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NON-CHEMICAL WATER TREATMENT TRIALS
Final Report

Clark County School District
Las Vegas, Nevada

DRAFT

Prepared for

Nevada Power Company
Las Vegas, Nevada

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1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

KEMA, Inc. is pleased to submit this final report for the Non-Chemical Cooling Tower Water Treatment Trials for the Clark County School District (CCSD). This study was funded by the Nevada Power Company, a subsidiary of Sierra Pacific Resources, in conjunction with its partnership program with the CCSD. This report is submitted by KEMA, Inc., 492 Ninth Street, Suite 220, Oakland, California 94607, (510) 891-0446. It was prepared by Mr. Steven J. Giampaoli, P.E. and Ms. Joo Ching Yong of that office.

These trials were conducted for the CCSD by KEMA in association with the Nevada Power Company. The program began in August 2004 and ended in September 2005. The Nevada Power representative for this project was Mr. John Hargrove and the CCSD representative was Mr. Eric Heinicke.

In addition to this evaluation, KEMA has been responsible for collecting data on water chemistry, power use, chemical use, and corrosion protection. KEMA is responsible for reporting results on a periodic basis and providing a final report that summarizes all the findings of the trials.

1.2 OBJECTIVE OF THE STUDY

The Non-Chemical Cooling Tower Water Treatment trials are designed to aid the CCSD in determining the effectiveness and costs of alternative cooling tower treatment systems for its facilities. The CCSD is interested in non-chemical treatment of its cooling tower water because it believes that non-chemical treatment may be more effective, less expensive, and use less water and power than the conventional chemical treatment program it has been using. The CCSD hopes to use the results of these trials to qualify one or more of these systems to be included in its procurement programs for new facilities as well as for possible retrofits of cooling towers in its existing facilities.

The CCSD operates approximately 166 grammar schools, 43 middle schools, 30 high schools, 15 alternative and special schools, and 30 administrative, and transportation offices throughout Clark County Nevada and is currently building 10 to 15 new schools each year. Many of these facilities employ water-cooled air conditioning equipment to maintain the comfort of the students and staff at each site. Waste heat from the buildings served by water-cooled air conditioning equipment is ultimately rejected to the atmosphere in evaporative cooling towers. The purity of the cooling tower water is of critical importance in keeping the air conditioning equipment functioning efficiently and reliably.

1.3 METHODOLOGY

The CCSD currently utilizes a chemical treatment program for its cooling towers to minimize fouling and reduce corrosion where the water comes in contact with heat exchange surfaces in the towers and chiller condensers. The District wishes to evaluate various alternative non-chemical treatment technologies to determine their effectiveness in preventing fouling and corrosion and to understand the savings in energy use, chemical costs, maintenance, and water consumption that may result from their use. The results of this evaluation may be used by the District to establish standards to be used in the specification of new non-chemical cooling tower/chiller systems.

Four high schools were initially selected as demonstration sites for non-chemical treatment systems based on the size and configuration of their central cooling plants. All four high schools have similar floor plans, materials of construction, operating schedules, and central cooling plants. Each central cooling plant consists of two 405-ton water chillers, a primary/secondary chilled-water distribution system, two variable-speed, single-cell cooling towers with side-stream filters, and a water-side economizer that is used in lieu of the chillers to provide cooling during cold weather periods. (See Appendix A for a listing of central plant equipment for each school.) All of the schools are monitored and controlled remotely at the CCSD maintenance center in Henderson, Nevada.

Four vendors of non-chemical water treatment equipment agreed to participate in the trials as shown in Table 1-1.

Table 1-1
Non-Chemical Equipment Installations

Location	Vendor	Treatment Technology
Coronado High School	Alpine Systems	Electrostatic Precipitation
Sierra Vista High School	VRTX	Hydrodynamic Cavitation
Palo Verde High School	Dolphin	Pulsed Electromagnetic Power
Mojave High School[1]	Nytrox	Ozonation

A fifth high school, Desert Pines, with a similar central cooling plant configuration was selected as a control site to maintain conventional chemical treatment for comparison purposes.

