Cleanup of the Closed Cooling Water System at AES Alamitos Units 5 and 6

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ABSTRACT

Early in 2016 it was discovered that the closed cooling water system at AES Alamitos Units 5 and 6 was severely fouled with bacteria slime. The buildup of slime occurred over time due to the chemical addition of nitrite-based corrosion inhibitor, inadequate monitoring, and an absence of biocide treatment. The fouling resulted in unit load restrictions due to cooling water temperatures becoming too hot. This paper describes the system cleanup and its restoration to normal conditions.

INTRODUCTION

Alamitos Units 5 and 6, with supercritical, once-through boilers, has been in operation since 1966. The owner/operator is the AES Corporation, who purchased the 2 075 MW capacity Alamitos Generating Station from Southern California Edison in 1996. The 495 MW capacity units utilize full-instream condensate polishing and oxygenated treatment for corrosion control. The condensers and heat exchangers for the closed cooling water are seawater cooled. Due to California's initiative to end once-through seawater cooling at coastal power stations, the units are on a timeline for retirement at the end of 2020.

The closed cooling water system (CCW) is common to both units and has an operating capacity of 325 000 L. The makeup source is demineralized water from the condensate storage tanks, and occasionally the CCW may become contaminated with small amounts of city water. Components include a storage tank, three pumps, and three seawater-cooled heat exchangers. Nitrite-based corrosion inhibitor treatment has been used since the late 1970s. The schematic in Figure 1 shows the diversity of plant equipment and instrumentation served by the CCW. The system provides cooling to many important components:

- The main lube oil coolers for the high-pressure (HP) and low-pressure (LP) turbines.
- The oil coolers for the auxiliary turbines and boiler feed pumps.
- The hydrogen coolers for the HP and LP generators.
- The digital electro-hydraulic (DEH) oil coolers that cool the oil used for the turbine control valves.
- The oil coolers for the air preheaters, gas recirculation booster fans, gas recirculation fans, and booster fans.
- The main seal heat exchangers, bearings, and oil coolers for the boiler feed booster pumps.
- The oil coolers for the auxiliary turbines and boiler feed pumps.
- Coolers for the main vacuum pump, air compressors, seal oil, seal water injection pump, air dryer, air preheaters, and control room air conditioner.
- The local sample coolers and secondary coolers at the sample conditioning rack.
- The cameras that monitor the burner flames.

Figure 2 is a picture that includes the CCW heat exchangers, pumps, and heat exchangers (from left to right). The tank's operating capacity is 210 000 L.

In early 2016 it was discovered that the system was severely fouled with biological slime during inspections of individual coolers. The inspections were done because cooling water temperatures had become too hot, causing load restrictions.

