test Results

Pad Weight Gain Analysis for 8-Week Study Period

						Adjusted Values			
Pads		Initial Pad Weight (oz)	Final Pad Weight (oz)	Weight Gain Scale (oz)	% Gain	Water Use (Gal) During Study Period*	Bleed (gal) During Study Period**	Evaporation During Study	Weight Gain (oz) per 1000 gallons of Evaporation
	Control 1	8.2	12.6	4.4	54%	6492.5	2946.15	3546.35	1.24
	Control 2	8.9	14.3	5.4	61%	6492.5	2946.15	3546.35	1.52
	FreFlo 3	9.1	16.7	7.6	84%	11126.3	3878	7248.3	1.05
	FreFlo 4	9	15.6	6.6	73%	11126.3	3878	7248.3	0.91
						* Not including the week of Aug 20-27 on FreFlo equipped unit due to system overflow			
						** Added average blowdown per hour x hours of operation for the week of Aug 12-20 due to meter failure			
					`				
						Raw Values			
Pads		Initial Pad Weight (oz)	Final Pad Weight (oz)	Weight Gain Scale (oz)	% Gain	Water Use (Gal) During Study Period	Bleed (gal) During Study Period	Evaporation During Study	Weight Gain (oz) per 1000 gallons of Evaporation
	Control 1	8.2	12.6	4.4	54%	6492.5	2276.55	4215.95	1.04
	Control 2	8.9	14.3	5.4	61%	6492.5	2276.55	4215.95	1.28
	FreFlo 3	9.1	16.7	7.6	84%	17657.3	3878	13779.3	0.55
	FreFlo 4	9	15.6	6.6	73%	17657.3	3878	13779.3	0.48

Water Test Results, Week 1

Date	Location	Study Start			
6-Aug-03	Interpress Technologies Inc.	Result		Cycle Calculations	
Make- Up Water				Control	
	Conductivity (µS)	268		Based on Conductivity	1.53
	pH	7.7		Hardness	1.58
	P-Alkalinity (ppm)	0		Chlorides	1.25
	M-Alkalinity (ppm)	90		Water Meter	N/A
	T-Alkalinity (ppm)	90			
	Hardness (ppm)	60		Freflo	
	Silica (ppm)	40		Based on Conductivity	2.09
	Chlorides (ppm)	40		Hardness	2.00
	Iron (ppm)	0		Chlorides	1.75
	Turbidity (NTU)	1.4		Water Meter	N/A
		Control		Freflo	
	Conductivity (µS)	410		560	
	pH	8.4		8.5	
	P-Alkalinity (ppm)	10		10	
	M-Alkalinity (ppm)	120		150	
	T-Alkalinity (ppm)	130		160	
	Hardness (ppm)	95		120	
	Silica (ppm)	60		80	
	Chlorides (ppm)	50		70	
	Iron (ppm)	0		0	
	Turbidity (NTU)	0.4	Diff	0.65	Diff
	Make-Up Water Initial Reading (Gal)	89.9	0	33.5	0
	Blow-Down Water Meter Initial Reading (gal)	324.75	0	41.4	0
	Hour Meter Initial Reading	19.5		1	
	Bacteria	<1000		1000	
	Fungi	<1000		None Detected	

Water Test Results, Week 2

Date	Location				
12-Aug-03	Interpress Technologies Inc.	Result		Cycle Calculations	
Make- Up Water				Control	
	Conductivity (µS)	269		Based on Conductivity	1.82
	pH	7.7		Hardness	1.75
	P-Alkalinity (ppm)	0		Chlorides	2.00
	M-Alkalinity (ppm)	100		Water Meter	1.76
	T-Alkalinity (ppm)	100			
	Hardness (ppm)	60		Freflo	
	Silica (ppm)	70		Based on Conductivity	1.72
	Chlorides (ppm)	30		Hardness	1.58
	Iron (ppm)	0		Chlorides	2.00
	Turbidity (NTU)	0.25		Water Meter	2.18
		Control		Freflo	
	Conductivity (µS)	490		463	
	pH	8.5		8.5	
	P-Alkalinity (ppm)	25		25	
	M-Alkalinity (ppm)	150		125	
	T-Alkalinity (ppm)	175		150	
	Hardness (ppm)	105		95	
	Silica (ppm)	80		80	
	Chlorides (ppm)	60		60	
	Iron (ppm)	0		0	
	Turbidity (NTU)	0.3	Diff	0.35	Diff
	Make-Up Water Reading (Gal)	946.3	856.4	2436.3	2402.8
	Blow-Down Water Meter Reading (gal)	812.6	487.85	1146	1104.6
	Hour Meter Reading	55.6	36.1	109.2	108.2
	Calcualted Gallons/Hour of runtime		23.7		22.2
	Calcualted Blowdown Gallons/Hour of runtime		13.5		10.2
	Bacteria	<1000 CFU/ml		<1000 CFU/ml	
	Fungi	None Detected		None Detected	

