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BlueTrak: Automatic Monitoring and Control of Cooling Water Treatment Products

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Control of cooling water inhibitor dosage is one of the critical issues in achieving good results as to control of scale, corrosion and deposition; minimization of water management program operating cost; and environmental compliance. While manual test and control using easy to test for actives such as chromate, phosphate, and molybdate can provide acceptable results, automation of the dosage generally provides much superior results and is generally used at the present time.

Current Control Technology

Automatic control of cooling water inhibitor dosage is generally based upon measurement of a system parameter; such as on time, conductivity, or makeup water amount; and dosing of the inhibitor based upon a relationship between the measured parameter and the amount of inhibitor needed to treat the system. Thus we have simple timer devices where a chemical pump is activated based on system operating time, control systems where a chemical pump is activated whenever the system blows down based on conductivity, and makeup proportional systems where a chemical pump is activated based on addition of a set amount of makeup to the cooling system[1]. These control schemes all suffer from one, or more, problems in the real world where the relationship between the measured parameter and the amount of inhibitor needed is broken due to such things as leakage, cross ties (in leakage), thermal load changes, and changes in the makeup water quality.

Attempts have been made in the past to utilize on-line monitoring of various cooling water parameters, such as ortho phosphate and molybdate, as either product components or tracers to control feed of inhibitor. These methods suffer due to use of costly automated wet chemical analyzers and in the case of phosphate, potential precipitation of the tracer. Responding to this inhibitor dosage control problem, Nalco Chemical successfully developed a tracer technology based upon addition of ultraviolet (UV) fluorescent compounds[2] to the inhibitor formulation along with development of an on-line UV florescent monitor/controller. This unique tracer and control method allows automatic monitoring and control of inhibitor dosage and is currently marketed as their “TRASAR” technology. Unfortunately for the rest of the water management industry, TRASER is managed as a proprietary technology for marketing advantage.

Colorant Technology Development

Molybdate has been used for many years as both a corrosion inhibitor, at higher dosage levels, as an easy to test for tracer in many cooling water products. The current high prices for molybdate s have made its use as either a corrosion inhibitor or tracer quite costly. In response to this problem, ProChemTech began researching use of optical colorants as tracers and in 2005 developed a colorant tracer technology[3] based on determination of the colorant concentration in cooling water at 620 nm using a hand held spectrophotometer. This tracer technology has been commercialized and is currently marketed as “BlueTrace”. The patent application on this technology anticipated development of an on-line spectrophotometer for automated control of color traced products.

Handheld Spectrophotometer

Colorant tracer technology is currently used in over 100 cooling towers across the country and has proven to be both accurate and precise as a tracer control technology. The two colorants used, one for alkaline and one for acidic formulations, are compatible with almost all commonly used cooling water actives, exceptions being cationic biocides and higher levels of oxidants.

Unlike the Nalco technology, this colorant technology is available to the water management industry with both products supplied as liquid concentrates normalized to produce the same absorption at 620 nm. Currently at least two AWT member toll blenders are providing colorant traced products based on this technology with evaluations under way by several more as well as by self supplied firms.

A side benefit of the organic colorant technology is that it reduces the growth of algae in open cooling towers by partial blocking of the light needed for algae growth. Less algae growth means reduced use of costly biocides.

Automatic Controller Development

Based on the success of the organic colorant technology as a tracer, a joint development project was initiated in late 2006 between Advantage Controls and ProChemTech to devise and commercialize an on-line spectrophotometer based monitor and controller to control feed of traced inhibitors. After review of the technology in the hand held spectrophotometers used to monitor the organic colorant in cooling waters, it was determined that an LED light source coupled with a photocell set to measure absorbance at close to 620 nm through an approximately 1 inch cell path would provide sufficient sensitivity and measurement differentiation (or range) for an automatic control sensor.

A prototype on-line spectrophotometer sensor was constructed by Advantage with an existing controller, Model 2EZ, used as the control interface between the sensor and chemical feed pump.

The prototype sensor was found to provide sufficient sensitivity to detect the colorant at levels as low as 0.2 mg/l. For control, the sensor voltage output was used to drive the existing controller which was modified to accept the 0-5 vac signal from the prototype sensor. Laboratory testing of the prototype sensor involved setting the unit zero with deionized water and then filling it with solution made up at different concentrations of the blue colorant to determine sensitivity and precision. This work demonstrated that the prototype cell was suitable for further development work in that a change in the colorant absorbance typical of lower and upper control limits for a cooling tower system gave sufficient response to provide the desired control function.