The trials were designed to collect and analyze data to evaluate the effectiveness and costs of the various treatment systems. Data collected include:

- Water chemistry data
- Power consumption data
- Water consumption data

[1] The Nytrox system was uninstalled and removed from Mojave High School on 6/1/2005. Chemical treatment was restored at Mojave High School upon removal of the Nytrox system.

- Corrosion data.

Data was collected throughout a 12-month test period for each cooling tower studied. Samples of fresh city water and cooling tower water were collected periodically from each site for laboratory analysis. Several analyses were conducted to determine how the treatment systems were performing. See Appendix B for a summary of the testing protocols and results of each analysis. These tests included:

- pH
- Hardness as $CaCO_3$
- Alkalinity as $CaCO_3$
- Chlorides as Cl^-
- Aerobic count
- Legionella
- Conductivity
- Metal Content
- Sulfates.

Power consumption data were recorded and trended on the existing energy management system at each school and on portable trend loggers for kW, amps, Volts, and motor run times for the central cooling plant equipment. See Appendix C for a summary of the measurement points at each site and Appendix D for historic electrical consumption for each high school.

Water meters were installed at each school to record the total water addition to the cooling tower. These meters were read periodically to track the overall consumption of each tower. See Appendix E for a summary of historic water consumption at each high school.

Corrosion coupon racks were installed at each chilled-water plant to provide a basis for understanding the effectiveness of each system at protecting the heat exchange surfaces, piping, vessels, and cooling tower from corrosion. Calibrated metal strips were installed in the racks where they were exposed to the water stream. The coupons were removed periodically and weighed to determine any loss of metal due to corrosion.

1.4 SUMMARY OF FINDINGS

Findings are summarized in Section 2 of this report. As can be seen by the graphs and tables presented in Section 2, results are somewhat variable for each system. It was recognized that the first several months of operation would be used to make adjustments to each system to get them operating in an optimal manner. It is assumed that the preliminary variation in testing results is caused by these adjustments in all systems. However, variations later in the study may indicate stability problems with specific systems and should be considered by the District in its deliberations on which systems to deploy.

A summary of findings comparing the effectiveness of each treatment system relative to the other systems in the study is presented Table 1-2.

Table 1-2
System Effectiveness Ranking

High School	Treatment System	Corrosion Protection	Water Use	Energy Use	Operating Cost
Desert Pines	Chemical	1	3	3	3
Sierra Vista	VRTX	2	1	2	1
Palo Verde	Dolphin	3	4	1	2
Coronado	EST	4	2	4	4

Corrosion protection rankings were based on the results of the analysis of the corrosion coupons. Water use rankings were based on cycles of concentration as determined by 17 water samples taken over the course of the study. Energy use is based on the total kWh used by each system as recorded by portable power meters; however, because of widely varying operating schedules between sites, this is not a meaningful comparison. Operating cost is the cost of chemicals plus the cost of labor for surveillance and maintenance.

Other factors that the District might consider are more subjective, like water clarity and solids build up in the fill. Though aesthetically important, these factors probably mean little as far as system protection and protection from fouling.

It should be noted that all of the non-chemical systems had problems preventing algae growth in areas of the tower where sunlight penetrated. Algae was not present in any of the non-chemical systems in areas where sunlight could not penetrate. Also, no algae growth was observed on heat exchange surfaces of the condenser heat exchangers for any system studied. Therefore, it is assumed that all systems are equally effective at preventing algae growth in lines and on heat exchange surfaces.

Other factors should be considered by the District in its decisions on whether, when, and where to deploy these systems. These include:

- The ability of the vendor to support its equipment. Good local technical support is a must with these systems.
- Training and ability of District staff to operate and adjust non-chemical systems for reliable operation.
- Use of continuous monitoring systems that alert maintenance crews to problems with the non-chemical systems.
- Compatibility of the non-chemical treatment system with existing metallurgy and elastomers at each site.

A Nytrox ozone water treatment system (Figure 2-4) was installed at the central plant of Mojave High School to treat the tower water stream without using chemicals. Ozone is a powerful biocide that kills microorganisms, and at low concentrations it has been shown to an effective water treatment system. However, at high concentrations it is also an extremely aggressive oxidizing agent. Because of control problems related to a blocked sensor pipe, elevated levels of ozone accumulated that attacked the elastomers in the cooling tower basin, causing extensive leaks. The high levels of ozone also increased corrosion rates beyond acceptable levels. Consequently, the trial of this system was aborted and the tower was returned to chemical treatment in June of 2005.