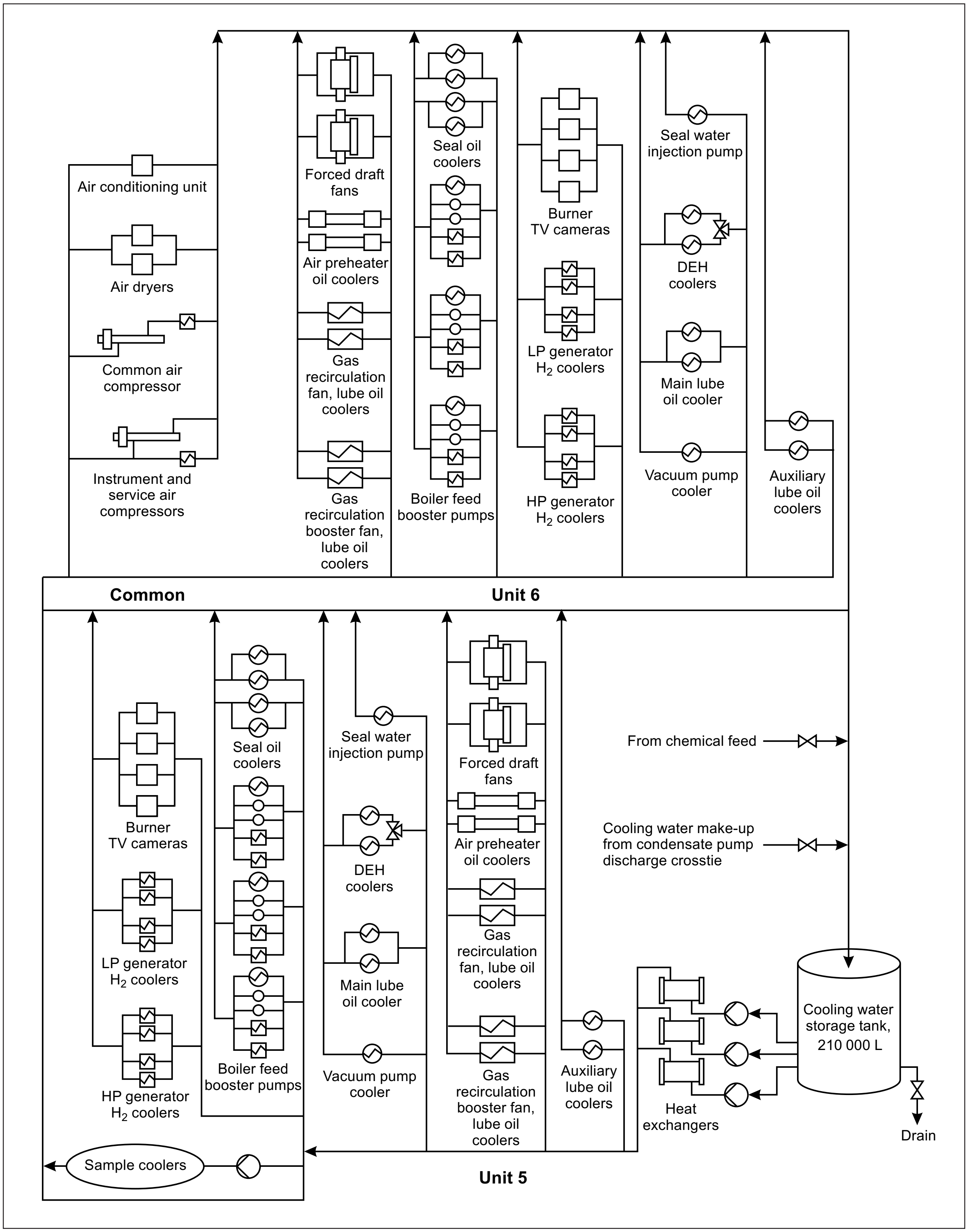

Figure 1:
Closed cooling water system schematic [1].

Figure 2:
CCW heat exchangers and storage tank.

SCOPE OF FOULING

Figures 3 and 4 are pictures of the DEH oil coolers after their tops were removed. The tube sheets to the coolers were found largely occluded with foulant. The same issues were found in other coolers.

The storage tank was then drained and opened for inspection. Up to the fill line, the tank walls were covered with a layer of foulant, averaging 1 cm thick (Figure 5). The foulant was a gelatinous mixture of bacteria slime and iron. The foulant likely contained iron-reducing as well as nitrite-reducing bacteria.

When a tank wall sample collected by the station (shown in Figure 6) was inspected, the sample would jiggle (like a gelatin) when the container was gently shaken. This indicated it was gelatinous.

It is estimated that the CCW had been out of chemical control for a decade. With good chemical control, the conductivity should be $> 1\,400\ \mu S \cdot cm^{-1}$ and nitrite $\geq 500\ mg \cdot L^{-1}$ [2]. Monitoring data from July 2013 to February 2015 indicated the pH ranged from 7.8 to 9.3, specific conductivity ranged from 300 to $1\,400\ \mu S \cdot cm^{-1}$, and nitrite ranged from 0 to 40 $mg \cdot L^{-1}$. Chemical additions were made monthly. No monitoring data was found for March 2015 through January 2016.

A recommendation was made to the station to replace nitrite treatment with a treatment that would not cause problems with bacteria growing in the system. Continuing sodium nitrite treatment would simply add more bacteria food that promotes bacteria growth, and would necessitate the use of more chemicals to make up for nitrite losses because of nitrite-reducing bacteria.

After careful evaluation from a regulatory perspective, the AES Alamitos environmental team decided to stay with nitrite treatment and to commence operations to improve the system maintenance.

SYSTEM CLEANUP

Cleanup of the closed cooling water system started on February 14, 2016 with the draining of the tank and the cleaning out of the DEH oil coolers. After the tank was cleaned by water blasting, it was refilled with deionized water (Figures 7 and 8).

Figure 3:
Unit 5 DEH cooler No. 2.

Figure 4:
Unit 6 DEH coolers.

Figure 5:
Inside of tank access cover.

Figure 6:
Tank wall sample.

Figure 8:
CCW tank floor after water blasting.