A typical calibration test would consist of calibrating the sensor to 0% absorbance with DI water, draining, and adding known solutions. For instance in one test conducted on March 25, 2007, a solution containing 0.28 mg/l of colorant gave an absorbance of 17% while a second solution with 0.56 mg/l colorant present read at 31%. A final test again with DI water to check the 0 set point gave 0% absorbance.

Of course to get to the above calibration results, there were many conversations back and forth between ProChemTech chemists and Advantage engineers as to such things as electronic gain in the sensor, absorbance being a log function, Beer's Law (some days everyone needed more than one!), and of course the fun of using a hand wired prototype circuit board with open wires around water solutions.

In any event, all of these little problems were resolved to the point where a "beta" sensor was constructed and a 2EZ-D1L controller provided to work with its output to control feed of inhibitor based upon the measured absorbance of water passing through it.

Field Testing

A plant close to our headquarters was selected for the first installation, Phoenix Sintered Metals in Brockway, PA, being less than a mile down the road. This plant manufactures sintered metal parts from metal powders and in addition to being close had a history of poor chemical inhibitor control due to load changes, leaks, and changing makeup water conductivity "defeating" the existing makeup proportional inhibitor control and feed system.. The "beta" sensor and chemical inhibitor feed controller were installed at the plant in April, 2007.

The city supplied makeup water to this plant has a variable conductivity with very low hardness and alkalinity, making it quite corrosive. A PVC fill BAC FXT 115 cross flow cooling tower with a 5,000 gallon volume hot well – cold well design cooling system supplied by ProChemTech is used to cool several metal part sintering furnaces operating at over 2200 F, air compressors, and hydraulic presses. System metallurgy is mostly steel with some copper heat exchangers. We have found that sintered metal parts plants present a severe cooling water treatment challenge as water temperatures in the carbon steel sinter furnace cooling jackets can range from 95 to 195 F, with very low water flow velocities. Due to the potential to "melt" the PVC fill in the cooling tower, the system design provides for 50+ gpm of overflow from the cold well to the hot well to cool, or "temper" the hot water prior to entry into the cooling tower to protect the fill.

Shown to the left is the panel mounted sensor, 2EZ-D1L controller, and a sensor prefilter to prevent "positive" errors from the sensor caused by blockage of light by suspended solids. Upon start-up we found that the sensor prefilter, using 10 micron cartridges, required a change on a weekly basis. After some discussion, we switched to 50 micron filters with a substantial increase in change-out time.

A note on the filter changes, this plant had just been re-started after several months of "shutdown" due to a Chapter 7 bankruptcy and the cooling system equipment had a substantial amount of rust in it. After a year of successful water treatment, the filter changes are now a monthly affair handled during the routine monthly service call

We have also found that the sensor cell, constructed of cast polyacrylate plastic, requires a monthly cleaning with a soft brush to remove fines which cause a positive error. On this sensor, threaded end caps prove entry for the cleaning brush, later designs have ball valves installed.

Water Analysis Data

The following table summarizes the analytical results from makeup and cooling water samples taken February 1, 2008, which are typical for the cooling system when the city water conductivity is low.

Parameter	Makeup Water	Cooling Water
pH	6.6	7.6
total alkalinity mg/l	6	55
conductivity mmhos	37	223
total hardness mg/l	9.0	14.2
chloride mg/l	7	17
sulfate mg/l	< 5	< 5
total phosphate mg/l	0.92	30.2
suspended solids mg/l	-	< 2
cycles on conductivity	-	6
saturation index	-3.4	-1.4

