MARLEY

thermal science

Cooling Tower Water Quality

MANAGEMENT, TREATMENT AND SYSTEM MONITORING

While it is important to consider equipment concerns at all times, maintaining system water condition is equally important for keeping the cooling processes at full capacity and continuing effective operation of the cooling tower.

Consider the cooling tower, along with the other mechanical components, as the cooling system hardware, while the water flowing through the cooling tower is the system software.

Water condition is not often thought of as a potential variable over time. The cooling water essentially is invisible to the operator, but when left unattended, water supports biological growth, and corrodes or scales equipment. Proper ongoing treatment is important to process operation and efficiency.

Cooling loops remove waste heat from the process and function by allowing water to evaporate to the atmosphere. The evaporated water must be replaced continuously by fresh make-up water.

Without a bleed stream, commonly known as blowdown, the dissolved solids in the original system's water volume, plus dissolved solids added by the make-up water, will accumulate in the system until precipitation begins. Eventually an unbled system will fill with solid scale material.

To balance the incoming water solids, a small portion of the circulating water stream with its elevated solids level is removed to drain. An equilibrium is then established between the added water replacing evaporation and high solids water losses, drift and blowdown.

The term cycles of concentration is defined as the resulting ratio of concentrated solids in the circulating water compared to that in the fresh makeup. Calculation of cycles is performed using the following equation. Alternatively, the blowdown required to establish a given equilibrium-cycles level can be derived from this equation:

$$C = (E+D+B) / (D+B)$$ where:

C = cycles of concentration
E = evaporation, approximately gpm x °F range x 0.0008
D = drift loss, approximately gpm x 0.0002
B = blowdown gpm

It is the open nature of these systems that determines the unique water problems that they exhibit. Cooling towers concentrate solids and the air contact in these open systems allows the buildup of contaminants, organics, bacteria and their food sources in the circulating cooling water.

These unique evaporative water system problems — concentration and air washing — must be dealt with or process disasters will follow. Water is both the static and dynamic basis for controlling such problems.

Poor Water Maintenance Illustrated

Poor water maintenance will create certain and predictable problems in open cooling loops. These problems are detailed below:

Scale formation: Scale formation is the creation of a precipitated solid. By coating heat exchange surfaces, this solid material interferes with efficiency of the system's heat exchange surface and also blocks water flow at the cooling tower's basin or fill. Cooling-loop precipitates generally are calcium carbonate crystals. In a few cases, these are calcium sulfate or silica solids.

Scaling occurs because specific dissolved solids, in the case of calcium carbonate scale, namely calcium and bicarbonate alkalinity, have exceeded their solubility limits and are forming solids. Calcium carbonate crystals commonly precipitate on critical surfaces, like the heat exchanger tube interior walls. The scale thickens the barrier to heat transfer, thus reducing the efficiency of the cooling system. Severe scaling is shown in **Figure 1**.

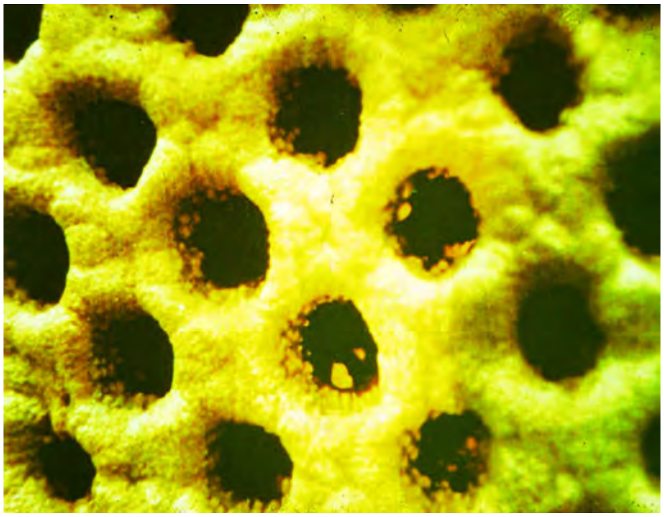

FIGURE 1 *Scale thickens the barrier to heat transfer, thus reducing the efficiency of the cooling system*

Corrosion: Corrosion is the process of metal dissolution, usually by oxidation, resulting in substantial material breakdown and premature degradation of system equipment. The oxidation process, in a very simplified form, is the movement of electrons from metal system components into the water medium provided in wet systems and subsequently to a corrosion product of substantially different form than the original base material. This process degrades the metal, reduces its strength, thickness, and in some extreme cases, creates pits and then holes in the material. At some point in the corrosion process, the metal can no longer do its job as a system component. Corrosion, in general, and pitting corrosion, in particular, must be guarded against in order to ensure the long term integrity of the cooling system. Extensive corrosion is shown in **Figure 2**.