Water Test Results, Week 3

Date	Location					
20-Aug-03	Interpress Technologies Inc.	Result		Cycle Calculations		
Make- Up Water				Control		
	Conductivity (µS)	270		Based on Conductivity	2.27	
	pH	7.7		Hardness	2.14	
	P-Alkalinity (ppm)	0		Chlorides	2.00	
	M-Alkalinity (ppm)	100		Water Meter	N/A Meter failure	
	T-Alkalinity (ppm)	100				
	Hardness (ppm)	70		Freflo		
	Silica (ppm)	60		Based on Conductivity	1.77	
	Chlorides (ppm)	30		Hardness	1.79	
	Iron (ppm)	0		Chlorides	1.67	
	Turbidity (NTU)	1.3		Water Meter	2.27	
		Control		Freflo		
	Conductivity (µS)	614		477		
	pH	8.4		8.4		
	P-Alkalinity (ppm)	25		25		
	M-Alkalinity (ppm)	200		175		
	T-Alkalinity (ppm)	225		200		
	Hardness (ppm)	150		125		
	Silica (ppm)	between 100-200 ppm - approximately 130	130	100		
	Chlorides (ppm)	60		50		
	Iron (ppm)	0		0		
	Turbidity (NTU)	0.05	Diff	0.05	Diff	
	Make-Up Water Reading (Gal)	1960.8	1014.5	5750.5	3314.2	
	Blow-Down Water Meter Reading (gal)	813.5	Meter failure - angled so it was not recording - fixed and secured. Adjusted flow to approx 7 GPH	2604.7	1458.7	Adjusted blowdown flow to approximately 7 GPH
	Hour Meter Reading	105.2	49.6	259.3	150.1	
	Calcualted Gallons/Hour of runtime		20.5		22.1	
	Calcualted Blowdown Gallons/Hour of runtime		N/A - Meter failure		9.7	Target per Adobe Air Recommendations - 7-9 GPH. Adjusted valve to provide 7 GPH
	Bacteria	1000 CFU/ml		<1000 CFU/ml		
	Fungi	None		None		

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Water Test Results, Week 4

Date	Location					
27-Aug-03	Interpress Technologies Inc.	Result		Cycle Calculations		
Make- Up Water				Control		
	Conductivity (µS)	271		Based on Conductivity	2.01	
	pH	7.8		Hardness	2.00	
	P-Alkalinity (ppm)	0		Chlorides	2.33	
	M-Alkalinity (ppm)	100		Water Meter	2.30	
	T-Alkalinity (ppm)	100				
	Hardness (ppm)	70		Freflo		
	Silica (ppm)	60		Based on Conductivity	N/A	
	Chlorides (ppm)	30		Hardness	N/A	
	Iron (ppm)	0		Chlorides	N/A	
	Turbidity (NTU)	0.3		Water Meter	N/A	
		Control		Freflo		
	Conductivity (µS)	545				
	pH	8.5				
	P-Alkalinity (ppm)	25				
	M-Alkalinity (ppm)	175				
	T-Alkalinity (ppm)	200		Sump Dry - Water turned off		Sump was dry and fan was running. Make-up water valve shut off - float had stuck open flooding unit - no sample. Restored flow and float operation
	Hardness (ppm)	140				
	Silica (ppm)	125				
	Chlorides (ppm)	70				
	Iron (ppm)	0				
	Turbidity (NTU)	0.25	Usage		Usage	
	Make-Up Water Reading (Gal)	3357.9	1397.1	12315	6564.5	
	Blow-Down Water Meter Reading (gal)	1458	644.5	2878.7	274	
	Hour Meter Reading	191.1	85.9	350	90.7	
	Calcualted Gallons/Hour of runtime		16.3		72.4	
	Calcualted Blowdown Gallons/Hour of runtime		7.5		3.0	
	Bacteria	<1000 CFU/ml		N/A		
	Fungi	None Detected		N/A		