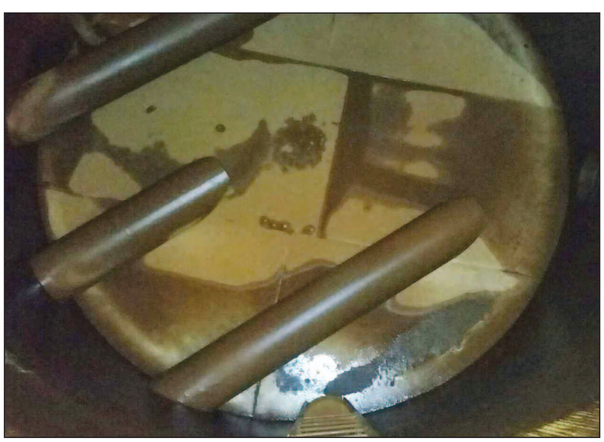

Figure 7:
CCW tank floor before water blasting.

Figure 9:
Skid used for side-stream filtration.

Figure 11:
CCW sample containing uranine dye.

Figure 10:
Filter and storage tank.

A side-stream filter was then set up for bio-solids removal, using a filter skid with four bag filters (Figure 9). Using hoses, the skid was configured to receive filter water from a point downstream and return filtered water to the storage tank (Figure 10). At the top of each filter housing there were inlet and outlet pressure gauges for monitoring differential pressure.

During the first week of filtering (starting on March 14, 2016), the station used "25-micron" bag filters; however, differential pressures indicated very little removal. On the fourth day, bio-detergent and biocide chemicals were added. The first chemical added was Nalsperse™ 72551, a soft foulant deposit cleaner. The second chemical was Nalco 7468 defoamer. The third chemical added (after waiting at least two hours) was 80 $mg \cdot L^{-1}$ of Nalco 7330, an isothiazolin biocide. The result for the heterotrophic plate count before the addition of isothiazolin was 5 040 colony forming units (CFU) per milliliter. The result for the heterotrophic plate count several days later was 53 $CFU \cdot mL^{-1}$.

To begin the second week of filtering, the "25-micron" bags were replaced with "5-micron" bags and bio-detergent, defoamer, and isothiazolin chemicals were added a second time. The result for the heterotrophic plate count several days later was 44 $CFU \cdot mL^{-1}$. At the end of the second week, nitrite-based corrosion inhibitor and sodium fluorescein (uranine dye) were added. The uranine dye colors the water green (Figure 11), to serve as an indicator for leaks (because of Southern California's coastal climate, glycol antifreeze is not used).

Over the next eight weeks the "5-micron" bags needed changing nine times. The solids removed primarily consisted of rust-orange, spherical globules about 2 mm in diameter. Heaviest loading on the filters occurred when Unit 5 and Unit 6 had their first runs.

After nine weeks of filtering, the "5-micron" bags were replaced with "1-micron" bags. The first set of bag filters quickly plugged when Unit 6 ran.

Throughout the weeks of filtering, results for heterotrophic plate count steadily increased after the initial two treat-

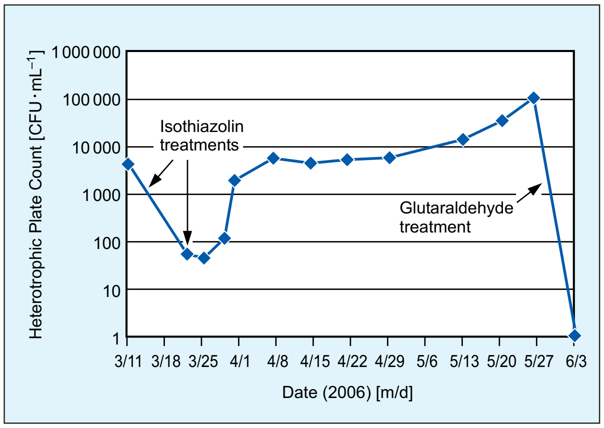

Figure 12:
Heterotrophic plate count results.

ments with isothiazolin, as shown in Figure 12. In fact, the bacteria count reached 101 000 CFU · mL^{-1} after ten weeks; however, even with this high bacteria population there was no nitrite loss from nitrite-reducing bacteria.

After eleven weeks of filtering, the side-stream filter was removed and 125 mg · L^{-1} of Nalco H-550 (50 % active, glutaraldehyde biocide) was added to the system. The glutaraldehyde treatment resulted in a bacteria count result of < 1 CFU · mL^{-1}. In addition, the station identified leakage of cooling water at the main cooling water pump packings, and tightening them resulted in a tight system.

NORMAL CHEMICAL TARGETS

The chemical targets and monitoring parameters for the closed cooling water system throughout and after the cleanup are shown in Table 1.