Figure 2-4
Nytrox System, Palo Verde High School

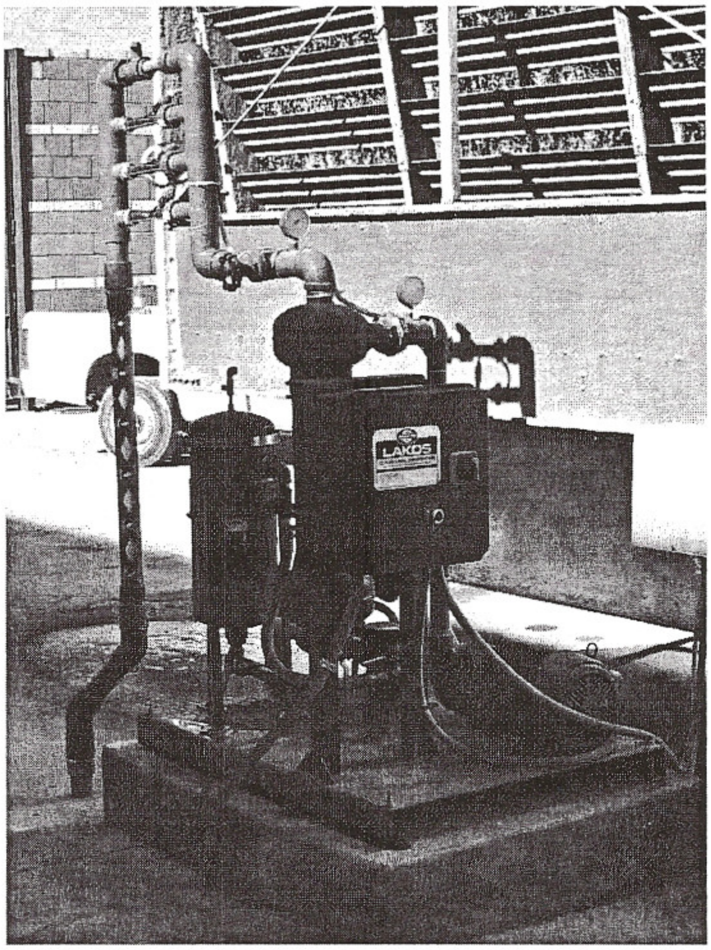

Table 2-5
Annual Water Savings

Facility	Treatment Technology	CR_1	CR_2	Evaporation +Drift gpm/ton	$1/CR_1$-$1/CR_2$	Savings gpm/ton	min/hr	Average hr/yr	Savings gpy/ton
Palo Verde	Dolphin	2.68	2.95	0.0315	0.0342	0.0011	60	4,136	267
Desert Pines	Chemical	2.68	3.44	0.0315	0.0824	0.0026	60	4,136	644
Coronado	ETS	2.68	3.95	0.0315	0.1200	0.0038	60	4,136	938
Sierra Vista	VRTX	2.68	4.11	0.0315	0.1298	0.0041	60	4,136	1,015

It is interesting to note that the performance of the Desert Pines chemical treatment system during the study period far exceeded what was achieved by the average baseline system. During the course of the study, it was observed that District personnel were paying very close attention to the control site. These results and the corrosion results show just how effective a chemical treatment system can be when operated diligently by District personnel.

Tables 2-6 through 2-9 summarize the readings of the cycles of concentration of all 4 components for the 17 sampling sets taken throughout the testing period. These results are also presented graphically in Appendix G.