FIGURE 2 *Corrosion, in general, and pitting corrosion, in particular, must be guarded against in order to ensure the long-term integrity of the cooling system*

Biological fouling: Water left unattended for any significant length of time will grow bacteria, fungi, algae and even protozoa. This diversity of growth, allowing organisms to flourish in a protected environment, results in well established and difficult-to-remove biofilm.

This growth process and its attachment to system surfaces is called biological fouling. This growth is considered by many to be the root of most cooling-loop water treatment problems. Those problems include heat transfer efficiency reduction, cooling tower fill fouling, water flow blockages, microbiologically induced corrosion and human health concerns.

All of these effects are dramatic and serious. Biological control must, therefore, be a primary part of good water system control. A picture of a biologically fouled cooling tower fill is shown in **Figure 3**.

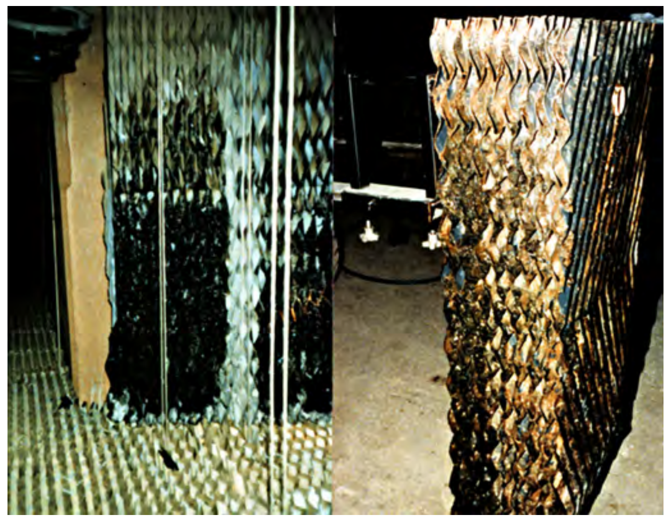

FIGURE 3 *Biological fouling is the root of most cooling-loop water treatment problems, according to many experts*

Water Management Strategies

There are a number of strategies for combating each of the problems described above. One must evaluate the system components, the available water and water management techniques available for a given site to determine the best solution for a specific case. Below are discussions of the control techniques for each problem area.

Preventing scale: To prevent buildup of mineral scales, the first and most important choice is the operating water chemistry of the cooling loop as determined by the inlet and outlet water volumes from the system. An operator must choose this operating cycles level, using the equation cited earlier in this article, before any subsequent treatment choices can be made.

Practical tools for automating water removal from the system are an instrument to measure circulating water conductivity, solids in the water and a signaled solenoid valve to bleed the water system when necessary. The conductivity set point is the most critical factor in operating an open evaporative cooling loop. Once the type of solids and their concentrations are known, an effective inhibitor selection can be made to ensure that deposition does not occur on vital heat exchange surfaces in the process equipment. One can inhibit the most common scales by using sequestering agents like HEDP (HydroxyEthylidene 1, 1 DiPhosphonicacid) and/or polymers like polyacrylate.

Other control strategies might include calcium reduction by water softening or solubility modification by pH reduction.

Preventing corrosion: Corrosion is prevented by a number of system choices and on-going prevention strategies. First, the bulk water chemistry at operating cycles of concentration as determined in the scaling section will dramatically impact the corrosion rates in a cooling system.

Once the system chemistry is known, one can then carefully choose the system materials for the environment and for compatibility with one another. Third, it is essential to keep the system clean. Deposits provide locations where bacteria can act to create non-standard water conditions that dramatically increase the local corrosion rate.

Therefore, the system must be substantially free from biological activity and largely clear of debris on surfaces, particularly in areas where suspended solids will settle. Continuous filtration or regular and thorough maintenance cleaning will accomplish this.