Parameter		Targets
pH		8.5–10.5
Conductivity	[µS · cm^{-1}]	≤ 5 000
Nitrite	[mg · L^{-1}]	500–1 000
Tolytriazole	[mg · L^{-1}]	15–100
Total hardness	[µmol · L^{-1}]	≤ 100
Chloride	[mg · L^{-1}]	≤ 10
Iron and copper	[mg · L^{-1}]	≤ 1
Nitrate	[mg · L^{-1}]	trend
Sulfate	[mg · L^{-1}]	trend
Turbidity	[NTU]	trend
Heterotrophic plate count	[CFU · mL^{-1}]	< 100

Table 1:
Chemical targets and monitoring parameters for the closed cooling water system.

The proprietary corrosion inhibitor is Nalco 8338. It contains sodium nitrite as a carbon steel corrosion inhibitor, sodium nitrate as an aluminum corrosion inhibitor, tolytriazole as a copper alloy corrosion inhibitor, sodium tetra - borate for pH control, and an anionic polymer that is both a dispersant and scale inhibitor.

Because sodium nitrite is an anodic inhibitor, a minimum residual must always be present in the cooling water to re-establish the protective film if a break occurs. A minimum of 400 mg · L^{-1} for nitrite is considered the critical amount needed. If breaks are not repaired, the small exposed area of metal becomes susceptible to pitting corrosion. The nitrite level must be closely monitored since nitrites are a food source for microbes.

Corrosion studies done by San Onofre Nuclear Generating Station have indicated that nitrite and nitrite-molybdate treatments provide equal corrosion protection.

NITRITE TEST METHOD

A variety of test methods are available to measure nitrite in closed cooling water systems. Best results are achieved using ion chromatography with ultraviolet (UV) detection at 225 nm. Although ion chromatography with conductivity detection is more popular for nitrite and nitrate, it is less precise than UV detection. Other known methods are the chloramine-T (indirect iodimetric titration) procedure, potassium permanganate titration, direct UV measurement, and the CHEMetrics ampoule test.

The test kit available from Nalco is very good for power station use although Nalco's written procedure contains an error in the calculation. Samples containing indicator are titrated with a standard solution of acidified ceric sulfate until there is a color change from orange-red to blue. By making primary standards it was found that the multiplier of 40 printed in Nalco's method to calculate "mg · L^{-1} as NO_2" is in error. The correct multiplier for "mg · L^{-1} as NO_2" is 26.7, not 40. A multiplier of 40 calculates "mg · L^{-1} as $NaNO_2$." Using the correct multiplier, the Nalco method is quite accurate.

When comparing results for nitrite using the Nalco method to results by ion chromatography, the agreement was within ±10 %.

ISOTHIAZOLIN VERSUS GLUTARALDEHYDE

The glutaraldehyde treatment was more effective than the isothiazolin treatment. It was also more effective when used at Alamitos Units 3 and 4. In addition, glutaraldehyde did not change the pH or add additional minerals, whereas isothiazolin treatments have coincided with pH reductions and contributed a small amount of magnesium. According to Nalco, they have customers who switch back and forth between these two biocides so the bacteria do not become resistant to one product.

Based on experience, it is very important to do biocide treatments regularly for both nitrite and nitrite-molybdate treated systems. In addition, losses of glycol occur because of bacteria, too. Tight systems require less frequent biocide treatments.

NINE MONTHS FOLLOWING SYSTEM CLEANUP

During the nine months following the cleanup of the Alamitos Units 5 and 6 CCW there have been no problems or loss of nitrite due to nitrite-reducing bacteria. The specific conductivity has averaged 1 614 $\mu S \cdot cm^{-1}$, the nitrite concentration has averaged 525 $mg \cdot L^{-1}$, and iron has averaged 1.0 $mg \cdot L^{-1}$.

ACKNOWLEDGMENTS

Major contributors are the operations staff at AES Alamitos 5 and 6 led by David Cordero. Mike Griffith took the early initiative by taking many photographs for the station's records. Mike Livingston planned and managed the rental of the filter skid. Michael Fruhwirth shared his technical knowledge with the author. Chuck Davis and Jorge Negrete were cooperative and helpful during service visits.

REFERENCES

[1] *Piping and Instrumentation Diagram Cooling Water, Alamitos Generating Station, Revision 4*, **1972**. Southern California Edison Company, Los Angeles, CA, U.S.A.

[2] *Closed Cooling Water Chemistry Guideline, Revision 1*, **2004**. Electric Power Research Institute, Palo Alto, CA, U.S.A., EPRI 1007820.

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