Table 2-6
Cycles of Concentration by Chloride

	Desert Pines	Palo Verde	Sierra Vista	Coronado
10/26/2004	3.2	4.3	3.1	5.3
11/02/2004	0.5	0.1	3.1	1.3
11/09/2004	2.8	3.8	2.2	3.3
11/16/2004	1.8	3.6	8.2	2.5
12/02/2004	3.2	3.2	2.7	2.7
12/14/2004	3.2	7.0	8.3	1.3
12/29/2004	3.6	4.1	1.6	5.2
01/14/2005	5.0	3.6	2.7	3.6
01/25/2005	3.9	3.9	4.5	8.2
02/08/2005	3.2	4.4	1.9	2.5
03/07/2005	6.8	12.3	4.5	4.1
04/04/2005	6.0	7.4	4.0	5.3
05/03/2005	6.5	6.0	16.3	9.5
06/01/2005	3.8	1.7	8.8	5.2
07/05/2005	2.8	3.6	5.6	2.8
08/03/2005	2.6	1.5	7.5	7.8
09/07/2005	3.3	2.1	6.7	5.5

The District has set a maximum allowable corrosion rate for copper of 0.30 mils per year. Based on this, the EST system at Coronado High School should only be considered for further deployment unless it can be demonstrated that it can consistently provide results acceptable to the District. (Recommendation 5 in Section 3 of this report particularly applies to the EST system at Coronado HS.)

As shown in the graph, Coronado (EST System) has consistently shown the highest corrosion rate of any of the other systems studied for both copper and mild steel, and its corrosion rates worsened as the study progressed and cycles of concentration were increased. In an effort to eliminate all variables that may have contributed to the high corrosion rate, the coupon rack and piping was converted to PVC plastic from copper and steel in May; however, this did not improve the apparent corrosion rate. Overall, this system performed poorly in this area. Laboratory testing revealed elevated levels of perchlorates in the cooling water stream that were substantially higher than the perchlorate levels in the make-up water. Therefore, it was concluded that as set up, the EST process was manufacturing perchlorates from chlorides present in the make-up water. This effect was not detected at any other test site. Since perchlorates are highly corrosive, it is thought that this effect may partially explain the high corrosion rates measured at this site. The District should review its minimum requirements for corrosion protection before deploying this system further.

The chemical treatment system at Desert Pines High School (control site) achieved the lowest corrosion rates[2] as compared to the other testing sites and improved over the course of the study. Overall, the corrosion rates achieved at Desert Pines with the chemical treatment system are very, very low and demonstrate an extremely high level of protection.

The corrosion rates at Palo Verde High School (Dolphin System) deteriorated over the course of the study for both copper and mild steel.[3] It should be noted, however, that at the beginning of the study period, the Dolphin pulsed power module was running continuously. At the instruction of the manufacturer's representative, the controls were to have been reset so that the pulsed power module was only energized when the chillers were running and for 1 hour each day along with the tower pumps on weekends and holidays to maintain corrosion protection in case the chillers did not run on those days. However, it is clear from the monitoring data that this does not occur. Table 2-17 shows metering data recorded for Sunday July 3 and Monday July 4, 2005. It can be seen that the tower pump starts up at midnight and runs for an hour until 1:00 a.m., on both days, but the Dolphin unit does not. This should be corrected as soon as possible. It is assumed that the deterioration in corrosion protection detected through coupon analysis is at least partially explained by this problem. Please note that when chiller 2 runs on the morning of July 3, the Dolphin unit does run, as intended (Recommendation 19).

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[2] Note that the MPY for the copper coupon at Desert Pines decreased to 0.0719 MPY from the second set of copper corrosion coupons. The third set of copper coupons increased to 0.1748 MPY.

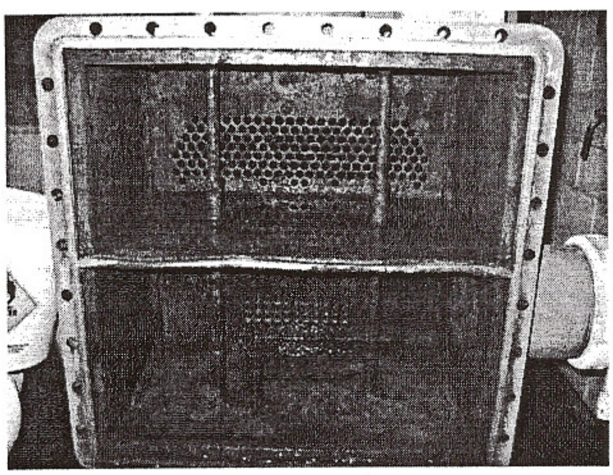
[3] Note that the MPY for the copper coupon at Palo Verde decreased to 0.1078 MPY from the second set of copper corrosion coupons. The third set of copper coupons increased to 0.2158 MPY.

