White Paper – Monitoring Water Quality for Cooling Towers Sanitization

Introduction

Problems with cooling towers are usually due to the cooling water quality. As water evaporates and dissolved solids in the water begin to concentrate, there is a huge potential for scaling and corrosion of the heat exchange equipment. Control of water quality to reduce scaling is imperative. Lack of water and the need of conservation are asking for more recycled water. Monitoring the water quality improves the cycle number of water uses as well reduces cooling system maintenance cost.

It is important to monitor and control the chlorine or bromine levels in this application where accuracy, resolution and response time are very important. HG-702 Blue I analyzer is able to provide high resolution, high accuracy and faster response time to changes in chlorine levels. Due to the pre-measurement automated self calibration for each reading the analyzer can adjust to changes in the process and increase system reliability. As well the self cleaning mechanism allows the analyzer to work under hard condition. Likewise, the Blue I analyzer is able to provide measurements for both free chlorine and total chlorine measurements in a single system improving the management of the process.

Cooling Towers

Most of the water employed for industrial purposes is used for product or process cooling. The availability of water in most industrialized areas and its high heat capacity have made water the favored heat transfer medium in industrial and utility type applications. Cooling towers are installed in office buildings and manufacturing plants throughout the world to dissipate waste heat from air conditioning, industrial and power generation processes. Re-circulating water transfer thermal energy from the building or industrial process to the atmosphere. Atmosphere air blown through the cooling tower carries away the heat. Environmental problems arise when water escapes from the system in the form of droplets. Such water droplets carry with them various chemicals that are used in the system. Some of these chemicals are environmentally harmful.

Cooling water system in an industrial plant contains a circulating pump that takes suction from the cooling tower basin and pumps cooling water through the plant heat exchangers. The warm water returns to an evaporative cooling tower and the cycle continue. Chlorine is added to the tower basin to reduce the growth of algae and bacteria in the tower and heat exchangers. To control the buildup of dissolved solids some of the cooling water is continuously sent to waste through the slowdown line. Because the cooling water contains chlorine, the blowdown contains chlorine (See figure 1).

Understanding cooling water characteristics is essential when choosing a chemical treatment program. Pre-treating cooling water, by mechanical means to remove excess hardness or alkalinity is sometimes required in order to allow for increased cycles of concentration. Higher cycles of concentration result in reduced water and chemical usage.

Cooling tower water requires extensive treatment. During cooling tower water treatment, three main factors must be controlled:
- Corrosion of pipes and heat exchanger units
- Scaling in pipes and (mainly) in heat exchangers
- Microorganism growth (bacteria, algae)
these three aspects cannot be viewed separately. For example, lower pH values can prevent scaling, but they increase metal corrosion. Conventional treatment techniques are mainly applications of chemical biocides, corrosion inhibitors and scale inhibitors.

Scaling

In cooling water applications, scale forms mainly as a result of calcium and magnesium ion deposits on the units of a cooling system. This causes the formation of a solids deposit, which forms an isolation layer in heat exchangers. This negatively influences heat transfer. Consequentially to water loss by evaporation, salt concentrations in the water increase. This process is called thickening. At a certain point, the saturation rate for these salts is reached, causing them to precipitate. This limits the number of times the cooling water can be recycled and require addition of makeup water. The thickening factor N is a measure for the increase in salt and ion concentrations in cooling water. As such, it indicates the number of times the water requires refreshment, in order to prevent salt precipitation. The mineral scaling creating solid deposits on the surfaces will enhance biological fouling.

Corrosion

Each material has a limited life-span. The length of the life-span depends on the nature of the material and on environmental conditions. The first method of corrosion prevention is the choice for the most persistent material and a solid construction of the cooling system. Once the cooling water system is in use, corrosion can be prevented by alteration of the water quality. In practice, this is

Figure 1: Measuring Free Chlorine in a Re-circulating Cooling Water System
achieved by pH adjustment and alteration of the dissolved solids concentration. When these measures do not provide the desired result, corrosion-inhibitors may be added to the cooling water. However, corrosion-inhibitors are quite expensive, because of the supervision that must be carried out to guarantee the affectivity of the measure. Microorganisms enhance corrosion forming conditions hence the use of chlorine or bromide limits microbial growth.

**Microorganism growth or Bio-film**

One cannot prevent microbial growth in a water system as we always use water and air that contains bacteria. Chlorine and bromine are efficient disinfectant for preventing the development of Legionella bacteria. Usually, one cannot thicken the water in organic water treatment preparations more than three to five times. This means that of each 1000 liters of water supplement, at least 200 liters is carried off to the sewer (20%). When a significant microbial growth takes place, a slime layer is formed. This contains both organic and inorganic matter. Some microorganisms excrete polymers, which can form a gel-like network around cells after hydrolysis takes place. This is called a bio film. As a result of bio film formation, microorganisms can attach themselves to surface layers. This causes microorganisms to no longer be flushed away by cooling tower water flow. Bio films protect microorganisms from other microorganisms and from toxic disinfectants. This causes water disinfection to be much more difficult when a bio film is present.

Bio film partly consists of microbiological cells and components. Bio film, which is very sticky, also contains organic and inorganic matter that is present in the water and is absorbed by the film. This concerns chemical precipitation, organic flakes and dead cell mass. Bio film consists of 90% water. Within the protected slime layer microorganisms can cause a speedy corrosion, causing the walls of cooling towers and heat exchange systems to be corroded. The bio film prevents materials that cause corrosion protection from reaching the surface. Furthermore, microbiological reactions can accelerate corrosion reactions and microbial products can corrode materials. Bio film creates an isolation layer on heat-exchange systems, causing them to no longer function properly. Microorganisms present in the bio film accelerate oxygen uptake. This can cause an oxygen deficiency in the system. Some microorganisms switch to fermentative metabolisms and produce a number of organic acids, which causes a decrease in pH. Anaerobic bacteria form sulphide byproducts, which are corrosive.