Finally, use corrosion inhibition or retardation products to protect metal surfaces, especially the thin heat-exchange tubes where corrosion problems can cost the system owner the most money. Common yellow metals, such as copper and brass, usually are protected with tolyltriazole, while steels are protected with ortho-phosphate.

Biological growth: In order to continuously and effectively operate a cooling system and establish sound biological control, first eliminate nutrient sources that may add material to the system, such as oil leaks, process fluid leaks and the like.

FIGURE 4 *A modern packaged treatment pump and controller system is shown*

Second, limit the air-wash effect of the cooling tower, which naturally adds nutrients and bacteria to the system, by filtration for removal of suspended solids and the bacteria that reside on them. Effective filtration can be done either with centrifugal separators or sand filters. A front-end strainer also is essential.

Finally, it is critical to provide a consistent and effective biocide addition to the system. In most cases this is a chlorine or bromine. Because of regulatory pressures, one might consider other cooling water biocides like ozone or hydrogen peroxide. These compounds are very effective biocides when properly applied and ozone can be used as a stand-alone treatment in most HVAC cooling systems.

In a conventional chemical treatment system, a service provider or self-administered water maintenance program consists of adding an oxidizing biocide and a combination scale and corrosion inhibitor to the water system. One should monitor chemical treatment to determine the effectiveness of the program. This will prevent major operating problems in the system.

In a number of cases, additional, specific additives may be necessary to avoid unique problems presented by operating water chemistries and specific site issues. A modern pre-packaged treatment pump and controller system is shown in **Figure 4**.

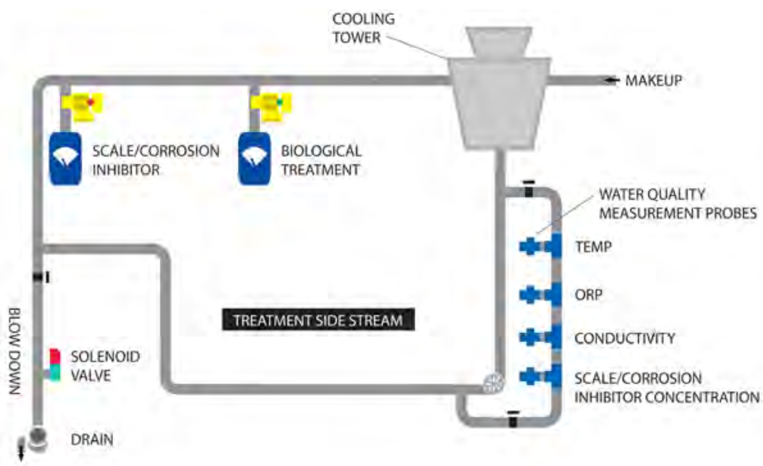

FIGURE 5 *An example of a cooling-loop water treatment schematic*

Verification: How can an operator effectively track the condition and treatment of cooling system water? A good water treatment program requires vigilance and attention to system control parameters. Primary monitoring targets typically include conductivity, oxidation reduction potential (ORP), treatment chemical concentration levels, general water analysis, and corrosion coupons and probes. Several of these methods for verifying system effectiveness are discussed below.

Manual method: The traditional water treatment model includes evaluation, primarily consisting of monthly service visits that check product inventories, corrosion coupons, probes, pumps and general equipment maintenance. This type of program is personnel-dependent and, by its very design, noncontinuous.

Automated method: Newer water treatment systems use electronic monitoring to evaluate the reliability of treatment delivery and the effectiveness of the treatment system in keeping the control parameters within specified limits. By using this type of control, a technician is dispatched only when problems requiring on-site resolution are encountered.

This labor efficiency increase may offset the additional equipment cost in setting up automated sites. The effectiveness of treatment systems can be evaluated every day by remote, trained technicians using the automated system. This superior servicing model probably will dominate over time in cooling-loop water treatment and equipment monitoring.

An example of a cooling-loop water treatment schematic is shown in **Figure 5**. This is the electronic monitor and adjustment interface for a cooling loop. It includes a representation of the cooling tower, the treatment side stream, the blow-down value and drain and the water quality measurement probes.

In conclusion, cooling-loop water maintenance is essential to efficient operation of the process served. Control of biological growth is critical along with control of scaling and corrosion.

Water treatment is a complex undertaking with many parameters to consider when properly treating a specific application. Consult a qualified water services company to create the proper program for your system.

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