Water Test Results, Week 5

Date	Location					
3-Sep-03	Interpress Technologies Inc.	Result		Cycle Calculations		
Make- Up Water				Control		
	Conductivity (µS)	268		Based on Conductivity	2.17	
	pH	7.6		Hardness	1.80	
	P-Alkalinity (ppm)	0		Chlorides	1.75	
	M-Alkalinity (ppm)	100		Water Meter	2.43	
	T-Alkalinity (ppm)	100				
	Hardness (ppm)	75		Freflo		
	Silica (ppm)	60		Based on Conductivity	1.16	
	Chlorides (ppm)	40		Hardness	1.13	
	Iron (ppm)	0		Chlorides	1.25	
	Turbidity (NTU)	0		Water Meter	3.06	
		Control		Freflo		
	Conductivity (µS)	581		311		Freflo equipped unit had water in the sump but the circulation pump was not running. Shut off below.
	pH	8.2		7.6		
	P-Alkalinity (ppm)	25		0		
	M-Alkalinity (ppm)	225		125		
	T-Alkalinity (ppm)	250		125		
	Hardness (ppm)	135		85		
	Silica (ppm)	100		70		
	Chlorides (ppm)	70		50		
	Iron (ppm)	0		0		
	Turbidity (NTU)	0.5	Usage	0.15	Usage	
	Make-Up Water Reading (Gal)	4231.7	873.8	13060.3	745.3	
	Blow-Down Water Meter Reading (gal)	1818.3	360.3	3122.5	243.8	
	Hour Meter Reading	245.2	54.1	415.5	65.5	
	Calcualted Gallons/Hour of runtime		16.2		11.4	Note pump was not running
	Calcualted Blowdown Gallons/Hour of runtime		6.7		3.7	Note pump was not running
	Bacteria	1000 CFU/ml		10000 CFU/ml		
	Fungi	1000 CFU/ml Yeast		1000 CFU/ml yeast		

Water Test Results, Week 6

Date	Location					
10-Sep-03	Interpress Technologies Inc.	Result		Cycle Calculations		
Make- Up Water				Control		
	Conductivity (µS)	268		Based on Conductivity	2.34	
	pH	7.9		Hardness	2.46	
	P-Alkalinity (ppm)	0		Chlorides	2.00	
	M-Alkalinity (ppm)	125		Water Meter	3.79	
	T-Alkalinity (ppm)	125				
	Hardness (ppm)	65		Freflo		
	Silica (ppm)	70		Based on Conductivity	1.87	
	Chlorides (ppm)	40		Hardness	2.31	
	Iron (ppm)	0		Chlorides	1.75	
	Turbidity (NTU)	0		Water Meter	3.93	
		Control		Freflo		
	Conductivity (µS)	626		501		
	pH	8.3		8.2		
	P-Alkalinity (ppm)	25		0		
	M-Alkalinity (ppm)	225		200		Freflo equipped unit had water in the sump but the circulation pump was not running - shut off from below since additional cooling was not required
	T-Alkalinity (ppm)	250		200		
	Hardness (ppm)	160		150		
	Silica (ppm)	<200, approximately 120 based on color	120	100		
	Chlorides (ppm)	80		70		
	Iron (ppm)	0		0		
	Turbidity (NTU)	0.05	Usage	0.3	Usage	
	Make-Up Water Reading (Gal)	4953.3	721.6	14162.9	1102.6	
	Blow-Down Water Meter Reading (gal)	2008.5	190.2	3403.2	280.7	
	Hour Meter Reading	294.6	49.4	484.6	69.1	
	Calcualted Gallons/Hour of runtime		14.6		16.0	Note pump was not running when sample was taken
	Calcualted Blowdown Gallons/Hour of runtime		3.9		4.1	Note pump was not running when sample was taken
	Bacteria	1000 CFU/ml		<10,000 CFU/ml		
	Fungi/Yeast	100,000 CFU/ml		100 CFU/ml		