Sanitization treatment using chlorine or Bromine limits Bio-film scaling. Chlorine and Bromine decompose bio film. This causes a decrease in scale formation. Even water with high dissolved solids content can now be recycled, decreasing cooling water discharges. Hyper-chlorination of water distribution systems requires the installation of a chlorinator. Shock hyper-chlorination involves the addition of chlorine to a water system, raising chlorine throughout the system to a concentration of 20 to 50 mg/L. The chlorine levels of the system are returned to 0.5 to 1mg/L after one to two hours (Lin et al. 1998). Continuous hyperchlorination entails the addition of chlorinated salts (e.g., calcium hypochlorite (solid) or sodium hypochlorite (aqueous)) to the water at concentrations ranging from 2 to 6 mg/L (ppm) (Stout and Yu 1997, Muraca et al. 1990). Domestic residual levels are typically 1 mg/L (ppm) (Muraca et al. 1990). The 1985 Legionella Criteria Document suggests using chlorine levels of 1-2 mg/L (ppm), however, recent studies have shown that using chlorine levels of 3-5 mg/L is more effective (Helmes et al. 1988). The chlorinator will maintain a set level of chlorine throughout the system, which should completely eliminate Legionella.
Overview of Application

In most cases, too much emphasis is placed on the control and feed of cooling water treatment chemicals and not nearly enough emphasis is placed on continuous monitoring of the system. While most end users of cooling water specialty chemicals are aware of the monitoring capabilities of the major specialty suppliers, few are aware that having the on equipment for monitoring helps them in getting better results. There are a number of good reasons for continuous performance monitoring of cooling systems:

- Changes in make-up water chemistry.
- Changes in temperature due to seasonal variations.
- Changes in system heat load due to production level changes.
- Changes in biological control requirements due to seasonal variations.
- Chemical treatment quality control problems.
- System feed and control problems.
- System contamination from atmospheric or process leaks.

Most systems control and monitor pH and conductivity levels on a continuous basis. While these two parameters are of primary importance, one other parameter warrants attention - Chlorine level.

The importance of monitoring and control of chlorine levels in cooling water systems, which utilize oxidizing biocides such as chlorine, chlorine/bromine, or sodium hypochlorite, is very important. If a true chlorine residual is not maintained, biological deposition and/or under deposit corrosion will occur. If chlorine residuals are too high, corrosion will occur.

Federal and state agencies regulate the amount of chlorine allowed in water discharged into lakes, rivers, and oceans. Limits are between 0.01 to 0.30 ppm of chlorine. Chlorine is closely regulated because even small amounts are harmful to the environment. Typically, dischargers are required to monitor their waste streams and report chlorine levels to a regulatory agency. Agencies can require either continuous or grab-sample testing.
Blue I solution

Technology:
Multi-parameter analyzer based on DPD colorimetric method for free and/or total chlorine control

Objective:
- Measurement and control of free chlorine with high resolution (0.01 ppm) and accuracy
- Provides a fully controlled shock chlorine process for punctual treatment
- Conductivity Measurement
- Correlates with free Bromine levels as free chlorine equivalent

Technology Description:
The method of determining chlorine employed in our analyzer relies on a color indicator, usually N, N-diethyl-p-phenylene-diamine, denoted in its short and known term 'DPD'. In the presence of chlorine, DPD reacts rapidly to form a red color, the intensity of which is an indicator of chlorine concentration. When the absorbance is low it means that the chlorine concentration is low. Though the photochemical reaction is pH sensitive, DPD/chlorine system typically appears in a red color, measured at about 515 nm. At a near neutral pH, the primary oxidation product is a semi-quinoid cationic compound known as a Wurster dye. The DPD Wurster dye color has been measured photo-metrically at wavelengths ranging from 490 to 555 nm.

The analyzer comprise of a novel spectrophotometric measuring cell, useful for automated reagent mixing and for hands free physical cleansing. The measuring cell is characterized by that whereat fluids and/or reagents are filling the measuring tube; they are effectively mixed by to obtain a homogenized solution. In this way, a tedious necessity of manually cleansing routine is thus avoided. A detector is used, which has means to measure the emission of the solution and determine the chlorine concentration with high accuracy and repeatability.
Technology benefits

- Maintenance advantages
  - Very low reagents consumption (~0.03mL/sample)
  - Self calibration and true zero with every measurement without any need for initial calibration
  - Automatic self cleaning photocell by a build in piston in each unit (patent pending)
- Performances advantages
  - Measurement range: 0-10 ppm
  - Measurement interval: 2 to 10 minutes
  - Measurement accuracy (+/- 5%)
- System benefits
  - Six independent relays for equipment control
  - Having means to measure additional parameters such as pH, Redox, conductivity, turbidity and temperature.

Summary

The chlorine levels in this application should be maintained and continually monitored. Many analyzers were tested for this application most of them are based on amperometric method. In most cases the amperometric method was found not suited for this application as the cooling tower water contains many chemicals and interference to the amperometric electrode. Also, cooling towers water in most cases is not clean and has a lot of suspended and dissolved solids which result in high turbidity that may influence directly the maintenance cycle of the monitoring equipment.

The Blue I analyzer however is able to provide a correct and online measurements in harsh environment due to the pre-measurement calibration with each reading automatically adjusting to changes in the process. pH, temperature and conductivity are also monitored. Likewise, the Blue I analyzer is able to provide measurements for both free chlorine and total chlorine measurements in a single system allowing for easier management of the process.