Results

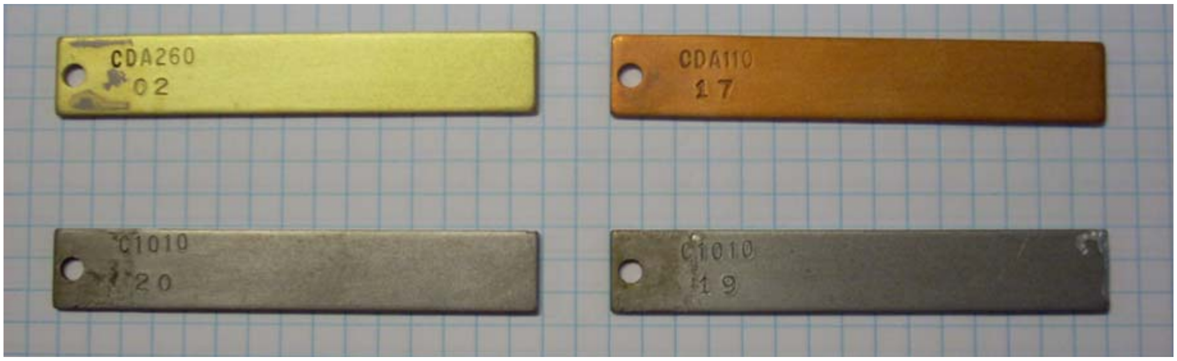
We utilized the time period from 11/09/07 to 01/25/08, which coincided with a corrosion coupon study, to examine performance of the sensor and automatic controller. The following service report data was collected during the course of study by our field service technicians using field test equipment and plant makeup water meter readings.

Date	Makeup – gpd	BlueTrace abs	makeup conductivity	cycles	ATP – rlu
01/25/08	2,255	0.10	30	7.3	92
12/28/07	1,291	0.11	32	10.6	127
12/21/07	2,010	0.11	32	11.3	-
12/13/07	2,058	0.09	42	11.0	126
12/07/07	1,560	0.12	46	16	182
11/27/07	1,137	0.11	150	5.5	211
11/16/07	1,966	0.11	140	4.7	203
11/09/07	1,717	0.12	160	4.9	157
11/02/07	1,703	0.09	150	3.5	98
Control Limits		0.08/0.11		5/6	< 2000

Cycles on conductivity, readings in mmhos

The corrosion coupon study run between 11/09/07 and 01/25/08 provided the following results:

Mild Steel C1010, coupon #19 – 0.50 mil/yr
Mild Steel C1010, coupon #20 – 0.45 mil/yr
Copper CDA110, coupon #17 – 0.08 mil/yr
Brass CDA 260, coupon #02 – 0.06 mil/yr



Cleaned coupons from the corrosion coupon study.

We then compared this data with corrosion coupon rates for a one year period prior to the plant shutdown, where corrosion rates averaged 1.72 mil/yr on mild steel and 0.03 mil/yr on copper and brass. Note that the same corrosion inhibitor, a specialized product formulated for use in soft, corrosive waters, was used in both study periods with the same control limits. In the first time period studied, n,n,dibromosulfamate (stabilized bromine) was used as the sole biocide. In the second, sensor control on-line, time period the n,n,dibromosulfamate had been replaced as the sole biocide by electrolytic bromine. As both biocides utilize bromine as the active, we do not expect this change to have affected the results in a significant manner.

Field Test Discussion

Looking first at the service report data, we see that the makeup water had a considerable change in conductivity during the course of the study period, going from a high of 160 mmhos to as low as 30 mmhos, more than a five fold change. This, coupled with changing thermal loads and some system leakage, caused substantial swings in the cycles obtained, from 3.5 to 16, in the system during the course of the study. **The sensor control unit, however, maintained the level of chemical inhibitor within set control limits throughout the entire study time period, regardless of cycles.**

Review of field service reports for a three month period when the system operated with a makeup proportional control system shows that the chemical inhibitor level was outside, either higher or lower, than control limits for the entire period. From this data, it is clear that installation and operation of the sensor control unit substantially improved chemical inhibitor control.

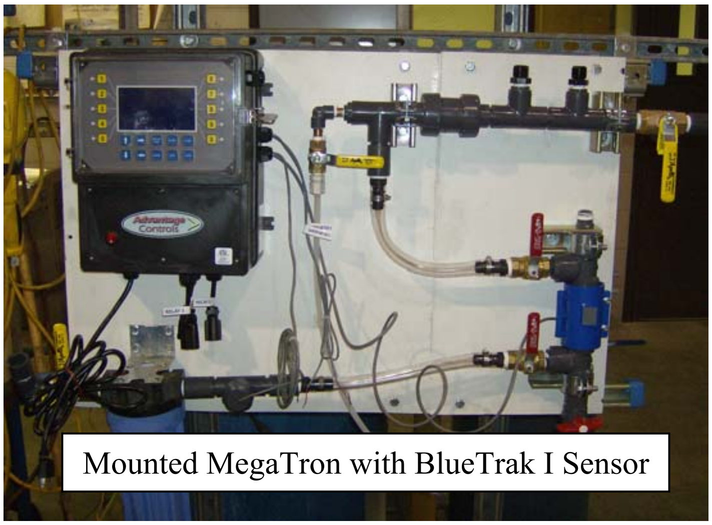
Biological control of the system, using only electrolytic bromine set to three doses a week, was excellent with the highest ATP rlu reading observed being just 211 on a maximum control limit of 2000 rlu.