Water Test Results, Week 7

Date	Location					
18-Sep-03	Interpress Technologies Inc.	Result		Cycle Calculations		
Make- Up Water				Control		
	Conductivity (µS)	274.4		Based on Conductivity	2.27	
	pH	7.6		Hardness	1.81	
	P-Alkalinity (ppm)	0		Chlorides	2.00	
	M-Alkalinity (ppm)	125		Water Meter	2.45	
	T-Alkalinity (ppm)	125				
	Hardness (ppm)	80		Freflo		
	Silica (ppm)	50		Based on Conductivity	2.33	
	Chlorides (ppm)	40		Hardness	2.13	
	Iron (ppm)	0		Chlorides	2.00	
	Turbidity (NTU)	0		Water Meter	8.32	
		Control		Freflo		
	Conductivity (µS)	624		639		Freflo equipped unit had water in the sump but the circulation pump was not running - shut off from below since additional cooling was not required
	pH	8.49		8.37		
	P-Alkalinity (ppm)	25		25		
	M-Alkalinity (ppm)	225		250		
	T-Alkalinity (ppm)	250		275		
	Hardness (ppm)	145		170		
	Silica (ppm)	100		100		
	Chlorides (ppm)	80		80		
	Iron (ppm)	0		0		
	Turbidity (NTU)	0.3	Usage	0.05	Usage	
	Make-Up Water Reading (Gal)	5890	936.7	16027	1864.1	
	Blow-Down Water Meter Reading (gal)	2391	382.5	3627.2	224	
	Hour Meter Reading	339.3	44.7	587.1	102.5	
	Calcualted Water Usage (gal) /Hour of runtime		21.0		18.2	Note pump was not running when sample was taken
	Calcualted Blowdown Gallons/Hour of runtime		8.6		2.2	Note pump was not running when sample was taken
	Bacteria	<1000 CFU/ml		1000 CFU/ml		
	Fungi/Yeast	<1000 CFU/ml Yeast		10,000 CFU/ml Yeast		

Water Test Results, Week 8

Date	Location					
24-Sep-03	Interpress Technologies Inc.	Result		Cycle Calculations		
Make- Up Water				Control		
	Conductivity (µS)	276		Based on Conductivity	2.44	
	pH	7.9		Hardness	2.38	
	P-Alkalinity (ppm)	0		Chlorides	2.00	
	M-Alkalinity (ppm)	125		Water Meter	3.29	
	T-Alkalinity (ppm)	125				
	Hardness (ppm)	80		Freflo		
	Silica (ppm)	60		Based on Conductivity	1.95	
	Chlorides (ppm)	40		Hardness	1.63	
	Iron (ppm)	0		Chlorides	1.50	
	Turbidity (NTU)	0		Water Meter	5.69	
		Control		Freflo		
	Conductivity (µS)	674		539		
	pH	8.4		8.6		
	P-Alkalinity (ppm)	25		25		
	M-Alkalinity (ppm)	225		175		
	T-Alkalinity (ppm)	250		200		
	Hardness (ppm)	190		130		
	Silica (ppm)	100-200	125	100		
	Chlorides (ppm)	80		60		
	Iron (ppm)	0		0		
	Turbidity (NTU)	0.1	Usage	0.1	Usage	
	Make-Up Water Reading (Gal)	6582.4	692.4	17690.8	1663.8	
	Blow-Down Water Meter Reading (gal)	2601.3	210.3	3919.4	292.2	
	Hour Meter Reading	379.3	40	667.1	80	
	Calcualted Water Usage (gal) /Hour of runtime		17.3		20.8	Freflo Unit Running, Control not running when sample taken
	Calcualted Blowdown Gallons/Hour of runtime		5.3		3.7	
	Bacteria	10,000		10,000		
	Fungi/Yeast	moderate fungi		moderate fungi		