The non-chemical system at Sierra Vista High School (VRTX system) has shown a reduction in mild steel corrosion rates over the course of the study.[4] Unlike mild steel, copper corrosion rates have increased from 0.1581 to 0.2928 MPY. However, overall corrosion rates achieved with the VRTX system for both copper and mild steel are very good by industry standards; thus, this system could be considered for further deployment by the District. It should be noted that in order to provide continuous corrosion protection, this system was set up to run continuously 24 hours per day, along with the side-stream pumps, regardless of whether the chillers or the other pumps were running. This continuous load measured at 11.2 kW will undoubtedly lead to higher energy usage and costs.

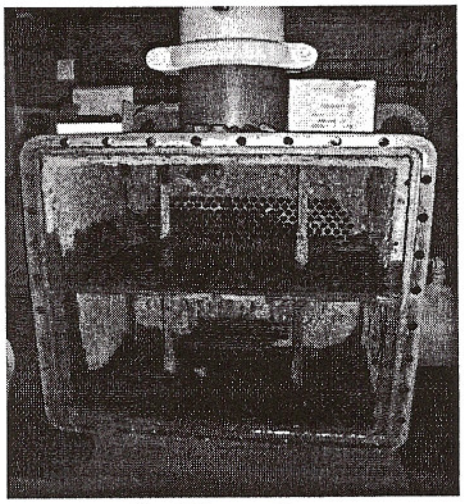
Although Mojave High School (Nytrox system) was discontinued as a test site during the later half of the test period, corrosion results achieved by the Nytrox system are included in this report. The lab results show that there was improvement in the mild steel corrosion rate but not with the copper coupons. Please note that following the discontinuance of the Nytrox system, chemical treatment was resumed at Mojave HS. Therefore, the third set of coupons show the effect of chemical treatment.

Figures 2-7 through 2-10 show chiller tube inspections.

Figure 2-7 Desert Pines (control site) Chiller Pictures



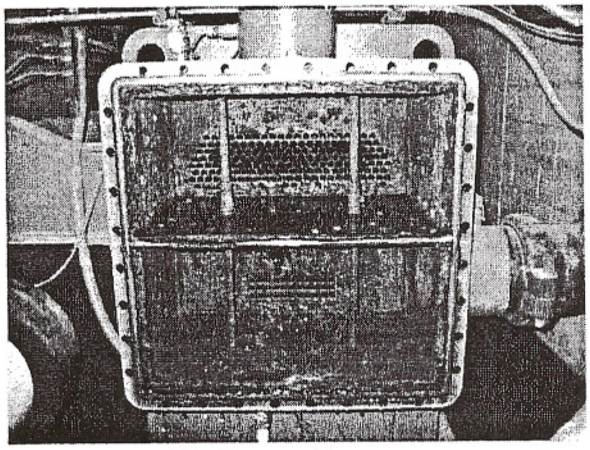
Pre-Inspection



Post Inspection

[4] Note there is a slight increment comparing the second and third set of mild steel coupons (from 1.2292 MPY to 1.4043 MPY).