Installation of the sensor control unit substantially improved the chemical inhibitor control in a cooling system with wide swings in cycles due to load changes, leaks, and changing makeup water quality.

For a three month period 100% control was maintained in contrast to a previous three month period where the system was continuously out of control. Steel corrosion control was substantially improved while copper and brass corrosion levels remained at acceptable levels.

Further Developments

Since this first installation, the organic colorant sensor technology has been commercialized by Advantage as the "BlueTrak I" and it is currently an option for the 2EZ, MegaTron SS, and MegaTron cooling tower controllers. Several additional 2EZ based units have been installed in Arizona, Pennsylvania, Florida, and Colorado; while Megatron SS units have been installed in Pennsylvania and two units shipped to Australia.



Mounted MegaTron with BlueTrak I Sensor

Advantage has improved the sensor electronics which allowed the optical path to be reduced to 0.75 inch, reducing the overall size of the sensor and the valves and fittings, this in turn has reduced the cost of the sensor. A new "overcover" is also under development to further protect the sensor electronic assembly from damage in the field.

Health, Safety, and Environmental

No paper presentation would be complete today without a discussion of health, safety, and environmental effects of any new technology. Looking at the two organic colorants used, both have very low human toxicity values as shown by their approval for use as food colorants by the USFDA [4]. The oral LD 50 for rats of both organic colorants is greater than 2 g/kg. Our provision of the colorants only as concentrated solutions eliminates the problem of dealing with small amounts of intensely colored, fine particle size materials in blending operations. We would note that several "Smurf" sightings have been reported in the Brockway area.

While the organic colorants are sufficiently stable for use in a cooling tower environment as tracers with a half life in the area of 4 weeks; they are fully biodegradable in the environment, contain no heavy metals, and can be decolorized by use of standard bleach in the unlikely event that traced product is ever spilled and the resulting blue mess must be cleaned up. Aquatic toxicity of both colorants, 96 hr LC 50 for both rainbow trout and bluegill sunfish, has been reported to be greater than 96 mg/l, while the 48 hr LC 50 for daphnia magna is greater than 97 mg/l.

Is It "Green"

Is this technology "green"? We believe that by permitting much closer control of critical scale, corrosion, and deposition inhibition chemistry, which minimizes chemical use and blowdown, and the very low environmental impact of the organic colorants used; this technology is "green".

Looking at the USGBC LEED program, credits may be obtainable for this technology for either, or both, innovation in design and controllability of systems. We would note that this technology was selected and installed in one LEED platinum certified level project[5], which is in start-up as of June, 2008.

Economics

While we do not have any firm cost data to work with, it is believed that the automated control technology using optical organic colorants is substantially less costly than the proprietary technology currently offered in the water management marketplace.

Looking at a cost comparison between the two organic colorants and molybdate as a tracer in a typical cooling water product, we obtained the following tracer cost per pound of product:

sodium molybdate - $0.186
acidic colorant - $0.095
alkaline colorant - $0.176

Please note that these costs are a comparison based on various levels of use of all three materials as a tracer and can very by a factor of at least two dependent upon desired accuracy and precision in testing..

Conclusion

An automated cooling water inhibitor dosage control system based on optical organic colorants has been developed and field proven. The technology presents AWT water management firms with a competitive technology to the proprietary technology they are faced with in the market place and may provide USGBC LEED credits for their customers.

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[1] Frayne, Cooling Water Treatment Principles and Practice, Chemical Publishing Company, New York, NY, 1999.
[2] US Patents 5413719, 5986030, 5998632, and 6255118 issued to Nalco Chemical Company.
[3] US Patent Application 11/700,643, published 01/24/08 to ProChemTech International
[4] Color Index, Volume 7, 3 rd edition, American Association of Textile Chemists and Colorists, Research Triangle Park, NC, 1982.
[5] Tempe Transportation Center, Tempe, AZ