Figure 2-8 Coronado (Alpine System) Chiller Pictures



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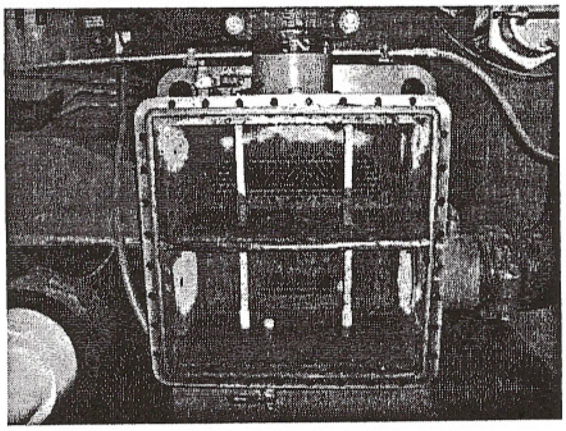
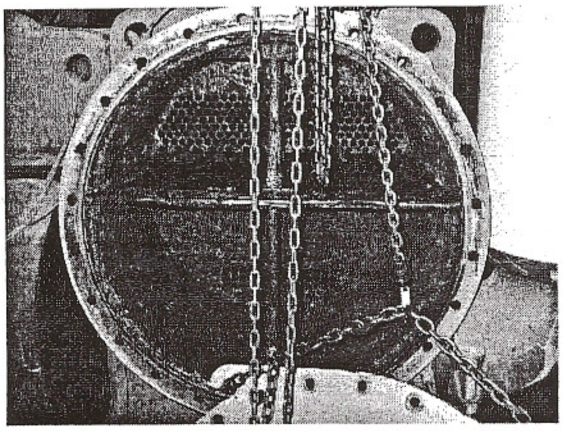


Post Inspection

Figure 2-9 Palo Verde (Dolphin System) Chiller Pictures



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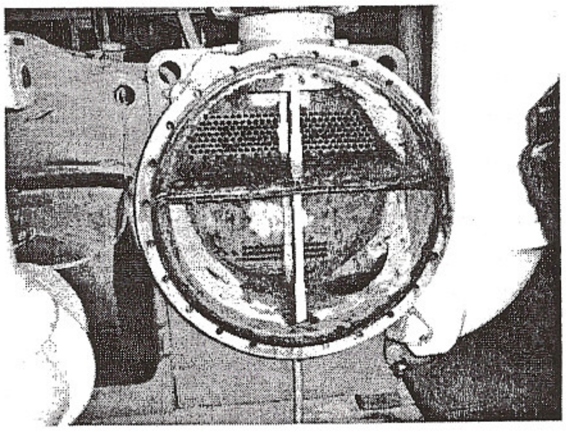
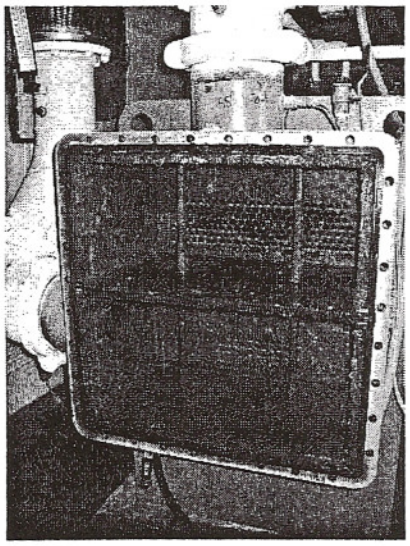


Post Inspection

Figure 2-10 Sierra Vista (VRTX System) Chiller Pictures



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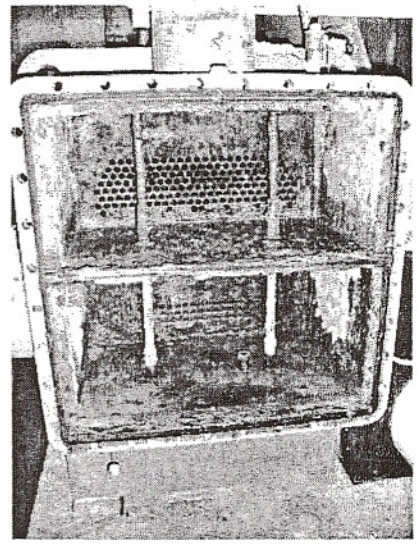

Post Inspection

It should be noted that boroscope inspection revealed white scale on the ID of the tubes in the systems with non-chemical treatment. In general, deposits like these interfere with efficient heat transfer and can lead to corrosion problems if not removed. The scale on the tube ID found at Sierra Vista High School (VRTX system) was particularly heavy. This will need to be removed either mechanically or chemically to restore proper heat transfer and to preclude future under-deposit corrosion damage.

2.5 ALGAE CONTROL

From observations, algae was growing in the tower basins of all three remaining test sites (see Figures 2-11a through 2-11c). The tower basin condition at Desert Pines (control site) could not be inspected since it is a closed tower design, unlike the open tower designs at other testing sites. All the towers were cleaned at the beginning of the trial so all of them started in similar condition. One of the solutions to better algae control is by improving and maintaining the sweeper systems in the tower basins.

Table 2-23
Summary of Expected Annual O&M Costs

High School	Treatment System	Chemicals[1]	Cleaning	Acid Wash	Surveillance Cost[3]	Total
Sierra Vista	VRTX	$500	$0	$600	$3,570	$4,670
Palo Verde	Dolphin	$500	$0	$600	$3,960	$5,060
Desert Pines	Chemical	$3,640	$0	$0	$4,260	$7,900
Coronado	EST[2]	$500	$2,880	$600	$6,810	$10,790

[1]Includes the cost of biocide treatment at all schools for algae control.
[2]Added cleaning of reaction vessel of 8 manhours per month at $30/hr
[3]Labor cost incurred by District personnel during course of the study at $30/hr
Does not include costs for Vendor labor.

The District has concluded that some sort of chemical treatment will be required to eliminate algae growth in areas of the tower systems exposed to sunlight. The District has estimated this at $500 per site per year based on the cost of conventional chemicals and its labor cost. The equipment vendors have suggested alternatives such as a U.S. Department of Forestry-approved dye that blocks photosynthetic light or bromine-chlorine donor tablets. As all of these are in the same cost range, it will be up to the District to decide which agents perform best. (Recommendation 18 in Section 3.)

Because of scale found at all three non-chemical sites, the District asked that the cost of acid cleaning be included as a part of the annual maintenance cost for these systems. Acid cleaning is not recommended as an ongoing routine maintenance practice as it can corrode the heat exchanger tubes. Therefore, if the scaling problem cannot be solved through better operation of the non-chemical systems, then the District must consider other means to either stop scale deposition or remove scale mechanically rather than chemically. Reducing the cycles of concentration may be the easiest way to reduce the tendency to precipitate scale and should be tried first (See Recommendation 5 in Section 3). Hydroblasting is an effective means of mechanically removing most scale from heat exchanger tubes. This technique involves the use of a high-pressure water spray to break up and flush away scale.

Surveillance costs for non-chemical systems can be expected to be higher than shown once the costs for vendor support are included. It is expected that the District will not be able to avoid the need for ongoing vendor support. Also, it should be expected that surveillance costs will not diminish over time. It is critical that close and diligent surveillance be maintained to ensure that the non-chemical systems operate in the intended range and that sensors and timers are functioning correctly.

It is expected that water use will be highest at Palo Verde High School and lowest at Sierra Vista High School on a per-ton-of-cooling basis. It could not be determined how much energy each system uses on a per-ton basis, so no comparison is possible for electrical costs.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

The following conclusions can be drawn from this study:

1. Chemical treatment is an effective system for providing corrosion control and water conservation. Through close and diligent attention, District personnel were able to demonstrate that the existing treatment systems can provide excellent corrosion protection without excessive water consumption.
2. Non-chemical systems can provide acceptable corrosion protection when closely controlled and monitored.
3. Non-chemical systems can use less water than chemical treatment systems; however, at very high concentration ratios, corrosion rates can be unacceptable.
4. Non-chemical systems require different surveillance and maintenance skills than chemical systems.
5. Malfunctioning non-chemical systems can result in damage to equipment if not detected and corrected quickly.
6. None of the non-chemical systems that finished the trial could eliminate algae growth where sunlight penetrates into the cooling tower. It was reported that this is also a problem in chemically treated systems where sunlight enters the tower.

3.2 LESSONS LEARNED

The following lessons were learned during the course of this study:

1. Good water clarity does not necessarily mean good corrosion protection.
2. Reliance on school janitors for maintenance of cooling tower systems led to several problems with non-chemical systems. This practice should be discontinued if further deployment of non-chemical systems occurs. Only trained technicians should be responsible for the towers, appurtenances, and the operation of the non-chemical treatment devices.
3. A thorough review of system metallurgy and elastomers should be made and provided to non-chemical system vendors before installation on any tower system to assure compatibility.
4. Commissioning of new systems should involve a complete review and test of the time-of-day schedules in the building automation system to ensure that the equipment is running as intended.
5. Critical sensors must be checked for proper operation on a periodic basis.